Is Pesticide Use Sustainable in Lowland Rice Intensification in West Africa?

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1. Introduction

Rice is a major staple food for about 3 billion people (Nguyen and Ferrero 2006). In West Africa, it is indeed no longer a luxury food and has become a major source of calories for the urban poor. The poorest urban households obtain 33% of their cereal-based calories from rice (NISER, 2005). Urbanization, changes in employment patterns, income levels, and rapid population growth have contributed to widening the gap between supply and demand (Figure 1). The gap between production and consumption is made up by imports, which are estimated at 2 million metric tones per annum.

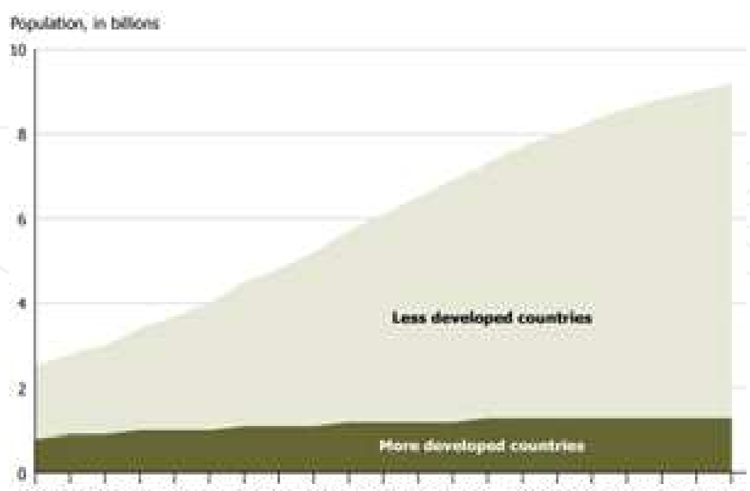

Fig. 1. World Population Growth 1950–2050 (Source: United Nations, 2009).

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Rice remains one major crop in which West Africa can easily become self-sufficient given the potentials that abound in the region. The potential land area for rice production in West Africa is between 4.6 million and 4.9 million ha. Out of this, only about 3.7 million ha—or 75 percent of the available land area—is presently cropped for rice. Cultivable land to rice is spread over five ecologies, namely: rainfed upland, rainfed lowland or shallow swamp, irrigated rice, deepwater or floating rice and tidal mangrove swamp. The commonly used ecosystems and share of rice area for the rice ecosystems are presented in Table 1.

Ecology	**Share (%)**		**Yield (t/ha)**	
	Area	Production	Current	Potential
Upland	40	37	1.0	1.5-4.5
Rainfed lowland	48	49	1.4	2.5-5.0
Irrigated lowland	6	14	2.8	5.0-7.0

Upland: area expansion and yield increase may be fulfilled
Rainfed lowland: most promising
Irrigated lowland: dam construction is too expensive at current rice price
Source: Sakurai, 2006

Table 1. Rice production ecology in West Africa

Amongst these, lowland rice has the highest priority, being the ecology that represents the largest share of rice area and rice production. Smallholder farmers with farm holdings of less than 1 ha cultivate most of the rice produced in West Africa. However, rice productivity and production at the farm level are constrained by several factors. These constraints include insufficient appropriate technologies, poor supply of inputs, ineffective farmer organizations and groups, poor quality of rice, poor marketing arrangements, inconsistent agricultural input and rice trade policies, and environmental constraints. These environmental constraints include poor drainage and iron toxicity in undeveloped lowland swamps, poor maintenance of developed lowland swamps, drought, deficiencies of N and P, poor soil management practices, seasonal over-flooding of rice fields, pests and diseases.

1.1 Hypothetical shift in production system

With the increasing awareness of the limited potential for intensification of rice production in the uplands, farmers are gradually moving into the lowlands, which are less fragile (permits residual moisture use), more fertile and ecologically robust. The lowland areas are underutilized in West Africa. The lowland areas are expected to meet the growing demand for rice in West Africa because they provide potential for expansion, diversification and intensification of rice production in the region. This change in farming practice has been accompanied by an increase in the use of agrochemicals (pesticides and fertilisers), high-yielding varieties and monoculture/ continuous cropping, which further disrupt traditional farming and natural ecosystem functioning. Most West African countries are currently undergoing intensification in rice production to cope with the high population pressure. However, these may have adverse consequences on pest outbreaks, if it lacked the vision on the conservation of renewable inputs (biodiversity), and the whole issue of sustainability. This prediction is based on the hypothesis that with the improvement in the irrigation system, farmers will be able to grow high-yielding, photo-insensitive rice crops, and more crops per year on the same field. In such systems, the pest and beneficial cycles will be uninterrupted.

