Formal system and farmers' system: the impact of CIMMYT maize germplasm in South-western China[1]

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Abstract

China has followed a modern technology oriented approach and has relied predominantly on its public agricultural research system to ensure the national food security. However, national food security not necessary mean food security for all. Poverty and food insecurity are still issues in China. The impact of agricultural research on poverty alleviation has increasingly drawn attention from the International Agricultural Research Centers of Consultive Group on International Agricultural Research (CGIAR) and National Agricultural Research System (NARS).

The present paper is based on an impact study of a CIMMYT's Collaborative Programme on Maize Breeding in South-western China, which was carried out by the author from 1994 to 1998[2]. The impact study has revealed that the impact of CIMMYT's maize germplasm on food security and poverty alleviation is quite significant and is actually being achieved through both the formal system and farmers' system. The paper intends to address the inter-related national and household food security and poverty alleviation issues by assessing the impact of the Programme and analysing the capabilities of public research and farmers' indigenous knowledge to deal with these issues at different levels. It concludes by suggesting that China will benefit from a twin-truck approach, i.e. a combination of modern technology oriented approach and participatory approach. Collaboration between the formal and farmers' knowledge systems are highly necessary for the design of agricultural

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[1] South-West in the article hereon refers to the CIMMYT Programme area, including three provinces, Guangxi, Yunan and Guizhou.

[2] The research result is concluded in a published PhD thesis entitled " 'New' Seed in 'Old' China: Impact of CIMMYT Collaborative Programme on Maize Breeding in South-western China". The electronical copy of the book is available at: http://www.cimmyt.cgiar.org/research/economics/Index.htm

research projects which could better address the confronting challenges in poverty alleviation, food security and natural resource conservation.

Introduction

The need for increasing sustainable crop yields continues to grow with increasing population and environmental limitation. This is especially true in the case of China which is the most populated country with the most limited amount of arable land per head in the world. China is a country likely occupying one of the highest positions on the international food security agenda in the coming century. However, food security is a complex and debating issue. Food productivity and availability do not necessarily equate with food security for all. Poverty is a major determinant of chronic food insecurity. Given the context of this paper the impact of agricultural research on food security, at both national and household levels, and poverty alleviation is addressed through the impact study of CIMMYT Programme in the context of China.

CIMMYT in collaboration with Chinese Academy of Agricultural Science (CAAS) initiated a maize-breeding programme in Southwest China with the general objective of poverty alleviation in the end of 1970s. The 25 million poor farmers who reside in the remote upland areas in the Southwest basically depend on maize for their staple food, but the production circumstances there are quite different from the Northern "Corn Belt"[3], as are the socio-economic conditions.

The present paper, which is based on the impact study, intends to address the inter-related national and household food security and poverty alleviation issues by assessing the impact of the Programme and analysing the capabilities of public research and farmers' indigenous knowledge to deal with these issues at different levels. It concludes by suggesting that China will benefit from a combination of modern technology oriented approach and participatory approach. Collaboration between the formal and farmers' knowledge systems are highly necessary for the design of agricultural research projects which could better address the confronting challenges in poverty alleviation, food security and natural resource conservation.

The paper first have an overview of the modern technology oriented approach followed by the Chinese government and the emerging changes and confronting challenges in the context of China in the following section. Then, it presents the great impact of CIMMYT's maize germplasm at both macro and micro levels achieved through the formal breeding system and farmers' indigenous system. After that, a comparative analysis of formal and informal breeding systems with reference to the Chinese NAR and two different cases of farmer

[3] The maize growing area in China can be roughly divided into two main distinct part, i.e. the Northern Plain and the Southwest. The former is some similar to the Corn Belt of the USA in soil types and climatic conditions. Maize production there is mainly for feed. Whereas, the Southwest is a remote mountainous areas with a tropical and sub-tropical climate. Maize produced there is mainly for human food.

breeding is presented to illustrate the linkages and differences between the two systems and variation among farmers in diverse farming systems. Finally, the conclusion is drawn and the implication for policy making is discussed and suggested.

Changing context and confronting challenges

China turned to the power of modern agricultural technology to solve the problems revealed by the great famines of the end 1950s and beginning of 1960s. The most noteworthy development was the establishment of the public agricultural research and extension systems for modern varieties. Some 30 per cent or so of Chinese food security since then is attributable to development and rigorous promotion of improved planting materials, especially hybrid wheat, rice and maize (Lin, 1998, Fan and Pardey, 1997). China was the first country in the world to plant significant areas of genetically modified crops in the early 1990s. But the modern-tech approach can not work in all areas or for all farmers. Besides, the social context and natural environment are rapidly changing, and the poor, with limited resources, is the most fragile group to adapt to the changes.

