The Role of Biodiversity, Traditional Knowledge and Participatory Plant Breeding in Climate Change Adaptation in Karst Mountain Areas in SW China

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I. Introduction

This is a report of a country case study on the impacts of climate change and local people's adaptation. The research sites are located in the karst mountainous region in 3 SW China provinces - Guangxi, Guizhou and Yunnan – an area inhabited by 33 ethnic groups of small farmers and the poor, with rich Plant Genetic Resources (PGR) and culture. Climate change is exacerbating already harsh natural conditions and impacting on biodiversity of remote farmers living in extreme poverty, with very limited arable land. Genetic diversity has also suffered from the adoption of high yielding hybrids. Yet traditional varieties, related TK and Participatory Plant Breeding (PPB) for maize and rice are showing real potential for resilience and adaptation.

Participatory Plant Breeding (PPB) action research has been carried out for the past 10 years in the 3 SW provinces by local farmer groups (women and men) and breeding institutions, coordinated by the Center for Chinese Agricultural Policy (CCAP). PPB methodology was adapted to the local context by facilitating close collaboration among researchers and farmers, and other potential stakeholders, to bring about genetic improvements using related TK and farmers' selection experiences. Collaboration occurs throughout the whole research and development cycle. Trials at the research station and in villages include landraces, open-pollinated varieties, so-called waxy maize varieties, and varieties introduced by CIMMYT 30 years ago. These varieties have been locally improved and adapted through cross-breeding and selection by farmers and breeders jointly, building on local women farmers' maize breeding experience and expertise developed over many years.

This report is based on a systematic study of climate change impacts and adaptation including a survey and semi-structured interviews in PPB project villages and non-project villages in SW China. The data and information of this report are from three major sources. The first is a survey carried out in the three southwest provinces i.e. Yunnan, Guangxi and Guizhou, during 2009 and 2010. The survey[1] included 54 villages and 162 households from 6 counties of the 3 SW provinces. The second source is semi-structured interviews carried out in 6 PPB villages and 6 non-PPB

[1] The survey used systematic sampling for household and village selection, i.e. according to their income level (high, middle and low) we stratified them into three groups and picked one from each at random.

villages in Guangxi province in 2010. The third one is mainly qualitative results and findings from our PPB action research process. The main study contents are: 1) the changes and impacts in 10 years (1998 to 2008), 2) local adaptation tools and practices (TK, biodiversity, Participatory Plant Breeding, community group's collective actions etc), 3) results of adaptation, by comparing PPB project villages and non-ones, i.e. TK and local varieties with modern technologies and varieties, 4) taking gender as a cross cutting aspect integrated in the above 3 items given the popular phenomena of feminization of agriculture and aging agriculture in China.

II. Socio-economic and Climatic Changes and Impacts

We found that climate change and socio-economic change are interlinked and mutually affected complex processes. Given the rapid socio-economic changes in China in the last 30 years, we have to understand the socio-economic and farmers' livelihood changes first to better understand climate change and its impacts in the local context and from the farmers' perspectives.

2.1. Socio-economic change and Impact:

Migration and on-farm labor:

Out migration is the biggest change in rural China after China's opening to the market economy and its rural reform in the early 80s. In the SW China study areas, migration in general has increased from 18% of the population in 1998, to 25% in 2003 and to 31% in 2008 (table 1). At the household (HH) level, in general, 64% of the respondent HHs have migrating family members, 54% have permanent migrants, 18% have seasonal migrants, and 8% have both these migrants (table 2). Taking each province in turn, 76% of the respondent HH of Guangxi has migrant(s), in Guizhou and Yunnan, it is 65% and 52% (table 3). The difference among provinces is because farmers in Guangxi and Guizhou face land shortage more seriously than those in Yunnan, and need to find more job opportunities and income sources from off-farm work. For a long period, migration was seen as one of the effective national strategies for transferring leftover rural labor and increasing farmers' income in SW China. However recent research starts to question and reflect on this strategy, as it has caused a series of social problems.

