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Challenges and opportunities for increasing rice production in sub saharan Africa

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ABSTRACT

Sub Saharan Africa (SSA) faces multiple problems. The main one is improving the lives of the 30% of its population that suffers from extreme poverty and food insecurity. Because of strong demand, rice area expansion in SSA is larger than for any other crop. The abundant supply of agroclimatically suitable wetlands (239 million ha) and water resources can support a large expansion in rice area and productivity. Expansion and intensification of rice cultivation in SSA will not compete with other crops in terms of land and water resources because, during the rainy season, only rice can be grown on low lying wetlands, including inland valleys. Rice is cultivated in four ecosystems of SSA: dryland (38% of the cultivated rice area), rainfed wetland (33%), deepwater and mangrove swamps (9%), and irrigated wetland (20%). Many abiotic stresses (drought, flood, and variable rainfall; extreme temperatures; salinity; acidity/alkalinity and poor soils, soil erosion, and high P fixation) and biotic constraints [weeds, blast, Rice yellow mottle virus (RYMV), and African rice gall midge limit rice production on the continent.

Key words: Rice, ecosystem, Sub Saharan Africa.

Sub Saharan Africa (SSA) is the world's poorest region. More than 30% of the 900 million people living in SSA suffer from pernicious hunger and malnutrition (Farm Africa, 2004; IAC, 2005; Rosegrant *et al.*, 2007; Sanchez and Swaminathan, 2005). The prevalence of diseases such as malaria and AIDS is very high (FAO, 2006b) and many countries have been disrupted by civil war. The adoption of more productive agricultural practices coupled with the development of rural infrastructure and local markets and supportive agricultural policy is crucial to improving both rural and urban living conditions. African agriculture consists of a diverse set of farming systems that have arisen in response to the large variations in ecological, social, and economic conditions. Dixon et al. (2001) delineated 15 broad farming systems, including forest based systems; systems dominated by livestock, cereals, and root crops; and mixed systems. It is thus evident that improving the production of several crops and livestock will have a role in agricultural development in SSA. From a low base, rice consumption and production have increased tremendously in SSA over the past decades, and this trend is expected to continue. Moreover, rice can be very productive and sustainable and be produced in areas where other crops cannot be grown. Yet the potential for growth in the African rice sector is enormous. In this chapter, we first assess the potential resources for rice production and characterize the rice growing environments in SSA.

Rice demand and supply

Rice is a traditional staple food in parts of West Africa and Madagascar, and it is increasingly becoming an important food in East, Central, and Southern Africa. In recent years, the relative growth in demand for rice is faster in SSA than anywhere else in the world. Rice consumption increased steadily in all countries, except Madagascar. Mean per capita rice consumption is high in Madagascar (122 kg), Guinea Bissau (103 kg), Coˆte d'Ivoire (Ivory Coast; 100 kg), Senegal (100 kg), Sierra Leone (93 kg), the Gambia (90 kg), Guinea (73 kg), and Gabon (72 kg). In 2002, four of the six largest rice importers were Coˆte d'Ivoire, Nigeria, Senegal, and South Africa. Currently, SSA accounts for 25% of global rice imports at a cost of more than US$1.5

billion per year. Projected rice imports into West Africa alone will be between 6.5 and 10.1 million MT in 2020 (Lancon and Erenstein, 2002). Declining global rice stocks and the predicted doubling of the rice price by 2008 will put additional strains on rice importing countries in SSA. Therefore, national, regional, and international agencies are now placing a high priority on developing the local rice sector in SSA as an important component of food security, national economic growth, and poverty alleviation. In 1960–2000, rice area increased in SSA, but rice yields stagnated at a low level or decreased. From 2000 to 2005, average rice yields continued to decline in West Africa and Nigeria, and increased only slightly in East Africa and Madagascar. Therefore, any increase in national rice production came from an expansion in area rather than a substantial increase in productivity. This is a disturbing trend given the escalating demand for rice in many SSA countries

Wetlands: The potential resource for rice production in SSA

Wetlands in SSA are grouped into four categories: inland basins and drainage depressions, inland valleys, river floodplains, and coastal wetlands. A brief description of each category is given below.

