The Second Hugh Bunting Memorial Lecture

INTRODUCTORY ADDRESS:

Remembering Professor Hugh Bunting

R.D.W.Betts

I was very touched when the Tropical Agriculture Association and the School of Agriculture invited me to reminisce a little this evening about Hugh. He was a much-loved and respected tutor, mentor, guide and friend of many of us gathered here to honour his memory.

I had hoped to play you an excerpt of my recorded chat with Hugh that resulted from Hugh's first encounter with our previous Vice-Chancellor, Sir Roger Williams, in 2002. Hugh was by then 85, and so impressed Williams that he asked Hugh if he would agree to be interviewed so that his fascinating story could be kept for posterity in the University's Archive. Sadly that interview was my last meeting with Hugh. He died suddenly and peacefully at his home in Caversham the following month. I hope you will be patient and return for our 2008 memorial lecture to hear something of Hugh's early life before I met him.

Now let me turn the calendar back more than half a century to the day of my first meeting with Hugh, after his outstanding maiden lecture in the old Soil Science Lecture Theatre on our London Road campus in 1956. Hugh had just returned to England after a distinguished decade of scientific work, first in Tanganyika and then in what was Anglo-Egyptian Sudan. His first academic appointment was to the Chair of Agricultural Botany in this University. His course to the B.Sc. Agriculture finalists was in Plant Ecology, covering aspects of grassland and weed biology. Not only did Hugh cover the prescribed subject very thoroughly and provocatively, he drew many relevant examples from his native South Africa and from his other African experiences. In doing so he made us very conscious of the great challenges and opportunities that existed in Africa, Asia and the Caribbean.

At that time, Britain still had an Empire and recruited officers for the Colonial Agricultural Service from eligible graduates throughout the Commonwealth. Undoubtedly as a result of Hugh's inspirational teaching, this was, by far, the most sought-after career opportunity. In 1957, no fewer than twelve of Hugh's students were awarded Colonial Office Postgraduate Studentships at the University of Cambridge, followed by a further year at the Imperial College of Tropical Agriculture in Trinidad, known widely as ICTA. This extra-ordinarily large Reading contingent was always very prominent on both courses – the next largest groups were mere pairs from the Universities of Edinburgh, and Natal in South Africa. In 1959 the ICTA postgrads produced the best results ever recorded by the College - testimony to the solid foundations laid by Hugh in one third of the whole cohort whilst at Reading. The Colonial Secretary of the day, Alan Lennox-Boyd, was so impressed by these results that he cabled the Principal of ICTA, "Congratulations to you all. Send my men home First Class". This was on the "Antilles", a French luxury liner cruising the Caribbean – a brief taste of the good life before the start of our more spartan lives in remote corners of the Empire

A decade later, the University of East Africa, with its three constituent colleges in the now independent Kenya, Uganda and Tanzania was preparing for its agreed dissolution in 1970; coupled with the creation of three new universities based on the three colleges. The Faculty of Agriculture was located at Makerere College in Uganda and the Veterinary Faculty was in Kenya. Kenya's Minister of Agri-culture, Bruce McKenzie, said, "Let's not just crack this particular problem, let's get some wise men together to assess Kenya's agricultural manpower needs at every level, in both the private and public sectors, for as far into the future as they can reasonably predict; and then draw up a realistic plan to meet those needs".

Hugh by then was in his second term as Dean of Agriculture at Reading when he accepted the invitation of the Kenya Government to become a member of its Agricultural Education Commission, and I was appointed as its Executive Secretary. Our reunion, ten years after my graduation, took place in

