Gary Skinner

The price of rice

Using genetics to increase crop production

A rice paddy in Thailand

Rice is the most important food crop in the developing world and the staple food of more than half of the world's population. These people are very vulnerable, therefore, to a rise in the price of rice. If you eat a few kilograms of rice a year, then even a doubling in price will have little effect. But, if you were already spending more than half of your income on rice, then a doubling in price would be devastating. In the most rice-dependent regions people eat over 100 kg per year, a phenomenal amount.

More than 3.3 billion people depend on rice for more than 20% of their calories and one fifth of the world's population depends on rice cultivation for their livelihoods.

Rice has twice the value of production in the developing world of any other food crop: more than $150 billion per year. Nearly 560 million people living on less than US$1.25 per day are in rice-producing areas, far more than for any other crop. Rice has been, and will be, essential for the future, especially in Asia. In the 1960s many Asian countries were thought of as failing states and Western politicians agreed there was little that could be done, there would be major famine and that was that. There were those, however, who felt otherwise.

A Cambodian family eat rice for lunch.

Key words
photosynthesis
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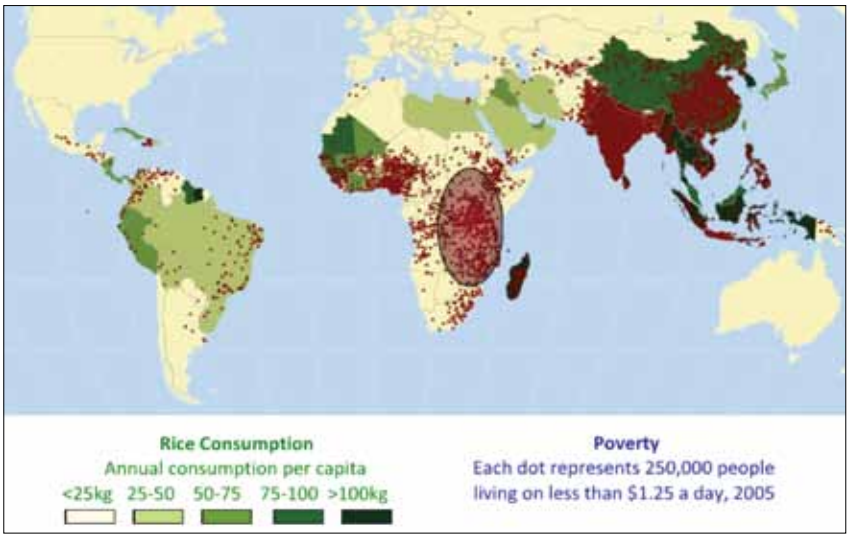
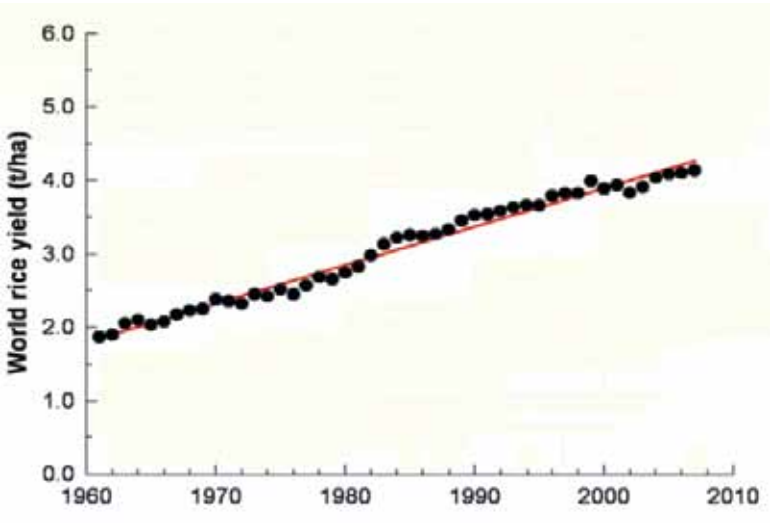


The people who eat the most rice are amongst poorest in the world living on less than $1.25 per day. The oval area over East Africa represents an area where there is little data on rice consumption, but it is known to be high.

The Green Revolution

Through research, improving the crop, and better management techniques, yields went from 1.5 tonnes per hectare in the 60s to over 4 tonnes per hectare now.

