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Sawah Technology「アフリカ水田農法」 (3-2): Evolution of sawah platforms in Madagascar, UR Tanzania, Uganda, Kenya, Rwanda, Burundi, Malawi, and Zambia

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Contents

1. Madagascar: Asian-style irrigated sawah platform brought by Malay-Indonesian immigrants >1000 years ago

According to FAOSTAT (2021) and Sawah technology 「アフリカ水田農法」(1), Madagascar has been a leading rice producing country of Sub-Saharan Africa (SSA) in terms of paddy production and yield from 1961–2010. However, paddy production and yield improvement stagnated from 2010–2021. Rice supplied 60-70% of the calories in foods from 1961-2013 (Figure 25b, Sawah technology「アフリカ水田農法」 (1)). Madagascar is a unique country among SSA. Madagascar's inhabitants are a mix of indigenous Africans and people who migrated from what is now Malaysia and Indonesia more than 1,000 years ago (Crowther et al. 2016).
Thus, the Asian-style irrigated sawah platform for rice cultivation brought by Malay-Indonesian immigrants has spread over the country over 1000 years. Therefore, Madagascar has a wide spread distribution of irrigated rice cultivation platforms similar to Malay-Indonesian sawah-based rice cultivation platforms in Asia as shown below. However, the shape of some sawah plots in large-scale irrigated sites led by the government is influenced by French colonial rule. More than 50% of the paddy production in Madagascar is in the Fianarantsoa and the Antananarivo states of the central highlands and the other major rice state is the Mahajanga (23%) in northeastern Madagascar (USDA 2017). Therefore the evolutional stages of sawah platform was evaluated based on the Google Earth observations in conjunction with ground truth field survey data and photographs published by previous researchers.

1-1: The Fianarantsoa state

The Fianarantsosa is the primary rice-produching state, including parts of central highland and southeastern Madagascar. The paired Figure 1 and Photo 1 of Figure 4, as well as on Figure 2 and Photo 2 of Figure 4, are the Google Earth images and the two photos were taken on at the almost same sites respectively. Please note that the exact positions do not match, and the shooting times differ. The two photographs were taken by Horiuchi in 1993 (Horiuchi 1996). The location of Figure 1 is in the northeastern part of Fianarantsoa state, 120 km south of

Antananarivo, Central Highland, showing numerous beautiful, long, and narrow terraced sawah rice platforms on the steep slopes. The slope is gentle at the valley bottom. Therefore, the sawah plots are relatively wide. The altitude is 1500–1350 m in Photo 1. The location of Figure 2 is also in the Fianarantsoa state, but the altitude is approximately 200 m. This is a sawah platform developed in a valley with gently undulating hills. The location is 50 km from the coastal city of Manakara

Figure 1. Google Earth image at Fandriana area (location: 20.212S 47.407E; central maker length is 300m (26February 2000).

Figure 2. Google earth image of the Ikongo area (location: 21.963S 47.436E; central marker length is 300m) of the Eastern Fianarantsoa state (28July2019).

Figure 3. Google Earth image at Ambohibary (location 19.121S 46.915E; central marker length is 300m) (28July2019).

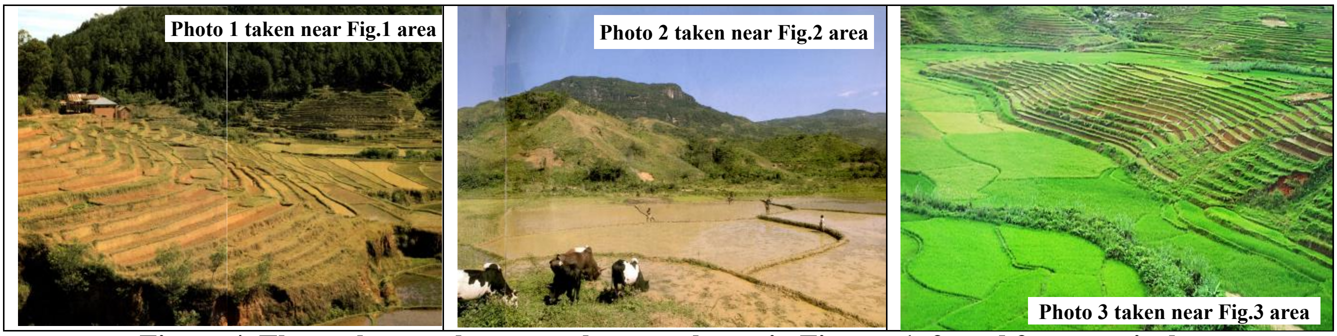


Figure 4. Three photos taken near the area shown in Figures 1, 2, and 3, respectively.

1-2: The Antananarivo state, core rice state of central highland

Figure 5. Two Google Earth images of Ambohimandroso (location: 19.7679S 46.683E; central marker length is 300m) in the Antananarivo state, central highland area

Figure 3 shows the traditional sawah system platform at Ambohibary, 60km southeast from Antananaribo. Photo 3 of Figure 4 was taken by Mr. Lantonirina, a JICA trainee in 2009, near the Ambohibary area. The site where Photo 3 was taken is in the central highland area, but the exact location is unknown. These sawah platforms are evolutionary stage 4 or 5, similar to the one seen on the Google Earth image on the left, and is quite similar to the sawah system at Batu Sangkar, West Sumatra, Indonesia. Please see Figure 3① and ⑤ of separate manuscript of Sawah Technology「アフリカ水田農法」(2).

Figure 5 shows Abohimandroso, Antananarivo, central highland. The site has a similar sawah platform to the one in Figure 3. The sawah platform at an evolutionary stage 4 or 5 is the basic requirement to operate good agronomic practices for green revolution technology, including such as System Rice Intensification (SRI)(Katambara et al 2013, Tsujimoto 2015). These SRI farming methods cannot be applied to a sawah platform with an evolutionary level of 0–3 since the platform that can support healthy growth of the transplanted young rice seedlings of 2-3 weeks after sowing rice seedlings should be at least level 4 or 5. In SRI practices, younger seedlings (milk seedlings) less than 2 weeks are general (Toriyama 2012, Mizoguchi 2012), and the sawah platform requires a higher degree of levelling than ±5 cm of the stage 4-5 platform.

1-3: Surrounding Antananarivo city and the Lake Aloatra area of the Toamasina state

This area, which can be seen around the capital of Antananarivo, is the centre of rice production and the most well-developed high-standard irrigated sawah system platforms under animal, power tiller, and tractor cultivation. Figure 6 shows various shapes of sawah plots in the wetlands around the capital of Antananarivo. In addition to elongated rectangular sawah plots suitable for plowing with oxen, the contour bunding sawah plots can be seen. In addition to the endogenously sawah platforms developed by Malay-Indonesian immigrants during the 7^{th} to 18^{th} century (Crowther et al. 2016), there are "parallelogram plots" and "sawah plots that are intricately oriented", which are irrigated platforms with sharp angles. As seen in Figure 6D at the Aloatra site and Figure 7B (right side) at the Malbue site, these are thought to be the influence of French colonial rule and ignoring the agricultural efficiency of using conventional sawah system layouts However, irrigation and drainage channels cannot be appropriately arranged in these irrigated sawah platforms, complicating water management. colonialism

In addition to these unconventional sawah plot layouts, widespread standard sawah platforms can be found around the capital and the Marovoay area in the northwest. These sawah systems are estimated to be evolutionary stages 4–5.

Figure 6. Google earth images showing standard sawah platform evolutional stage 4 and 5 around the capital city of Antananarivo and Lake Aloatra area. Figure 6A: North of Antananarivo (location 18.757S 47.509E), Figure 6B： Western side of the capital showing a flood plain of the upper stream of the Ikopa river (location 18.835S 47.387E), Figure 6C: South of the capital showing flood plains of the additional upper stream of the Sisaony river(location 19.0S 47.482E), Figure 6D: Polder/flood plain of Lake Aloatra (location 17.764S 48.254E), 150km north from Antananaribo. Scale marker is 300m except for Figure 6D, which is 200m.

1-4. Marovoay district of Mahajanga state, northwestern Madagascar

Figure 7A: Google Earth image showing a sawah platform, evolutionary stage 4–5, developed by the government or farmers in the Tsararano village (location: 16.175S 46.677E, scale 300 m); Figure 7B: Expanded Google Earth image of a possibly French engineer-led sawah platform, evolutionary stage 5, just below the lake (location: 16.1325S 46.739E, scale 700 m).

Figure 7A shows a stage 4–5 sawah platform at the Tasararano village (16.175S 46.677E), which is situated on the marshy bank of the permanent Beltsiboka river (Rakotondranivo et al. 2018). At first this sawah platform was formed by general irrigation by the local government and the drainage layout. After that farmers finalised the bunding and levelling quality of the sawah platform using traditional skills to satisfy the standard evolutionary stage 4 which makes possible transplanting young rice seedlings. Figure 7B shows acute-angled parallelogram sawah plots, which are probably the work of a French colonial engineer. This irrigation site was developed on the coastal delta/flood plains of the Ikopa River and tributary in the Marovoay district of the Mahajanga Province, northwestern Madagascar. This area is flood-prone based on Google Earth images' topographic and wet season observations. Most sawah and fish plots have a size of 1 ha or more.

2. Tanzania and Surrounding Countries

2-1. Distribution comparison of major rice region and soil map in Tanzania and surrounding countries

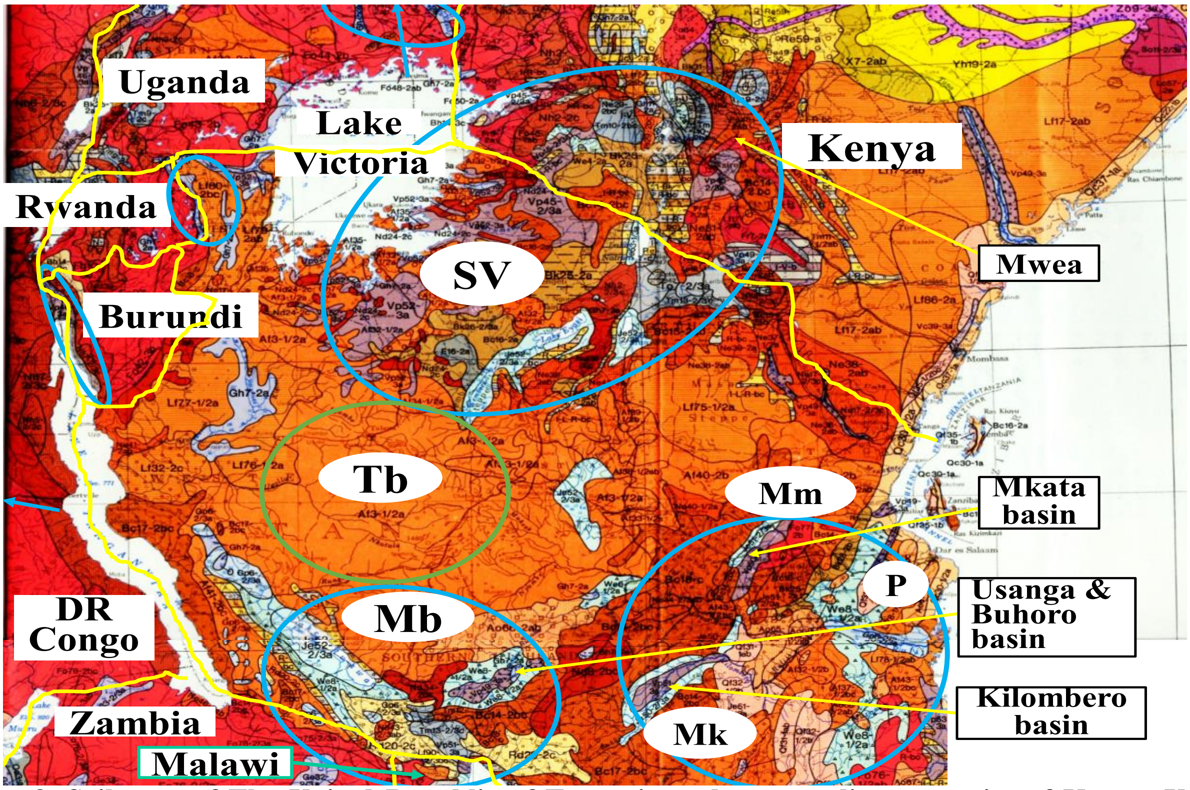


Figure 8. Soil map of The United Republic of Tanzania and surrounding countries of Kenya, Uganda, Rwanda, Burundi, DR Congo, Zambia, and Malawi by FAO-Unesco "Soil map of the world. 1:5000,000 (FAO-Unesco 1977). The light blue circled areas indicated by SV depict the soil map of Geita / Mwanza / Shinyanga / Northern Tabora region, which is rich distribution of Vertisols and home of the Sukuma people south of Lake Victoria. Tb denotes Tabora area, Mb Mbeya area, Mm Mkata plain, and Mk Kilombero basin, respectively. P denotes the Pwani region.

The area marked Vp ((45, 50, 51, 52, 53) in purple indicates the soil mapping units of Pellic Vertisols, which are very fertile clayey lowland soils and very suitable for sawah-based rice cultivation. Major distribution areas are south of Lake Victoria, the Mkata basin, Usanga, Buhoro, and Kilombero basins in Tanzania. The same type of soil is distributed in Kenya (the Mwea and Ahero areas) and Burundi (the Imo plain, where the capital is located). Planosols are also suitable for sawah-based rice cultivation. In the SV area (Figure 8), Vertisols are distributed over approximately 300,000 ha, which is the soil of the sawah platform developed by the Sukuma people. In the Mb areas around Lake Rukuwa in the Mbeya region and the Mk area in the Morogoro region, about 200,000 ha of Vertisol, 300,000 ha of Planosols, and 250,000 ha of alluvial soil are distributed in the Kilombero basin (Mk) and Dakawa-Wami river basin of Mkata Plain (Mm). The Pwani (P) and Lindi regions also have vast floodplains. By observing the progress of the sawah system platform development and evolution in Unite Republic of Tanzania on Google Earth images, the FAO-Unesco soil map (1977) can be used to evaluate suitable sites for sawah platform development in SSA in the future.

2-2, Sawah system Evolutional stage of United Republic of Tanzania, including of northern end of Malawi

According to the sampled survey on paddy production statistics in 2016/2017 (The United Republic of Tanzania 2018, Figure 9), among the total 2.9 million tons of national paddy production, the northern four regions of Geita/Mwanza/Shinyanga/Tabora produced 30–40%, followed by the Morogoro and Pwani regions (20–30%), and the Mbeya region 15–20% (FAOSTAT 2020). The evolutionary levels of the Sawah system platform for each region are evaluated in this order based on Google Earth image observations presented below in Figures 10-31.

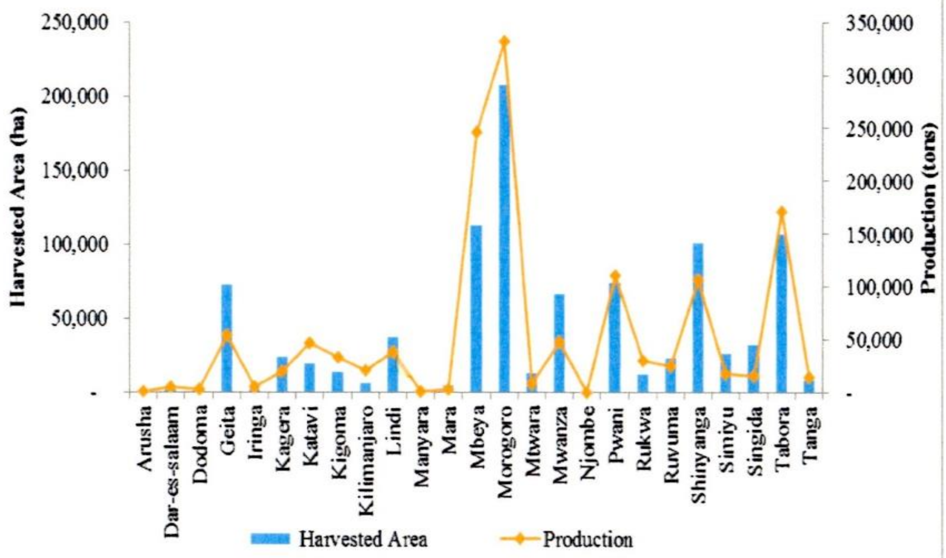


Figure 9. Harvested area (ha) and production (tons) of paddy by region in Tanzania Mainland, 2016/17

According to Meertens et al. (1999), Kato (2007, 2010, 2011a, 2011b, 2019), Kanyeka et al. (1994), and Sekiya et al. (2017), rice cultivation in Tanzania may have a history of more than 200 years through the influences of India, Arabic people, and Madagascar via Zanzibar. In Tanzania, since 1900, the sawah platform system seems to have been evolving endogenously, mainly through the contribution of Sukuma farmers, who are herders. In the early 1900s, Indian plough was introduced to Sukuma land, and sawah-based rice cultivation expanded over the Sukuma land at the southern shore of Lake Victoria. By the 1980s it had expanded to the southern districts of Mbeya region and some areas in Morogoro region.

Since 1974, the Japanese government has developed approximately 1100 ha of Japanese-style irrigated sawah platforms, i.e., Lower Moshi project, of evolutionary stage 5 in the Kilimanjaro region, and transferred knowledge and skills of the sawah-based rice cultivation technology. This is typical Official Development Assistance (ODA) project. But never transferred the technology and skills need to develop such large-scale irrigated sawah platform development. If we compare it to the automobile industry, the knowledge of driving a car, that is, the sawah-based rice cultivation technology and skills, could be transferred, but the knowledge of manufacturing a car that is, irrigated sawah platform development technology, could not be transferred. Our sawah technology can cover both sawah platform development and sawah platform operation, which can make possible endogenous sawah based rice production sustainably in SSA.

In the Morogoro region, many large-scale irrigation projects (20,000 ha), including those of private companies such as Kilimanjaro Plantation Ltd., are operating. However, these projects are extrinsically developed model irrigated sawah platforms, including other western styles of irrigation platforms by foreign engineers.

