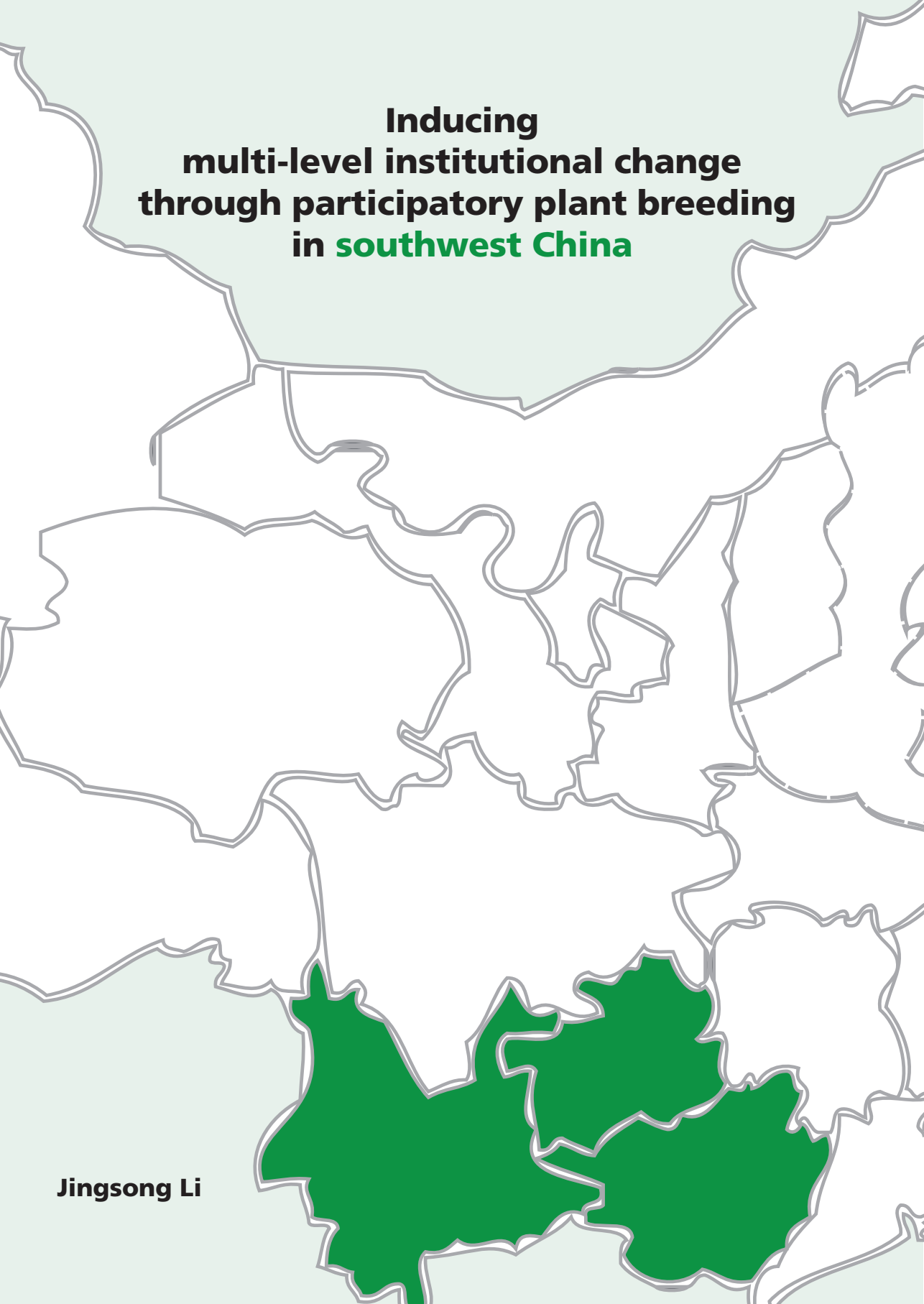
Inducing multi-level institutional change through participatory plant breeding in southwest China



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Inducing multi-level institutional change through participatory plant breeding in southwest China

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Jingsong Li

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Abstract

This study is about understanding and inducing multi-level institutional change through participatory plant breeding (PPB) with maize (*Zea mays* L.) in southwest China. The PPB programme deals with smallholder farmers who need improved and locally adapted varieties in their farming system. The objectives of this study are to investigate (i) the incentives and options for strengthening the relation between communities' and farmers' plant genetic resources (PGRs) management, conservation and plant breeding in Guangxi, and (ii) the institutional options at different levels for formalising and rewarding PGR management and conservation by farmers and communities. This research explores farmers' adoption of maize hybrids and the persistence of landraces, examines the opportunities for change within existing seed systems and addresses the public value of plant genetic resources. Although hybrids have been promoted and pushed rather heavily by the state and private organizations, there is a range of functional preferences that maintain landraces and farmers' varieties, related to food culture, land quality and economic infrastructure. In southwest China there is thus still considerable need and scope for improving the quality and adaptability of landraces, farmers' varieties and locally adopted hybrids. The PPB programme is an important and effective strategy for on-farm crop improvement, and has generated a series of successful technical outputs; but it also has amplified the tensions within current seed-related institutional provisions in China, from local to international levels. To solve the PPB-related institutional challenges, action research on institutional innovation was conducted, in order to develop access and benefit sharing mechanisms in the context of the PPB programme. Action research, positioned as the vehicle for multi-actor learning that mediates the tensions that arise from multi-level change processes, in this case resulted in strategic shifts that evolved as shared learning accumulated among niche- and regime-level actors. The research ends by examining the public value of plant genetic resources in relation to participatory plant breeding, as well as a range of options for balancing public and private interests in the conservation of agro-biodiversity and in bringing to market the products of PPB and farmers' varieties. The creation of public value is shown to require the integration of innovations in the value chain that recognize the joint efforts of producers, consumers, market actors and the public sector. The main findings presented in this study relate to: i. the identification of the reasons why farmers choose to retain some farmers' varieties and landraces in production; ii. the identification of the technical opportunities and challenges in participatory hybrid breeding, in addition to developing open-pollinated varieties; iii. insights into the functioning of the seed regime in China, the challenges that PPB offers to the existing regime, and the options for opening up the regime to the potential that PPB creates; iv. demonstration of the contribution of action researching to the development of a multi-scale and multi-actor mechanism for access and benefit sharing, that is suited to the Chinese context; and v. how the public value of plant genetic resources, PPB and farmers' varieties could be supported, and of which the options analysed might be best suited to China's needs and opportunities.

Keywords

Participatory plant breeding;

seed systems;

public value;

action research;

plant genetic resources;

institutional innovation;

China

Table of content

ACKNOWLEDGMENTS ..... **I**
ABSTRACT ..... **III**
KEYWORDS ..... **IV**
FIGURES ..... **X**
TABLES ..... **XI**
ABBREVIATIONS ..... **XIII**

CHAPTER1
INTRODUCTION **1**

1.1. INTRODUCTION 2
1.2. BACKGROUND 3
1.2.1 Maize in China 3
1.2.2 Cultivar improvement in southwest China 4
1.3. PROBLEM STATEMENT 5
1.3.1 Challenges for PPB in China 5
1.3.2 International problem context 6
1.4. RESEARCH OBJECTIVES, MAIN RESEARCH QUESTIONS 7
1.5. ANALYTIC CONCEPTS 9
1.5.1 Action researching and the multi-level perspective 11
1.5.2 Creating public value from farmers' plant genetic resources through participatory plant breeding 11
1.6. METHODOLOGY 12
1.7. OVERVIEW OF THE THESIS 14

CHAPTER 2
FARMERS' ADOPTION OF MAIZE (*Zea mays* L.) HYBRIDS AND THE PERSISTENCE OF LANDRACES IN SOUTHWEST CHINA: IMPLICATIONS FOR POLICY AND BREEDING **17**

2.1. INTRODUCTION 19
2.2. MATERIALS AND METHODS 22
2.2.1 Design and methods 22
2.2.2 Data analysis 22
2.3. RESULTS 23
2.3.1 Change in seed policy 23
2.3.2 Changes in proportion of hybrids and landraces 23
2.3.3 Change in hybrid cultivars and landraces 26
2.3.4 Farmers' reasons for choosing hybrids or landraces 26
2.3.5 Discussion 31
2.4. CONCLUSIONS 35

CHAPTER 3
THE POTENTIAL OF PARTICIPATORY HYBRID BREEDING..... 41

3.1. INTRODUCTION..... 43
3.1.1 Participatory plant breeding..... 44
3.1.2 Current limitations of participatory approaches..... 44
3.2. A CONCEPTUAL MODEL FOR PARTICIPATORY HYBRID BREEDING..... 45
3.2.1 Improved adaptation..... 45
3.2.2 Genetic diversity..... 46
3.2.3 Farmers' involvement in the stages of breeding..... 46
3.2.4 Seed production integrated into farmers' seed system 48
3.2.5 Intellectual property rights and access and benefit sharing issues..... 49
3.3. CASE OF PARTICIPATORY MAIZE (*Zea Mays* L.) BREEDING IN GUANGXI, SOUTHWEST CHINA..... 50
3.3.1 Background..... 50
3.3.2 Participatory hybrid improvement: the Guangxi PPB model..... 51
3.3.3 Participatory breeding of open-pollinated varieties 57
3.3.4 Intellectual property rights and access and benefit sharing issues..... 58
3.4. DISCUSSION AND CONCLUSIONS..... 60

CHAPTER 4
TOWARDS A REGIME CHANGE IN THE ORGANIZATION OF THE SEED SUPPLY SYSTEM IN CHINA..... 65

4.1. INTRODUCTION..... 67
4.2. METHODS..... 69
4.3. FINDINGS..... 69
4.3.1 Landscape-level trends..... 70
4.3.2 Regime-level change..... 72
4.3.3 Niche-level responses..... 75
4.3.4 Emergent tensions between levels..... 78
4.4. DISCUSSION AND CONCLUSIONS..... 81
4.4.1 Emerging opportunities at regime level..... 81
4.4.2 Potential for evolution at the landscape level..... 84
4.5. OUTLOOK..... 85

CHAPTER 5
CONTRIBUTION OF ACTION RESEARCHING TO INSTITUTIONAL INNOVATION: A CASE STUDY OF ACCESS AND BENEFIT SHARING (ABS) MECHANISMS IN PARTICIPATORY PLANT BREEDING (PPB) IN SOUTHWEST CHINA..... 87

5.1. INTRODUCTION..... 89
5.2. CONCEPTUAL FRAMEWORK..... 91
5.2.1 A multi-level perspective on system innovation..... 91
5.2.2 Action research..... 92
5.3. METHODOLOGY..... 92
5.3.1 Data generation..... 92
5.3.2 Data analysis..... 94
5.4. CRITICAL EVENTS DRIVING THE ARTICULATION BETWEEN LEVELS.... 94
5.4.1 Episode 1: Formal breeders realize farmers' expertise in seed selection and breeding and accept farmers as valuable partners..... 94
5.4.2 Episode 2: Whose varieties are they? Challenges encountered in registration of PPB varieties..... 95
5.4.3 Episode 3: Reaching an agreement on sharing benefits at community level..... 96
5.4.4 Episode 4: Recognizing the potential value of landraces for formal breeding..... 97
5.4.5 Episode 5: Recognizing the tensions between local ABS practice and regulatory frameworks..... 98
5.4.6 Episode 6: Overcoming problems in mainstreaming PPB – creating incentives for breeders..... 99
5.4.7 Episode 7: Developing ambitions to create incentives for farmers in relation to agro-biodiversity enhancement..... 99
5.4.8 Episode 8: Making an ABS agreement among PPB stakeholders..... 100
5.5. ANALYSIS AND DISCUSSION..... 102
5.5.1 Niche-Regime interactions foster institutional innovation..... 102
5.5.2 Action Research and 'adaptive co-management'..... 104
5.5.3 Networked (regime) actors in action research..... 105
5.5.4 Institutional change in relation to ABS..... 106
5.6. CONCLUSIONS..... 107

CHAPTER 6
EXPRESSING THE PUBLIC VALUE OF PLANT GENETIC RESOURCES BY ORGANISING NOVEL RELATIONSHIPS: THE CONTRIBUTION OF SELECTED PARTICIPATORY PLANT BREEDING AND MARKET-BASED ARRANGEMENTS..... 109

6.1. INTRODUCTION..... 111
6.2. THE CONCEPT OF VALUE..... 113
6.2.1 Public interest and public value..... 114
6.2.2 Determining preferences..... 114
6.2.3 Framing questions..... 115
6.3. METHODOLOGY..... 116
6.3.1 Approach..... 116
6.3.2 Data generation and analysis..... 117
6.4. MAIN FINDINGS..... 117
6.4.1 Securing direct, indirect and options values through contrasting PPB-led arrangements..... 117
6.4.2 PGRs conservation in farmers' fields: options related to novel marketing and trading arrangements..... 122
6.5. ANALYSIS AND DISCUSSION..... 128
6.5.1 The importance of public values..... 128
6.5.2 Legitimacy and support..... 129
6.5.3 Balancing interests and benefits..... 130
6.5.4 Innovations in breeding..... 131
6.5.5 The development of a combination of property rights regimes..... 131
6.5.6 Networked governance..... 134
6.6. CONCLUSION..... 135

CHAPTER 7
DISCUSSION AND CONCLUSION..... 137

7.1. INTRODUCTION..... 138
7.2. OVERVIEW OF MAIN FINDINGS..... 138
7.3. DISCUSSION AND CONCLUSIONS..... 140
7.3.1 From an unbalanced to an integrated and harmonised breeding research, conservation and seed supply system..... 140
7.3.2 Institutional innovation in breeding and seed supply in China..... 143
7.3.3 Policy options for pursuing China's ambitions to modernise crop development whilst conserving plant genetic resources and improving smallholder farmers' livelihoods..... 144
7.3.4 Challenges, difficulties, and opportunities revealed by the study..... 146
7.3.5 Discussion of methodological issues encountered in this study..... 148
7.4. OUTLOOK..... 151

REFERENCES..... 153

SUMMARY..... 173

ABOUT THE AUTHOR..... 185

EDUCATION CERTIFICATE..... 189

FUNDING..... 190

Figures

Figure1.1. Mainland of China, showing the two main maize production areas in China, including the three provinces of the research project, Guangxi, Yunnan and Guizhou in the mountain areas of southwest China..... 2

Figure 1.2. The multi-level perspective (MLP) model..... 10

Figure 1.3. Interrelationship of the chapters..... 16

Figure 2.1. 'Reasons for action' model..... 20

Figure 2.2. Typology of maize hybrid and landrace distribution in farmers' field, according to the percentage of households and the percentage of production areas..... 21

Figure 2.3. The pathway of change in maize landraces in farmers' fields, from 1998 to 2008..... 33

Figure 3.1. Creating open-pollinated and hybrid maize varieties through participatory plant breeding in the Guangxi model..... 52

Figure 3.2. Participatory breeding scheme for the development of the hybrid Guinuo 2006..... 54

Figure 3.3. (a) Participatory breeding scheme for three open pollinated maize varieties Xin Mo 1, Zhong Mo 1 and Zhong Mo 2, produced in Guangxi, southwest China, from 2000 to 2007 59

Figure 3.3. (b) Participatory breeding scheme for the 4th open pollinated maize variety Guisuzong, produced in Guangxi, southwest China, from 2004 through 2009..... 59

Figure 4.1. The waves of application and approval of plant breeders' rights in China, from 1999 to 2009..... 73

Figure 7.1. (a) The inter-linkage of public and commercial research and seed systems in pursuit of competition..... 142

Figure 7.1. (b) The inter-linkage of public, commercial and farmers' seed systems in pursuit of complementarity..... 142

Tables

Table 2.1. Changes in percentage of household growing maize hybrids and landraces in Guangxi, Yunnan and Guizhou from 1998 to 2008... 24

Table 2.2. Changes in percentage of land cultivated with maize hybrids and landraces in Guangxi, Yunnan and Guizhou from 1998 to 2008.... 25

Table 2.3. Farmers' reasons for cultivating hybrids and landraces in relation to the biophysical dimension..... 28

Table 2.4. Farmers' reasons for cultivating hybrids and landraces in relation to the economic dimension..... 29

Table 2.5. Farmer-perceived abilities and inabilities in adopting hybrids and landraces..... 30

Table 2.6. Farmer-perceived social pressures in terms of incentives and disincentives for growing hybrids and landraces..... 31

Table 3.1. Potential and technically feasible roles of farmers and breeders in a participatory maize breeding programme, comparing population and hybrid breeding process..... 47

Table 3.2. Overview of on-farm testing for adaptation of potential F1 varieties (including 'Guinuo 2006'), showing the number of households and the average plot size per household in the involved trial villages, Guangxi province, 2000-2003..... 55

Table 3.3. Community-based hybrid production of 'Guinuo 2006' seed in Guzhai village, from 2005 through 2011..... 56

Table 4.1. Penetration of transnational seed companies into China through collaboration with their local partners, from 1996 to 2009..... 75

Table 4.2. Maize hybrid distribution among households, in relation to the source of hybrid maize in Guangxi, Yunnan and Guizhou from 1998 to 2008..... 77

Table 4.3. Emerging technical, organizational and market tensions in relation to niche, regime and landscape levels..... 82

Table 5.1. Highlights of eight episodes in a participatory maize breeding project in southwest China, in relation to 'niche-regime interaction', 'strategic shift', 'role of action research' and

'institutional change' of each..... 103

Table 6.1. Three types of legal system already operating in China for the protection of traditional and origin-linked food products..... 126

Table 6.2. Structure of GI applications in China..... 126

Table 6.3. Cross-case comparison on 'public value creation', 'legitimacy and support' and 'operational capabilities'..... 132

Abbreviations

ABS	Access and benefit sharing
AQSIQ	General Administration of Quality Supervision Inspection and Quarantine
AR	Action research
ASEAN	Association of Southeast Asian Nations
CAAS	Chinese Academy of Agricultural Sciences
CBD	Convention on Biological Diversity
CCAP	Centre for Chinese Agricultural Policy
CCAs	Community-conserved areas
CIMMYT	International Maize and Wheat Improvement Centre
CSA	Community-supported agriculture
DUS	Testing for distinctiveness, uniformity and stability
EU	European Union
FSO	Farm Seed Opportunities
GAAS	Guangxi Academy of Agricultural Sciences
GI	Geographical Indication
GMRI	Guangxi Maize Research Institute
ICARDA	International Centre for Agricultural Research in the Dry Areas
IDRC	International Development Research Centre
IPRs	Intellectual property rights
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
LI-BIRD	Local Initiative for Biodiversity Research and Development
MAT	Mutually agreed terms
MLP	Multi-level perspective
MoA	Ministry of Agriculture
MoEP	Ministry of Environmental Protection
MoST	Ministry of Science and Technology
NARS	The national agricultural research system
NGO	Non-governmental organization
OPV	Open-pollinated variety
PACs	Payments for Agro-biodiversity Conservation services
PBRs	Plant breeders' rights
PGRs	Plant genetic resources
PIC	Prior informed consent
PPB	Participatory plant breeding
PVP	Plant variety protection
PVS	Participatory variety selection
R&D	Research and development
RQ	Research question
SAIC	State Administration for Industry and Commerce
SOEs	State-owned seed enterprises
SSIs	Semi-structured interviews
TRIPS	The Trade-Related Intellectual Property Rights Agreement
UPOV	International Union for the Protection of New Varieties and Plants (known under its original French designation as UPOV)
VCU	Test for the value of a cultivar for cultivation and use
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

Chapter 1

Introduction

1.1. Introduction

This thesis is about understanding and inducing multi-level institutional change through participatory plant breeding (PPB) with maize (*Zea mays* L.) in southwest China (see Figure 1.1). The study was carried out from 2007 to 2011 within the context of an on-going PPB programme for maize (operating since 2000) in the three provinces of Guangxi, Yunnan and Guizhou. The PPB programme's main objectives are to mitigate the systematic separation between the formal, nationally organised seed system and local farmers' seed systems and bridge the gap between professional maize breeders and farmers, in order to develop locally adapted varieties and enhance *in-situ* and on-farm management and conservation of plant genetic resources (PGRs). This research explores farmers' adoption of maize hybrids and the persistence of landraces, examines the opportunities for change within existing seed systems and addresses the public value of plant genetic resources through action researching processes. The current thesis encompasses and integrates technical and social science research.

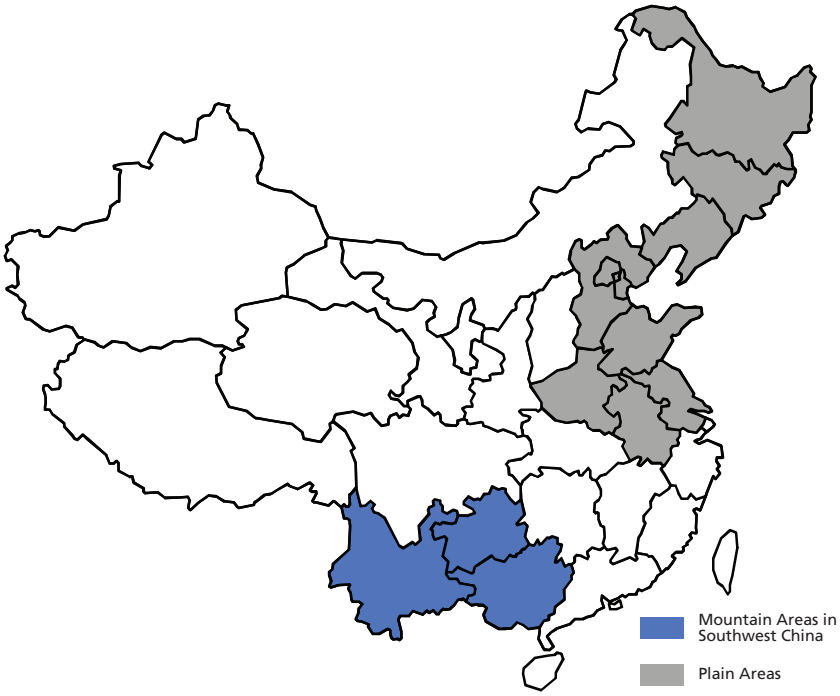

Figure1.1. Mainland of China, showing the two main maize production areas in China, including the three provinces of the research project, Guangxi, Yunnan and Guizhou in the mountain areas of southwest China.
Source: this research.