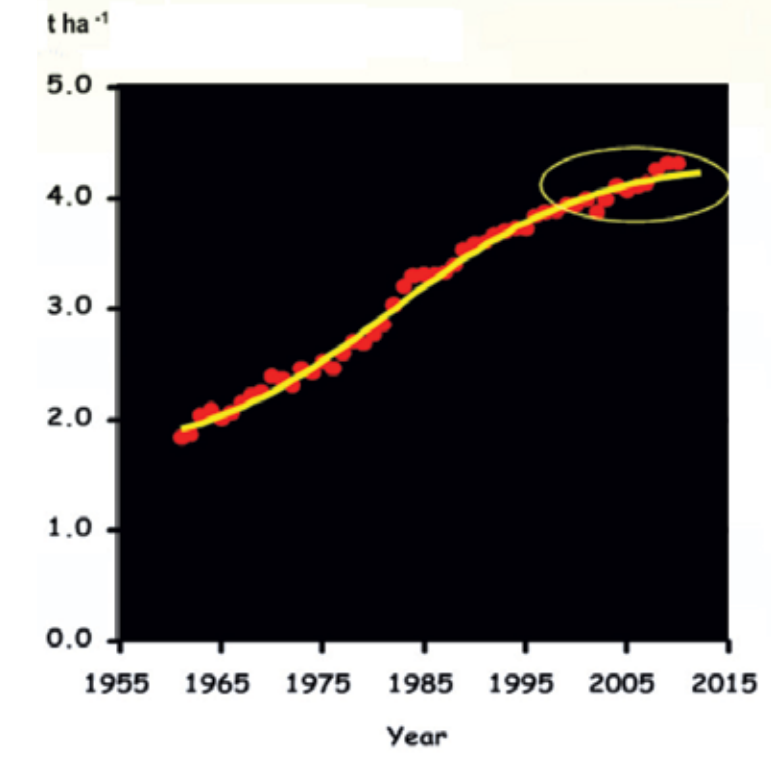


The trend in rice yields over the last 50 years

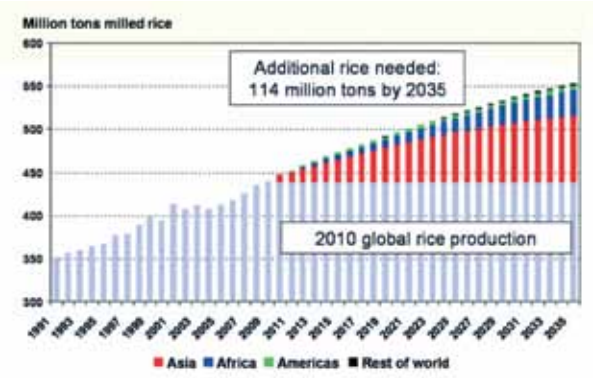
A hectare is an area of 10 000 m^2, or about 2.4 acres.

The consequent fall in the price of rice (from an average of $1000 per tonne to a 2002 low of $200) is probably at the root of the so-called economic miracle in Asia over the last 50 years.

However, there are three problems. First, the growth trend is flattening in the face of further population growth and therefore demands for more rice.



The worrying recent (since 1995) trend in rice production



World rice production will need to increase to meet rising population.

Second, the changes to climate that global warming is likely to bring. Thirdly, land and water are moving away from rice. The mayor of Manila would sooner release water from reservoirs to urban dwellers in a drought than to rice paddies. All the land suitable for rice is already being used.

A second, science-based, green revolution is needed to sustain growth in yield in the face of climate change.

Science to the rescue?

Rice is extremely genetically diverse. The International Rice Research Institute (IRRI) has over 110 000 different varieties, all now stored in the Svalbard Seed Bank in Norway. This could be vital for future research, as could the 20 species of wild rice in the genus Oryza that still exist.

One issue that has already been addressed is the problem of flooding. Rice is cultivated in a paddy, a flooded field, and it thrives in these conditions. However, it will not withstand complete submersion, it only likes its feet wet! Much rice is grown in deltas, which already suffer from floods and will do more so as sea levels rise. In 1978 an Indian rice variety (FR13A) was discovered which showed flood tolerance, but it gave a very poor yield of very poor quality grain. After over twenty years of experimentation, and with new tools from rice genome sequencing work, cultivated strains of rice were rendered flood-tolerant.

A trial of rice plants which have had a flood resistant gene called Sub 1 added to them. Plots with a yellow label have plants with the Sub 1 gene, while white labels indicate the same varieties without Sub 1. The paddy is shown some days after the rice had been immersed in water for over 2 weeks.

The variety (called Swarma_Sub1) is now being distributed to over a million farmers and it will change the lives of tens of millions as a result.

A farmer in Uttar Pradesh state, Eastern India with his badly flooded rice crop in July. Some months later the crop has recovered and he has a good yield. Traditional varieties would simply fail after such flooding.