1967 over a few cold Nile beers on the verandah of the Speke Hotel in Kampala, Uganda. The Rockefeller Foundation funded the work of the Agricultural Education Commission and this enabled Hugh to commute between Reading and Nairobi to work, particularly, on the University section of the Commission's report. The report of the Commission was duly accepted by the Ministries of Agriculture and Education, and finally by the Kenya Cabinet. Hugh remained with me on the project to complete a successful bid to the World Bank that included funding for a new Faculty of Agriculture alongside, and in partnership with, the existing Veterinary Faculty at Kabete, near Nairobi. Then came the matter of staffing the new Faculty. Again, Hugh stepped up with an offer to help. He served, in effect, as the Faculty's ambassador in Europe and was successful in persuading several distinguished European agricultural scientists to seek chairs in the Faculty of Agriculture of the new University of Nairobi. An international team of British, German, Dutch and Kenyan professors duly got the new Faculty off to a flying start with a syllabus largely custom-built by Hugh to meet Kenya's needs. This was probably unique, as most new Faculties of Agriculture in Africa at that time were following syllabuses that were almost direct transplants from universities in Wyoming, Wisconsin or Alabama. [I don't think Cornell was ever guilty of this].

By now, Britain had ceased being an imperial power. The need to staff a Colonial Agricultural Service had disappeared, and the postgraduate courses at Cambridge and Trinidad were discontinued. ICTA was handed over to the new University of the West Indies as a ready-made Faculty of Agriculture.

Hugh's teaching continued to fire up young British agriculturalists with the desire to serve overseas with international bodies such as the World Bank, FAO and UNDP, and also with British aid organizations like DFID, Oxfam, ActionAid, Tear Fund and CAFOD. But no longer was there anywhere in Britain where they could go for a postgraduate course to prepare them for a career in tropical agriculture.

During his two terms as Dean, Hugh had built up a substantial body of tropical experience in the Faculty by persuading the University to appoint more people like himself, people who had sound British academic qualifications backed up by substantial senior-level scientific experience in the tropics. Thus Reading attracted to tenured posts in the Faculty of Agriculture people like Walter Russell from Kenya, Eric Roberts from Sierra Leone, Peter le Mare from Tanganyika and Peter Ellis from Latin America. With this strength, together with the Plant Environment Laboratory that he had successfully established at Shinfield, Hugh felt confident that the University of Reading could offer a set of worthy postgraduate courses in Tropical Agriculture. He planned the syllabuses with great care, and a lectureship in tropical agriculture was created for a course tutor.

By 1972 I had a young family and was still working in Kenya when Hugh encouraged me to apply for the lectureship. I had no home in England but learned that the University was also seeking a Warden for its new Wells Hall. So I applied for that post as well and was fortunate to be appointed to both. Professor Richard Ellis, now Head of this School was also a founding member of Wells Hall. He was a member of the first JCR committee and helped to develop the Hall Library. Hugh Bunting was a very convivial person who contributed to the social life of the University and was a generous host at the two great international conferences he convened here. He was always a welcome guest at Hall dinners and Richard may recall a very amusing after-dinner speech that Hugh gave in 1974 on the quaint traditions of some English universities.

At the time of my return to Reading, Hugh Bunting had completed two terms as Dean, and had become the Chairman of the University's International Committee. This was mainly concerned with the welfare of our many overseas students and articulating the University's contributions to the development of new academic departments in some of the fledgling universities of the Commonwealth. One of these, Ahmadu Bello in Nigeria, awarded Hugh an honorary doctorate in recognition of his great contribution to their development.

Hugh soon had me appointed to the International Committee and in due course I became its Secretary. Hugh and I were working in double harness once again, and so it continued until Hugh's retirement from the University in 1982, when I was delighted to be asked to arrange his farewell dinner in Wessex Hall where he had served for many years on the Hall Committee.

Hugh and I also worked together for the Tropical Agriculture Association. Although Hugh was not an alumnus of the Imperial College of Tropical Agriculture, he was one of its greatest friends, and many of the College's alumni were among his closest friends. Hugh duly became a member of the Executive Committee of the ICTA Association. By the 1970s the membership of the ICTA Association was shrinking rapidly, with no new hatchings and the older birds falling off their perches. It was facing extinction, as a dwindling old boy's drinking club.

Hugh encouraged the Committee to widen the membership and transform the ICTA Association into a learned society open to all professionals engaged in tropical agriculture. Thus the idea of the Tropical Agriculture Association was conceived in London. Hugh and I were asked by the Committee to return to Reading to draft a constitution and make a bid to the Charity Commissioners for charitable status for the TAA.

