Crop genetic resources manage risks in China. How to manage risks to crop genetic resources?

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KEY MESSAGES:

- China is facing risks of a growing population, deterioration of agricultural lands, poor nutrition and poverty.
- China is one of the centres of diversity for the world's crops and still maintains high levels of between-species and within-species diversity.
- Crop diversity represents a potential resource, which can be used to promote healthy, diverse diets, income-generation opportunities and low-input agricultural practices.
- Crop diversity is threatened by climate change, expansion of modern agriculture, insufficient exploration of crop collections, and gaps in the Chinese crop genetic resource management system.
- In response, China is taking several measures to reduce risks to its valuable crop diversity, which we outline here.

What risks does China face?

1.3 billion of the world's 7.7 billion people live in China. With so many people to feed, the country cultivates 120 million hectares of land (twice the size of Ukraine or Madagascar) and in 2016 produced 61.6 million tonnes of food. The population in China is estimated to reach 1.6 billion by 2030, when food demand will be 73.6 million tonnes (1). Current food production needs to increase by 1% every year to meet these food requirements.

For a long time, China attempted to increase crop productivity by increasing inputs and enlarging the area of cultivation. Doing so has inevitably overused natural resources and resulted in deterioration of the land and environment. For example, water used in agriculture accounted for over 60% of total water usage in the country, however, only about 50% was effectively used by crops, while another 50% was lost due to improper irrigating methods and poor diversion canals (2). China applied 59.9 million tonnes of chemical fertilizers in 2016 (3), which was more than 30% of all the fertilizers used worldwide (4). Green development with reduced inputs is becoming an urgent requirement in Chinese agriculture.

Currently, 30.6% of Chinese people over 18 years old are overweight (5, 6). The prevalence of hypertension is 25.2%, and that of diabetes 9.7%. All these rates are on the rise (7). Many of these problems are caused by lack of micronutrients critical for health. To address this growing problem, China issued a National Nutrition Plan in 2017, which proposes to vigorously promote nutritional agricultural products, especially organic, green and pollution-free food, as well as double-protein (soybean and milk) foods. It also promotes good health through diets, including traditional health-preserving foods (8), such as buckwheat and oats which can help improve body functions.

The Chinese government is making concerted efforts to eliminate poverty in the country. However, while the proportion of poor people has plummeted since the 1990s, there were still an estimated 43.4 million poor in 2016, mainly living in marginal rural areas inland and dependent on agriculture for a living (9). Farmers are now being helped to develop special high-quality agricultural products so that they can increase their incomes. The focus of farming production is shifting from increasing productivity to increasing effectiveness. The value chain linking farmers' production to processing and markets is key to adding more value to agricultural products so that they earn higher incomes.

What role can genetic diversity play in managing these risks?

High levels of genetic diversity in China are potential resources to manage the four risks of growing population, deteriorating environment, poor nutrition, and poverty, and turn them into opportunities:

- Nutrient-dense diverse species and varieties of crops are available which constitute an opportunity to contribute to healthy diets
- Income generation opportunities by using special local crops, varieties or even landscapes to produce organic or ecological products to meet market demand
- Resources for agroecological intensification by adapting a diversity of species, varieties or both to address climate change and increase yields
- Green development with low inputs by using landraces to produce organic or ecological products for sustainable agriculture.

Each of these opportunities requires access and availability of crop genetic diversity and knowledge – scientific and traditional – about them and how to use them.

Crop genetic resources in China

China is recognized as one of the centres of origin of many of the world's crops. Over 10,000 plant species have been used by Chinese people to support their livelihoods in their long history (10). Currently, 3,528 plant species are used in food and agriculture, including 1,356 cultivated species and 2,172 wild species of crops (Table 1) (11). Among these species, about 350 were domesticated in China (12). Grain crops, such as rice, wheat and maize, are the staple food crops in China. There are also numerous minor grain crops such as barley, buckwheat, millets, oat, sorghum and beans.