Chinese rural economy has experienced a rapid growth since the adoption of a broad program of rural economic reforms beginning in 1978, and China is widely recognized for its achievements in reducing absolute poverty since then. Nevertheless, there are about 60 million people who still live under the absolute poverty line, and they comprise the majority of the food insecure population. They are mainly farmers cultivated in resource-constrained remote upland areas, where are agro-ecologically diverse, resource poor and risk-prone regions in Southwestern and Northwestern China. They are small subsistence farmers with an average land size of less than 0.2 hectares. Although these poor have land use right, in most cases the land itself is of such low quality that it is not possible to achieve subsistence levels of crop production. Consequently, most poor consume grain and other subsistence foods beyond their own production levels, and are negatively affected by price increases for these products after the reforms (UNDP, 1995. World Bank 1995). Minority peoples are known to represent a highly disproportionate share of the rural poor.

Feminisation of agriculture is quite a severe phenomenon, women constitute more than 80% of the agricultural work force resulting from male out-migration (Gao, 1995, Song, 1998). This is especially true in the remote and upland communities, where most of the male farmers have migrated to urban and economic booming areas for income earning opportunities. Women, who were left behind in agriculture, were overburdened with low or non-profit agricultural activities as unpaid laborers within the household. There were fewer opportunities for women-headed households to adopt MVs owing to their limited access to resources and services (Jiggins, 1986. Ashby, 1985. Song, 1998). Those poor women-headed households are facing problems of food insecurity, poor access to basic health and education services and other public services. They comprise the poorest group of the poor.

Meanwhile, when we discuss food production and security, with special respect to the rural poor, the issues of environment and biodiversity conservation should be also addressed. It is argued by some researchers that poverty and environment degradation are closely linked, often in a self-perpetuating negative spiral in which poverty accelerates environmental degradation, which in turn results in, or exacerbates, poverty (Rosegrand, Agcaoili-Sombilla, and Perez 1995). Continuing to neglect these less-favored, vulnerable areas where many of the poor live will make degradation worse and perpetuate poverty. Furthermore, with little regard for the chaotic variation in environment and emerging changes in social contexts, the continuous exploitation guided by the state's single-minded aim of targeting only yields to ensure national food security, since the Green Revolution era, has tended to degrade natural resources and agro-ecology. For example, the wide-adoption of modern varieties (MVs) was accompanied by the disappearance of indigenous varieties, soil erosion resulting from over-use of chemical fertilizer, and insect resistance caused by over and repeated use of pesticide. This, in turn, has tended to destroy the resilience of the ecosystem and the sustainable livelihood of farmers, particularly the poor, mainly women.

In China, rice, wheat and maize have long been the three traditional main food crops. Each of these three grains accounts for roughly 100 million tons of the 340 million tons annual grain harvested. However, rice and wheat are now the two national staples, with rice dominating in the South and wheat in the North. Maize used to be staple food in the North-East, South-West and North-West. It is now increasingly used as feed. About 70% of the maize harvest now is used as feed (Dong, 1995). Maize is now the most important feed crop and the third important food crop in China. And most importantly, it is the main staple food crop for the rural poor in the remote upland areas in the Northwest and Southwest. The later is an agro-ecologically diverse area and the major source of maize genetic diversity in China. Previous researches revealed that the narrow genetic base is one of the main technical constraints in maize plant improvement in China (Li, 1990). Recent studies and evidence further show those local varieties and landraces are continuously disappearing at a rapid rate. Genetic base broadening and biodiversity enhancement have a crucial role to play in sustainable food production and food security in China.

Under such circumstances, some research questions arise as: what has happened in areas where environmental resource endowments are too variable and marginal for modern-tech strategies to succeed? What are the poor cultivators in these areas looking for in improved planting materials? And how have their needs been met? What can agricultural research, in our case plant breeding, do to bretter address the confronting inter-linked issues of food security, poverty alleviation and natural resource conservation in a sustainable and equitable way? The impact study of CIMMYT Collaborative Maize Breeding Programme in Southwestern China intended to answer these questions by assessing the impact of the MVs and analysing the capabilities of public research and farmers' indigenous knowledge to deal with the food security and poverty alleviation issues at different levels.

