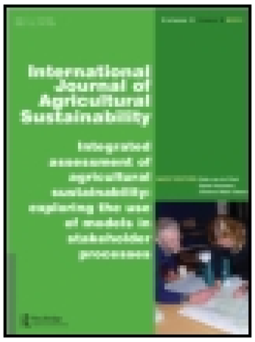

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New Approaches to Supporting the Agricultural Biodiversity Important for Sustainable Rural Livelihoods

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Today, less than 3% of the 250,000 plant varieties available to agriculture are in use. Sources of (agricultural) biodiversity are under threat and disappearing in many regions. Increasing industrialisation of agriculture and top-down agricultural research have contributed to this dependence on a relatively few plant varieties. This article argues that new approaches to agricultural development research are needed to conserve agricultural diversity, improve crops, and produce food of quality for all. Such an approach should enable small farmers on marginal lands to participate as equal partners alongside agricultural scientists, fairly sharing their know-how, expertise and seeds. Three case studies illustrate how farmers and plant breeders are working together in a diversity of agro-ecological, socio-economic and political contexts to put these new approaches into practice. New forms of collaboration are producing an increase in diversity and a number of promising improved varieties in terms of yields, agronomic traits and taste. These varieties are showing better adaptation to the local environmental conditions without requiring extra external inputs. Long-term success requires that these efforts be backed up by supportive policies, by actions to ensure that policies are implemented, and where necessary by related legislation.

Keywords: agricultural biodiversity, participatory plant breeding, research and development partnerships, China, Syria, Cuba

Introduction: Agricultural Biodiversity Under Pressure

The sustainable use of biological resources is a matter of global concern. Distinct types and varieties of plants, animals and micro-organisms are vital for our food and health security. Biologically diverse ecosystems provide essential, although often poorly appreciated, environmental services that make life possible (Pretty, 2002). Variety among species is crucial for the development of agricultural, pharmaceutical and technological innovations. Genetic variability within plant and animal species is the base for resistance to diseases, pests, and climatic stresses. Agricultural biodiversity is vital for sustainable rural livelihoods. Male and female farmers, gatherers and fishers in rural communities around the world have been and continue to be the stewards of the greater share of this (agricultural) diversity.

However, today's agriculture is like a huge inverted pyramid; globally, it rests on a precariously narrow genetic base. Less than 3% of the 250,000 plant varieties available to agriculture are in use today. Sources of (agricultural) biodiversity are under threat and disappearing in many regions (FAO, 1998: 30–40; Fowler & Mooney, 1990; Secretariat of the Convention on Biological Diversity, 2001; Thrupp, 1998: 21–37). The top-down system of agricultural research, where farmers are seen merely as recipients of research rather than as participants in it, has contributed to this dependence on a relatively few plant varieties. Modern plant breeding approaches have contributed to this genetic diversity reduction, in particular of the staple cereals. This trend and the increasing industrialisation of agriculture are key factors in what can only be called genetic erosion: the disappearance and displacement of diverse, local populations of crops (Brush, 2000: 4).

We argue that a new approach to agricultural development research is needed in order to conserve agricultural diversity, improve crops, and produce food of quality for all. Such an approach should enable small farmers – both men and women – on marginal lands to participate in research as equal partners alongside the agricultural scientists, fairly sharing their know-how, expertise and seeds (deGrassi & Rosset, 2003; Pound *et al.*, 2003). This will require fundamental changes in agricultural and related policies and legislation (Crucible Group, 1994, 2000a, 2000b; Gauchan *et al.*, 2000). Through three case studies we illustrate how farmers and plant breeders are working together in a diversity of agro-ecological, socio-economic and political contexts to put this new approach into practice. These innovators are contributing to the development of a research paradigm and practice that has as cornerstones social constructivism, decentralisation and participation, and a holistic perspective. The cases demonstrate that through strong collaborative and sound participatory methodologies involving researchers, farmers, extension agents and government staff *both* productivity and diversity can be enhanced while at the same time research management and organisational capacities are strengthened. Other examples of how this new research practice and paradigm is evolving around the world can be found in a number of recent related studies (Brush (ed.), 2000; CIP-UPWARD, 2003; Friis-Hansen & Sthapit, 2000; Vernooy, 2003).

