

Sustainable rice and productivity, what does it mean? And who is going to make it a reality?

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This is an article on sustainable rice. It could just as easily have been written about cotton, corn, soybean or even mangoes. The basic principles of sustainability go even beyond agriculture and include such inherent concepts as ownership of responsibility and property as well as stewardship.

I have worked globally on rice for nearly 30 years, not in the role of a policy setter but on the periphery in development of crop protection concepts and more importantly as an observer and student of farmer practices. I have no vested interest in promoting my position. I receive no grants or support from governments or NGOs. I have a passion for all things relating to rice production and the deepest respect for the diversity in the farmers who produce it.

The objective of this paper is to clearly set forth how global rice production has evolved to where it is today and to suggest a less politically charged and more farmer amenable definition for sustainable rice.

Who is responsible for sustainability and productivity?

Sustainable agriculture encompasses a myriad of occupations and interests. To help make my points and provide a clearer understanding, I will focus my discussion and examples to a single segment, the rice farmer, and the drivers behind his decisions. In doing so, we must also recognize the diversity within and personal interests of the segment. Take these insights and transfer them to all the other upstream and downstream influencers and it becomes apparent that we all have a role to play in determining the future sustainability and productivity of rice. We either set the limitations or we open to the opportunities.

Sustainable agriculture defined

Sustainable.org defines sustainable agriculture as, "a way of raising food that is healthy for consumers and animals, does not harm the environment, is humane for workers, respects animals, provides a fair wage to the farmer, and supports and enhances rural communities" (<http://www.sustainabletable.org/intro/whatis>).

Wikipedia.org defines sustainable agriculture as, "the practice of farming using principles of ecology, the study of relationships between organisms and their environment. It has been defined as "an

integrated system of plant and animal production practices having a site-specific application that will last over the long term (http://en.wikipedia.org/wiki/Sustainable_agriculture).

Dr. Bas Bouman, a Senior Scientist at the International Rice Research Institute (IRRI) and Head of the Crop & Environmental Sciences Division has been quoted as saying, "Our aim is to develop a set of criteria for sustainable rice ... because globally, we don't really have a definition" (<http://www.foodnavigator-asia.com/Markets/Global-sustainable-rice-scheme-launched>).

There are at least two weaknesses in the above definitions of sustainable agriculture. It appears to be a loosely defined, politically correct term embracing an environmental approach to agriculture placing responsibility for sustainability on the farmer.

Although there is merit in embracing environmentalism, there is an implication in the above definitions that farmers are not good stewards of the environment and need some higher help in developing and sustaining their business. Consequently, some farmers have taken exception to the definition for sustainable agriculture. It would be more constructive to recognize that farmers strive to be good stewards of the land they own, produce and consume healthy, safe food and earn a good wage for their efforts.

And second, although the farmer is the producer of the crop, are not others also responsible for the sustainability of agriculture? What about government policy makers, bankers, providers of products and services to the farmers, truckers, buyers, millers and more? Are not they and their sustainability tied to the crop as well?

What is an ecosystem?

The definitions for sustainable agriculture have a strong environmental and ecological component and it may be helpful to explain in basic terms what an ecosystem is and its relevancy to agriculture.

Ecosystems are complex, living, dynamic, interactive communities. They are composed of the continuous interaction and balancing that goes on between the: sun; air; soil; water; and associated organisms. Agricultural ecosystems are artificial ecosystems created by manipulation and management

of the: land or soil; water; the crop; weeds; insects; and diseases in order to maximize the productivity of a desired crop.

Agriculture was at the start of the transition of humans from hunter gatherers to modern civilizations. It required the domestication of plants and animals and the management of resources, particularly the land and water. For this to occur, establishing a permanency was required. Permanency led to a sense of ownership which in turn leads to stewardship. Good farmers are good stewards of the land they own.

When a technology is proven beneficial and farmers can afford it they embrace it. Technologies that have made significant contributions to the environment and agricultural productivity that have occurred within the past century include mechanization, hybrid crops, crop protection chemicals (CPCs), Integrated Pest/Crop Management (IPM/ICM), and no-till farming.