1. Inland Basins

They comprise drainage depressions and inland deltas of rivers, with imperfectly to poorly drained and potentially acidic soils (Ultisols, Oxisols, Alfisols, Entisols, and Vertisols). Examples are the Upper Nile, Sokoto, Lake Chad, and Congo basins; the shallow swamps around Lake Bangweulu and the Kafue flats; and the lacustrine deposits of Lake Rukwa and Lake Eyasi.

2. Inland Valleys

Inland valley wetlands occupy 85 million ha (36% of the total wetland area in SSA); only 10–15% of the inland valley area is used for agriculture. Narrow inland valleys are located upstream from river flood-plains that are much wider. Each inland valley represents a topo sequence of a valley bottom with its hydromorphic edges, and the contiguous dryland slopes and crests that contribute runoff and seepage to the valley bottom. Most inland valley wetlands are concentrated in the inter tropical zone where rainfall is superior to 700 mm, and their catchment sizes generally range from 100 to 2000 ha. The soils (Entisols) in the valley bottoms are flooded during the rainy season, whereas the soils (Ultisols, Oxisols, Alfisols, and Inceptisols) on adjacent drylands are aerobic and erosion-prone.

3. River Floodplains

An estimated area of 30 million ha (12% of the total wetland area) is under river floodplains in SSA. A floodplain is a wide, flat plain of alluvium bordering streams and rivers that flood it periodically. Soils of the floodplains (Entisols, Inceptisols) are moderately well to poorly drained and medium- to fine- textured with moderate to high fertility. Soils can be saline and/or alkaline in drier regions.

4. Coastal Wetlands

Coastal wetlands cover an estimated area of 16.5 million ha (7% of the total wetland area in SSA). They comprise Deltas (e.g., Niger in Nigeria, Rufiji in Tanzania, and Zambezi in Mozambique), Soils (Entisols, Inceptisols, Histosols) are poorly drained and non saline in freshwater swamps, acid sulfate (Entisols, Inceptisols) in mangrove swamps, poorly drained and saline (Inceptisols) in lagoons, coarse-textured (Entisols, Inceptisols) in sand bars and dunes, and organic (Histosols) in permanently flooded areas.

Agroclimatic zones and rice ecosystems

The suitability of land for various crops is determined by climate and weather variables (agroclimatic zones), landscape moisture regimes (physio hydrographic positions), and soil characteristics. Rice thrives in areas with warm temperatures (above 20^{o}C during the cropping season), annual rain-fall ranging from 0.5 to >1.5 m, and growing periods of 90þ days. Rainfall distribution is generally mono modal with a distinct humid period in areas with a rainfall range of 500–1000 mm per annum (e.g., northern and southern Guinea savanna zones) and bimodal with two growing seasons toward the equator (Andriesse, 1986).

A. Dryland rice ecosystems

Dryland rice is also known as ‘‘upland’’ or ‘‘pluvial’’ rice. It is cultivated on level or sloping lands and on hydromorphic fringes in fields that do not have bunds to retain surface water (Sie, 1991).

Flooding is rare in this ecosystem, and dryland rice depends solely on rainfall and should have a water table that remains at 0.5 m or more below the soil surface.

1. Dryland Rice Area

Of the global dryland rice area of 14 million ha in the 1990s, 2.7 million ha are planted to dryland rice in Africa; it accounts for an estimated 38% of the total rice area in SSA. Nearly 97% of the cultivated rice area in the Central African Republic is in drylands. Other countries with domi-nant dryland rice ecosystems (more than 65% of the cultivated rice area) are Liberia, Benin, Congo DR, Togo, Coˆte d'Ivoire, and Sierra Leone. Countries with more than 100,000 ha of dryland rice are Congo DR, Guinea, Madagascar and Sierra leone.

2. Cropping Systems

Dryland rice systems range from shifting to permanent cultivation. Shifting or slash and burn cultivation is common in humid forest zones of West Africa where farmers cut and burn the bush fallow vegetation and plant rice as the first crop to exploit the soil fertility built up during the fallow period and the ash from burning. They may apply a little manure or compost, but no chemical fertilizers are used. As this practice depletes the soil, weeds build up and rice yields decline drastically after the second crop, when farmers plant cassava on old plots and move to a new area for rice cultivation. Nutrient mining degrades the soil in this type of slash and burn system (Fernandez *et al.*, 2000; Oldeman *et al.*, 1991). Farmers plant rice as a sole crop or mixed with maize, beans, yam, cassava, or plantains (mixed cropping) to avoid risks. In areas with a long growing season and sufficient rainfall, dryland rice is rotated with maize, cowpea, beans, soybean, or sweet potato.

