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Sawah Technology (3Paper) Principles: *Sawah* hypothesis (1) the platform for scientific technology evolution and *Sawah* hypothesis (2) the platform for sustainable intensification in watershed agroforestry (Africa SATOYAMA System)*

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Summary

Sawah is Malay-Indonesian terms to describe man-made enclosed rice fields to facilitate water control. Essential component of standard *sawah* system is farmers' fields' demarcation by quality bunds (ridges or levees) based on topography, hydrology and soils. The basic facilities are (1) bunding with appropriate height, width with compaction/surface sealing to control leakage, (2) levelling surface soil within 10cm height difference within one *sawah* plot bunded, (3) water inlet connecting to water sources and water outlet to drain, (4) ordinary surface of sawah is puddled to facilitate levelling for water and weed control.

Sustainable lowland rice production is realized by co-improvement or co-evolution of both (1) varietal improvement through biotechnology and (2) *sawah* system improvement and evolution through ecotechnology of the farmers' rice fields. Compared to biotechnological science, technology and innovation (STI), the eco-technological STI for improvement of rice growing ecology, i.e.,*sawah* system evolution, has been largely neglected in SSA during the last 50 years. Although all three GRs have been available during the past 50 years, they have not been effective at majority of farmers' fields in SSA. Almost all institute-based technologies could not scale up to farmers' fields. Thus, the GR has never been realized. All scientific technologies essentially have limited operational platform conditions. As shown in this paper, farmers' fields have to improve to the evolutional stages of *sawah* higher than 4th for animal cultivation or 5th stages for power-tiller cultivation among the six evolutional stages, i.e., standard *Sawah* plots, which have irrigation/drainage and are surrounded by quality bund to stop water leaking and the inside of *sawah* plot has leveling quality of ±5cm (*Sawah* Hypothesis 1: Scientific platform). The size of one *sawah* plot has to be big enough area, >100-200m^2, to make possible water management of rice cultivation area that can preserve livelihood of each farmer, which can be estimated

to be about 1 ha or more. This sawah size is also important to manage by one family with smooth operation of animal plow or powertillers cultivation. The advanced irrigated and drainaged large *sawah* plots have >0.3-1ha with quality bund and leveling quality of ±2.5cm in a large sawah plot using laser lever tractor (Stage 6 th). The rudimentary stages of *sawah* plots are bushy non *sawah* both upland and lowland open rice fields (Stage 1 st), lowland ridge planted rice, i.e., no leveling, with land demarcation bunds and with or without irrigation (Stage 2nd) , lowland micro rudimentary *sawah* plots smaller than 30-50m^2 with poor bunds and with or without irrigation (Stage 3rd). The intermediate stage *sawah* systems between the 2nd , 3rd and the 4th are also common in many irrigation schemes in Nigeria, Mali and Tanzania. The characteristics of the intermediate *sawah* systems are ①The cultivation of livestock utilization is common, thus ②bunded demarcated land use plot's shape is long and narrow, typically 100m long and 5m width, and ③ micro *sawah* plots or ridge planting inside of the bunded demarcated land use plots.

As we described in the separate paper, **'*Sawah* technology (4paper, 4ppt) Practices and Potential of Irrigated Sawah System Development by Farmers Self-help Efforts**, the *sawah* technology will make possible 'Site specific farmers' personal irrigated *sawah* system development and *sawah* based rice farming by farmers' self-support efforts'. If *sawah* system and *sawah* mamagement skills can reach to the standards levels, the *sawah* can improve irrigation and fertilizer efficiency, and thus can cope with water shortages & excess and poor nutrient supplies (especially N & P as well as Si, Ca, Mg and K). It can also neutralize acidity and/or alkalinity, thus improve micronutrient supplies. With this, the improved HYVs can perform better and we will be able to realize Green Revolution in Africa. Through the control of water and puddling, weeds can be also controlled. The lowland *sawah* system can thus sustain rice yields higher than 4 t/ha through macro-scale natural geological fertilization and micro-scale mechanisms to enhance the supply of various nutrients (*Sawah* hypthesis 2: Intensive sustainability platform). For optimum results, appropriate lowlands must be selected and developed at least to standards quality of *sawah* system, and soil and water of *sawah* systems must be managed properly. If we can also apply improved agronomic practices such as System Rice Intensification (SRI) or others under the advanced *sawah* system platform, paddy yields can exceed 10 t/ha. However without advanced *sawah* foundation, such improved agronomic practices are useless and innovations are impossible.

What is the core strategy to realize the rice green revolution in Sub Saharan Africa (SSA)? There are 6 on-going major strategies to realize rice revolution in SSA. **(1) Biotechnology priority, such as upland NERICA, targeting current bushy open non-consolidated farmlands.** This is the mistaken strategy that good variety can solve major low productivity problems even in current bushy open non-consolidated farmlands in SSA. **The (2nd) is the introduction of Asian green revolution (GR) technology.** Among the three GRs, high-yielding varieties (HYV) was core with irrigation/drainage and fertilizer/agrochemical input in Asia. This strategy is only effective on the irrigated *sawah* fields of quality infrastructure consolidation. However among the estimated potential irrigated rice land, *sawah,* 50 million ha, only 2 million ha, less than 5%, are irrigated including micro *sawah* plots. Thus this strategy has no priority currently. As we described as *Sawah* Hypothesis (I), the success of the Asian green revolution was based on the prehistory that the *sawah* systems had been developed by farmers before GRs arrived in 1960s during last hundreds and thousands years. The same thing is true to the British Agricultural revolution in 18th century, which was realized based on the long continued enclosure movement during 15th to 18th centuries. Unfortunately SSA has no such history. The 500 years of history of slave trade and colonial rule had been disturbed such nation building ground works. **The (3rd) is the introduction of advanced agronomy and hybrid seeds for super high yield.** This strategy has only reasonable cost performance in the fields with advanced sawah of quality infrastructure consolidation in the region and countries no more frontiers space for new sawah development such as System Rice Intensification technology (SRI) in Madagascar and Asian countries. **The (4th) is contractors based irrigated sawah system development using ODA funds such as World Bank, African Development Bank and other donors.** Since farmers, extension officers, engineers, scientists and policy makers in SSA have no or very limited knowledge, experience, and skills on irrigated sawah based rice cultivation, investment cost for development, management, rehabilitation and training costs are all expensive compare to Asian countries. Both environmental and social degradation are often serious, such as land grab, land conflict, and corruption as well as lowland submergence by dam, topsoil erosion, and forest destruction. ODA projects are also likely to destroy autonomy of African government. **The (5th) is Irrigated *Sawah* System Development by Private Big Business Enterprise.** The private business based irrigated *sawah* system developments are more efficient than ODA based projects. However still similar environmental and social degradations have to consider. The investment and technology gap between SSA farmers and big business enterprises are too big to fill. In addition, the private big business farms will enclose a big good lowlands of the nation, i.e., land grab. Numerous small farmers who are the most important national resource will be excluded from autonomous rice cultivation and empowerment. **The (6th) is our *sawah* technology strategy for endogenous *sawah* system development and *sawah* based rice farming with sustainable mechanization.** As described in this paper, SSA needs *sawah* system development for rice green revolution. In order to realize this target, SSA needs the innovative technology for breaking through the two big barriers of both area and time, i.e. 50 million ha of irrigated *sawah* system development by 2050, within several decades, not historical several hundred years like Asia and British, before the explosion of population bomb. Among the 6 strategy, only our S strategy will make possible these two targets above.