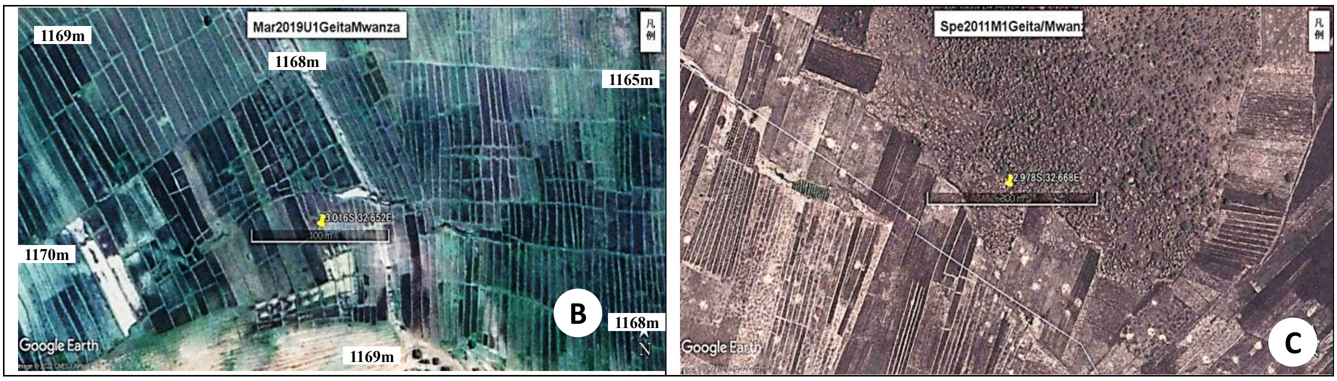
These big-scale projects differ from the endogenously developed irrigation sawah platforms, such as Sukuma style sawah platform. It is difficult and time-consuming to transfer such exogenous irrigated rice technology to Tanzanian farmers. On the other hand, the endogenous irrigated rice cultivation of indigenous Sukuma people, as described below, is relatively easy to transfer to other Tanzanian farmers, which does not take much time, and has a large impact. The reason for this could be that Sukuma farmers transfer technological knowledge of sawah-based rice cultivation to other ethnic groups in Tanzania. As seen in southern districts in the Mbeya region, the Sukuma-style endogenous small-scale irrigated sawah platforms are very small, with one to more than 10 hectares per farm family. However, as a whole, it could realise an irrigated sawah system platform with a scale of 50,000–100,000

ha or more by countless farmers. Sawah development in Mbeya in Tanzania is comparable to the Kebbi rice revolution in Nigeria. Mbeya-style Sukuma-induced endogenous sawah platform development can simultaneously realise innumerable farmers' training. Therefore, the formation of two platforms for nation-building, i.e., the farmland platform and the trained human group platform, can be realised simultaneously.
However, ODA-led projects are extrinsic development of model irrigated sawah platforms including other western styles of irrigation platforms by foreign engineers. These big scale projects are different from the above-mentioned endogenous development of irrigation sawah platform and farmers to farmers' technology transfer of sawah based rice cultivation by Sukuma people to other ethnic groups in Tanzania. As seen in southern districts in Mbeya region, Sukuma-style endogenous small-scale irrigated sawah platform is small, one to several hectares per one farm family. However, as a whole, it could realize an irrigated sawah system platform with a scale of 50,000-100,000 ha or more by countless farmers based on their own power. Sawah development in Mbeya in Tanzania is comparable to the Kebbi rice revolution in Nigeria. Mbeya style Sukuma induced endogenous sawah platform development can realize training of innumerable farmers at the same time, so the formation of fundamental platforms for nation-building, i.e., the farmland platform and the skilled human group platform, can be realized at the same time.

2-2-1. Geita and Mwanza regions, south of the Lake Victoria

Figure 10A: A catchment area near the border between the Geita region (southern part of the white line) and the Mwanza region (northern part) on lake Victoria shore. The scale marker is 4 km. Numerous square parcels of the black colored areas indicate rice-growing lowlands, which area is about 6000ha. These parcels are sawah platform of evolutionary stages 1-5, mainly stage 4-5, as shown in Figure 10B-10E.

As shown in Figure 10B-10E, the sawah plots are clear with strong bunds and well-organized along the contour lines. Unlike hoe cultivation, common in West African countries, Sukuma farmers have cow-cultivation techniques using ploughs. Therefore, sawah plots have an elongated shape. The majority of these sawah plots are evolutionary level 4. Thus, by standard bunds management against water leakage and weed management as well as puddling, levelling, and transplanting, paddy yield can potentially be higher than 4 t/ha using standard agronomic practices, such as good water management, varieties, and fertilization.



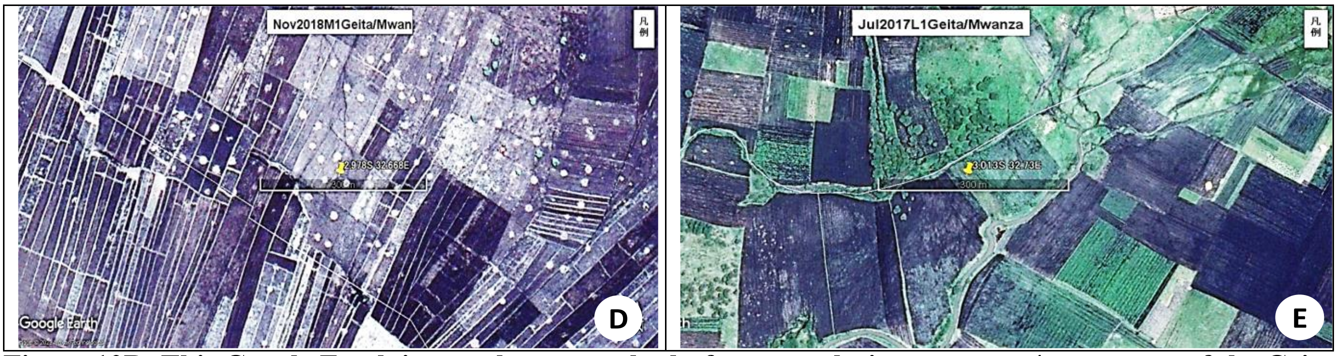


Figure 10B: This Google Earth image shows sawah platforms, evolutionary stage 4, upstream of the Geita catchment area in Figure 10A. Figure 10C and 10D: sawah platforms of evolutionary stages 4 and 5 of midstream. Figure 10C was taken on September 2011, and 10D was taken in November 2018. Figure 10E show the non-sawah platforms, mainly evolutional stages 1 and 2 at downstream area, just 4 km west of Lake Victoria. All scale markers are 300 m.

The altitude in the image of Figure 10B at upstream is in the range of 1170-1165m. The altitudes in the images of 10C and 10D in the middle stream are in the range of 1149m to 1146m. The altitude of 10E is in the range of 1142m to 1140m. The area of Figure 10E is in the farthest downstream part near the Lake Victoria shore. It is challenging to drain flooding water in this area, complicating water management. Sawah system development starts from the upstream part and progresses to the middle and downstream parts. A robust flood control embankment and a large pump are required for sawah platform development in the downstream area. Thus, the area indicated in Figure 10E has a lot of undeveloped wetlands.

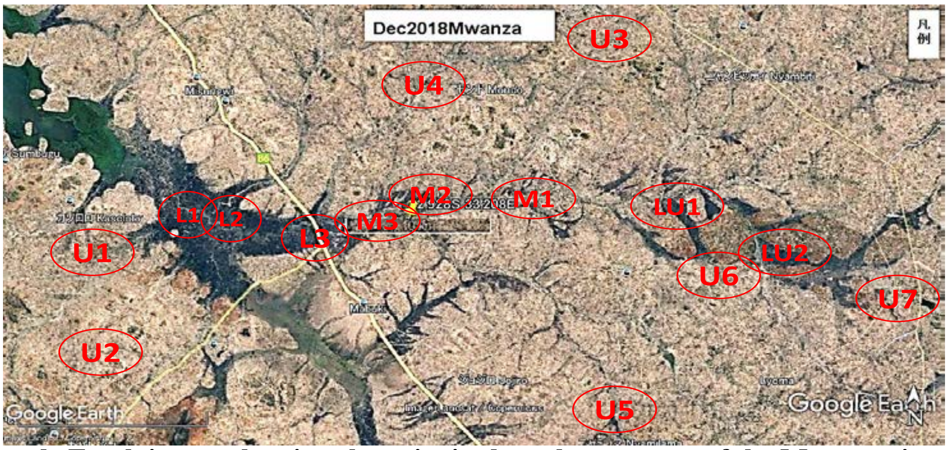
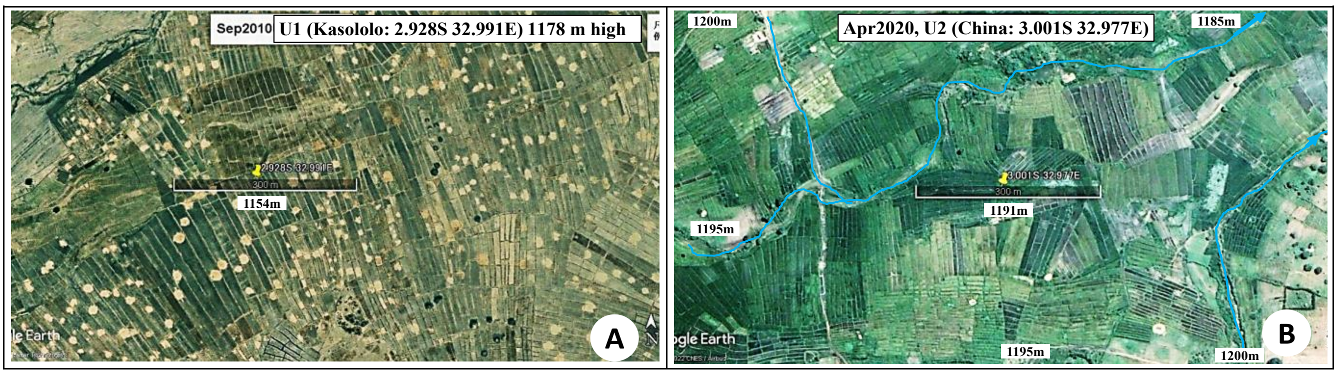


Figure 11 : A Google Earth image showing the principal catchment area of the Magogo river in the Mwanza region. The scale marker is 10 km.

The total area of this figure is approximately 240,000 ha. The black areas are floodplains and small deltas of the middle and lower reaches, indicated by M1–M3 and L1–L3. Basin-like lowlands floodplains are also distributed in the upper reaches (indicated by LU1 and LU2). U1–U7: Numerous inland lowlands suitable for sawah-based rice cultivation upstream. The total area of these small inland valleys is estimated to reach 10% (24,000 ha) of the total catchment area. L1–L2, LU1–LIU2, M1–M3: Floodplains and small deltas, reaching 24,000 ha.



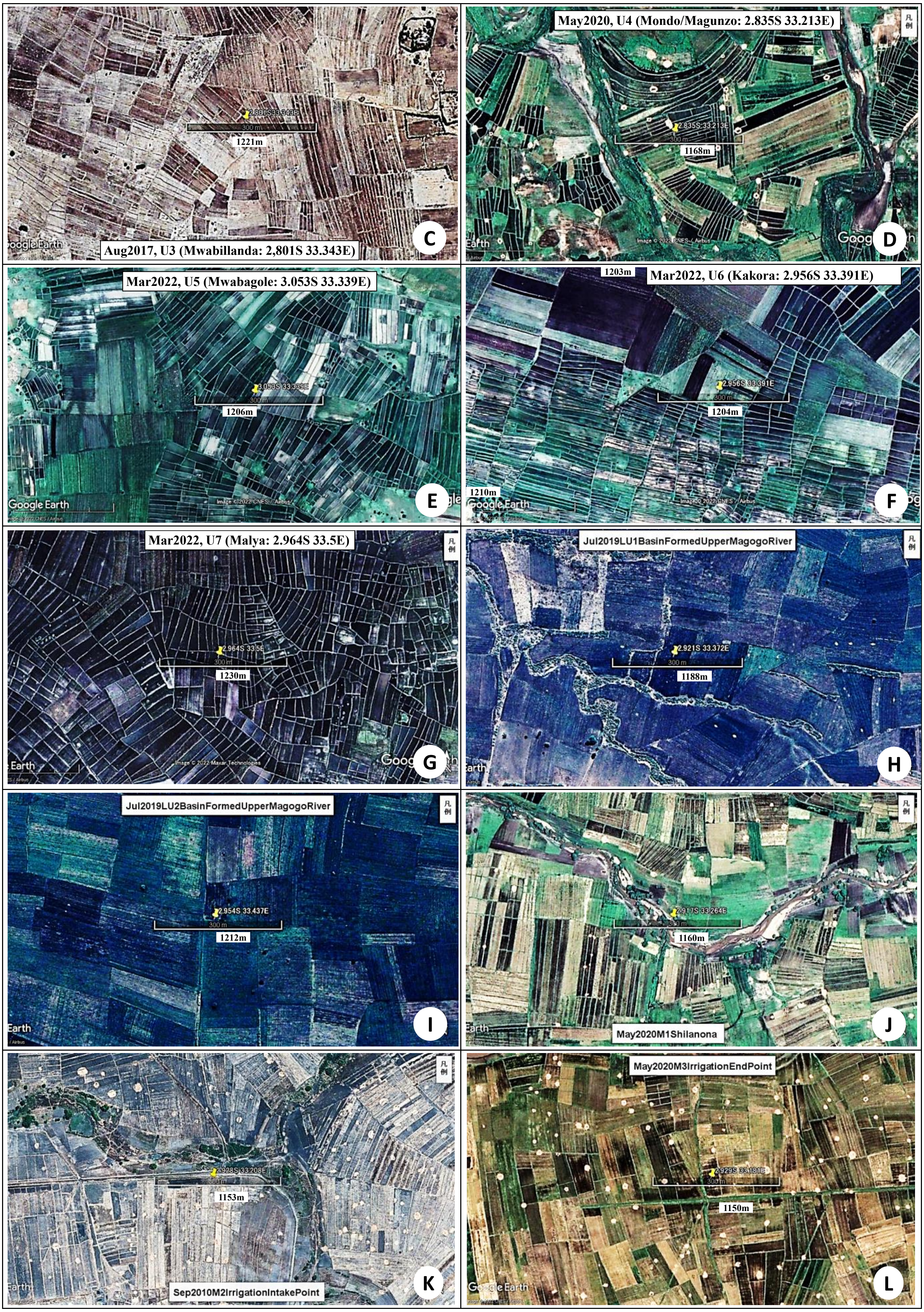

1221m
Aug2017, U3 (Mwabillanda: 2,801S 33.343E)
C
May2020, U4 (Mondo/Magunzo: 2.835S 33.213E)
2.835S 33.213E
300 m
1168m
D
Mar2022, U5 (Mwabagole: 3.053S 33.339E)
300 m
1206m
E
1203m
Mar2022, U6 (Kakora: 2.956S 33.391E)
2.956S 33.391E
300 m
1204m
1210m
F
Mar2022, U7 (Malya: 2.964S 33.5E)
2.964S 33.5E
300 m
1230m
G
Jul2019LU1BasinFormedUpperMagogoRiver
2.921S 33.372E
300 m
1188m
H
Jul2019LU2BasinFormedUpperMagogoRiver
2.954S 33.437E
300 m
1212m
I
2.917S 33.264E
300 m
1160m
May2020M1Shilanona
J
1153m
Sep2010M2IrrigationIntakePoint
K
May2020M3IrrigationEndPoint
300 m
1150m
L

Figure 12. Various sawah platforms along the Magogo River watershed. Figures A-G: Evolutionary stage 4 sawah platforms developed endogenously by Sukuma farmers at the upper reaches (U1–U7). Figures J-K: Evolutionary stage 4 sawah platform developed endogenously by Sukuma farmers at the middle reaches (M1–M3). Figures H-I and M-P: Evolutionary stage 1 and 2 sawah platforms at high flood risk lowlands areas (LU1–LU2 and L1–L3). Central marker length of all figures is 300m.

Although it cannot be distinguished from the Figure 11, as shown by Figure 12A-12G and Figure 12J-12L expanded Google earth images, innumerable inland lowlands suitable for sawah platform based rice cultivation are distributed in the upstream and midstream areas. The following 16 Google earth images show the evolution level of the sawah platform by expanding each area up to U1-L1 shown in Figure 11, that is,
Figure 12A expanded the U1 area of Kasololo: 2.928S 32.991E, 1178m high,
Figure 12B expanded the U2 area of China: 3.001S 32.977E, 1200m high,
Figure 12C expanded the U3 area of Mwabilanda: 2.801S 33.343E, 1221m high,
Figure 12D expanded the U4 area of Mondo/Nagunzo: 2.835S 33.213E, 1168m high,
Figure 12E expanded the U5 area of Mwabagole: 3.053S 33.339, 1206m high,
Figure 12F expanded the U6 area of Kakora: 2.956S 33.391E, 1204m high,
Figure 12G expanded the U7 area of Malya: 2.964S 33.5E, 1230m high,
Figure 12J expanded the M1 area of Shilanona: 2.917S 33.264E, 1160m high,
Figure 12K expanded the M2 area of Irrigation intake pint: 2.928% 33.208E, 1153m high, and
Figure 12L expanded the M3 area the end point of irrigation canal: 2.929S 33.181E, 1150m high.

The sawah plots are clear with strong bunds and well-organized along the contour lines. As indicated before, Sukuma farmers have cow farming techniques using ploughs. Therefore, the sawah plots have elongated shapes. The majority of sawah plots are evolutionary level 4. Thus by standard bunds management against water leaking and weed management as well as puddling, levelling, and transplanting, paddy yield can be possible higher than 4t/ha using standard agronomic good practices, such as good water management, varieties and fertilization.
However, it is essential to note that the altitude is 1150–1230 m; therefore, the lowest temperature during the growing season of rice is about 14 °C (the maximum is 35 °C). Consequently, farmers need to be careful about low-temperature measures.
A sawah platform with evolutionary level 4 or higher has not been developed due to the high risk of flooding in the basin-like topographical surface areas as shown in Figure 12H and Figure 12I at LU1 and LU2 areas in the middle of the Magogo River basin and the downstream part (Figure 12M-Figure 12P at L1-L3 areas) near Lake Victoria. Thus, the rice cultivation platforms in these areas are evolutionary levels 1-2. The farmers may not have enough resources to control the flood damage risk in these areas. Therefore, major civil engineering works by the government are required to control the flood damage risk. If drainage facilities are improved and flooding controlled in the future, the sawah level could be improved to evolutionary stage 6 using laser levelers. Currently, most rice fields are in evolutionary stages 1–2, and water management is complex; therefore, the paddy yield is considered 3 t/ha or less.

2-2-2. Shinyanga and Tabora regions

Figure 13 is a Google earth image of the Vertisols zone (described as Vp52-3a in the soil map of Figure 8) in the northern part of the Shinyanga region near the boundary with the Mwanza region. As shown by the thin, light blue lines, countless smaller tributaries flow into the main stream from the north and south. Vertisols are distributed in the main stream and tributaries' lowlands and are rice-growing areas. The areas seen in brown are uplands of Ferric Acrisols (described as Af32-1/2a in the soil map of Figure 7). The red-lined sections of U1 and U2 in Figure 13 are enlarged as Figures 14A and 14B.