3. Cultivation Practices and Yields

In this ecosystem, the fields are not bunded, there is no flooding, and the soil remains aerobic (not saturated with water) for most of the growing season. Rice seeds are sown by broadcasting or dibbling in hand hoed fields. An adequate supply of soil water is critical for good plant growth and yield. This can be achieved by in situ rainwater harvesting (RWH) through improved infiltration of rainwater by proper tillage, reduced water loss from the soil surface by proper mulching or plant cover, and improved crop water use by selecting adapted varieties and following moisture conserving cultivation practices (Hatibu, 2000). Yields are low on subsistence farms because of poor cultivation methods, low input use, excessive weeds, and depleted soils.

4. Production Constraints

Both abiotic and biotic constraints limit rice production in drylands. Serious abiotic constraints include variable rainfall, low temperature in high altitude areas, and poor soils. The total rainfall of 0.9–2.0 m is adequate in the humid and sub humid areas where dryland rice is generally grown in SSA, but the rainfall distribution can be poor, with unpredictable dry spells. Degradation of soil structure and surface sealing constrain crop emergence and growth in semiarid areas (Andriesse and Fresco, 1991). Drought is another serious problem for dryland rice due to the inadequate quantity and/or poor distribution of rainfall and shallow depth of and surface crusting in some soils. Among biotic factors, weeds are the most serious, followed by blast and brown spot diseases. Estimated yield losses due to weeds range from 30 to 100%. Weed infestation and loss of N reduce yields by 25% on intensive dryland rice farms of West Africa (Becker and Johnson, 2001).

B. Wetland rice ecosystems

Unlike the dryland ecosystem, rice fields in the wetland ecosystem are flooded during the growing season. We distinguish three types of wetland rice ecosystems as rainfed wetland, deepwater, and irrigated as determined by the surface water regime.

1. Rainfed Wetland Rice Ecosystem

Rainfed wetland rice is grown on lower parts of the topo sequence and in valley bottoms in level to slightly sloping bunded fields that are flooded by rainwater for a part of the growing season to water depths that may exceed 1.0 m for not more than 10 consecutive days. Both rainwater and stored groundwater support rainfed wetland rice. Four types of flooded wetlands are recognized in Africa: riverine shallow, riverine deep, boliland (grassy inland swamps), and mangrove (Andriesse and Fresco, 1991; Buddenhagen, 1986). Rainfed wetlands are characterized by a lack of water control, with droughts and floods being potential problems (Hatibu, 2000; McLean *et al.*, 2002). On the basis of the constraints, rainfed wetlands can be divided into four sub ecosystems: (1) favorable, (2) drought prone, (3) submergence prone, and (4) drought and submergence prone. All four sub ecosystems occur in SSA. Rice varieties and production technologies developed for the irrigated ecology can be easily adapted for rice in favorable rainfed wetlands. Other rainfed wetland (drought, flood, and drought and flood prone) sub ecosystems are found in riverine shallow, riverine deep, hydromorphic edges of inland valleys, and mangrove ecologies. They are highly diverse, with often variable rainfall patterns, adverse soils, and many abiotic and biotic constraints.

2. Deepwater and Mangrove Rice Ecosystems

The deep-water ecosystem covers several environments where rice is planted, which is adapted to increasing water depths of 1.0 m or more for durations of 10 days to 5 months. These rice plants must have the ability to elongate rapidly to stay above the water surface. No varieties are available that are adapted to rapid or irregular rise of flood water or sediment laden floodwater that can cover crops for longer than 10 days in some deep-water areas (McLean *et al.,* 2002). In low lying coastal areas, we can differentiate perennially fresh, seasonally saline, and perennially saline tidal wetlands where rice plants are subject to daily tidal submergence. Plants in tidal lands do not elongate greatly, but tillering and tiller survival may be reduced in saline soils. In problem soils (acid sulfate and sodic or alkaline soils), excess water accumulates in fields due to poor drainage, but no prolonged submergence occurs (McLean *et al.,* 2002). Al or Fe toxicity is a serious risk when acid sulfate soils of coastal wetlands are drained (Sahrawat, 2004a), whereas deep peat soils constrain rice production in high altitude areas.