Productivity and sustainability

What is productivity and how is it relevant to sustainability? How are they measured? And, how have they changed through time in the production of rice?

Productivity is the measure of the input costs against the value of the output; while sustainability requires the output value to be greater than the input costs. It is a basic principle of economics; production cannot be sustained at a loss.

Productivity is the measure of efficiency in production. It is a measure of the inputs required relative to the value of the product produced. A simple equation in agriculture can demonstrate this:

Area planted + inputs + labor = yield

Doubling the area planted to double production does not double productivity unless the labor involved is not doubled.

$2(\text{area planted} + \text{inputs}) + 1.5(\text{labor}) = 2\text{yield}$

Mechanization has modernized agriculture and improved productivity in much of the world. Dr. Elwyn Taylor of Iowa State University provides a personal example of this. Prior to owning a tractor after World War II, one third of his family's farm in Utah, USA was devoted to growing crops to feed the draft animal required to till and harvest.



After acquiring a tractor, that land could be used for growing other crops that could be sold to pay for the tractor, its fuel and maintenance and still have money left over. In much of the rice growing world, mechanization remains limited and is being so also limits the productivity of the farmers.

Factors affecting yield

Yield effecting environmental factors such as light intensity, day length, the amount of rainfall, and temperature are beyond our control. Other than plant breeders developing varieties that favor a different light intensity or day length, or are more tolerant of either drought or flooding, or lower or higher temperatures, production scientists and farmers have had to focus on those factors that can be directly controlled.

Rice breeders continue to develop new higher yielding varieties. Hybrid rice is playing an ever increasing role in increasing yield by increasing the yield potential of rice. Yield potential is the "yield of a crop cultivar when grown in environments to which it is adapted, with nutrients and water non-limiting, and pests and diseases effectively controlled"

(http://www.hybridmaize.unl.edu/Assets/UserManual/Section_1.pdf). To this we would like to include weeds, lodging, and other stresses. This differs from potential yield which is the maximum yield which can be attained by a crop in a given environment.

Yield potentials will differ between varieties and for each variety is set under its optimum growing conditions. Potential yield is a variety's expected maximum reproductive capability under optimum existing environmental conditions.

The potential yield for a rice variety will differ between locations due to biotic and abiotic influences. While a rice variety grown in Hazen, AR, USA may not have the same potential yield when it is grown in Kalyani, WB, India, its yield potential will remain the same.

The yield potential of a variety is its genetic reproductive capacity under optimum conditions. And yield itself, is the plant's expression of its reproductive potential under the conditions in which it is grown.

The progression to sustainable rice

Rice, like all crops, has passed through a series of technological steps or innovations that have each contributed to increasing yield, and improving productivity and the lives of farmers. The most dramatic innovations have perhaps occurred in the last one hundred years. Yet it is still possible to find farming situations in much of the rice growing world where these innovations have not been adopted for innumerable of reasons.

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Under traditional or pre-industrial agriculture, farmers were dependent on human and animal muscle power for every aspect of growing a crop. The intensive labor requirement placed a limit on the cropping area a farmer could manage. Farmers practicing this level of farming today are typically operating, at or near a subsistence level. They are in this situation primarily because they lack the resources to improve the inputs required to improve productivity.

The advances that took us out of traditional, pre-industrial agriculture began to make their greatest impact after World War II. These technological advances ushered in modern agriculture by replacing or reducing physical input with the introduction of mechanization, use of petroleum based fertilizers and crop protection products. Each of these technological advances enabled faster cultivation of larger tracks of land with less labor. Advances continue with such innovations as GPS guided tractors and precision aerial application as well as laser leveling and precision field mapping for soil type and nutrition as well as use in targeted crop protection chemical applications.

The Green Revolution played a particularly important role in improving rice productivity and is closely associated with the International Rice Research Institute (IRRI). The Green Revolution introduced modern plant breeding methods to select for desired traits, which on rice included shortening the growing cycle, reducing vegetative growth and lodging, and increasing the yield potential of modern rice varieties. Insect and disease tolerance or resistance traits were also bred into the modern rice varieties which reduced dependence on insecticides and fungicides.