Hugh would be pleased that the constitution we drafted some thirty years ago has stood the test of time, with the minimum of subsequent tinkering; and the TAA's principal charitable activity, its Award Scheme, continues to flourish. This provides funding and assistance for young British graduates to travel to the tropics to gain practical experience in development work, as a first step towards a career in tropical agriculture. Hugh would certainly have enjoyed the afternoons we now have each year in the Linnean Society in Burlington House in London when our returned Awardees make their presentations to the TAA on their projects and experiences in the tropics.

Looking back on life, I realize that meeting Hugh in 1956 was probably one of my most fortunate moments. He gave me a great stimulus, a wealth of useful knowledge, a ready source of advice and encouragement, opportunities to serve and, above all, a much-treasured friendship. It is very fitting that members of the University of Reading and the Tropical Agriculture Association should gather this evening to honour the memory of Hugh Bunting with a lecture on a topic very much in keeping with his own farsightedness and deep concern for the future welfare of mankind; and then to enjoy some food, wine and conversation together.

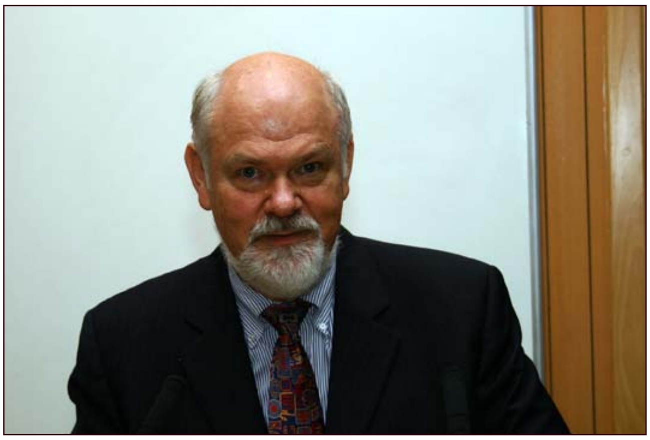
THE SECOND HUGH BUNTING MEMORIAL LECTURE DELIVERED AT THE UNIVERSITY OF READING, 4 JUNE 2007:

Agricultural Futures: What lies beyond 'Modern Agriculture'?

Norman Uphoff

Introduction

What is known now as 'modern agriculture' has been the most successful system of production in history, so the observations and suggestions that follow are not to be taken as a criticism of this technological mode. Between 1961 and 2001, while the world's population doubled, the world's food production increased by 180%, an expansion attributable more to gains in productivity than to expansion of cultivated area. However, as we embark on a new century, we should ask: how advisable is it to continue along this present technological path in agriculture – doing essentially more of the same, only better – or should we considering other directions?



Modern agriculture as developed and practiced in the latter half of the 20th century culminated in 'the Green Revolution,' which greatly increased world production of cereals. This is commonly regarded as the key indicator for assessing agricultural sector performance because it reflects our cumulated ability to meet basic food needs. Should Green Revolution technologies be extended, and even intensified, or are there other alternatives to be considered? This is a timely question because the Green Revolution has been losing momentum. Figure 1, constructed from FAO and USDA data through 2006, shows that on a worldwide scale, the production of cereals plateaued about ten years ago, in the mid-1990s. And in per capita terms, cereal production peaked actually about a decade earlier and has been declining since.

It is certainly true that more grain could be produced with available and new technology than grown in recent years if there were high prices offered for cereal production. But this would be done only at higher unit cost, and the higher prices would worsen rather than reduce the hunger of the 800 million persons who are not currently adequately fed. So this strategy would be nugatory if combating hunger and poverty is the objective. Moreover, the hundreds of millions of small and marginal producers who constitute the core of persistent world poverty would find the more costly technologies inaccessible. So there are reasons to seek productivity gains rather than to use price incentives to move the agricultural sector forward.