1.2 Insect pests of rice in West Africa

The major insect pests of lowland rice in West Africa include: the African rice gall midge (AfRGM), *Orseolia oryzivora* Harris and Gagné (Diptera: Cecidomyiidae); the rice stem borer complex: the stalk-eyed flies – *Diopsis* spp. (Diptera: Diopsidae); the African white borer – *Maliarpha separatella* Ragonot (Lepidoptera: Pyralidae); the yellow stem borers – *Scirpophaga* spp. (Lepidoptera: Pyralidae). Other important pests of rice include: vectors of rice yellow mottle virus (*Trichispa sericea* Guérin, *Chaetocnema pulla* Chapius, *Chnootriba similis* Thunberg and *Oxya hyla* Serville, etc.). All these pests are indigenous to West Africa except *Maliarpha separatella* that can also be found in Asia.

1.3 Yield losses caused by insect pests

Serious damage to the rice crop by the complex of insect pests result in significant yield losses which are typically in the range 10-30% yields and, in some regions or years, may exceed 90% (Nguu, 2008) (Table 2). Pests cause considerable and unacceptable crop losses in the field and in storage. The very high food losses in West Africa, attributable to pests, highlight their role in causing food shortages that lead to hunger.

Country	Pests	Estimated crop loss
Ghana	Stem borers	30%
Nigeria	Stem borers	25 – 30%
	African rice gall midge	10 – 35%
Burkina Faso	Stem borers	10 – 40%
	African rice gall midge	20 – 60%
Mali	African rice gall midge	20 – 35%
Cameroon	Stem borers	26 – 30%

Source: Youdeowei (1989, 2004)

Table 2. Examples of average losses attributable to pests of rice in selected West African countries

1.4 The race for pesticide sales in West Africa

The yield potential of rice cultivated in the intensified systems is continually challenged by chronic pest infestations and by pest outbreaks. This challenge is seen by the chemical industries mostly based in Asia and developing countries as an avenue to aggressively market their products in West Africa. The products are sold without proper training of smallholder farmers on how to safely apply it and without warning of the harmful effect on the environment. The sad aspect of the race for pesticide sales is that many banned pesticides in Asia and other developed countries of the world are being dumped in West Africa. The indiscriminate use of the pesticides has posed a lot of danger to the environment and ecosystem making human life to be under threat. The current article, therefore, not only meets a demand expressed from the regional entomologists but also makes an important contribution to raise alarm of the danger of pesticides in lowland rice which is currently being targeted for intensification.

2. Importation of pesticides into West Africa

As agricultural production system moves more and more from subsistence to market – oriented large scale farming, a concomitant increase in pesticide usage arise (Sosan *et al,* 2008). The climatic conditions of West Africa especially rainfed lowland ecology is conducive for build up of pest populations. Pesticide use in Africa accounts for less than 5% of global pesticide use and per hectare averages are low, estimated at around 1 kg/ ha active ingredient applied (compared with 3- 7kg/ ha in Latin America and Asia (PAN, 2010). However, low use volumes do not necessarily equate to low risk, particularly as some of the most toxic pesticides continue to be applied in Africa especially in West Africa, often under extremely dangerous conditions (PAN, 2010). Though, there are differences in the rate of agrochemicals application across the agroecological zones, pesticide use was high in dry savannah of West Africa (Ephraim *et al.,* 2010). Pesticide use in Africa accounts for only 2–4% of the global pesticide market of US$31 billion (Williamson *et al.,* 2008). Although Africa is currently neither a major consumer nor producer of chemicals in global terms, pesticides use in the African agricultural sector is likely to increase as a result of the growing commercialization as well as the growing focus of development agencies on improving yields of small farmers (Nelson *et al.,* 2006). Most African countries were net importers of pesticides. In Ghana, the number of pesticides dumped by the chemical industries was between 163 to 180 units as at 2002 (Suglo, 2002). In Kabba area of Kogi State, Nigeria, the number of pesticide users increased dramatically from 42% in 1971 to 78% in 1998 (Youm *et al.,* 1990). Importation of agrochemicals into sub-Sahara Africa increased in monetary values from $16.1 million in 1973 to $30 million in 1977 (Youm *et al.,* 1990). Most of the pesticides brought into West African countries have been banned. Pesticide that is banned for agricultural purposes in 52 countries due to its hazardous nature is being used in Ghanaian agriculture (Glover *et al.,* 2008). Most farmers in Africa increasingly depend on pesticides alone to control insect pest, and without satisfactory understanding of the associated hazards. Nigeria ranked first among West African countries in terms of quantities of pesticides use (Abete *et al.,* 2000). Thus, Nigeria alone accounted for nearly 93% of UK pesticide exports to West African countries. Pesticides are the main sources of pollution in

