Is Science Failing Poor Farmers? Getting Results into the Village

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ABSTRACT

Despite significant improvements over the last 40 years in the capacity to produce the food and fibre requirements of an increasing population, the number of rural poor is unacceptably high. Much of the improvement in agricultural production has resulted from scientific advances in germplasm, pest and disease control, and the management of soil and water resources, combined with improved transport and market linkages. Technology packages were developed to address production problems, resulting in many astounding successes. In many situations, however, there is a large gap between what farmers can achieve on their farms and the potential production, as achieved on research stations. Reducing this gap would go a long way to solving agricultural production and food security problems.

There are two main reasons why some of the advances in agricultural science are not reaching a large number of farmers, particularly those with greatest needs – those marginalized poor rural communities who have limited and low quality resources. Firstly, many of the technology packages have not been developed for the more marginal situations in terms of natural and socioeconomic resources. Secondly, even when appropriate production strategies exist, the matching of these strategies to particular combinations of resources has not been effective.

Significant advances have been made in addressing these issues through the use of more participatory research and extension methods that involve farmers in the development and validation of production strategies, and subsequently in the adaptation and adoption on their fields of the approaches they rank most highly. As farmers have become more involved in these developments, rural communities have been able to work together to identify approaches that suit their sets of biophysical, social, political, and economic resources.

Still, the gap between potential and realized yield exists. These yield gaps need to be analysed to identify new areas of research and, perhaps more importantly, to identify those gaps that can be minimized through the appropriate application of existing technologies and strategies.

Examples are provided of some of the areas of agricultural production where improvements in productivity can be achieved most easily, particularly for the marginal uplands of Southeast Asia. These examples include cassava production, livestock systems, soil erosion control, and soil fertility management. From these we can conclude that science is not failing the poor, but it could do much better.

ACHIEVEMENTS IN AGRICULTURAL PRODUCTION FROM 1960 TO 2000

The world food supply has basically doubled over the last 40 years, resulting in an increase in the average food supply per person of 24% (UNDP *et al.*, 2000). While this increase outpaced the growth in population significantly, the world still lacks the capacity to meet the full nutritional requirements of all of

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humankind. Much of this deficit is due to the very inequitable distribution of the world supply of food, with particular problems in Sub-Saharan Africa and South Asia.

The dramatic increase in food production over the past 40 years was due to a combination of increases in the area of land in use, the cropping intensity, the area irrigated, fertilizer inputs, and the yield potential of different crop species. The area of land used for agriculture grew by only about 11 percent during this period (FAO, 2000), thus it was the other factors that where the major driving forces for increased production. By the year 2000, the area of irrigated had increased fourfold over the area used in 1960. The 17 percent of farmland that was irrigated in 2000 produced 40 percent of all agricultural production. Over the same period, fertilizer inputs of phosphorus, potassium, and most particularly nitrogen, tripled (IFA, 2000), resulting in large yield increases but, in many cases, creating large imbalances between the inputs of nutrients and the off-take in crops (Sheldrick *et al.*, 2002). Other factors behind the increase in food production include the impacts of infrastructure and market access resulting from expanded road networks and transport systems, the access to inputs, and the establishment of improved marketing. But in all these changes, a most important factor has been the application of science, particularly through improved germplasm and crop management resulting in greatly increased yield potential for major crop species.

Science has provided farmers with fairly prescriptive technology packages for the highly favorable agricultural environments, consisting of improved germplasm and management. While these have been highly effective where ideally suited, they have been presented as a relatively limited range of packages and not so well adapted to all the areas where applied. While the overall impact has been impressive growth in agricultural production, the fact that the prescriptive packages were not suited ideally to many of the production areas meant that there were negative impacts on the natural resource base in terms of nutrients, pests, diseases, and overall sustainability.

Why were these technology packages designed for the highly favourable environments and why were they so prescriptive? Firstly, these favourable environments yield the greatest returns to the expensive investments in roads and other infrastructure that governments need to recoup in taxes, as well as good returns for the farmer to cover the additional inputs. Secondly, the favourable environments are more uniform and have less complex constraints – although that does not mean they can be treated in exactly the same way! The uniformity and reduced complexity at the experimental level is something that biophysical scientists both like and need. Thirdly, in some ways, the high input prescriptive technology packages that were developed were more applicable to the areas from which much of the science came, namely, the developed world, with its high-input agriculture.

Most of the constraints in these favourable areas are biophysical, and the non-biophysical constraints such as transport, markets, economics, labour, and political instability, where they existed, have been removed through public investment. While this rather prescriptive approach has meant that management was not as well tailored as possible for each set of conditions and has led to problems to do with the misuse of pesticides, herbicides, and fertilizers, there has been an evolution from prescriptive technologies to more adaptive strategies better aimed at fitting the constraints to production. Two well recognized attempts at such adaptive strategies are integrated pest management and integrated nutrient management, both of which have incorporated the more prescriptive technologies into much more adaptive strategies that suit their biophysical environments.