Introduction

In 1935, Dr. Gonjiro Inazuka, a rice breeder at Iwate Prefectural Experimental Station, Japan, successfully bred the NORIN-10 variety of wheat. This was collected in 1948 after World War II by scientists of US-occupied forces in Japan. In 1953, the variety was transferred to Dr. N. Borlaug at Chapingo, Mexico. By 1957, Dr. Borlaug used the NORIN-10 to quickly breed and released 14 high-yielding wheat varieties. This was the start of the dramatically successful green revolution innovation (GR) and the start of the Consultative Group of International Agricultural Research (CG) centers in the 1960s and '70s (Evenson and Gollin 2003, Hesser 2006, Hardin 2008, Renkow and Byerlee 2010). The NORIN-10 was the first crop variety in which the characteristics of a semi-dwarf gene, *sd1* to realize high yield, were identified. The Miracle rice of IR-8 was bred by IRRI through the application of the same concept which developed by Dr. Inazuka. We now know that all high-yielding varieties (HYVs) of wheat, maize and rice of the *Gramineae* family have the same *sd1* gene (Ashikali et al. 2002, Matsuoka 2004). Thus Dr. Gonjiro Inazuka is actually the "grandfather" of the GR.

The green revolution from semi-dwarf gene (sd1) crops from Japan originally was named for increased food production in Asia and Latin America, but in parallel with that, it also contributed to the increase in wheat production in Europe and the United States of America in the same time. The yield of wheat and core increased dramatically since 1950 as shown in Figure.10 in this paper, the green revolution of advanced European countries (Nishio 1998, Borojevic and Borojevic 2005).

As described in ***Sawah* Technology (2)Background,** we can summarize major contributors of Science, Technology, and Innovation (STI) in Asian/Latin American's first GR as follows, i.e., **Dr. Inazuka for the development of GR technology in 1935, Dr. Borlaug for GR innovation in 1957 and Dr. Matsuoka and Ashikari for scientific foundation of GR in 2002.** Since the dramatic success in Latin America and tropical Asia in the 1960s and '70s, the similar variety-oriented research for GRs has been intensively and extensively conducted in sub-Saharan Africa (SSA). Probably in response to the view that the failure to realize a GR was due to the absence of appropriate varieties for the continent (Sanchez 2002), the Africa Rice Center (AfricaRice) developed the new rice cultivar for Africa (NERICA). The NERICA technology has indeed been hoped to be very promising (FAO 2007). In 2005, the Millennium Village Project (MVP) was established in 14 hunger and poverty hotspots cutting across diverse agro-ecological zones in SSA. This was in fulfilment of one of the recommendations in accordance with the Millennium Development Goals (MDGs) of the UN. Despite all these interventions, the GR is yet to be realized in SSA. Hence, SSA remains the only region where the population continues to grow while per capita agricultural production has stagnated, with cereal yields rarely exceeding 1 t/ha (Hazell and Wood 2008). It is even more worrisome to note that despite the intensive variety-oriented research and wide technology dissemination, the path to successfully realizing a GR in SSA remains unclear (Otsuka 2006, Otsuka and Kalirajan 2006, Orr et al. 2008, Wopereis et al. 2008) except for our strategy, i.e., **GR through Sawah Technology and Irrigated Sawah System Evolution**.

In 2007, the Alliance for Green Revolution in Africa (AGRA) began large-scale activities (Toenniessen et al. 2008). The government of Japan has committed strong support to increasing rice production in Africa through the establishment of the Coalition for African Rice Development (CARD 2008) based on the Fourth Tokyo International Conference on African Development (TICAD 4) held in May 2008 at Yokohama, Japan. Similar to the UN MVPs, AGRA and CARD have large-scale activities targeted toward a GR. All of these world major organizations have hypothesized that the core technology to realizing a GR in Africa will be varietal improvements achieved by biotechnology, as was the case in tropical Asia 50 years ago. However, now their advocacy for HYVs emphasizes the need for natural resources management (NRM)-oriented modifications.

As described in this paper, however, a more realistic approach to sustainable agricultural production is by balanced application at farmers' fields of both (1) varietal improvement through biotechnology, and (2) improvement, ie., evolution of *sawah* (man-made rice ecological environment) through ecotechnology. We believe at the present condition that the core technology to contribute to GR in Africa is rather ecotechnology, such as the *sawah* technology. CARD also now looks shifted from variety strategy to somewhat more weight on ecological improvement than past. This became clear at the TICAD V, Yokohama, Japan, in June 2013.

Quite recent FAOSTAT(2017-2018) as shown in ***Sawah* Technology (1) Statistics**, data during 2007-2016, which indicates that Madagascar, Mali, Cote d'Ivore, Benin, Mauritania and Senegal, as well as Kebbi state in Nigeria, which is described in this companion paper of sawah technology(4), have now almost realized the GR. Although we have to examine the reliability of their statistics and still the impact to all SSA is not big through these countries or areas, if we examined the *sawah* system quality or stage of sawah system evolution, these countries or areas may have reached to **'standards stage of *sawah* evlolution'** as shown in the next chapter of this paper and in the separate paper of '***Sawah* Technology (2) Background'**, which may have reach to the similar evolutionary stage of Asian rice farming, i.e., standard level of sawah system. This facts support the *Sawah* hypothesis 1, i.e, GR through *sawah* system evolution of farmers' rice fields.

