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## The new green revolution

# A bigger rice bowl

### Another green revolution is stirring in the world's paddy fields

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A SEED of rice that could transform the developing world saved Asha Ram Pal's farm in the Indian state of Uttar Pradesh in the summer of 2008. Mr Pal had planted rice on his small plot, not much bigger than a football field. Floods are an ever-present threat in the state, making it one of the poorest places in the world. And that year the monsoon was particularly heavy, remembers Bob Zeigler, director of the International Rice Research Institute (IRRI). Mr Pal's fields flooded for two weeks after he planted the rice seedlings; a few weeks later, they were inundated again. He thought his crop was lost. His neighbours advised him to do what they have always done when the floods come: prepare for hunger.



But this time Mr Pal had planted an experimental seed developed by scientists from IRRI in the Philippines. The seed has a genetic sequence bred into it which puts it into a sort of suspended animation when submerged. Instead of drowning, Mr Pal's rice sprang back when the water receded. In a normal year he gets a tonne or so from his 1-hectare (2.5-acre) plot; in a bad year nothing. In that terrible flooded season, he harvested 4.5 tonnes—as good a yield as on any rain-fed paddy in the world.

Flood-resistant rice is now spreading as fast as the waters themselves. Five years after the first field trials, 5m farmers across the world are planting more than a dozen varieties of rice with flood-resistant genes, collectively called “Sub 1”. They are proliferating even faster than new rice varieties during the heady early days of the first green revolution in the 1960s. “And Sub 1 is the first of a new generation of seeds,” says Mr Zeigler. If all goes well, over the next few years plants that tolerate

drought, salinity and extreme heat will revolutionise the cultivation of mankind's most important source of calories. But that will depend on the technology working as promised and, in particular, on public policies that support a second green revolution. Neither is guaranteed.

The first green revolution helped save the developing world from disaster. Two plant breeders, Norman Borlaug with wheat and M.S. Swaminathan with rice, persuaded governments in Asia and elsewhere to encourage the planting of higher-yielding varieties, especially of rice; 3.5 billion people, half of mankind, get a fifth of their calories or more from the stuff. When the men started work in the early 1960s, China was suffering the famine of the Great Leap Forward. And India was widely thought to be on the brink of starvation.

Today in Asia, famines are things of the past. One reason is the spread of democracy. Another is the green revolution, which has ensured that there is plenty of rice—India even exports it. And demand seems to be shrinking: the richest Asian countries, Japan, Taiwan and South Korea, are eating less rice. This has led governments which once supported the green revolution to think that a new one would be unnecessary. Rice, they reason, is a problem that has been solved. Better to improve the diets that are causing obesity or change the intensive-farming practices that are damaging the environment.

But it is not clear that the mission has been accomplished. In Asia as a whole, consumption per person is flat, not falling. The population is still growing, so demand for rice is rising on the continent where 90% of the crop is raised. In Africa, where a third of the population depends on rice, demand is rising by almost 20% a year. At that rate rice will surpass maize as Africa's main source of calories within 20 years.

