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Science & Policy Comment

Innovative Agriculture for Food Security

An integrated agro-ecosystems approach

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If agricultural research and innovation are to deliver acceptable levels of food and nutrition security to poor communities at a global scale, a rethink is needed of how current approaches to research-for-development are planned and executed.

Obstacles lie in three factors:

- Today's vertical and supply driven focus – by many research leaders and development agencies.
- The current short-term and project focus to funding agricultural research and development.
- A need for practical policy options, that help countries respond to the realities they face.



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Science and Policy Comment is published by ICARDA to inform policy discussions and to stimulate new thinking and debate on science, technology and development issues to support developing countries to improve agriculture and livelihoods in the dry areas.

Key Words: Agricultural policy; agricultural research policy; investments in research for development; agricultural science, technology and Innovation.

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Compiled and editorial support by Michael Devlin & Richard Sanders (ICARDA).

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ISBN: 92-9127-292-2

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Summary

Innovative Agriculture for Food Security

Agricultural research has improved the lives of millions of people in the past three decades. But today, poverty, hunger, lack of access to food and nutrition remain a daily fact of life for millions of people in many of the world's low-income regions of sub-Saharan Africa and Asia.

If agricultural research and innovation are to deliver acceptable levels of food and nutrition security to poor communities, a rethink is needed of how current approaches to research-for-development are planned and executed.

The obstacles to taking food security to the next level lie in three factors: the current vertical and agricultural commodity or thematic focus – by, researchers, research leaders and development agencies – that do not effectively address countries' needs; the current short-term project focus to agricultural research and development funding; and a lack of practical policy options that can help countries respond to the realities they face of chronic food insecurity and nutrition deficit.

If we can shift thinking in these areas, agricultural innovation will take a more holistic approach and deliver more benefits to smallholder farmers and their communities. This is the path to achieve global food security.

The research approach needs to be broadened. Current project-focused and vertical approaches of research programs and development agencies – that focus on solutions based on one commodity crop or a series of 'mandate' disciplinary technologies – should be replaced with a view that looks at all combinations of approaches (e.g. crops, livestock, trees, fish, natural resources management, policies, income options) that best respond to a country's nutrition and food security needs and can increase income for small farmers.

Low-income countries need less 'global policy advice' and more practical policy options that help improve income for smallholders and communities, and that work in their reality of imperfect institutions and capacity and lack of adequate funding.

The obstacles to taking food security to the next level lie in three factors: the current vertical and agricultural commodity focus; today's short-term project focus to agricultural research and development funding; and a lack of practical policy options to help countries respond to the realities they face - of chronic food insecurity and nutrition deficit.

Short-term and vertical research approaches are past their 'sell-by' date

An argument is now building which asserts that past trends in some organizations have over-emphasized piecemeal and reductionist approaches to agricultural research. While some of these efforts have produced impressive dividends from the 1960s to the 1980s, many now feel that these vertical approaches have passed their sell-by date.

This argument, and the associated debate that says that overall too little investment is being made in researching future farming to feed a hungry world, now has powerful backers.

Among them is President Barack Obama, who announced new approaches to food security (particularly in Africa) at the G8 meeting in May 2012 - "It's a moral imperative, it's an economic imperative and it's a security imperative," said the President. Bill Gates is also focused on the issue, with a call for new approaches to agricultural research to build food security, especially for smallholders, as the key theme of his 2012 Annual Letter.

We know from recent history that successful and sustained innovation in agricultural research, and its adoption in the field, is possible.

In the early 1960s India stood on the brink of mass famine. Its population had simply outgrown its capacity to feed itself and, even if the money was available, there was little food to spare or to be purchased elsewhere on the planet.

At the time, the world population was some three billion and global agriculture was struggling to recover from the effects of the Second World War. The vision of one man – the US agriculturalist Norman Borlaug – and the adoption of his advice by the Indian Government to use new, high-yielding cultivars of cereals, to expand irrigation infrastructure, modernize management techniques, promote the use of synthetic fertilizers, and pesticides to farmers, and strengthen these integrated technologies by supportive policies, delivered to India - and the World - the Green Revolution. Unbeknown to many, he in effect took a holistic approach to agricultural reform, but this was not the case in many subsequent single-commodity interventions.