In this chapter, we first elaborate the research background in Section 1.2, then explain the research objectives and research questions in Section 1.3, and Section 1.4; the analytic concepts and methodology are introduced in Section 1.5, and finally an overview of the thesis and the interrelationship of the chapters is given in Section 1.6.

1.2. Background

1.2.1 Maize in China

In China as a whole maize is the third most important food crop by area cultivated after rice and wheat. As Song (1998) elaborates, the maize growing area in China can be divided into two distinct regions, the northern plain and the southwest region that encompasses the three provinces of Guangxi, Yunnan and Guizhou (see Figure 1.1). The two regions lie in different ecological zones. The northern plain is in the temperate zone extending from the central plain while the southwest region is tropical to sub-tropical. The southwest region is characterised by karst mountain landforms and inhabited by 25 million people, mainly from minority groups. Farmers' motivation to cultivate maize and their maize cropping systems are different in the two zones. In the northern plain, more than 90 per cent of maize is produced commercially either for export or as animal feed. In the southwest, maize is the staple food and cultivated primarily by small-scale farmers with average land holdings not greater than 0.05 ha (Guangxi Statistical Yearbook, 2006). Because the northern plain enjoys a favourable, irrigated environment, a narrow range of hybrids has been adopted widely, covering more than 95% of the maize area. In the southwest current commercial hybrid varieties also have been introduced but are not optimally adapted to the diverse mountainous environment and hybrids cover less than 50% of the maize area. Even if commercial hybrid varieties were more widely available in the southwest, most of the current hybrid maize varieties developed by professional breeders do not meet the requirements of the diverse socio-ecological niches of the mountains, nor could the farmers afford the necessary input costs to allow these hybrids to perform optimally. Other agricultural technologies and services hardly reach the farmers in these areas. The farmers especially in the more remote mountain valleys continue to rely on local landraces selected by themselves through on-farm practices. The entire zone, reliant on small-scale, rain-fed agriculture, has been classified as a zone of "low productive potential" and the incidence of absolute rural poverty is six times the national average (Fitting, 2006). The incomes of most people living in these remote mountain areas fall below the poverty line.

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[1] **A karst landscape is characterized by a geologic formation shaped by the dissolution of a layer or layers of soluble bedrock.**

1.2.2 Cultivar improvement in southwest China

In Guangxi maize is the second food crop, after irrigated rice, and for farmers living in the remote mountain valleys, maize is the only staple food. Song (1998) demonstrated that in this region local landraces have been maintained for many years by farmers themselves through continuous selection by farmer breeders, based on their experience and farming knowledge. Song's study also analysed why modern maize technologies and services had not been provided by the national or provincial agricultural research system and suggested PPB might provide an effective response to the constraints identified. With the opening of the seed markets (2001) under China's economic reform programme, breeders from the Guangxi Maize Research Institute (GMRI) began to show interest in both the local landraces and in farmers' seed selection processes. A PPB initiative was developed by Song on behalf of the Centre for Chinese Agricultural Policy (CCAP) in collaboration with the GMRI, and supported by the International Development Research Centre (IDRC, Ottawa). From 2000 onwards the PPB programme has included GMRI breeders interested in assisting local farmers to develop a range of adequately adapted varieties, including landraces, open-pollinated varieties and modern hybrid varieties (Vernooy and Song, 2004). The varieties selected by farmers have been shown to have adequate adaptation to the local environmental diversity, especially in relation to drought and other stresses. The programme is the first PPB effort in China.

Participatory plant breeding can be seen as a strategy to develop well-tailored seed for local farmers. It is important for agricultural development since it can bridge the gaps between conventional, centralized breeding effort focusing mainly on the more developed agricultural areas and the specific needs of subsistence farmers living in remote rural areas. The central breeding approach that dominates modern agriculture systems has been criticized on the grounds of its limited adaptation, inadequate farm-level testing and weak links to end users under less favourable farming conditions (Morris and Bellon, 2004). PPB is expected to have comparative advantages and produce significant benefits for situations where a centralized approach is inappropriate to meet the needs of a diversity of agro-ecosystems (Weltzien et al., 2000). PPB in various forms has been developed and introduced in an increasing number of countries, including Nepal, Vietnam, Bhutan, Laos, the Philippines, Syria, Jordan, Ethiopia, Nicaragua, Cuba, Peru, Mexico, and since the turn of the millennium also into China. PPB is based on a process and methods that involve close farmer-researcher collaboration to bring about plant genetic improvement within a crop. Ideally, PPB also seeks the formal recognition of farmers' contribution to PGRs maintenance and farmers' empowerment. In general, there are at least three aspects of concern in relation to the issues related to PPB (Tansey and Rajotte, 2008):

1. Varieties derived from PPB processes are unlikely to comply with the DUS variety release criteria (Louwaars, 2007) and therefore cannot be registered and marketed,
2. There is no legal framework or institutional mechanism that enables farmers to share the benefit generated by varieties that are created through PPB.
3. Participation in World Trade Organization (WTO) fosters countries to sign UPOV 1991, which restricts farmers' rights as seed entrepreneurs and breeders i.e. to sell their seeds and to set up seed businesses.

1.3. Problem statement

1.3.1 Challenges for PPB in China

In the context described above, innovation is linked to both technical and institutional constraints and opportunities. The research presented in this thesis was designed to contribute to the on-going PPB initiative in the southwest of China. After more than ten years of collaboration (2000-2012), five maize varieties have been bred together by farmers and professional breeders from the national and provincial public maize research institutes. However, the PPB varieties could not be registered under the current national Seed Law (2001), since by their nature they did not meet the requirements for distinctiveness, uniformity and stability (DUS) – the internationally recognised standard for seed registration. Moreover, there is no policy or legal recognition in China for PPB products that have been jointly developed and, as a result, there are neither formal protections nor incentive mechanisms in place to support this kind of innovation. Furthermore, recognition of farmers' rights is still weak in China. There is no policy or law in place to guide how farmers might develop their own seed markets and share the benefits derived from their varieties (such as PPB varieties) with other stakeholders. Besides, when China entered into the World Trade Organisation in 2001, increasing barriers to implement farmers' rights to use, exchange and sell their on-farm saved seeds have been encountered, chiefly in the form of trade pressures and the expansion of the scope of plant breeders' rights (PBRs).

The core of the challenge is: that while optimisation of the technical aspects of PPB has institutional consequences, conversely, inappropriate or unbalanced

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[2] **Testing for distinctiveness, uniformity and stability.**

[3] **This is explained further in Chapter 4.**

institutional developments may limit or distort technical potentials that could significantly reward millions of small producers in southwest China. Moreover, if China could evolve institutional provisions appropriate to its own context, then there would be significant opportunity to use PGRs to improve agriculture and livelihoods in ways that also conserves the agro-biodiversity of the southwest.

1.3.2 International problem context

This thesis addresses issues as yet unresolved in international discussion of the management of plant genetic resources. The problem context of this research encompasses both technical and institutional aspects in relation to the knowledge gaps identified in these discussions. The scope of this study is bounded by a) managing crop development for diverse agro-ecosystems, b) managing plant genetic resources for both conservation and utilization, and c) balancing the public value of and private interests in plant genetic resources.

a. Managing crop development for diverse agro-ecosystems

The promotion of homogenizing forms of agriculture has resulted in a rapid extension of modern cultivars. A number of studies have shown that formal breeding and seed systems do not have the capacity to supply the variability needed in diverse, low input farming systems, nor to meet the specific need for locally adapted varieties (Jarvis et al., 2011). Landraces that may have resilience to certain pests, diseases and abiotic stresses are being lost at an increasing rate and thereby a valuable, dynamically evolving germplasm resource is disappearing at the very time it is needed for developing sustainable agriculture in the context of climate change (Newton et al., 2010). The rapid loss of genetic diversity among crop landraces may threaten both local and global food security and it has become a shared concern worldwide. It seems sensible to maintain or improve capacity to manage crop development for diverse agro-ecosystems. PPB attempts to develop crops and varieties that are better adapted to farmers' local environmental and management conditions and to give more attention to the diverse traits that farmers and consumers value in their specific localities (Sthapit et al., 2006).

b. Managing plant genetic resources for both conservation and utilization

Protection of crop landraces is linked to the interrelationship of conservation and utilization. According to Veteläinen et al. (2009), if agro-biodiversity is to be sustained the conserved biodiversity must have some form of value to society and value implies some form of utilization. Support and development of landrace use in this view must enhance landrace maintenance within dynamic on-farm management systems. PPB is recognized as one among other strategies to combine landrace conservation with further crop improvement and utilization. It seeks to conserve agro-biodiversity and improve quality in terms of local adaptation, disease resistance, yield, taste, and other locally preferred traits, through joint varietal selection and seed development by breeders together

with farmers, the development of seed supply networks, and modified farming systems to serve local users' and consumers' needs.

c. Balancing the public value of and private interests in plant genetic resources

Given that global market demand for food crops hardly distinguishes between crop varieties (Eyzaguirre and Dennis, 2007), the full range of public values that are latent in farmers' PGRs and its management and development cannot be adequately expressed through current market processes. These values might include, for instance, issues of trust, equity, respect and fairness in how plant breeders treat farmers during plant breeding; social and agro-ecological values that might be taken into account in the development of food value chains, and values such as knowledge-sharing, benefit-sharing, trait preferences, local food security and entrepreneurial risk. There is a growing awareness of the public value of PGRs among public agencies, civil society and some consumers, as shown by the willingness to take into account – and pay for – the environmental, health and social aspects of seeds and food systems. Reconciling or harmonizing private and public benefits in PGRs is under development through a range of initiatives.

1.4. Research objectives, main research questions

The objectives of this research are to investigate (i) the incentives and options for strengthening the relation between communities' and farmers' PGRs management, conservation and plant breeding in Guangxi, and (ii) the institutional options at different levels for formalising and rewarding PGRs management and conservation by farmers and communities. Below we introduce the five core research questions of this study.

Research Question 1: What are the changes in distribution of maize landraces and hybrids from 1998 to 2008 in the three southwest provinces, Guangxi, Yunnan and Guizhou?

In southwest China, although there is strong farmers' interest in accessing modern cultivars, farmers also express strong reasons for maintaining at least some of the landraces that satisfy local preferences (bio-physical, cultural and socio-economic). To analyse the changes in distribution of maize landraces and hybrids from 1998 to 2008 in the three southwest provinces, Guangxi, Yunnan and Guizhou, we investigated (i) to what extent farmers have adopted hybrids and conserved landraces, (ii) the reasons for farmers to adopt hybrids and conserve landraces, and (iii) the implications for national policies in relation to seed production, breeding and conservation.

Research Question 2: What is the potential for involving smallholder farmers in hybrid breeding and seed production for low-external input farming systems?

Next to open-pollinated varieties, smallholder farmers in low-external input farming systems also have a need for better adapted hybrids which are technically more complicated to breed for. To explore the potential of involving farmers in hybrid development we identified and explored the feasibility of various types of cooperation between breeders and farmers, and the extent to which it is possible to involve farmers in the early stages of participatory hybrid breeding. We also considered how to solve associated issues relating to intellectual property, fair access and benefit-sharing.

Research Question 3: How do the institutional changes in the organization of the seed supply system in China influence small holder-oriented seed supply?

To analyse how the institutional changes in the organization of the seed supply system in China have influenced small holder-oriented seed supply, we investigated (i) the dynamics of system innovation within the seed supply system, and (ii) the tensions and opportunities for a smallholder-oriented seed supply system, taking the case of participatory plant breeding.

Research Question 4: What is the contribution of action researching to institutional innovation in the case of developing access and benefit sharing mechanisms in the context of the participatory plant breeding programme in southwest China?

Action researchers may play an active role in fostering conducive interaction between local innovation and regime level change and thereby support multi-level institutional evolution and networked governance of seed systems. To analyse the contribution of action researching to institutional innovation in the case of developing access and benefit sharing mechanisms, we investigated (i) how institutional innovation in relation to farmers' access to improved seed, maintaining farmers' roles in PGRs conservation, and the development of benefit-sharing mechanisms has been achieved, and (ii) how action researching has developed conducive interactions between local institutional innovation and regime change.

Research Question 5: How has public value been created, strengthened and rewarded through participatory plant breeding and related market mechanisms in selected cases?

The creation of and reward for public value in plant genetic resources require supportive public interventions through either public policy or re-designed market mechanisms. To further explore this issue, we analysed (i) the mechanisms through which public value has been created, strengthened and rewarded in selected cases, and (ii) the lessons to be learned for and from China.

1.5. Analytic concepts

To better address processes of change, this research adopts a multi-level perspective (MLP) (Geels, 2006) taken from innovation studies, which provides an evolutionary perspective on change and innovation processes, and draws attention especially to system innovation. System innovation from this perspective means innovations that fundamentally change social relationships and formal and informal rules in society.

The multi-level perspective distinguishes analytical and heuristic concepts to understand system innovations through introducing a hierarchy, from higher to lower, of social and technical change at landscape, regime, and niche levels. The relationship among the three levels can be understood as a nested hierarchy, meaning that niches are embedded within regimes and regimes are embedded within landscapes (Geels, 2006). The distinction between the levels is made on the basis of the stability and structuration of relationships at each level (Deuten, 2003):

- At niche levels, there is limited stability in rules and uncertainty about future directions. Change is created at the micro-level where radical novelties in technique, practice or organisation emerge and are carried and developed by small networks of dedicated actors, often outsiders and fringe actors in the local situation. Niches open a space for experimentation and learning.
- Regimes are semi-coherent sets of inter-linked rules that constitute and reinforce the existing system. They are more stable than niches, since the rules are shared among many different locations. Regimes offer greater structuration to local practices and socio-technical relationships (Raven, 2004).Transitions occur when processes emerge either at niche or landscape levels that catalyse change from one socio-technical regime to another (Geels and Schot, 2007). Regimes provide stability by guiding perceptions and actions, while the niches act as incubators of radical novelties. The creative work in niches often is geared to the problems created by the existing dominant regimes; the niche actors typically hope that promising novelties eventually are used in or even replace the dominant regime. However, radical novelties may not 'match' the existing regime and do not easily break through. The nature and timing of catalytic action thus becomes an important research question.
- Landscapes refer to aspects of the wider exogenous environment that affect socio-technical development. They are beyond the direct influence of actors in the regime or at niche level and cannot be changed at will. The landscape level can be thought of in evolutionary terms as a dynamic selection environment that is linked to wider external developments in the natural and human worlds.

During a process of system innovation actors in the dominant regime tend to resist change. The initiative for change starts in an isolated niche environment, usually a protected space created, for instance, by a project. Local initiatives

compete with each other in a selection environment that includes the existing socio-technical regime, as well as the wider developments at the landscape level. Niche initiatives persist and grow only when changes are achieved at the regime level. Those that cannot influence or bypass the regime ultimately fail. The space for change can be enlarged when constraints caused by the dominant regime are modified, removed or transformed (Leeuwis and Aarts, 2011). Changes in the various dimensions of the regime, such as legal rules, norms and values, procedures, and relationships among commercial and public organisations over time may lead to structural change at the regime level (see Figure 1.2).

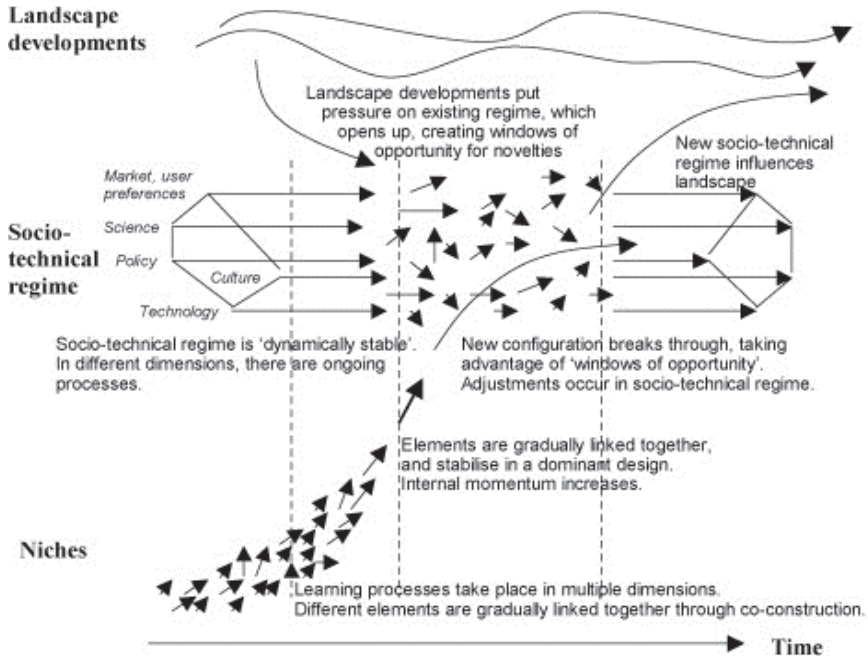

Figure 1.2. The multi-level perspective (MLP) model.

Source: Genus and Coles, 2008, who adapted Geels, 2004

It is argued by some Chinese policy actors that bringing about transition in current institutional regimes is crucial in determining whether or not farmers will benefit from their access to and development of genetic material (Qin, 2009). However, transition processes necessarily are shaped by a range of stakeholders' perspectives and research that aims to help bring about transition thus requires an emphasis on facilitation of learning at both the niche and the regime level.

In the case of PPB, in Guangxi the institutions constraining and enabling the development of a PPB niche at the start of this study were thought to include the formal breeding system, farmers' seed system, national seed regulations, international PGRs-related treaties and agreements, and local cultural practices and norms related to PGRs maintenance. On the basis of PPB experience, we

perceived that the stakeholders in each institution were seeking to satisfy their interests within the currently dominant regime but also striving to develop the potential 'space for change' as well. This study analyses which aspects of PPB practice could be stabilised and accepted by the existing institutions at a range of levels; which aspects are in direct conflict with the dominant regime; and subsequently, reports and assesses research that tests how the identified conflicts could be overcome.

The research draws on two related concepts: (a) action researching as a mode of placing science in society in order to test options for change at multiple levels, and (b) public value.

1.5.1 Action researching and the multi-level perspective

Action research is adopted as a research strategy that also provides a perspective for understanding the system for which purposeful change is sought, and for understanding the dynamic of change through niche-regime interactions. Because the research is associated with activities in which the actors are seeking to learn their way toward new scientific and policy practices appropriate to China's development needs, action research is an analytic concept used also for the policy-related aspects of the study (Reason and Bradbury, 2006; Chisholm, 2001; Kesby, 2007; Kindon et al., 2007). The associated learning theories are discussed in depth in Blackmore (2007). Analysis of multi-level institutional change in action researching mode extends action research beyond the PPB activity, which remains, at present in China, a radical novelty at niche level.

1.5.2 Creating public value from farmers' plant genetic resources through participatory plant breeding

In today's world it is the market that tends to determine how capital, labour and natural resources such as PGRs are used. China is opening up its markets to private seed sales and market-driven demand for maize and rice with traits that suit dominant market actors' interests. However, the way in which the power of the state is used when, for instance, acting through agencies such as a provincial maize research institute, is determined in part by a non-market process that has potential to accommodate a larger (or different) set of values and interests than only those of market actors (Moore, 1995). Market processes on the whole do not adequately express the full range of public values that are latent in farmers' PGRs and its management and conservation in farming practice. That is, public value necessarily is a multi-dimensional construct grounded in a context. It aims to capture what different publics' value in relation to the use of the power of the state.

The expression of public values may be read as public preferences. An important aspect of public preferences is that typically they express more than the aggregate of individual values for what individuals' value is dependent on others'

behaviour and preferences. So it might be said that the socio-economic and technical potential of PPB relates to plant breeders' and market actors' inter-dependence with farmers' PGRs and its management. A second important aspect is that there is a role for public agencies actively to shape these preferences and to make them amenable to change through enabling new experiences and evidence to be developed. A third aspect is that because there is no equivalent mechanism to the price mechanism for aggregating the preferences of individuals, it becomes part of the function of public agencies (and perhaps programme teams might be included here) to actively seek to understand and identify public preferences and how they change over time.

1.6. Methodology

Chapters 2-6 each address one of the research questions (RQs); the methods used are explained in detail in the respective chapters. This section provides a brief overview.

RQ1 was answered through a questionnaire survey at the household level, designed by the present author and carried out in 2009-2010 by project researchers including the present author. The survey investigated the distribution and changes in the distribution of maize PGRs over ten years (1998-2008) in the Guangxi, Yunnan and Guizhou provinces. The survey covered local level maize seed supply, including maize hybrid adoption and varietal distribution in farmers' fields. Farmers' reasons for variety adoption were recorded in the dimensions of their beliefs, aspirations, ability and social pressures (Leeuwis, 2004). A comparative analysis of the survey data was made in order to analyse the differences in farmers' variety adoption and conservation by location and by year. In addition, semi-structured interviews (SSIs) were conducted with farmer-breeders and professional-breeders in each of the three provinces concerning farmer improved varieties and the socio-economic and the technical impacts of the PPB outputs on local communities in the three provinces.

RQ2 is adressed by first developing a conceptual model for participatory hybrid breeding for smallholder farmers in unfavourable farming conditions, and then the options for involving farmers in hybrid improvement were illustrated by the field experiments of the participatory maize breeding programme from 2000 to 2011 in Guangxi. This PPB programme was based on various local maize genetic resources and aimed at improving both hybrid and open-pollinated varieties, in a range of parallel activities both in farmers' field and on-station, to identify appropriate crossing parents, make improved base populations and conduct further selections. We then analysed the differences between the hybrid and the OPV breeding activities, including intellectual property issues. The data for this case was collected by previous project publications (Song et al., 2010 & 2012), (unpublished) project documentation, and the authors' observations during

participation as breeders and researchers.