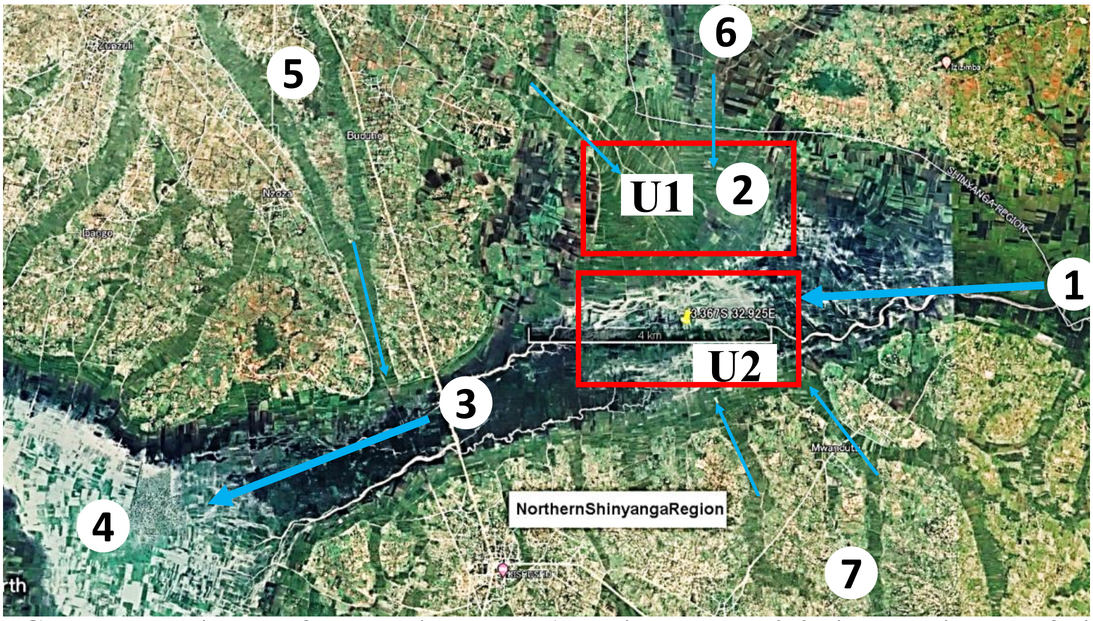


Figure 13: Google Earth image of the Vertisols zone (described as Vp52-3a in the soil map of Figure 8) in the northern part of the Shinyanga region near the boundary with the Mwanza region. The location information of the image centre is 3.367S 32.925E. Lowland Vertisols are distributed in the lowland areas, the black-green coloured area. The thick light blue lines indicate the direction of mainstream water flow. The main stream flows west from (1) to (4) via (2) and (3) and then northward from the junction at (4) into Lake Victoria. The altitudes are as follows; (1): 1158 m, (2): 1156 m, (3): 1151 m, (4): 1149 m, (5): 1187 m, (6): 1161 m, and (7): 1174 m.

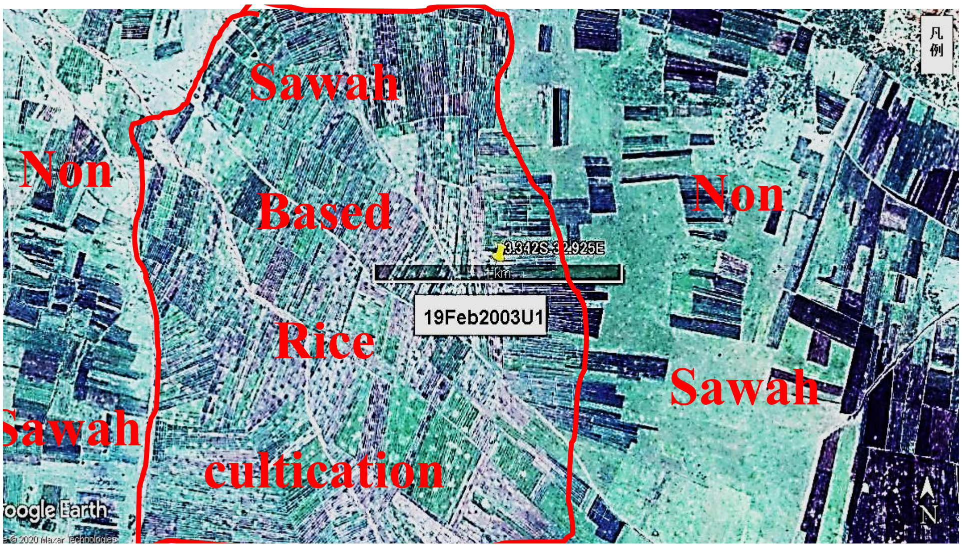


Figure 14A: Enlarged (Scale marker 1 km) view of U1 in the Google image in Figure 13 (19^{th} of February, 2003), location: 3.342S 32.925E. The scale marker is 1 km. The areas shown in black are the non-sawah fields (Evolutionary stage 1 or 2). All others are evolutionary stage 4 sawah fields, which bunds are clearer, suggesting that the quality of the sawah platform has improved for the standard transplanting method.

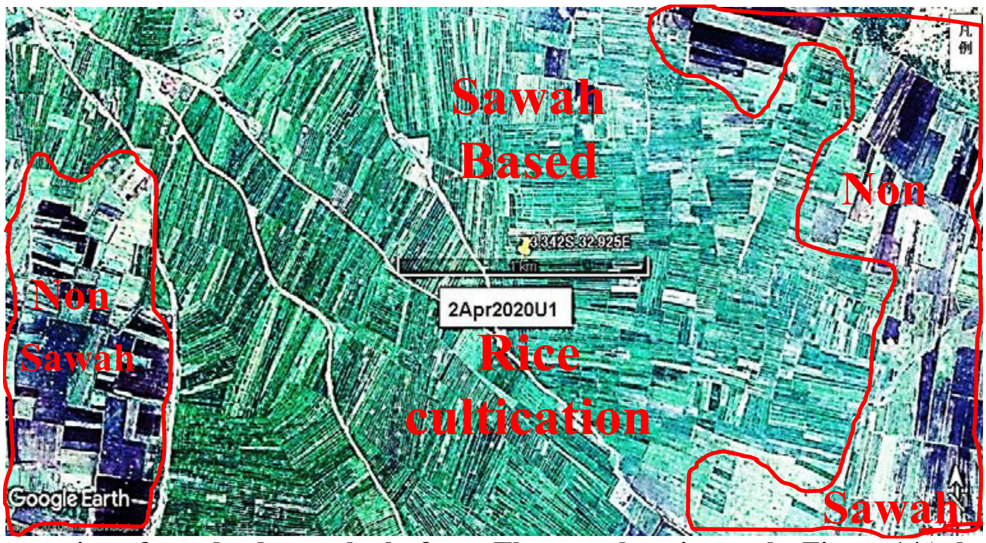


Figure 14B: Expansion of standards sawah platform. The same location to the Figure 14A, but taken on the 2nd of April 2020.

This U1 part of Figure 14A includes the tributaries from the plateau on the north side flowing down and joining the main stream, creating an alluvial fan-like terrain. As of 2003, the area of the sawah plots cultivated by cattle ploughing and transplanting methods (evolutionary stage 4) is estimated to be approximately 30% of the total area of 660 ha shown in Figure 14A. Otherwise, it seems to be cultivated directly using the sowing method in non-sawah plots. Sawah platform development was promoted from non-sawah fields in the lowlands where the risk of flooding in the rainy season is high and from areas with a low risk of flooding on gentle slopes. However as of 2020, 7 years after (Figure 14 B), the sawah platform of evolutionary stage 4 have expanded to almost 80% of the total area of 660 ha.

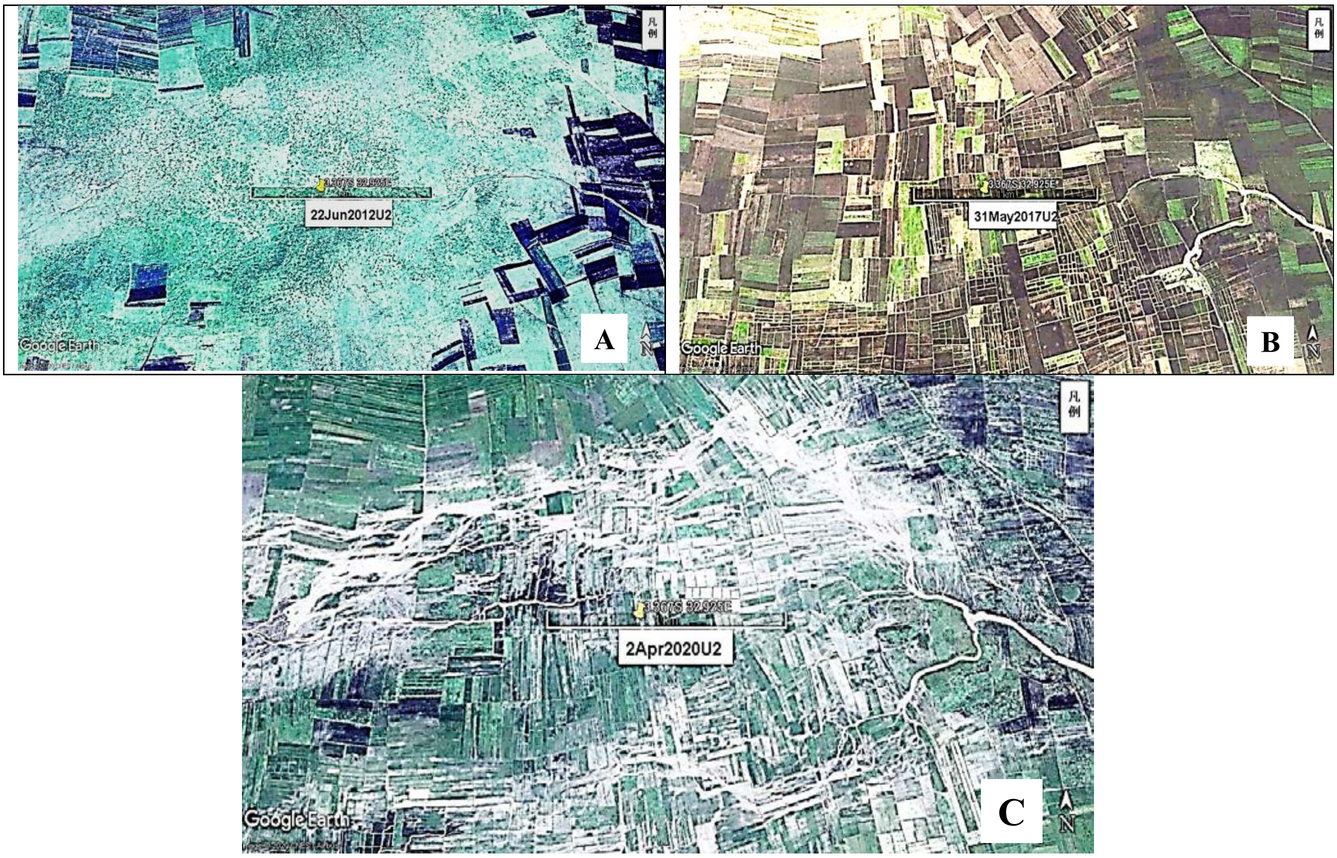


Figure 15: The U2, part of Figure 13, is the lowland created by the main stream. The location is 3.367S 32.925E. Figure 15A: Google image was taken in June 2012, 15B April 2017 and 15C April 2020. The scale marker length is 1 km. The altitude is 1155–57 m at the right end and 1153–54 m at the left, 3.5 km west.

As shown in Figures 15A, 15B, and 15C, there is a risk of flooding damage in this mainstream area of U2, and unlike the foot sloped U1 area, sawah fields have hardly been developed before 2012. Sawah based rice cultivation was rarely carried out, even if only direct sowing cultivation of non-sawah (evolutionary stage 1) was carried out. The photo in 2017 shown in Figure 15B shows the development of sawah fields was underway in about 40% of the area, mainly in the southern area of the central part. This development was possibly being done because the base of the slope from the southern plateau is wide, and the flood risk was relatively small. Upper areas of the Figure 15B rice were directly sown in non-sawah fields. It could be seen that the rice cultivation area expanded from 2012–2017. However, looking at Figure 15C taken in April 2020, which showed the sawah platform had expanded to more than 70% of the main lowland U2 area, but there is a risk that the bunding system of sawah platform will be destroyed by floods during the rainy season (November-April).

Figure 16: Stage 4 sawah platforms developed by Sukuma farmers. The left side is the same area as Figure 13.(5) (location: 3.334S 32.868E), and the right side is the same area as Figure 13.(7) (location: 3.407S 32.953E).

As shown in Fig. 13, the tributary (5) joins the main stream from the north, and the tributary (7) joins the main stream from the south. The lowlands of these tributaries are less prone to flooding than the main stream. Although area for irrigation is small, water control is relatively easy compared to the lowland areas along the main stream. As of 2020, as shown in Figure 16, it is being used almost entirely for sawah-based rice cultivation.

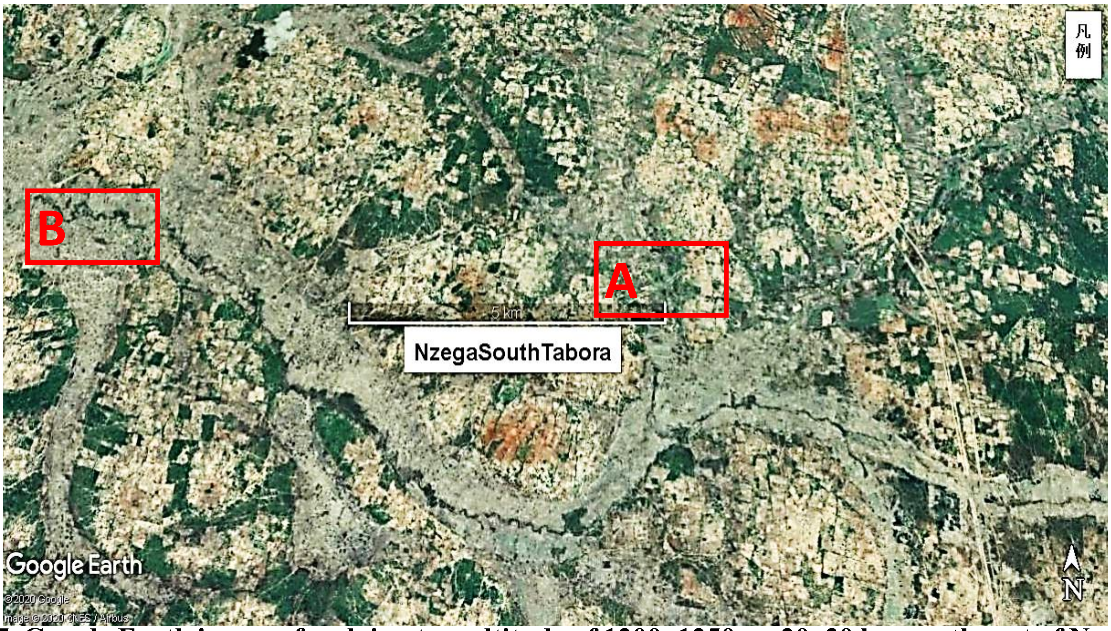


Figure 17. Google Earth image of a plain at an altitude of 1200–1250 m, 20–30 km southwest of Nzega town, the Tabora region. Scale marker length: The A enclosed by the red rectangle shows the tributary lowland and the B shows the main lowland. Scale marker length is 5km. Figure 18A and 18B below show enlarged view of each lowland to compare the evolutionary features of the Sawah platform.

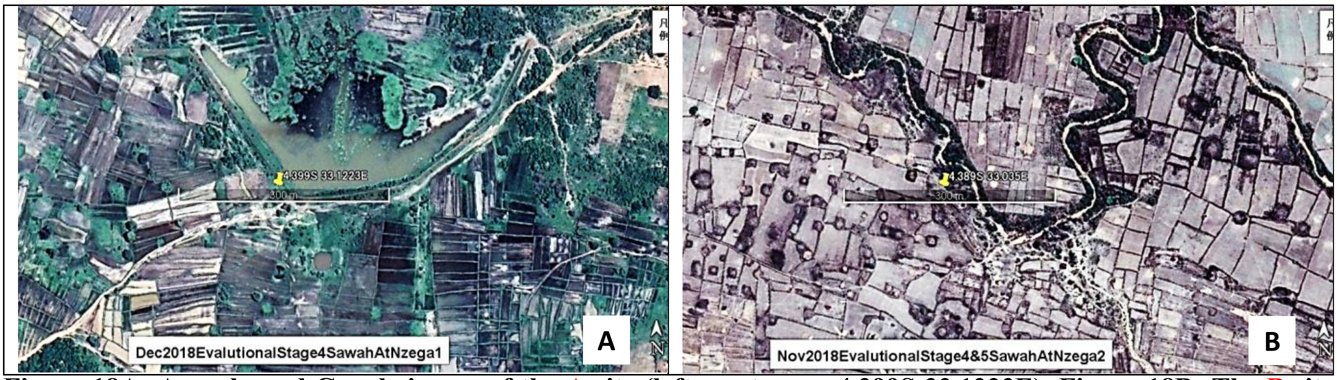


Figure 18A: An enlarged Google image of the A site (left, upstream, 4.399S 33.1223E), Figure 18B: The B site (right, downstream, 4.389S 33.035E). The scale markers of both Figure A and Figure B are 300 m. The respective watershed positions of A site and B site can be seen in Figure 17.

Several branches in Figure 17 are lowlands with a gentle slope, and a small black meandering river flow can be seen in the central main stream. This river can be shallowly flooded, with a small, destructive power in the rainy season of October to May, during which precipitation is 800–1000 mm. Additionally, the maximum temperature during this season is 28–32 °C, and the minimum is 16–20 °C. Although upland soil types are mainly Ferric Acrisols, several soil types are suitable for sawah-based rice cultivation and are distributed in the inland valleys that are branched and appear greyish brown in Figure 17. These soil types are Eutric, Dystric or Dystric Fulvisols (Je or Jd), Gleysols (Ge or Gd), or Cambisols (Be or Bd), which have a relatively high clay content. However, these soil types are not shown in Figure 8 because it is distributed less than 20% only in the lowlands of small rivers.

The Sukuma people cultivate rice using the sawah system platform and cattle and tractors to plough the platform. The enlarged morphology of each sawah plot can be seen in Figure 18A (upstream part) and Figure 18B (downstream part). However, the altitude is relatively high, at approximately 1200 m, and the rainfall may not be enough for double rice cultivation.