Following this introduction we discuss a number of key elements of the different perspectives concerning crop improvement and the role of agrobiodiversity. This is followed by the presentation and analysis of three illustrative case studies from China, Syria, and Cuba. We conclude with a number of recommendations for research and development.

Perspectives on Crop Improvement and Agrobiodiversity

In most countries, the majority of crop research and extension continues to be guided by on-station experimentation. This is nearly always carried out under favourable environmental conditions with research design and execution fully controlled by plant breeders and/or agronomists. Yield increase is considered to be the ultimate, main and often single variable to measure variety improvement. Following a series of on-station testing cycles, improved varieties are then released by breeders, and with the collaboration of extension agents channelled to farmers. These new, so-called modern varieties are promoted in lieu of varieties locally used, often in the company of other prescribed inputs such as fertiliser and pesticides. Underlying this still dominant research and extension practice – although at times more implicit than explicit – are a number of important notions about how science and society operate. These are positivism, centralisation and reductionism.

Conventional crop research is strongly positivist in nature. A logical positivist or empiricist research paradigm seeks the 'accumulation of *objective* knowledge through the production of empirically testable hypotheses' (Braun, 2001). This paradigm is mirrored in a so-called reproductive learning perspective (Loevinsohn *et al.*, 2000; Van der Veen, 2000) that assumes that there is a body of objectively verifiable knowledge and that this can be taught by breaking down content into its essential elements. However, alternatives exist. A social constructivist paradigm opposes such a view and sees the role of science as the creation of concepts or theories that expand flexibility and choice (Röling, 2000). This view postulates that all social action is open to multiple interpretations, none of which is superior in any objective sense (Braun, 2001).

Social constructivist learning therefore assumes that important features of the external world are uncertain and disputed, and that people actively construct their understanding of it. (Re)discovery and innovation, not repetition, are essential parts of this construction process. In practice, researchers/development workers often assume roles as facilitators, rather than instructors. They encourage work in groups and shared planning, action and reflection. A social constructivist perspective also can be informed by transformative learning (Van der Veen, 2000). In this approach, learners together build a more integrated or inclusive perspective of the world. Through the learning process they jointly transform some part of their worldview, for example, their understanding of social relations in their own community. Such transformation is often stimulated by communicative learning, but goes beyond it, in terms of internalisation and transformation of understanding. Manifestations of transformative learning in natural resource management include, for example, new values or patterns of decision-making that farmers generate and apply outside the immediate arena of the learning intervention (Vernooy & McDougall, 2003).

Conventional crop research in most countries is largely centralised. Key research decisions are made at the top of the organisational hierarchy: Which crops to focus on? Which researchers to fund? Which methods to use? Experiments take place at one or a few experimental stations. Variety release requires approval from a central body, and seed regulations are defined centrally. This practice is characterised by top-down decision-making and information flows. Farmers or others interested in crop development have no say in the process nor are they able to provide meaningful feedback to the results produced. The research process is very much inward-oriented and disconnected from the diverse and often rapidly changing environment(s).

Reductionist thinking influences conventional crop improvement most notably in two ways. First, reductionist measurement fails to take into account the multiple and interrelated variables that farmers rely on to judge the value of a crop and cropping system. deGrassi and Rosset (2003: 40–43) make the point that these farmer variables are often if not always site- and season- specific (embedded in particular genotype–environment variations), informed by social variables such as gender, class, ethnicity, and influenced by socio-economic factors, such as market access, and access to services such as credit, research and extension.

Second, conventional crop research disregards local biodiversity or at best considers it very instrumentally – as inputs for breeding, and best maintained *ex situ* in the proximity of the breeding station. It neglects the importance of biodiversity at the landscape and agro-ecological levels. As Scott (1998: 353, emphasis in the original) has argued, diversity has many advantages:

> Old-growth forests, poly-cropping, and agriculture with open-pollinated landraces *may* not be as productive, in the short run, as single-species forests and fields or identical hybrids. But they are demonstrably more stable, self-sufficient, and less vulnerable to epidemics and environmental stress, needing far less in the way of external infusions to keep them on track.