The impact of CIMMYT maize germplasm in South-western China

The impact study had been done at five levels (i.e. state, province, county, village and farmers' household), by using exploratory qualitative methods and quantitative formal survey methods. The impact assessment, at both macro and micro levels, and comparative analysis of formal and informal breeding with in-depth case studies provide a comprehensive view of the Programme. The impact study has clearly revealed that:

- The general impact of this programme is quite impressive. It can be concluded that the collaboration between CIMMYT Maize Programme and Maize Breeding Programmes in the three provinces of south-western China has been fruitful in general. Now 65% of the total maize area is covered by MVs (improved open pollen varieties and hybrids), with 46% hybrids and 19% improved open pollen varieties (OPVs), while the rest are landraces. About 957,000 hectares are planted to the CIMMYT-related materials every year, which comprises about 43% of the total maize area in the three provinces. 73% of the total local releases have been based on CIMMYT germplasm during the period from 1980 to 1996. 87.3. % of the MVs currently used are CIMMYT-related materials. The total adoption of improved germplasm has been growing for both favoured and less-favoured areas during the implementation of the Programme in the last 15 years. There is little doubt that the wide adoption of the MVs has contributed significantly to the continuous increment in maize production and productivity in the last 15 years (cf. Figure 1: maize production trends in the three provinces).

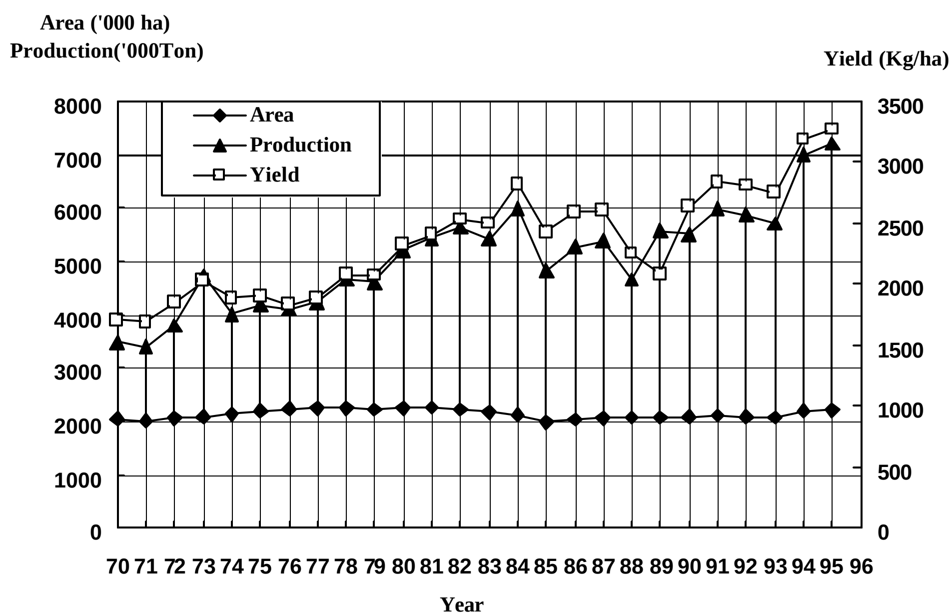

Figure 1: Maize production trends in the three provinces, 1970-95
Source: Song. Y., 1998

- Despite the impressive achievement at the macro level, further in-depth case studies and participatory observation have revealed great variation among regions, and differentiation among farmers, in coping with the MVs. Farming level study showed that the types of materials adopted are obviously different in different environments.

Improved OPVs are adopted mainly by farmers in environmentally harsh and rainfed areas. For instance, the three improved populations from CIMMYT , *Tuxpeño 1, Tuxpeño P.B. C15* and *Suwan 1* have had an annual adoption of 310,000 hectares, comprising about 15% of the total maize area since the early 1980s. They are mainly cultivated by poor farmers in the marginal and environmentally less-favoured areas with difficult and complex maize farming systems. The three improved populations, which were held and directly used by farmers, have become dominant varieties and contributed significantly to household food security and poverty alleviation in the rocky mountainous areas in the Southwest. Although this is not reflected in the state's statistic of modern technology (mainly hybrid) adoption, however, great impact through farmer's informal ways has contributed considerably to the realisation of the general objective of the Programme for poverty alleviation. In the environmentally favoured areas, top-cross and three-way cross hybrids are widely accepted and dominant, such as *Guangxi Top-cross 1 to 5,* which have dominated in the relatively favoured areas in Guangxi for about ten years. These are CIMMYT-related hybrids. The adoption of the government recommended single cross F1 hybrids is limited despite the large number of releases available at the public breeding institutions and with the strong recommendation and intervention by the government.