Mass famine was averted, with the Green Revolution improving the lives and nutrition of millions of poor people in an unparalleled way and raising the global standard of living in many rural areas. In the 1960s, rice yields in India were reckoned to be about 1.5 metric tons per hectare; by the mid-1990s they had risen to 3 metric tons per hectare. Overall, cereal production - in crops like maize, wheat and rice - more than doubled in developing nations between the years 1961 and 1985.

But even after 60 years of agricultural and technological advance there is still much that needs to be done. Borlaug himself accepted that his Green Revolution has delivered - "a change in the right direction, but it has not transformed the world into a Utopia".

Of the 6.5 billion people who now walk this Earth, nearly a quarter (1.4 billion), says the International Fund for Agricultural development (IFAD), continue to live in extreme poverty, struggling to survive on less than US\$ 1.25 a day. More than two thirds of these people live in the rural areas of developing countries, many of them in Africa.

A re-thinking of the Green Revolution

Now is the time for a rethink of how far we have come, and whether a new conceptual framework is needed to further reduce hunger and poverty. A new paradigm needs to be developed, working with low-income countries, to deliver policies, practices and technologies to ensure that we can sustainably feed a planet of more than nine billion people (projected for 2050).

And this time the challenge is not simply a boost to crop production, but also a fight against poverty. The added twist is that the challenge is now set against a backdrop of unpredictable climate change and unpredictable weather patterns and the need to intensify farming results while protecting the environment and without depleting non-renewable resources such as hydrocarbons and phosphate.

How then do we achieve a marked, step change without demanding increased resources of water, fertilizers, energy and land – all of which are in short supply?

It is a huge task, but a task that is just possible to achieve. The world does have the knowledge and the skills to deliver, based on contemporary agricultural research and innovation. But there's a problem. Approaches that are vertical or theme-based, or focused on a small set of commodities - have long been the accepted thinking of a considerable amount of agricultural research. And this has also been the predominant thinking favored by most funders and development investors. This means it will be difficult to achieve food security for all, particularly in the world's poorest regions.

A new development paradigm is needed. One that works with low-income countries, to deliver policies, practices and technologies to ensure that we can sustainably feed a planet of more than nine billion people (projected for 2050).

Three things that need to change - to re-energize agricultural research approaches

As we sit in 2013 contemplating the prospect of possibility of a significant increase in the absolute number of underfed people, there are three key factors limiting the potential of agricultural research to deliver innovations to poor communities on the massive scale that is needed. We owe it to the future-hungry to banish this worn-out thinking.

First on the list is vertical thinking in research; focusing on solutions based on one commodity crop or a series of 'mandate' disciplinary technologies. This ignores the broader focus on being clear on which integrated multiple-component approaches are best for a country's food and nutrition security needs and production system – at national, region and farm levels.

Too many research organizations and government agencies take a 'technology looking for a solution' approach rather than letting farmers' demands dictate what is needed.

The day-to-day reality for farmers, agro-pastoralists' or pastoralists' is a complex arena in which synergies among 'technologies' abound, and in which linear extrapolation of the contribution of individual technologies is unrealistic. Too many research organizations and government agencies take a 'technology looking for a solution' approach rather than letting farmers' demands dictate what is needed.

Then there is current short-term and project-focused thinking (1-3 years, and sometimes even less) and development agencies' behavior and pet themes and approaches that limit the potential for interdisciplinary work and a real systems approach to providing better agricultural and rural economy solutions to low-income countries. Some development investors' funding calls limit individual organizations to be a member of just one submission. If more inter-organization collaborative projects are to be encouraged, individual organizations should be allowed to be involved in more than one multi-organization bid.

The last in this trio is a lack of implementation of practical policies and institutional innovations that can work alongside the complex social, political, environmental and economic realities faced by countries today. Examples of practical policies are: those that support infrastructure investment to facilitate farmers' access to markets; that strengthen agricultural education and extension that increase the flow of information, knowledge, and technologies to farmers; and policies that help smallholder farmers to get timely market information so they can decide what and when to produce and where and for how much to sell their produce. Stronger policies are also needed that address the degradation of natural resources. Linked to this is the need for regional food security strategies that need to be agreed between countries. In other words, we face a failure to embrace joined-up thinking.