TABLE 1 – Number of species of cultivated and wild species used for food and agriculture in China

Categories	Cultivated species	Crop wild relatives	Total
Grain crops	103	311	414
Cash crops	98	454	552
Fruits	149	420	569
Vegetables	222	150	372
Forage and green manure	196	353	549
Others	588	484	1072
Total	**1,356**	**2,172**	**3,528**

Each species contains high levels of within-species diversity too. China conserves these precious genetic resources through a national system with two complementary realms: *in situ* and *ex situ*.

In situ conservation refers to conservation in a plant's natural habitat, be that the wild or a farmer's field, so that the plant continues to evolve. As a centre of diversity, China is home to many naturally occurring populations of relatives of important crops, which may contain traits useful in breeding programmes. Efforts have been made to set up protected sites for many of these (13). By the end of 2017, China had established 206 protected sites in 27 provinces, in which 69 species of crop wild relatives are being conserved.

For *ex situ* conservation (collecting samples of seeds and safeguarding them in offsite facilities, e.g. in a seedbank), China has conducted two large-scale collecting missions, the first in the 1950s and the second in the 1980s. A third national collecting mission is in progress at the moment. The seeds are stored in a network of national and local genebanks.

Through these collecting activities, a total of 481,000 samples of 350 crops have been collected and their basic 'passport' information (e.g. origin, species, source) documented (11, 14). About 85% of these are landraces (farmer-bred, ancient varieties).

It is possible that these crops contain useful characteristics to help China reduce the risks associated with a growing population, poor diets, environmental degradation and poverty. For example, naturally occurring resistance to pests and diseases or to conditions such as flooding, cold or salinity, can stabilize yields under difficult conditions and reduce the need for chemical inputs.

Over 62% of the crop samples conserved in China's genebanks have been evaluated for resistance to pests and diseases, 57% for nutrient content, and 43% for resistance to drought, wet, cold, salinity or a combination of these (15).

Collecting and evaluating crop genetic materials is not the end of the story. If these materials are going to realize their potential in addressing China's challenges, they need to be used. The main users in China are breeders, who screen samples to find potential parents of future varieties. Farmers and companies also use varieties directly in their fields, public organizations for education and research, and museums as specimens (16). Since 2001, over 245,900 samples have been multiplied and made available through genebanks. They have distributed 273,900 samples to users based in 5,504 units across China (15) and more than 40,000 samples of various crops have been provided to foreign users and international organizations (11).

Risks to crop genetic resources in China

Despite the potential of genetic diversity to help China to address the risks of poor diets, environmental degradation, growing population and rural poverty, this diversity itself is at risk for several reasons:

1. Crops are no longer performing well in their original environments because of climate change

Climate change has resulted in temperature rises, increased evaporation from the earth's surface, aggravated drought, changing environments and increasing damage by pests and diseases. The average annual surface air temperature in China has increased by 0.79°C in the last 100 years (17). Consequently, climate change has had serious impacts on crop production. For example, a severe frost in the southern area of the Yangtze River in 2008 seriously damaged local crop production, while a drought in the north of Hubei province in April–May 2011 delayed the time for rice transplanting and seeding for other crops, so that yields of these crops were dramatically reduced (18).

Climate changes in some areas are having a positive impact. For example, the northern limit for planting rice, wheat and maize has extended further north due to temperature increases. However, this still requires a change in genetic resource strategy. Early maturing varieties have been replaced by mid or late varieties, which are better adapted to the longer growing period (18).

Climate change may threaten *in situ* conservation of crop wild relatives through drought, floods and frosts. During a long drought in Yunnan over the last decade, many crop wild relative populations decreased dramatically (11). For example, there were many sites where wild species of rice (*Oryza* spp.) could be found in Yunnan Province. After a decade of drought, *Oryza rufipogon* sites were reduced from 26 sites to two, *O. officinalis* from 13 to two, and *O. meyeriana* reduced from 105 sites to 35 (19).