- It is noted that there exists a large gap between farmers heterogeneous needs and interests and the formal breeders' single minded pursuit of yield, and their profit incentive in hybrid. Most public efforts went into the development and diffusion of several uniform high yielding hybrids. As a result, regional variation and user differentiation, in terms of gender, are largely neglected by the formal knowledge system. This has resulted in the activation of the farmers' indigenous system for OPV improvement, landrace maintenance and seed exchange. As few public efforts were made to distribut*e* and improv*e* these varieties as a result of the public seed system's low interest in OPVs.

- Consequently, the impact of CIMMYT's maize germplasm is actually being achieved through both the formal system and farmers' system. The macro-level impact is mainly achieved through the public breeding efforts, and is reflected in the adoption of CIMMYT-related hybrids and yield increment*s,* which, however, have limited benefit for resource poor farmers in marginal rain-fed areas. The considerable impact of CIMMYT's maize germplasm on the household food security and poverty alleviation of the poor and women farmers is achieved through the informal system which has assured the wide distribution of CIMMYT's improved populations through farmers' own systems.

The formal system, its policy orientation and hybrid bias

The great famine in China in the late fifties to early sixties, and the poor socio-economic situation of agriculture at the time, stimulated the construction of a modern technology-oriented approach. Since then, national food security via food self-sufficiency has been the central government’s number one goal for agriculture. Government policy started to emphases modern inputs in terms of MVs, fertilizers and irrigation schemes. The most noteworthy development was the establishment of an agricultural research and extension systems for modern varieties. The development and distribution of MVs for the three main staples, *i.e.,* rice, wheat and maize, has been the core task and the first priority for this system from the very beginning. F1 hybrid breeding has become an universal tool for the formal plant breeding system to achieve the overall goal of national food security.

Unlike the situation in other developing countries, in China, CIMMYT’s breeding material goes entirely through the dominant public system(*s)* (Figure 2).

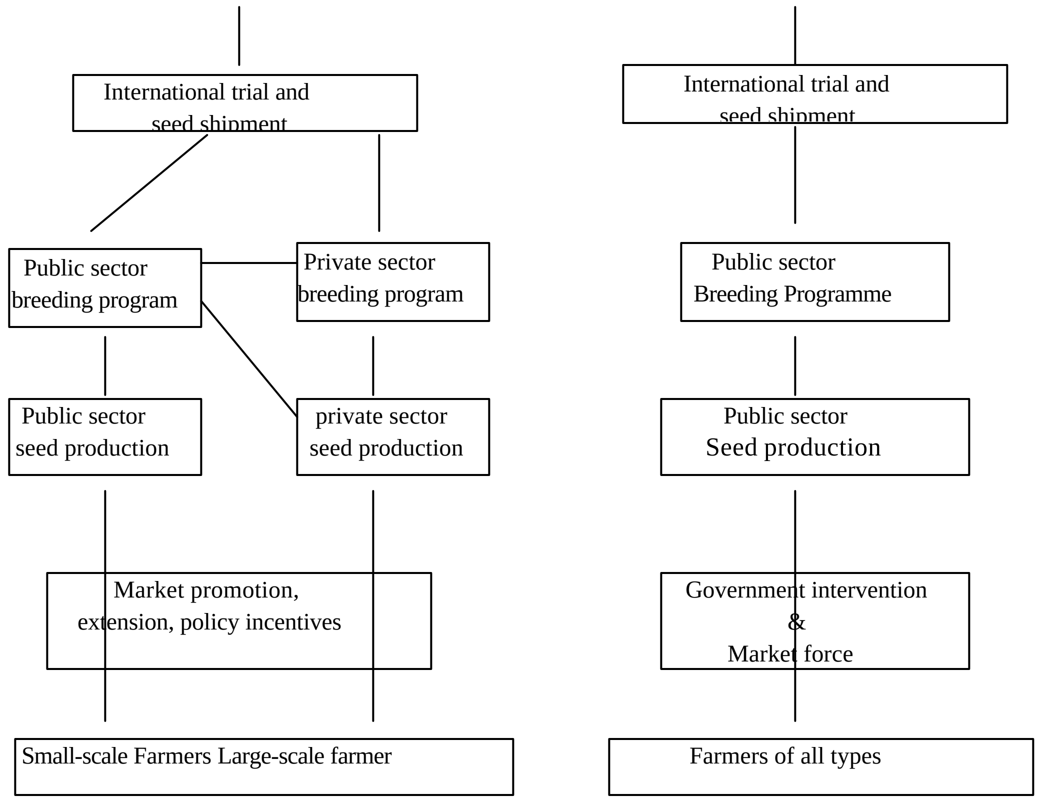

Figure 2. Flow of CIMMYT breeding material in most countries (left) and in China (right).
Source: Lopez and Morris, 1994 and Song. Y., 1998