Lessen agrobiodiversity and you weaken the resilience of the system and its capacity to deal with change. When this happens, communities face more limited options in managing their land and resources. And the end result is that opportunities for the creation and re-creation of farmer knowledge and experimentation – the very processes that are essential for agrobiodiversity conservation, evolution, and improvement – are lost (Prain *et al.*, 1999). This relationship between social and biological diversity is often overlooked.

So far we have discussed and critiqued the key conceptual elements that inform mainstream crop development research. We have argued for alternative, more holistic and dynamic approaches informed by transformative learning. We now present three case studies to demonstrate how new practices and approaches to crop improvement are emerging in a variety of agro-ecological and socio-economic and political settings around the world.

Case studies

The selected cases are above all illustrative of new relationship-building between the formal research and seeds' sectors, and those maintained by farmers as a way forward to overcome the problems described in the introduction. We present the cases as exploratory evidence of the advantages of these alternative approaches and to identify some of the emerging challenges to be dealt with. Table 1 summarises some of the main features of the case studies.

Case study 1: Linking formal and farmers' seeds systems in China

China is one of the countries with a very rich biodiversity. There are more than 30,000 species of higher plants and 6347 species of vertebrates accounting for 10% and 14% respectively of the world total. The various ecosystems in China give rise to this rich biological diversity. As a result of 7000 years of adaptive agricultural activities carried out in a variety of farming systems, rich genetic resources of agricultural crops and domesticated animals have persisted until now. However, increasingly biodiversity in the country is being threatened due to a large and still growing population, rapid economic expansion, intensive utilisation of biological resources, and fragmentation of the natural habitats. Contradictions between conservation and exploitation (policies) are also harmful.

Maize, now the number one feed crop and number three food crop in China, is one of the crops facing *in situ* or field-level genetic erosion. The genetic base for maize-breeding in China has been dramatically reduced during the last decade. Although the total national maize germplasm collection has around 16,000 entries, five dominant hybrid maize varieties now cover 53% of the total maize growing area in the country. In Guangxi province the total maize germplasm collection has around 2700 entries and among them more than 1700 are landraces from the region. However, the utilisation of these collected materials in breeding is very limited. Only

Table 1 Main features of the case studies

Features	*China*	*Syria*	*Cuba*
Crop system	Maize (uplands)	Barley (drylands)	Maize/beans (hillsides)
Economy	Small farmer/ subsistence; transition to market economy under communist regime	Small farmer/ subsistence; market economy	Small farmer/ subsistence; communist regime
Research organisation(s)	National and provincial agricultural research and extension system	International agricultural research centre	National agricultural research system
Research focus	Diversity/ productivity/ empowerment	Productivity/ diversity/ empowerment	Diversity/ productivity/ empowerment
Type of participation	Researcher-initiated collaborative	Researcher-initiated collaborative	Researcher-initiated collaborative
Type of social analysis	Gender-transformative	Gender-descriptive	Gender-descriptive

Source: Adapted from Vernooy, 2003

three main hybrid breeding crosses are used and all the 14 hybrids bred out in the last 20 years share the same inbred line to different degrees. These hybrids show poor adaptability to the diverse and fragile agro-ecological conditions in Guangxi and other provinces in the southwest. They are also susceptible to diseases. Meanwhile, in several provinces landraces in farmers' fields are degrading and some are disappearing as a result of the push and spread of modern varieties (CCAP, 1999).

The government of China has realised the need for the sustainable use of biological resources in order to have crop yields that can keep pace with the increasing population while faced with environmental limitations. China, the most populated country with the lowest amount of arable land per capita in the world has no choice but to keep food security high on its agenda in this century. Several related initiatives have been developed in the last decade to translate these crucial insights in practical terms. One of these efforts is a participatory maize breeding project coordinated by the Center for Chinese Agricultural Policy (CCAP), a leading agricultural policy research institution part of the Chinese Academy of Sciences (CAS). The CCAP project aims to identify technological and institutional options for developing more effective linkages and mutually beneficial partnerships between the formal and farmers' seed systems. The main hypothesis is that only such new institutional development can enhance sustainable crop development and in-situ/on-farm management of genetic resources. It also aims to strengthen male and female farmers' research and management capacities to maintain agrobiodiversity in the specific Chinese context (CCAP, 1999; Song, 2003).