3. Irrigated Wetland Rice Ecosystem

Irrigated rice is grown in bunded fields with assured irrigation for one or more crops per year. Usually, farmers try to maintain 0.05–0.1 m of water in rice fields. Irrigated rice areas are concentrated mostly in the humid, subhumid, semiarid, and high altitude tropics of the continent. Dams across rivers, diversion of water from rivers, or tube wells provide water for irrigation. We can distinguish three types of irrigated rice ecologies in SSA: the irrigated rice in the arid and semiarid Sahel, the irrigated rice in the humid forest and savanna zones (Defoer *et al.,* 2002), and the irrigated rice of the tropical highlands (Balasubramanian *et al.*, 1995).

Rice production constraints in SSA

Biophysical, management, human resource, and socioeconomic/policy constraints plague rice farming in SSA.

A. Physical, biological and management constraints

Physical, biological, and management constraints vary with rice ecosystems as discussed above in Section IV.

B. Human resource constraints

Particularly serious is the lack of researchers. As is pointed out by Evenson and Golin (2003), the ratio of researchers to extension workers is much lower in SSA than in Asia. This is truly a serious problem because the lack of profitable technology, but not the lack of extending it, is the most basic constraint to improving farming efficiency in SSA. Once new profitable technologies are developed, demand for extension services will increase. In such a situation, it is expected that capacity enhancement programs for extension workers, which will have high payoffs, will be undertaken. The lack of education among rice farmers is another major constraint, as better educated farmers are more willing to adopt new technologies (Schultz, 1975). Given the substitutability between farmers' education and extension services, and the lack of education among farmers in SSA, strengthening the extension system is likely to be an appropriate strategy once new technologies become available. Other human resource related constraints are as follows:

- Weak or nonexistent research-extension-farmer linkage
- Poor or no farmer organizations
- Lack of public–private partnerships
- Reduced labor availability due to poor nutrition and/or diseases such as AIDS, cholera, malaria, bilharzia, and so on.

C. Socioeconomic and policy constraints

In addition to biophysical and human resource constraints, rice production in SSA is affected by socioeconomic and policy constraints:

- Unfavorable input and output pricing policies at the national level. Low output prices vis-a-vis high and rising input prices reduce profit and the competitiveness of smallholder farms in local, regional, and global markets.
- Limited access to credit, inputs (seed, fertilizers, pesticides, implements, and so on), markets, and market information.
- Poor rural infrastructure and transportation.

This unfavorable price structure reflects the inefficient marketing systems in SSA. The establishment of efficient marketing systems requires trust between local traders and farmers and between local and urban traders, because dishonest behavior, such as cheating on product quality and late delivery, can easily occur in any transaction (Hayami and Kikuchi, 2000). To prevent such behavior, trust must be developed through long term and repeated transactions. Experience shows that socioeconomic institutions are not rigid, but are subject to change as new profitable opportunities arise not only in Asia (Hayami and Kikuchi, 1982) but also in SSA (Otsuka and Place, 2001).

Rice intensification issues and thoughts for the future

A. Rice intensification in relation to vector-borne human diseases

Farmers consider flooded wetland rice cultivation risky for health reasons the fear of contracting wetland-related human diseases such as malaria and bilharzia. Malaria caused by mosquitoes (*Anopheles gambiae* s.l.) is the single biggest killer disease in SSA; about half a million children die of malaria ever year. Research findings indicate that the expansion of rice cultivation to a new area or conversion of single-rice to double-rice cropping will not further increase the incidence of malaria in the already endemic humid and savanna zones. However, in new irrigation schemes or with the expansion of existing irrigation schemes to new areas in the Sahel, the risk of malaria may increase in the short term as new people and laborers settle the area. As the settlers acquire immunity, the danger of malaria goes down steeply (WARDA, 1996).