Compared to the biotechnological research and varietal improvement, ecotechnological research and *sawah* improvement/evolution have been largely neglected in SSA during the last 50 years. Although there is a research concept to improve natural resource management (NRM), no clear research concept to improve and to evolve the lowland soil and water management system in Africa. The *sawah* hypotheses 1 and 2 and *sawah* technology described in this paper are such missing concepts and technology to improve natural resources in the majority of African rice farmers' fields. For over 30 years (1986–2016), we have been using various research funds to engage in basic and action research in collaborations with mainly national teams, such as Ghana Soil Research Institute (SRI-CSIR) and Crops Research Institute (CRI-CSIR), the National Center for Agricultural Mechanization (NCAM), the National Cereals Research Institute (NCRI), and the University of Nigeria, Nsukka (UNN) as well as the University of Agriculture, Abeokuta in Nigeria.

Sawah Technology research started in 1983-88 under IITA's Wetland Research Project (Juo and Lowe 1985, Wakatsuki et al 1988). This project has been succeeded by Hirose Project at IITA during 1992-2008 (Hirose and Wakatsuki 2002, IITA 2008) and JICA/CRI-CSIR Ghana *Sawah* project during 1994-2001(Wakatsuki et al 2002). During the JICA/CRI *sawah* project, the collaboration with Africa Rice Center for sawah technology development had started (Wakatsuki et al 2001a and 2001b), then materialized through Center Commissioned External Review (CCER) in 2006 (Khush, Wakatsuki and Adole 2006). Based on these preliminary collaborations, *Sawah* Technology transfer and dissemination through Africa Rice Center's SMART-IV(*Sawah*, market access and rice technology in inland valleys) program started and is on-going successfully during 2009 to 2019, which is supported financially by International Cooperation Division of Ministry of Agriculture, Forestry, and Fisheries (MAFF), Japan (Africa Rice 2013, 2014a, 2014b, 2015, 2016, Mohapatra 2016). The first step was SMART-IV kickoff workshop at AfricaRice headquarters at Benin (Wakatsuki 2010, Buri 2010), then workshop and on-the-job training of SMART-IV staffs of Benin and Togo at Kumasi, Ghana (Buri et al 2011, SMART 2010-2014 and 2016). Working with farmers to improve control in inland valleys using *Sawah* Technology, AfricaRice 2012 Annual Report published in 2013. High Scalability of *Sawah* Technology in Sub Sahara Africa, AfricaRice 2013 Annual Report published in 2014. Scaling up of *Sawah* Technology in Benin and Togo, AfricaRice 2014 Annual Report published in 2015. *Sawah* technology for rehabilitating the rice sector in post-conflict countries of Liberia and Sierra Leone, AfricaRice 2015 and 2016 Annual Reports published in 2016 and 2018. In 2017 AfricaRice published the manual of this technology (Defoer et al. 2017). However, it is not the name of *Sawah* Technology but is changed to the abbreviated Smart-valleys approach and it is described as AfricaRice's proprietary technology

After a long stagnation, in the last forty years finally the appearance of the agricultural revolution of SSA different from Asia (the center is the rice revolution) began to appear now. After continued long-term basic and action research in 1986 through 2016, our *sawah* research team could establish basic technology sets. This is the "site–specific, personal irrigated *sawah* systems development and sawah based rice farming by farmers' self-support efforts (i.e., Sawah Technology)" in diverse inland valley agro-ecologies as primary targeted rice ecology in Ghana and Nigeria. We believe that the core technology to contribute to the GR in Africa is the *sawah* technology. During 2011-2016 our *sawah* team demonstrated and trained *sawah* technology successfully at the huge Niger river's flood plains and inland deltas in collaboration with Kebbi state Fadama III and ADP staff in Nigeria. Two power tillers could develop or make evolve 20 ha of the pump-based irrigated standard *sawah* systems with 5-8 t/ha of paddy yield during April 2011 to May 2014. By the end May 2014, Kebbi farmers bought additional 22 sets of powertillers by their own budget and developed 326 ha of sawah and produced 2100 tons of paddy (Kebbi Rice revolution, Dakingari 2013 and Yeldu 2014, World Bank 2016). Thus 2015-16, Nigerian government, especially Kebbi state government, have started the dissemination and implementation project (Kebbi Rice revolution and ESTRASERIF, Expansion strategy for sustainable sawah eco-technology for rice farming) to scale-up the past successful results in nationwide. Kebbi state government had bought 1000 sets of power tillers and started to distribute farmers for new 10000 ha of *sawah* development and rice cultivation. Our *sawah* technology has just arrived at the stage of conducting large-scale implementation to the nation wide scale up of the past successful results. This Kebbi rice revolution as described in ***Sawah* Technology (4) Practices** will be the first step to implement the *sawah* technology in all over the Nigeria in order to realize rice GR, and this is expected to extend to Ghana, Togo and Benin as well as to the entire West Africa and SSA. Sawah based rice farming in SSA has entered the stage of rapid evolution and development.

What is *Sawah*, Paddy and Irrigation?

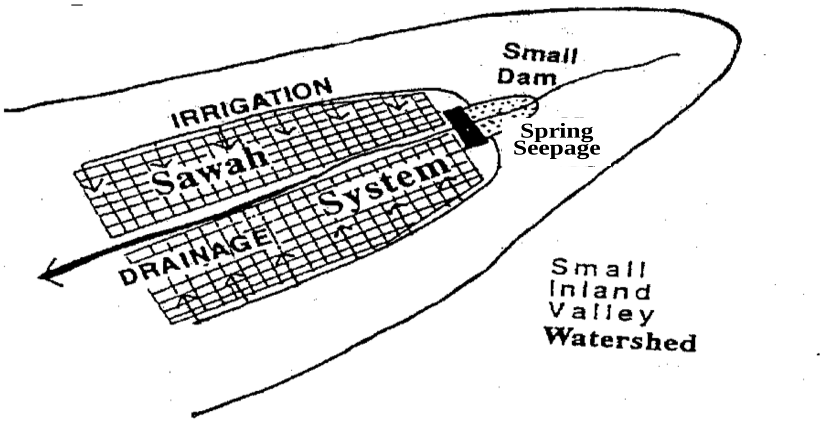


Figure 1. Sawah system with irrigation and drainage facilities for control of water in an inland valley watershed

Quality of Sawah determines the performance of various agronomic practices . The quality of a sawah can be determined mainly by the quality of leveling. If height difference in a plot of Sawah is within 5cm, excellent, within 10cm, good, within 20cm marginal to get the targeted yield 4t/ha, if more than 30cm, paddy yield will be less than 3t/hahe.