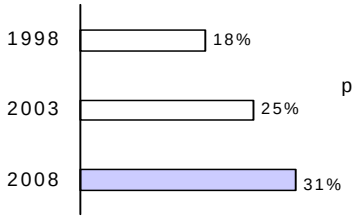


Table 1 Percentage change of out-farm labors (unit: %)

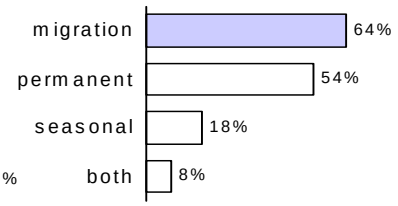


Table 2 Types of migration of three provinces (Unit %)

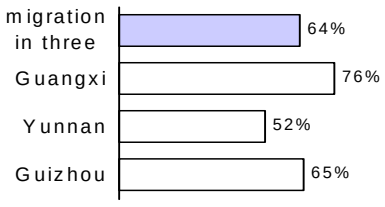


Table 3 Total Migration in 3 P (Unit %)

When facing such a large percentage of migration, we are curious to know who is left behind and working on farm in SW rural China. What is their age distribution, education experience and on-farm labor input? The data shows that, 65% of farmers are aged 26-55, and 28% are over 55 (table 4). 66% of farmers work 10-12 month per year and 13% work 7-9 months. These are staying and full time farmers with intensive farming activities. 21% work less than 6 month per year and are considered seasonal migrants and part time farmers (table 5).

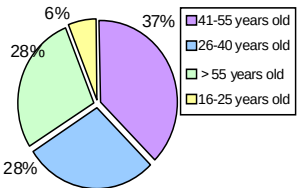


Table 4: Age distribution on-farm Farmers

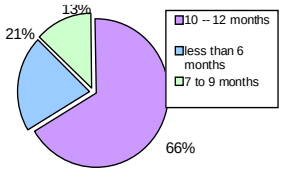


Table 5. Annual farming time of on-farm farmers (unit: month)

From the gender aspect, the following table 6 shows that over the last 12 years migrants have doubled, yet women's migration is less in number and slower in speed compared to men. This is a typical situation representing all the 3 SW provinces.

Table 6: Migration Situation in 6 Villages in NW Yunnan, 1995-2007

Items:	Total migrants	Permanent Migrants	Seasonal migrants	Permanent women migrants	Seasonal women migrants
year	person	Person	person	Person	Person
1995	34	12	22	5	7
2000	47	15	32	6	10
2007	68	25	43	9	18

This research result indicates that, the old people and women are staying farmers and the main farming labor forces in villages; they are playing predominant roles in sustainable farming and bio-cultural system maintenance and management.

Income and income structure:

In the research region, the average income per capita is 1140, 1472 and 2105 RMB in 1998, 2003 and 2008 respectively (table 7). Comparing with the national average income per capita we can find that, the income level in the three SW provinces is far below the national average income, in many cases it is even less than 50% of the national average. More severe is that compared with the national average the income gap has increased and some equity issues came out.

Table 7 Average income per capital from survey and national statistics (unit: RMB[1])

year	average	Guangxi	Yunnan	Guizhou	National
1998	1140	1707	829	869	2162
2003	1472	2111	1004	1290	2622
2008	2105	2623	1902	1792	4761

The income structure of households has also changed (table 8). From 1998 to 2008, the contribution from crops is still dominant but in decline, accompanied by the obvious increasing contribution from migration. The income contribution from livestock keeps stable.

Table 8 Household income structure and its change

From table 8, it is easy to recognize that, there are two tendencies in income structural change, 1) on-farm activities play a less important role than before, compared with off-farm work; and 2) within agricultural systems, crops, especially food crops cannot satisfy farmers' on-farm needs, and they transfer their interest to cash crops and livestock.

Farming structure and varietal change

From variety adoption of three main traditional crops (table 9) – maize, rice and soybean, we can find that 1) varieties of both maize and rice, as staple food crops, have been highly commercialized with a large area of hybrids; 2) the cultivating areas of landraces of maize and rice have rapidly decreased, the reduction in maize is even more serious than rice; 3) soybean landraces, as traditional intercropping and supplementary crops, have been well conserved and adopted, staying dominant and stable in SW region. This is also because soybean is not a staple food crop (like rice, maize and wheat) and is not the target of hybrid breeding and extension by both public and private sectors. Yet, in the last few years soybean hybrid breeding has drawn increasing efforts from government and companies.