RQ3 draws on data from 2000 onwards, a period in which fundamental change within the seed sector has occurred following China's entry into WTO (2001) and the implementation of a national plant variety protection law (1997) and seed law (2001). The PPB initiative was introduced in Guangxi in 2000 and subsequently extended to Yunnan and Guizhou. Niche-level data are based on PPB participant observation, project documentation and the questionnaire survey that covered local level maize seed supply, including maize hybrid adoption and varietal distribution in farmers' fields. A follow-up tracer study identified the sources (breeder, seed producer and/or distributing agent) of the hybrids identified in the survey. Data on the higher-levels of the seed supply system are based on key informant interviews. Relevant national and international agreements, seed regulations, seed enterprises, public institutes, and PPB projects, also were reviewed.

RQ 4 was answered through a range of activities that were designed and redesigned in successive action researching cycles:
- At the niche level, a series of institutional experiments has been executed, which has never been attempted before in China – in which 'experiment' was understood as an early stage of an on-going process of institutional development, in which specifically 'proof of the Access and Benefit-sharing concept' was explored.
- *At regime level,* the programme stakeholders, guided and facilitated by the PPB programme, entered into dialogue with key actors positioned in higher level institutions responsible for breeding, seed production and ABS within the Chinese national context. Twelve policy workshops and round table discussions were held at provincial, regional (including the southwest provinces), national and international levels from 2000 onwards, with the direct and indirect involvement of policy makers, researchers and breeders, and ABS colleagues from other countries. Policy events, decisions and processes were monitored and documented throughout by means of: 1) the documentation of the research practices and the participant observations of the field researchers; 2) joint identification of key episodes, distilled during reflection meetings in the successive AR cycles in the field and at the level of the PPB programme; 3) planning and design of further actions, on the basis of the co-learning built around each episode.

RQ5 was explored through a cross-case analysis. Seven cases were purposefully selected to represent a range of options for participatory plant breeding and PGR conservation in relation to innovative institutional arrangements and to alternative market systems, and for their potential relevance within and to China. Four of the cases were embedded in contrasting production contexts and three additional cases were embedded in market-related innovations. The selection, compilation and analysis of the cases were based primarily on 13 workshops and policy roundtables (with complementary desk research) organized for PPB

practitioners and researchers in the context of a larger study.

1.7. Overview of the thesis

Chapter 2, 'Farmers' adoption of maize (*Zea mays* L.) hybrids and the persistence of landraces in southwest China: implications for policy and breeding', specifically aims to examine the changes in the distribution of maize landraces and hybrids from 1998 to 2008 in Guangxi, Yunnan and Guizhou, and to further explore the extent to which farmers adopt hybrids and conserve landraces, for what reasons. The chapter concludes by drawing out the implications for national policies in relation to seed production, breeding and conservation.

In Chapter 3, 'The potential of participatory hybrid breeding', the methodology and practices of participatory hybrid and open-pollinated variety development are described and compared, taking the PPB maize programme in southwest China as a case example. The chapter presents mainly a technical point of view, while also linking to the local social and institutional context. We assume that hybrid development can serve small holders of marginal, resource poor farming systems under certain prerequisites: a) the hybrids are bred for yield stability and adaptation to the local needs and preferences, b) the dependence on and need for genetic diversity is taken into account, c) breeders collaborate closely with farmers not only in the last stages but also in the initial stages of the breeding programme, d) the hybrid seed production can be integrated into the farmers' local seed system, and e) farmers and breeders can agree on issues dealing with intellectual property rights (IPR) and access and benefit sharing (ABS) in a fair and transparent way.

Chapter 4, 'Towards a regime change in the organization of the seed supply system in China', explores recent changes in seed supply from a multi-level perspective, and analyses the innovations brought about by PPB at niche level in response to such changes. The institutional tensions and opportunities for further expansion of PPB in the changing configuration of the seed supply system are considered.

Chapter 5, 'Contribution of action researching to institutional innovation: a case study of access and benefit sharing (ABS) mechanisms in the participatory plant breeding (PPB) in southwest China', investigates the contribution of action research (AR) to systemic institutional innovation, through a case study of access and benefit sharing (ABS) mechanisms developed in the context of the PPB programme. It is based on the evolving processes of the PPB programme for maize in Guangxi, as the context through which to probe the space for institutional innovation in relation to farmers' access to improved seed, farmers' roles in PGR conservation, and the development of benefit-sharing mechanisms. The analysis teases out the evidence, presented in eight episodes, for conducive interactions

between local institutional innovation and regime change. The chosen research practice, action research, is positioned as the vehicle for multi-actor learning that mediates the tensions that arise from the multi-level change processes.

Chapter 6, 'Expressing the public value of plant genetic resources by organising novel relationships: the contribution of selected participatory plant breeding and market-based arrangements', explores by means of cross-case comparison how public value has been created, strengthened and rewarded through participatory plant breeding and related market mechanisms in selected countries. Lessons are drawn concerning the options for establishing public interest and assigning value, and for reconciling or harmonizing private and public interests. The article concludes by discussing what can be learnt from innovations within China itself, that may be relevant to other countries also, and how public value in PGR can be better created and protected in the future in China.

Chapter 7 sketches a number of conclusions. First, a synthesis is made of the evidence presented in this thesis in order to assess the current institutional context and prospects for PPB and farmer' varieties in China. Secondly, a number of policy options for pursuing China's ambitions to modernise crop development whilst conserving PGR and improving small farmers' livelihoods are presented and discussed. Thirdly, the specific role of action researching and its contribution to driving the changes is discussed. The advantages (and disadvantages) of conducting and integrating technical, policy-related and social science studies in AR mode are examined in the light of the experiences presented in the thesis. Fourthly, the desirability of protecting the public value of plant genetic resources in China through public policy and new market mechanisms is emphasized.

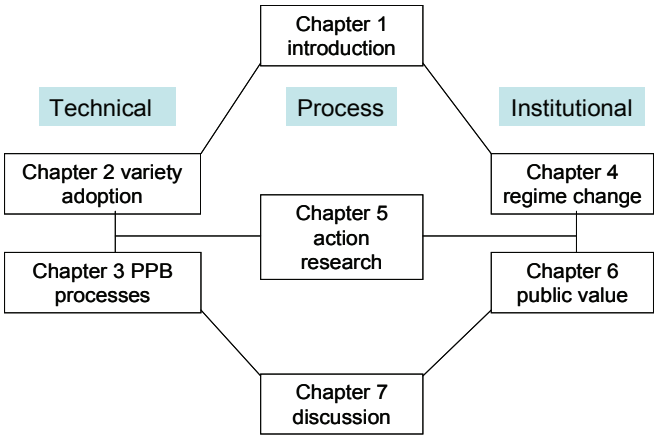

Figure 1.3. Interrelationship of the chapters.

Source: this thesis.

The interrelationship of these chapters is indicated in Figure 1.3. Chapter 1 offers a general introduction to this study. Thereafter the thesis addresses in turn two aspects, i.e. chapters 2 and 3 focus basically on the technical aspects of on-farm plant genetic resource management, and chapters 4 and 6 elaborate the seed-related regulatory framework in China and different institutional arrangements around plant genetic resources. The action researching process presented and analysed in Chapter 5 crosses technical and institutional barriers, and shows how this is bringing opportunities for innovation through niche-regime interactions. Chapter 7 provides a general discussion and conclusions.

Chapter 2

Farmers' adoption of maize (Zea mays L.) hybrids and the persistence of landraces in southwest China: implications for policy and breeding

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Abstract

This paper examines changes in the distribution of maize hybrids and landraces in the mountainous areas of southwest China over 1998-2008, farmers' reasons for cultivar adoption and the implications for national policies in relation to seed production and breeding, based on baseline data and a survey conducted in Guangxi, Yunnan and Guizhou. The study traced the dynamic changes in the adoption of hybrids and landraces in farmers' fields, explored how individual farmer's choices can influence local landrace distribution, and investigated the space for conducive policy and innovative action for on-farm conservation of maize genetic resources. The research showed that although there is strong farmers' interest in accessing modern maize hybrids, farmers also express strong reasons for maintaining at least some of the landraces that satisfy local agronomic context and social preferences. Farmers recognized that hybrids have a number of advantages but they also indicated some disadvantages of the current available hybrids e.g. with respect to seed quality, local adaptability, taste and cost of seeds, but also lack of information on the performances of the new hybrids. Based on-farmers' reasoning and experiences, the requirements have been identified for improving yield combined with local preferences (agronomic, cultural and socio-economic). The paper concludes by identifying options for how China might seek to develop resilient seed systems for smallholder farmers in poor areas, under changing climatical conditions and volatile markets. Participatory plant breeding is among the options considered for bringing farmers' needs into conservation and breeding strategies for improving local adaptation.

Keywords

Maize hybrids; maize landraces; plant breeding; southwest China

2.1. Introduction

China has been identified as one of the twelve mega-diversity countries in the world. Its southwest mountainous region of Guangxi, Yunnan and Guizhou provinces consists of a range of eco-systems, which conserve numerous unique species and varieties of agricultural, medicinal and botanical importance, and is a recognised 'hotspot' of plant genetic resources. Maize is the staple food crop in that region but under small-scale, rain-fed agricultural conditions the crop's productivity has remained low. The significant vertical climatic differences in the karst mountain areas (with altitudes ranging from 200 to above 3000 meters) and diverse landforms and ecosystems, make farming difficult and vulnerable to local disruptions. Most of the cultivated land is occupied by smallholder farmers who cannot bear the cost of high-input modern farming (Song, 1998; CCAP, 2007). It remains one of the most densely populated poor areas in China.

A study of the impact of maize hybrids carried out in the middle of 1990s in southwest China revealed systematic division between the formal and the farmers' seed systems. More than 80% of the maize seed (mainly sourced from local landraces) was supplied by local farmers and their communities (Song, 1998). There are two starch types of landraces in this region: waxy and non-waxy maize. The former is characterized by a specific type of endosperm known as 'waxy' and people of these areas are familiar with waxy maize, rice, sorghum and millet, accustomed to using them for special purposes.

Hybrid maize cultivars have been introduced and adopted in the region from the late 1990s onwards, leading to a fast expansion of hybrid maize and the gradual replacement of local landraces. However, to an unknown extent, farmer-saved maize landraces are still grown in the mountain areas, mainly because of local adaptation of the landraces and other agronomic, cultural and socio-economic factors that limit the adoption of commercial hybrids (Yao et al., 2007). Today, at the national level, there is a lack of information about a) what (type of) varieties are grown in farmers' fields, especially in the economically poor areas, b) what factors might influence hybrid adoption within poor regions, and c) what farmers' views on hybrid cultivars are. This information gap hampers the development of national seed policies that would support the livelihoods of the millions of poor people in southwest China, as well as biodiversity conservation policies. This paper aims to contribute to the required information. The research specifically aimed to examine changes in distribution of maize landraces and hybrids from 1998 to 2008 in the Guangxi, Yunnan and Guizhou provinces, and to further explore to what extent farmers adopt hybrids and conserve landraces, for what reasons, and the implications for national policies in relation to seed production, breeding and conservation.

The research applies a two-level conceptual framework: (i) a 'reasons for action' model (adapted from Leeuwis, 2004; Röling and Kuiper, 1994) that can help to explain farmers' practices in relation to the adoption of maize landraces

and hybrids at the individual level; and (ii), a 'vulnerability of production and conservation' matrix, a tool to demonstrate the distribution and aggregation of different maize landraces and hybrids within a changing context (adapted from Sthapit et al., 2006).

'Reasons for action' model

The 'reasons for action' model (figure 2.1) can help us understand why farmers engage in certain practices (or not) at a given time. Figure 2.1 illustrates that what farmers do and what they refuse to do depends on their knowledge and beliefs, their aspirations, their individual and collective abilities and the social pressures they experience within a certain social context. Farming is a carefully coordinated activity and such considerations can relate to technical, economic and social-organizational issues (Leeuwis, 2004; Van der Ploeg, 2008).

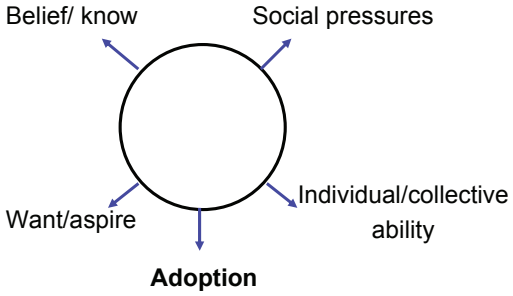

Figure 2.1. 'Reasons for action' model (adapted from Leeuwis, 2004; Röling and Kuiper, 1994)

The main elements in the model are defined as follows:

Beliefs - What farmers believe to be true about the agro-ecological and social world includes their multiple beliefs about technical and socio-economic consequences of their practices, and perceptions of (un)certainty, likelihood and risks under given bio-physical, cultural and socio-economic conditions.

Aspirations - What farmers do or do not do is associated with a set of interrelated and possibly contradictory aspirations of various kinds, including technical, economic, cultural and relational aspirations.

Individual and collective ability - Farmers' practices are shaped by what they are able to do individually, and also by the collective abilities of agro-support networks and community organizations. At the individual level we can think of the availability of skills and the ability to mobilize resources (e.g. financial) and accommodate risk. At the collective level, farmers' practices may critically depend on the ability of others to deliver inputs like fertilizer, seeds and water, and/or the effectiveness of marketing channels and policies.

Pressures from social environment – In performing practices farmers might depend not only on the ability of others but might be, influenced and pressured

through the exercise of power-related rewards and sanctions. Thus, the social environment can enable and constrain the actors through imposing certain expectations. What farmers think they are allowed and/or expected to do is related to the perceived desires and expectations of others, the 'rewards' and 'sanctions' (resources) imposed on them, and the relative importance that farmers assign to these seed-related social pressures.

The model provides a framework of interlinked elements for understanding farmers' reasons for seed adoption within a given agronomic and socio-economic context. In order to operationalize the framework the study explored farmers' perceptions of the agronomic, cultural and economic advantages and disadvantages of hybrids and landraces. The recognition of a (dis)advantage is essentially an integration of a belief that a certain outcome will occur, and the evaluation of that outcome vis-à-vis certain aspirations. In addition, we investigated farmers' references to individual and collective abilities when they discussed reasons for adoption, and their references to social pressures in the form of incentives and disincentives provided by others.

'Vulnerability of production and conservation' model

Practices here are understood as essentially patterns of human action or regular activities (Leeuwis, 2004). Farmers' practices with regard to cultivar adoption generate, within a certain span of time and space, aggregated outputs and impacts on the distribution of crop genetic resources within a local context. Figure 2.2 provides a two-dimensional tool for assessing the vulnerability of production and conservation of crop genetic resources and changes over time and between communities. The production dimension is related to the growing area, and the conservation dimension is linked to the number of households cultivating the resource. The distribution of maize landraces in this study accordingly can be differentiated by means of four patterns, i.e. type A refers to those landraces in farmers' fields that are cultivated by a few households within small areas, and considered vulnerable (endangered) in both conservation and production terms; type B refers to landraces offering functional preferences to farmers and that are conserved by many households for limited self-consumption, such as making traditional food or wine during a festival; type C refers to landraces that are specifically favoured by a small number of farmers but are grown throughout the area; type D refers to locally dominant landraces that are grown by many households for large area production.

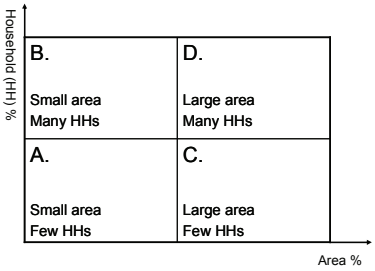

Figure 2.2. Typology of maize hybrid and landrace distribution in farmers' field, according to the percentage of households (HH %) and the percentage of production areas (area %) (adapted from Sthapit et al., 2006)

2.2. Materials and methods

2.2.1 Design and methods

The study is based on a sample survey, semi-structured interviews (SSIs), and a documentary and literature review conducted in the period 2009-2010. In order to trace changes over time the survey compares, on the basis of farmers' recall maize hybrid adoption and landrace distribution at three points in time, i.e. 1998, 2003 and 2008. The survey was conducted in Guangxi, Yunnan and Guizhou in succession from March to June of 2009. A stepwise sampling strategy was employed: first, for each province two counties were selected; then for each selected county, three townships were selected; for each selected township, three villages were selected; for each selected village, three households were selected. In total this procedure yielded 162 respondent households, from 54 villages, 18 townships and 6 counties of three provinces. Judgmental non-random sampling was used in the selections of province and county in order to administer the survey within an on-going participatory plant breeding project sites (CCAP, 2009). When selecting village and household, systematic sampling was used i.e. villages and households were stratified according to income level (i.e. high, middle and low) into one from each category was selected.

Semi-structured interviews (SSIs) with in total 162 farmers (54 for each of the three provinces) were conducted in parallel with the survey in order to document their views on hybrids and landraces. Other secondary data and information were generated from interviews with breeders in the formal seed sector, official village-level documentation on hybrid distribution, and a documentary and literature review.

2.2.2 Data analysis

The data obtained from household questionnaires was converted into percentages. Based on these percentages the chi-square and Kruskal-Wallis test was carried out using SPSS 15.0. Chi-square on numbers of households was used to establish differences between locations (provinces) or years in farmers' choices for hybrids or landraces. Kruskal-Wallis on percentage of land cultivated with maize hybrids and landraces was used to analyse the changes across locations or years. The qualitative information from the SSIs was transcribed and analysed in four steps: 1) open coding to identify ideas, themes and concerns; 2) identification of general categories and subcategories of advantages and disadvantages; 3) summarization of the interview using the categories, with subheadings and specific details or examples related by an interviewee; and 4) calculation of the frequencies of each categories and /or subcategories and comparison of categories within and between interviews.

2.3. Results

In order to provide a background to better understand the context of farmers' choices for hybrids and landraces, we will first in short describe the change in seed policy in China and how this was implemented in the three provinces of southwest China. Then we will analyse the results from the farmers' interviews.

2.3.1 Change in seed policy

There has been a government extension campaign to encourage hybrid adoption nation-wide since the end of 1990s, following the opening up of the commercial seed market and the implementation of new seed regulations, i.e. the Regulation on Plant New Variety Protection (1997), the national Seed Law (2001) and the Subsidy on Quality Seed (2008). National seed policies emphasised the extension of hybrid seeds and farmers were encouraged to adopt hybrids through subsidies and promotions. According to formal sector interviews with maize breeders, we learned that on provincial level seed policies slightly differed. Seed policy in Guangxi was open to the idea that companies and breeding institutes located outside the province should play a role in seed provisioning, and to the penetration of transnational seed companies that had entered into the Guangxi seed market since the late 1990s. In Yunnan and Guizhou the local breeding institutes and seed companies played a stronger role in the local seed provisioning. Here the provincial authorities were more cautious about opening up to transnational seed companies than in Guangxi.

2.3.2 Changes in proportion of hybrids and landraces

Tables 2.1 and 2.2 list the changes in the proportion of hybrids and landraces grown within the survey regions, expressed as the means of the percentage of the households among respondent households (HH%), and the percentage of the area among the total maize growing area (area%). According to the data provided in Table 2.1, within each test year, the HH% that used landraces differed significantly per province ($P \geq 0.001$). Also the change in HH% that used landraces across the three test years, was different per province. The reduction in HH% using landraces was significant both in Guangxi ($P = 0.02$) and Yunnan ($P = 0.027$), but the situation in Guizhou was fairly stable ($P = 0.548$). In Yunnan the change mostly occurred in the last five years, i.e. 2003-2008, but in Guangxi the reduction in landrace use started already in the period between 1998-2003.

Also the changes in terms of percentage of area cultivated with hybrids and landraces, differed in each testing year per province, see Table 2.2. In Guangxi and Yunnan, the landrace area was reduced significantly over the three test years between 1998-2008 from 65% to 7%, and from 84% to 18% of the land. In Guizhou the reduction was not (yet) significant. The overall reduction in Guangxi and Yunnan accounted mostly for the normal landraces, whereas the use of waxy maize landraces had not been reduced significantly, neither

in area% nor in HH%, see Table 2.1 and 2.2. This means that for the waxy landraces more on-farm conservation was practiced, compared to the normal, non-waxy maize.

The reduction in landraces was accompanied by a rapid expansion of hybrids, especially in Guangxi where the area under hybrids reached 93%, see Table 2.2. On the other hand, the reduction in the percentage of households growing landraces was less than the reduction in the area%. This means that many farmers were persisting with landraces, albeit on a reduced scale.

Table 2.1. Changes in percentage of household (HH) growing maize hybrids and landraces in Guangxi, Yunnan and Guizhou from 1998 to 2008

Year	Guangxi (n=54)	Yunnan (n=54)	Guizhou (n=54)	χ^2
Percentage of HH growing hybrids				
1998	46	19	20	7.5 (P=0.024)
2003	74	50	48	2.4 (P=0.298)
2008	96	93	72	12.8 (P=0.002)
χ^2	33.8 (P=0.000)	59.6 (P=0.000)	27.7 (P=0.000)	
Percentage of HH growing landraces (including waxy and non-waxy landraces)				
1998	80	89	91	13.4 (P<0.001)
2003	48	83	81	14.8 (P<0.001)
2008	22	67	76	26.1 (P<0.001)
χ^2	12.1 (P=0.002)	7.2 (P=0.027)	1.2 (P=0.548)	
- waxy maize landraces of the total				
1998	15	58	28	19.9 (P=0.000)
2003	22	58	25	13.9 (P<0.001)
2008	17	48	32	10.2 (P=0.006)
χ^2	1.1 (P=0.579)	1.0 (P=0.595)	0.1 (P=0.964)	
- normal maize landraces of the total				
1998	72	87	90	14.1 (P<0.001)
2003	39	73	77	14.1 (P<0.001)
2008	8	44	70	31.4 (P=0.000)
χ^2	21.1(P=0.000)	15.8 (P=0.000)	2.0 (P=0.370)	

Source: Questionnaire survey (n = 162) in Guangxi, Guizhou and Yunnan, 2009-2010.