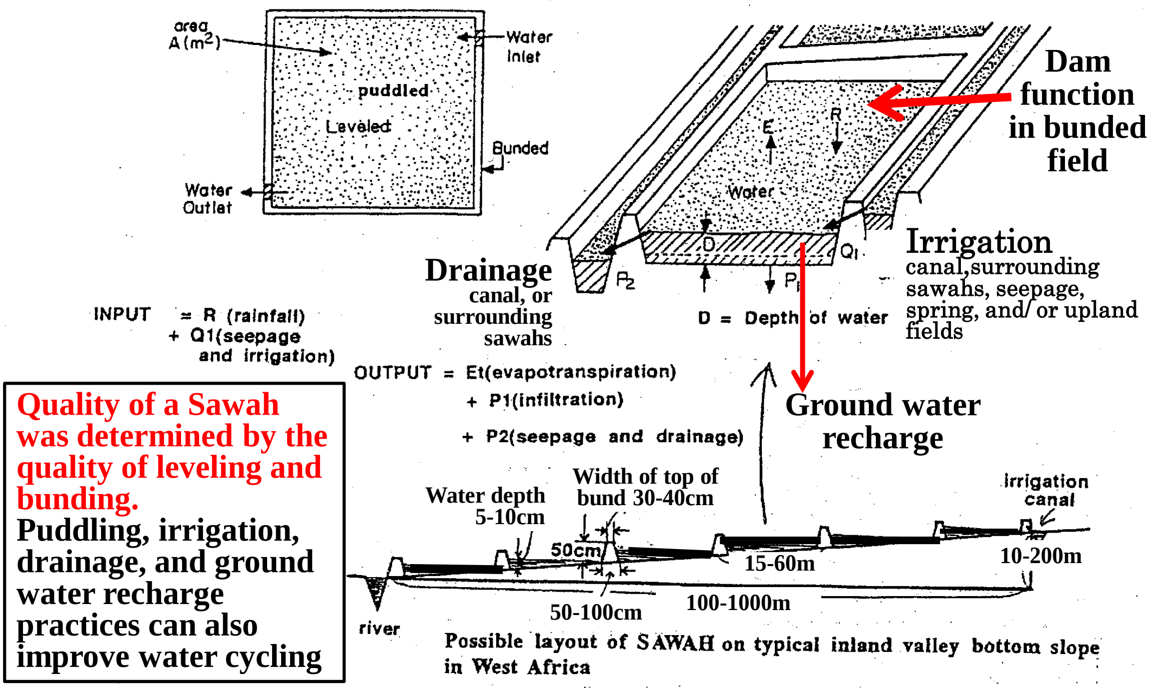


Figure 2. Sawah: A bunded, leveled, and puddled rice field with inlet of irrigation and outlet to drainage, thus control water and weeds as well as manage nutrients

The English term, "paddy," originates from Indonesia, and means rice plant or rice grain with husk, such as paddy yield and paddy production. The term "*sawah*" is also of Indonesian origin, and refers to a bunded, puddled and leveled rice field with water inlet and outlet to improve water control, especially control of water depth and flow in rice fields, and thus soil fertility (Wakatsuki et al. 1998). Historically SSA farmers, except for Madagascar and a part of UR Tanzania, have no sawah based rice cultivation skills, there is no *sawah* concept and word of *sawah*. The English paddy field means all kinds of rice production fields in SSA, it does not distinguish all 6 stages of sawah fields as shown in the Photographs 5. Under this circumstance, in order to promote the development of the sawah system platform, we proposed to use the term of sawah. Since it is the starting point of scientific research to use clearly defined technical term. The *sawah* technology can improve irrigation and fertilizer efficiency, and with the *sawah* technology the improved varieties can perform well to realize a GR in SSA. Suffice it to say that the *sawah* technology is the prerequisite platform condition to apply the three GR technologies successfully (*Sawah* hypothesis 1). As shown in Figure 1 and 2, a *sawah* system is composed of *sawah* fields and irrigation/drainage facilities in a lowland. The lowland *sawah* can also sustain rice yields higher than 4 t/ha through macro-scale natural geological fertilization from upland and micro-scale mechanisms to enhance various nutrients' supplies as described later in Fig 6 (*Sawah* hypothesis 2), if appropriate lowlands are selected, developed to standard *sawah* and the soil and water can be managed properly.

Most of the paddy fields in Asian countries correspond to the definition of the term standard *sawah*. Therefore, the paddy fields are almost equivalent to standard *sawah* for Asian scientists. However in West Africa and SSA, the term paddy refers to just a rice field, including upland, lowland, and irrigated rice fields. In order to avoid confusion and to stress the focal point for realizing the long-awaited rice GR through the improvement of the rice ecological environment using ecotechnology, the term *sawah* is proposed to use as a scientific foundation to describe the improved man-made rice-growing environment and the rice plants growing in it (Wakatsuki et al 1988 and 1998).

Photograph 1. Google Earth image showing micro rudimentary sawah system, evolutionary stage II, in which three green revolution technology can not be applied effectively. As shown of 50m scale marker, each micro sawah plot has an area of 5-30m^2 only. These are large schale Irrigated rice schemes of Kura, Kano State, upper photo and Kadawa, Kano State, lower pohoto, Northern Nigeria,.

Another frequent source of misunderstanding in Africa is the term "irrigated rice." In Asia, the meaning of this term is clear, as the *sawah* was developed by local farmers over the past hundreds or thousands of years as described later in Figures 7 and 8, before the recent advent of irrigation projects (after the 1970s) by Asian governments. However, in West Africa and SSA, since both irrigation and *sawah* are new and the concept of *sawah* has been lacking, there have been many irrigation systems without standard *sawah* system as shown below of the Google earth image (Photograph 1, which is the biggest rice irrigation project of northern Nigeria) or one of the oldest rice irrigated project site of Edozhigi, Kaduna river flood plain, Niger state. These are also described in **Sawah Technology (2) Background and Sawah Syestm Evolution.** The poor performance of past irrigation projects in SSA (Fujiie et al 2011) can be explained by lacking the *sawah* concept and *sawah* system management skills in rice scientists, engineers, extension officers and farmers. Standards *Sawah* systems are few in majority of African rice farmers including huge rice irrigation schemes, especially in Nigeria as shown in the Photograph 1 above.