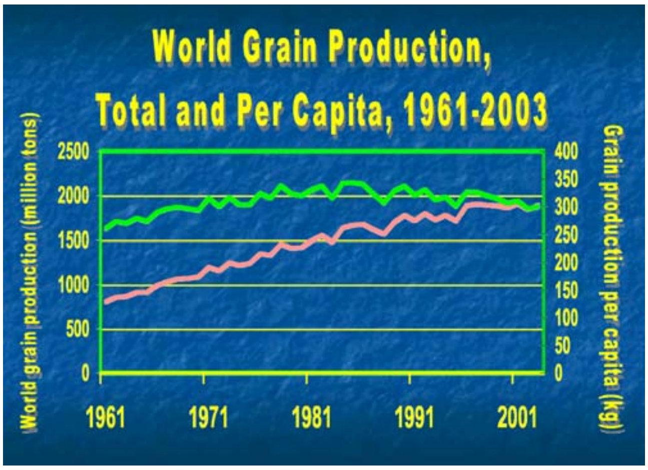


Figure 1. World grain production, 1951-2006: total (left axis/red) and per capita (right axis/green). (Sources: FAO and USDA data, in Worldwatch Institute data archive)

While acknowledging the successes of modern agriculture to date, we should look at its essential features analytically and critically, asking:

- How well-suited is this mode of production for the conditions that we anticipate facing in this 21st century? It turns out that there are many objective trends which prompt certain apprehension, which leads to the question:
- What might lie beyond modern agriculture? In other words, what might 'post-modern agriculture' look like? This will be the main focus of the discussion here.

'Post-modern agriculture' is a challenging and provocative concept that deserves serious consideration. To begin, it should be said that this concept differs from 'post-modernism' in the humanities and social sciences because it entails *no rejection of science.* Indeed, post-modern agriculture aspires to build upon the most current knowledge and insights of contemporary science, i.e., to be the 'most modern' agriculture. Further, it rejects the *nihilism* that has often been characteristic of 'post-modernist' philosophy. There are some similarities, however, in that both post-modern perspectives are critical of what has emerged in the name of 'modernity.' Classifying something as 'modern' has become a self-justifying means for establishing and maintaining a hegemony that puts down alternatives by deprecating or simply ignoring them. In the agricultural sector, there clearly has been a dominant 'modernization project' which has shaped not only research, evaluations and investments but also the distribution of benefits.

The concept of 'post-modernism' is ambiguous because it has two different meanings. 'Modernity' can be used either *descriptively*, as a neutral term referring to whatever currently exists, whatever is most recent; or *normatively*, as a value-laden term referring to what is considered good and superior because of certain characteristics that are deemed 'modern.' From the first perspective, 'post-modernism' is an impossibility; from the second, it is a reality.

Modern Agriculture

During the first half of the 20th century, the initiatives associated with modern agriculture aimed to 'industrialize' agriculture, making it more and more like the manufacturing enterprises and processes that had been transforming Western economies and societies since the start of the Industrial Revolution. Key elements included:

- *Standardization* of operations according to the latest available scientific knowledge, even though variability in soil and climate created a strong logic in agriculture of site-specific adaptation;
- *Mechanization* of operations, making larger scale of production possible and promoting consolidation of production units into ever-larger entities. This was linked then with
- *Labour-saving technologies*, that raised labour productivity and reduced the need for labour; plus
- *Use of chemical inputs* to enhance soil fertility, achieve weed control and crop protection.

These trends were set back by the economic disruptions of worldwide economic depression in the 1930s, which was worsened (or in part caused) by adverse climatic conditions affecting agriculture. But there was no loss of confidence in this strategy, which resumed after World War II.

In the latter half of the 20th century, modern agriculture was increasingly shaped according to what were regarded as 'scientific formulations' of agriculture:

- *Genetic potentials* were more emphasized, although breeding 'better' plants and animals had been important already in the first half of the century. Varietal and breed improvement became evermore central in agricultural thinking, linked with
- *Input utilization*, once breeding had enhanced the input-responsiveness of genotypes, which made the use of fertilizer and agrochemicals more profitable. This combination of thrusts was accompanied by

- *Energy-intensity*, with growing substitution of fossil-fuel inputs for human energy; and
- *Capital-intensity*, which became ever-greater, further displacing for labour and making for larger-scale operations.