REQUIREMENTS OF AGRICULTURE PRODUCTION IN THE FUTURE

Over the coming decades, the world will require an estimated 40 percent increase in agricultural yields in order to feed the growing population a nutritionally adequate diet (Pinstrup-Andersen and Pandya-Lorch, 1994). One of the challenges to increased production is that there are limited areas of potentially arable land that are not in use already, and these reserves of arable land are concentrated in a small number of countries, particularly in South America and Sub-Saharan Africa. There are few reserves of arable land in North Africa or in Asia, particularly South Asia, where many of the poorest people of Asia live. A second challenge is that the majority of unused arable land and the areas that will need to show the greatest increases in production are marginal in terms of production potential, either because of inherent problems or as a result of degradation. In the main, marginal lands are more challenging to manage due to their high variability, the highly complex sets of biophysical constraints, and the complex non-biophysical constraints related to socioeconomics, culture, politics, and so on, which public investment has rarely addressed, due to the perceived low financial returns. The lower return on investment from most marginal lands constitutes a tremendous management challenge that requires interventions to be more cost effective and to be highly adapted to the particular physical and social environment.

These challenges once more underline the need for researchers and farmers to develop more adaptive strategies that fit the biophysical, economic, political, social, cultural, and biodiversity-related conditions that the farmers experience. Multidisciplinary and participatory research development and extension approaches are an essential component of such developments.

GETTING SCIENCE INTO VILLAGES: EXAMPLES FROM THE FIELD

Cassava production

One of the mandate crops of the Centro International de Agricultura Tropical (CIAT) is cassava, one of the "orphan crops" that are grown by the poor (van Ginkel, this volume). The advantages of cassava as a crop for the poor are its ability to grow in poor soil and the multiple uses to which it can be put.

The first of these attributes is the reason that cassava has a rather bad reputation as a crop that degrades soils. The capacity of cassava to grow in poor soils does mean that cassava can produce some yield on poor soils without inputs and that there may not be sufficient fertility remaining for subsequent crops. As such, cassava can be a *symptom* of a fertility degrading system, but this does not mean that it is a greater *cause* of degradation than other crops. Like any crop, cassava removes nutrients from the soil, although the low nutrient requirement of cassava and the low rate of nutrient removal in the harvested roots mean that it is less degrading than most crops.

The multiple uses of cassava include use as a human food, as a feed for animals, and as a product that can be processed into starch for use in a wide range of subsequent processes. All of these uses, including the processing of starch, can be on-farm, for local sale and use, or for more developed marketing, including large-scale processing and export.

Though consumption by humans has decreased somewhat as livelihoods improve, cassava remains a valuable human feed, even if only as an occasional food or for use in emergencies. Currently, there is increased interest in improving the quality of cassava roots as a feedstuff through the selection of varieties with higher vitamin and protein contents.

The use of cassava as an animal feed is widespread, using both the starch-rich roots and the high-protein leaves. Chipping and drying the roots means that they can be stored for some time and that varieties with unacceptable levels of HCN are rendered safe for use. In addition, there is increasing use of ensiling techniques for animal feed, using roots, leaves, or both.

While cassava has been used traditionally to produce starch for noodles and other foods, increasingly cassava starch is used for processing into a much wider range of products, including monosodium glutamate, alcohol, industrial starch, and modified starch for further processing. The cassava industry in Thailand has moved from one based on exporting chipped and dried roots to Europe for animal feed to much greater reliance on processing to starch and other products in the country. A similar increase has been witnessed more recently in Vietnam, where there is at least one major starch factory in nearly every non-delta province (or where there is one planned), whereas ten years ago not a single major processing plant had been established.

This wide range of uses and levels of use means that cassava is an ideal crop to promote the involvement of small farmers in markets and agro-industry, while involving the transition from on-farm use, through local sale a processing, to direct involvement with large industry.

As with many crops, there is a gap between the yield researchers can achieve and the yields farmers achieve. Researchers working with advanced technologies and newly developed breeding lines in research stations in Indonesia and East Timor have achieved yields of 58 and 39 tons of cassava per hectare, while farmers in the same regions produce yields averaging only 13 and 4 tons, respectively.