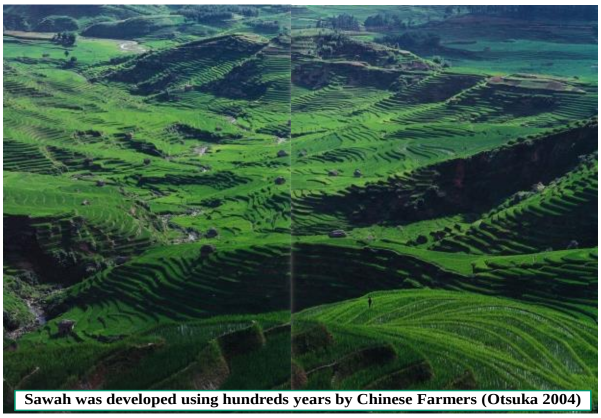
In a standard *sawah* plot, the water inlet and outlet should be installed at the bunds with gates that connect with the irrigation and drainage (Fig. 2, upper part). Proper knowledge and practical skills — especially of sloping pattern and hydrology in a watershed — of the field is needed to do this. In an extensive watershed, the interval of bunding is guided by the slope (lower part of Fig. 2). The aim should be to maintain an interval that will permit standard leveling (within 10cm height difference in a sawah plot) of the puddled soil for optimum water control. The quality of a sawah can be determined by the quality of leveling. If height difference in a plot of Sawah is within 5cm, excellent, within 10cm, standards, 10-20cm marginal to get the targeted yield 4t/ha, if more than 30cm, paddy yield will be less than 3t/ha (Fig. 2, Matsushita 2013).

Six stages of Sawah system evolution in Asia and Africa

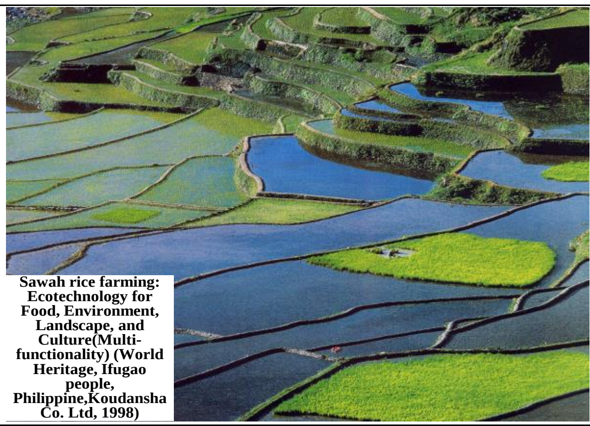
Basic infrastructures and skills necessary for *Sawah* based rice farming are common in the world, nothing special in Asia. Although all standard sawah plots have common structures to control water of rice fields (i.e, bunded to control sideway water flow, leveled topsoil with irrigation inlet and drainage outlet of water, and normally topsoil was puddled to control weed and excessive percolation water loss), there are diverse evolutionary stages of *sawah* systems in the world depending on the diversity of topography, soils, hydrology, climate, socio-

Forest Destruction by Shifting Upland Paddy Cultivation in Guinea Highland: Upland rice can not be sustainable without sawah or soil conservation measures (Guinea highland, 2002)

Sawahs of Madagascar may have thousand years of history with the migration of "old" Maly-Indonesian. Sawah systems are the base of "System Rice Intensification (SRI)" (from 2009 JICA trainee of Mr. Lantonirina Gilles)



Sawah was developed using hundreds years by Chinese Farmers (Otsuka 2004)



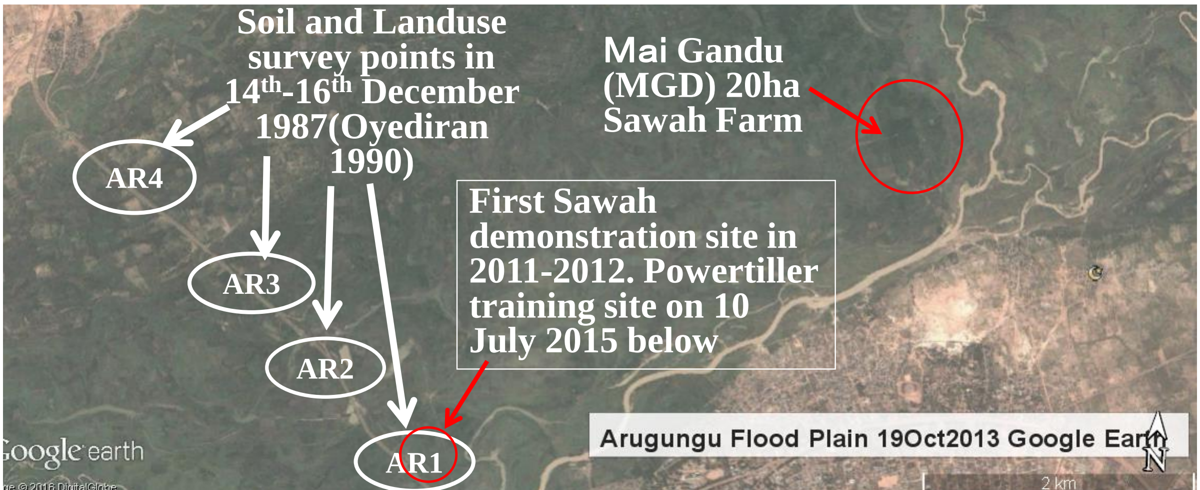
Sawah rice farming: Ecotechnology for Food, Environment, Landscape, and Culture(Multi-functionality) (World Heritage, Ifugao people, Philippine,Koudansha Co. Ltd, 1998)

Photograph 2. Standard quality Sawah systems in China, Philippines, and Madagascar and non-sawah system in Guinea highland, West Africa