### Seeds of stagnation

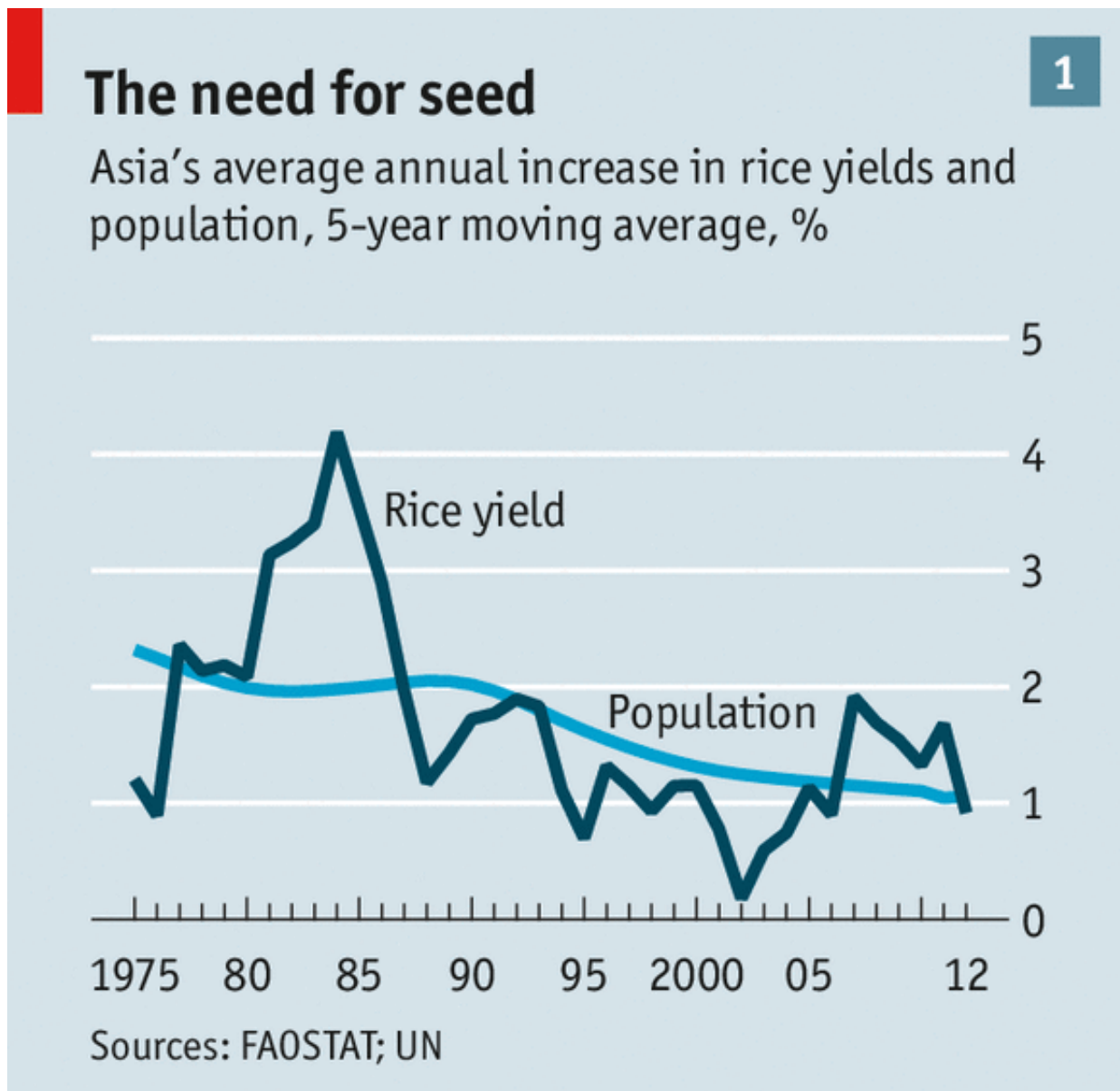
As a rule of thumb, if the world's population grows by 1 billion, an extra 100m tonnes of rice is required to feed them. Given current world-population forecasts, total rice consumption, now under 450m tonnes, is likely to grow to 500m tonnes a year by 2020 and to 555m by 2035—an increase of 1.2-1.5% a year. That would be manageable if rice yields were also growing at that rate. But they are not. They are rising at barely half that pace.

The first green revolution almost doubled yields from 1.9 tonnes a hectare in 1950-64 to 3.5 tonnes in 1985-98. Even that was only enough to keep pace with population growth: yields and population rose at the same rate (1.75% a year) in the half century after the green revolution started.

Now the gains seem to have levelled off. Plant breeders fear that, with current technology, ten

tonnes a hectare for rice in intensive-farming systems may be the limit, though it is not clear why. What is clear is that, out in the fields, output per hectare is stalling, and in some places falling.

For 25 years, IRRI has been planting a field using its best seeds. The field itself has remained much the same: the bugs and microbes that live in the roots of the rice plant mean that soil fertility is



maintained even if three crops are grown each year. But output from the plot has fallen from nine to ten tonnes a hectare in the early 1990s to seven to eight tonnes now, as pests and diseases have taken their toll. Rice yields were rising at 2.5% a year between 1962 and 1982. But between 1992 and 2012 growth fell to just 0.8% a year (see chart 1).