Figures 18A show that a small pond is built in the centre of the A site, which is relatively upstream. This pond seems to be built for water shortage. Numerous rectangular sawah plots (Evolutional Stage 4) have been developed along the lowlands of 300-600 m wide. The plateaus of both sides of the lowlands are upland fields and bushes. Figure 18B shows sawah system platforms (stage 4 or 5) developed in all over the lowlands of the main stream. Some sawah plots are flooded after puddling. Therefore, it is thought that this image was taken before or immediately after transplanting. The width of the lowlands is about 1000–2000 m, and the river meanders, indicating that the slope is very gentle.

2-2-3. Mbeya and Rukwa Regions, including northern border area of Malawi

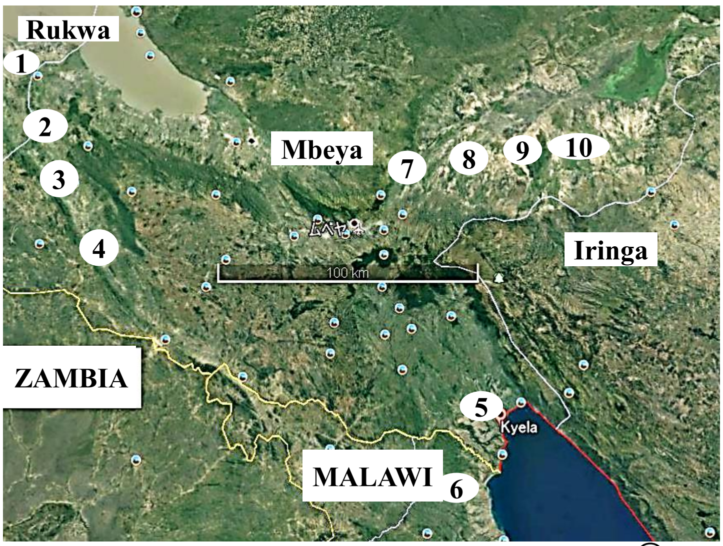


Figure 19: The major rice cultivation areas in the Mbeya region, including ① the southern part of Rukwa. The ①-④ areas belong to the Msangano trough. The ⑦-⑩ areas belong to the Usanga and Buhoro flats/depression. ②: The Nsoche village, and ④: Ntinga village. ⑤: Kyela, and ⑥: Kapora, Malawi.

These areas coincide with the distribution of the lowland soil We8-1/2 (Eutric Planosols) around Lake Rukwa in Figure 8. The soil types of ⑦-⑩ are Vertisols and Eutric Planosols, as shown in Figure 8. The soil characteristics overlap with the distribution area of the Vertisols in the Geita, Mwanza, Shinyanga, and Tabora regions.

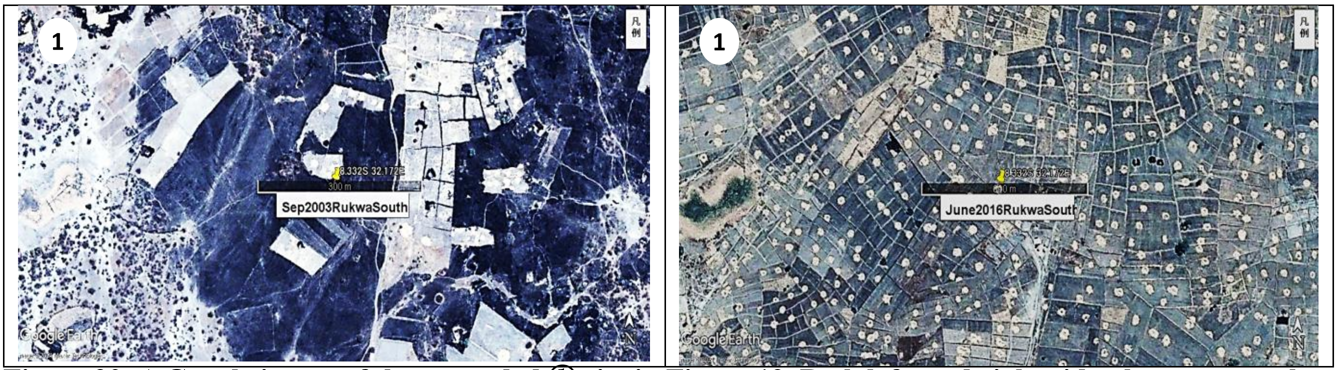


Figure 20: **A Google image of the expanded ① site in Figure 19. Both left- and right-side photos were taken at the same location (8.332S 32.172E). Scale marker: 300 m.**

The left side image was taken in September 2003, showing that the development of sawah plots had just started. The right-side image was taken in June 2016, showing that sawah system platforms, evolutional stage 4 or 5, are abundant. The white dots in almost every sawah plot are piled rice straw collected and threshed after harvesting.

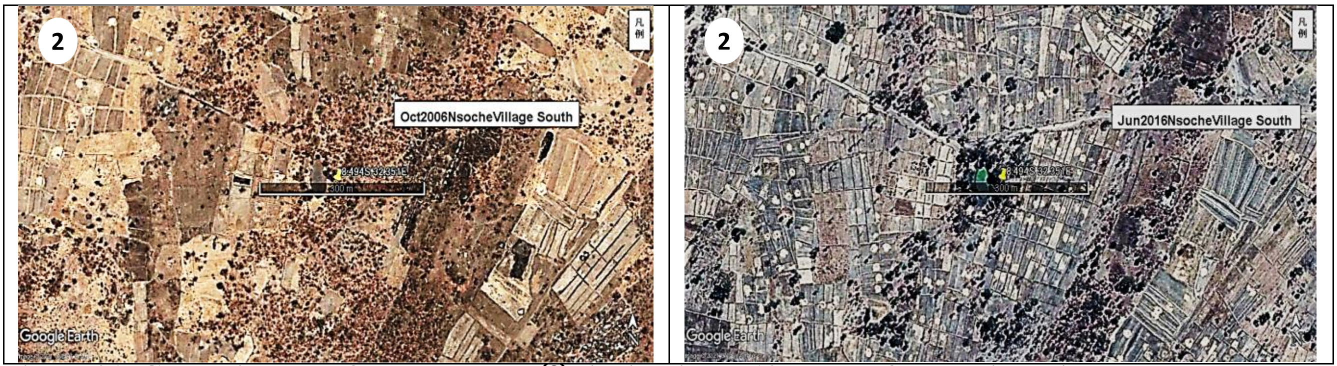


Figure 21: **Google images of the expanded ② site in Figure 19. Both left- and right-side photos were taken at the same location (8.494S 32.351E). Scale marker: 300 m.**

The left image was taken in October 2006, showing that the development of sawah plots had just started. The right image was taken in June 2016, showing sawah system platforms, evolutionary stage 4 or 5 is abundant except in the rows of dunes, which are slightly higher and run in the northwest direction.

Figure 22. Photos taken at ②Nsoche village and ④Ntinga village in 2006-2007 (Cited from Kanda et al 2011 and Shimomura 2011).

Kanda et al. (2011) reported that sawah-based rice cultivation expanded endogenously in Noche village between 1990 and 2005. The Google Earth images of Figures 21, 23 and 24 indicate that the expansion has accelerated further from 2006–2019.

Figure 23: **Two Google images of the③site in Figure 19 (8.825S 32.453E), middle between Nsoche and Ntinga villages. Scale marker: 300 m.**

The left image was taken in August 2008, indicating that the development of sawah plots had just started. The right image was taken in August 2019, showing full of sawah system platforms of evolutionary stage 4 or 5.

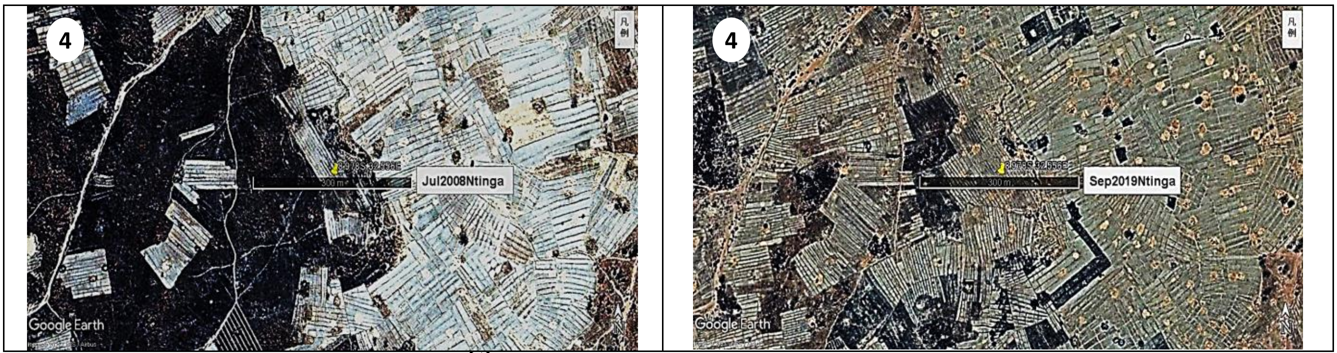


Figure 24: **Two Google images of the ④Ntinga village site in Figure 19 (8.978S 32.556E). Scale marker: 300 m.**

As shown in Figure 24, in the ④Ntinga village, in Musangano local government area, sawah development had already progressed considerably as of August 2008. In 2019, the entire surface was covered with sawah platforms (stages 4 and 5).

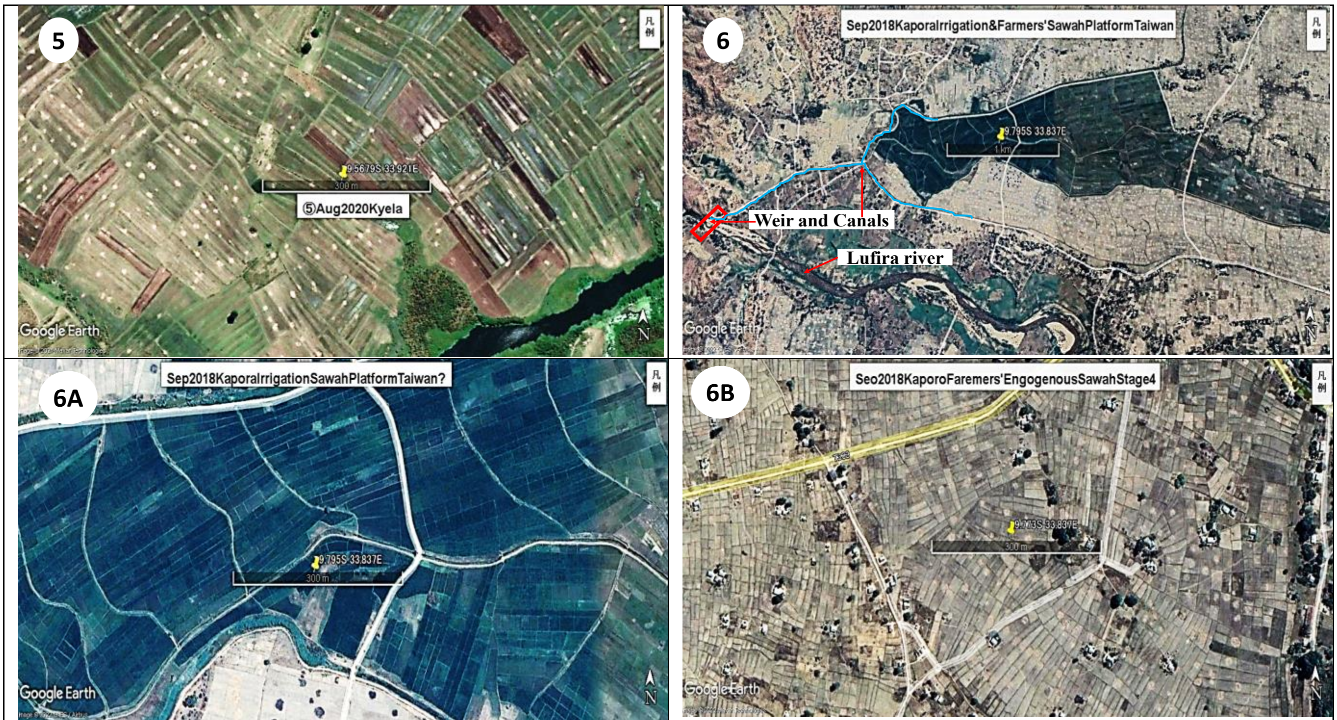


Figure 25. **Expanded Google images of ⑤Kyela, Mbeya and ⑥(6A and 6B) Kaporo, Malawi. Locations are shown in Figure 19.**

Figure 25 above shows the sawah platform in the alluvial plain of northern shore of the lake Tangahyika near Kyela in Tanzania and Kapora in Malawi. These positions are shown in Figure 19. As shown in Figure 8, the soil types are Vertisols in the Kyela area. Vertisols (Vp 52) and Fulvisols (Je 53) are distributed in Kapora area. These soil types are suitable for irrigated sawah platform development. The Google Earth images of Figure 25⑤ shows the evolutional stage 4 of sawah platforms for plough- and cattle-based rice cultivation by Sukuma farmers in Tanzania. The Google Earth image of Figure 25⑥ shows a weir-irrigated sawah platform of about 1000 ha based on the assistance of the Taiwan team in 1966–2008. In September of the dry season, approximately 300 ha of rice is cultivated in the central part, which looks blackish green. It is estimated from Google Earth images that a total of approximately 15,000 ha of irrigated or rainfed sawah platform-based rice cultivation was ongoing in 2021.

From 1966 to 2008, a Taiwanese team provided technical cooperation for sawah-based rice cultivation throughout Malawi, and Kapora (Sawah evolutionary stage 4–5) in northern Malawi was one of the bases of Taiwan (Hsieh 2001, 2003, Wakatsuki and Hsieh 2003). Kapora is less than 20 km from Kyela in the Mbeya region and is connected by a main road across the border. Currently, Kyela has Sukuma-style rice fields of evolutionary stages 2–5 and is a production centre of high-quality rice with good taste and aroma in Tanzania (Shimomura 2011). The assumption can be made that sawah-based rice cultivation technology spread to the Mbozi district of the Mbeya region via Kapora and Kyela. Through the above process, the Mbeya region has continued to develop sawah-based rice farming endogenously by incorporating various external technologies into the traditional agricultural system.

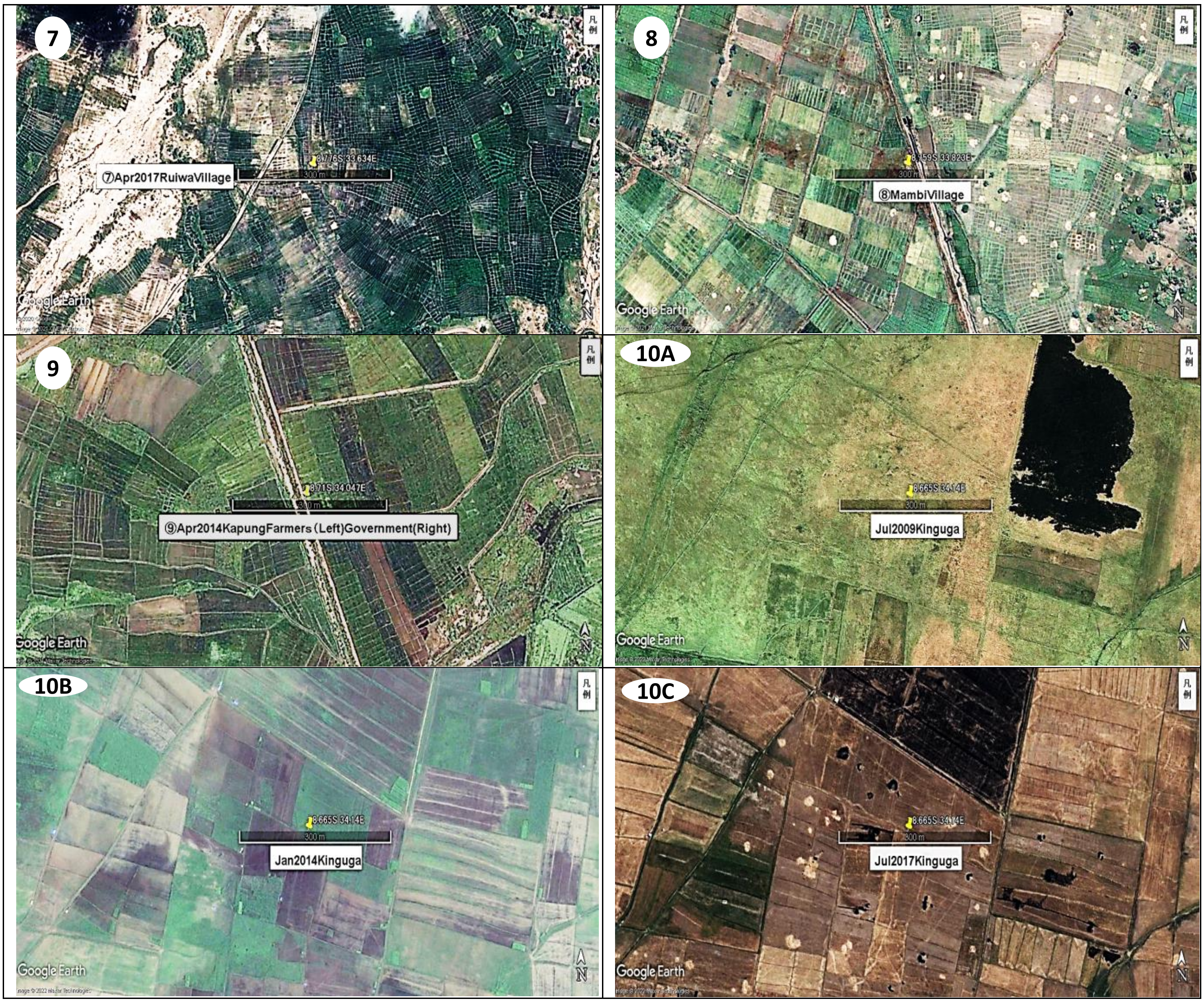


Figure 26. **Google image of expanded ⑦-⑩sites of Figure 19. Scale marker: 300 m. ⑦: 8.776S 33.634E, ⑧: 8.759S 33.823E, ⑨: 8.71S 34.047E, and ⑩: 8.665 34.14E**

These sites belong to the Usanga and Buhoro flats/depression. As shown in Figure 8, the major soil types are

Vertisols, Planosols, and Gleysols, which are suitable for irrigated and rainfed sawah platform development. The altitude is 1000-1040 m, the slope is approximately 1/1000, and it is extremely flat. Irrigated sawah system platforms with a scale of 50,000 ha have been developed in areas of ⑦-⑩. A total of 0.5–1 million hectares of suitable soil for paddy production is distributed, but most of it is undeveloped. In this area as a whole, sawah development is in the initial stage (sawah evolutionary stage 3 of the micro sawah plots of 20–50 m^2 per plot), shown in Figure 26 ⑦⑧. There are some government irrigation project sites of approximately 10,000 ha, but the sawah system development is left to farmers to develop, as shown in ⑨. Bunding quality of the sawah system in ⑩ is inferior. Thus, the evolutionary stages of sawah plots are estimated to be evolutional stages 4 and 5. However, their quality has not reached standard levels.
In the vicinity of the site ⑩, irrigated and rainfed sawah platforms developed by farmers have expanded rapidly from 2009 to 2017. Figure 26 (10A) shows the Google Earth image in 2009 when sawah development had just begun. In Figure 26 (10B) of 2014, large-sized sawah plots of about 1 ha have been developed. Figure 26 (10C), taken in 2017, shows that mechanised rice cultivation using a combine harvester is being carried out based on the evolutionary stage 5 sawah platform. It seems that private companies or lead farmers developed the platform. The areas of such irrigated sawah development that the government is not directly involved in are thought to have reached more than 10,000 ha during 2009–2021.