According to the SSIs, maize in this region was produced mainly for self-consumption (as food and feed); only a small portion was for sale. The waxy landraces with special taste qualities was usually destined for use in traditional

foods and wine during festivals. Farmers' decision-making was also related to the condition of their land. The land quality in this region was not uniform and each household cultivated several pieces of land with different qualities. Therefore farmers distributed their land resources among a range of crops and cultivars. They normally left fertile land for cash crops, including maize hybrids, and upland or infertile land for maize landraces. Farmers thus perceived it as a necessity to cultivate both the hybrids and landraces during the same season.

Table 2.2. Changes in percentage of land cultivated with maize hybrids and landraces in Guangxi, Yunnan and Guizhou from 1998 to 2008

Year		Guangxi (n=54)	Yunnan (n=54)	Guizhou (n=54)	Kruskal-Wallis test χ^2	P
Percentage of land cultivated with hybrids						
1998		35	16	19	3.6	0.1627
2003		55	39	42	0.9	0.6374
2008		93	82	63	5.9	0.0532
Kruskal-Wallis test	χ^2	31.9	47.1	20.7	-	-
	P	0.0001	0.0001	0.0001	-	-
Percentage of land cultivated with landraces (including waxy and non-waxy landraces)						
1998		65	84	81	12.7	0.0017
2003		45	61	58	13.1	0.0015
2008		7	18	37	26.5	0.0001
Kruskal-Wallis test	χ^2	13.7	26.4	5.2	-	-
	P	0.0011	0.0001	0.0756	-	-
- percentage of land cultivated with waxy landraces						
1998		5	58	1	12.6	0.0018
2003		5	58	1	10.4	0.0056
2008		1	48	2	7.7	0.0213
Kruskal-Wallis test	χ^2	0.4	0.4	0.059	-	-
	P	0.8021	0.8237	0.9708	-	-
- percentage of land cultivated with normal landraces						
1998		60	87	80	11.7	0.0028
2003		40	73	57	12.0	0.0024
2008		6	44	35	22.8	0.0001
Kruskal-Wallis test	χ^2	14.1	25.6	7.0	-	-
	P	0.0009	0.0001	0.0296	-	-

Source: Questionnaire survey (n = 162) in Guangxi, Guizhou and Yunnan, 2009-2010.

2.3.3 Change in hybrid cultivars and landraces

The survey identified 87 hybrids that have been adopted by the respondent farmers: 43 in Guangxi, 21 in Yunnan and 23 in Guizhou, see Supplementary Material 1. A few were reported as grown in all three reference years i.e. 1998, 2003 and 2008, see Supplementary Material 2. The distribution of and breeding agents for the top (where 'top' is identified in the survey in terms of area grown) five hybrid maize cultivars were traced in Guangxi, Yunnan and Guizhou provinces in each of the three test years. To a certain extent the diversity of hybrids at the cultivar level increased in each of the three provinces, but over the same period a number of cultivars became more dominant within local communities. For instance, ZD619, released by a transnational seed company, covered 44.9% of the maize area of Guangxi by 2008 (Supplementary Material 3).

According to our data there were differences among three provinces in the rate and scale of cultivar change, see Supplementary Material 1 and 2. This may be related to differences in provincial seed policy as described above. Further, biophysical and landscape conditions in Yunnan and Guizhou were more severe, with the higher altitudes ranging from 1350 to 2760 m.

The landraces conserved in these regions are listed in Supplementary Material 4, with their names and specific characteristics. At the provincial level, most of the landraces noted for 1998 were still grown in farmers' fields in 2008. That means that the reduction in the landrace area did not directly lead to a reduction in cultivar diversity. However, it may be inaccurate to judge the diversity of landraces merely on the basis of their local names. Landraces may be distinguished most keenly by name if more than one is grown in the same community. If only one landrace is cultivated the farmer may use a more general or a very local crop name, or provenance name, giving rise to a confusion of identity with landraces in other parts of the region (Zeven, 1998). It is therefore difficult to differentiate landraces from each other by their names only or to draw firm conclusions as to diversity.

2.3.4 Farmers' reasons for choosing hybrids or landraces

Farmers' reasons for adopting hybrids and landraces can be categorized in four dimensions, i.e. agronomic and economic (dis)advantages, individual and collective abilities, and pressures within their social context. Because both hybrids and landraces have their strengths and weaknesses within the local biophysical and social context, farmers need to balance their multiple aspirations and make decisions based on a number of considerations.

Agronomic advantages and disadvantages

The agronomic characteristics of a cultivar were important criteria for farmers when adopting or refusing a certain cultivar, and were mainly related to its yield potential, and to its performance under biotic and abiotic stresses. Many farm-

ers recognized the advantages of hybrids, citing for instance yield potential, lodging resistance due to short stems and suitability for intensive planting (such as intercropping with soybean or cassava). Although farmers indicated that hybrids provided higher yields than landraces and 71% of respondents were positive about the yield of hybrids, 54% of farmers indicated that they were concerned about the yield stability of hybrids (see Table 2.3). Farmers reported that the hybrids bred by seed companies or research institutes from other regions were not adapted to upland and infertile land, and that their performance was easily influenced by (and vulnerable to) weather variations, pests and diseases, which were the main challenges to yield stability in these low input farming regions. Farmers considered the uncertainty of local adaptation as a risk for them when choosing to grow new and unknown commercial seeds. Farmers' experience with the local adaptation of hybrids had not yet fully convinced farmers to abandon their landraces.

As to landraces in general, 62% of farmers considered that, compared to hybrids, landraces were better adapted to local conditions and offered stable productivity. Landraces were valued also for their quality as food and feed. At the same time farmers also cited many disadvantages such as degradation of maize landraces (drift toward unfavourable traits, lower yield, increased plant height, loss of stress resistance, and vulnerability to new pests and diseases) in cases of too little time and attention for maintenance and continuous mass selection. As more and more farmers switched to hybrids, there was less concern among farmers for this problem.

According to the interviews with farmers, adoption of hybrids or landraces to a certain degree was determined by the different roles maize play within their food system. A common strategy in the local communities was to cultivate several hybrid cultivars and landraces at the same time, in order to balance the multiple use functions of maize on the one hand and to fit their crop to different land qualities on the other hand. The strategy demanded regular seed replacement of the landraces, i.e. every 2-3 years farmers exchanged or purchased the seeds from other villages. Such seed replacement was connected to the risks of gradual seed degradation and poor landrace maintenance. In order to avoid degradation and further enhance the productivity and stability of landraces, some farmers continually practiced 'non-stop selection' within landraces across the marginal production environments (Newton *et al.*, 2010).

Table 2.3. Farmers' reasons (% of respondents) for cultivating hybrids and landraces in relation to the biophysical dimension

	Advantages (%)		Disadvantages (%)	
Hybrids	High yield	71	Yield instability due to poor adaptability to local weather and upland condition, susceptible to insects and diseases	54
	Lodging resistance, with short stem	48	Poor lodging resistance	26
	Planting with higher density	12	Variety degradation due to sowing F2	14
	Yield stability	6	Bad taste	3
	Cold resistance	1	Unfit for feeding	1
			Hard to store	1
Landraces	Yield stability due to better adaptability to local climate and upland conditions	62	Loss of lodging resistance due to degradation, evolving to unfavourable traits	14
	Tasty	43	Poor resistance for newly emerged pests and diseases	9
	Suitable for feeding with higher biological yield	13		
	High yielding with big cobs and deep kernels	13		

Source: Semi-structured Interviews (n=162) in Guangxi, Guizhou and Yunnan, 2009-2010.

Economic advantages and disadvantages

Data of Table 2.4 reveals that 71% of the respondents acknowledged that hybrids have a high yielding potential but only 4% mentioned that their income had increased greatly as a result of adopting hybrids. 18% respondents pointed out that the commercial seed market was not well regulated with regard to seed quality control and 15% felt that there was lack of information on the performance of the new hybrid cultivars. The farmers' seed market was perceived to be more reliable than the commercial one. For farmers who could not afford the cost of hybrid seed for each cropping season, local landraces provided alternatives. In some cases poor farmers also saved the seeds of the hybrids to re-sow in the next season in order to reduce the seed cost but suffered from the segregation of the F2 seeds. On the other hand, the degradation of landraces also caused harvest losses and accelerated the replacement of landraces by hybrids, and thus increased farmers' reliance on commercial seed markets.

Table 2.4. Farmers' reasons (% of respondents) for cultivating hybrids and landraces in relation to the economic dimension

	Advantages (%)		Disadvantages (%)	
Hybrids	More grain to sell	71	The market is less regulated on seed quality control	18
	Higher income from the market	4	Lack of market information on new varieties	15
			Less grain to sell due to variety degradation (sowing F2)	14
			Dependence on market, which has increased price of seed and other inputs	11
Landraces	Saving cost on seed for the old and the poor	18	Less income due to harvest loss caused by lodging and diseases	23
	Farmers' seed market is more reliable	13		

Source: Semi-structured Interviews (n=162) in Guangxi, Guizhou and Yunnan, 2009-2010.

Because of the limited yield potential of this low-input region, maize usually was seen as a staple food and insurance grain. The increasing cost of hybrid seeds and other inputs (pesticides and herbicides) meant that hybrid adoption did not result in increased farm income, especially because the farming scale was limited and the yield stability of hybrids was not yet proven in these growing conditions. On the contrary, small scale farmers, especially the poor farmers, who were more sensitive to monetary costs, persisted with landraces as their insurance, for both economic and agronomic reasons.

During each cropping season, there were many hybrids sold on the county or township seed markets, most of which were new to farmers. Farmers had to buy the new hybrid seeds from the market for each cropping season, which implied a need for precise cultivar information and a stable seed market. However, such information and service provision was not yet in place in the marginalized areas in the southwest. The decision making process of farmers under these circumstances was based mainly on their own experience or the experience of others' in their neighbourhood. According to the SSIs farmers had experienced frequent instances of poor quality seed sold as a named hybrid and sometimes also of counterfeit seed.

Individual and collective abilities

When discussing farmers' reasons for (non-)adoption in the sphere of individual and collective abilities, farmers tended to emphasize issues related to accessing

the seed within their social contexts (Table 2.5). 87% of the farmers mentioned that they could easily access hybrids from commercial seed markets; a few (3%) preferred to follow their neighbours' and relatives' choices in order to reduce the risks from using unfamiliar cultivars. Experience of poor adaptability was the key perceived risk for farmers (mentioned by 54%), and sometimes there was lack of sufficient information about the new cultivars (15%). The cost of hybrid seed limited poor farmers' adoption (18%). Farmers obtained the seed of landraces mainly from their own harvest (66%), and also from niche markets (13%) and their neighbourhood (11%). For 14% of respondents, the shortage of farming labour and insufficient on-farm experience and knowledge had fostered landrace degradation and their replacement by hybrids. Although the survey reveals that the area under landraces was decreasing rapidly (Table 2.2), only 1% respondents mentioned this as a concern.

Table 2.5. Farmer-perceived abilities and inabilities in adopting hybrids and landraces (% of respondents)

	Ability (%)		Barriers (%)	
Hybrids	Easily access the seed from the market	87	Difficult to find the suitable varieties	54
	Easily introduced by neighbours and relatives	3	The old/poor have difficulties to afford the economic cost on seed	18
	Labour-saving	1	Difficult access to the information of new varieties	15
Landraces	Easy to save the seed from harvest	66	Lack of labour and knowledge to prevent the degradation	14
	Easy to purchase the seed from niche market	13	Landraces are disappearing and difficult to access	1
	Easy to exchange the seed with neighbours and relatives	11		

Source: Semi-structured Interviews (n=162) in Guangxi, Guizhou and Yunnan, 2009-2010.

As the rate of out-migration had increased (Song and Zhang, 2006), the remaining farmers were gradually moving into labour-saving crops and cultivars, and this trend clearly pushed the shift from maize landraces to hybrids. According to the key informant interviews with farmers, in order to save labour, some farming activities had been simplified. For example, previously, in order to ensure good adaptation to the weather, farmers used to sow 3 seeds of their landraces in one hole and subsequently observed and selected the most robust plants during thinning. However, currently farmers chose to grow uniform hybrids in part because they did not need thinning. Farmers also indicated that the on-farm storage of landrace sowing seed after harvest costs labour and attention (especially under the sub-tropical weather conditions of the southwest), and that

labour shortages accelerated farmers' abandonment of landraces.

Social pressure

Only a few farmers in the survey referred to social pressures when discussing their reasons for choice of hybrid or landrace adoption (see Table 2.6); they mentioned in particular two competing social pressures, each emerging from a different direction. On the one hand, 8% of the farmers mentioned that they were encouraged to adopt hybrids by extension workers and local governments. On the other hand, 13% farmers indicated cultural and traditional incentives for the continued use of local landraces. In a sense the two social pressures are in conflict with each other. But, at the same time, a considerable proportion of farmers remained able and motivated to combine hybrids and landraces (see Table 2.1).

Table 2.6. Farmer-perceived social pressures in terms of incentives and disincentives for growing hybrids and landraces (% of respondents)

	Incentives from social environment (%)	
Hybrids	Introduced and promoted by agricultural extension stations and local governments	8
Landraces	Culture/ tradition reliance experienced by farming communities	13

Source: Semi-structured Interviews (n=162) in Guangxi, Guizhou and Yunnan, 2009-2010.

2.3.5 Discussion

Synthesis of farmers' reasons for hybrid and landrace adoption

Although hybrids have been promoted and pushed rather heavily by state and private organizations, remarkably few farmers actually indicated that they felt pressured to adopt such seeds. The findings of our study indicate that in all three provinces maize hybrids had rapidly become dominant in the period from 1998 to 2008. The data indicate that farmers see several economic and many agronomic advantages for using hybrids, which indicates that they are indeed internally motivated to use hybrids. The most important advantages that farmers considered are related to higher yields and lodging resistance. However, farmers also associated hybrids with a large number of disadvantages, especially regarding poor adaptability and inadequate service provision in seed quality control, availability of cultivar information and accessibility of seed. Moreover, a considerable proportion of farmers still reserved a portion of their land for landraces, even if hybrids dominated. Farmers indicated that landraces had several advantages over hybrids, especially regarding their adaptability to local conditions, their taste, and the relatively ease of gaining access to seed. Farmers also had different functional preferences for landraces, related to their food culture, land quality and economic infrastructure. Even so, the expansion of hybrids led to a sharp reduction of landraces in farmers' fields, and their interest

in and care for the genetic resources seemed to have dwindled. However, in the seed systems of poor and vulnerable farmers especially, landraces still play an important role, since they often cannot afford the seed costs of hybrids and/or accommodate the agronomic and economic risks associated with them. Overall, we can say that despite the large scale adoption of hybrids, there is still considerable scope for improving their quality and adaptability. This calls for local hybrid cultivar improvement, using strategies such as on-farm cultivar testing, demonstration and evaluation.

Agro-biodiversity conservation in relation to changes in the structure of agriculture

The changes in the proportions of maize landraces and hybrids per household within this region can be analysed through distinguishing four patterns of distribution (figure 2.2).

- The shift toward hybrids

The cultivation of maize hybrids expanded rapidly in the three southwest provinces. The shift in pattern, changed from A to D (in figure 2.2), i.e. from 23% of the area by 28% of households in 1998, to 79% area by 87% of households in 2008. With the hybrid becoming dominant in local seed provisioning, farmers became more dependent on commercial seed companies and formal breeding institutes. However, as the commercial seed market in China was still underdeveloped, the proper mechanisms which can transfer sufficient cultivar information to farmers and farmers' feedback to breeders and companies had not yet been set in place. What can be done to improve the current situation? Seed companies, public sector actors and farmers might consider the following: 1) seed companies can better evaluate the potential of hybrids for farmers and facilitate their entry into the market, through on-farm demonstration and farmer-oriented on-farm trainings; 2) public sector actors can monitor the demonstrations, organize independent cultivar testing (comparing cultivars from different sources), and provide the testing results and recommendations to farmers.

- The persistence of landraces

The distribution of landraces changed over the past ten years. Broadly speaking, the study identified three pathways of change, i.e. 1) shifting from D to B in figure 2.3; 2) keeping stable, as in B; and 3), shifting from D to A. According to Tables 2.1 and 2.2, the change in non-waxy maize landraces in the three provinces on average was from type D to B, i.e. from 73% of the area by 83% of households in 1998 to 19% of the area by 41% of households in 2008. The distribution of waxy landraces was stable as type B, i.e. from 3% of the growing area by 34% of households in 1998 to 2% of the area by 32% of households in 2008. As elaborated above, farmers' persistence with waxy landraces is based on their roles in their traditional food and farming systems.

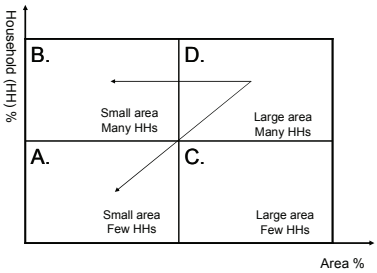

Figure 2.3. The pathway of change in maize landraces in farmers' fields, from 1998 to 2008.

The changing situation in the three provinces can be further distinguished. In Guangxi, the distribution of normal landraces changed from type D via B to A, i.e. from 60% of the area and by 72% of households in 1998, to 40% of the area and by 39% of households in 2003, declining to 6% of the area and by 8% of households in 2008. This trend indicates that farmers' conservation of non-waxy maize landraces in Guangxi is extremely vulnerable. In Yunnan and Guizhou, more than 60% of households still cultivated landraces on-farm, although on a limited scale (in about 20% of the maize growing area).

Implications for breeding strategy

The expansion of hybrids influenced agro-biodiversity in farmers' field and farmers' access to landraces. Because of the risks of the current available hybrids mentioned above, small scale farmers became more vulnerable within their agronomic and market conditions but, paradoxically, this was also the result in part of farmers' own choices. Farmers' landraces have been marginalized during the implementation of the new seed policies and the development of commercial seed markets. Farmers gradually switched to commercial hybrids and gave less attention to landraces, resulting in considerable degradation of their quality and this in turn motivates further abandonment. The erosion of locally adapted landraces was experienced by farmers as increasing the crop's vulnerability to insect pests and diseases and accelerating the loss of local knowledge about diversity. These effects have been reported also elsewhere (Thrupp, 2003; Eyzaguirre and Dennis, 2007).

The reduction in landraces maintained on-farm also challenges future breeding. Many maize breeders in China have come to realize that the narrow genetic base of hybrid varieties is one of the urgent issues in breeding. In China, the parentage of 91.6% of the available hybrids consists of approximately 20 elite inbred lines (Li et al., 2002; Yao et al., 2007). There are more than 15,000 accessions of maize collected in the gene banks, of which approximately 90% consist of landraces. Yet the investigation and utilization of the landraces by formal breeders is limited; only less than 3% of the landrace material has been used in breeding (Liu et al., 2004). There is a wide gap between the landraces conserved both in gene banks and in farmers' fields and modern hybrid breeding strategies. Farmers' adoption of hybrids in a regional genetic resources hotspot has

strong externalities for the poorest and for the broader conservation goals of society. In principle, the maintenance of landraces in agriculture can enhance local seed exchange and supply, and broaden the opportunities for accessing diversified quality seed. But for this to happen in practice, there needs to be both policy support and application of breeding strategies such as those fostered by participatory plant breeding. We now examine this point in more detail.

Implications for seed policy and action

According to the survey, the average landrace distribution (by area) across the three southwest provinces has decreased from 77% in 1998 to 21% in 2008. It has also been estimated that 75% of the genetic diversity of crop plants worldwide was lost in the last century (IAASTD, 2009). Yet very few respondents (only 1%) mentioned the loss of landraces as a concern; only some farmers consider it their responsibility to conserve the landraces transferred from older generations as their family heritage. Since the rate of replacement of landraces by hybrids increased and local seed provision was eroding, both these trends were limiting farmers' access to local genetic resources. This could lead to the situation that in the long run farmers could have no choice but to adopt hybrids, when any other interventions in crop breeding and seed provisioning will remain absent.

As the loss of biodiversity seems to be neglected by most individual farmers, it is an urgent matter for government and public research institutes to conserve and utilize genetic resources of landraces as a safeguard against an unpredictable future (Bragdon et al., 2009; Newton et al., 2010). On the other hand, the advantages of currently released hybrids had not yet been convincingly demonstrated to local farmers and there is a need to investigate how these might be improved and adapted to local agronomic and socio-economic contexts. In order to move forward on both landrace conservation and hybrid improvement, there are various approaches that might be considered: the *ex-situ* (genebank) approach, the *in-situ* (on-farm) approach and the participative approach to crop breeding, such like participatory plant breeding (PPB) (Morris and Bellon, 2004; Jarvis and Hodgkin, 2008). Compared to the formal, centralised plant breeding, the advantages of the participative approach are that it targets specific environments and designs the selection criteria together with end-users (usually farmers) (Witcombe et al., 2005).

Based on the analysis in figure 2.3, differentiated strategies for crop conservation and improvement can be identified:

- Cell A refers to the endangered landraces, such as non-waxy maize landraces in Guangxi. Here it would be necessary to encourage both on-farm conservation by local farmers and *ex-situ* conservation via gene banks. However, to motivate farmers to continue on-farm management of landraces, subsidies or incentives would need to be provided by government or other actors in the public sector.
- Landraces in cell D play the dominant role in farmers' field and need no

specific support; landraces in cell B they have functional values that are favoured by many households. These include waxy maize landraces and could be supported more easily in an on-farm conservation strategy, as part of farmers' regular on-farm management, varietal maintenance and seed selection practices.

- Varieties in cell C are found in other provinces, such as the northern plains area, but have not emerged in the sample survey region, probably because the land scale is so small.