Integrated Pest Management (IPM), which originated in California orchards, increased environmental awareness in crop production and found a fit on Green Revolution rice varieties with insect and disease resistance traits. The fundamental principle of IPM is to rely on monitoring the crop for arthropod infestations and to time prescription pesticide applications of the most environmentally compatible and specific insecticides when biological controls (beneficial insects and mites) were not adequately controlling the pest, rather than rely on a calendar based spray program for crop protection.

IPM soon morphed into Integrated Crop Management to include crop nutrition and disease and weed control.

Crop protection chemicals have been an integral part of and valuable tools in IPM's arsenal from its inception. However, a shift occurred in rice,

by the late 1980s the leadership of the Green Revolution turned environmentally green and had removed the use of crop protection chemicals from consideration in rice production practices. This subject will be covered further later in this paper.

Hybrid rice was the next step in increasing the yield potential of rice. It was first commercialized in China in the mid-1970s by the father of hybrid rice, Dr. Yuan Longping. This technology continues to spread throughout the rice growing world (http://en.wikipedia.org/wiki/Yuan_Longping). However, there remain unresolved drawbacks to hybridizing rice.

The first drawback is that the relative sophistication in hybrid seed production limits supply. Couple this with farmers not being able to retain and plant seed from his previous crop and you have an additional dependency placed on farmers who switch to growing hybrid rice.

Another drawback to hybrid rice has been its inferior milling qualities which result in grain breakage during the milling process. This in turn lowers the value the farmer can get for his crop. Hybrid rice breeding programs are addressing this problem and hopefully a solution will eventually be found.

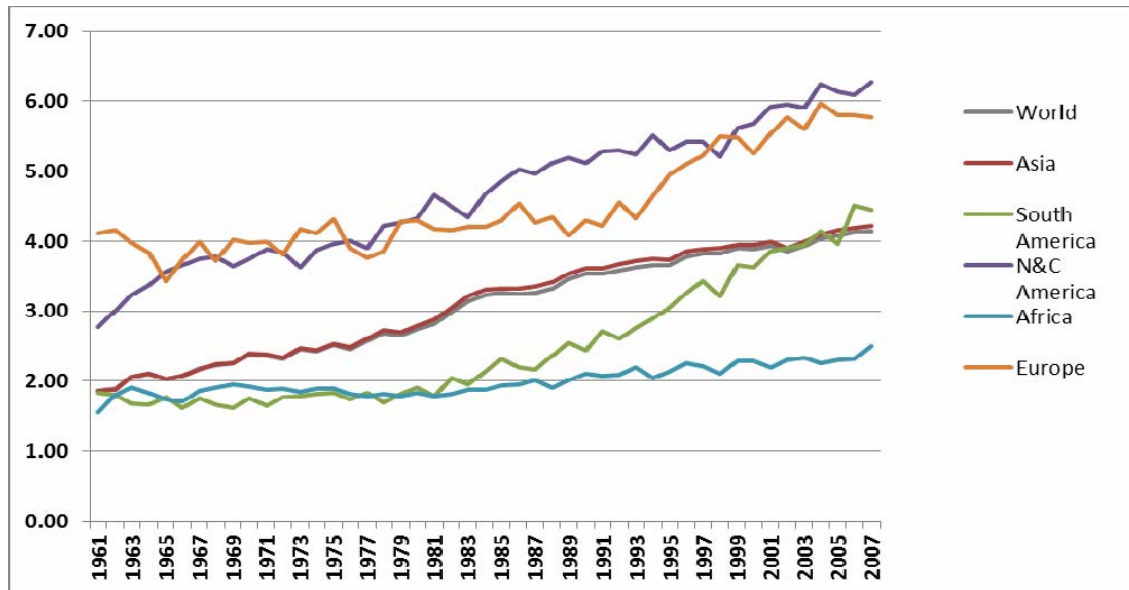
That brings us to where we are today, on the cusp of what sustainable agriculture and sustainable rice are meant to be.

Yield improvement since the start of the green revolution

The data used in this section was sourced from the IRRI web site (http://beta.irri.org/solutions/index.php?option=com_content&task=view&id=250).