2-2-4. The Morogoro and Pwani Regions

Figure 27 presents the central rice cultivation area in the Morogoro and Pwani regions. The (1G) is an official irrigation site on the Ruvu river flood plain, near Mlandizi in Pwani Region. The (2G) is the official pump irrigation site on the Wami River floodplain near Dakawa. The site of (3A) and (3B) are farmers' site near Kilosa city. Both (2F) and (2G) as well as (3A) and (3B) sites are located in the Mkata basin (Mm) as shown in Fig. 8. The (4A) and (4B) have Eutric Fulvisols (Je50-2/3a in Soil map of Fig 8) in the Great Ruaha river flood plain, which is a part of extension of the Kilombero basin. The Kilombero sugar cane plantation, 50,000 ha, is operating in the (4A) and (4B) area. The (5)-(7) sites are in the core area of the Kilombero basin (Mk in the Fig 8), located upstream of the Rufiji River. The sites (5A), (5B) and (5C) are near Ifakara town. The sites of (6A) and (6B) are near Itete and (6C) and (6D) are near Mtimbira villages. Sites of (7A) is a Kilombero plantation of 5000 ha. Site of (7B) is near Chita city.

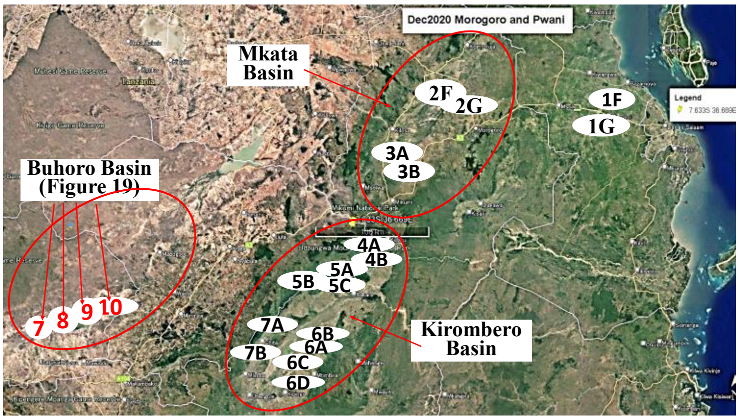


Figure 27: The core rice area in Morogoro and Pwani region (compare to Figure 8). Marker length is 100km

Figure 28. (1G)site. A government-developed (before 2002) irrigated sawah platform of about 1000 ha on the Ruvu River floodplain near Mlandizi in the Pwani Region (6.732S 38.676E). Marker length is 1km.

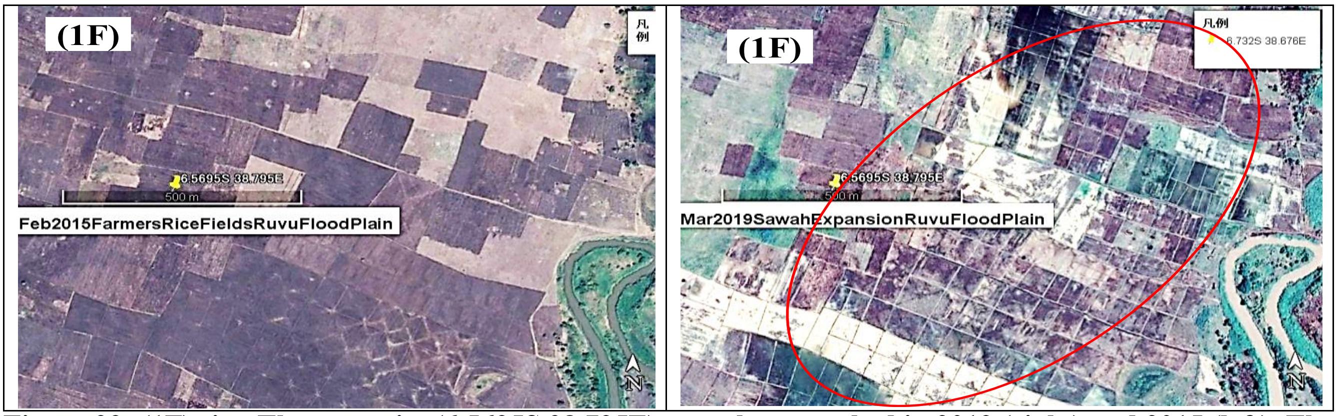


Figure 29: (1F) site. The same site (6.5695S 38.795E) was photographed in 2019 (right) and 2015 (left). The red circle on the left side has stages 4 and 5 sawah platforms which farmers recently developed from stages 1 and 2 in 2015. This site is located in the Ruvu river floodplains between Mlandizi and Bagamoyo.

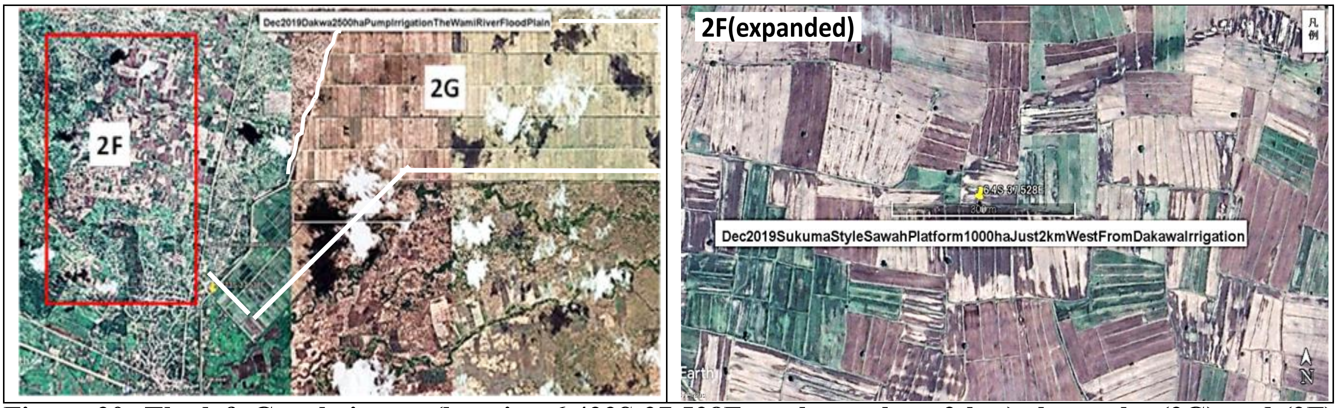


Figure 30: The left Google image (location 6.423S 37.538E, scale marker: 2 km) shows the (2G) and (2F) areas of Figure 27. The white-lined site is a 2500 ha pump irrigated site developed on the Wami River floodplain. The right side photo of (2F) (6.4S 37.528E, scale marker: 300 m) shows Sukuma farmers' 1000 ha irrigated sawah platform (evolutionary stage close to 4), which is the expanded photo of a part of the red rectangular area of the left side image.

Figures 31 and 32 below show expanded Google earth images of the two sites of (3A):6.906S 37.087E and (3B): 6.899S 37.15E in Figure 27, both of which are15km and 20 km southeast from Kilosa town respectively. Both of Fig 31 and 32 show paired Google Earth images taken in 2014 and 2017, which are indicating the rapid expansion of farmers' self-help sawah platform development since 2014. These two sites are 70km southwest from (2G) and (2F) sites of Figure 30, but still in the same Mkata basin as shown in Figure 27. The Wami River flows down from the northwest part of the central city of Kilosa to join the Mkata river and form the Mkata basin of about 1 million hectares, which has a wide distribution of Vertisols and Fulvisols suitable for sawah-based rice cultivation. Currently, most areas are undeveloped. The Mikumi national park is also nearby.

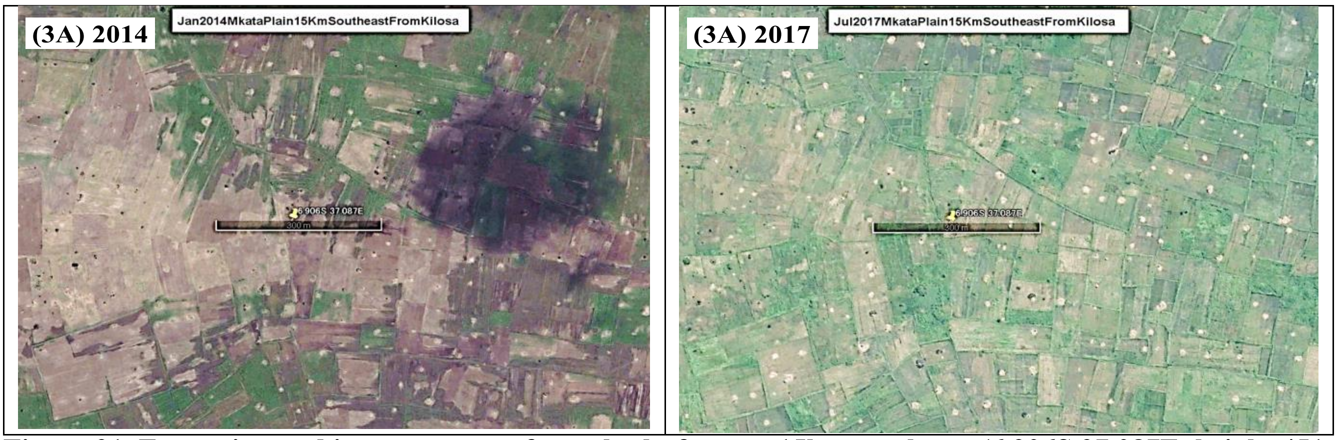


Figure 31. Expansion and improvement of sawah platform at 15km southeast (6.906S 37.087E, height 451-452m) from Kilosa, Mkata plain, in 2014–2017.

Figure 32. Expansion of sawah platform at 20km southeast (6.899S 37.15E, height 438-451m) from Kilosa and 10km west from the Mkata river bottom, Mkata basin, in 2014–2017

The site shown in Figure 31 has 451-452m height, where is 5 km nearer from Kilosa town than the site shown in Figure 32, which has 451-438m height and 10km west from the central stream of the Mkata river of about 420m height. The location of the two Google earth images in Figure 31 is the same (6.906S 37.087E), which indicates that in the Google Earth image in 2014, individual farmers are cultivating rice by developing 0.1–5 ha farm plots surrounded by bunds. Most plots were presumed to be unlevelled evolutionary levels 1–2 of sawah platforms. However, some sawah plots seem to have reached evolutionary level 4. In the 2017 image, most sawah plots seem to have been levelled and reached evolutional level 4. Therefore, it can be assumed that in the vicinity of 6.906S 37.087E sawah based rice cultivation using cattle and tractors has been practised over 1000 ha.
The location of the two Google earth images is the same (6.899S 37.15E) in Figure 32. In 2014, extensive rice cultivation was carried out in non-sawah fields using tractors (evolutionary stage 1). However, in 2017, it can be seen that sawah platforms with evolutionary levels 4 and 5 were developed and in abundance. In addition, similar sawah platform development had already been carried out by 2017 on a scale of several thousand ha by the farmers themselves in the surrounding area. The development from 2017 to 2021 is estimated to have been even more rapid.
As shown in Figure 9, Morogoro has become the largest rice-growing region in Tanzania in recent years. The Mkata and Kilombero basins, each with an area of 1 million hectares, are the major rice-growing areas. Farmers, governments, and private companies are competing, but the contribution of the Sukuma people stand out, who have the most experience in sawah platform-based rice cultivation using animal ploughs and power tillers/tractors among SSA countries, except for in Madagascar. Though Madagascar had been No.1 irrigated sawah based paddy production among the SSA countries, Tanzania will overtake Madagascar within a decade.

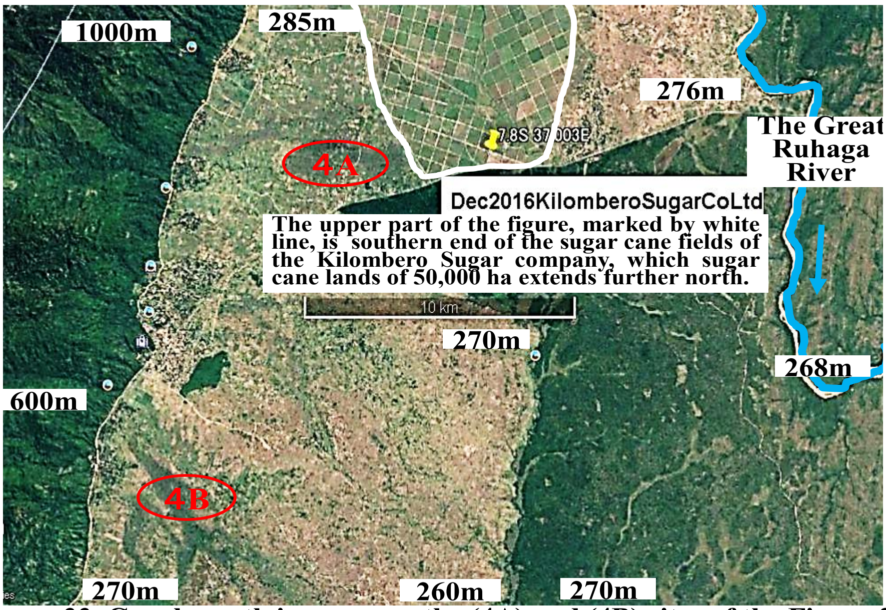


Figure 33. Google earth image near the (4A) and (4B) sites of the Figure 27.

The dark green part on the left side in Figure 33 is a mountain higher than 1000 m in the northern part and about 600-400 m in the southern area. The upper brown-coloured part of the central belt is a 15 km wide floodplain of the Great Ruhaga River, where a plantation company cultivates sugar cane. The river crosses the central part of the 50,000 ha of sugar cane fields from west to east (the crossing line is not shown in Figure 33). The river flows down the right side, as shown by the light blue arrow in Figure 33. The lower part of the brown-coloured part is an old floodplain of the Great Ruhaga River, but now it is an alluvial fan-like floodplain modified by tributaries of the Kilombero River (not shown in the Figure 33. The river flows outside the Figure 33's area). It is complicated due to the influence of crustal movements. The primary soil types are Fulvisols, suitable for rice and sugar cane cultivation. The sugar company's field is 280 m above sea level and 260-270 m at the figure's bottom (south end). The altitude of the green hills on the right side is 280-270 m. The endogenous sawah platform development by local farmers near (4A) and (4B) in Figure 34 are shown below.

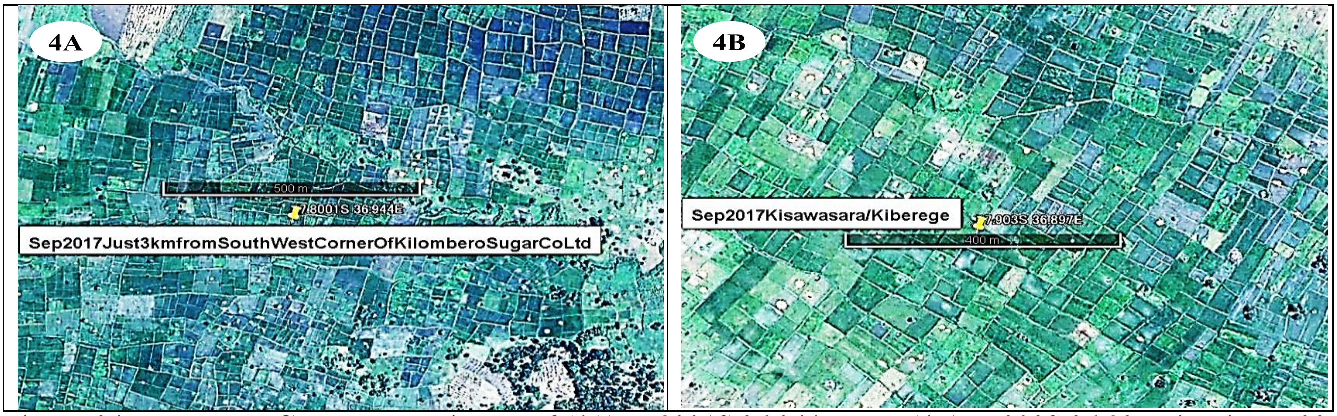
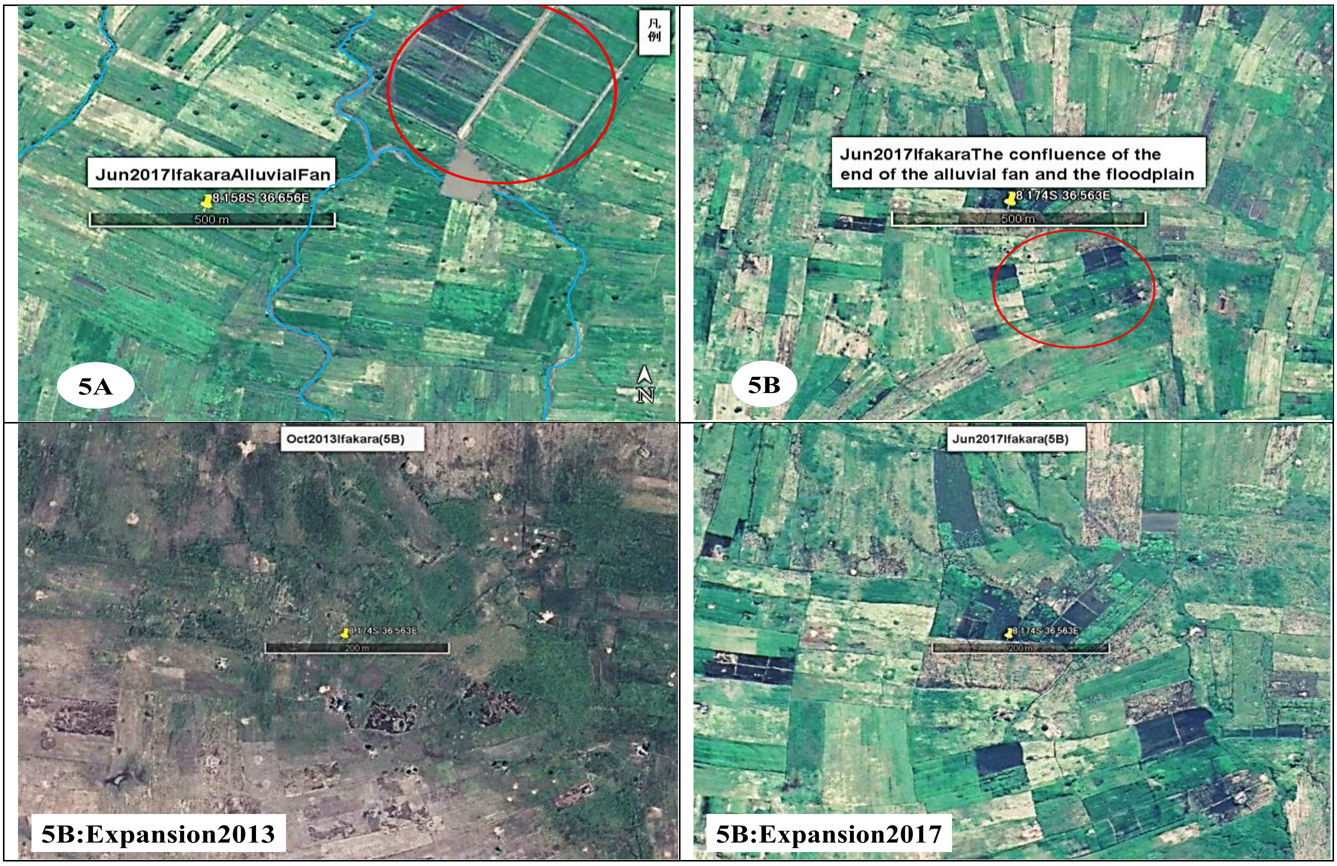


Figure 34: Expanded Google Earth image of (4A): 7.8001S 36.944E, and (4B): 7.903S 36.897E in Figure 33.