2.4. Conclusions

This study has shown that over the past ten years, there has been a rapid expansion of hybrids and the partial replacement of local landraces in mountainous regions of the three southwest provinces, Guangxi, Yunnan and Guizhou. Specifically in Guangxi some landraces have already become endangered as farmers have less interest in and concern for the future of local landraces for farmers living and with strong ethnic cultures. On the other hand, although there is a strong farmers' interest in accessing modern cultivars, farmers also indicate that landraces still play an important role within their agronomic and social-economic contexts and express strong reasons for maintaining at least some of the landraces that satisfy local preferences. The advantages of hybrids have been recognized but farmers recognize also a number of short comings, relating to the performance of the current applied hybrids in the bio-physical sphere (e.g. local adaptability) and in the socio-economic sphere (e.g. the taste and the low cost on seeds). Based on-farmers' reasoning and experiences, the need for the development of breeding strategies and support mechanisms for combining and integrating yield potential with local preferences (both bio-physical and socio-economic) has been identified. PPB is one such robustly demonstrated approach that can address smallholder farmers' needs, as well as combine conservation and crop improvement objectives of both landraces and hybrids.

The current breeding and seed policies put little emphasis on the maintenance and improvement of landraces. The utilization of landraces in modern breeding has been minimal in China so far, resulting in a narrowed genetic base in the hybrid seed made commercially available to farmers. This study has analysed different strategies for landrace conservation and utilization. For those endangered landraces, such as non-waxy maize landraces in Guangxi, it would be necessary to encourage both on-farm conservation by local farmers and *ex-situ* conservation via gene banks. Subsidies or incentives would need to be provided by government or other actors in the public sector. For landraces with functional values and still recognized by many households, such as the waxy landraces, on-farm conservation is more easily integrated into farmers' regular farm management, varietal maintenance and seed selection practices.

Supplementary material 1: List of hybrids planted by farmers in the survey areas, for 1998, 2003 and 2008.

Province	Variety	Source	1998	2003	2008
Guangxi	DH11	CPC	-	(2.8%) X	(4.7%) X
	AY3012	CPC	-	X	(3.7%) X
	LY16	CPC	-	X	-
	ZYW	CPC	-	-	X
	CC218	CPC	-	-	X
	DH13	CPC	-	-	X
	DH1	CPC	-	(2.5%) X	-
	CC	CPC	-	X	-
	DH2	CPC	-	X	-
	ZY18	CPI	-	-	X
	ZH6	CPI	-	X	X
	YY18/ZD14	CPI	-	X	-
	JKN	CPI	-	-	X
	ND108	CPI	-	X	X
	LY15	CPI	-	X	-
	ND102	CPI	-	X	-
	ND68	CPI	-	X	-
	LY	CPI	(5.2%) X	X	-
	HY	CPI	-	X	-
	LY13	CPI	X	-	-
	LY15	CPI	X	-	-
	HY4	CPI	-	-	X
	YY	CPI	-	-	X
	XY	CPI	-	-	X
	ND	CPI	-	X	-
	GD22	LIC	(6.4%) X	X	X
	GD30	LIC	-	-	X
	YMT168	LIC	-	-	X
	YMT601	LIC	-	-	X
	JK688	LIC	-	-	X
	NX15	LIC	(4.0%) X	(3.6%) X	-
	HD1	LIC	X	X	-
	GD26	LIC	-	X	-
	GY	LIC	-	X	-
	DA2	LIC	-	X	-
	GD	LIC	X	X	-
	GD1	LIC	(8.1%) X	-	-
	GD2	LIC	X	-	-
	ZD619	TNC	(2.7%) X	(18.6%) X	(44.9%) X
	ZD999	TNC	-	X	(12.2%) X
	DK007	TNC	X	(4.1%) X	(4.7%) X
	ZD818	TNC	-	X	X
	ZD618	TNC	X	-	-
	Number of hybrids		12	26	21
Yunnan	HH1	CPC	-	X	(25.5%) X
	HH2	CPC	-	-	(8.0%) X
	SQ1	CPC	X	X	X
	SY9	CPC	X	X	X

Yunnan	YY889	CPC	X	X	X
	YY15	CPC	-	-	X
	ZD2	CPI	(5.1%) X	X	X
	YD	CPI	-	(1.5%) X	-
	BY7	LIC	(7.1%) X	(20.5%) X	(21.3%) X
	HD4	LIC	(0.2%) X	(4.7%) X	(8.1%) X
	DY5	LIC	-	-	(4.5%) X
	BY16	LIC	(0.2%) X	X	X
	DY1	LIC	-	-	X
	BY2	LIC	-	-	X
	DY4	LIC	-	-	X
	DY6	LIC	-	-	X
	BY5	LIC	-	-	X
	YD3	LIC	(2.4%) X	(4.3%) X	-
	BY1	LIC	-	(4.3%) X	-
	QD	LIC	-	X	-
	XHD2	LIC	-	-	X
	Number of hybrids		8	12	17
Guizhou	LA1	CPC	-	-	(2.0%) X
	QC3	CPC	-	X	-
	LD527	CPI	-	-	X
	JD4	CPI	-	(5.0%) X	-
	CD	CPI	-	X	-
	PY5	LIC	-	X	(17.1%) X
	QX4	LIC	X	X	(9.2%) X
	PY2	LIC	(2.8%) X	(5.8%) X	(6.4%) X
	PY4	LIC	X	(2.3%) X	(2.5%) X
	BD4	LIC	-	X	X
	QD5	LIC	-	-	X
	GB302	LIC	(2.8%) X	(4.8%) X	X
	AD3	LIC	-	-	X
	GN318	LIC	-	-	X
	PY1	LIC	(8.7%) X	(7.5%) X	X
	PY3	LIC	-	X	X
	XHD999	LIC	-	-	X
	QD18	LIC	-	-	X
	QY3	LIC	-	-	X
	GB303	LIC	(1.3%) X	X	-
	QD4	LIC	(0.9%) X	-	-
	GB301	LIC	X	-	-
	JD136	LIC	-	X	-
	Number of hybrids		8	13	16

Notes: 1. 'X' means the respondent farmers plant this hybrid variety in responding year; '-' means farmers do not plant this variety. 2. TNC – transnational seed company; CPC – cross provincial seed company; CPI – cross-provincial breeding institute; LIC – local breeding institute & seed company within the province. 3. The top 5 hybrids of each year have been identified according to their growing area.

Source: Questionnaire survey in Guangxi, Guizhou and Yunnan, 2009-2010.

Supplementary material 2. Number of hybrids adopted in three provinces in 1998, 2003 and 2008.

	Guangxi	Yunnan	Guizhou
1998	12	8	8
2003	26	12	13
2008	21	17	16
Total	43	21	23
The same hybrid grown in all three years	3	7	5

Source: Questionnaire survey in Guangxi, Guizhou and Yunnan, 2009-2010.

Supplementary material 3. The percentage area and source of the top five hybrid maize varieties adopted in Guangxi, Yunnan and Guizhou provinces in years 1998, 2003 and 2008.

	1998			2003			2008		
	Variety	Area%	Source	Variety	Area%	Source	Variety	Area%	Source
Guangxi	GD1	8.1	LIC	ZD619	18.6	TNC	ZD619	44.9	TNC
	GD22	6.4	LIC	DK007	4.1	TNC	ZD999	12.2	TNC
	LY	5.2	CPI	NX15	3.6	LIC	DK007	4.7	TNC
	NX15	4.0	LIC	DH11	2.8	CPC	DH11	4.7	CPC
	ZD619	2.7	TNC	DH1	2.5	CPC	AY3012	3.7	CPC
Yunnan	BY7	7.1	LIC	BY7	20.5	LIC	HH1	25.5	CPC
	ZD2	5.1	CPI	HD4	4.7	LIC	BY7	21.3	LIC
	YD3	2.4	LIC	YD3	4.3	LIC	HD4	8.1	LIC
	HD4	0.2	LIC	BY1	4.3	LIC	HH2	8.0	CPC
	BY16	0.2	LIC	YD	1.5	CPI	DY5	4.5	LIC
Guizhou	PY1	8.7	LIC	PY1	7.5	LIC	PY5	17.1	LIC
	PY2	2.8	LIC	PY2	5.8	LIC	QX4	9.2	LIC
	GB302	2.8	LIC	JD4	5.0	CPI	PY2	6.4	LIC
	GB303	1.3	LIC	GB302	4.8	LIC	PY4	2.5	LIC
	QD4	0.9	LIC	PY4	2.3	LIC	LA1	2.0	CPC

Notes: TNC – transnational seed company; CPC – cross provincial seed company; CPI – cross-provincial breeding institute; LIC – local breeding institute & seed company within the province.

Source: Questionnaire survey in Guangxi, Guizhou and Yunnan, 2009-2010.

Supplementary material 4. List of landraces planted by farmers in the survey areas in 1998, 2003 and 2008.

Province	Name of landraces	Specific characteristics according to their naming by farmers	1998	2003	2008
Guangxi	Bendinuo	Waxy	X	X	X
	Bendihuang	Yellow kernel	X	X	X
	Bainuo	White kernel, waxy	X	X	X
	Hongnuo	Red kernel, waxy	X	-	-
	Baimaya	White kernel, dent kernel	X	X	X
	Mobai	White kernel, improved Tuxpeno 1, introduced from CIMMYT	-	X	-
	Hongyumi	Red kernel	-	X	X
	Jiahebai	White kernel, introduced from Jiahe1	-	X	-
	Huangnuo	Yellow kernel, waxy	-	X	-
	Bendibai	White kernel	-	X	X
	Total number		5	9	6
Yunnan	Bendinuo	Waxy	X	X	X
	Jiahebai	White kernel, introduced from Jiahe	X	-	-
	Huangnuo	Yellow kernel, waxy	X	X	X
	Bainuo	White kernel, waxy	X	X	X
	Bendibai	White kernel	X	X	X
	Huangmaya	Yellow kernel, dent kernel	X	X	X
	Hongnuo	Red kernel, waxy	X	X	X
	Baimaya	White kernel, dent kernel	-	X	X
	Bendihuang	Yellow kernel	-	X	-
	Huayumi	Mix-colored with white, yellow and red kernels	-	X	-
	Mobai	White kernel, improved Tuxpeno 1, introduced from CIMMYT	-	X	-
	Total number		7	10	7
Guizhou	Bendibai	White kernel	X	X	X
	Bendihuang	Yellow kernel	X	X	X
	Bendibai	White kernel	X	X	X
	Huangnuo	Yellow kernel, waxy	X	X	X
	Erjizao	Early maturity	X	X	X
	Bendinuo	Waxy	X	X	X
	Jiahebai	White kernel, introduced from Jiahe	X	-	-
	Baimaya	White kernel, dent kernel	X	X	X
	Hongyumi	Red kernel	X	X	X
	Mobai	White kernel, improved Tuxpeno 1, introduced from CIMMYT	X	X	X
	Huayumi	Mix-colored with white, yellow and red kernels	X	X	X
	Huanuo	Mix-colored with white, yellow and red kernels, waxy	-	-	X
	Total number		11	10	11

Notes: 'X' means the respondent farmers plant this landrace in responding year; '-' means farmers do not plant this landrace. As different landraces from different communities can share the same local name, while at the same time some landraces from different communities may not genetically exclude each other, the varietal diversity of landraces cannot be simply measured by their names.

Source: Questionnaire survey in Guangxi, Guizhou and Yunnan, 2009-2010.

Chapter 3

The potential of participatory hybrid breeding

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(submitted)

Abstract

Participatory plant breeding (PPB) offers a way to meet the needs of smallholder farmers for varietal improvement under unfavourable growing conditions. Current PPB programmes involve farmers mainly in the last stage of the breeding cycle before variety release, and target primarily open-pollinated varieties (OPV). However, smallholder farmers also have a need for better adapted hybrids. This paper explores the potential of involving smallholder farmers in hybrid development for low-external input farming systems. Hybrid breeding is technically more complicated than breeding improved open-pollinated varieties. We have developed a conceptual model of the procedures, based on five assumptions a) the hybrids are bred for adaptation to local needs and preferences, b) the dependence on and need for genetic diversity is taken into account, c) breeders collaborate closely with farmers also in the initial stages of the breeding programme i.e. in establishing the breeding goals by identifying the desired traits and preferred local populations as (one of the) crossing parents, d) hybrid seed production can be integrated into the farmers' local seed system, and e) farmers and breeders can agree intellectual property rights, access and benefit sharing in a fair and transparent way. We illustrate the procedural consequences of these assumptions with reference to the case of a PPB maize programme in Guangxi, southwest China, from 2000 to 2012, that included both OPV and hybrid maize improvement. We show how farmers' early involvement in hybrid development during the pre-breeding stage, including broadening the base populations with farmer-maintained local landraces, can support co-evolution of the genetic resources in farmers' fields.

Keywords

Participatory plant breeding; hybrid development; hybrid seed production; access and benefit sharing; maize; China

3.1. Introduction

Modern plant breeding programmes throughout the world have successfully improved crops in terms of improved yields, disease resistance, nutritional qualities and other traits of commercial value, especially for the major food staple crops such as maize (Duvick, 2005) or other cereals (Fischer and Edmeades, 2010). Most breeding programmes focus on conventional or high-tech farming systems where farmers' have access to synthetic chemical inputs for disease, pest and weed control and nutrient management. In such a context, where the external inputs compensate and smooth the effects of large environmental variability, commercial breeding companies can focus on the yield potential and wide adaptability of their cultivars, i.e. on the capacity of a crop cultivar to produce a high average yield across a wide range of growing environments and seasons. The resultant high-yielding cultivars have contributed greatly to yield increases, but the largest gains have been achieved mainly in the favourable production environments. They have proven less useful for farmers in marginal and variable environments who have no access to or cannot afford to purchase the inputs, and because the cultivars may lack sufficient plasticity to adapt to the spatial and temporal variability and diversity of the production environment or do not meet the farmers' cultural preferences with respect to characteristics such as taste, cooking quality, colour or marketability on local markets (Ceccarelli, 1989, 1996). To meet the needs of smallholder farmers in low-external input farming systems under unfavourable growing conditions a different approach is needed (e.g. Smith et al., 2001; Witcombe et al., 2003; Gyawali et al., 2007).

Most formal breeding programmes have come to be organised in a centralised way i.e. by conducting germplasm collection, crossings and selection in early generations and a number of stages of yield testing entirely on one or more breeding station, although the final stages of the cycle, such as evaluation and seed distribution, might be more de-centralised. Breeding goals are set by the breeding institute based on the breeders' knowledge of the targeted farming systems. However, breeding for marginal, low-external input farming systems in highly diverse agro-ecosystems requires information that might not be known to mainstream breeders. In these cases there are acknowledged benefits in participatory procedures in which farmers are included to varying degrees throughout the breeding cycles (Ceccarelli et al., 2000; Ceccarelli and Grando, 2007; Ceccarelli, 2009). The development of what is known today as participatory plant breeding (PPB) has become established since the 1980s as a complementary breeding approach with acknowledged advantages where, by strengthening the link between breeders and end-users, improved varieties can be developed that are adapted to low-external input and highly diverse farming systems (Ashby and Sperling, 1995).

3.1.1 Participatory plant breeding

Close collaboration between breeders and smallholder farmers can bring mutual benefits. Farmers can learn from breeders how to maintain and improve their local varieties and enhance seed production quality (Morris and Bellon, 2004). Breeders can benefit from farmers' knowledge and genetic materials from agro-ecosystems with which they were not yet familiar. PPB has been shown to increase breeding efficiency and varietal adoption and also to contribute institutional changes such as the socio-economic empowerment of an community and strengthening farmers' roles in maintaining and utilizing local genetic resources (Ceccarelli et al., 2000; Ceccarelli et al., 2003).

PPB is not a standard procedure; it has numerous forms, depending on the specific goals, crop and context. The term PPB commonly is used in a broad sense, regardless of how exactly farmers are involved, or in which stages of the breeding cycle. The main stages are (i) defining breeding objectives, (ii) creating genetic variability, (iii) observation of and selection among early generations, (iv) testing and evaluation of promising genotypes, and (v) variety release, including seed production and distribution (Sperling et al., 2001). These stages apply to both self-pollinating and open-pollinating species.

3.1.2 Current limitations of participatory approaches

The PPB activities described in the literature also have acknowledged limitations. First, it has been noted that most PPB activity involves farmers only in the last stage of the breeding cycle, before variety release and therefore they should be defined as participatory variety selection (PVS). This enables farmers to select, both on-farm and on-station, the best performing advanced varieties from a pre-screened set produced by professional breeders (e.g. Witcombe et al., 2006; Gyawali et al., 2010). Less effort has been devoted to developing and testing options for farmer involvement in the early stages of a breeding programme (Weltzien et al., 2003). Secondly, many examples of PPB focus on self-pollinating species such as barley (Ceccarelli et al., 2001), common bean (Almekinders et al., 2007) and rice (Sthapit and Rao, 2009). This is partly because on-farm selection of numerous lines of self-pollinating crops is more practical than for cross-pollinating species such as maize (Witcombe and Virk, 2001), where the individual lines have to be grown in spatially isolated plots. Modern maize breeding focuses mostly on hybrid development, in part precisely because the technical demands are more exacting, whereas PPB for maize usually addresses open-pollinated varieties (OPVs). Moreover, seed production of OPVs is easier for farmers to handle than hybrid seed production (Smith et al., 2001; Bänziger and Cooper, 2001; Duvick, 2009). Hybrid breeding also requires the performance of additional activities i.e. of developing parental inbred lines, and testing large numbers for their crossing abilities. Not only is hybrid breeding technically more complicated, it would demand more labour, land, capital and genetic expertise from farmers than in case of OPVs. Nonetheless, also

smallholder farmers in unfavourable production environments demand hybrids because carefully adapted hybrids can contribute to yield improvement even under these conditions (Li et al., 2011).

Although Duvick (2009) has indicated that in principle the involvement of farmers in hybrid breeding is possible, to our best knowledge it has not yet been described in the literature as a practical PPB activity. The aim of this paper is to discuss the potential of involving smallholder farmers in hybrid development for low external input farming systems. We argue that farmers' involvement in setting up the breeding goals, by identifying the desired traits and the preferred local populations to be used as crossing parents, provides the necessary foundation of the following breeding activities. We illustrate our discussion with reference to the case of a PPB programme in Guangxi in southwest China (2000-2012), that included both OPV and hybrid maize improvement. We identify and explore the feasibility of various types of cooperation between breeders and the extent to which it is possible to involve farmers in the early stages of participatory hybrid breeding. We also consider how to solve associated issues relating to intellectual property, access, and benefit-sharing.

3.2. A conceptual model for participatory hybrid breeding

Our conceptual model for participatory hybrid breeding is based on five assumptions: a) the hybrids are bred for adaptation to local needs and preferences, b) farmers' dependence on and need for genetic diversity is taken into account, c) breeders collaborate closely with farmers also in the initial stages of the breeding programme, d) hybrid seed production can be integrated into the farmers' local seed system, and e) farmers and breeders can agree fair arrangements in relation to intellectual property rights (IPR), access and benefit sharing (ABS). The model is first placed in context and then described.

3.2.1 Improved adaptation

The rise of hybrids impacted agricultural and food systems by increasing yields significantly. The first successes were achieved in maize (Duvick, 2005) and later in other crops such as rice (Zhang et al., 2009). Hybrids are varieties in which the F1 population is used as commercial seed, and include both cross- and self-pollinating species. Parents of the F1 can be inbred lines, varieties or populations. Hybrids have advantages for farmers themselves if the financial return from the yield increase conferred by hybrid vigour (heterosis) outweighs the extra cost of purchasing the seed. Hybrids can outperform OPVs not only in high-yielding environments but also in stressful growing environments, partly because the heterosis effect can increase stress tolerance, as shown e.g. in sorghum (Haussmann et al., 2000) and in maize (Kamara et al., 2003; Duvick, 2005). Duvick (2009) has stressed that as smallholder farmers have limited means to compensate adverse

growing conditions, maize varieties (either OPV or hybrid) should be bred for adaptation to local farm conditions and management and for yield that is reliable across good and adverse years.

3.2.2 Genetic diversity

Farmers maintain a diversity of varieties not only to meet their diverse cultural needs but also to match the different levels of water retention, soil fertility, aspect, and altitude of the numerous, often scattered pieces of land they own or use (e.g. in SW China, unpublished survey data, Li, 2010). PPB models encourage the in situ maintenance of diverse, locally adapted plant populations because farmers learn how to improve landraces that are adapted to each type of micro-production environment (Witcombe et al., 1996).

In addition to trans-varietal variation, the within-varietal genetic variation needs to be considered. In case that a hybrid is an F1 of inbred lines, the crop will consist of genetically uniform individuals. For cross-pollinating crops this uniformity can create an added value for farmers whenever uniform expression of traits is required e.g. the time of maturity, where the crop is mechanically harvested or in product performance (as required for some vegetable crops). However, Duvick (2009) has pointed out that the within-varietal uniformity of hybrids also can be a disadvantage e.g. in the case of susceptibility to a disease. In contrast, landraces or OPVs may have better plasticity due to the large diversity of genotypes in the population. Moreover, production risks can be reduced by growing different varieties of a crop within one field, either in alternating rows (see e.g. in rice Zhu et al., 2005) or as mixtures (see e.g. in cereals Mundt, 2002).

3.2.3 Farmers' involvement in the stages of breeding

In principle, farmers can be involved in all stages of a breeding programme. However, the stage at which it is necessary or useful for farmers to be involved is different for OPVs and hybrids, as discussed below and summarized in Table 3.1.

The initial stages. Weltzien and Christinck (2009) stress that, first of all, it is important for breeders to understand the complexity of the targeted farming systems with respect to the main agro-ecological and socio-economic limitations, the use of varieties, and seed management.

Regardless of whether the objective is an OPV or a hybrid, the involvement of farmers in the early stages of the breeding activity leads to better adoption rates (Soleri et al., 2002; Cleveland and Soleri, 2007). The earlier farmer participation occurs in a breeding cycle, the more opportunity farmers are given to influence the objectives, breeding strategy, and final outcomes. The extent

Table 3.1. Potential and technically feasible roles of farmers and breeders in a participatory maize breeding programme, comparing population and hybrid breeding process.