Fig. 2. Pesticide application on rice field

the Senegal River Valley of Senegal, Mauritania, and Mali principally for vegetable production and herbicides/ fertilizers for irrigated rice cultivation. Overall, we do not want to experience pest and disease resurgence as a result of high use of chemical pesticides (Figure 2). The only way we can prevent it or reduce the negative effect is to educate irrigated rice farmers on the danger ahead of the indiscriminately use of pesticides. There is high overuse of chemical fertilizers and pesticides in cotton compared to rice in West Africa.

3. Cases of pesticide mis-use

Over the decades, chemical pesticide use has posed a threat to subsistence farming in West Africa because of the well known technical drawbacks such as high cost, lack of adequate protection for the user, absence of safety warnings, excessive and wasteful use leading to environmental pollution. A case in point is the Gezira irrigation scheme in Sudan, where continuous use of pesticides against the cotton jassid, *Empoaca lybica* has led to resistance in the whitefly (*Bemisia tabaci*), cotton bollworm (*Helicoverpa armigera*), and aphids (*Aphis gossypii*). This, in turn, has led to even higher rates of pesticide application and the consequent emergence of secondary pest outbreaks due to the selective removal of natural enemies from the crop system. For instance, citrus leafminer (*Liriomyza trifolii*) is native to Asia but has been a minor pest of citrus in Africa until recent years when it is now considered as the major threat to citrus (Abete *et al.,* 2000). The picture was not different in Madagascar where *Spodoptera littoralis* became a serious pest due to over-use of chlorinated hydrocarbons including monophos-DDT against cotton pests. Pesticide overuse to control pests in other crops such as cotton, coffee, cacao, groundnuts has resulted in the development of resistance to dieldrin and DDT by two mosquito species, *Anopheles gambiae* Giles and *Anopheles rofipes* (Gough) in the West African countries of Ivory Coast, Nigeria, Ghana, Mali, Burkina Faso, Togo, and Senegal.

In South East Asia, Brown Planthopper (BPH), a secondary pest of rice, suddenly became a major pest due to insecticide misuse. Since 2005, outbreaks of rice BPH have occurred in East-Asian countries such as Vietnam, China and Japan.

3.1 Destruction of non-target organisms and natural enemies

Non-target organisms are organisms that the pesticides are not intended to kill. Natural enemies include insect predators, insect parasitoids, and insect pathogens. Over 98% of sprayed insecticides reach a destination other than their target species, including non- target species. Successful biological control using five exotic parasitoids against the potato tuber moth, *Phthorimaea operculella*, both native of South America was achieved in Zimbabwe and Zambia. Unfortunately, this system has broken down due to increase in pesticide use by farmers unaware of the value of biological control, and due to the need other pests. Overuse of pesticides in Ghana to control cocoa mirids resulted in the killing of numerous non-target beneficial organisms. As a consequence, the shield bug, *Batl1ycoelia thalassina* (HerrichSchaeffer), a secondary pest resurged and caused a yield loss of 18% of the cocoa crop in Ghana's Eastern and Brong-Ahafo Regions (Owusu, 1971, Alfred *et al.,* 2001,).

3.2 Human and animal health hazards

Chemicals pollute the water body thus making it unsafe for human use e.g. drinking, washing of farm produce, etc. Many of the pesticides used are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation (USEPA, 2007). Pesticide related poisoning deaths are often caused by using pesticide packages or containers after they are emptied of toxicants. It was reported by Youm *et al.* (1990) that forty six residents in Ilorin area of Nigeria were hospitalized as a result of "mistakenly drinking or eating pesticides". Also, in a study conducted by Hotton *et al.* (2010) in the northeastern part of Nigeria on effect of pesticide use, he found out various ailments associated with pesticide use and the use of pesticide container. These include: bronchilis chest pain, asthma, cough, running nose, vomiting, nausea, excessive sweating, diarrhea, burning on urination, abdominal pain, irritation of eye, temporarily and permanent lost of vision, weakness of arms, hands and legs, stiffeners of the waist, fatigue, etc. Empty pesticide containers are used to store food because of a lack of understanding on dangers of pesticides, poor pesticide labeling, and a low literacy rate. Pesticides that are applied to crops can volatilize and may be blown by winds into nearby areas, potentially posing a threat to wildlife (Sequoia & Kings, 2007). More importantly, the remains of these pesticides flow back to the streams and river. Some people at the other end will fetch it for drinking and for other domestic activities thus resulting to one ailment or the other depending on the concentration. Fish and other aquatic biota may be harmed by pesticide-contaminated water (Collin *et al.,* 2008).