2. The rapid development of modern agriculture is causing loss of crop diversity managed by farmers on farm

In the last 30 years, modern agriculture has developed very fast in China. For major crops such as rice, wheat, maize and soybean, many farmer varieties were replaced by modern ones. The number of varieties used in production has decreased dramatically. With the change of planting patterns and land use, many farmer varieties have disappeared. Some of which had been cultivated for several hundred years no longer exist.

A survey in 79 counties of Hunan Province found that there were 1,366 farmer varieties of rice grown in 1956, which dwindled to 644 by 1981 and only 84 by 2014, accounting for a 90% loss (20) (Figure 1). In addition, hybrid maize is now grown at higher altitudes and latitudes taking over the area planted to farmer varieties and leading to a decrease of minor crops directly managed by farmers (21).

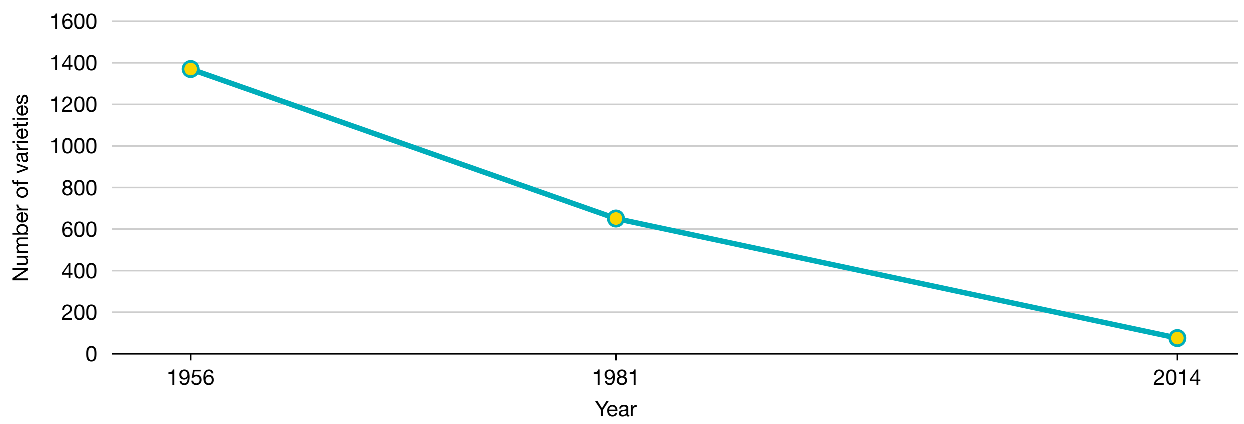
3. Insufficient exploration of the values of crop collections is leading to unrealized potential of crop genetic resources

As mentioned above, China has characterized and evaluated important agronomic traits of its genetic resource collection. Many elite resources have been identified and made available to breeders and other users (11). However, compared with the huge size of the collections, efforts to evaluate valuable traits have been insufficient, mainly because of a lack of coordination and funds (11). Another reason for underuse of crop genetic resources in collections is that multilocation evaluations are lacking, so we only know how they perform in a limited number of environments. In addition, breeding organizations and enterprises did not actively participate in the evaluation work, and so the putative values of crop germplasm for breeding and production have not been explored and demonstrated.

4. Gaps in China's crop genetic resource management system mean that crop collections are insecure

With the support of the Ministry of Agriculture and Rural Affairs, China has established a national system of crop genetic resource conservation and research, coordinated by the Chinese Academy of Agricultural Sciences (CAAS) with the participation of relevant provincial academies of agricultural sciences and universities. However, it lacks an effective mechanism for managing and coordinating the system. Although CAAS has strong technical functions in coordination and management, it has no direct administrative relations with many mid-term genebanks and field genebanks. Management is largely dependent on projects and lacks a long-term financial mechanism. Therefore, the management of these genebanks is constrained by local development plans. For example, in one case a field genebank had to be moved due to building a road for local development. These kinds of disruption can lead to the loss of genetic resources.