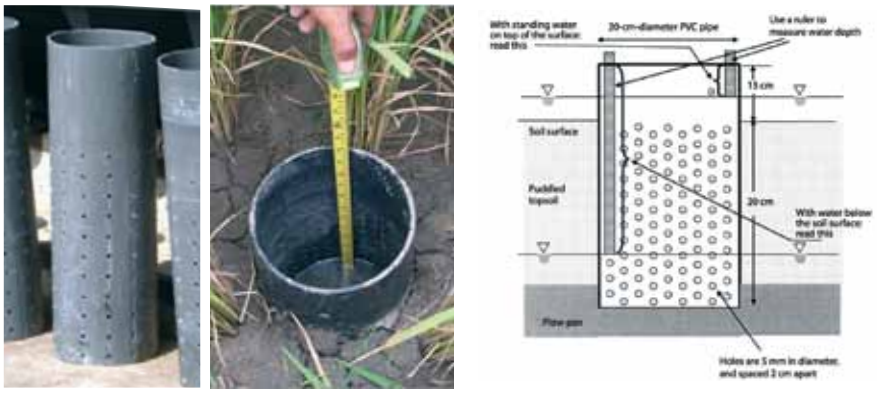
Similar work is also being done on salinity, temperature and drought tolerance, all using the rice genome sequencing work that went earlier.

Sustainability

So, the future of rice as a staple food seems assured. But, most of the world's rice is grown in intensive irrigated systems where two vital factors are large water supplies and the use of fertiliser. Is this system itself sustainable; that is, can it go on into the future as it is now?

IRRI set up experiments, starting in 1963, in which the land has been intensively cropped, more so than anywhere in the world. Yields have remained as high as can be expected. In fact, it was shown that the fields would go along very well even without fertiliser!

But what about water? It takes 500 litres of water to grow a bowl of rice but can it grow on less? Work has been done on this because water is becoming more and more scarce. Scientists have shown that the amount of water around the rice can be managed such that the irrigation requirement can be cut in half and the rice will grow just as well. The key is to make sure that farmers have a simple way to know when to irrigate and only do it when it is needed. The method used is called, in the Far East where the 'magic pipe' technique is being applied.



A magic pipe is a simple device which allows famers to irrigate rice only when it is needed, saving about 50% over traditional paddy field methods.

C3	C4	CAM
C3 because CO_2 is first incorporated into a 3-carbon compound.	Called C4 because the CO_2 is first incorporated into a 4-carbon compound.	Called Crassulacean Acid Metabolism (CAM) after the plant family in which it was first found (Crassulaceae) and because the CO_2 is stored as an acid before use.
Stomata open during day.	Stomata are open during the day.	Stomata open at night (when evaporation rates lower).
RUBISCO, the major photosynthesis enzyme, is also involved in the uptake of CO_2.	Uses PEP Carboxylase for uptake of CO_2 so CO_2 is be taken in very quickly, and delivered to RUBISCO. Photosynthesis takes place in inner cells (requires special anatomy called Kranz Anatomy).	The CO_2 is converted to an acid and stored during the night. During the day, acid is broken down and the CO_2 is released to RUBISCO for photosynthesis.
More efficient than C4 and CAM when cool and moist.	Photosynthesizes faster than C3 plants under high light/high temperatures because CO_2 is delivered directly to RUBISCO, not allowing it to grab oxygen and undergo photorespiration. Has better water use efficiency because PEP carboxylase brings in CO_2 faster and so does not need to keep stomata open as much (less water lost by transpiration) for the same amount of CO_2 gain for photosynthesis.	Better water use efficiency than C3 plants under arid conditions due to opening stomata at night when transpiration rates are lower (no sunlight, lower temperatures, lower wind speeds, etc.).

Three kinds of photosynthesis

There are in fact three kinds of photosynthesis, C3, C4 and CAM. Most plants are C3.

Plant science at work

Plants are at the base of all food chains, including those with humans. For half the world's population, the plant is rice. So plant science, and especially rice science, is one of the best ways to have an effect on people's lives as a scientist today. New projects include efforts to convert rice, a relatively inefficient C3 plant, into a much more efficient C4 plant (see Box) and to more fully sequence the rice genome. As Bob Zeigler, director of IRRI, puts it:

"By addressing the challenges of the very poorest people we are also addressing climate change issues of the future. You can do great science, you can make a huge difference to millions of people's lives, you can have a very satisfying career and you can make politicians very happy!"

Written by ***Gary Skinner,*** *based on a lecture by* ***Bob Zeigler,*** *Director of IRRI and delivered at the 2011 Gatsby Summer School at York University.*