The facts of rice

Without new seeds, yields will decline further. Global warming will tend to push harvests down: higher night-time temperatures are associated with lower yields. The richest rice-growing areas in

the world are the deltas of Asia's great rivers, such as the Mekong, Brahmaputra and Irawaddy; they are vulnerable to rising sea levels and increased salinity, which kills rice. The plant uses two to three times as much water as other cereals (largely for levelling the paddies; the plant itself consumes no more than wheat or maize), but water is scarce everywhere. And each year the spread of Asian—especially Chinese—cities converts millions of acres of good rice-growing land into buildings and roads.

The consequences could be momentous. Rice plays a role in Asian societies that is hard for outsiders to appreciate. (A small example: Toyota means “bountiful rice field” and Honda means “main rice field”.) In the river basins that are the world's rice bowls, nothing else will grow with the same productivity. It is rice or nothing, and if there are problems with rice, there are problems with everything. A rice shortage would have geopolitical implications. No Indian or Chinese government could contemplate the possibility with equanimity. They would do whatever it takes to ensure they have enough rice. If this pushes up world food prices, so be it. If they must twist the arms of exporting countries, they will. If Asia's giants feel insecure, their neighbours will tremble.

So a lot is riding on boosting rice yields. But how likely is it that a second green revolution will take off?

The first was a relatively simple affair, technologically at least. Conventional rice varieties were long and leggy. If you gave them fertiliser, they grew too tall and fell over. That changed in 1962, when IRRI released a dwarf variety called IR8. Because its stem was short, it was able to absorb fertiliser without collapsing. So now farmers had a crop they could feed. And with stem growth restricted, more of the increase in plant size went into the head of seeds (called a panicle). IR8 spread from the Punjab to the Philippines, transforming farming wherever water could be controlled and fertiliser delivered.

The second revolution will be different. Farmers will not adopt a single miracle variety. Instead, researchers will tailor seeds for particular environments (dry, flooded, salty and so on). And they are also trying to boost the nutritional quality of rice, not just the number of calories. As a result, the second revolution will be felt most profoundly in the poorest areas and among the poorest farmers. In contrast, the first had the biggest impact in the richest fields, with the most water and fertiliser.

The flood-resistant trait that rescued Mr Pal's crop was first identified in the 1980s, in a few old-fashioned varieties native to Odisha, another flood-prone state in eastern India. After more than a decade of false starts, plant scientists identified the genes that make the Odisha varieties flood-tolerant. They went back to IR8's descendants, spliced these genes into them and bred from the

result. Having spent years getting nowhere with traditional plant-breeding methods, scientists went from marking the genetic sequence to producing flood-resistant seeds in four short years.

Abdelbagi Ismail, IRRI's principal scientist, hopes to do the same for other traits that have so far eluded breeders, such as drought resistance and heat tolerance. High temperatures during rice flowering can lead to sterility. If it is too hot, the anthers of the plant, which contain the pollen, do not open properly; the pollen is not released, the stigma are not pollinated and the crop is lost. The problem occurs during the hour or so when the plant flowers. It could be overcome if it were possible to encourage rice to flower in the cool of the early morning—as opposed to scorching midday, its usual hour. Tom Ishimaru, who works at IRRI and the Japan International Research Centre for Agricultural Sciences, has found a gene which codes for early-morning flowering, raising hopes of solving the problem.

Such breeding programmes will not have the same dramatic impact that IR8 did. But developing miracle seeds is not the only way to boost yields. During the 1990s China did it by improving hybrids: crossing different lines to combine the advantages of both. This is the usual way of improving maize, but it is less common with rice. Unlike maize, rice breeds true in successive generations, so farmers can retain seeds from one harvest and plant them for the next. Farmers will switch if a new variety gives them a big one-off boost, but not just to get the small increments offered through hybrid improvements. Hence, it takes a long time to boost yields using hybrids—unless the government forces farmers to use new seeds. China's rulers could do that; less authoritarian regimes cannot.