The endogenous sawah platform development by local farmers near (4A) and (4B) in Figure 34 are shown below. The evolutionary stage of these sawah system platforms is four. In contrast to the elongated sawah platform shape adapted to the Sukuma cultivation method using cattle plough, many regular square sawah plot fields exist. It is presumed that rice cultivation is mainly done by human power.



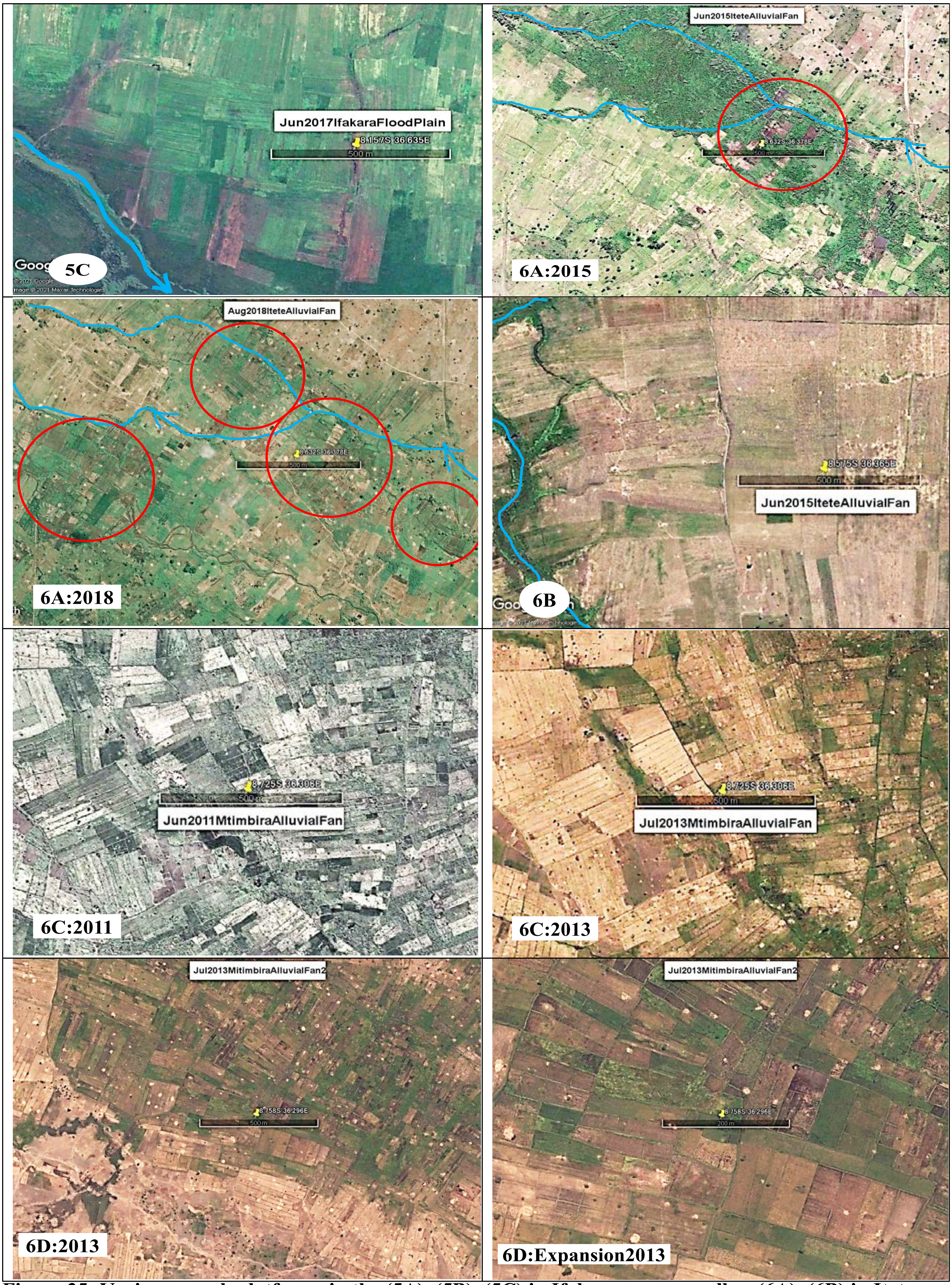


Figure 35: Various sawah platforms in the (5A), (5B), (5C) in Ifakara area as well as (6A), (6B) in Itete aera and (6C), (6D) in Mtimbira areas in Figure 27. 5A: 8.158S 36.656E; 5B: 8.174S 36.563E; 5C: 8.157S 36.635E; 6A: 8.632S 36.378E; 6B: 8.575S 36.365E; 6C: 8.725S 36.306E; 6D:8.758S 36.296E

Locations (5A), (5B) and (5C) are Google Earth images showing rice farming platforms in the alluvial fan to the floodplain in the Ifakara area of Figure 27. Ifakara is located near the basin exit of the Kirombeiro River. In the upper right part of the (5A) location, distinct bunds are constructed using heavy machines to make 1–2 ha sized sawah plots, but it was not sufficiently levelled (within ±10 cm) to standard transplanting or direct sawing practices for rice cultivation. As shown in Google Earth images of (5B) and (5C), as of 2013, 99% of the rice fields in this area have never reached stage 4. However, tractor or cattle cultivation and direct sowing are common, producing poor-quality sawah platforms. The site of (5B) is located at the centre of the alluvial fan. In the (5B) image, the red circle area has some sawah plots with levelled and surrounded by bunds. These sawah plots are clearly identified in the image of (5B:Expansion2017). However, as shown in (5B: Expansion2013), such improvements of the sawah platform began after 2013. Therefore, the evolutionary stage of the sawah platform in the Ifakara area appears, as a whole, to be lower than 4.

Figure 35(6A) to (6D) show the rice farming platforms in the alluvial fan and floodplain at the Itete and Mtimbira villages, which is distributed on the southeastern slope of the Kirombero basin (Figure 27). As shown in Figures 35(6A) and (6B), around the Itete village area, the evolutionary stage 1 sawah platform is common. Farmers use a tractor, cattle ploughing, and hand hoes for direct sowing rice farming. Thus, the paddy yield is less than 2 t/ha. A rare example of stage 2–4 sawah developed by farmers in Itete area can be seen in the lowland of the red-circled area in image (6A:2018). Transplanting is practiced in such sawah plots (Kato 2019). However , as of 2015, the area of such rice cultivation platforms is estimated to be less than a few %.
As shown in Figures 35(6C) and (6D), the Mtimbira village areas have considerable acreage of the stage 4 sawah platform development that can be recognized. However, the quality of sawah plots is generally poor. Although bunds are made and levelled in each sawah plot to some extent, the quality is not good. Irrigation and drainage canal are not properly installed. Bundings are made around the plots and constructed according to the height difference to create a terraced sawah platform system. However, these sawah system platform developments are rarely seen outside the Mtimbira village. In general, the level of water management seemed low. In addition, the levelling of each Sawah plot, which is essential for weed management, also seems insufficient. Therefore, most sawah fields have not reached evolutionary level 4.

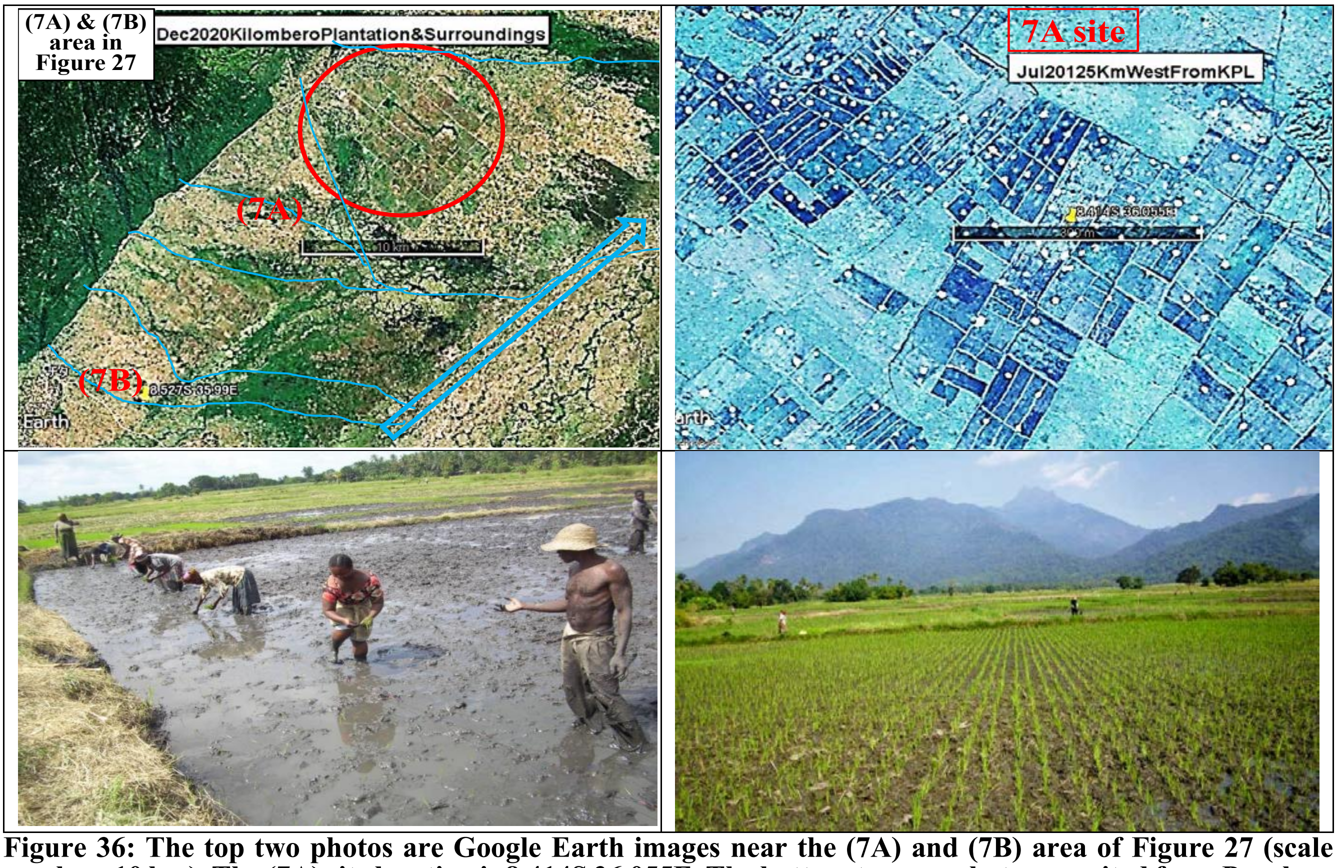


Figure 36: The top two photos are Google Earth images near the (7A) and (7B) area of Figure 27 (scale marker: 10 km). The (7A) site location is 8.414S 36.055E. The bottom two are photos are cited from Penrhys-Evans(2019):https://www.future-agricultures.org/blog/sri-in-kilombero-valley-potential-misconception-and-reality/

The upper left of Figure 36 shows a Google Earth image of Kilombero Plantation Ltd (KPL: Public-private partnership between Rufiji Basin Authority, Tanzania, and Agrica Tanzania Limited) and its surroundings. The total area indicated in this image is approximately 150,000 ha. The large blue arrow at the bottom right side indicates the direction of the main stream of the Kilombero River, which collects water from several meandering diversion rivers. As shown by the blue lines, many small rivers flow from the green-coloured mountains on the left side that forms alluvial fans and floodplains. These alluvial fans and floodplains appear in brown with light green coloured swampy areas. The altitudes of these lowlands are 280–260 m. Thus, the average gradient is about 0.05%, an extremely gentle slope. The total width of the Kilombero Basin is 30–70 km, the length is 200 km, and the total area is approximately 1 million ha. Vertisols are predominantly distributed in the central part of the basin, and Fulvisols are distributed in the alluvial fans and floodplains on the mountainsides (corresponding to the units Vp51-3a and Je50-2/3a shown in Figure 8, respectively), making it a suitable site for a vast irrigated sawah system platform.

The red-circled area of the upper left image of (7A) and (7B) area of Figure 36 shows the irrigated rice cultivation in the rainy season (paddy yield 5 t/ha in 5000 ha of the KPL) and irrigated maize cultivation area in the dry season. The evolutionary level of the sawah platform is estimated to be 5. Approximately 2500 ha of irrigated sawah platforms were developed by Korean technical cooperation (1986–1993) and expanded to 5500 ha by the KPL by 2011. However, since 2018, the KPL has defaulted on these development investment and maintenance costs. The KPL also brought about the loss of rural communities in the surrounding area since they controlled the vast land. For this reason, this kind of large-scale development is considered unsustainable (Oakland Institute 2019, Farmlandgrab.org 2021).

The (7A) site in Figure 36 is an irrigated sawah platform developed by farmers in an alluvial fan several kilometers west of the KPL. The total area is estimated to be approximately 100 ha. Google Earth took this image in 2012. The two pictures below (Figure 36) are a sawah platform of evolutionary stage 4 taken near this (7A) site, showing farmers transplanting young rice seedlings in a standard Asian style rice cultivation as well as so called "System Rice Intensification(SRI)" manner (Penrhys-Evans 2019). As of 2012, the rice farms of farmers around the KPL are estimated to be over 10,000 ha. Most appear to be sawah platform evolutionary stages 1–3. However, based on the photographs taken in 2019, paddy production in Morogoro in recent years reached 300,000 tons (Figure 9). In 2016/2017, the author estimated that farmers' sawah platform development would expand and improve rapidly from 2012 to 2021.

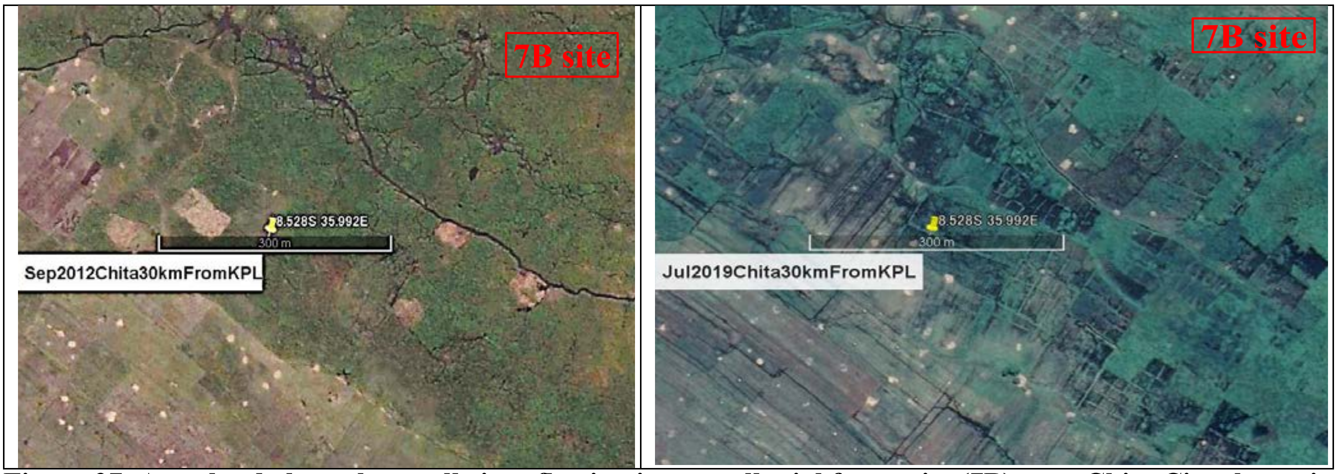


Figure 37: A wetland along the small river flowing into an alluvial fan at site (7B) near Chita City shown in Figures 27 and 36. This site is about 30 km southwest of the KPL (8.528S 35.992E). The left image was taken in September 2012, and the right in July 2019.

On the left side image of Figure 37, there are no sawah plots in 2012. However, the right side in 2019 Google Earth image of the same location shows approximately 20 ha of levelled and bunded sawah plots (evolutional stage 4) have been developed. The elongated plots without bunds seem to be ploughed by cattle. However, as of 2019, most farmers' rice fields near Chita City are estimated to be the sawah platforms of evolutionary stage 1 or 2.