4. Beyond pesticide application

Resistance in pests due to chemical application is one of the major factors disrupting traditional pest management practices in West Africa. In order to maximize rice production and agricultural intensification while minimizing reliance on expensive pesticides, a long-term pest management strategies including varietal resistance, biological control and improved cultural practices is needed. IPM seeks to integrate multidisciplinary approach (combination of options) with limited pesticide use to provide effective environmentally sound, socially acceptable and economically safe solution to pest problems. AfricaRice and partners have developed some chemical free products for smallholder farmers in West Africa. Specific examples are provided below:

4.1 Varietal resistance

Improving varietal resistance or tolerance to insect pests is one of the most promising options for managing insect pests in West Africa. AfricaRice and partners have identified several Oyrza sativa varieties with resistance/ tolerance to the AfRGM. Cisadane (from Indonesia) has been selected as a variety tolerant to AfRGM and released in Nigeria as FARO 51 based on initial selection at NCRI and on-farm studies in Abakaliki by AfricaRice. BW 348-1 (from Sri Lanka) has good tolerance to AfRGM *and* iron toxicity under field conditions. It has been released in Burkina Faso and Mali (WARDA, 2003). Leizhung (from South Korea) is another tolerant variety to AfRGM released in Mali. Suitable lowland NERICAs being screened for insect resistance or tolerance include: NERICA L-25 and NERICA L-49 (Nwilene *et al.,* unpubl. data). AfricaRice identified one tropical *O. sativa* variety (TOS 14519 from The Gambia) with moderate resistance to AfRGM, which is currently used as a resistant check variety in screening. Several traditional *Oryza glaberrimas* (e.g. TOG 7106 – from Mali, TOG 7206 – from Côte d'Ivoire, TOG 7442 – from Nigeria and TOG 6346 – from Liberia) have been found to be highly resistant to the pest (Nwilene *et al.,* 2002).

4.2 Biological control

Biological control is a major component of sustainable agricultural systems that are designed and managed to reduce dependence on chemical and other energy-based inputs, minimize ecological risk resulting from farming practices, and enhance agricultural productivity in relation to resources available. To ensure that biological control will contribute to sustainable agriculture, AfricaRice identified the gregarious endoparasitoid *Platygaster diplosisae* (Hymenoptera: Platygastridae) and the solitary ectoparasitoid *Aprostocetus procerae* (Hymenoptera: Eulophidae) are the most important wasps attacking AfRGM. The *Paspalum* gall midge (PGM) *Orseolia bonzii* Harris (Diptera: Cecidomyiidae) which infests *Paspalum scrobiculatum* L. (Poaceae), a common weed in rice agroecosystems, is distinct from AfRGM, and is an alternative host for the two main parasitoids of AfRGM. The delay between the destruction of *Paspalum scrobiculatum* and the appearance of AfRGM populations on a rice crop means that the large majority of the parasitoids from *O. bonzii* die before AfRGM population is available – asynchrony between pest and associated natural enemies. AfricaRice has shown that habitat manipulation with *Paspalum scrobiculatum* management at the edge of rice fields had significantly increased the carry-over of parasitoids from *Paspalum* gall midge (*Orseolia bonzii*) to AfRGM. The combination of beneficial organisms, tolerant varieties and habitat management suppressed AfRGM, restored nature's balance, and resulted in increased rice yields (Nwilene et al., 2008a).

4.3 Chemical-free products

Chemical free products for insect pest control include the use of botanicals and biological control using pathogens. AfricaRice has demonstrated that neem seed powder and neem oil can provide effective control against termites in West Africa (Nwilene et al., 2008b). Termites constitute a major biotic constraint to upland rice production in West Africa. The control of termites has largely relied on broad spectrum and persistent organochlorine insecticides. Land use practices can affect the flow of water and persistent pesticides along toposequences from the fragile upland to the lowlands thereby causing harmful effect to humans. To meet the needs of upland rice farmers in West Africa, AfricaRice has shown that the biological control pathogen – the entomopathogenic fungus *Metarhizium anisopliae* is effective against termites on rice fields and can also be used as alternative to persistent chemical pesticides because of the serious health and environmental risks in terms of pollution, destruction/ death of non-target/ useful insects, and the reduction of biodiversity.