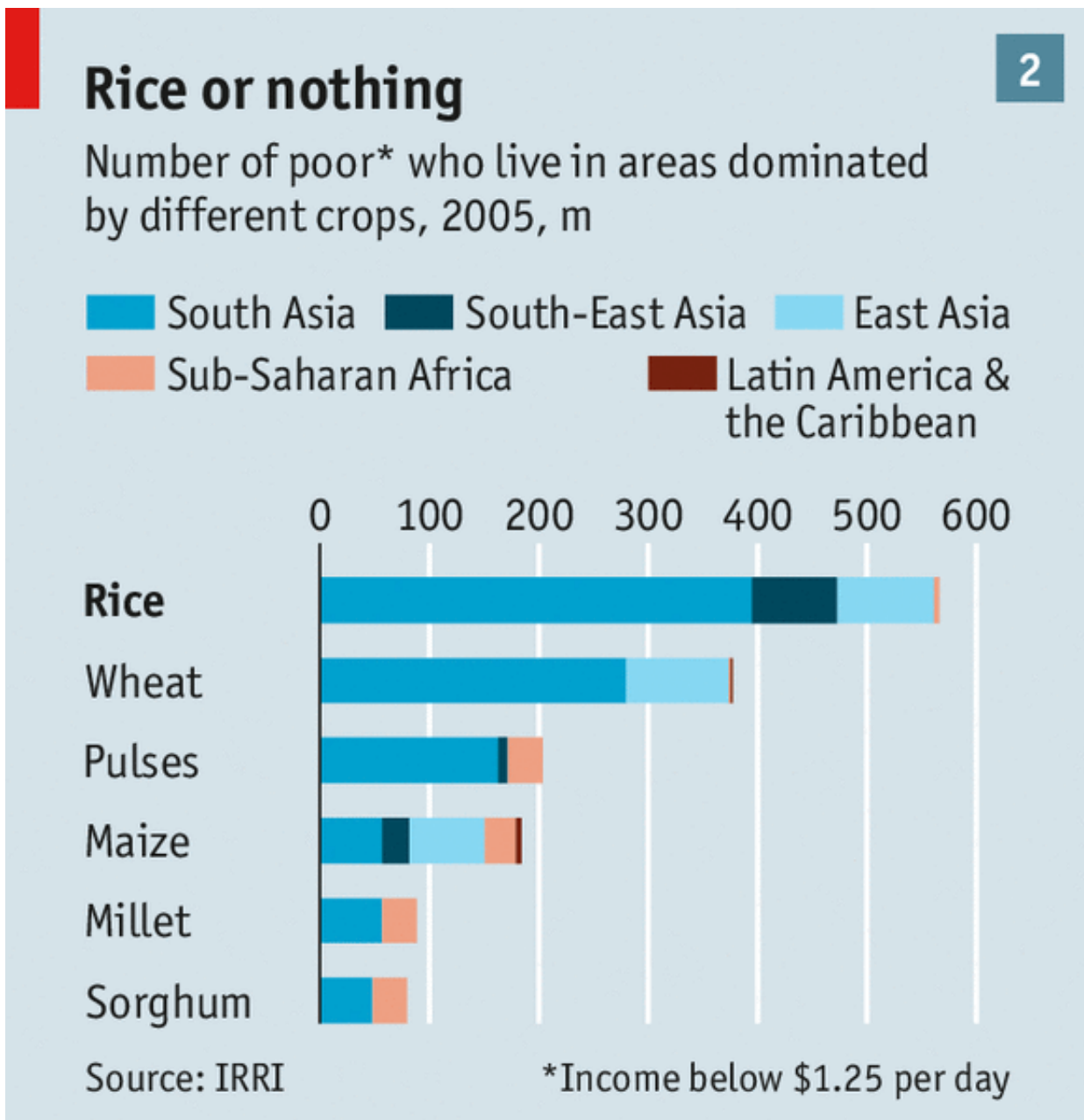
### Cereal killers

China's experience shows that a series of small improvements can add up to something large. This will be true of the second revolution on the poorest lands. The first green revolution had most impact on irrigated land and, thanks to it, the 80m hectares which are irrigated (an area equivalent to Vietnam, Laos and Cambodia put together) now have yields of five to six tonnes a hectare; they produce three-quarters of the world's rice. But there is nearly as much rice land which depends on rainwater. Yields there are far lower—between one and two and a half tonnes a hectare—and rain-fed lands produce only a quarter of the world's rice. Yields are low because almost half this land is prone to drought and a third to floods. Most African paddies fall into this category, which is why the first green revolution passed Africa by.