2-3. Sawah system evolutional stage of Uganda, Kenya, Burundi, Rwanda, Malawi and Zambia

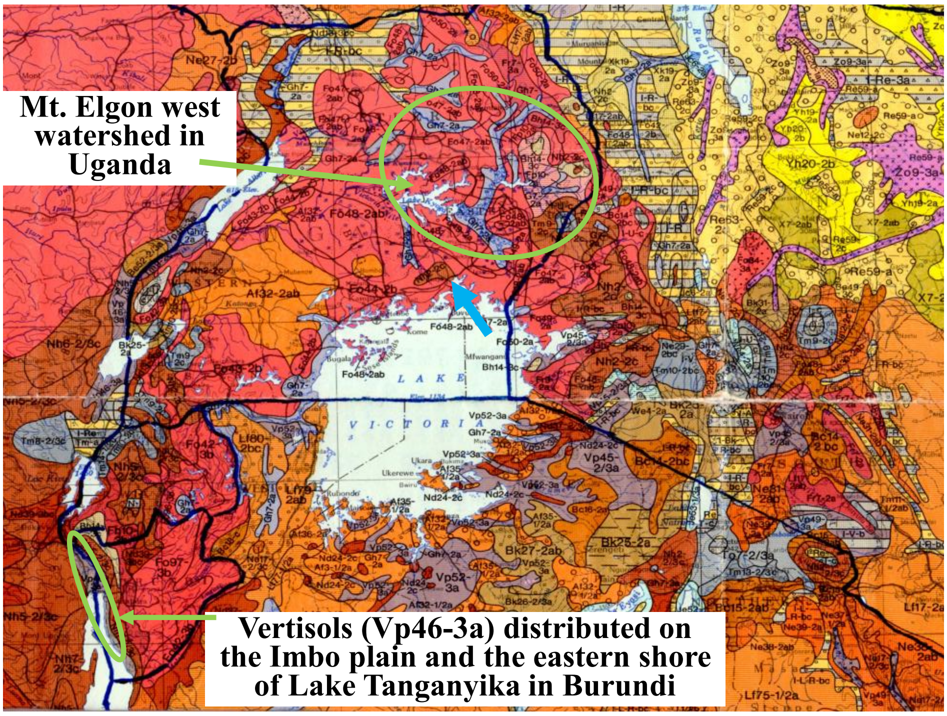


Figure 38. Soil map of Uganda, Kenya, Rwanda and Burundi (FAO-Unesco 1977)

2-3-1. Uganda

The distribution characteristics of rice production areas and soil types in the countries surrounding The United Republic of Tanzania were summarised. Uganda, located north of Lake Victoria, has an exit (blue arrow) of the White Nile. The main stream of the White Nile merges with rivers flowing from the foot of Mt. Elgon (Figure 39 below) on the Kenyan border, forming a part of the source of the Sudd inland delta in South Sudan. Approximately 1.8 million ha of fertile alluvial soil types, i.e., Humic Gleysols (Gh7-2a), are distributed in these water source areas in Uganda (Figure 39 below, cited from FAO-Unesco, 1977). Irrigated sawah platforms developed by farmers and by Official Development Assistant (ODA) of China and Japan are distributed on these soil types (GH7-2) near Doho (Figures 38-40).

Kenya's Ahero area has some endogenous irrigated sawah platform development on the clay-like fertile Vertisols (Vp45), similar to the Vertilsols (Vp 45 and 52) distributed in the Sukuma land in the Southern areas of Lake Victoria, as shown in Figure 38. The evolution level of these sawah platforms seems to be at stages 4–5.

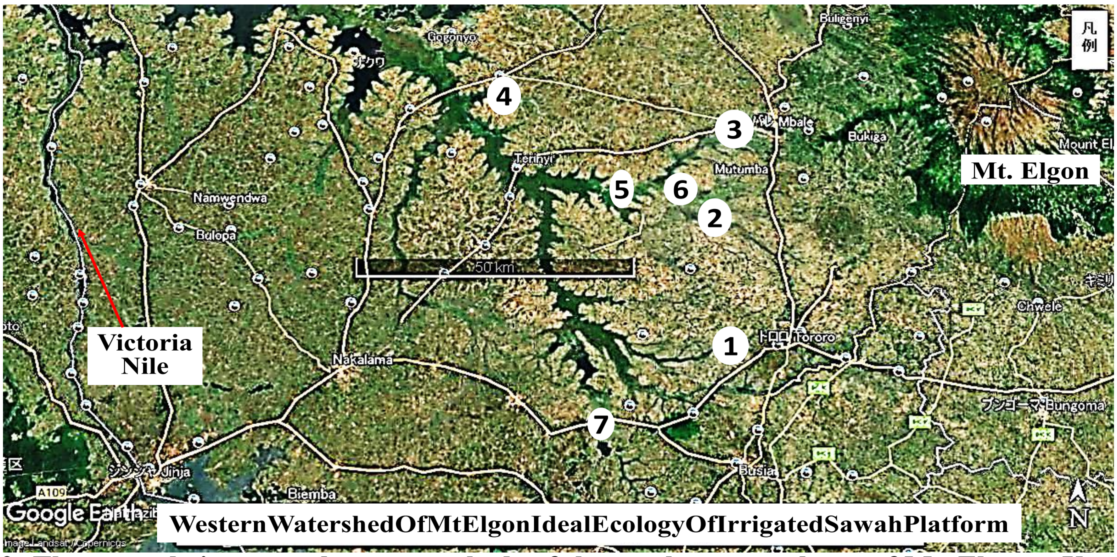


Figure 39: The central rice area along watersheds of the southwestern slopes of Mt. Elogon, Uganda. The Humic Gleysols (Gh7-2a) in Figure 38 are the primary rice soil type in lowlands in these watersheds.

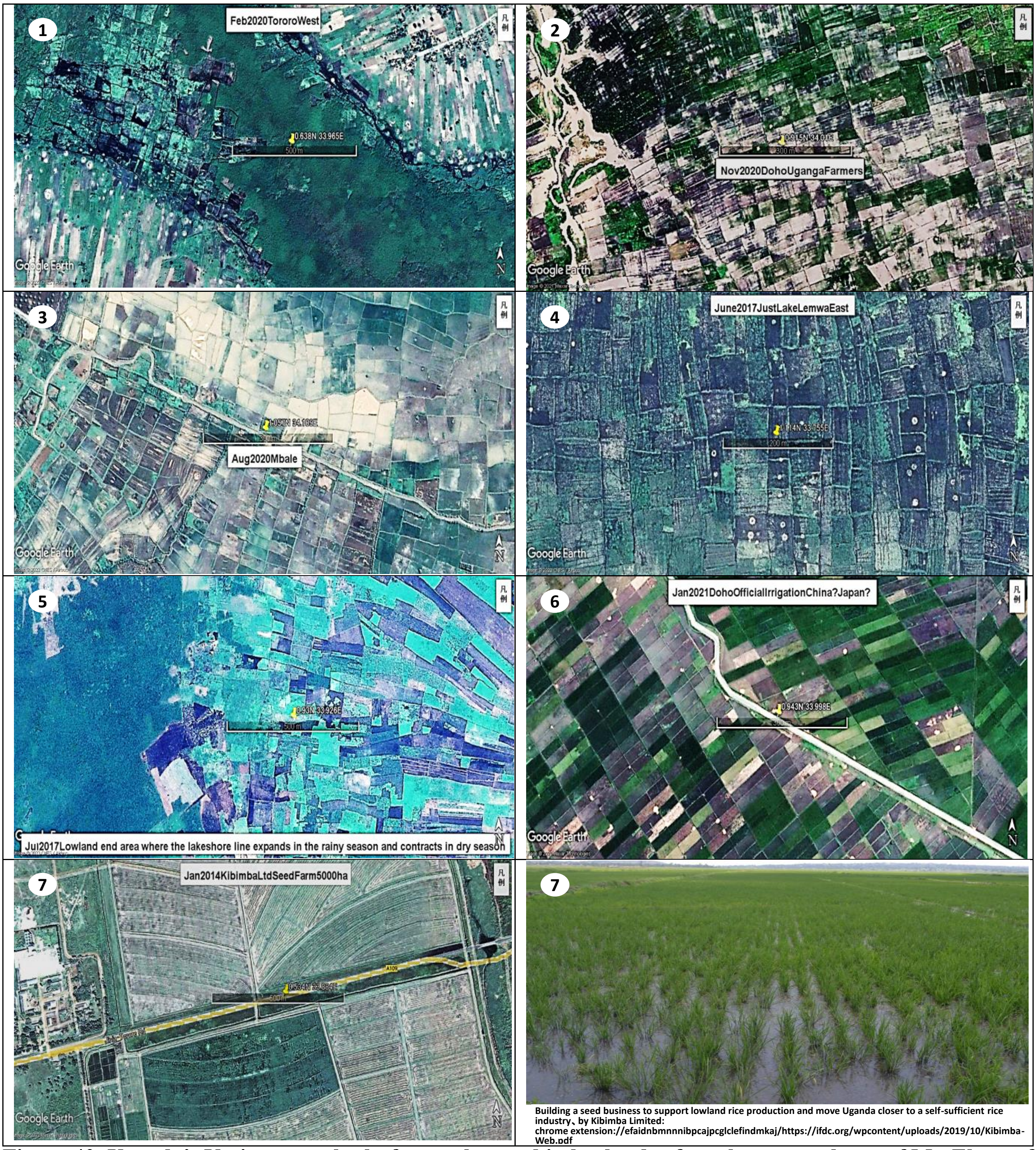


Figure 40. Uganda's Various sawah platforms observed in lowlands of southwestern slopes of Mt. Elgon of Figure 39.

Site (1) is a sawah platform at evolutionary stages 1–2, 30 km west of the Malaba Kenya border, with an altitude of 1081 m. The wetlands in this area are government-managed nature reserves and are underutilised by farmers. However, since 2005, the value of rice cultivation has been recognized, and farmers have had frequent disputes over developing new rice land in the wetlands. The site at Doho south has evolutionary stages 2–3 and stage 4 sawah platforms at an altitude of 1075 m. The altitude at Mbele is 1093 m and irrigated sawah platforms at stages 4, and 5 can be found. The sawah platforms at site four are mainly at stage 2, with some at stage 4 at an altitude of 1047 m. Some sawah platforms at site (5) are at evolutionary stage 4, but most are at evolutionary stage 1–2. These platforms are located at an altitude of 1066 m. The Doho official irrigation site is approximately 2000 ha at an altitude of 1091–1072 m.

Site (7) is evolutionary stages 4 and 5 sawah platforms, initially supported by China in the 1970s and are currently supported by the Kingdom of the Netherlands, IFDC, and Cardno. Sawah platform at level 5 are planted with rice using rice transplanters. The photo of the right side of (7) shows levelling quality is poor. Many defective spots are found in the rows of seedlings that are thought to have been mechanically transplanted.

2-3-2. Kenya

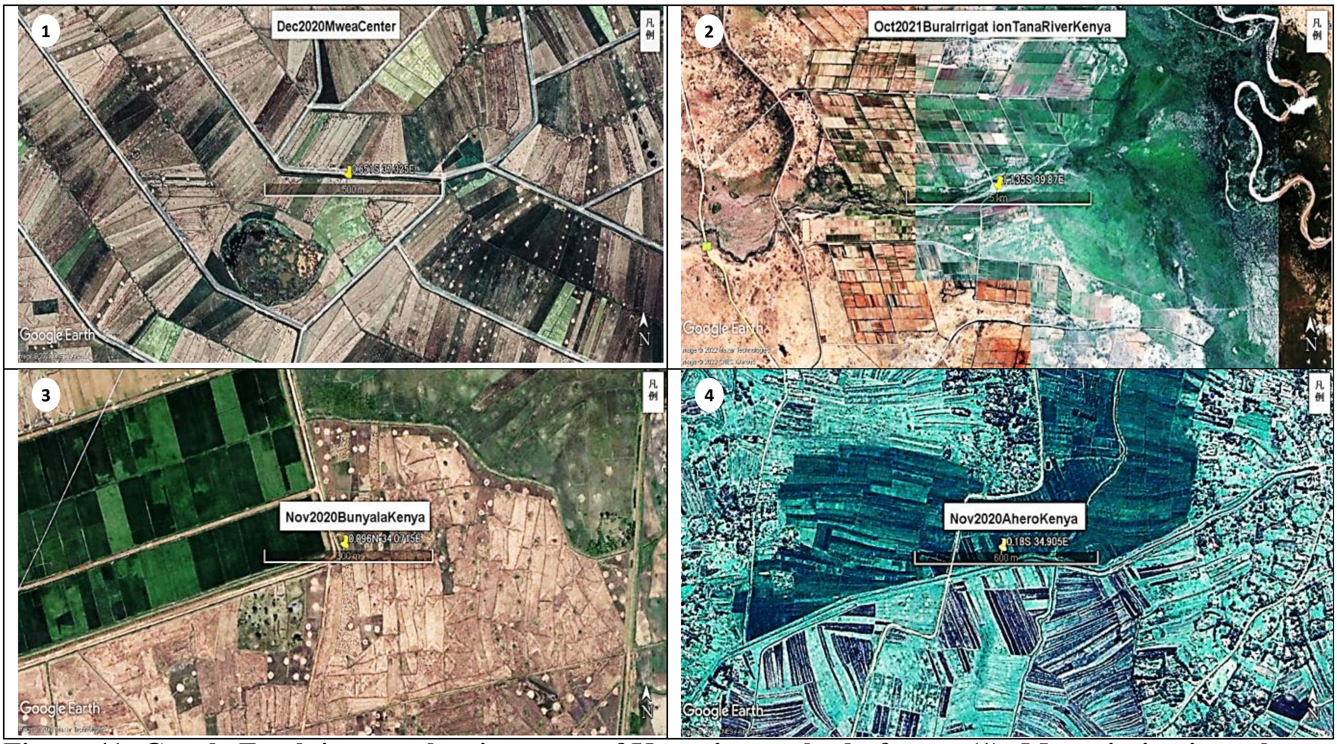


Figure 41: Google Earth images showing some of Kenya's sawah platforms: (1): Mwea irrigation scheme, south of Mt, Kenya; (2): Bura irrigation along the Tana river; (3): Bunyala irrigation scheme; (4): Ahero farmers' endogenous sawah platform. Both (3) and (4) are developed along the east shore of Lake Victoria.

More than 80% of paddy production comes from the (1) Mwea irrigation scheme, which is 15,000 ha (National Irrigation Authority, Kenya 2022). The evolutionary stage 5 or 6 is fully mechanised rice farming. However, the Mwea scheme has been based on continuous foreign technical and financial assistance for more than 50 years, and self-development by the Kenyan government and farmers seems impossible. This is different from Tanzania and Uganda. Unlike Kenya, Tanzania and Uganda seem to emphasize the development of an endogenous sawah platform based on self-help efforts rather than relying excessively on ODA. As for the Bura scheme (2) in the Tana River floodplain, a 10,000 ha or more irrigation scheme was developed by foreign ODA, but due to the lack of available irrigation water, it currently contributes little to paddy production in Kenya. It seems that some areas of both (3) and (4) sites can be applied to Sukuma's rice cultivation platform, such as in the Mwanza region of Tanzania. However, the irrigation scheme at site (3) is an ODA-dependent sawah platform at evolutionary stage 5 (like Mwea). Although mechanized rice cultivation is being carried out, it seems challenging to expand the area. The (4) area can use the Mwanza method, as shown in Figure 10–12, but the platforms are at evolutionary stages 1–2. Therefore, it seems necessary to shift to a rice cultivation promotion policy through farmers' ingenuity and self-help efforts.

The soil map shown in Figure 42 below is a primary source of information for finding suitable areas for irrigated sawah platform development (Sombroek et al., 1982). As of 2022, by comparing this soil map with the development area of irrigated sawah fields in Kenya, we consider the areas suitable for future irrigated sawah development, especially the areas with farmers taking the lead and government support. Blue coloured areas in yellow circles (M) and (MS) indicate Vertisols soils suitable for sawah platform development. The altitude is about 1100 m. (M) corresponds to 15,000 ha of irrigated sawah platform at Mwea. Approximately 15,000 ha of various sawah platforms, evolutionary stages 1–5, have been developed in (MS), south of Mwea, but the rice cultivation area is small due to the lack of irrigation water. About 1 million ha of Vertisols are distributed in the (N-R):Nanyuki-Rumuruti area, in the northwestern direction of Mt. Kenya, and (T-M):Thika-Machakos area, in the southwestern direction of Mt. Kenya. However, rice cultivation in these Vertisols areas is impossible due to the low temperature in the highland (N-R) area (altitude of 1800–2000 m) and a lack of irrigation water due to the dry climate (T-M) (altitude of 1500–1600 m).

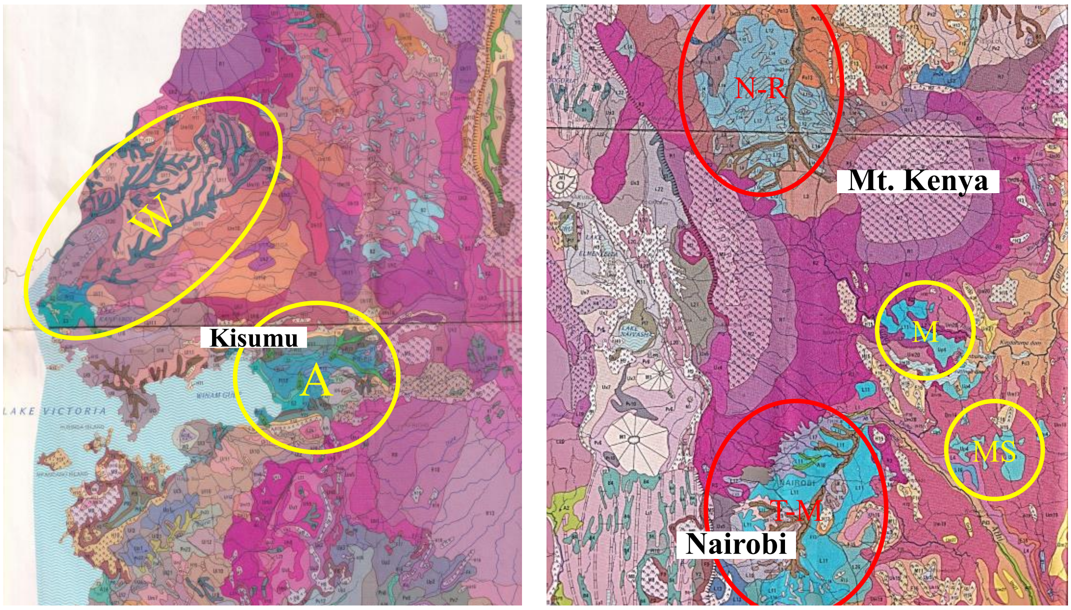


Figure 42. Exploratory soil map of Kenya (Sombroek et al 1982) and new sawah platform potential area

In contrast, in (A), the Ahero area on the shore of Lake Victoria, and (W), the Webuye river basin, which is the catchment area of the southeastern slopes of Mt. Elgon, the irrigated sawah platform potential is 3–4 times higher than in the Mwea area, which should be more significant than 20,000 ha. If a policy is adopted to support irrigated sawah platform development through encouraging self-help efforts similar to the Sukuma farmers in Tanzania, it would be possible to increase the current paddy production in Kenya by 2–3 times within 10 years.