To decrease this large yield gap, the Nippon Foundation funded CIAT for ten years to introduce far more farmer-participatory approaches in cassava research and extension in Thailand, Vietnam, and China. CIAT has been working with national agricultural research and extension systems in all of those countries with large support from their governments, particularly in Thailand. Recent figures from Vietnam illustrate the dramatic improvement that can be achieved through farmer-participatory research and extension. At the outset of the project, farmers using conventional practices in different parts of the country yielded an average of only 12 tons of cassava per hectare. With the introduction of improved management and the combination of improved management and new cassava varieties, the yields were increased to 21 and 31 t/ha, respectively. While the biggest gain came from improved management (soil fertility management, plant spacing, and soil erosion control), the introduction of new varieties had a significant impact and, more importantly, was an excellent entry point with which the interest of farmers was attracted and thus work could be initiated to improve the management of cassava.

Through the efforts of this project and others like it, more than a million farmers now use these improved varieties derived from breeding material introduced from CIAT, on up to 1.5 million hectares. Conservatively estimated, this has earned the farmers some US$100 million in extra revenue per year.

In Indonesia, East Timor, and many other areas where participatory approaches to research and extension have been less widespread, the results in the researchers' fields have had far less impact for the farmers.

Soil Erosion

Through some very detailed work on soil erosion by many different research groups, agricultural researchers now have a reasonably thorough understanding of the scientific bases of this process. Put very simply, soil erosion is a process of detachment and subsequent movement of soil particles. The forms of erosion and the extent to which it occurs depend on a range of factors related to rainfall, soil type, and the soil surface conditions. The effects of rainfall vary with the amounts, temporal distribution, and intensity, while the soil conditions, particularly the mineralogy and the amount of carbon, determine the amount of water that infiltrates the soil and the energy required to detach soil particles. The most important soil surface conditions are the plant cover, the surface roughness, and the angle and length of the slope.

Though these factors have been identified and their impact is understood, the adoption of soil erosion control remains limited. One of the main reasons for this may be that the soil erosion control methods are extended as methods for soil conservation rather than as methods for improved productivity. It is very difficult to convince an impoverished farmer to conserve his soil when his real interest lies in productivity. After a short period of practicing soil conservation, farmers may appreciate the benefits, but their initial interest will be based on improvements in productivity.

One way to introduce such soil conservation practices is to introduce them along with something the farmers are very keen to try, as was the case when new varieties of cassava were used to introduce improved management, including erosion control. Another important factor is that the methods adopted must be very well suited to the biophysical and socio-economic conditions of the farmers. As such, the farmers must be involved in determining the methods they can and will use – hence the need for adaptive strategies that are selected and fine-tuned by the farmers, rather than prescriptive technology packages, which may work in particular climates, soils and slopes, but may not suit the particular situation of individual farmers. The driving factors of soil erosion - rainfall, slope, and soil type - must be matched to a very simple set of rules that are understood by scientists but are applied by farmers. These simple principles include maintenance of ground cover, appropriate cultivation and cropping system, and management of the slope length with non-cultivated strips, strip cropping, or various physical (biological or non-biological) barriers that are appropriate for the steepness of the slope. To this end, agronomists need to develop approaches whereby farmers and extension officers, not scientists, can readily determine which soil erosion control methods will work, and then the farmers can select from among these methods based on available labor, capital, land, and cropping systems. The farmers' initial aim in this selection process is likely to be enhanced productivity, while the long-term benefit will be improved sustainability resulting from the soil conservation.

Dramatic reductions in soil erosion, along with increased medium-term productivity, have been achieved already, but these methods are not spreading as quickly as desired.

Livestock

Livestock is very important for poor households. In addition to providing wealth and capital, as the equivalent of a bank account or insurance, livestock provides farmers with both economic and biophysical diversity by overcoming the seasonal aspects of cropping, insulating farmers against the up-and-down cycles of markets, and adding complexity to systems through the introduction of manures and perennial forages.

With the increasing demand for animal products, as populations increase and dietary habits change with poverty decline, the so-called Livestock Revolution is of great interest to governments and donor agencies, as this demand can be harnessed as a driving force for reducing poverty in poor upland areas that are well-suited to livestock.

A major limit to the expansion of livestock production by poor farmers is the high risk from livestock diseases. Though veterinary medications are both available and effective, many have been developed for intensive systems that rely on high quality laboratory diagnostics and medications that require a "cold chain", whereby the medications are maintained at low temperatures to ensure their effectiveness.

In many cases, what the farmers require to maintain the health of their livestock is good feed, improved housing, and better management. Such improvements in management reduce the need for diagnosis and medication, at the same time as increase the capacity of farmers and village veterinary workers to deliver improved health care, as the livestock are managed more easily. When health interventions are necessary, scientists need to work to develop simple and cost-effective village-level diagnostic procedures, and to develop veterinary medications that are cost effective and can be administered easily in the village, which means that they should be heat stable. Rather than bringing "high-tech" science to the villages, as "silver bullet medications", this approach needs "low-tech" implementation or delivery methods at the village, but with the backing of "high-tech" science to develop the diagnostics and medications.