The CCAP project is carried out in Guangxi province in Southwest China and follows an impact study carried out from 1994 to 1998 by the International Maize and Wheat Improvement Centre (CIMMYT) to assess the impact of CIMMYT's maize germplasm on poor farmers in Southwest China (Song, 1999). That study critically analysed the processes of technology development and diffusion. One of the key findings of the impact study was the systematic separation between the formal and the farmers' seeds systems. This resulted in inadequate variety development, poor adoption of formally bred modern varieties, an increasingly narrow genetic base for breeding, and a decrease in genetic biodiversity in farmers' fields (Song, 1999).

The project team support farmers' groups through training, linkages and networks building, and market involvement among farmers and with the formal system actors. Policy changes aim to bring about conceptual change among formal research and seed systems' actors so that they better understand farmers' roles and enable farmers' participation. The project is implemented by a team of men and women from various institutions and groups, from different disciplinary backgrounds and operating at different levels. Five women farmer groups, six villages, six township extension stations, two formal breeding institutes and CCAP have been directly involved in the project design and implementation.

The research uses a participatory plant breeding methodology adapted to the local context. Participatory plant breeding covers approaches that involve close collaboration between researchers and farmers and potentially other stakeholders, to bring about plant genetic improvements within a species. This occurs during the whole research and development cycle of activities associated with plant genetic improvement. Improvements can be made through a number of crossing techniques and/or through various variety selection processes. Trials in the six Guangxi villages and on-station include both participatory plant breeding and participatory variety selection experiments. The trials allow for comparison in terms of locality, approach, objectives and the types of varieties tested. Varieties include landraces, open-pollinated varieties, so-called waxy maize varieties and varieties introduced by CIMMYT (CCAP, 1999). Some of the CIMMYT varieties have been locally improved through crossings and selections.

Field experiments

So far, based on four years of experimentation, three farmer-preferred varieties have been selected and released in the project villages. In addition, five varieties from CIMMYT that were showing increasingly poor results have been locally adapted. Another five landraces from the trial villages have been improved with joint efforts of farmers and formal breeders. Agronomic traits, yields, taste and palatability of all these varieties are satisfactory. Varieties are also showing better adaptation to the local environments (CCAP, 2004). A female farmer's improved variety has been tested over a number of cycles and certified by the formal breeding institution. Its robustness and taste make it a very popular variety that is now widely used in the area. Farmers from neighbouring areas who heard about it are coming to learn more and to ask for seeds. In the area, varietal diversity is increasing. Meanwhile, formal breeders have identified in farmers' fields a number of very useful breeding materials and inbred lines that have a valuable, broad genetic base.

The project's participatory plant breeding field experiments, both in farmers' fields and on-station, have been functioning successfully as a platform to involve the main stakeholders from both formal and farmers' systems. They have facilitated effective interaction, communication and collaboration among them. Farmers, women in particular, are now speaking up in meetings and expressing their ideas, needs and interests. In a still strongly top-down research and policy environment this represents a major change. The participatory breeding activities have also strengthened the local level organisational and decision-making capacity of farmers. Groups of farmers have started to define specific support that they would like to receive from the extension service. They have put forward the idea to initiate seed production and marketing in particular of pollen variety maize seeds. Marketing research is underway in Guangxi and neighbouring provinces (CCAP, 2004). The aim is to add value to the women farmers' produce. This is expected to make the on-going activities and process of participatory plant breeding and agrobiodiversity management more sustainable. In addition, following the organisation of a first successful diversity fair in 2003 in the township they are now planning follow-up fairs in their villages and possibly in the city of Nanning, the provincial capital (CCAP, 2004; Vernooy & Song, 2003). They plan to sell their seeds at these fairs.

Meanwhile, there has been impressive impact in attitude change and policy consideration in formal systems. For instance, farmers' needs and interests have been considered and included in the breeding plan and research priorities of the breeding institutions starting from the year 2001. The Ministry of Agriculture has recently agreed to include the project's approach and methodology in its national extension reform pilot programme. As another result of the project the Guangxi Maize Research Institute has adopted an approach to combine gene bank conservation with *in situ* conservation of landraces. In addition, the Guangxi local germplasm conservation efforts are considered to be included in the national plan for the broadening of the genetic base by the China Crop Science Institute.