Drought- and flood-tolerant seeds could double yields from these areas. That would boost harvests from 110m tonnes to 220m, and push global output to 550m tonnes—enough to meet expected

demand in 2035. In short, all the extra rice could come from rain-fed areas alone.

Because yields on rain-fed lands are low, even a doubling would not increase total



production by as much as the first green revolution did. But the impact on poverty would be greater. More than 500m of the absolute poor (those with \$1.25 a day or less) depend on rice, far more than on any other food (see chart 2). A disproportionate number of them live in north-east India, Bangladesh and the Irrawaddy delta of Myanmar. In these areas the lowest castes and tribes have been forced onto the worst lands.

Those are the very places where the second green revolution would make the biggest impact. Flood-resistant rice “differentially benefits [India’s] scheduled castes and tribes”, a recent study of one of



the early field trials concludes. If these improvements were combined with another programme to boost the nutritional quality of rice—the so-called Golden Rice project which genetically modifies rice to include additional vitamin A—then the benefits to some of the poorest people in the world would be vast.

The first green revolution did not improve people's livelihoods just by providing technological fixes. It did so because the new seeds attracted new capital into farming, encouraged mechanisation, credit markets, new management techniques and so on. The second revolution will also do this. Already, rice farming is changing faster than for generations. Age-old habits of raising seedlings, transplanting them into the fields and threshing, drying and storing the plant are being rejected. Now, seeds are planted directly into the field by machine and everything from threshing to milling is done by specialist firms. For such changes to become more widespread, though, incentives and policies need to push in the right direction. Alas, they don't all do so.

On the face of it, the second revolution is subsidised. Not only do governments finance the basic research. In many Asian countries, from rice importers such as Indonesia to exporters



Seeding the next revolution

such as Thailand, they also pay farmers above the world price. Thailand's scheme is so generous that it ran out of money this year. Such price distortions artificially boost demand for green-revolution seeds in the short run.

But high domestic prices are also bad for the economy. They impose heavy costs on consumers. And they undermine incentives to export, making world prices more volatile and international markets thinner. This hurts farmers who stand to gain from the shift of comparative advantage in rice-growing towards India and Bangladesh thanks to the second green revolution. If world trade becomes even more marginal, any advantage those countries gain will be muted.

High domestic prices also tend to drive up local wages, reducing the competitiveness of manufacturing and making rural labour dearer. And by making rice farming a safe bet, the policies blunt entrepreneurship in agriculture too, reducing farmers' incentives to invest in new machinery and new ways of farming. On balance, therefore, artificially high rice prices make the new generation of seeds attractive, but by less than one might expect.

Land-use policy is equally messed up. In America and Europe technological change has tended to make farms bigger. The bigger the operation, the greater the gains from technology. That has not happened in Asia. In the most productive irrigated areas, farms are often smaller than two hectares and, despite mass migration from the countryside, have been getting even smaller during the past three decades. Governments have intervened to prevent farm consolidation partly because they want to slow down urbanisation, fearing that it could drive up unemployment in cities. Such policies have only not done considerable harm because of an extraordinary proliferation of efficient rental markets ([see article \(http://www.economist.com/news/briefing/21601816-seeds-are-not-only-miracle-components-new-green-revolution-rental-markets\)](http://www.economist.com/news/briefing/21601816-seeds-are-not-only-miracle-components-new-green-revolution-rental-markets) ).

The original green revolution transformed Asia from a continent stalked by hunger into one that could think and plan beyond the next harvest. It helped lay the foundation for the continent's economic miracle and made possible Asia's demographic transition from high fertility and high mortality to smaller, richer families. The second green revolution will not do that. But it should complete the first one, mainly by bringing benefits to the poorest, who missed out first time round. It will help mechanise and move more people off farms and into more productive labour. And it should prevent Asia slipping back under the shadow of hunger and all the political and social disruptions that such misery causes. Few other things can promise as much.

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