While implementing our work on forages and livestock systems with farmers and district officers in the uplands of Laos, CIAT has been able to show the impact of such a simple and appropriate technology to virtually eliminate the death of large numbers of buffalo calves from Toxacariasis. A key to the successful use of this very simple and affordable treatment is having the medicine on hand so that it can be delivered at the right time, when the calves are very young. Improving the overall management, through the production of forages for livestock, was a key to enabling such improvements in management.

The majority of the work of CIAT in livestock systems has focused on the selection and use of forage species to benefit the production and health of village livestock. The greatest benefits of research have been reaped when the district officers have worked with the farmers to do this work. Given the tremendous complexity of these systems, it is only the farmers who can choose the species that suit them best and then test them to determine how they can be used. In some recent cases in Vietnam, CIAT introduced forage species to feed cattle and goats, only to find that the farmers ended up developing systems to feed forages to fish in on-farm ponds.

As work on forage systems continues, we are able to document many cases in which farmers have had life-changing experiences through greatly improved livestock systems. For instance, we find farmers who have halved the area of upland rice and moved to mixed "garden" systems, in which they grow a wide range of forages, vegetables, and fruits, and, as a result, have improved their livelihoods significantly through increased livestock productivity. These farmers are now becoming agents of change, by providing successful working examples to other farmers in their village, and in nearby villages.

Soil Fertility Management

The management and maintenance of soil fertility is critical for the sustainability of farming systems, and this is particularly so in the low-input systems of many of the rural poor. Science can provide us with a good understanding of the major factors that affect soil fertility, through an understanding of detailed soil chemistry and soil physics, but to use this information to develop reasonable soil fertility management recommendations we need the backing of detailed laboratory analyses and much accumulated experience for interpretation of the results. What farmers require, however, is the capacity to develop such management regimes for their own soils and farming systems on their own, or with the assistance of local extension agents, but without the backing of laboratories and scientists.

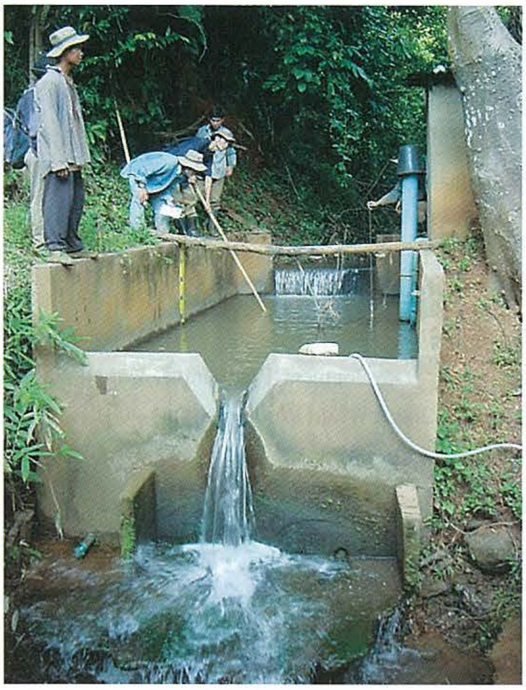
Farmers possess a wealth of local knowledge of their systems, through knowledge of the soils, crops, weeds, etc. It appears that the key to improved soil fertility management is the combination of the farmers' indigenous technical knowledge with the scientific understanding of soil factors and crop demands. An adequate management system might rely on an improved decision-support system based on soil colour, texture, pH, cropping systems, crop health, and various weed types, with no or limited reliance on chemical analyses. When better analyses are deemed essential, then researchers must focus on methods to perform them at modest cost and at the farm or district level, rather than in laboratories. The focuses of such improved management systems must encompass more sustainable systems with increased productivity, decreased degradation, and better management of resources.

CONCLUSION

Science has made significant contributions in many areas to contribute to the large increases in agricultural production, particularly in the areas of crop varieties, fertilizer and water use, and pest and disease management, all based on sound scientific research. But science needs to be more relevant in order to support research initiatives that are more closely tailored to local needs. As examples, we need improved on-site assessment of soil fertility, development of village level diagnoses and treatments for livestock diseases, and easy methods to help farmers decide on the appropriate soil erosion control measures to maintain or improve productivity. The challenge for organizations such as CIAT is to use the best outcomes of scientific research and form close linkages with farmers and extension services so as to provide them with "best bet" strategies that have high probability of success and low risk of failure.

In conclusion, perhaps it is appropriate to say that science is not failing the poor farmers, but that poor farmers could be better served by making the best achievements of science more easily available.

cassava production



soil erosion control (a)

soil erosion control (b)

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Examples from the field sciences

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