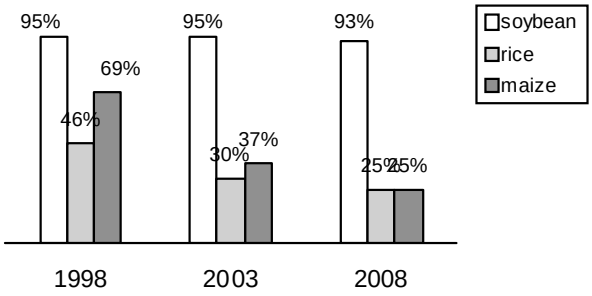


Table 9: Percentage change of landraces planting area

2.2. Farmers' perspective on climate change and impact

It is difficult to measure climate change and its impacts directly from household and village levels. What we can do is collect farmers' opinions and attitudes on climate change and its impacts on local livelihood systems. Such information was generated and collected from key informant interview and group discussion. The aim is to obtain a common sense on these issues.

Table 10 shows a scale for measuring changes in drought, rainfall, temperature, wind force, sunshine, runoff and newly emerged pests and diseases. It is an explorative diagnosis, however subject to farmers' understanding, opinions and attitudes. The information collected can hardly be precise, but to some extent the group discussion can balance the errors caused by individual differences. For each aspect, there is a peak which can represent the similar situations among villages. It is noticeable that: 1) 70% of the respondent villages face the drought problem, 2) 77% feel lack of rainfall, 3) 87% realize that the temperature has increased, 4) 62% feels stronger wind force (need more anti-dislodging varieties), 5) 56% of the villages feels stronger sunshine, 6) 72% have more runoff, and 7) in 64% of the villages, new pests and diseases have emerged[2].

Table 10: Farmers' attitudes towards effects of climatic change

attitude / indicators	-2 (much less /lower)	-1 (less/lower)	0 (normal)	+1 (more/higher)	+2 (much more /higher)
Drought		2%	28%	70%	
Rainfall	4%	77%	17%	2%	
Temperature			13%	87%	
Wind force		4%	34%	62%	
Sunshine		8%	37%	56%	
Runoff	13%	8%	8%	72%	
New pests/disease			27%	64%	9%

From this picture, we realize that, local impacts from climate change are severely represented and most farmers felt the effects of increasing temperature, drought and less rainfall. As a result there were more new pests/diseases and more runoff given the features of the Karst mountainous area. Our research also revealed that there is more extreme weather in this areas than before, like big droughts, big floods, colder winters etc. Farmers there, mainly women and old people, are relying on their TK and genetic resources in their bio-cultural system and at the same time, collaborating with public institutions and scientists for adaptation and resilience as described in the next

[2] Scientists have paid great attention to those new diseases such as BLSB, grey spot, rust, ear rot and MRDV, reported by scientists from the Chinese Academy of Agricultural Sciences.

section.

III. Local Adaptation Practices and Tools

3.1.Landrace conservation and management

Landrace conservation and biodiversity management is the basis for the adaptation and resilience. From the survey, we know that there are still 53% respondent HH that use landraces. The reasons for conserving landraces have focused on good taste, better adaptation, easy and cheap access and drought resistance (table 11). For those who insist that landraces cannot be replaced by hybrids, this is based on their varietal features, economic benefit and cultural values (table 12).

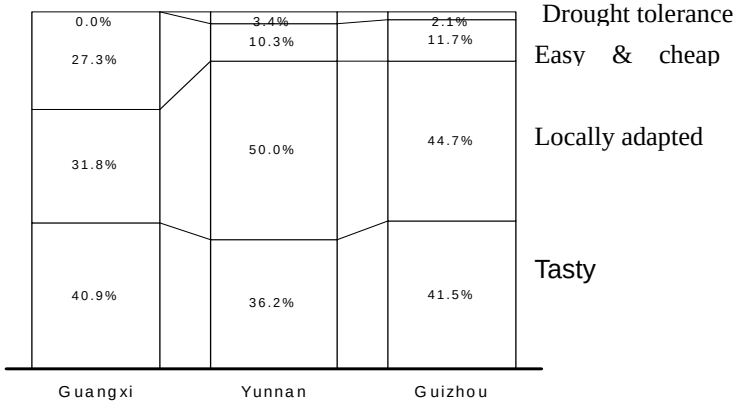
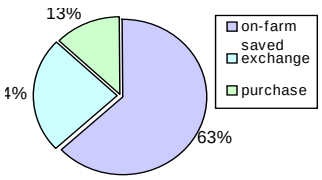