FIGURE 1 – Farmer rice varieties on farm in Hunan province have decreased dramatically since 1956



What is China doing to minimize risks to the conservation and use of crop genetic resources?

Recognizing the risks to crop genetic resources, China has been running comprehensive national programmes to improve the conservation and use of crop genetic resources. The programmes were mainly supported by the Ministry of Agriculture and the Ministry of Science and Technology and implemented by the Institute of Crop Sciences of CAAS with participation of organizations who hold mid-term genebanks and field genebanks and those maintaining local genebanks at different provinces.

Enhanced *in situ* conservation and on-farm management to improve the adaptability of crops and varieties no longer performing well in their original environments because of climate change

Strengthened in situ conservation and monitoring for crop wild relatives

Establishment of protected sites *in situ* has been strengthened for crops originating in China such as soybean, buckwheat and millets. At the same time, efforts have been made to link the conservation of crop wild relatives with sustainable use of these natural resources for livelihoods by reducing farmers' dependence on the habitat where crop wild relatives grow, and providing alternative pathways out of poverty, including financial support for developing livelihoods. One example is that human pressures on the environments of wild rice, wild soybean and wild relatives of wheat were reduced in eight provinces, through improved policy options, infrastructure, financial incentives and awareness raising for communities near the sites (13).

Strengthened on-farm management of farmers' ancient landraces

The Ministry of Agriculture has supported a national programme for screening farmer varieties of different crops to identify varieties with special traits for developing products. The National Chinese Pear Repository provided the traditional pear varieties, Golden pear and Cuiguan pear to farmers in Enshi in Hubei province, which greatly improved the income of farmers who adopted these local varieties. Development of value chains and business models, including organic, special and nutritional products, for Wuchang rice, Nanfeng orange, and Laiyang pear, succeeded by establishing geographical indication certification. This has made great contributions to farmers' incomes.

Enhanced exploration and collecting activities to safeguard crop diversity against the continuous loss resulting from modern agricultural practices

The Ministry of Agriculture has been strengthening nationwide comprehensive surveys and systematic collecting of crop genetic resources. The priority is to conduct the current third national survey and collection of crop germplasm resources with a focus on remote areas, mountainous areas and the western part of China. Since 2015, surveys and collecting have been completed in 12 provinces including 830 counties, from which some 31,000 samples of various crop species have been collected, including grain crops, vegetables, fruits and medicinal plants. 85% of these are farmer varieties with elite characteristics (14). For example, 4,800 accessions collected in Guizhou Province were evaluated and 150 accessions were found resistant to various diseases or to have stress resistance, superior quality, early maturing or high-yield potential, which will be valuable for breeding and other research and use (22).

Enhanced research into identification and use of elite planting materials to increase use

To demonstrate the value of crop genetic resources, China is strengthening research capacity for identification of crop genetic resources. For phenotypic characterization (i.e. assessing how different crop varieties perform under different conditions), major traits have been recorded for all the crop samples stored in the national genebank. Evaluation of resistance to pests and diseases as well as abiotic stresses such as drought, wet and cold were conducted on the collections of rice, wheat, maize, soybean, cotton, oilseed and vegetables. Through multilocation trials, more than 10,000 samples of these crops were evaluated to identify elite germplasm for the needs of breeding (14). Catalogues listing all the genetic information of these crops have been produced, and all data are now documented in a National Crop Germplasm Information System for ease of access (11,14).