Breeding steps	Population breeding		Hybrid breeding	
	Farmers	Breeders	Farmers	Breeders
Defining objectives				
• Evaluating existing varieties on-farm	X	X	X	X
• Prioritising preferred traits and preferred diversity	X	X	X	X
Creating genetic variation				
• Collecting, maintaining and/or creating diverse (base) populations	X	X	X	X
• Identifying crossing parents	X	X	X	X
• Making crossings:				
for OP breeding	X	X		
for hybrid breeding			-	X
• Producing inbred lines			-	X
• Making test crosses			-	X
• Improving inbred lines			-	X
Selection (including test cross evaluation)				
• In field (on-station and in multi-locational farmers' fields and kitchens)	X	X	X	X
• In lab (e.g. disease resistance and quality tests)	-	X	-	X
Testing and evaluating expected varieties	X	X	X	X
Registration	X	X	?	X
Seed production				
• Parental seed provision	X	X	?	X
• On-farm seed production	X	X	?	X

Notes: X = yes; - = no; grey = not applicable; ? = depending on institutional options.

Source: this research.

to which farmers can realize this opportunity depends upon the degree of participation (Weltzien et al., 2003). Farmers also need to (learn to) understand various sources of variation. For instance, populations maintained by farmers, on a single farm or within a community, can vary within a single region, and even between men and women in the same community if they are involved in managing different plots and seed mixes, or are involved in different stages of crop production, utilisation and marketing (Bellon, 2002).

The collection and improvement of base populations is necessary for breeding both improved OPVs and hybrids. Usually the best local-adapted landraces are

used, often enriched with elite germplasm taken from other locations and gene banks. Breeders have knowledge and access to a worldwide collection of germplasm but farmers have access to the best adapted local varieties and knowledge about the characteristics preferred for their own growing conditions, end uses and markets. In addition, breeders have the skills to select base populations that can create an optimal heterosis effect in hybrid development.

Crossing and selection. In the development of OPVs farmers in principle can be involved in all stages of the breeding cycle. Farmers can learn to make crossings on-farm themselves (e.g. in rice, Medina, 2012), and can conduct selection for OPVs on-farm according to their preferences.

Hybrid development is more challenging for farmers since spatially isolated fields are needed to prevent out-crossing and because their landraces in many cases cannot be utilized directly in hybrid breeding (Duvick, 2009). It may take three to four years first to develop and select inbred lines for best combinability. Inbred lines are less vigorous and can be hard to maintain on-farm. They also need to be selected for high yield of the female line and sufficient and timely pollen production of the male line. The management of the inbred lines is also demanding because, for instance in maize, many thousands of inbred lines are produced but only a small proportion of the lines will be selected and further used. Our target farmers may find it difficult to carry out selection of large numbers of inbred lines in their own fields, given the size of their plots and the technical skills, energy and time required (Duvick, 2009). As an alternative one could consider subdividing the large number of inbred lines among several farmers with common checks. The requirements limit farmers' involvement in breeding single-cross (a cross of two inbred lines) and three-way cross (single-cross female × inbred male) hybrids, both of which are depend on the prior development of inbred lines. Professional breeders may have a comparative advantage in performing these tasks since they can more easily make the crosses on-station. Farmers still can be invited to evaluate the crossings on-station, to select better performing lines, and further test these on-farm. The professional breeders then can conduct further screening tests both on-station and on-farm before finally releasing and maintaining the variety. However, there are other ways to create hybrids and these might be easier for farmers themselves to perform: a top-cross hybrid (local OPV or landrace female × single cross male), a double-cross hybrid (cross of two single cross-hybrids) or varietal-cross hybrid (cross of two local OPVs or landraces, or exotic populations).

3.2.4 Seed production integrated into farmers' seed system

On-farm saving of OPV seed of can be relatively easy for those crops which produce grains for consumption, as with beans, barley and maize. However, farmers have (to learn) to apply mass selection to maintain quality and prevent degradation of the seed quality. When hybrid seed is saved on-farm for use in the next growing season the advantages of heterosis and uniformity will disap-

pear due to segregation in the next generations. The saved seed of hybrids will thus yield significantly lower than the original F1. In contrast, the saved seed of an OPV or landrace has more trans-generational stability. Farmers can only use a hybrid successfully if they purchase fresh F1 seed (in most cases the result of the cross of the parental inbred lines maintained by the breeder/seed producer), each growing season. This is commercially attractive for seed companies but makes farmers more dependent on the commercial seed sector. This dependency has been criticized by several authors in relation to farmers' seed sovereignty (e.g. Kloppenburg, 2010).

Duvick (2009) argues that a crucial precondition to the introduction of hybrid seed into low-external input farming systems is that the seed supply or supplier is reliable in the sense that the seed is reliably labelled, delivered in time and adequately priced. However, an aspect of the empowerment agenda of PPB is that it provides varieties that can be integrated into local seed systems by being maintained and bulked in the communities themselves. However, hybrid seed production is more complicated than that of OPVs as it requires isolation from other maize varieties to prevent undesired out-crossing, but also the separation of male and female parent rows and (for maize) the female rows need to be detasseled, operations which demand more space and labour.

If farmers are to produce the F1 hybrid seed on-farm, the breeders and farmers need to negotiate whether the farmers also will maintain the parental inbred lines or will make use of the breeders' expertise in maintaining the parental inbred lines on-station and in providing the farmers every year with appropriate seed for local seed production.

3.2.5 Intellectual property rights and access and benefit sharing issues

Even if a PPB programme is publicly funded a kind of plant variety protection (PVP) or other way of ensuring exclusive rights in commercial remuneration will be required. With respect to PVP, we note that there is a basic tension: if one aims at commercial remuneration, a strong interpretation of UPOV '91 is required that maximises PVP by means of so-called breeders' rights and limits farmers' privilege, but if one aims at maintaining a free exchange of farmers' seeds, then a wider farmers' privilege is required. Further, we distinguish that IPR issues arise in relation to at least three stages of a PPB breeding programme: i) breeders' access to farmer maintained maize genetic resources (landraces and local OPVs), ii) farmers' access to (by seed law) protected inbred lines and parent lines during the crossing and selection stages, iii) farmers' ability to save seeds of improved OPVs and produce hybrid seed for local market purposes. Several PPB programmes are experimenting with agreements between breeders and farmers on both the IPR and related ABS issues (Lammerts van Bueren et al., 2009; Song et al., 2012, and see Chapter 5 in this Thesis).

3.3. Case of participatory maize (*Zea mays* L.) breeding in Guangxi, southwest China

In this section we introduce the case of participatory maize breeding in Guangxi, by first discussing the general context of the programme and then analysing the applied hybrid breeding programme that has developed. We then analyse the differences between the hybrid and the OPV breeding activity, including technical intellectual property issues.

Information on this case was collected by previous project publications (Song et al., 2010, 2012), (unpublished) project documentation, and the authors' observations during participation as breeders and researchers.

3.3.1 Background

As one of the three most important food crops in China, maize is cultivated in a wide range of climatic and geographical conditions, resulting in significant differences in maize cropping patterns and practices (Meng, 2006). In 2008, a total of 30 million ha were used for maize growing, yielding in total 166 million tons (MoA, 2009). The current consumption of maize products for food (fresh cobs, maize flour for porridge) is only 5% of the total production; 66% is used for feed and 26% for starch, ethanol and other industrial purposes. In contrast, for small scale farmers in the southwest of China, where production is challenged by biotic and abiotic stresses relating to market, agronomic and climatic conditions, maize is the main staple food and its use as food, feed and raw material for processing are given equal importance.

Song (1998) has described how farmers in the southwest actively improve their local maize populations by applying their traditional knowledge. For instance, a white endospermed population variety Tuxpeño 1, previously introduced in China in 1978 by CIMMYT, became popular in the mountainous areas of the southwest because of its adaptability, stability and stress tolerance. However, over the years this variety, under farmers' management, degenerated because of out-crossing. A few women farmers decided to improve this variety by using traditional practices of positive mass selection of the best plants (good plants with big ears from the middle of the field), best ears (based on cob size, length, number of seed rows) and best kernels (from the middle part of the ear seeds selected for kernel size, shape, quality, colour) (Song, 1998).

It is generally thought that continuous selection among crosses of genetically related cultivars has led to a narrowing of the genetic base of the crops on which modern agriculture depends, contributing to the genetic erosion of the crop gene pools on which breeding is based (Plucknett et al., 1987; Sachs, 2009). Modern maize breeding in China relies greatly on a few inbred lines (Li et al., 2002; Yao et al., 2007). There has been a fast spread of modern high-yielding hy-

brids throughout China over the past decade, even in the remote mountainous regions of Guangxi, Yunnan and Guizhou provinces, but there is still a demonstrated need for improved adaptation of both open pollinated varieties (OPVs) and hybrids (Song, 1998; Li et al., 2011).

A participatory plant breeding programme in maize was initiated in 2000 in Guangxi to address small scale farmers' needs for improved locally adapted maize hybrids and open-pollinated varieties. The programme (see Figure 3.1) is on-going (2012). The project was initiated and facilitated by the Centre for Chinese Agricultural Policy (CCAP). During the first stage, the PPB team consisted of six farmer breeding villages from five counties of Guangxi, local extensionists from the five counties, and the public maize breeders from the formal, provincial breeding institute Guangxi Maize Research Institute (GMRI). The public maize breeders from the national Institute of Crop Science under the Chinese Academy of Agricultural Sciences (CAAS) worked on technological and policy issues related to maize improvement and genetic biodiversity management; sociologists from CCAP, the host institute of the PPB initiative, coordinated the activities and provided policy analysis and suggestions. The team overall consisted of farmers, institute breeders and policy researchers, i.e. it was purposefully multi-disciplinary.

3.3.2 Participatory hybrid improvement: the Guangxi PPB model

Hybrid improvement. The GMRI hybrid breeding programme focused mostly on single-cross hybrid development. It produced and tested the inbred lines on-station. The inbred lines were produced by the classical method of manual self-pollination over six cycles (three years × two cropping seasons per year) (only since 2007 some 20% of the inbred lines have been produced by applying the double haploid method). When the PPB initiative started in 2000, the GMRI breeders began to create several improved base populations based on farmers' trait priorities and they began also to maintain landraces, varieties and improved breeders' lines to enrich the genetic base of their formal breeding programmes. Based on farmers' trait and landrace preferences the breeders started the PPB hybrid breeding by selecting 50 sister lines (including Moyi W Wax) from a cross between the landrace Yishan Wax and an inbred line Mo17, and 50 sister lines (including Huang C Du W) between the landrace Duan Wax and an inbred line C-7002, see Figure 3.2. In spring 2000, the breeders made some 2500 crossings on-station by pairwise crossing the lines of the two groups, and tested the progenies for their combining abilities in the autumn of 2000, and pre-selected 15 experimental F1s.

In spring 2001 farmers were invited on-station to evaluate and select their most preferred F1s out of the 15 experimental waxy maize hybrids, and selected three F1s ('Guinuo 2006', 'Guinuo 2007', 'Guinuo 2008') to test in their own fields, mainly based on their performance related to drought conditions, lodging resistance, taste of the fresh cobs, yield and estimated local market value (price).

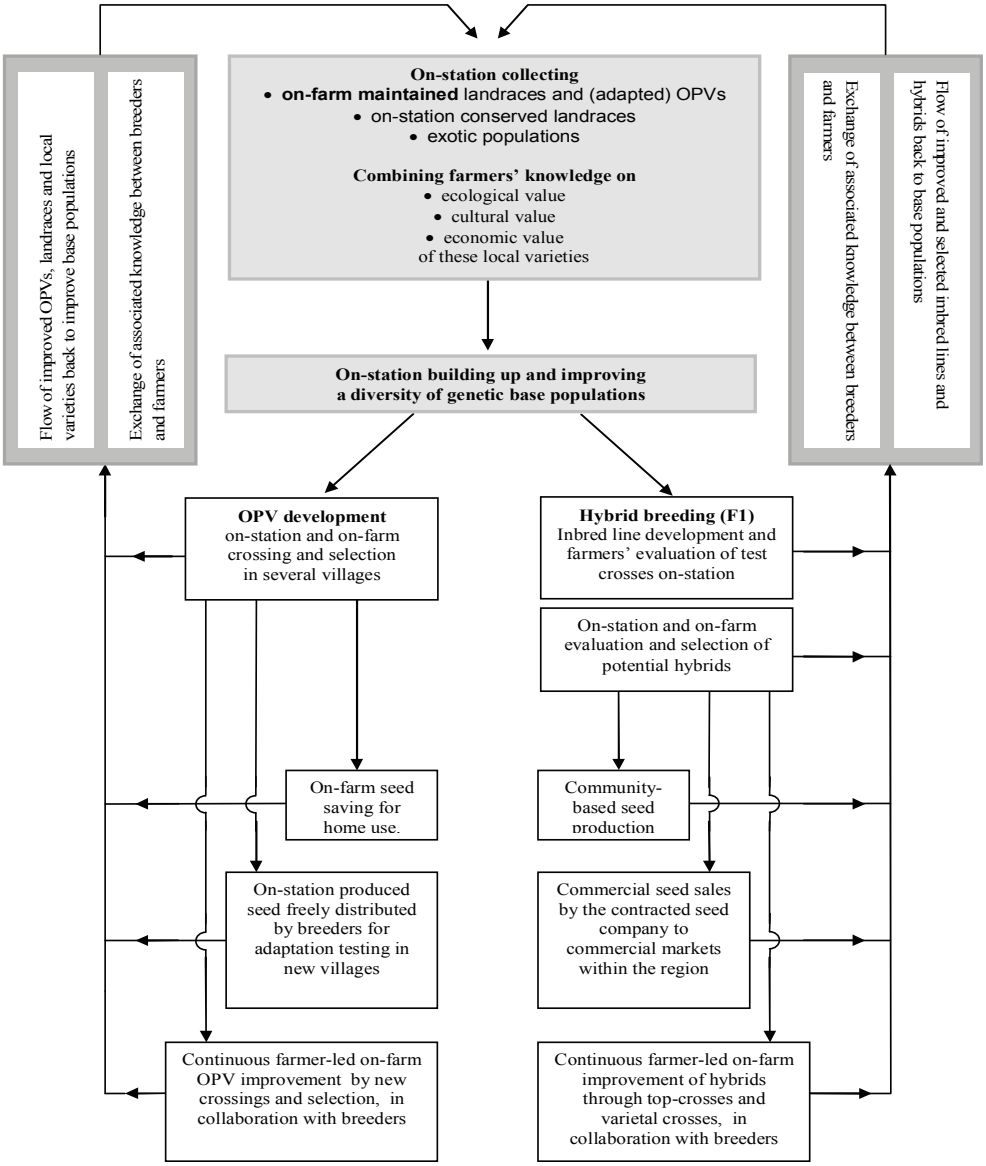

Figure 3.1. Creating open-pollinated and hybrid maize varieties through participatory plant breeding in the Guangxi model.

Source: this research.

In the autumn of 2001 the three experimental hybrids were introduced to two trial villages and in 2002-03 to three trial villages that were located at different altitudes, for adaptation testing by farmers, who planted 20 plants in two rows for each variety (see Table 3.2). The farmers evaluated the F1s in the field at least twice per growing season, and in addition: (i) after flowering they visually evaluated the cobs (kernel size, kernel rows, shape, top and depth); (ii) after harvesting they evaluated the kernels (colour, shape, kernel test weight). Farmers in each of the trial villages first discussed their preferences and then the farmers from all the trial villages met in combined meetings to pool and further discuss their preferences. The waxy hybrid 'Guinuo 2006' was identified through this process as the top shared preference, mostly for its taste and yield potential. An additional reason the farmers gave for choosing 'Guinuo 2006' was because one of the original parent lines is from a PPB trial village. The fresh cob of 'Guinuo 2006' also was judged suitable for selling as a steamed, warm snack, which is quite popular in the local food culture and profitable for farmers. The farmers' and breeders' final choice of 'Guinou 2006' was based on the on-station results, farmers' field testing and subsequently also on the seed production performance. 'Guinuo 2006' was officially registered and released in 2003.

The 'Guinuo 2006' was a single-cross hybrid produced on-station by the GMRI breeders in 2001 (see Figure 3.2.). The base for this hybrid was a crossing between two inbred lines; these parents were derived from two different crosses (made in 1998) of inbred lines of two landraces. One of the landraces was collected from a local village, Zicheng in Duan county, during the impact study carried out in 1996 (Song, 1998). Zicheng had become involved in the PPB programme in 2000. The other landrace was from a local village in Yishan county. Although the selection of the base for this hybrid started in 1996 before the PPB programme was officially initiated, it was nevertheless considered by the partners as a PPB variety because farmer maintained landraces formed the base of the hybrid, and because farmers had been involved in the on-station selection, and on-farm testing (see Figure 3.2.).

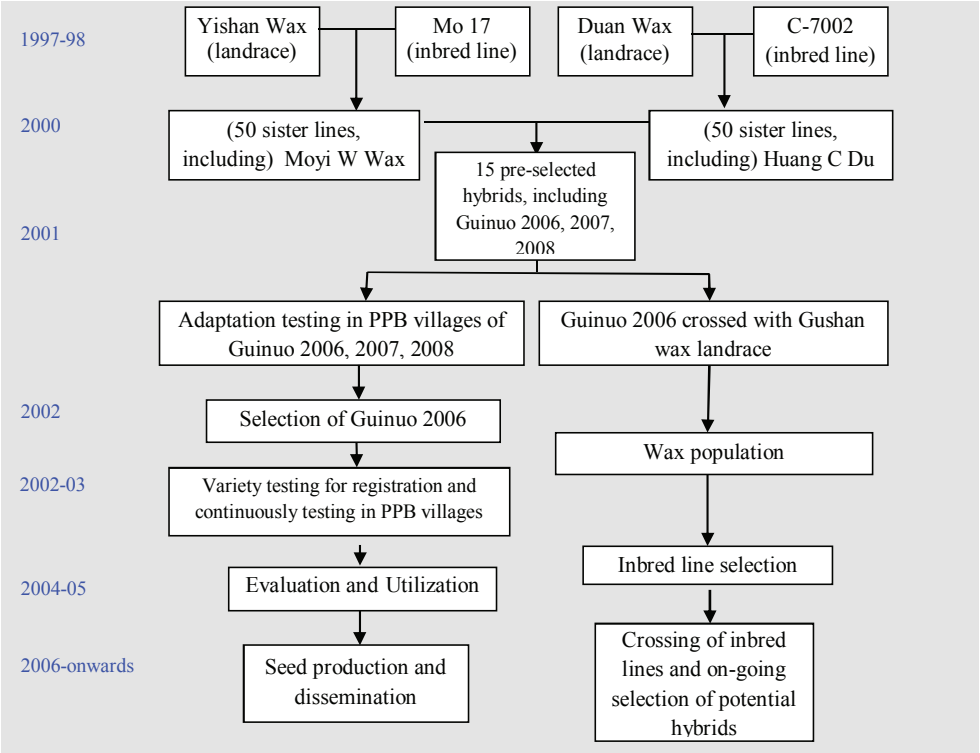

Figure 3.2. Participatory breeding scheme for the development of the hybrid Guinuo 2006 (adapted after Song et al., 2010).

Hybrid seed production. The PPB hybrid Guinuo 2006 soon became one of the most popular waxy varieties among the local communities, and farmers wanted to produce the hybrid seed themselves. Within the framework of the PPB programme, the institute breeders were willing to experiment on developing a fair access and benefit sharing (ABS) arrangement by sharing with the farmers both the seed and inbred lines for community seed production. Under the final benefit sharing agreement between the involved farmers and breeders, the farmers of two trial villages (of which only one (Guzhai) decided to continue after the first year) were allowed to produce the hybrid seed for their local farmers' seed market. In addition, the breeders contracted a commercial seed company to produce seed for the regional commercial seed market. Table 3.3 shows the number of farmer households involved in seed production in one of the selected villages, Guzhai village.

From 2005 through 2008 the farmers in Guzhai who were interested in becoming seed producers (all women) were trained by the breeders in on-farm hybrid seed production. To prevent outcrossing, the farmers were trained to use spatial isolation (remotely positioned plots) or time isolation (by planting

earlier or later than other varieties to prevent outcrossing or at least to reduce the risk of this to an acceptably low level). In some cases they put 'paper hats' onto the ears before silking if there was still a risk of undesired outcrossing. The breeders visited Guzhai several times each season, especially during the stages of sowing, flowering, crossing, and harvest. On a number of occasions, female and male flowering proved to be asynchronous and so the farmers were not able to produce the hybrid seed. In these instances they allowed the plants to be pollinated by the maize plants on the adjoining land and used the resultant cobs only for home consumption. The scale of community-based seed production in Guzhai was discussed and planned during annual meetings organised for programme staff, the farmers and breeders, and at the appropriate time the breeders provided parental seeds for the village's designated seed producers. Each seed producer household provided one plot for seed production, and planted four female rows next to one male row. They detasseled the female plants by hand.

Table 3.2. Overview of on-farm testing for adaptation of potential F1 varieties (including 'Guinuo 2006'), showing the number of households and the average plot size per household (in m²) in the involved trial villages, Guangxi province, 2000-2003.

Villages / Year	2001	2002	2003
Guzhai (at approx. 800m altitude)			
Nr of households	5	6	6
Average plot size (m^2)	130	110	110
Wentan (at approx. 100-200m altitude)			
Nr of households	7	8	8
Average plot size (m^2)	190	170	170
Zicheng(at approx. 1000m altitude)			
Nr of households		3	3
Average plot size (m^2)		110	110

Source: this research.

Table 3.3. Community-based hybrid production of 'Guinuo 2006' seed in Guzhai village, from 2005 through 2011.

Year	Nr. HH	Total area (m^2)	Seed yield (kg)	Seed price (US $/kg)[1]	Income (US $)[1]	Challenge
2005-S	5	1300	7.5	0	0, all for self-consumption	drought, lack of technical skills
2006-S	2	700	49	3.79	185	
2006-A	5	1400	44	3.79	167	
2007-S	7	1400	85	3.79	322	
2007-A	6	1300	55.2	3.16	179	
2008-S	11	3300	205	3.79	712	could not sell the whole quantity in one season; difficult to enlarge local market, so decision to reduce area for next season
2008-A	6	2000	0	0	0	failed because of flood
2009-S	6	1400	78.5	4.58	364	technical problem, market
2009-A	7	2000	48	5.68	273	drought
2010-S	6	2000	148.5	5.05	747	drought
2010-A	8	2300	73.5	5.05	371	
2011-S	6	2000	165.5	5.14	851	

Notes: S = Spring season; A = Autumn season. HH = household; [1] calculated from the exchange rate of 1 yuan = 0.16 US dollar

Source: this research.