Since the start of the Green Revolution in the 1960s global rice yields have risen steadily. The average global rice yield per hectare has increased by 122% in 46 years and is currently at 4.15 metric tons per hectare.

If one compares the average yields per hectare between regions, Asia tracts well with the world average due to the vast majority of rice hectares are grown within that region. The combined North and Central American average is high due to the high yields in the USA pulling the regional average up. South America's yields began to increase in the 1980s and have recently surpassed both the Asian and world averages. South America's average yield is expected to continue to increase. Africa's yields have remained far below the world average; primarily held back by infrastructural limitations in everything from irrigation to transportation.



The average global rice yield per hectare

Role of production scientists and who are they?

The role of production scientists is to recognize the diversity of systems for growing rice and to identify and optimize the rate limiting factors within each production system. This requires a holistic, integrated, systems approach to both studying production and finding solutions.

A holistic, integrated systems approach to rice production involves collaboration among a

diverse set of disciplines including: land preparation; water management; variety and planting rate; planting methods; fertilization and plant nutrition; levee management; insect, disease and weed management; mechanization; harvest methods; and post-harvest handling and storage. If you work in any of the above disciplines you may consider yourself a production scientist.



There is one thing in common among the photos above. Each photo documents an herbicide application to a rice field. Just as the photos demonstrate there are many ways of applying an herbicide to rice, there are many ways for growing rice. And, if that be the case, there must be multiple ways to sustainable rice.

The System of Rice Intensification (SRI) has been demonstrated to dramatically improve rice yields

when intensive human resources per hectare are involved. SRI has demonstrated its place in producing rice and improving the livelihoods of small landholder farmers. It is being highly promoted to governments throughout Asia, Africa and Latin America as an alternative to conventional production and a path to sustainable rice. Government policy makers are in turn strongly encouraging research into and the promotion of SRI by rice production scientists.

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However, SRI is not the answer in all rice production systems. When does SRI fail to be practical because of the size of the field or availability of labor? When is a paddy too large for manual weeding? What then are the alternatives?



Conversely, when is a paddy too small for an herbicide application by air?



In the over 30 years of experience I have had on rice, I have witnessed dramatic changes in the agronomic practices in rice production. These changes have been largely driven by economic pressures placed upon rice farmers due to the loss of farm labor with the advent of industrialization within their countries. The changes in agronomic practices have led to shifts in pests, predominantly weeds, which in turn have forced further adaptations to be made. These changes in agronomic practice are occurring everywhere rice is grown from lesser technified farmers shifting from transplanting to direct seeding rice to more technified farmers shifting from conventional rice to Clearfield/hybrid rice.

What has been consistently observed is that, with every adoption of a new production practice, rice yields (productivity) has increased. And, that although each technological change has had an increase in

input cost, it has been covered by the value of the improved productivity.

A missed opportunity

All too often, the current leaders of the Green Revolution and advocates of SRI and sustainable rice production have discouraged the consideration of crop protection chemicals (CPCs) for environmental reasons. This has been a missed opportunity. Their end customer, the rice farmer, continues to rely on CPCs. Knowledge of CPCs is critical to their safe and judicious use. IRRI's guidance to the rice farmers' safe and judicious use of the more selective and environmentally benign chemistries would have been an asset in the past and could be in the future.

I was the New York State Extension Tree Fruit Entomologist in the late 1970s and worked in close association with the award winning Tree Fruit IPM Program at Cornell University. That program, then and now, included monitoring and the judicious use of CPCs as a part of its program. Unfortunately this has not been the case with IPM on rice.

Although it is admirable to minimize the footprint of CPCs, it is wrong to reject their use outright. When used properly, CPCs can: be safe for the applicator and the environment; reduce labor; reduce overall input costs; increase yield; and improve productivity.

A thorough knowledge of CPC's, their attributes and how to safely apply them are fundamental principles of IPM or ICM. It is critical to know their toxicity, physical and chemical properties, modes of action, product concentrations and use rates, compatibility with other chemistries, crop safety, the species controlled as well as their effect on non-target species, environmental fates and half-lives, and pre harvest intervals.