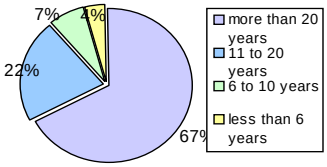
Table 11. Reasons for conserving landraces and reasons why they cannot be replaced by hybrids

Table 12. Reasons for conserving landraces and reasons why they cannot be replaced by hybrids

Reasons for conserving landraces	Landraces cannot be replaced, because –
-taste good	*Features of varieties*
-easy and cheap access	-suitable for local climate
-adopt to mountainous and barren land	-suitable for uplands and barren fields
-tolerant to drought	-stable performance
- dislodging resistance	*Cost and benefits*
	-the old and poor cannot afford hybrids
	-saving cost on hybrid
	-can save seeds of landrace on farm
	- *Preferences and customs in the locality*
	-taste good
	-emotional reliance
	-to match different land
	-cultivating diverse varieties can help reduce risks

There are three channels for farmers to access local landrace seeds – purchase, exchange and on-farm saved (table 13). Most of the landraces come from farmers' own on-farm saved seeds. However, the local landrace seed market also plays an important role. To a great extent, those landrace seeds are saved by women and the old (table15), and most of them are experienced in seed saving and selection, with several years' experience (table14).





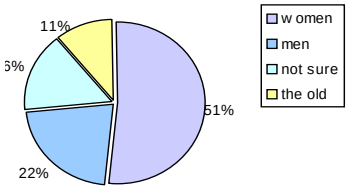


Table 13 Sources of landraces **Table 14 Experience in saving seed** **Table15 Labor division for saving seeds in HH**

3.2. Pioneering PPB Action Research:

When such climate changes happen, farmers require well adapted characteristics of crops and varieties, such as drought resistance, anti-dislodging, and new pests and diseases resistance. For generations farmers have done seed selection for preferred and adaptive characteristics and some innovative farmers even try to cross some lines for crop improvement. PPB is based on this TK, local experience and genetic resources to encourage joint breeding and selection between scientists and farmers, for better achieving these locally preferred and adapted characteristics.

The PPB initiative started in early 2000 in SW provinces. The main aim of the PPB initiative is to establish cooperative and complementary relations between the formal seed system and farmers' seed systems. Cooperation is necessary to provide opportunities for the empowerment of farmers, mainly women farmers, as most men have migrated to the cities. The farmers become active partners in plant breeding, on-farm biodiversity management and seed marketing (Ashby 2009, Song and Vernooy 2010b).

The PPB method is adapted to the local context. The work of the entire team, including the farmers, builds on local women farmers' maize breeding experience and expertise developed over many years (Song 1998). At the same time, the team involves and seeks knowledge and expertise from formally trained plant breeders. Crop improvements are made through a number of crossing techniques and various variety selection processes, which involve de-tasseling[3], mass selection and line selection by farmers with support from breeders. The work has covered a range of parallel activities over a number of years using various methods to identify parental materials (through participatory variety selection), improve populations (involving local and formal-system genetic materials) and select further to obtain individual varieties. Trials in six villages and at GMRI (Guangxi Maize Research Institute) include both PPB and participatory variety selection. These trials are evaluated by

[3] Removal of pollen producing flowers of one variety to cross-breed or hybridise it with another variety

both breeders and farmers after each cycle and, subsequently, new designs are discussed and agreed jointly. The trials allow for comparisons in terms of locality, approach, objectives and the types of varieties tested (Song 2003, Song and Jiggins 2003, Song, Zhang S. et al. 2006, Song et al. 2010).