After World War II, a global policy objective was established for modern agriculture, the expectation that it would 'feed the world,' helping nations avoid famine and promoting their economic and social development. Fears in the 1960s and 1970s that there would be widespread famines if population continued to grow ahead of food production capabilities, prompted a fixation on *yield* as the overriding goal and criterion of success. While *total factor productivity* was preferred by economists as a yardstick, it was eclipsed in policy and practical terms because it was difficult to measure. Yield, on the other hand, was a simple, physical standard for measuring success. This tension between agronomists and economists was never really resolved. More production could always be stimulated if higher commodity prices would prevail, but this strategy would not contribute to reducing poverty or to accelerating economic growth, which would be spurred by lower food prices.

What took shape by the latter decades of the 20th century was a consensus on agriculture which stressed mechanization, reliance on genetic enhancement and exogenous inputs, and increasingly the influence of market forces and globalization. Land-extensive, capital-intensive and large operations were favoured, with labour-saving technology that was genetically-focused and chemically-intensive as well as energy-dependent and water-consuming.

Monoculture was a natural concomitant of these trends, with specialization of production units and intensified division of labour, seeking to lower costs of production and extend the international division of labour with long-distance trade, not just in commodities but eventually also perishable crops. This system of production became for many reasons politically-favoured and influential, with major institutions of all kinds aligning with the assumptions and values that this system represented.

The terms used here to characterize 'modern agriculture' are descriptors, not value judgements. These factors shaped the dominant patterns of production, although the majority of agricultural producers in the world still have not become full (and many not even partial) participants in this system. Is it their fate to be absorbed into this system, or to be further estranged from the sector? A decade ago, the answer seemed to be yes; all agricultural producers must become part of 'the modern agriculture project' or exit from the agricultural sector. Now the answer is not so certain.

21st Century Realities

In this new century, there are a number of objective forces and trends that are changing the conditions under which food and fibre are produced.

- **Arable land available per capita will decline,** given that (a) *population* will continue to grow at least through mid-century, and (b) *cultivable land area* has little scope for expansion and is more likely to decline, due to land degradation or urban expansion. This means that the kind of large-scale, land-extensive production that was ascendant in the 20th century will be less appropriate in the future, as productive land will need to be used more intensively, to maximize output per unit of land, increasingly a limiting factor.
- **Water available for agriculture will also decline,** given *population growth* and *competing alternative demands* for water from industrial and domestic-use sectors. The effects of any *climate change* that reduces rainfall or makes it so unreliable as to be less productive for agriculture will exacerbate the predictable competition from other uses. Where agriculture depends on groundwater rather than surface flows, this becomes more serious as water tables are dropping in many agricultural areas.[1]
- **Energy costs are rising,** and are unlikely to return to their relatively low 20th century level. 'Modern agriculture' was developed with petroleum prices around $25/barrel, whereas they are now three times as much, and could go even higher. The era of 'cheap energy' that subsidized large-scale, mechanized production is literally now 'history.' This shift is also likely to affect the economic viability of a radical global division of labour where agricultural goods are produced far from their point of consumption and transported long distances.
- **Diminishing returns to inputs are starting to set in.** Nitrogen fertilizer in particular is now being used so abundantly that its productivity is declining. In China, where farmers could get 15-20 kg of rice by using 1 kg of N fertilizer at the start of the Green Revolution in the mid-1960s, today they get only about 5 kg of rice per kilogram of fertilizer (Peng et al., 2004), and this ratio continues to fall. Worldwide, as seen in Table 1, the growth of fertilizer use for grains has started declining even

in absolute, not just relative terms. Pimentel (1997) reports that while pesticide use in the United States has gone up 10-fold since World War II, total crop losses in America due to insect damage did not decline but instead went up from 7% to 13%. Thus, chemical inputs have not evidently reduced pest damage in the aggregate and may have added to this, perhaps explainable by the theory of trophobiosis (Chaboussou, 2004).