4.4 Adoption of IPM practices

The Food and Agriculture Organization of the United Nations in collaboration with technical assistance from AfricaRice introduced the concept of IPM training in farmer field school (FFS) to West Africa through a series of technical cooperation projects in irrigated rice schemes in Ghana, Cote d'Ivoire and Burkina Faso. Following the success of this programme, IPM farmer field school projects were extended to several other countries in West, Eastern and Southern Africa. The initial results obtained by farmers who applied IPM practices for irrigated rice production in Ghana showed that yields of rice were consistently higher in IPM fields than in fields where conventional farming practices were adopted. In the rice fields where farmers adopted IPM practices, pesticide use for pest control was reduced by over 90% and savings on pesticide use amounted to $100 per ha. Net returns from such fields were 32% higher than in farmer practice fields. Data from Mali show conclusively that by adopting IPM practices farmers are able to increase the production of rice by 9 - 21%, increase revenue by 14% to 35% while at the same time significantly reducing pesticide use by up to 100% (Nacro, 2000; Youdeowei, 2001 and 2004).

5. Conclusion

The need to increase rice yields for present and future generation requires that solutions to these pest problems are found that are both sustainable and adoptable in the socio-economic environment of farming communities. Why are there abundant and diverse natural enemies in West Africa rice ecosystems? The answer is simple – low use of pesticides in rice fields. The high cost of pesticides means that few farmers have access to them at present. AfricaRice has demonstrated that managing, rather than destroying, a "friendly weed" (*Paspalum scrobiculatum*) at the edge of rice fields (good sources of parasitoids - *Platygaster diplosisae* & *Aprostocetus procerae* close to the rice crop) offers African farmers free, non-chemical control of the continent's worst rice insect pest - African rice gall midge (Nwilene *et al.,* 2008b). It is significant to note that the natural enemy populations of rice pests are high and the species diverse in West African rice ecosystems. This is evident in the high levels of parasitism of the AfRGM. This may be the reason why West Africa has not suffered the insect resurgent crisis, that occur in Asian rice ecosystems, where the natural enemies of the brown planthopper, *Nilaparvata lugens* (Stål) are being killed through the misuse and inefficient application of insecticides. This provides evidence that pesticide use is less in West African rice ecosystems and that the natural enemies are being conserved. All future IPM strategies development should be designed to preserve, and possibly enhance, the existing and abundant natural enemy populations in West African rice ecosystems. Whereas the challenge in Asia is to stop farmers from overuse of pesticides, in West Africa, it is to prevent future overuse of pesticides. IPM is the only preventive approach and the way out for pest management in lowland rice ecology. In the long-term, everyone benefits from a healthier environment. This generation must rise up to the task of saving the global environment from pollution by discouraging production and importation of synthetic pesticides into West Africa. Smallholder farmers who use pesticides are often unaware of the adverse effect of pesticide applications. In implementing integrated pest management options, existing farmers' knowledge should be carefully analyzed, refined and integrated into the basket of options for them to choose from. There is a need to revisit a number of national policies related to food production and protection, in order to encourage partnership and participation in the identification, analysis, advocacy, and follow-up of plant protection issues as well as public awareness of the effect of pesticides on food and the environment.

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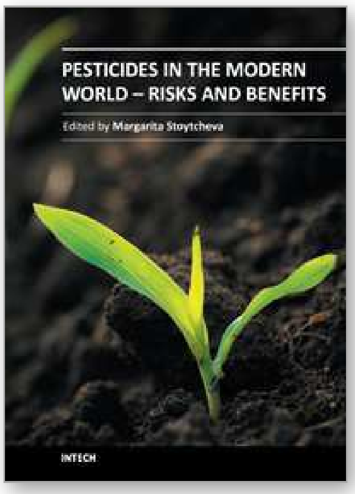

Pesticides in the Modern World - Risks and Benefits
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This book is a compilation of 29 chapters focused on: pesticides and food production, environmental effects of pesticides, and pesticides mobility, transport and fate. The first book section addresses the benefits of the pest control for crop protection and food supply increasing, and the associated risks of food contamination. The second book section is dedicated to the effects of pesticides on the non-target organisms and the environment such as: effects involving pollinators, effects on nutrient cycling in ecosystems, effects on soil erosion, structure and fertility, effects on water quality, and pesticides resistance development. The third book section furnishes numerous data contributing to the better understanding of the pesticides mobility, transport and fate. The addressed in this book issues should attract the public concern to support rational decisions to pesticides use.