The project approaches, activities and achievements have been introduced and presented in various important policy occasions and conferences. For example, the project was presented and discussed in a national policy-planning workshop on maize research priority setting, coordinated by CCAP and CIMMYT in Beijing, March 2002. This was the first time that the farmer participatory approach as an alternative and complementary methodology for crop improvement and agrobiodiversity management was discussed and considered by the group of 40 prominent national policymakers and scientists gathered in this important conference (Vernooy, 2003: 40).

Case study 2: Decentralised, participatory barley breeding in Syria

In many parts of arid North Africa and the Middle East, yields of key crops such as barley are chronically low, and crop failures are common. Malnutrition is widespread in the poorest regions, and famine is a constant threat. Conventional breeding programmes aimed at improving the crop have had little effect. Most farmers have not been able to adopt the new varieties due to their high input requirements. The conventional approach has been a centralised, top-down approach that pays little regard to the actual and diverse conditions that farmers face. In the late 1990s, a team of researchers at the International Centre for Agricultural Research in the Dry Areas (ICARDA) pioneered a new way to work with farmers in the marginal rainfall environments of Morocco, Syria, and Tunisia. The team brought together farmers and breeders with the common goal of fulfilling the needs of people living and working in the harsh conditions of the region (ICARDA, 2000, 2001).

In Syria, experimenting farmers in nine communities were linked with two research stations. These farmers and their neighbours took care of the participatory variety trials which involved experimental lines from the research station and the farmers' own varieties. Farmers and breeders assessed the results independently in successive trials from 1997 to 1999. Several promising new varieties were identified from these trials. It quickly became apparent that the farmers' selection criteria, largely based on environmental factors, were quite different from those used by the national breeding programmes. To the surprise of many, the selections made by the farmers were at least as effective as those made by the breeders. Yields increased in areas where plant breeding had not previously been successful. Seeing these results, breeders quickly adopted new ideas and attitudes becoming supporters of the participatory approach (Cecarrelli *et al.*, 2000). Farmers also gained better access to varieties that better responded to preferred traits such as tall plants, large kernels, good early growth vigour, high tillering and lodging resistance (Ceccarelli *et al.*, 2000: 101).

The researchers learned a number of other critical lessons from the project. They learned that farmers are able to handle a large number of lines or populations, or both. Most notably, in Syria in phase 2 of the work, the number of lines assessed increased from around 200 up to 400 (Ceccarelli, 2000: 161). In fact, farmers warmly welcomed the opportunity to select among a large number of lines; some farmers have started seed multiplication of selected varieties. Together with giving farmers ongoing access to new materials this is leading to a more dynamic process.

The researchers also noted that women's selection criteria often differed from the men's. And they noted that farmers became empowered by their involvement in participatory plant breeding, gaining the confidence to take decisions on crosses as well as on factors such as plot size and the number of locations. Perhaps of equal importance to the researchers themselves, the project revealed the need for specific training in areas such as experimental design and data analysis suitable for situations where the environment (a farmer's field under farmer's management) cannot be under the scientists' control as it is in the research stations.

So successful has been this pioneering approach that farmers have requested breeders to work with them using a similar approach to improve other crops. It has also spread to other countries in the region. ICARDA currently supports programmes on barley in Egypt, Eritrea, Jordan, and Yemen. In Bangladesh, Syria, Turkey, and Yemen, the same approach is being applied to research on lentils. Complementary to the efforts, ICARDA has begun participatory research in natural resource management, in particular on sustainable land management in dry areas. In each country, the success has been repeated. In Yemen, for example, a project that began with just three villages in the Northern Highlands quickly doubled to include three more villages in the Central Highlands. And the participatory approach has been used as a model in other projects carried out by the Agricultural Research and Extension Authority

(AREA), ICARDA's national partner research organisation. Another example, agricultural research authorities in Jordan have started to transform the national barley programme into a decentralised breeding programme. In addition, they have initiated similar efforts with bread and durum wheat.