Crop Life Foundation in the USA produced a report: "The Importance of Herbicides for Natural Resource Conservation in the U.S." This report documented a reduction in tillage, made possible by herbicide use, has resulted in a: 32% reduction in soil erosion from farmland; 20% reduction in the farm use of water for irrigation; 50% reduction in fallow acreage; and 26% reduction in farm energy use (<http://www.croplifefoundation.org/Documents/Articles/Importance%20of%20Herbicides.pdf>).

Without a knowledge of CPCs

Herbicides have been documented to reduce the time spent controlling weeds in rice paddies by 500 hours per hectare over the back breaking drudgery of hand weeding (Mazid *et al.*, 1996; Nai-Kin, 1996). Without proper knowledge of herbicides what alternatives does a rice farmer have to control weed infestations when he lacks labor or his planted area is too large for either hand or mechanical weeding?

Rice farmers need to know what herbicide control the weeds that are present, whether it is safe to rice, if there is an adequate pre-harvest interval.



Fungicide applications have been shown to increase rice yields by 35% and 45% when controlling sheath blight and blast ([http://www.croplifefoundation.org / upload /137%20CropLife%20 Foundation % 20 Fungicide% 20 Benefits. pdf](http://www.croplifefoundation.org/upload/137%20CropLife%20Foundation%20Fungicide%20Benefits.pdf)). Without knowledge of fungicides how can a rice farmer be expected to adequately control rice diseases?



Rice farmers need to know which fungicides control blast and which control blight, which have preventative activity and which have curative activity. Not knowing what proper insecticide to use can cause brown plant hopper outbreaks that can totally devastate a crop.

Rice farmers need to know which insecticide controls the insect in question, is safe to beneficial arthropods and has an adequate pre-harvest interval.



Attaining sustainability

Ultimately it is the individual farmer who decides what he will grow, when he will grow it, and how he will grow it. Those decisions are largely economically driven. Points that are factored into the decision may include: the cost of production (inputs); the value of crop (price of rice); local prices; the import/export market; personal, local or world consumption and demand; food security; social issues; and the return on growing alternative crops. The significance of each factor will vary between countries, seasons and the agronomic practice employed. The farmer's sustainability and livelihood are dependent on the decisions made.

The economic influencers in the farmer's decisions are the providers or sellers of inputs, including the bank or money lender as well as the cost of seed, fuel, equipment, labor, water, land, fertilizer and crop protection chemicals. At the other end of the production line, the farmer must consider his customer, the buyer of the crop and what they will pay for it.

There are also non-economic influencers. Although they do not have a direct financial interest in the outcome, they play an important role in providing the farmer with information. They can be local or regional extension agents, specialists at nationally funded rice research stations or affiliated with NGO's such as IRRI and SRI. They provide information through classes and workshops, on farm recommendations, printed literature, the worldwide web and even by cell phone.

Just as an ecosystem is a complex, living, dynamic, interactive community where the parts are continuously interacting and balancing, the influencers, both the economic and non-economic, must find means to work together for the common good; providing the individual farmer with resources for making informed decisions that fit his situation. Hopefully, sustainable agriculture will provide that means.

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The bottom line for a rice farmer is that the difference in the price of rice from the cost of production must be positive. A farmer will grow rice if he can manage his input costs and sell his crop at a price that will allow for a reasonable, competitive return on his investment. Without the farmer making a decent living his operation will not be sustainable.

Similar constraints and economic considerations that were described in this article occur all along the rice production and value adding chain. Without each link in the chain being profitable and therefore sustainable there will never be sustainable rice.

Based on this observation I would like to suggest a more inclusive definition for sustainable rice that encompasses all aspects of the rice production process, recognizes and appreciates the diversity in the chain of production practices and is respectful of the environment and those involved. Sustainable rice is a holistic, integrated systems approach to rice production that endeavors to improve productivity as well as the livelihoods of everyone in the production chain, based on environmentally sound inputs that are applicable within individual systems and that the user can afford.

The future is ours to create. What role will you play?

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