The farmers' participation in hybrid seed production increased their on-farm income (Table 3.3). However, the seed yield proved to be very unstable across years (see Table 3.3). Such instability may be caused by a) severe weather conditions, for example drought or extreme rainfall, b) farmers' inexperience in hybrid seed production techniques, and c) the heterogeneous land conditions available to each household. Even when the yield was satisfactory, the farmers learned that they still needed to be pay attention to the storage and marketing of the seeds. Considering the (varying) demands of the local market, the farmers decided not to expand seed production too fast, recognising that they needed to build their experience and competence gradually. From the autumn season of 2007 onwards, the seed production group decided to charge 1 yuan (= approx. 0.16 US dollars) per kg from the sales as a management fee; this was distributed among the three leading farmers. These three took on responsibility for the technical training, daily farm management, communication with the formal breeders, and selling the seeds on the local market. From the autumn season of 2009, besides the management fee, the farmers decided to deduct 2 yuan (= approx. 0.32 US dollars) per kg from the sales in order to create a community fund that could sustain their activities.

3.3.3 Participatory breeding of open-pollinated varieties

Participatory breeding of OPVs differed from hybrid breeding in several ways (see further below). However, the start of the OPV programme was in general the same as for the hybrid breeding programme, (see Figure 3.1): the breeders discussed with the farmers their needs and transformed the findings into a strategy for both hybrid and OPV improvement which were then carried out as parallel activities.

OPV breeding. First, a number of farmer-maintained varieties that might be suitable as potential crossing parents and form the base of the OPV breeding programme were selected by the programme researchers and institutional breeders. (The step of deriving base inbred lines, which is necessary for breeding hybrids, is not necessary in OPV breeding). The breeders at the start of the OPV programme thus could select and use directly the white endospermed OP variety Tuxpeño 1 from Wentan Village as the female line. A a white endospermed, local landrace from Zicheng Village was selected as the male line (see Figure 3.3). The crosses of these varieties were carried out both on-station at GMRI and in Wentan and Zicheng. The breeders trained the farmers who wanted to make the manual crossings. However, the first crossings made in the villages were not successful because of natural failures and environmental stresses. The crossing on-station were successful and they were passed to the trial farmers in the two villages, who carried out on-farm selection over the following generations. The first cross that emerged ('Xin Mo 1') was thus a varietal cross selected by farmers (PVS). It was highly appreciated by the farmers as it proved to be very drought resistant. 'Xin Mo 1' was further improved over five cycles of positive mass selection (two per year), carried out in six trial villages. The number of seeds planted in each selection cycle depended on the farmers' field size but a minimum of 250 plants was recommended in order to impose a selection pressure of approximately 20% i.e. to select some 50 plants from which to collect seeds for use in the next cropping season. On-station normally the population size under mass selection is approximately 2000 to 2500 plants. Throughout the on-farm selection cycle the farmers in the trial villages discussed their preferences, first in each village and then and across villages in combined meetings. This effort resulted in the white endospermed 'Improved Xin Mo 1', which yielded approximately 15% more than other local farmers' varieties (unpublished project reports). Farmers' preferences were incorporated successively in the subsequent selection cycles, focusing on the dominant preference for a higher market value by changing the kernel colour from white to yellow, and by improving the taste. The breeders assisted in achieving this ideotype by making two new crosses on-station, first between the 'Improved Xin Mo 1' and a breeder's line ('Amarinto 96') as the male line, in order to improve the kernel colour. The farmers in six villages then selected Zhong Mo 1 among the F1 progenies when they observed that this new yellow endospermed selection resulted in approx. 20% more yield and in 5% more income than the existing local white varieties (Song et al. 2006). However, they then decided that they wanted to improve the stress resistance

and taste quality a bit more and therefore an additional cross was made on-station between 'Zhong Mo 1' and 'Suwan 1' (an exotic variety from Thailand introduced by the breeders). This resulted after farmer selection in 'Zhong Mo 2' which was further improved in three cycles of full sib family selection (ear-to-row selection from 100 to 250 plants each cycle).

The farmers evaluated the breeding populations at least twice per generation: after flowering and after harvest. The farmers marked their individually preferred plants in the field by tying a leaf around the stem, and then selected the best ears on the marked plant for planting in the next generation.

The institute breeders continuously facilitated the whole selection process and collected and analysed the information on farmers' needs and selections. In addition, the breeders trained the farmers in both positive and negative selection so that they would have the skills to further maintain and improve their landraces.

OPV seed production. The OPV seed was initially provided in the first growing period by the institute breeders, to ensure that the farmers' seed production efforts started with quality seed. In the following years, the farmers managed their own seed production by on-farm seed saving. The GMRI breeders provided some extra, free seed when farmers encountered seed shortages because of adverse weather and other unexpected reasons.

'Xin Mo 1' and 'Zhong Mo 1' were planted continuously in all the PPB villages. They proved to be better adapted and more popular in two villages (Wentan and Zicheng) from Wuming and Duan provinces for the reason that the two parent lines are from the two villages respectively. Farmers also planted and tested 'Zhong Mo 2' for two years (2005-2006), but concluded that its productivity and kernel was not as good as 'Zhong Mo 1' and they disposed it.

3.3.4 Intellectual property rights and access and benefit sharing issues

During the more recent years of the PPB programme, China's policy has favoured two seed systems (developing the commercial seed sector and supporting small farmers' need for improved seed). Smallholder development has been central in the PPB programme's work. Smallholder farmers need public research and PPB because private and commercial seed breeders have not shown any interest in breeding for the specific problems of particular regional landscapes, minority crops, and particular categories of smallholder farmers. By recognising farmers' input to the PPB programme, the institute breeders implicitly took farmer-breeders' rights into account; this subsequently was formally expressed by joint negotiation of an agreement for sharing the benefits of PPB hybrids (Song et al., 2012). The institute breeders agreed to continue to support the farmers' PPB activities and allowed designated farmers from selected villages to produce the hybrid seed in limited quantities (for their local market only). The

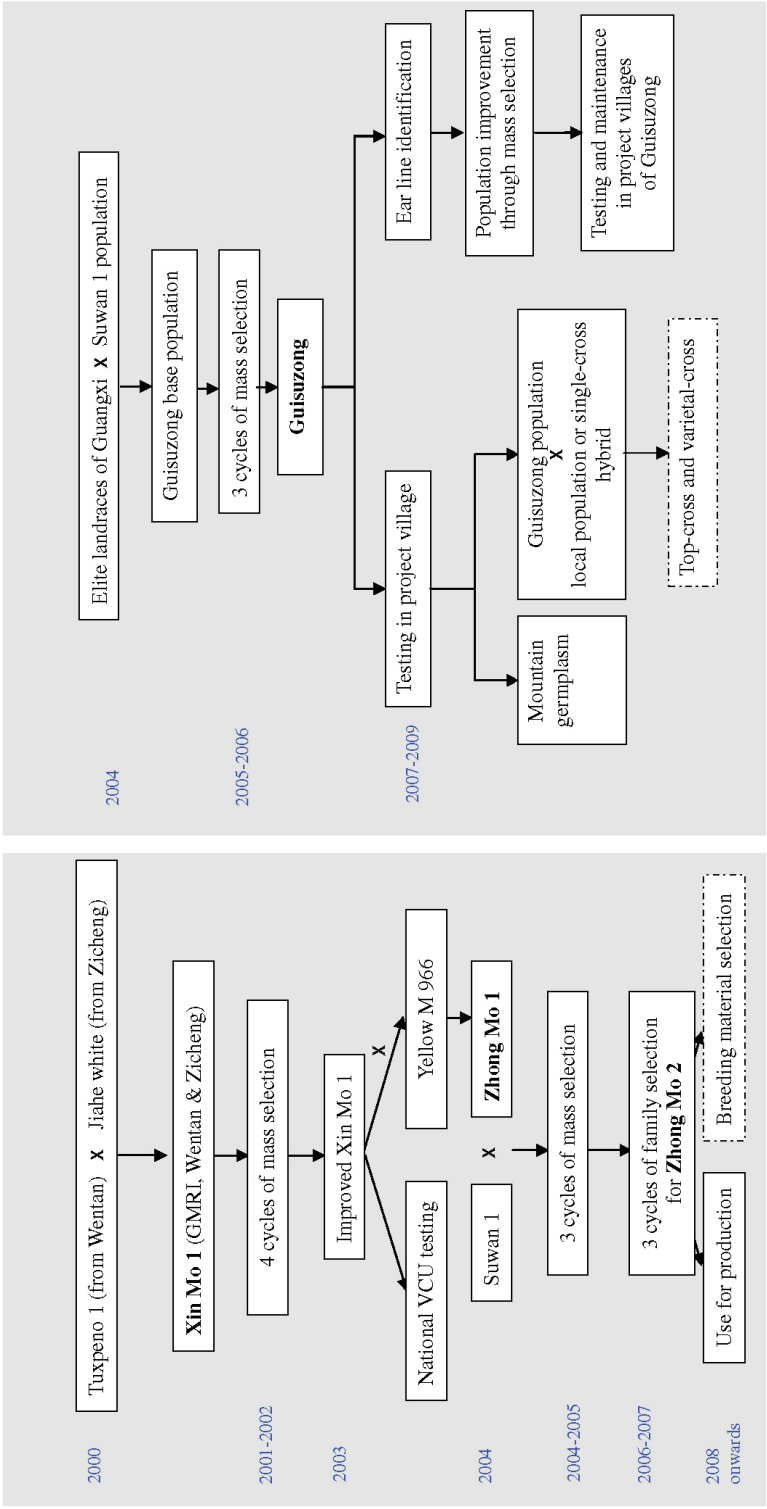

Figure 3.3.a and b. (a). Participatory breeding scheme for three open pollinated maize varieties Xin Mo 1, Zhong Mo 1 and Zhong Mo 2, produced in Guangxi, southwest China, from 2000 to 2007 (adapted after Song et al. 2010). 3.3. (b). Participatory breeding scheme for the 4th open pollinated maize variety Guisuzong, produced in Guangxi, southwest China, from 2004 through 2009.
Note to figure: there are two maize growing cycles per year.

villages were selected based on their isolated location and remoteness from commercial markets in order to reduce the risks of bio-piracy. In addition, the PPB team negotiated a contract describing the process to be followed so that PPB farmer-breeders could apply for plant breeders' rights jointly with the institute breeders.

An ABS contract also was jointly negotiated. It was designed and signed in 2010, under which the Guangxi PPB programme agreed on the right of the participating farmers to receive a maximum of 25% of the royalties whenever a farmer-maintained landrace was more or less directly adopted as a parent line in development of a hybrid (Song et al., 2012). In addition the programme negotiated a related ABS contract that set out the terms of agreement for the continued conservation, management and by farmers of *in-situ* landraces. Under this contract the farmers are compensated for their contribution whenever the institute breeders' collect and utilize the farmers' landraces.

From 2000 through 2011 four OPVs and one hybrid has been bred under the participatory maize breeding programme in Guangxi. There are five test sites for waxy maize in Guangxi, for testing the Value for Cultivation and Use (VCU) at GMRI, agricultural research agencies in Liuzhou, Hechi, Beihai, and the Tianyang seed company. The PPB hybrid Guinuo 2006 passed the Guangxi (regional) VCU test in 2002 and was officially released into the provincial seed market in 2003. For non-waxy maize, the test sites are located in Guilin, Nanning (at a GMRI sub-station), Jingxi, Tiandeng and Hechi. A PPB OPV, 'Xin Mo 1', was tested in the national VCU trials in 2003 but did not pass the test. In 2005 and 2006, another PPB OPV 'Zhong Mo 1' was entered in the regional Guangxi multi-location variety trials and performed well. Because the PPB farmers highly appreciated the new varieties they decided, with the continued support of the GMRI breeders, to continue to produce the seed and circulate these varieties in the local communities, mainly for self-consumption, and on a limited scale. No attempt was made to register the subsequent improved OPVs and further production and utilization of these has relied on their comparative advantage in local adaptation and in meeting farmers' preferences.

3.4. Discussion and conclusions

In this paper we have analysed the potential of involving farmers in the development of hybrids adapted to low-external input farm management, and the advantages of including them in early stages of the breeding cycle.

Morris and Bellon (2004) indicated that a major challenge in managing a participatory breeding programme is structuring the design, so that the end-users participate in the stages of the breeding cycle where participation can improve the effectiveness of the programme and better serve the specific needs of the end-users. In order to create such a design the breeders need to understand the

agronomic, cultural and socio-economic drivers of farmers' the needs and this information can be gained only where there is close communication between farmers and breeders in the workplace of both parties i.e. on-farm and on-station. This does not necessarily imply that the farmers should be involved in all technical handling procedures but they do need to be involved in critical decisions– we have argued that this starts at the point at which the starting material is chosen. The fact that in our PPB example the Guangxi maize breeders recognised farmers for their contribution to the maintenance of genetic resources, and also recognised some landraces and farmer-improved OPVs as a good base for further hybrid and OPV improvement, positioned their interaction with farmers at the base in the cycle of crop improvement. From the start the farmers have profited from the breeders' knowledge and have become further skilled in selection, seed production and maintenance and the breeders have come to realise through the collaboration the value of farmers' knowledge and to appreciate what they can, technically, bring to crop improvement. Their close collaboration in the early stages of breeding cycle demonstrated to the breeders how they could access unknown germplasm and knowledge, and how opportunities for broadening the genetic base of their base populations could be developed. The a continuous process of interaction enabled them to better serve smallholder farmers within their institute's public breeding function, for both OPV and hybrid improvement.

The Guangxi farmers participated and contributed technically more in the OPV selection cycles than in the hybrid breeding process, in terms of decision making, knowledge, labour, and land. They profited from the expertise and facilities of the institute breeders especially in generating parental inbred lines that could be combined to obtain optimal heterosis effects, At the same time, the farmers were involved in testing and evaluating advanced experimental hybrids. Farmers' endogenous roles in crop improvement have been enhanced rather than replaced through the collaboration. The breeding institute became more appreciative of farmers' contribution to the pool of knowledge and of the feedback farmers' contributed during the selection of the starting material and during the evaluation of experimental hybrids on-station. They also valued farmers' contribution during the on-farm field evaluations, which provided understanding that they could not acquire by relying only on multi-environment Genotype × Environment testing in fields rented from farmers.

According to the varying degrees of farmers' participation in PPB programmes Weltzien et al. (2003) described, the Guangxi participatory hybrid breeding allowed a form of collaboration in which breeders and farmers shared tasks, along lines determined by the formal research institute; whereas the participatory OPV development allowed a more collegial participation, whereby the institute breeders supported a farmer-initiated and farmer-managed programme.

Farmers are more challenged by hybrid compared to OPV seed production because it is not only a risky but also costly activity. For instance, there is the risk

that weather events will influence the synchronisation of the flowering of the male and female parents. It involves complicated procedures that require specialised genetic expertise, labour and capital. For example, if the land is used for seed production, then it cannot be used for intercropping and seed production is labour-intensive compared with the cultivation of other field crops. Despite the risks, some farmers are attracted by the opportunity to improve their skills and understanding and by the additional income they can gain by marketing the seed. The Guangxi programme has shown over several years that farmers can produce and market hybrid seeds successfully. However, we note that not all farmers will be willing and become capable of handling on-farm hybrid seed production. From the Guangxi experience we observe that commitment to hybrid seed development, seed production, and marketing tends to be carried out by farmers who are interested in becoming specialists, who are motivated by entrepreneurial opportunity and have the managerial capacity to maintain demanding technical and quality standards through the seed value chain to the point of sale.

Integrating hybrid seed production into the local seed systems, by allowing farmers to carry out hybrid seed production and marketing, can be considered an important aspect of the empowerment effects of PPB. However, the farmers still rely on parent lines provided by the breeders. We propose that there are at least three prerequisites for successful integration: 1) formal breeders continue to provide parental seeds and technical training; 2) farmers obtain permission, encoded in formal agreements, from the breeders and related seed company; and 3) the quality and quantity of farmer produced seed can be controlled.

As hybrid breeding is more costly than OPV development, intellectual property rights in the form of breeders' rights increasingly are demanded by formal breeders. Inbred lines are their capital but they are not officially protected and that is why breeders are not very keen on allowing those parent lines to be grown outside the station's own fields. The largest institutional challenge in the Guangxi example has been to develop an agreement on IPR and ABS issues - there was no standard format available that is suitable for use a PPB context. The Guangxi experience suggests that the development of mutual respect through structured interaction over time is an essential base for coming to such an agreement between farmers and breeders in a transparent way (see Chapter 5). Bänziger and De Meyer (2002) also note that trust is an essential element in collaborative approaches and this cannot be simply taken for granted or replicated under different circumstances.

Maize hybrid seed production is conceptually simple because maize has separate male (in the tassel) and female flowers (in the ears). Rows of detasselled plants can be used as female parent material that receives pollen by the wind from adjacent rows of non-detasselled plants of a contrasting genotype. For other crops, such as brassicas, production of hybrid seed is more complicated as male sterility or self-incompatibility must be available or introduced into the

female parental line if laborious manual emasculation of each plant is to be avoided. But once parent lines have been developed and can be made available to farmers, the production of hybrid seed for other crops also should be feasible for smallholder farmers, so long as the required isolation distances are taken into account to avoid undesired outcrossing.

In other words, we suggest that the fact that hybrid breeding in some stages is technically complicated should not prevent the involvement of farmers in the early stages of the breeding cycle - to discuss preferred starting material and prioritize traits, to evaluate and select testcrosses on-station, and to enable the collaborating farmers to test the preferred crosses on-farm. Nevertheless, hybrid breeding will not be the only solution for smallholder farmers. Bellon and Hellin (2010) have argued from their experience with maize breeding in Mexico that there is a need for both local landraces and hybrids to serve the multifunctionality of the maize crop. In the Guangxi case, the hybrids were planted for sale because they satisfied the farmers' commercial aspirations, while the landraces were kept for self-consumption because they satisfied their consumption preferences and food security concerns. The Guangxi PPB example shows how hybrid and OPV improvement can be integrated as parallel efforts in one breeding programme.

One important challenge remains for the future. As hybrids have to be created anew every year and cannot be usefully saved on-farm, they do not contribute to the on-farm evolution of genetic materials that maintains adaptation to local farm conditions. Yet, if farmers and their PGRs continue to participate in prebreeding activities, and at the same time maintain their PGRs on-farm, evolution continues on-farm at the same time that it contributes to hybrid breeding. This would provide strong incentives for both breeders and farmers to continue to engage in PPB and biodiversity conservation, and for policy-makers to provide support for such collaboration. However, this would require more appropriate supporting institutions and the negotiation of fair ABS regulations and mechanisms as standard practice.

Chapter 4

Towards a regime change in the organization of the seed supply system in China

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(submitted)

Abstract

This article explores changes in the organization of seed supply in China over the last decade, by means of a multi-level institutional analysis. At the landscape level, the implications for China of the regulation of plant genetic resources through various international treaties and conventions are reviewed in the light of the evolution of the global seed industry. At the regime level, the transition in the Chinese context to market-based seed supply and the development of commercial and public seed sectors are examined. The study then analyses trends in seed supply at the niche level, with reference to participatory maize (*Zea mays* L.) breeding in three provinces in southwest China where high rural poverty persists. This work offers radical novelty in variety development and seed provision on behalf of smallholder farmers. However, a series of technical, organizational and market 'mismatches' are demonstrated within the existing seed regime. The participatory work emphasizes breeding for diverse cultivars adapted to specific eco-systems but these are prevented from reaching commercial markets by existing varietal testing procedures. Participatory breeding has potential to address farmers' varietal needs as agriculture modernises and to support the public function of research institutes but within mainstream intellectual property regimes the public value of participatory breeding cannot be accommodated adequately. Yet, when coupled to institutional innovations for recognising intellectual property and sharing benefit among all those who contribute, participatory breeding, may initiate a powerful dynamic for change within seed regimes and a sui generis seed system suited to the Chinese context.

Keywords

Seed supply system; China; institutional innovation; participatory plant breeding

4.1. Introduction

The development of biotechnology and the commercialization of plant genetic resources (PGRs) over the last decades have fostered multi-level institutional transformation in seed sectors worldwide. There are a range of interests involved, expressed in and through international treaties and agreements, and this has led to some tension among the competing interests (Louwaars, 2007). At the national level, the opening up of the Chinese domestic seed market in 2001 and China's compliance with international agreements on entry into the global trading system, has caused a series of institutional transformations in seed supply, accompanied by the expansion of the market share of transnational seed companies, the emergence of domestic commercial seed sectors and changes in the functions of public research institutes. An increasing number of public-private partnerships among various private and public actors in agricultural research and development (R&D) have been created over the past ten years (Wang, 2005; Zhu, 2010). However, the shift towards commercialisation of the functions of the Chinese public breeding sector has led to a growing neglect of smallholder farmers' interests, especially in relation to their requirements for suitable cultivars and quality seeds for less-favourable environments (Liu and Jiang, 2010).