Case study 3: Rebuilding the national seed systems for maize and beans in Cuba

The tourism industry notwithstanding, agriculture is still the backbone of Cuba's battered economy. One of the consequences of the severe economic crisis in Cuba is that agricultural production in the country is moving away from an industrialised, export-oriented, monoculture-based model that is dependent on high inputs. With the access to fertilisers and other agricultural inputs almost completely cut off, agricultural producers are moving to more diversified, low-input production systems that are oriented to local markets. Another consequence of the crisis has been the rapid deterioration of the conventional, centralised system for seed production, improvement, and distribution. These unlooked-for circumstances have combined to open up a space for agricultural researchers and policymakers to turn their attention to alternative seed production, improvement, and distribution practices, as a crucial contribution to the need to build a new agricultural sector in the country.

In 2000 a multi-disciplinary group of dynamic researchers (agronomists, biologists, biochemists, and social scientists) at the National Institute for Agricultural Sciences (INCA) began a project designed to improve the yield and quality of the corn and bean crops through a combined effort of increased varietal diversity and strengthened local farmer organisations. The aim of this innovative project is to strengthen the agricultural biodiversity base in Cuba making a more diverse and better quality range of varieties available to farmers, agricultural research institutions and, in the end, to consumers. To achieve these aims, the INCA team has researched local farmers' knowledge about the management and flow of corn and bean seeds. At the same time they have developed a methodology for selecting corn and bean varieties combining seed fairs with the establishment of farmer research groups. These groups are building on the experiences from other Latin American countries with the successful local farmer research committee methodology (known by its Spanish acronym CIAL) developed by CIAT in Colombia (Ashby *et al*., 2000; Humphries *et al*., 2000; Vernooy, 2003).

Results from the participatory variety and participatory breeding trials have been promising. The average number of productive bean varieties with better yield and improved agronomic traits now grown in farmers' fields has doubled (La Palma area) and increased seven-fold (Havana site). Pest and disease incidence is decreasing in beans and maize. Bean yields have gone up on average by 15% (Havana area) and 36% (La Palma area). Specific adaptation has improved. A promising maize variety developed through a farmer-led participatory plant breeding process in the Havana area yields better (average yields increased from 1.5 ton/ha to 2.7 ton/ha), has a much better taste according to consumers, and requires up to 20% less water. Seed production and commercialisation of this variety has started. Farmer households and cooperatives involved in the experiments receive non-monetary and monetary benefits from these improvements (INCA, 2003). The team is currently disseminating these results obtained with the selection, production, and distribution of improved corn and bean seeds to other areas in the country.

A secondary but nonetheless important result has been the strengthened research and management capacities of the various agencies involved – including INCA, the farmers, seed companies, and university staff – through learning by doing. Stronger organisation of farmers has clearly increased their capacity to experiment and innovate and to make stronger demands on the formal agricultural research system. Following the beans and maize research started by INCA, farmers requested that a similar methodology be used for rice, and later on for tomatoes. INCA has responded positively to these requests (INCA, 2003).

One method the researchers use to introduce farmers to new or unknown varieties or lines is the seed or biodiversity fair. Fairs were originally organised by breeders and took place at the INCA station. The fairs proved to be hugely popular, so much so that farmes quite spontaneously started to organise similar fairs in their own communities. Farmers, breeders, and extension agents come together at the fairs, exchanging knowledge about and assessing varieties and selecting the ones they like best. Fairs are key interfacing events of the formal and informal research and seeds systems. The materials are distributed to other farmers for further testing on-farm. Breeders assist farmers with the experimental design, but all trials are adapted to the local context. To learn more about farmers' preferences, the project team organises regular field days, where farmers, both men and women, are interviewed about their preferences. The information gathered is crucial to plant breeders in identifying parental materials and selection criteria. Through these seed fairs farmers have gained knowledge about and access to close to 100 maize and over 60 bean varieties of various kinds including hybrids, local varieties, and experimental lines (INCA, 2003). Farmers themselves are now setting up new breeding and variety selection experiments with these materials.

Conclusions of the Case Studies

Table 2 presents a synthesis of the main results achieved to date by the three case studies.