It is obvious that the formal system's program followed a top-down linear technology transfer process, through which CIMMYT's breeding materials made their way to farmers. With the single purpose on increasing productivity in order to ensure national food security, most of public efforts went into the development and distribution of several uniform high yielding hybrids, especially single-cross F1 hybrids. This is especially true after the policy reform[4] in 1990. The formal breeding and seed distribution system has increasingly been forced to commercialize its operations leading to an increasing focus on hybrid breeding and seed production and to an increasing neglect of OPVs and the deterioration of the quality of hybrid seed.

[4] In 1990 the government started *to* reform *its* agricultural research funding policy. The government reduced its fiscal appropriation for agricultural research, shifted funding from institutional supports to competitive grants, and encouraged research institutes to commercialise their technologies, using part of the proceeds to subsidise their research (Lin, 1998). The agricultural research institutes have had to become more profit driven either through their research or other activities. For this reason, hybrid breeding and hybrid seed production have drawn more attention and effort than ever before. This has resulted in *a* strong public sector focus on several profitable hybrids and neglect of non-profitable Open Pollinated Varieties (OPVs) needed by farmers in unfavourable marginal areas.

Table 1: Trend in public maize breeding in South-western China, 1980-1996

Period / Types	1980-96	1980-85	1986-90	1991-96
Total Release	48	23	18	7
Hybrids	39	18	14	7
OPVs	9	5	4	0

Source: Song. Y., 1998

The field work revealed that the total of 48 maize varieties released by the formal breeding system in the Southwest from 1980 to 1996 consisted of 39 hybrids and only 9 OPVs *(*cf. table 1). Within the total 39 hybrids, 31 are combined with one parent line from CIMMYT. The study also shows that CIMMYT germplasm has been playing an increasingly dominant role in formal, mainly hybrid, maize breeding (Fig. 3).

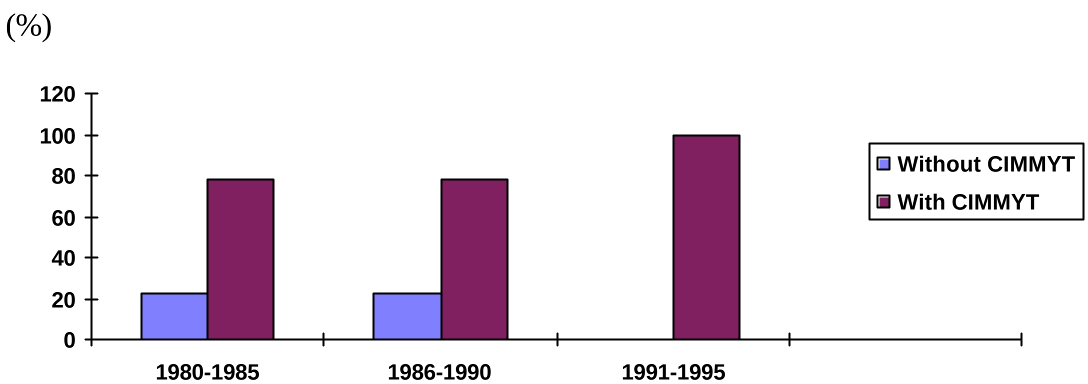

Figure 3: Releases with CIMMYT breeding material in South-western China, 1980-95
Source: Song, 1998

However, table 1 also illustrates the worrisome trend for the total number of release by public breeding to decrease considerably after 1985, especially after 1990s. This is mainly due to the government's reduced funding for public research resulting from structural adjustment and privatization. As a result, the hybrid policy together with the reduced funding situation and the inadequate profit incentives led the formal seed system to provide fewer and more limited options for farmers.

The farmers' system, its initiatives and efforts

Geographical variation is one of the major characteristics in Chinese agriculture. Regional variability in farming systems and differentiation among users are increasing as a result of the changes which emerged after the recent reforms, e.g., the development of rural industry, the commercialisation of agriculture, the feminisation of agriculture, etc. Farmers dependent on varied farming systems with diverse patterns of usage of maize have a quite different and heterogeneous needs for, and interests in, technology and genetic diversity. The big gap between the breeders' limited supply and farmers' diverse needs led to the activation and development of indigenous knowledge systems through which farmers work on the neglected improved OPVs and landraces to meet their own needs. Owing to the feminisation of agriculture and other socio-economic factors, local seed selection and breeding are mainly done by women.