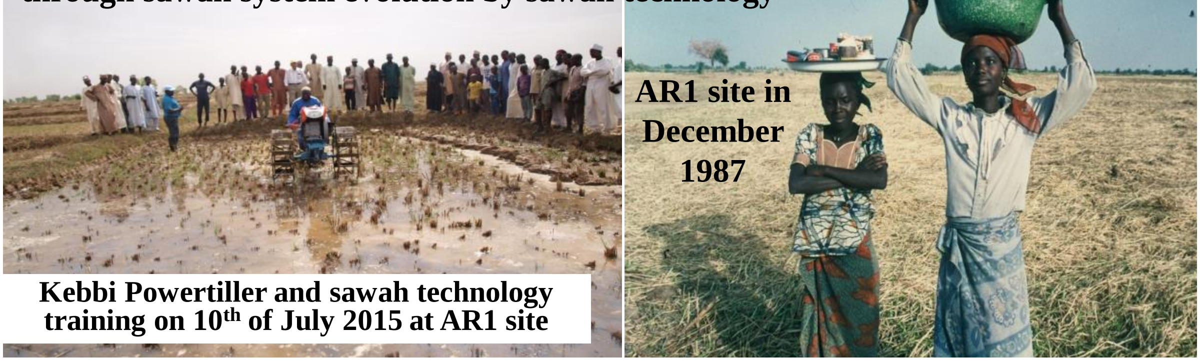
Figure 1 a. Lowland paddy field at Sokawe, Kumasi, Ghana Three Green Revolution technologies can't apply

Figure 1b. Once Sawah system was developed, yield can reach at least 4t/ha. If improved rice agronomy can practice, such as System Rice Intensification, yield reach to 10t/ha (CRI sawah team, Ghana)

Photograph 3. Traditional rice cultivation on non-sawah open bush lowland and sawah system developed by farmers using sawah technology, Ashanti, Ghana



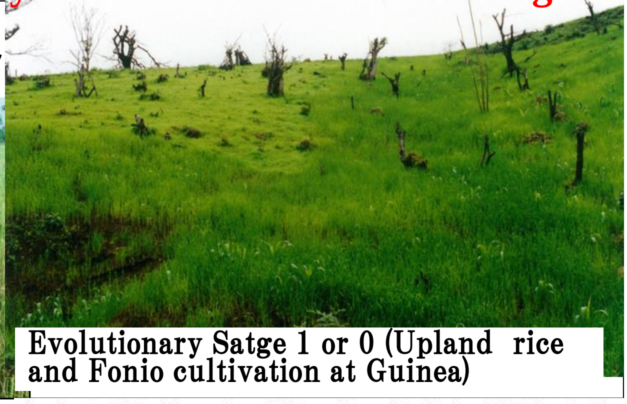
Photograph 4. Arugung in 1987 and 2015. Starting site of Kebbi rice revolution through sawah system evolution by sawah technology



6 Stages of Sawah System Evolution (I)

Green Revolution is possible only after the 4th Evolutional Stage

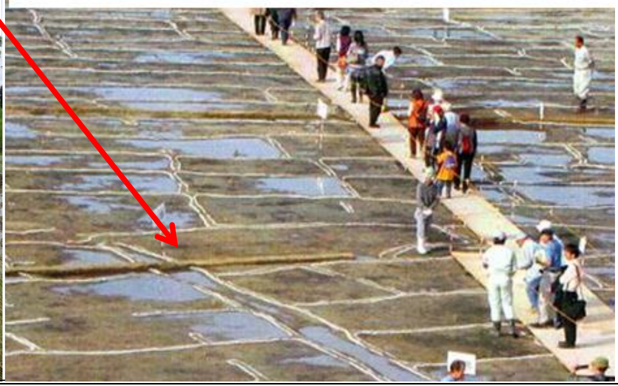
1st (L) stage : Lowland non sawah rice cultivation, Inland Valley, Sierra Leone, 1987



Evolutionary Satge 1 or 0 (Upland rice and Fonio cultivation at Guinea)

3rd stage: Irrigated micro rudimentary sawah. 2nd stage: ridge planted rice in Inland valley, Nupe, Nigeria

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



6 Stages of Sawah System Evolution (II)

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

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

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

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

Photograph 5. Six Stages of Sawah System Evolution. Three green revolution technologies will be only effective in the 4th to 6th Stages of Sawah Systems

economy and history in each region of the world. *Sawah* system's evolutional stages will co-evolve with the evolution of agricultural tools, machinery and methods. Photograph 4 shows *sawah* system evolution on the flood plain at Arugungu, Kebbi state between 1986 (Oyediran 1990) and 2015.

In order to realize GR in Africa, it may be enough to distinguish six evolutionary stages of sawah systems as seen in the following photographs 2 to 5. **The 1st stage is non-sawah system in either upland (U) or lowland (L). The 2nd** stage is ridge planted rice with irrigation or non-irrigation typically in flood plain. **The 3rd stage** is micro rudimentary sawah system with the size 5 to 30m^2 with irrigation or non-irrigation. These system are typically observed in inland valleys in Nupe land, Niger state, Nigeria. As shown the right side of the Nupe's micro sawah system, very interestingly, this stage of sawah seems to equivalent to Japanese archaeological sawah stage which appeared 2500 years ago at the time irrigated sawah based rice farming had started through the technology transfer from Chinese and Korean immigrants. However, even major irrigation schemes still have this system in current Nigeria as shown above Google earth images (Photograp 1)**.** The three green revolution technologies can not be used efficiently in these 1st, 2nd and 3rd stages. Mainly because water control is difficult in these three evolutionary stages of Sawah. If available agricultural tools are only hoe and cutlass, sawah systems can not evolve beyond these three stages even under irrigation.

If animal plow is available, the sawah system can evolve to the **4th stage**, which has been typically seen in Asia before starting mechanization in 2010s. This stage has standard sawah plots with leveling quality of ±5cm in a sawah plot through animal assisted plowing, puddling and leveling. **The 5th stage** has also standard sawah plots with leveling quality of ±5cm using powertiller or bulldozer. **The 6th stage** is advanced and large sawah plot of >1ha with leveling quality of ±2.5cm using laser leveler tractor. Only the rice fields higher than **4th stage**, the three green revolution technologies and more advanced agronomy technology can be used efficiently

Possible similarity of *Sawah* system development, British Enclosure for Agricultural Revolution and the Characteristics of Modern Sciences

As shown in Figure 3 (Salgado 2012), medieval manors were characterized with a set of open fields and rural community. The period of the modernization progresses were also the ages of enclosure, that is, the arable