For genotypic evaluation (i.e. the genetic profile of crop varieties), biotechnology has been used in genetic diversity analysis to understand the origins and evolutionary pathways of important crops and to identify useful traits for crop improvement (23). With various molecular markers, genetic diversity was analyzed for rice (24), wheat (25) and maize (26). Cloning has been successfully carried out of 237 genes associated with important agronomic traits of rice, wheat and maize, which provide a pathway for genetic improvement in these crops (11). Twelve thousand genes associated with various agronomic traits have been newly identified in rice by genotyping 3,000 rice samples (27).

Gaps filled in the national management system to deal with the insecurity of existing crop collections

To complete the national legal system and put forward recommended policies for management of crop genetic resources, China has revised its Seed Law, released 'Regulations on crop germplasm resources' by the Ministry of Agriculture, and published the 'National plan for conservation and sustainable use of crop genetic resources' (28), which are key national legislation and policies for management of crop genetic resources in China. Currently, discussions are underway for development of access and benefit-sharing polices, and for the possibility of joining the International Treaty of Plant Genetic Resources for Food and Agriculture (29).[i]

We have strengthened the national network for conservation and use of crop genetic resources involving the national long-term genebank, duplicate genebanks, mid-term genebanks, field genebanks and genebanks[ii] located in different provinces (14). Efforts are being made to establish a national centre for conservation and use of crop germplasm resources in a unified management system under the leadership of the Ministry of Agriculture and Rural Affairs.

The national information system for crop germplasm resources for digital and standard information sharing and management of genetic resources has been improved and upgraded. The system is composed of databases of germplasm catalogues, surveys and collecting missions, evaluation traits and images (14).

Conclusion

Addressing risks to crop genetic resources is crucial for their safe conservation and sustainable use, allowing them to continue to contribute to building resilient food and nutrition security and green development. China is rich in crop genetic resources in terms of species diversity and within-species diversity. China has made great efforts to strengthen research and management on acquisition, evaluation and use of crop genetic resources with strong support from local and national governments. Although crop genetic resources in China are at risk from several threats, including climate change, development of modern agriculture and incomplete management systems, there are opportunities for using them sustainably that the national plans for nutrition and health, green development and poverty elimination present in the country. To manage risks, efforts should be made to comprehensively collect and conserve germplasm throughout the country, deeply evaluate germplasm and actively use the valuable diversity in breeding new varieties and supporting livelihoods, and improve the national policy and management system. In this way genetic diversity will be well placed to contribute to reducing the risks that China faces of a growing population, poor nutrition, poverty and deteriorating agricultural lands.

Notes

[i] The International Treaty on Plant Genetic Resources for Food and Agriculture, adopted by the 31st Session of the Conference of the Food and Agriculture Organization of the UN on 3 November 2001, aims at:

- Recognizing the enormous contribution of farmers to the diversity of crops that feed the world
- Establishing a global system to provide farmers, plant breeders and scientists with access to plant genetic materials
- Ensuring that recipients share benefits they derive from the use of these genetic materials with the countries where they have been originated.

http://www.fao.org/plant-treaty/en/

[ii] China deploys a network of different kinds of genebanks with different functions:

Long-term genebank – Located in Beijing for conserving crop base collections for long-term under conditions of temperature -18ºC and relative humidity≤50%.

Duplicate genebank – Located in Qinghai for conserving duplicates of crop base collections for safety under conditions of temperature -18ºC and relative humidity≤50%.

Mid-term genebanks – Located in different institutes of CAAS for conserving crop active collections for distribution under conditions of -4ºC to +4ºC.

Field genebanks – Located in different organizations throughout the country for conserving living collections of vegetatively propagated and perennial species in the protected fields.

Provincial genebanks – Located in provincial academies of agricultural sciences for conserving local crop collections of different provinces.

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Farmer displays quinoa varieties at a diversity fair, Bolivia.
Farmers obtain seeds from diverse sources through different mechanisms. 60%-90% of the seeds on which smallholder farmers in low-income countries depend is saved on farm or obtained through local distribution channels.
Credit: Bioversity International/S. Padulosi

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