The two cases, Zhichen and Wenteng villages, represent the two contrasting environmental and economic conditions of maize farming in the South-western China. The former case represents the poorest remote mountainous communities, which use maize for subsistence food production, while the latter represents relatively better-off communities in the valleys and flat areas which use maize as pig feed. Zhichen villagers considered improved OPVs and some landraces as appropriate technologies to meet their needs in their harsh environment, whereas Wenteng villagers used to cultivate hybrid maize. However, most of them recently have shifted to improved OPVs due mainly to the decreasing quality of government supply hybrid seed. As a result, *Tuxpeño 1* (see box 1*),* now become the dominant variety in both villages.

Box 1: The experience of *Tuxpeño 1* in Southwestern China

Tuxpeño 1 (local name *Mexican 1*) is an improved population which was developed by CIMMYT from a landrace that originated from Tuxpau, Mexico. *Tuxpeño 1* was introduced in Southwest China in 1978, originally as constituent for variety improvement and hybrid combination. However, *Tuxpeño* 1 was rapidly disseminated through the three provinces, mainly through informal seed exchange. Due to its broad adaptability and stability and strong tolerance to stress, especially lodging resistance, *Tuxpeño 1* became particularly popular with farmers in difficult farming systems in the remote mountainous areas. It has contributed significantly to the household food security and poverty alleviation in the last two decades in those areas. Meanwhile, due to the poor quality of government supplied hybrid seed *Tuxpeño 1* has been increasingly been adopted by farmers in relatively favourable areas. However, since maize is an out-breeding crop, without improvement effort from formal breeding, *Tuxpeño 1* has degenerated greatly by out-crossing, resulting in decrease of yield, increase in plant height and loss of stress resistant characteristics to a certain degree. Farmers requested the government to assist them to improve the material but no government attention was received. This led to significant efforts of local women farmers to engage in regeneration of *Tuxpeño 1* (cf. Box 2. Wenteng case).

The two case studies (Box 2 and Box 3) illustrate women farmers' initiatives and methods in maintaining and improving *Tuxpeño 1* and three landraces in two villages. Wenteng has maintained and improved *Tuxpeño 1,* while Zhichen has chosen to maintain local landrace varieties. The different choices made by the two villages offer insights into farmers' selection strategies. Given the fact that maize is their staple food crop, Zhichen farmers strategically chose maize varieties that reflect their risk-aversion strategies. Despite the agronomic popularity of *Tuxpeño 1,* for Zhichen farmers in subsistence agriculture and risk-prone environments, other varieties were maintained and improved due to a combination of nutritional value, cultural practices and reliable supply in the most adverse environmental conditions. The poorer villagers chose to maintain more diversity for managing risk. On the other hand, in Wenteng, *Tuxpeño* fits the requirement*s* for a commercial crop of Wenteng. The surplus in production extends the readiness of Wenteng's women to take risks. In addition, their more advanced knowledge and skills in varietal improvement and seed selection also reflect their greater external influence (e.g. the influence from barefoot scientists) and better access to information and education compared with Zhichen where women farmers live in isolation and often are illiterate.

Box 2: Wenteng Case

Wenteng has a relatively favourable environment, people are better-off, educated and integrated into the market economy. Maize used to be traditional staple food, now it is mainly used as pig feed. Pig raising is the main source of income for most villagers.

Due to the lack of institutional support, and the popularity of *Tuxpeño 1*, women in Wenteng village have organised themselves to maintain and improve *Tuxpeño 1* since the late eighties. This activity was initiated by an innovative woman who had tried to maintain *Tuxpeño* 1 since its adoption. The crop development methods used by the women include spatial separation through use of plots at different locations, temporal isolation and seed selection. These methods are critical for a population maintenance. The women explained that due to the popularity of *Tuxpeño 1* and the women's initiative in selection, it is easy to organise women farmers to grow *Tuxpeño 1* in adjoining fields isolated from other varieties. The main selection method the women farmers use is mass selection in-field and post-harvest. In breeding term it is stablizing selection for population maintenance. The three steps in seed selection are to select best plants in field (idea phenotypes with big ears and other preferred agronomic traits in the middle of the field), then best ears (based on cob size, length and number of seed rows) and then best grains (from the middle part of the ears seeds are selected for kernel size, shape, quality, colour). The women farmers claimed that their skills mainly have been passed-on for generations, as they have also used similar techniques for the maintenance of landraces. They also added that some of their selection knowledge and techniques are gained from bare-feet scientists[5] (breeders) in Mao's period by their parents or by themselves.