2-3-3. Rwanda

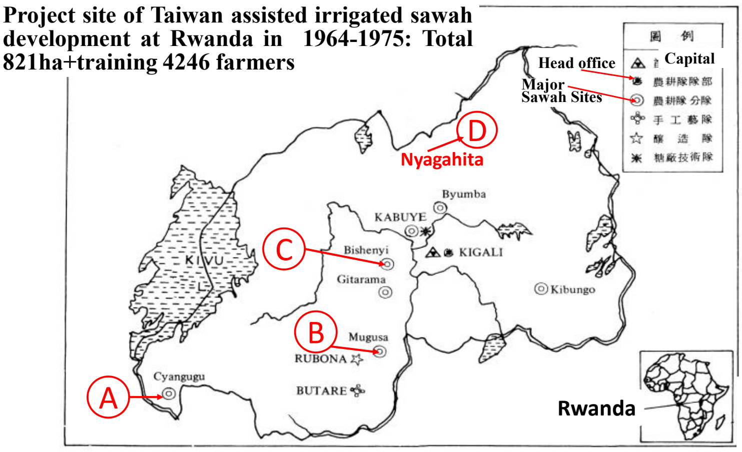


Figure 43: Demonstration and training sites of Asian-style irrigated rice cultivation supported by the Taiwan team in Rwanda in 1964–1975 (Hsieh, 2001 and 2003, Wakatsuki and Hsieh, 2003). Sawah platforms of (A): Cyangugu, (B):Mugusa, (C):Bishenyi, and (D): Nyagahita are shown in Figure 44 below. Please note that (D) was developed by the Rwanda government after 2012.

As shown in Figure 43, Rwanda's sawah-based rice cultivation started in 1962–1972 with technical cooperation from the Taiwanese team. Taiwan selected seven significant areas and developed a total of about 1000 ha in more than 10 sites throughout Rwanda. Through these activities, the Taiwan team transferred the sawah system development and sawah-based rice farming technology through on-the-job training to train more than 4,000 farmers, extension officers, and engineers.

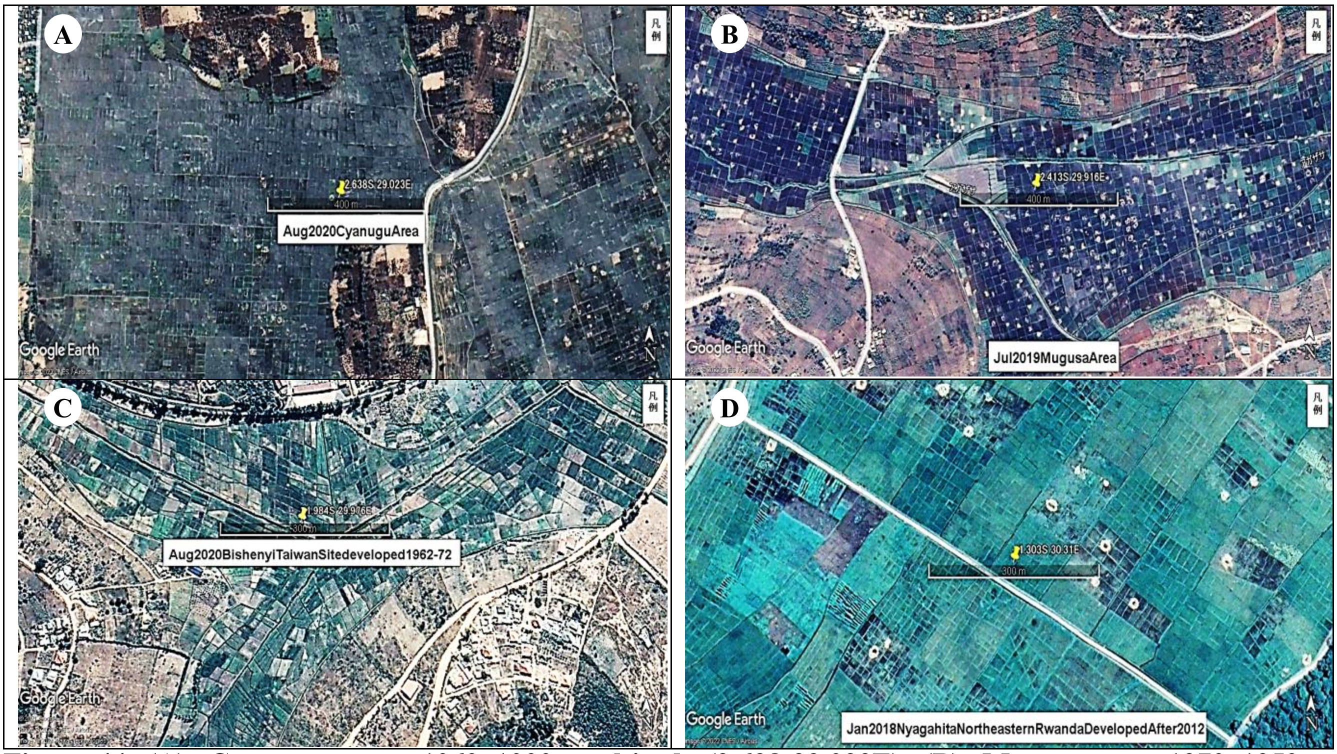


Figure 44: (A): Cyangugu area, 1060–1000 m altitude (2.638-29.023E); (B): Mugusa area, 1370–1350 m altitude (2.413S 29.916E); (C): Bishenyi area, 1380–1360 m altitude (1.984S 298.976E); (D): Nyagahita area, 1350–1345 m altitude (1.303S 30.31E). As shown in the Google earth image of Nyagahita area, after the Taiwanese team's assistance, the Rwanda government and farmers have expanded and maintained the stage 4 and 5 sawah platforms.

Rwanda is blessed with fertile volcanic soil, has a high population density, and has an ecological environment and well-organized social infrastructure. Figure 45 indicates the terraced agricultural land at Byumba, somewhat similar to Indonesia in Asia, and it is thought that it was relatively easy to accept Asian-type rice cultivation. Sawah-based rice cultivation has expanded even after the Taiwanese team left in 1975 (Figure 43(D): Nyagahita area). Despite the catastrophic civil wars and genocide in 1994, sawah rice cultivation has expanded rapidly since 2000, and the evolution level of the sawah platforms is at the top compared to Senegal and Madagascar among SSA countries. Thus, paddy yields exceeded 4.5 t/ha on average in 2011–2015 (FAOSTAT, 2020).

Figure 45: Traditional terraced farmlands near Byumba city. The ridge height (northeast end, yellow rectangle) is approximately 2150 m. The red-circled area shows a good tea plantation developed in the valley, with a height of approximately 1850 m. Residents live in villages and towns on the ridge. Byumba is about 2 km east on the ridge from the northeast end of the figure, with an altitude of about 2250 m. The scale marker length is 500 m.

2-3-4. Burundi

In Burundi, about 200,000 ha of Vertisols suitable for rice cultivation are distributed on the Imbo plain (Figures 8 and 38). The distribution of the Vertisols extends from Cyangugu (Figure 43), a town on the southwestern border of Rwanda, through Bujumbura, to Nyanza, a town with the same name as Kenya's Nyanza province, which is in the vicinity of Kigoma on the northeast shore of the Lake Tanzania. Some irrigated sawah platforms are being developed by refugee people from Rwanda, who might have some knowledge of the Taiwanese style sawah technology taught from 1962–1972 in Rwanda.

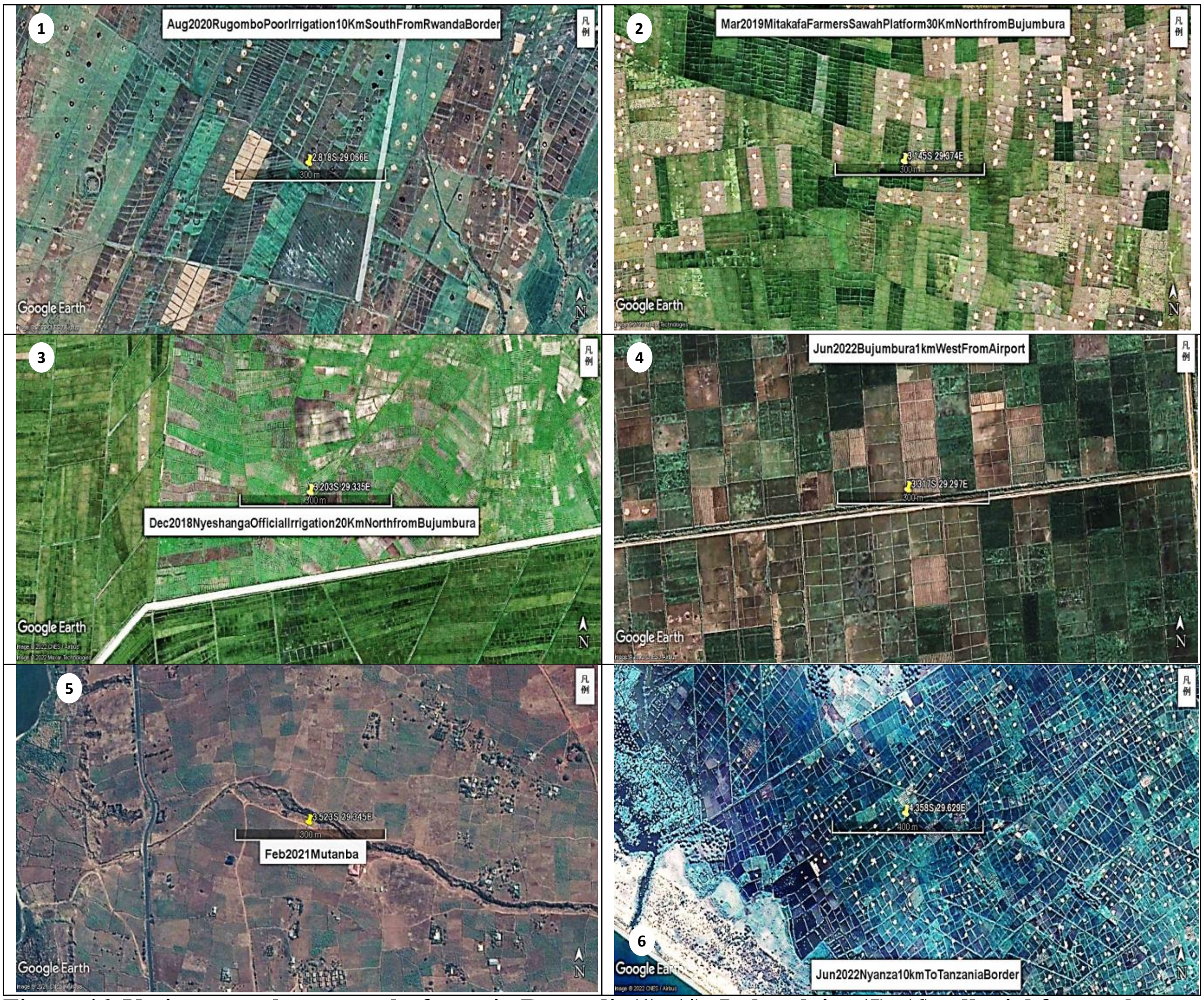


Figure 46. Various sawah system platforms in Burundi. (1)–(4): Imbo plain; (5)–(6): alluvial fan on the east bank of Lake Tanganyika. (1): Rugombo (10 km from Rwanda Border: 2.818S 29.066E, 900 m altitude); (2): Mitaka farmers' irrigated sawah (30 km north from Bujumbura: 3.145S 29.374E, 857 m altitude); (3): Nyeshanga official irrigated scheme (20 km north from Bujumbura: 3.203S 29.335E, 822 m altitude); (4): 1 km west from Bujumbura airport (3.317S 29.297E, 777 m altitude); (5): Mutanba (3.523S 29.345E, alluvial fan of 800–900 m altitude); (6): Nyanza (4.358S 29.629E, 300 ha of irrigated sawah platforms developed on an alluvial fan of 775–790 m altitude, 10 km from the Tanzanian border).

However, the former colonial powers, Belgium and Germany, do not have the technical background for rice farming in irrigated sawah platforms, and the extreme deterioration of security due to the Tutu and Hutu wars, which have the same roots as the civil war in Rwanda, continues. Thus, as shown in Figure 46, most of the evolutionary stages of sawah platforms are look like stage 4 and 5 but practical water management level is considered to lower than 4. Both must be official irrigation schemes in the Google Earth images of (1) and (3). Most farmland plots of 100–300 m^2 are intertwined vertically, horizontally, and diagonally. Irrigation canals and natural rivers are also intertwined, making water management difficult. Site (2) seems to be an example of an endogenous sawah platform development by farmers. Water management seems close to the sawah platform evolutionary stage 4, in conjunction with examples (4) and (6). The current problem with the Imbo plain's irrigated rice cultivation is that both irrigation systems and sawah platforms are poor. Thus, good agronomic practices cannot work due to poor water control, the poor performance of suitable varieties, and other agronomic practices. In addition, the Rusizi River, which flows through the Imbo plain, connecting Lake Kivu and Lake Tanganyika, cannot be used for irrigation due to alkalinity salt damage to the plants.

2-3-5. Zambia

Figures 47–49 show the sawah platforms in Zambia's main rice-growing areas. The potential of Zambia's irrigated sawah-based rice cultivation area is estimated to be 2 to 3 million ha, which is comparable to that of Tanzania. However, the sawah platforms for rice cultivation are mainly evolutionary stages 1–3. Thus, the national paddy yield is less than 2 t/ha and annual paddy production in 34000 ton in 2016-2020 mean (FAOSTAT 2022), No. 28 position among SSA countries.

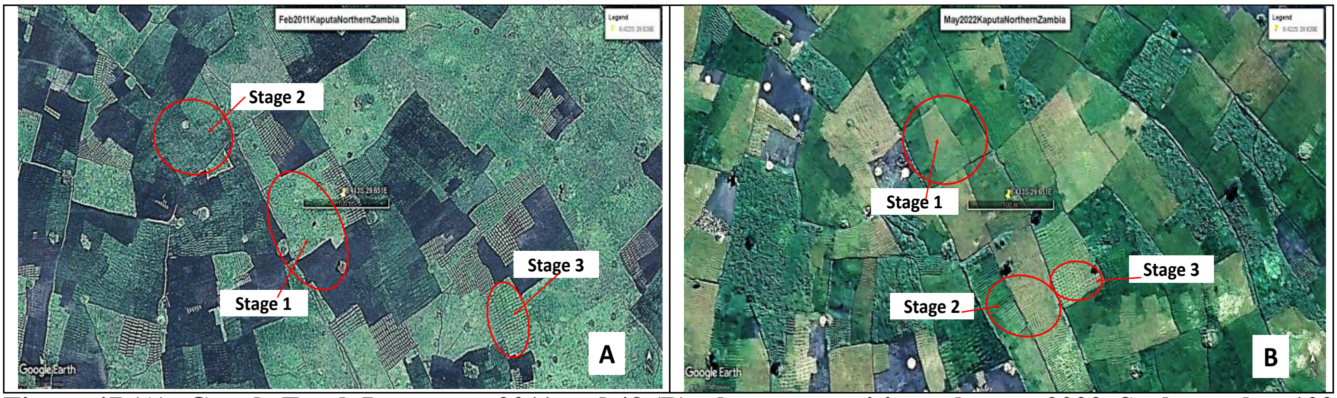


Figure 47 (A): Google Earth Images on 2011 and 48 (B): the same position taken on 2022. Scale marker 100 m. Sawah platforms of evolutionary stage 1 (non-sawah field), 2 (ridged rice cultivation), and 3 (rudimentary micro sawah) can be identified. These are developed in the alluvial lowland formed on the north side of Lake Mweru Wantipa near Kaputa, a rice centre in Zambia. GPS position is 8.413S 29.651E. Altitude is 950–960 m.

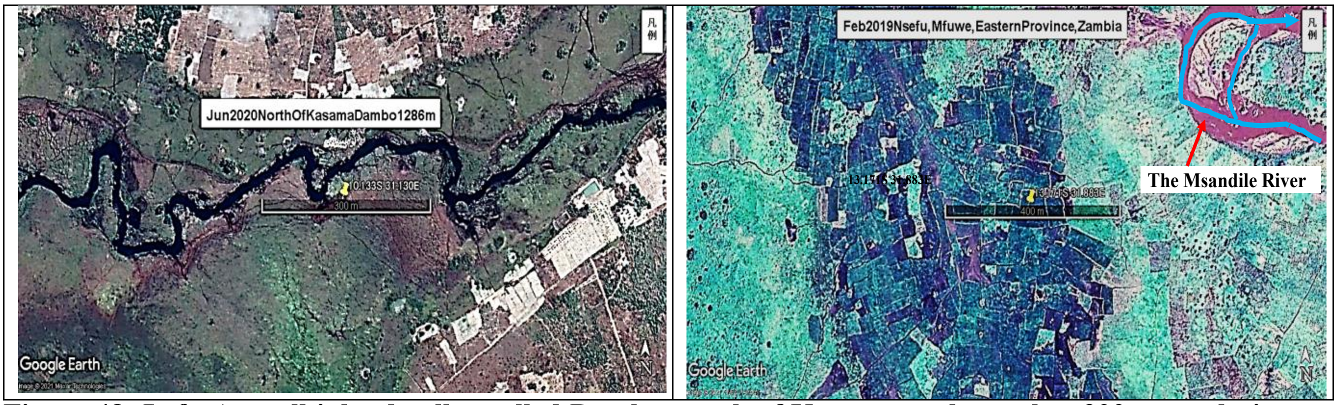


Figure 48: Left: A small inland valley called Dambo, north of Kasama, scale marker 300 m, evolutionary stage 1, non-sawah plot. GPS position 10.133S 31.13E; Right: Nsefu, near Mfuwe, scale maker 400 m. GPS position is 13.171S 31.883E. Rice fields are in the back swamps of the Msandile river shown by the blue arrow, which is a tributary of the Luangwa river.

The Msandile river floodplain is extremely flat (a gradient of 10 cm or less at 100 m) and approximately 541 m above sea level. It seems that the rice fields have a high degree of levelling naturally. Thus, each sawah plot can be made by bunding on a scale of 0.1–1 ha. However, since it is challenging to control irrigation and drainage artificially, the evolution level of the sawah platform is a mixture of 1–5 elements (average 3?).

Figure 49: Left: The Google Earth image shows the Zambezi floodplain 30 km wide near Mongu-Limulunga in western Zambia (scale marker 10 km). There is a road leading to Angola that crosses the floodplain. Right: The expanded Google Earth image near Limulunga in the upper right of the left side of Figure 49 (scale marker 400 m). The blues line indicates the irrigation canals, which intake water from the main stream of the Zambezi River. There are rice and vegetable fields on both sides of the waterway. The evolutionary stages of the sawah platforms are estimated to be 1 and 2.

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