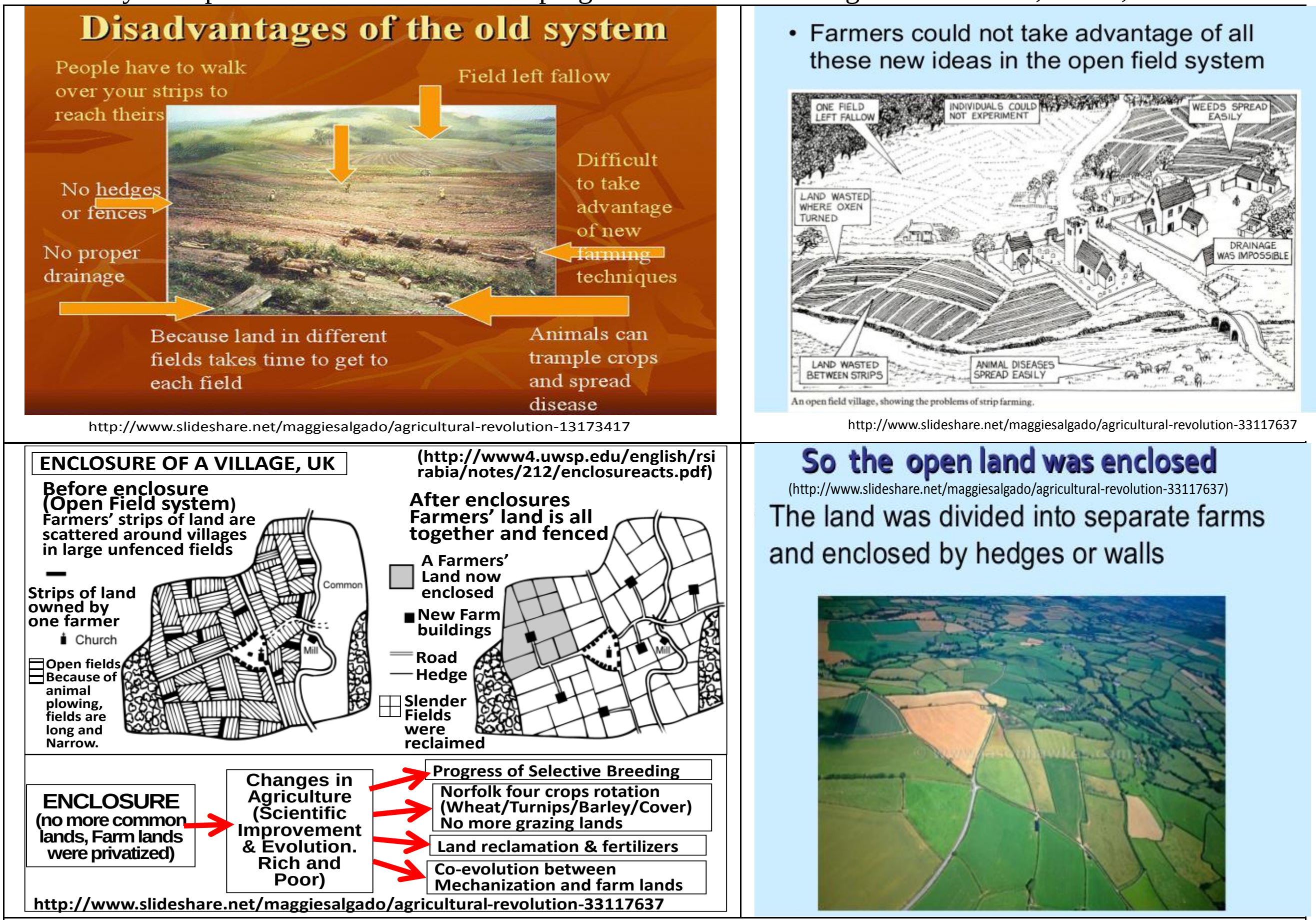
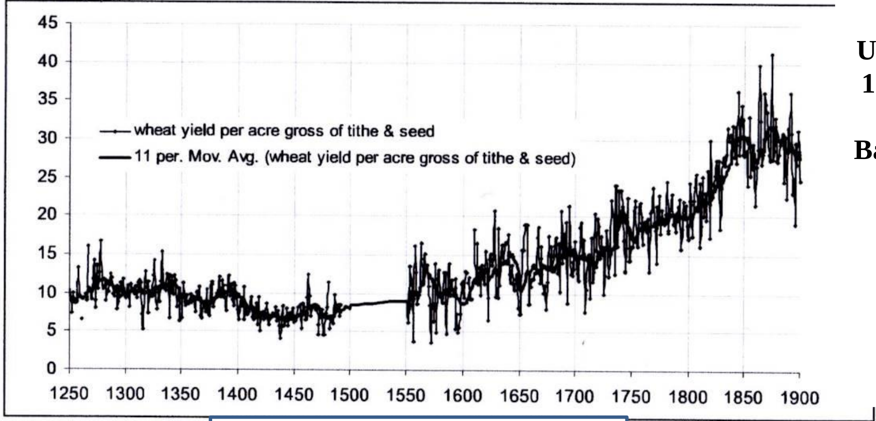


Figure 3. British Enclosure and Agricultural Revolution, Possible relation to Sawah System Platform

English Agricultural output and labour productivity, 1250-1850: Some preliminary estimate by A. Apostolider, S. Broadberry, B. Campbell, M. Overton, B. van Leeuwen, 26 Nov 2008 (http://www.basvanleeuwen.net/bestanden/agriclongrun1250to1850.pdf)

FIGURE 4: Weighted national average wheat yields per acre, gross of tithe and seed (bushels)



Enclosure in UK during 15-18th centuries Created Basic platform for scientific technology, Agricultural Revolution, then Industrial revolution

Table 1. Wheat, Rye, Barly, Oats

	A. Yield per acre gross of seed (bushels)					B. Seed sown per acre (bushels)				
	Wheat	Rye	Barley	Oats	Pulses	Wheat	Rye	Barley	Oats	Pulses
1250-1299	11.27	13.73	14.41	10.91	8.93	2.56	3.02	4.16	3.67	2.90
1300-1349	10.77	13.31	13.36	10.21	8.77	2.53	2.95	3.90	3.61	2.63
1350-1399	9.96	12.00	13.67	11.12	8.43	2.49	2.79	3.92	3.63	2.57
1400-1449	8.28	13.01	12.20	9.52	7.71	2.39	2.55	3.75	2.97	2.30
1450-1499	8.94	16.75	12.74	8.42	6.57	2.45	2.79	4.18	2.48	2.08
1550-1599	10.38	11.71	12.40	11.87	10.62	2.50	2.50	4.00	4.00	3.00
1600-1649	12.95	18.78	15.16	14.97	11.62	2.50	2.50	4.00	4.00	3.00
1650-1699	13.86	16.69	16.48	14.82	11.39	2.50	2.50	4.00	4.00	3.00
1700-1749	16.36	17.32	19.38	16.27	13.23	2.57	2.50	4.30	4.00	3.00
1750-1799	19.54	20.37	25.38	24.90	17.19	2.27	2.50	3.50	4.00	3.00
1800-1849	25.56	22.02	29.70	32.37	20.35	2.41	2.50	3.80	4.00	2.50
1850-1899	29.19	28.68	27.08	35.36	18.80	2.50	2.50	3.27	4.00	2.50