From 'magic bullet' to agro-ecosystem thinking

Agricultural science, the development community and the media, love high-tech 'silver bullets' and magic solutions. In world agriculture the holy grails of recent years have been "super wheat", "magic rice", the "super lentil", "super chickpea" or "super tilapia". These innovations have indeed brought benefits to millions in the world's poor areas. But have potential system synergies been sufficiently exploited? Sound scientific sense also says that the evolving nature of an agro-ecosystem means that there can be no one-shot, definitive and enduring solution. Pests, pathogens, and environmental pressures all fight back and start to erode such apparent, easy advances. The situation is now more acute and evolving more rapidly due to changing climate patterns.

For example, the new disease-resistant wheat varieties now being released cannot resist the deadly wheat stripe or stem rust forever, as climate, environment and disease pathology are continually changing. So the solutions proposed by researchers need to address other approaches that provide a complete and long-lasting solution to the problem.

Here the answer is to set the new resistant wheat variety at the center of a system-focused cropping and development strategy that includes: cropping with a mosaic of different wheat cultivars to stall and trick the disease; registered and available 'emergency' chemicals to deal rapidly with sudden short-term epidemic situations; mechanisms for cross-border co-operation, surveillance and early warning. To this mix we add policies to ensure that these approaches can work in countries and across regions that are at risk.

And why not include other crops in the mix that are not widely promoted or previously considered, that can improve a country's food security and nutrition balance? At high school we learn of the need for cereal-legume rotations to maintain soil health and sustainable production, while in many countries legume presence in the rotation is decreasing. These kinds of actions move toward 'systems thinking' and an innovative approach to agricultural research-for-development.

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From high-tech to the right combination of existing knowledge

Sometimes it is not necessarily the highest-tech finding that brings the biggest farming and income boost to low-income areas and households. More likely it is an approach that is most appropriate to a population's needs and linked to locally-relevant mechanisms to encourage successful adoption and scaling-up of a viable approach so it can benefit millions.

In dry areas of the world, a technique called conservation agriculture that uses zero or minimum plowing of fields is rapidly gaining popularity and proving successful. As this simple method avoids plowing and excessive cultivation, it saves fuel, facilitates moisture retention and soil fertility and limits environmental damage. At the heart of conservation agriculture is a need for specialist planting machines that can place seeds accurately into unplowed soil. Farmers working the marginal lands of Africa and Asia cannot afford the machines on offer from wealthy country manufacturers, that cost up to US\$ 60,000 each. Instead, agricultural researchers and local makers have teamed up to deliver innovative equipment at a fraction of that price (US\$ 1500 to US \$5000) whilst still delivering comparably successful crop results.

In South America and parts of China, conservation agriculture has already been widely adopted. In the Near East, farmers have voted with enthusiasm for this approach. In 2006-2007, three farmers in Syria planted just 15 hectares of crops using zero-tillage. In the 2010-2011 season, 400 farmers planted 20,000 hectares. In Iraq, adoption has seen growth from 52 hectares to nearly 8000 hectares in the same period.

To encourage uptake, NGOs and government extension services provided zero-tillage seeders on loan (sometimes using the micro-credit approach), but every farmer provided inputs from his own resources. This has been taken as a real vote of confidence and means they find the technology attractive and profitable.

Back in the field with those plant breeders following in Borlaug's footsteps, the breeding of new crop varieties that resist disease and extreme weather conditions (cold, drought and unpredictable rainfall, poor soils, salinization) is at the core of agricultural research-for-development. Some successes have been impressive, but from an holistic, agro-ecosystems perspective this is arguably only 30 percent of the picture.

Understanding how the system works

How will these new crop varieties be integrated into national or regional food the production systems? What mix of crops can bring better food security and enhanced nutrition to enhance the impact of these new variety introductions? What are the country and regional real multiple needs and priorities? What other policies and frameworks need to be in place? And what will scaling-up look like – what is the potential and risk of making this investment, and how will it increase food security and community-level incomes? Is it all sustainable on a planet increasingly short of resources?

The agro-ecosystems approach of agricultural research is an all-embracing way of addressing a complex and interactive set of problems. It aims to identify, quantify and integrate the driving forces and interactions that shape and constrain farming systems and the management of natural resources. And by working backwards from the intended impact in the farmer's field, it helps identify researchable issues, to generate testable hypotheses – and set a research agenda that is focused on the need of the rural – not the research –community.