In China and Cuba, the collaboration between the farmer and formal seed systems through participatory plant breeding activities such as field-experiments, diversity fairs, cross-field visits, joint workshops, and joint training, is overcoming the key limitations of the formal seed system. Both countries have been following a modern technology-oriented approach (with Cuba more recently shifting to a low industrial input system) and have relied predominantly on their public seed system to ensure national food security. In both countries, policymakers and researchers are now recognisant of the fact that insufficient national attention has been given to the farmers' seed system and to the importance of linking farmers' indigenous crop development process to the formal one. This new collaboration is producing promising breeding results and an improvement in farmers' livelihoods. Varietal diversity is increasing. A number of improved varieties in terms of yields, agronomic traits and taste are available. Varieties are better adapted to the local environmental conditions without requiring extra external inputs. In Cuba and China, new varieties have better pest and disease resistance. In all three countries new varieties show better drought resistance. A new maize variety developed in Cuba requires up to 20% less water. The new ways of working together are also leading to an increased recognition of and respect for farmers' experimental skills. In China, women maize breeders are gaining respect from formal system plant breeders and from extensionists. In all three countries, professional plant breeders and other scientists now treat farmer experimenters as colleagues.

The Syria study showed that traditional plant breeding programme were ineffective on marginal lands because they seldom included among their selection criteria those traits that are important to farmers. Decentralised selection combined with farmer participation from the initial stages of the breeding process has proven to be a good methodology to fit crops to specific biophysical and socio-economic contexts and not the other way around, and to respond to farmers' needs and knowledge. In addition, selection in farmers' fields avoids the risk of useful lines being discarded because of their relatively poor performance at experimental stations where conditions are almost always more favourable through fertilisation or irrigation, for example. Decentralisation favours an increased flow of diversity, but needs to be accompanied by active and meaningful participation of male and female farmers.

Joint learning through new forms of more 'horizontal' collaboration has been central in all three cases. This has contributed to the recognition by researchers and others, such as policymakers, of the value of local knowledge and capacities in the realms of experimentation, organisation, and dissemination. This is breaking down stereotyped perceptions. Adding value has also been achieved by linking *in situ* and *ex situ* conservation, and by strengthening or improving seed production systems through mechanisms such as seed fairs, very popular in China and Cuba, and local seed banks. The fairs are instrumental in encouraging exchanges of know-how, experiences, and of course, seeds.

In the three countries, decentralised control and decision-making are replacing the notion that crop varieties developed by the official system are widely useful and by definition appropriate in all local contexts; that pre-released materials should not be given out to farmers; that there is no role for farmers in testing pre-released varieties; and that farmers do not experiment or need to experiment with varieties to see if and when these are suitable to a wide range of conditions and requirements. The core elements of the new approach have slowly began to enter the policy domain.

The Cuban case may appear unique, but it is quite possible that a similar collapse of the

Table 2 Synthesis of main research results of three case studies

Results	*China*	*Syria*	*Cuba*
Breeding results	Improved varieties. Increased diversity. Farmers' efforts recognised at provincial levels.	Improved varieties. Diversity increased. Farmers' efforts recognised at national level.	Diversity increased. Improved varieties. Increased local adaptation of varieties.
Methodology innovation	Supporting farmer-led breeding efforts. Strengthened local organisation. Small (seed) enterprise development led by women.	PVS and PPB* methods pioneered in Middle East and North Africa. Decentralised trials. Increased attention to genotype × environment interactions.	PVS and PPB methods pioneered in Cuba. Introduction of (diversity) seed fairs. Introduction of CIAL*-like methodology.
New partnerships	NARS*-extension service-farmer groups	CGIAR*-NARS collaboration in various countries established	NARS-cooperatives and farmer groups
Policy influence	Farmer-bred variety released. Participatory approach gaining ground in formal research system.	PPB accepted by NARS. Decentralisation of breeding trials now a common feature.	Participatory approach gaining ground in formal research system. Application in other crop improvement programmes, (e.g. rice, tomato).
Capacity building	Attitudes and skills of scientists changed and strengthened. Farmers' research and organisation skills improved. Women breeders recognised for their knowledge and expertise.	Attitudes and skills of scientists changed and strengthened. Recognition of farmers' knowledge and capacities. Farmers' research skills improved.	Attitudes and skills of scientists changed and strengthened. Farmers' research and organisation skills strengthened. Women recognised for their experimentation and seed selection skills.