lands were enclosed with stone walls, bunds, or hedges, then reclaimed the enclosed lands. The first enclosure mainly on the 16th century was called that "Sheep eat men (Thomas More's Utopia)", because the landowner evicted the tenant farmers to expand pastureland for sheep rising. Whereas the second enclosure around 1700-1850 dramatically increased agricultural production as seen in Figure 4. As shown in the enclosed farmlands enabled reasonable land use plan and infrastructure development such as drainage improvement, the reduction of the waste land, conservation of land degradations originated from cultivation, pests and weed management, promotion of selective breeding, new farming techniques and the mechanization. Furthermore, various scientific farming techniques were innovated (evolved) through field experiments which were only became possible in enclosed lands. However, since the enclosures and infrastructure development needed investments, the rich capitalists who were able to carry out enclosure became increasingly rich and the tenant and the small farmers that were not able to enclose decreased agriculture income, lost their land and became wage labors at urban areas. Consequently, the gap between rich and poor was increased. The wage labors were important for the **Industrial Revolution** and the development of the **Capitalistic society**.

Scientific technology is defined as the whole of knowledges, experiences, skills and practices which can be systematically and reasonably classified and categorized, thus which can be transferred between human beings through learning, education and training. Enclosure was land demarcation, classification and rezoning practices. Modern Western world has only been materialized through the establishment of modern sciences (S. Nakayama, H. Butterfield). It may not be a rare coincidence that active period of contributors to establish modern science, such as Nicolaus Copernicus (1472-1543), Johannes Kepler (1571-1630), Galileo Galilei (1564-1642), René Descartes (1596-1650), Robert Boyle (1627-91), Isaac Newton (1642-1727), Antoine-Laurent de Lavoisier (1743-94), James Watt (1736-1819) and Justus Freiherr von Liebig (1803-73) had been overlapped with the period of Enclosure.

Sawah Hypothesis (1) Scientific platform for three Green Revolution Technology

There has been a considerable paddy yield gap between those of the African Research Institute (5–8 t/ha) and those of farmers (1–2 t/ha) for the past 50 years. During this period, three major components of GR technologies, (improved seeds, fertilizers and other agrochemicals, and irrigation) have been researched and developed. Although they have been available at the experimental fields of various research institutes in Africa, these technologies have not been effectively adapted in African rice farmers' fields. Almost all institute-based technologies have not been scaled up to farmers' fields. Thus, the GR is yet to be realized. The Google photograph and Figures 3, 5-6 below explain the reason. All scientific technologies have some limited operational conditions, platform, in the field. A high-skill requirement of the technology that calls for experience or skills acquired through training and practical field application is the demarcation of the field into basins using the bunds (*see* the Google photograph, photographs 1- 5, and Figures 3, 4-5) and as described above on leveling quality. A good demarcation and leveling not only helps to control water and conserve soils but also encourages the expression of the beneficial physical and biochemical interactions going on in either upland or lowland soil. As shown in the Google photographs, the necessity for field demarcation and appropriate leveling is not only lowland but upland as well. Thus the Sawah Hypothesis (1) is equivalent to the British Enclosure. Although the quality of demarcation and leveling at upland is not the same at lowland. Lowland demarcation and leveling are more critical than upland because of the difference of the power of water flow. The control of water in farmers' fields, for example, need standard *sawah* systems. The majority of African farmers' fields are not ready to accept most of the scientific technologies developed at research institutes such as the IITA and AfricaRice (Figure 6). The *sawah* system and sawah technology is the prerequisite platform condition for applying the three Green Revolution technologies (*Sawah* hypothesis 1).

Figure A. Lowland paddy field at Sokawe, Kumasi, Ghana Three Green Revolution technologies can't apply

Figure B. Once Sawah system was developed, yield can reach at least 4t/ha. If improved rice agronomy can practice, such as System Rice Intensification, yield reach to 10t/ha (CRI sawah team, Ghana)

Sawah System Development by Sawah Technology

Farmers' Paddy Fields: Diverse and mixed up environmental conditions: mixed farming systems, crops, varieties, and weeds. No clear field demarcations.

1. The improvement of field conditions are difficult. Water cannot be controlled, therefore no soil conservation possible.

2. Land right of the field has overlapping with diverse people and communities. Conflicts with nomads and fishermen No incentive to improve land.

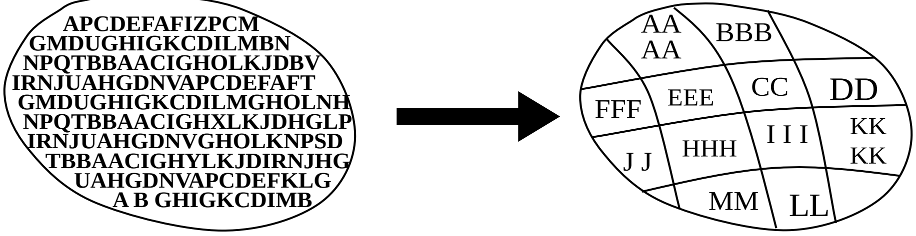
3. Post-harvest technology can not apply.

Sawah Fields: Lands are demarcated by bund based on topography, hydrology and soils, which makes diverse sawahs but homogeneous condition of each sawah.

1. Water can be controlled. Soil is conserved. Therefore field conditions are improve through the accumulation of every year.

2. Land can be surveyed and registration become possible, then private ownership is promoted, which makes incentives to improve land.

3. Market competitive standardized paddy production becomes possible



Green revolution (GR) technologies of fertilizer, irrigation, and high-yielding varieties (HYV) are not effective in the bushy open fields

Sawah is similar to British enclosured land, which realized Agricultural revolution. This is foundation for scientific technologies of GR

Fig 5. Sawah hypothesis (1): Farmers' Sawah should come the first to realize Green Revolution. Farmers fields have to be classified and demarcated ecotechnologically. Then scientific technologies can be applied effectively.