We know it works. The systems approach has demonstrated some notable successes. The High Plateau of Peru and Bolivia is one of the world's poorest areas, in sharp contrast to other areas in South America. Andean and international partners have been using a systems approach to develop strategies to reduce poverty and enhance natural resource management. This approach has enhanced the synergies and interactions between crops and livestock and even different non-farming activities.

The potato, which is extremely important for food security, has been complemented with other crops such as quinoa (particularly organic production), which has become a key income generator. In addition, livestock and dairy production are receiving increased attention for their importance in asset building for small rural businesses as well as a major income source for farming households. Recently, production of local Andean handicrafts have found favor in local markets, regional trade fairs, and, by means of private agents, to Japan and Canada, thus diversifying, enhancing and stabilizing livelihoods.

Another example is the integration of alley-cropping of fodder shrubs (salt-bush and cactus) into barley-based mixed livestock systems in North Africa. Crop-livestock systems in Morocco and Tunisia face two sets of problems: severe shortages of livestock feed (due to degradation of rangelands), and poor crop productivity, due to low rainfall, soil erosion and declining soil fertility. The alley-cropping technology addresses both sets of problems. Salt-bush (*Atriplex*) and spineless cactus (*Opuntia*) are grown between rows of barley. This provides a reliable supply of fodder to sheep and goats, reduces erosion and rainfall run-off, and increases soil moisture retention. Profits to farmers rise, while natural resources are sustained and improved.

The agro-ecosystems approach of agricultural research is an all-embracing way of addressing a complex and interactive set of problems.

Crop-livestock systems bring more income

Livestock systems in the drylands of Africa are notoriously risky and vulnerable as drought takes its toll on the animals. A systems based approach to tackle this has taken the form of an Index-based livestock insurance (IBLI).

The underlying concept is that policy holders (i.e., livestock owners) are compensated based on a clear, measurable outcome that neither insurer nor policyholder can influence, such as the amount and distribution of rainfall. IBLI represents a promising and exciting innovation for managing the climate extremity risks that vulnerable pastoralists face. It is easier to administer and more cost-effective to develop, than many other livelihood-interventions to support livelihoods or reduce risk.

A pilot IBLI product for individual pastoralists in the arid and semi-arid Marsabit District of northern Kenya was launched in 2010 and despite some teething problems it shows real promise as a practical tool.

These examples, and dozens more, show that the integrated agro-ecosystem approach is more than a concept. It is a practice that has been clearly validated, and, today, merits a more strategic position in development thinking and research investment.

In addition to these systems and to the new crops that are tolerant to problems such as salinity, cold snaps early or late in the growing season, drought or intense heat, a number of simple practices and approaches exist to manage natural resources better.

Using agro-ecosystems thinking, today a combination of water harvesting and supplemental irrigation can bring water to communities where there is literally no water, or very little rainfall in the year. Water harvesting is usually perceived as a way to catch rainwater that falls in abundance in places like South Asia, and keep it for later use.

New methods for assessing the potential of water availability – close to villages and remote communities – have been developed and tested in some of the world's driest lands of the Middle East, such as Jordan, Libya, Syria and Yemen. These innovations allow governments the possibility to literally bring water to places that have never had it – thanks to a combination of satellite mapping of slopes, soils and rainfall and on-the-ground observations and soil analysis.

Water harvesting combines with supplemental irrigation, to deliver water to crops at crucial periods in the growing cycle, boosting yields, or saving crops from drought. It also allows smallholder farmers to plan planting instead of waiting for rain – which climate change has made increasingly erratic in some areas. In highlands areas, for example, farmers use supplemental irrigation to plant later, avoiding the risk of crop-killing frost. The challenges are complex, so must be the solutions.

From tons per hectare to better livelihoods

Crop scientists display an innate interest (and are given the incentive to do so by their leaders) in improving tons per hectare and the nutritive value of food – it is a key strategy to increase food security. But it's just one component. If improved livelihoods is the goal then agricultural and socio-economic research needs to look beyond the paradigm of keeping the farmer and small community producing food for subsistence only. They should consider approaches to increasing income using a package of approaches where the farmer might grow high-value crops that generate income to purchase food, education, health care and the other components that build towards an 'improved livelihood'.