As a result, the quality of *Tuxpeño 1* in Wenteng village has been maintained and even improved in the sense that it is adapted better to the local conditions than before. Most villagers now consider it as a local variety rather than an alien one. It is not surprising that the improved *Tuxpeño 1* has spread rapidly to the neighbouring areas through farmers' informal seed exchange systems. Now Wenteng has become a source for quality *Tuxpeño 1* seed for a large area.

[5] During the Cultural Revolution Mao emphases the technicians and scientists' participation in everyday life and work of farmers. It was revealed by the case study that there were a few breeders who worked in Wenteng and other neighbouring villages in the late 60s and early 70s.

Box 3: Zhichen case

Zhichen, on the other hand, has a harsh and rugged environment. Farmers plant maize in minute pockets of soil on steep mountain slopes and between rocks in flat fields. Water is a serious problem due to calcareous rocks, while rains easily flood the land and wash away the crops. There are no roads and access to the market is very limited. Maize is produced for consumption. Maize has been a traditional staple crop in the area where has a diversity of maize landraces. For instance, waxy maize is considered to be originated from this area (Liu, 1991, Zhang, 1995, Song, 1998).

Tuxpeño 1 was introduced in Zhichen at the end of the 1970s and became the dominant maize variety soon after. In Zhichen, 90 percent of the farmers surveyed in this study said that resistance to lodging and higher yield are the most important criteria for their selection. Other preferred characteristics include white kernels, *a* good stalk with strong root system, relatively short plant stature; wide adaptability, and little external input (seed, fertiliser). In the last three to four decades the cultivated landraces are disappearing. From 20 local maize varieties planted in the 1960s, Zhichen villagers now only plant *Tuxpeño 1* along with three local varieties *(Local Sticky, Duan 1 and Local White*). However, *Tuxpeño 1* has degenerated greatly in Zhichen, as have the three landraces as a result of outcrossing.

However, different from Wenteng farmers Zhichen villagers did not do much to maintain *Tuxpeño 1* themselves, instead they maintain preferred landraces? Zhichen villagers feel that the *Tuxpeño 1* has degenerated beyond their skills to improve it. Instead, they hope that the government will improve the *Tuxpeño 1*, since they consider this a government or foreign variety rather than local one. Yet, they also know that they have to maintain their local varieties because no outside help will ever bother. The farmers chose to maintain and improve the three local varieties based on their complex farming system and livelihood. *Local white* is maintained by some farmers for its sweet stalks on which children like to chew as sugarcane. *Local sticky* is a waxy variety used as speciality food for local festivals. Almost every household maintains a small plot in its vegetable garden, despite its low yield. *Duan 1*, an OPV improved by the county extension station in the 1960s, is maintained due to its strong drought resistance. Despite its low yield, the variety is used by the farmers to grow in the second cropping season in the autumn, when no other variety survives the severe drought. The methods used by the women farmers to maintain the three local varieties include spatial isolation (grown in isolated gardens or separate valleys) and post-harvest seed selection for the best ears and then best kernels. Zhichen villagers also claim that this knowledge has been passed-on by their ancestors. Compared with the women farmers in Wenteng, farmers in Zhichen have less access to out-side world and less influence from external knowledge, and they maintain more diversity for risk management.

Farmer's contrary adaptive strategies towards *Tuxpeño 1* in the two cases show that farmer's selection priorities and objectives reflect their environmental conditions, market and institutional relations, socio-economic positions and risk management.

The case study also illustrates farmers' potential capability in selection and their benefit from exotic varieties, e.g. *Tuxpeño 1*. Some questions arise from the case studies; Why *Tuxpeño 1* has such broad adaptation and well accepted by farmers? Can formal system pay more attention to these types of varieties by bringing more appropriate germplasm for the needs and interests of the poor farmers as well as for genetic base broadening in the agro-ecological diverse, remote and resource poor upland areas? What should CG, in our case CIMMYT, and Chinese NAR do to enhance the local process that is already existing and expand the base that farmers already have genetically and institutionally?

Conclusion: facilitate interaction and collaboration between the formal and farmers' systems

The impact study has clearly showed that agricultural innovation and diffusion of new technologies are important factors in addressing food security, both at national and farmer's household levels, and poverty alleviation. This is especially true with the case of maize which is often grown in less favoured areas and remote uplands, and usually diets in these areas are based primarily on maize. However, farmers adopt an innovation only if it will work in their fields. The modern technology approach in China, which has contributed considerably to the national food security, does not work in the remote resource poor upland area. And the uniform MVs, mainly hybrids, are not sufficient to meet the heterogeneous needs of farmers, especially the poor and women in the marginal areas. In order to address the food security issues and to attack poverty and hunger, it is critical to direct agricultural research to cover these marginal areas and reach the un-reached poor populations by developing appropriate technology to meet their needs and interests.