As a result of a series of discussions among farmers and formal plant breeders, jointly and separately, the field experiments have targeted four types of OPVs (open pollinated varieties) and landraces: 'exotic' populations (from abroad), farmers' 'creolized' varieties (developed by breeders but further adapted by farmers, sometimes by crossing them with landraces), farmer-maintained landraces and formally conserved landraces. So far, more than 200 varieties have been used in trials at the GMRI station and in the villages. Based on 10 years of experimentation, 6 farmer-preferred PPB varieties have been selected and released in the research villages. They have also spread beyond these villages. In addition, five varieties from the International Maize and Wheat Improvement Center that were showing increasingly poor results have been adapted locally. Another five landraces from the trial villages have been improved thanks to the joint efforts of farmers and formal breeders. Agronomic traits, yields and palatability of all these varieties are satisfactory and they are better adapted to the local environment (CCAP 2004, Song, Zhang S. et al. 2006).

IV. Results of PPB and adaptation

4.1. PPB results at village level:

A PPB assessment was conducted in PPB project villages in comparison with neighboring non-project villages with similar situations in 2009 and 2010. The results show that:

- The project villages' income has increased about 30% more than those in non-project villages in the last 10 years. This was received by the farmers as a result of the project supported activities like productivity increase, value adding to locally specific products, women's seed production etc.

- The project has enhanced natural resources in terms of crop and animal diversity, forest and herbal medicines, and enhanced the related TK and culture system. For example, the number of maize and rice varieties used in the project villages are all more than these in non-project villages. The PPB villages have more cultural and collective activities.

- The average labor age in project villages is 44, yet that in the non-project

villages is 50 years old. The project activities have actually attracted some young people to work in their villages.

- Farmers in project villages are more confident and organized with better linkages to external world and market. For instance a women's group in project villages has organized themselves for contract organic vegetable production and marketing with an organic restaurant. This group activity has doubled their vegetable income and also expanded their network to city consumers for value adding to other local products.

- Comparatively women in project villages are in a better situation than those in non-project villages in terms of participation in decision making at both household and community levels. For example, a few women have been selected as village leaders in the project villages. One of them even became one of the 10 model provincial citizens in Guangxi in 2008.

4.2. Local Adaptation Cases

Farmers' Seed Fairs

As one of the PPB activities, the first Farmer Seed Fair was organized at the beginning of 2003 in Guangxi, and it is a new innovative way in China and a good start to encourage and enable women farmers and further strengthen, formalize and legalize the existing local process of farmers' seed exchange for adaptation. The farmers, especially women like such seed fair very much and very proud to share their seed and knowledge with each other to meet their newly emerged needs due to economic and climate changes. They organize, with assistance from the project, farmer seed fairs every year and gradually integrated more local culture and knowledge into it for local seed exchange and adaptation. So far such farmer seed fairs have expanded to more mountainous villages in neighboring provinces in every post-harvest season in SW China.

Community based seed production by women's group

Small scale and community based seed production has been conducted by a group of women farmers in Shanggula village since 2006. Normally women's groups select quality local varieties and PPB varieties for local needs in adaptation to climate and market changes. Seed production training for the groups was carried out in the field by experienced women farmer breeders, local extensionists and formal breeders. The farmer produced seed have been shared and exchanged among farmers within and between villages through farmers' exchange seed system. So far, a few farmer improved open pollen varieties (OPVs) and a waxy PPB hybrid variety have been produced and shared within and between PPB villages. The OPV are selected and preferred by farmers because of their specific traits like drought resistance, anti-dislodging etc., and more importantly, farmers can save seed themselves. The

hybrid, Gunou 2006, has very good market value, in both its seed and fresh cob, and became an important income generating item for the women's groups.

Farmer Improved landraces and OPVs survived the big spring drought
Evidence from the field in Guangxi has shown that most farmer improved landraces and OPVs survived the big spring drought in SW China in 2010, while most of the hybrids were lost. The PPB villages which have more landraces and OPVs had survived and adapted to the big drought. Yet other villages, which had grown only hybrids, lost all their production due to shortage of hybrid seed in market. This event has proved the importance of farmers' seed system for adaptation and resilience.