*PPB, Participatory Plant Breeding. PVS, Participatory Variety Selection. CIAL, Comité de Investigación Local or Local Agricultural Research Committee. NARS, National Agricultural Research System. CGIAR: Consultative Group on International Agricultural Research.
Source: adapted from Vernooy, 2003: 44–45.

industrial agricultural sector could occur before too long in other countries of the region, and perhaps beyond. The current agricultural production practices in many countries are highly dependent on expensive technology and chemical inputs as well as various kinds of government subsidies. This is simply not sustainable in the long term. Thus the Cuban experience will likely have relevance elsewhere in the future.

Lessons learned

Agrobiodiversity research demands a different, innovative way of addressing human needs that goes well beyond the aim of increasing productivity. Its goals are achieving productivity increase, diversity enhancement and empowerment. As we have seen, dynamic and transformative approaches that are collaborative, involve multiple stakeholders, and employ sound participatory methods, do contribute to food security and improved livelihoods. The three pillars of the conventional crop development approach are being replaced by new guideposts. Key new elements are reliance on a variety of sources of information and technologies, acknowledgement of farmers' knowledge, skills and experience, and responsiveness to farmers' needs. This requires gaining insight into how farmers procure seeds, what their requirements are, and what local ways already exist to satisfy farmers' needs. It involves building on local networks including cooperation with non-government and community-based organisations.

Plant breeding research requires a new orientation and learning approach. We suggest that more of the work be carried out *in situ* – on farms and in communities – with farmers as colleagues, each complementing the other's knowledge, skills, and experience. Decentralisation should replace centralisation as the main organising principle in order to address specific local contexts. Finally, there is a need for breeders to collaborate with social scientists in an interdisciplinary research mode that takes into account both the biophysical and the social dimensions of the dynamic processes involved in maintaining diversity. Participation in plant breeding also requires changes in how germplasm is selected, how experimental plots are designed, where experiments are implemented, and how assessment of the results takes place.

This reorganisation requires new or additional incentives and rewards that recognise promising and successful efforts. Farmers should be officially recognised as 'co-authors' of new varieties or of publications that document the processes and final results. Breeders should be recognised and rewarded not only for the release of new varieties, but also for their contribution to the process leading to the final products. Research grants need to be targeted to proposals that deal adequately with process management questions.

Recommendations

However, field-level interventions alone, both on the farm and in communities, are not enough to sustain these well-tested alternatives. Long-term success requires that these efforts be backed up by supportive policies, by actions to ensure that policies are implemented, and where necessary by related legislation. Bridging the divide between research in the field and widespread implementation of the methodology needed to support the processes that maintain diversity over time represents a major political challenge. Meeting that challenge requires affirmative action in key decision-making areas of government and research: the allocation of resources, inter-institutional and cross-sectoral partnerships, human resources management, the organisation of research, monitoring and evaluation, and staff training. New criteria and indicators are needed to measure the results of research and policies. For example:

- Improved farmer production. Examples of indicators: increased yield; improved cooking quality of grains; crops are more pest- and disease- resistant; crops require less water.
- Increased farmer-held diversity as evident in an increased number of varieties per crop, or, for example, by one or more drought-tolerant varieties introduced and added to the existing number of varieties.
- Strengthened local organisation of crop management and seed production. Examples of indicators: women establish seed production and marketing enterprises; farmers organise local research groups; farmers demand researchers for advice and access to germplasm.
- A more dynamic and participatory formal breeding process. Indicators include: breeders have a better understanding of farmers' criteria and take these seriously; decentralised experiments; regular collection of landraces and use in breeding programmes; farmers are members of formal variety release committees or boards.
- A more dynamic and integrated organisation of seed production as exemplified by open channels and regular germplasm flow between the formal and farmers' seed systems; the formal recognition of and supportive policies for farmers' seed production.
- Research programmes based on integrated genetic and natural resource management approaches as illustrated by research projects that go beyond crops *per se* and address interrelated questions of social, economic and environmental sustainability.
- Empowerment. Indicators include: farmers ask breeders to extend participatory plant breeding to other crops; farmers train other farmers in participatory plant breeding.

As the case studies demonstrate, changes can be made, even in difficult conditions, but (more) courage is needed.

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