Plenty of evidence and cases found in the research suggest that the real causes for the failure of the formal breeding programme to address the variation of farming systems and to respond to the heterogeneous needs of farmers in marginal areas are institutional rather than technical constraints. These institutional constraints are related mainly to the research priority and focus, and partially to the inefficiency and ineffectiveness of the formal system. Some technical factors, such as variety characteristics and environmental conditions, are responsible for the failure at first sight. However, technical constraints can be overcome by breeding varieties with desired traits for target area (CIMMYT, 1996).

The impact study provides us with a comprehensive picture of the great impact achieved through the public system and farmers' indigenous system and the operation and functioning of the two systems at different levels. The study also revealed a big growing gap between farmer's diverse needs in terms of stability, quality, yield and other agronomic and post-harvest characteristics, and formal system's single interest in yield increase through F1 hybrid breeding and distribution. This resulted in the initiatives of farmers and the activation of their indigenous system to meet their own needs and interests.

The experience of *Tuxpeño 1* and the two case studies show the great impact of CIMMYT's material on household food security and poverty alleviation and the potential role of CIMMYT through farmer's informal system. When CIMMYT's technologies reached the limit of success in terms of reaching the poor through the formal system, their impact has continued through farmer's system. These imply an urgent need for better institutional linkage and collaboration between the farmers' and formal systems in crop improvement in order to explore local dynamics and potential capability of farmers.

The impact study also revealed that "feminisation of agriculture" is an impressive phenomenon in the remote upland areas. Women there are playing a predominant roles in subsistence agriculture and food security. Seed maintenance and selection is carried out entirely by women based on their own knowledge. However, the women's access to resources and public services are much more limited than that of men. A gender analysis and involvement of women's participation and their expertise in technology design and development is vital in technology design and development to meet the specific needs and interests of women, which could substantially contribute to reduce poverty and ensure food security at the farmer household level (Jiggins, 1986, Quisumbing, Brown et al. 1995, Song 1998,).

Considering the main policy issues arise from the impact study and given the specific situation in China, a twin-truck approach i.e. a combination of the present modern technology-oriented approach and participatory approaches can be an alternative to address food security and poverty alleviation and enhance the sustainable use of genetic resources and biodiversity. As a combination of traditional technologies from farmers' indigenous level and modern technologies from the scientific level might provide a great opportunity for additional food production and productivity gains while conserving natural resources. Farmer's indigenous knowledge systems have a close relationship to the complex natural ecosystem and diverse farming systems. Farmers know their farming system best and scientists have the knowledge of scientific principle and biotechnology. A co-operative and complementary relationship between the two systems, rather than a separated and conflicting one, is logical combination to meet both the state's need for national food security at the macro level, and the farmers' diverse needs and interests in different areas at the micro level.

China should by all means take the technological high road in uniform and well-favoured environments to insure national food security. In addition, reconsideration and adoption of the Chinese traditional ecological knowledge and indigenous farming practice are highly necessary to maintain land productivity and minimise the negative side of the modern technologies on environment and natural resources. But in the more remote and difficult regions research on more location-specific technologies is needed to produce a wider range of technology options tailored to diverse environments, complex and fragile ecosystems.

Decentralisation of the formal systems and involvement of farmers, mainly women, in the technology design and development process is necessary and essential to stimulate collaboration between the two systems through mutual communication and understanding. The informal sector needs to know more about the complex ways of biotechnology, while the formal system need to know more about the complexity of poor farmers' farming system and their livelihood. For instance, the importance of farmers' knowledge of landraces and their understanding of the micro-variations in the environment could become the basis for local level breeding or location-specific breeding. Through farmers' participation and co-operation, breeders can gain new insight in criteria, objectives, or evaluation techniques of farmers and the differentiation between regions and types of farmers (in terms of gender). As a result, appropriate varieties within a wide range of options can be produced to meet the heterogeneous needs resulting from regional variation and user differentiation.

It can be concluded that interaction and collaboration between formal and informal knowledge systems through participatory methods and gender analysis is critical, not optional, in the design and development of agricultural technology which could better meet the needs and interest of the poor and women farmers. In return, it could substantially contribute to reduce poverty and ensure food security.

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