Table 1. World grain production and fertilizer use, and cumulative increases by decade, in million metric tons

Year(s)	*A*	*B*	*C%*	*D*	*E*	*F%*
1950	631	-	-	14	-	-
1961	805	174	28	31	17	121
1969-71	1,116	311	39	68	37	113
1979-81	1,442	326	29	116	48	70
1989-91	1,732	290	20	140	24	21
1999-2001	1,885	153	9	138	-2	-1.4

A ***Grain production***
B ***Decadal increase in production***
C ***Percent increase***
D ***Fertilizer use***
E ***Decadal increase in use***
F ***Percent increase***

Sources: FAO and USDA data, in Worldwatch Institute data archive

These three major trends are not matters of opinion, but rather well-established facts. There are also other objective considerations that add impetus for a rethinking of 'modern agriculture' and for charting some new directions.

- While there is not yet any full consensus on the causes and extent of **climate change,** this will, to some extent, have very disruptive impacts on 'modern agriculture' because (a) monoculture is less resilient than more diverse associations of plants (and animals), and (b) farmers when they have more capital tied up in production processes are at greater risk from variations in temperature and precipitation.
- **Stagnation of yield improvements** attained by plant breeding and genetic modification is also a fact to be reckoned with in the present and at least near-run (Figure 1).
- So is the bypassing of many millions of **poor households** by Green Revolution technologies that are input-dependent. The current refocusing of development policies and efforts on *poverty reduction* is less favorable for 'modern agriculture.'
- **Environmental concerns** continue to mount as global warming, pollution and other hazards increase, many traced back to agriculture. In this century there will not be the same freedom to ignore ecological impacts as there was in the 20th century.[2]

So, there are many reasons why a 'more of the same' strategy for agricultural development makes less and less sense. The underlying propensity of changing factor proportions to drive the transformation of technology over time has been well documented by Hayami and Ruttan (1985). Their *post hoc* analysis revealed dynamics and incentives that were not evident to practitioners or even theorists at the time (the 19th and early 20th centuries). But thanks to their work, we can now have a better idea of what technological changes might emerge and become prevalent in the future.

The System of Rice Intensification and Beyond

This is not the place to offer any full exposition on the System of Rice Intensification (SRI) which has emerged very opportunely from work done over half a lifetime by a French priest who lived and worked in Madagascar from 1961 to 1995, Pere Henri de Laulaniè (1993, 2003). There is now an increasing published literature on SRI to which readers can be referred.[3]

SRI represents a kind of agroecological approach to agricultural production (Altieri, 1995; Gliessman, 1997; Uphoff, 2002) that is quite different from the premises and practices of 'modern agriculture.' Its most prominent example, the Green Revolution, proceeded on the basis of two interlocking strategies: (a) investing in improving the *genetic potential* of crops through conventional plant breeding or genetic modification, and (b) increasing the *external inputs* that the plants were bred to be responsive to – water, fertilizer, agrochemical protection. SRI achieves higher rice yields with (a) *no change* in the varieties used – SRI methods work well with both improved and 'unimproved' cultivars, and (b) with a *reduction* rather than an increase in water and chemical inputs.

Instead of changing varieties and investing in more inputs, SRI *changes the way that plants, soil, water and nutrients are managed*, with the result that (a) plants' *root systems* grow much larger and remain healthier, and (b) populations of *soil biota* – bacteria, fungi, protozoa, earthworms, etc. – become larger, more abundant, more active and more diverse, rendering a variety of beneficial services and protection to crops.