After all, if you have more dollars in your pocket, even if you have not got home-grown food, you can buy it from your local or wider economy. You become an economic player and move beyond the subsistence level. Often, increased family income is spent on the education of the children, especially by mothers on their daughters – who are often traditionally doubly disadvantaged in marginal farming areas. Thus, building sustainable production systems that bolster livelihood resilience can improve the women, youth and other disadvantaged groups, allowing them to reach their personal potential.

Agro-ecosystem approaches to future farming recognize the urgent need to engage the world's rural, non-farm economy in positive ways. Off-farm activities can have both a push and pull effect on farming communities and practices: local populations, needing to be fed, drop as members leave for part of the time to non-agricultural employment. Outside remittances provide cash that can be used to introduce and promote new technologies on-farm.

Development economists have long recognized that agricultural advances play a central role in fostering development in the rest of the economy through a complex series of linkages. Farming also plays a predominant role in influencing the size and structure of the rural non-farm economy, by supplying raw materials for food and other processing; by providing a market for agricultural inputs and consumer goods and services and by supplying – and reducing the price – of food in the non-farm economy. But knowing how to balance these multiple aspects to rural existence is complex.

Economists at IFAD suggest that each dollar of additional value-added in agriculture generates between 30 and 80 cents in second-round income gains somewhere else in the economy. The proof, they say, is the evidence that where agriculture has displayed robust growth, the rural non-farm economy has also typically enjoyed rapid growth.

If improved livelihoods is the goal then agricultural and socio-economic research needs to look beyond the paradigm of keeping the farmer and small community producing food for subsistence only.

So the warning is stark. As long as development thinking pushes for those two dimensional 'magic bullets', and as long as there is a vertical focus to develop specific commodities – ignoring low-income countries' daily reality of complex, multi-component needs – the development community's goal of 'sustainable intensification' of smallholder agriculture, increased income for communities and improved livelihoods will remain elusive.

What does a practical policy look like (from a low income country's perspective)?

A wise person speaking at an agricultural research forum not long ago commented that '....poor people cannot eat policies'.

Yes, policies are an integral part of making an agro-ecosystem approach work and national policies are key to getting innovations into the field, to help achieve the elusive dream of scaling-up and wide field adoption. But too often, policy work is done without considering the context of a country, the specific needs of a specific food production system and its communities.

We should be asking the farmers, the smallholders, the men and women living on marginal lands. Their everyday activity is an agro-ecosystems approach in itself – rural people experience the complexity of nature every day of their lives. Scientists need to realize that the community-level of integration is often much higher than their disciplinary backgrounds. An effective agricultural innovation system must involve all players along the 'impact pathway' from farmer, to researcher to policy maker. This is also system thinking.

Global policies play an important role. They have helped us define the context of the Millennium Development Goals, and have mapped hunger and poverty trends to help direct World Bank and other development funding where it is most needed.

But countries also require something else. Global policy and economic trends tell countries, for example, that they need to create better access to markets, develop robust rules for property rights (addressing land tenure and increased land fragmentation) and strengthen the capacity of national institutions. While few would argue against these assertions, low-income countries need solutions that they can implement now, in the imperfect world in which they are living day-to-day.

Global policies play an important role.

Policy issues that work for low-income countries, are rather more down to earth, asking: '...what can we do today to make life better, with the current resources and institutional capacity we have now?'

Many practical and relevant country-level policies are available today. But they need to be adapted to each condition. They include policies on taxation, tariffs, reducing cost of marketing through public investments in infrastructure, investments in extension and agricultural R&D, disseminating market information, and support for farmer organizations, increasing access to finance, particularly smallholder and women farmers. Policies to reward the more sustainable use of natural resources and reduction of harmful practices can be also applied. A lack of political will is often the critical constraint to the implementation of practical and effective policies. This is caused by pressures from interest groups or by a lack of public awareness of the long-term food security implications of the practices and that these policies are aimed to address. Any policy shift produces losers and winners and the perceived losers may put pressure to keep the status quo.

Policy issues for low-income countries, full of hungry and poor people, are rather more down to earth. They are simply asking: '...what can we do today to make life better, with the current resources and institutional capacity we have now?' The agricultural research community needs to help them find new answers. This calls for innovative research that operates from systems modeling all the way to on-the-ground verification and feedback to the research community.