Aquatic snails and humans provide alternative hosts for the worms. The disease is prevalent where people are in contact with snail-infested water slow-moving rivers and streams and vegetation banks of lakes. Preventive health measures such as the use of boots and the destruction of snail-infested floating vegetation as well as timely treatment of infected people with a single dose of an appropriate anthelmintic drug will control the disease effectively in all areas, including wetland rice areas (WARDA, 1999).

B. Environmental issues related to rice intensification in SSA

Rice intensification in SSA must take preventive measures to protect the environment and ensure the long-term sustainability of rice farming. IRRI has developed five environmental indicators to monitor production, biodiversity, pollution, land degradation, and water (IRRI, 2004).

Production: For rice production to be sustainable in the long run, it is important to preserve the natural resources land, water, and soil fauna and flora that support rice production. Combining balanced fertilizer use with adequate weed control will enhance rice yields and maintain soil fertility in rainfed and irrigated wetlands of SSA (WARDA, 1998). Conservation agricultural methods such as zero tillage, planted fallows with legumes, and dryland rice-cover crop rotations are being developed to reduce soil erosion, conserve soil moisture, and improve soil fertility in drylands (Akanvou *et al.*, 2001a; Carsky *et al.*, 2001; Erenstein, 2003; Somado *et al.*, 2003).

Biodiversity: Preserving wild rice species and diverse cultivated rice varieties in situ in fields and outside in Gene Banks is critical to guard against pest outbreaks and to supply desirable genes for future needs. Many of the hardy *O. glaberrima* lines and varieties would be extinct had their seeds not been collected and preserved in Gene Banks, because African farmers had abandoned them to grow their distant Asian cousins (WARDA, 1999, 2001–2002). High-potential mangrove areas must be identified and developed for rice farming and the remaining mangrove forests preserved in their natural state to save the rich mangrove biodiversity and protect local communities against cyclones and tsunami-induced invasion of coastal lands. Acid sulfate soils must be kept flooded all the time to prevent irreversible drying into a non usable resource.

Pollution: Herbicides are effective in controlling weeds in all systems, but they have to be applied at the right time and at the right dose to destroy weeds with minimal impact on the environment. The use of IPM for pest control and SSNM and the LCC for precision nutrient management in rice will help reduce pesticide- and fertilizer-related pollution of water sources (Balasubramanian *et al.*, 2005; Buresh *et al.*, 2003; Dobermann *et al.*, 2004). Methane emissions from flooded rice fields are an environmental issue (IRRI, 2004). An estimated 5–10% of global methane emissions are attributed to flooded rice systems in Asia (Wassmann *et al.*, 2000). Methane mitigation measures developed during the past 20 years include crop residue management, the addition of various soil amendments, and midseason drainage (Wassmann *et al.*, 2000); these measures can be proactively applied in areas of rice intensification in SSA.

Land degradation: In irrigated rice areas of the semiarid savanna and Sahel zones, the danger of soil salinization and alkalization must be addressed through proper drainage and the application of adequate soil amendments and nutrients to minimize or prevent these types of land degradation (Massoud, 1977; WARDA, 1999). Conservation agricultural methods are needed to prevent soil erosion and soil degradation on drylands.

Water: Water is the most precious natural resource on Earth, and large amounts of fresh water are diverted to rice cultivation all over the world. It is therefore important to optimize water productivity by using water- saving technologies such as AWD, and water efficient short-duration and aerobic rice varieties (Bouman *et al.*, 2005, 2006) and hybrid varieties (Virmani, 1996). The use of less water does not have to obligate farmers to use more chemical inputs if we develop suitable row-seeding and line-transplanting methods and mechanical weed control options. In rainfed wetlands, RWH is critical to recharge groundwater, revive small streams and rivers, stabilize rice yields, and diversify farming and income sources.

C. Preparing for the impact of climate change

Climate change has become a major concern worldwide. SSA will also face new burdens due to climate change. In SSA, major symptoms of such a change include the disruption of normal climate patterns over large areas, increasing incidences of drought and temperature extremes, heavy flooding and soil erosion/landslides, and increasing levels of salt stress in both inlands and coastal areas. Solutions require multidisciplinary and integrated approaches to develop a combination of improved rice germplasm with tolerance of prevailing and anticipated stresses and adapted crop management as well as mitigation and amendment strategies that could help simultaneously protect farmers, consumers, and the environment.