An analysis of results from 11 evaluations undertaken in eight countries by a variety of Universities, International Research Centres, donor agencies, NGOs and private sector organizations shows the following results (with even incomplete use of SRI practices – transplanting very young seedlings singly, carefully and with wide spacing; not keeping fields continuously flooding; doing soil-aerating weeding; and enhancing soil organic matter):

- ❑ Average increase in yield (t/ha): 52% (range: 21 - 105%)
- ❑ Average reduction in water use: 44% (range: 24 - 60%)
- ❑ Average reduction in costs of production: 25% (range: 2.2 - 56%)
- ❑ Average increase in net income (ha-1): 128% (range: 59 - 412%) (Uphoff, 2007).

The most extensive evaluation of SRI results has been done in eastern Indonesia, over nine seasons (2002-2006) under the supervision of a Nippon Koei technical assistance team, with 12,133 on-farm comparison trials evaluated across eight provinces on an area totaling 9,429.1 ha:

- ❑ 78% average increase in yield (3.3 t/ha)
- ❑ 40% typical reduction in water use
- ❑ 50% recommended reduction in fertilizer use, and
- ❑ 20% calculated reduction in costs of production per ha (Sato and Uphoff, 2007).

Such increases with reduced inputs is unprecedented, reflecting the dynamics of a production process where rather than rely on external inputs, the management practices mobilize endogenous soil processes and potentials and symbiotic relationships between plants and soil organisms (Randriamiharisoa *et al.*, 2006).

Modern agriculture has regarded crops in a mechanistic way rather than in their ecological context, of myriad interactions among species. It has sought to redesign plants, like machines, to certain specifications, rather than study how to provide the most favorable growing environment for plants and their symbionts. This is not the place for an extended discussion of plant-microbial interactions, but citing a single piece of recent research will make the point.

Researchers who studied the movement of soil bacteria (rhizobia) into rice plant roots and then up through the roots and stems into the plants' leaves (phyllosphere) found that in controlled experiments that evaluated the effects of presence vs. absence of rhizobia in rice plant leaves, the *presence* of these soil organisms significantly enhanced (a) chlorophyll levels, (b) rates of photosynthesis, and (c) yields – all other conditions being equal (Feng *et al.*, 2005). We have only begun to penetrate slowly into the complexities and productive potentials of the many interdependencies among plant and other organisms that have co-evolved for over 400 million years (Margulis and Sagan, 1997).

The System of Rice Intensification has been illuminating these productive potentials with results that are hard to accommodate within the orthodox theorizing and practices of 'modern agriculture'. So far we have been seeing what can be done with rice genotypes to produce super-productive phenotypes, such as the rice plant shown in Figure 2, grown from a single seed in the middle of his field by a Nepali farmer in the terai (plains) near Biratnagar.

Figure 2. Nepali farmer holding up an SRI rice plant grown from a single seed in his unflooded paddy field in Morang district. (Picture courtesy of Rajendra Uprety, District Agricultural Development Office, Biratnagar.)

Similar enhancement of phenotype expression has been seen also with finger millet (*Eleusine coracana*), known as *ragi* in much of India. Staff of the NGO PRADAN working in Jharkhand state have adapted SRI concepts and methods to this crop, with the result seen in Figure 3.

Practically by definition, one cannot fully specify or even imagine what 'post-modern agriculture' will look like when we are just entering the development of this alternative production system, responding to

Figure 3. The finger millet (Eleusine coracana) plant on the left was grown with an adaptation of SRI practices, while the plants in centre and on right were grown with conventional practices. The finger millet plant on the right is a traditional local variety, while the plants in centre and on left are an improved variety (A404). (Picture courtesy of PRADAN.)

the conditions that will propel, shape and constrain agricultural development in the 21st century. What I have tried to do in this lecture is to sketch out reasons why we should be considering alternative paths for agriculture in this new century, not just projecting past assumptions and technologies into the (changing) future. The System of Rice Intensification and its derivations may also apply to other kinds of crop production (wheat, sugar cane, cotton, etc.) so that there are reasons to be optimistic about a very productive and sustainable agriculture in the future, provided we can advance our knowledge and practice with regard to growing crops in consonance with biologically-rich and -active soil systems, understanding 'soil' in a different and more dynamic way (Uphoff *et al.*, 2006).

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