The elements described above are all aspects of an agro-ecosystems approach. Agro-ecosystems thinking requires that agricultural research is planned and executed in a new context, determined by addressing needs and constraints in a way that pays close attention to the individual situation of farmers and communities, especially the estimated 2.5 billion people living on the world's most dry and marginal lands that make up some 40% of the earth's surface. The technologies may often be the same (although there may be surprises), but they are freshly assembled and aligned to meet countries' long-term needs, rather than those of a scientific program.

The partners are the same but the inclusive, participatory and transparent discussion is freshly focused on developing research technologies that directly address community needs, and on a better understanding of how they can be scaled-up. Innovation, then, is not only the highest technology, but the clever combination of novel elements to produce a bigger positive impact.

What is needed to drive forward the uptake of agricultural science?

The missing component in most of this is a much bigger and long-term investment in understanding what is needed to drive the uptake of science – looking at new ideas and revisiting those with potential that have never been taken forward. This is the first step in bringing real agro-ecosystems thinking to agricultural research-for-development. The development community - donors and international agencies - needs to understand and invest in this, as do countries national programs.

Given the central role that food plays in human welfare and national stability, it is shocking – not to mention short-sighted and potentially dangerous – just how little money is spent on agricultural research.

In his 2012 letter to the world, Bill Gates mentioned the importance of new and continued investments in agricultural research and development. He pointed out that more new research was needed, but in specific, targeted areas that will get innovations into the widest use.

“We can help poor farmers sustainably increase their productivity so they can feed themselves and their families. By doing so, they will contribute to global food security. But that will happen only if we prioritize agricultural innovation,” said Gates.

His letter said that given the central role that food plays in human welfare and national stability, it is shocking – not to mention short-sighted and potentially dangerous – just how little money is spent on agricultural research. In total, only US\$ 3 billion per year is spent on researching the seven most important crops. This includes US\$ 1.5 billion spent by countries, US\$ 1.2 billion by private sector, and US\$ 600 million by the CGIAR consortium of research centers. While CGIAR money is only 20 percent of total spending, it is critical because it produces international public goods and focuses exclusively on the needs of poor countries and small-scale farmers in low-income regions of the world.

This requires an agro-ecosystems approach to research-for-development. Three new CGIAR research programs – far-reaching new initiatives including hundreds of partners – are currently under construction. They are probably the first global effort that takes an agro-ecosystems approach to understand how agricultural production systems work, be improved and then scaled-up to directly improve food security in households.

Systems research: understanding what works... and why

Another neglected area in the food security and agriculture research field, where more investment is needed, is 'implementation or systems research'. Global health initiatives and countries pour hundreds of millions of dollars each year into Health Systems Research to better understand how health systems in countries work. This effort analyzes what works, or not, and how these systems can perform better.

There has not yet been a global program that validates and assembles complex integrated approaches into 'technology, policy and institutional baskets'...and recommends where they have high-potential to be scaled-up to improve the lives of millions.

In the health research sector, this systems discipline is distinct from the medical and biotechnology research. Many argue that biotech innovations – and vertical approaches that attempt precision cures for illness and disease – cannot achieve real impact without a deep understanding of the systems in which they need to work. In the health context, systems research looks at service delivery, pricing and subsidies, skill sets and human capacity. It attempts to measure the effectiveness of people, institutions and of the wider health research system.

In agriculture there have been pockets of monitoring and evaluation, systems studies and work with countries to track impact pathways. But it seems that there has not yet been a global program dedicated to validating and assembling complex integrated approaches into 'technology, policy and institutional baskets' with recommendations of where they have high-potential to be scaled-up to improve the lives of millions.

Climate change makes an agro-ecosystems approach to global drylands development especially relevant and urgent. Most of the people in the least food secure places on earth live on marginal lands, or lands that will be severely degraded over the coming decade. They have poor soils and limited access to water for irrigation, which is only projected to further decrease.

In 2010, India's President, Her Excellency Smt. Pratibha Devisingh Patil, spoke about the challenge her country faces in bringing equity and food security to the most difficult lands in her country. She said that the Green Revolution and its reinventions in the following four decades have still not succeeded in achieving the same wide level of adoption to transform people's livelihoods in the sub-continent's rain-fed areas. If this is to be, and irrigation is not a possibility, then innovative, agro-ecosystems approaches are the only viable option to deliver her vision.