D. Technology delivery and deployment issues

The new knowledge and technologies must be evaluated in producers' fields and promoted widely for real impact on productivity and livelihood of the poor. The technology deployment part is as important as the supply side of the research-innovation system. It is important to train, equip, and motivate field and extension staff of the public and private sectors, nongovernmental organizations, and civil society as well as farmer leaders, and to strengthen the research-extension-farmer linkage to effectively move new research findings and technologies from research stations to producers. Training of and technical support to farmers on new technologies, field demonstrations, the organization of farmers' days at harvest time, and encouragement of farmer-to-farmer communication are effective technology deployment tools. The development of a region-specific Rice Knowledge Bank for SSA is important for the effective deployment of rice technologies. The voluntary organization of farmers into groups is essential to effectively coordinate farming operations and allocate community resources (water, grazing land), shape supportive farm policy (crop insurance, minimum support price, and so on), develop processing and value addition enterprises, and take up direct marketing. In addition, training, extension, and delivery of knowledge are more effective with farmer groups than with individual farmers. Private sector-mediated and supported farmer groups will enable the timely delivery of the latest technologies with required inputs and technical support; guarantee farm credit through commercial banks; develop processing, storage, and marketing facilities in strategic locations; assure buyback of produce from farmers at a predetermined price in each season; and ensure a good-quality rice supply to national, regional, and global markets.

E. Policy support for rice intensification in SSA

It must be emphasized here that the advent of high-yielding rice varieties has triggered subsequent changes in supporting policies, such as investments in irrigation, initiation of credit programs, and the establishment or strengthening of national research and extension systems in Asia as the rates of return to such investments increased significantly (Barker and Herdt, 1985; Hayami and Kikuchi, 1982; Otsuka and Kalirajan, 2005, 2006). In particular, urgent analysis is needed on the benefits of rehabilitation of irrigation facilities, initiation of farm credit, creation of rural infrastructure and marketing facilities, and development of public–private partnerships. The NARIs in many African countries must be revamped and supported to do relevant research on the emerging issues of intensification of rice farming.

CONCLUSION

The cost of irrigated rice production is high in many SSA countries (FAO-CORIFA, 2005), mainly because of the high initial investment in irrigation infrastructure and the poor operation of many irrigated rice schemes (FAO-Aquastat, 2005). On the other hand, rainfed wetland rice production by smallholders is often constrained by many biotic and abiotic stresses as well as inadequate crop management all resulting in low yields, less than 1.5 mt ha^{-1}. Moreover, postharvest losses are high and the quality of milled rice is often poor in many countries. Therefore, the production of locally preferred rice at a competitive price is the biggest challenge to African farmers.

The most important challenge to developing high-yielding rice varieties with acceptable grain quality and resistance to or tolerance of local pests in rainfed and irrigated wetland ecosystems is being addressed progressively. Breeders are trying to incorporate tolerance of drought and local biotic stresses into the introduced high-yielding-irrigated rice varieties. Of course, combining high yield with grain quality is critical to transforming subsistence agriculture into commercial rice farming. The second challenge lies in identifying, branding, and promoting high- quality locally adapted rice varieties in national, regional, and international markets.

The third challenge, the most critical one, is the absence of a coherent and comprehensive policy, plan, and program to tackle the many constraints and deficiencies of the national rice sector in African countries. It must be emphasized here that the development of high-yielding rice varieties and profitable production technologies is a prerequisite to trigger changes in supporting policies, such as investments in irrigation, initiation of credit programs, revamping of national rice R&D systems, and development of rural infrastructure and market systems for local rice. Great opportunities exist to increase rice production and strengthen both household and national food security in SSA. First, national governments are trying to increase local rice production to reduce rice imports. Donors such as the Rockefeller Foundation and the USAID through Borlaug LEAP (Leadership Enhancement in Agriculture Program) Fellow-ships are willing to support the training of a large number of new African plant breeders and crop production scientists to help develop the agricultural sector on the continent. In addition, the NEPAD's (New Partnership for African Development) CAADP (Comprehensive African Agricultural Development Program) initiative and various other multilateral facilities can help develop the rice sector in SSA. The WARDA and IRRI have a wide array of international expertise in modern rice breeding, biotechnology, and production and postproduction management. These two centers are joining hands to help improve the rice sector in SSA.

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