V. Main Findings and Suggestions

5.1. Key Findings:

a) The biodiversity and related local TK and cultures are being lost rapidly due to both climate change and economic change which have negative impact on local people's livelihood and food security.

b) In confronting these changes, landraces, TK, local seed systems and PPB are playing crucial roles in adaptation and resilience, as seen from the local adaptation cases.

c) Women and old people are the key players and managers of biodiversity and local seed systems because of their traditional roles as seed selectors and keepers and the increasing male and youth out-migration in the last few decades with China's opening to the market economy and urbanization.

d) PPB and related TK and GR conservation has increased incomes by 30% more than non-project villages in the last 10 years.

5.2. Discussion and Suggestions

- In SW China, resource-poor farmers have their intensive management strategies for cropping and farming. Among those farmers, women and the old play an important role in landrace conservation and PGR management and their knowledge and experience have sustained the local PGR system for a long time.

We should support their improved access to public services and encourage exchange of their traditional knowledge and experiences with younger generations.

- Farmers' livelihood strategy in SW China has been altered from on-farm food production to off-farm work in the last 10 years, and this has led to a dramatic reduction in germplasm resources in SW China. Evidence from our field studies show that the biggest reason for the loss of landraces and agricultural GR is the extension of "modern" varieties, mainly hybrids so far. As a common good, agricultural germplasm resources should be enhanced by both government, public research institute and farmers. However, there is a lack of incentives and responsibilities amongst all these key stakeholders. There is an urgent need for policies and regulations to create incentives and encourage responsibilities for PGR management.

- Climate change has shown its negative effects in local communities, and farmers need support to enhance their resilience capacity and strategy to cope with these changes. While under the pressures of climate change, risks from hybrids and degeneration of landraces and local seed systems, farmers need better adapted varieties and local TK and seed systems. This requires changes in breeding, testing & release systems (such as DUS – Distinctness, Uniformity and Stability criteria) for 'modern' agriculture, because these standards lead to an increasingly narrow genetic base, less biodiversity and limited options for both breeders and farmers. The challenges of breeding in a climate-changing world may require the widest possible circulation and sharing of germplasm to ensure effective, timely and adaptive breeding with farmers as a key partner.

- As the seed market has not yet been well-regulated in China, it is necessary for public agricultural service systems to provide access facilitation and regulation for farmers. However, agricultural service system (previous called extension system) in SW China has been proved dysfunctional in public service provision. It needs to be strengthened, especially on (severe) weather broadcasting and pre-caution, varietal information provision and market monitoring, etc.

- The transformation of public breeding institutes from current mixed commercial and public roles to pure public functions, allows fairer market competition and brings more opportunities and resources (both technical and human resources) for seed enterprises. Having a clearly defined public role will also benefit fundamental research on issues such as meeting diversified varietal needs of farmers and other clients, conserving agro-biodiversity and broadening the genetic base in breeding. Currently, the public role played by these institutes is vague and weak. (Song,Y and Vernooy, R, 2010[4])

- In hybrid breeding, the narrowed genetic base should find resilience from local

[4] Seeds and Synergies. Innovating Rural Development in China. Yiching Song and Ronnie Vernnoy (Eds). 2010

germplasm, targeting quality improvement, drought tolerance, low nitrogen tolerance and tolerance to newly emerged pests and diseases. On the other hand, climate change also raises new challenges for breeding. Is it possible to better combine G by E (Genotype x Environment) interactions into breeding strategies?

- Another challenge is the negative impact of the big international seed companies, like DuPont, Pionire, Monsanto etc, and related IPRs. Their strategies are joint ventures with domestic companies, passing the national DUS and applying for IPRs. One hybrid maize, Zhenda 619, has wiped out half of the remaining maize landraces in Guangxi province since 2002 (CCAP report to IDRC, 2008). Another hybrid, Xianyu 335, by a joint venture (Pionire and Denhai) has become the second biggest maize seed in terms of growing area covered in China, in 2010. Issues and risks on seed safety, genetic narrowing, resilience and adaptation to change have caused increasing concerns and discussions.

In general our research in China's South-west mountainous areas confirms that farmers are key players in biodiversity conservation and climate change adaptation and that farmer-researcher collaboration can produce added value that farmers or researchers alone could never realize. Local TK, culture and seed systems are a crucial basis for adaptation to both economic problems and climate changes. Yet this basis is threatened and disappearing, and more recognition and support are needed. We need an integration of both farmers' and scientists' knowledge and seed systems and actors from different levels from the two systems to address this concern.