The current situation in China's seed systems is complex. A variety of changes are impacting the relationships among key actors, situated at different levels, but not necessarily in concert. A multi-level perspective (MLP) on such complexity has been developed and used as an analytical tool in innovation studies (e.g. Geels and Schot, 2007). It has not yet been applied to the analysis of seed systems in China. This paper explores the potential of a multi-level perspective to understand the seed system, particularly taking into account the tensions and opportunities for niche developments oriented toward smallholders, which we examine through the case of participatory plant breeding (PPB). Within current institutional arrangements the further expansion of PPB is challenged by cultivar testing procedures and organizational arrangements between public institutes and market actors. These issues call for institutional innovation at the local level but also for changes in existing institutions at higher levels. The paper addresses these issues by integrating a multi-level perspective of institutional change (Geels, 2006) into an analysis of the dynamics of system innovation in seed supply. System innovation refers to innovations that fundamentally change relationships and the rules of the game within a set of activities considered as a system. The multi-level perspective distinguishes analytical and heuristic concepts to understand system innovations through introducing a hierarchy, from higher to lower, of institutional change at landscape, regime, and niche levels. The relationship among the three levels can be understood as a nested hierarchy, meaning that niches are embedded within regimes and regimes are embedded within landscapes (Geels, 2006). The distinction between the levels is made on the basis of the stability and structuration of relationships at each level (Deuten, 2003):

- At **niche levels,** there is limited stability in rules and uncertainty about future directions. Change is created at the micro-level where radical novelties in technique, practice or organisation emerge and are carried and developed by small networks of dedicated actors, often outsiders and fringe actors in the local situation. Niches open a space for experimentation and learning.

- Regimes are semi-coherent sets of inter-linked rules. They are more stable than niches, since the rules are shared among many different locations. Regimes offer greater structuration to local practices and socio-technical relationships (Raven, 2004). Transitions occur when processes emerge either at niche or landscape levels that catalyse change from one socio-technical regime to another (Geels and Schot, 2007). Regimes provide stability by guiding perceptions and actions, while the niches act as incubators of radical novelties. The creative work in niches often is geared to the problems created by the existing dominant regimes; the niche actors typically hope that promising novelties eventually are used in or even replace the dominant regime. However, radical novelties may not 'match' the existing regime and do not easily break through. The nature and timing of the catalytic action thus becomes an important research question.

- Landscapes refer to aspects of the wider exogenous environment that affect socio-technical development. They are beyond the direct influence of actors in the regime or at niche level and cannot be changed at will. The landscape level can be thought of in evolutionary terms as a dynamic selection environment that is linked to wider external developments in the natural and human worlds.

During a process of system innovation actors in the dominant regime tend to resist change. The initiative for change starts in an isolated niche environment, usually a protected space created, for instance, by a project. Local initiatives compete with each other in a selection environment that includes the existing socio-technical regime, as well as the wider developments at the landscape level. Niche initiatives persist and grow only when changes are achieved at the regime level. Those that cannot influence the regime ultimately fail. The space for change can be enlarged when constraints caused by the dominant regime are modified, removed or transformed (Leeuwis and Aarts, 2011). Changes in the various dimensions of the regime, such as legal rules, norms and values, procedures, and relationships among commercial and public organisations over time may lead to structural change at the regime level. This paper takes the PPB project in southwest China as a model niche initiative that confronts and aspires to change regime-level constraints at a time when the institutional provisions governing seed supply at landscape level are themselves undergoing change.

4.2. Methods

The data used in this study are drawn from 2000 onwards, a period in which fundamental change within the seed sector has occurred following China's entry into WTO (2001) and the implementation of a national plant variety protection law (1997) and seed law (2001). The PPB initiative was introduced in Guangxi in 2000 and subsequently extended to Yunnan and Guizhou. The niche-level data are based on PPB participant observation, project documentation, and a questionnaire survey (Li et al., 2011) applied in 2009-2010 to a sample of 162 farming households from 54 villages, 18 townships and 6 counties in Guangxi, Yunnan and Guizhou. The survey covered local level maize (*Zea mays* L.) seed supply, including maize hybrid adoption and varietal distribution in farmers' fields. A follow-up tracer study identified the sources (breeder, seed producer and/or distributing agent) of the hybrids.

The higher-level data are based on key informant interviews with 40 farmers, 8 public breeders, 10 PPB practitioners, 5 extensionists and 7 government officers at provincial and national levels. Relevant national and international agreements, seed regulations, seed enterprises, public institutes, and PPB projects, also were reviewed.

The data obtained from the survey were converted into percentages and a chi-square test was carried out using SPSS 15.0 in order to establish differences in maize hybrid distribution among households (HH), in relation to the source of the hybrids (Table 4.2). The qualitative information from the interviews was transcribed and analysed in four steps (Table 4.3): 1) open coding to identify ideas, themes and concerns; 2) identification of general categories and subcategories of advantages and disadvantages; 3) summarization of the interview using the categories, with subheadings and specific details or examples related by an interviewee; and 4) calculation of the frequencies of each categories and /or subcategories and comparison of categories within and between interviews.

4.3. Findings

The findings are presented in turn from each of the three levels: section 4.3.1 elaborates the landscape settings around seed, including international agreements and treaties, that have impacted the evolution of the seed sector in China; section 4.3.2 presents regime level changes in China, including the evolution of the domestic seed market, changes in national seed regulations, the shifting functions of public research institutes, and the development of the commercial seed sector; section 4.3.3 presents niche level responses and motivations, including the emerging partnerships among public institutes and commercial sectors, and the on-going PPB initiatives in the southwest. Section 4.3.4 focuses on the emergent tensions between the levels.

4.3.1 Landscape-level trends

Key informants in this study pointed to four major international treaties and agreements governing the global food and seed sectors that have impacted the evolution of the seed sector in China:

The Trade-Related Intellectual Property Rights Agreement (TRIPS) under the World Trade Organisation (WTO) was formulated in 1994. Art. 27.3. (b) of TRIPS states that 'members shall provide for the protection of plant varieties either by patents or by an effective sui generis system or by any combination thereof'. The TRIPS does not define what 'effective' means but it is commonly taken to imply legally-defined intellectual property rights (IPRs) to protect Plant Breeders' Rights (PBRs). Patents do not allow breeders' exemptions (that allow free exchange of seed for the purposes of breeding) and farmers' privileges (that would allow farmers to continue to produce and sell seed), and so more and more developing countries have chosen to develop a sui generis system.

Plant Variety Protection (PVP) under the International Union for the Protection of New Varieties and Plants (known under its original French designation as UPOV) was introduced in 1961, creating a system of legal recognition and protection for named cultivars of plants among its member countries. The criteria for protection are: novelty, distinctiveness, uniformity, and stability (DUS). The standardization of DUS testing has reduced cultivar diversity in commercial seed markets. In contrast to patent law, PVP can provide exemptions both for breeders, allowing them to use protected cultivars for further breeding, and for farmers, allowing them to save seeds from their harvest. However, the 1991 revision of the 1978 version of UPOV expanded the scope for protection from 'traded reproductive material' to all materials, including the harvested product and the end product. The 1991 version has narrowed the so-called 'farmers' privilege' to manage, develop and exploit plant genetic resources (PGRs), such as their on-farm saved seed. Many developing countries therefore still enforce UPOV 1978 even though they are facing trade pressures to adopt the 1991 revisions into domestic law.

The Convention on Biological Diversity (CBD) (1992) has been ratified by nearly all countries. Its three objectives are: the conservation of biological diversity, the sustainable use of components of biodiversity, and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. Art. 8(j) states that, 'subject to its national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity […] and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices' (CBD, 1992).

The CBD emphasizes the sovereign rights of states over their biological resources, and that the access to genetic resources and related traditional knowledge

need to be provided upon mutually agreed terms (MAT), fair access and benefit sharing (ABS) agreements, and subject to prior informed consent (PIC), in order to respect and protect communities' rights over their PGRs. The implementation of the CBD so far has focused primarily on protection against abuse instead of facilitating access and developing creative benefit-sharing mechanisms. The evidence indicates the CBD has constrained the access to and exchange of PGRs among countries (Falcon and Fowler, 2002) while failing to protect farmers' rights.

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) was approved by the Food and Agriculture Organization (FAO) in 2001. It provides that 'in the exercise of their sovereign rights over their PGRs for food and agriculture, states may mutually benefit from the creation of an effective multilateral system for facilitated access to a negotiated selection of these resources and for the fair and equitable sharing of the benefits arising from their use' (ITPGRFA, 2001). It also recognizes the rights of farmers to 'save, use, exchange and sell farm-saved seed/ propagating material'. In Article 9, farmers' rights are defined as including (1) protection of traditional knowledge relevant to PGRFA; (2) the right to equitably participate in sharing benefits arising from the utilization of PGRFA; and (3) the right to participate in making decisions, at the national level, on matters related to conservation and sustainable use of PGRFA.

These four landscape-level instruments for the governance of seed are not in harmony; they set up powerful tensions that every country is forced to consider as national seed law and regulation evolves. At the same time, the process of institutional change in seed supply has accelerated greatly from the mid 1980s onwards with the growing power of plant breeders to manipulate PGRs and has resulted in a high degree of concentration in the ownership of intellectual property rights in the form of plant breeders' rights (Srinivasan, 2003) and patent rights. On the other hand, the TRIPS agreement has accelerated significantly the spread of PVP systems across countries. Many developing countries that used to rely on public sector breeders at the national and international level for the development of new cultivars (Evenson and Gollin, 2003a), currently are in the process of enacting PVP legislation in order to open up plant breeding and seed production to private and foreign investment (Srinivasan, 2003), even as they face an intense debate about the potential economic impacts of PVP on their agriculture and farmers (GRAIN, 2002).

The commercial seed industry over the last 40 years has consolidated worldwide (Howard 2009). This has had a number of impacts, including: declining rates of farmer-saved replanting seed, as companies successfully convince a growing percentage of farmers to purchase their products year after year (Mascarenhas and Busch, 2006); a shift in both public and private research toward the most profitable proprietary crops and cultivars and away from the improvement of cultivars that farmers can easily replant (Kloppenburg, 2005); and a reduction in

seed diversity, as companies reduce or remove less profitable lines from the seed lists of newly acquired subsidiaries (Volkening, 2006).

4.3.2 Regime-level change

Over the past three decades China has experienced a series of regime transitions, moving from a government-controlled, centrally planned seed development, supply and distribution system towards market-oriented seed provision. The transitions are presented here in relation to the regulatory framework, the public research institutes and the commercial seed sector.

Evolution of the domestic seed market

As one of the founder-members China signed the CBD in 1992; in 1999, China became a member of UPOV and adopted the provisions of the UPOV 1978 Act; and at the end of 2001, China joined the WTO. The 5-year transition period has ended, and the domestic seed market has gradually opened up to (trans)national commercial enterprises. China at the same time has realized the importance of ITPGRFA and has attended all working group meetings and negotiations through 2010.

The evolution of the domestic seed market under these obligations can be divided into three stages:

- before 1995, the seed market of all crops was fully dominated and con trolled by state-owned seed enterprises (SOEs);
- from 1995 to 2000, National Seed Project was launched by the central government in order to prepare the transition from a planned economy to a market economy, by means of a series of market-oriented trainings, such as technical training on seed quality control and monitoring, and personnel training on market management;
- in 2001, the government passed a new seed law, which allowed a commercial, competitive seed industry to evolve. By the end of 2009, there were more than 8700 seed companies operating in China. Most are small or medium-sized enterprises; about 3000 are operated by the 450 public agricultural research institutes (Dong, 2009).

National seed regulations

In order to comply with international agreements on the one hand, and to support the development of domestic seed markets on the other, the Chinese government passed the *Regulation on Plant New Variety Protection (the Regulation)* (1997) and the national *Seed Law* (2000):

The *Regulation* brings the Chinese PVP law into line with UPOV 1978. The *Regulation* has had positive effects: it has helped to reshape the structure of breeding institutes and seed enterprises in China, encouraged commercial seed sectors and individuals to participate in breeding and seed multiplication, and

encouraged public research institutes to become competitors in the seed industry. Figure 4.1 shows the waves of application and approval of PBR from 1999 to 2009. The number of approvals lags behind the number of applications, partly because some applications have been rejected and others are in the process of testing.

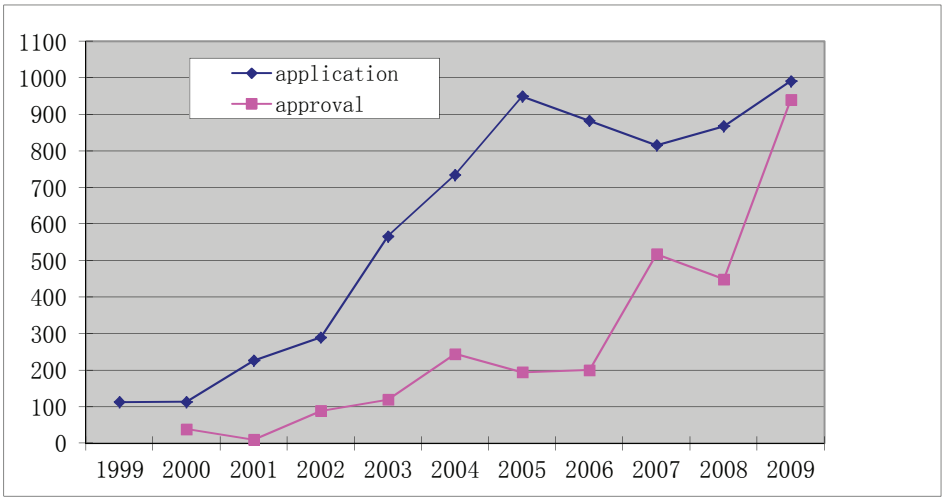

Figure 4.1. The waves of application and approval of plant breeders' rights in China, from 1999 to 2009.
Source: MoA database, 2010.

The Seed Law (2000) protects breeders' benefits and opens up the domestic seed market to private entities. It states that any company in compliance with the law can apply for a seed-breeding licence, or seed business licence and can conduct seed production and management within the permitted region i.e. the region designated for testing the value of a cultivar for cultivation and use (VCU). VCU testing admits to the market only those varieties that show 'clear improvement' compared to existing varieties. The main purpose of the Seed Law is to regulate the seed industry with regard to breeding and seed production, protect the legitimate rights and interests of plant breeders and seed producers, and monitor and guarantee seed quality on the market.

The inter-related logic of these two institutional provisions means that the granting of a PBR does not automatically lead to the commercialization of a new variety since it might still fail the VCU test; conversely, if a variety passes the VCU testing procedure and enters commercial production, it does not necessarily acquire exclusive market protection unless a PBR has been granted. The implementation of these two regulatory frameworks has provided incentives for public breeders and the commercial seed sector. They bring the Chinese seed sector into a global process that institutionalises intellectual property in plant breeding and commercial seed production.

Public research institutes

The public seed sector includes central and provincial-level agricultural research and crop breeding institutes, academic institutions, specialist government agencies and international research centres. The national agricultural research system (NARS) was set up in 1957 after the establishment of the People's Republic of China in 1949. The opening of the domestic seed market has stimulated both public research institutes and commercial seed enterprises. The value of professional breeders' knowledge and expertise has attracted a price as breeders' rights became protected by the new seed laws and seed companies (operated by both public institutes and private agents) have to pay IPR transfer fees and/or and royalties on released cultivars. Public institutes have come to see the commercialization of their work as a way to increase the revenue of the institutes, making them less dependent on state control and subsidy. However, key informants in the maize sector reported in this study that recent evaluation of the performance of the breeding institutes showed that the commercial value of released cultivars was not being recovered, and that only 30-40% of the cultivars released by the public maize research institutes have been commercialized. This implies that as the public-private functional division has become blurred within the public sector, compromising the efficiency of both breeding institutes and seed companies. Over the last two decades, the government has invested mainly in the development of hybrids and biotechnology research and varietal development, reducing its allocations to open-pollinated variety (OPV) improvement of maize and landraces for smallholder farmers under low-input conditions.

Commercial seed sector

The commercial seed sector in China includes domestic and multinational seed companies (Table 4.1). It is estimated that the top four seed firms today control 56% of the global proprietary (e.g. brand-name) seed market (Howard, 2009). Both the big global players and regional seed companies view the Chinese seed market as a huge and lucrative opportunity. The domestic seed companies established after the changes in regulations in the late 1990s, as well as public sector organizations, initially viewed the external companies' interest with trepidation. Among the 8700 seed companies in existence in 2009, about 3000 were operated by the public institutes. Most were small or medium-sized enterprises (Dong, 2009) and only 95 of these had an integrated R&D capacity for seed development.

In general, there are four types of seed enterprises: 1) enterprises with breeding capacity, such as the seed companies operated by the public agricultural research institutes and specialized breeding companies; 2) enterprises focusing on seed production, operating in specific natural and climatic conditions, such as companies located in northwest China; 3) enterprises that target seed-related trade; and 4) enterprises integrating capacities of the above three in breeding, seed production, extension and selling. The first works upstream of the seed industry through providing new varieties for other companies; the second usually contracts other seed companies or specialized farmer seed producers to carry

out seed production; the third covers most of the SOEs supplying local seed and specialized trade companies. The fourth usually has strong R&D capacity and integrated marketing channels; this group includes most of the transnational companies and large-scale domestic companies.

Table 4.1. Penetration of transnational seed companies into China through collaboration with their local partners, from 1996 to 2009.

Year	Events
1996	Monsanto invests in Hebei seed company in Hebei province
1998	DuPont sets up research company in Liaoning province
1998	Monsanto sets up the second biotech joint venture Andai Cotton Technology Co., Ltd in Anhui province
2001	Monsanto invests in China Seed company, sets up China Seed-Dekalb seed company
2002	DuPont invests in Denghai seed company in Shandong province
2006	DuPont invests in Dunhuang seed company in Gansu province
2009	Monsanto establishes its first research institute – Monsanto Biotechnology Research Centre in Beijing

Source: compiled by this research.

4.3.3 Niche-level responses

This section presents two types of local level innovation, led by a) seed agents and public-private partnerships, and b) participatory plant breeding.

Seed agents and public-private partnerships

The changing seed regulatory framework and the growing seed market has led to the emergence of commercial agents. Some of these have spun off from the public sector and others have been developed as joint ventures. Hybrid maize, as one of the most commercialised food crops, has attracted particular attention from commercial interests and can be used to exemplify these innovations.

As described in Li et al. (2011) a rapid change in the supply of hybrid maize seed has occurred over the last ten years in Guangxi, Yunnan and Guizhou, a karst mountain area with diverse micro-ecosystems, where maize is the staple food for farmers. The proportion of the area cultivated with hybrid varieties in Guangxi increased from 35% in 1998 to 93% in 2008. According to our survey findings, we distinguish four groups of companies that supply hybrid maize seed to local farmers:

- Local provincial or regional institutes and institute-owned seed companies. The rapid growth in the number of these relatively small companies indicates that the public agricultural research organisations are

re-orienting their functions towards the commercial seed market. Table 4.2 demonstrates that local institutes and their associated seed trade companies today play dominant roles in local seed markets, raising the danger of creating regional monopolies that restrict the penetration of cultivars developed elsewhere. However, the challenge of breeding cultivars adapted to the very diverse agro-ecosystems created by the mountainous landform favours the role of local companies.

- Cross-provincial breeding institutes and universities. Before the opening up of seed market, they were the only centres for breeding and release of new cultivars. Today these organisations face competition from the emerging commercial sectors, and some have developed a commercial role in seed markets.
- Cross-provincial seed companies. The opening up of the seed market provided opportunities and space for their development. In some cases they also produce the seed of cultivars released from public institutes, when accompanied by a PBR transfer payment.
- Transnational seed companies. The penetration of transnational enterprises is one of the results of the development of domestic seed enterprises. According to current seed regulations a transnational interested in the major food crops must collaborate with a domestic enterprise in the form of a joint venture, taking no more than 49% of the shares. The penetration of a transnational into and expansion within the regions, however, sometimes is challenged by provincial legislation and regulations.

The data in Table 4.2 show that the hybrid maize market, in Guangxi, by 2003 was dominated by transnational companies, and that the commercial sector played a significant role in seed supply. Public agents from local or other provinces gradually have lost their market share. In Yunnan and Guizhou maize hybrid seed supply still heavily relies on the local provincial and regional research institutes. The commercial sector in Guizhou remains at an early stage of development. According to key informants this is partly because the altitude in Yunnan and Guizhou ranges from 1500 to 3000 meters and local public research institutes play a more important role in seed provision for adaptation to such divers agro-climatic conditions and local pests and pathogens; Guangxi lies below 700 meters, which offers a greater market potential for the more uniform cultivars of interest to companies from outside the region.

Table 4.2. Maize hybrid distribution among households (HH), in relation to the source of hybrid maize in Guangxi, Yunnan and Guizhou from 1998 to 2008 (n=162) (unit :%).

Year	Guangxi (n=54)	Yunnan (n=54)	Guizhou (n=54)	χ^2
Local breeding institute operated seed company				
1998	88	70	91	49.9 (P=0.000)
2003	43	100	96	
2008	17	80	95	
Cross-provincial breeding institute				
1998	28	30	9	11.8 (P=0.019)
2003	28	7	4	
2008	14	4	3	
Cross-provincial seed company				
1998	0	0	0	27.5 (P=0.000)
2003	23	4	0	
2008	29	62	8	
Transnational seed company				
1998	8	0	0	(P=0.000)
2003	55	0	0	
2008	81	0	0	

Source: Questionnaire survey (n = 162) in Guangxi, Guizhou and Yunnan, 2009-2010.

The PPB initiative – collaboration between public research institutes and farmers

PPB seeks innovations in local cultivar development and seed provision through systematic collaboration between the public sector breeders, farmers and communities (Morris and Bellon, 2004). Prior to the PPB project a field study (Li et al., 2011) demonstrated that poor farmers found it difficult to benefit from the seed provided by formal breeders and the commercial seed market because of inadequate attention to the cultivar development needs of their diverse agro-ecosystems, and poor adaptation of the formally bred modern cultivars to local conditions. Local landraces on the other hand have been maintained for many years by farmers themselves through continuous selection by farmer breeders, based on their experience and farming knowledge. In order to strengthen the farmers' seed system, the PPB initiative on maize was established in 2000, funded by the International Development and Research Centre (IDRC, Canada) (Song, 2003). It is the first PPB effort in China, seeking to orient varietal development towards small farmers, as well as farmers' empowerment by means of the formal recognition of farmers' IPR, and their contribution to PGRs conservation, and the development of a fair access and benefit-sharing mechanism (Ashby, 2009).

The project in 2000 directly involved five women farmer groups, six villages, six township extension stations, two formal breeding institutes and one research institute. The participating farmers were encouraged to take part in a range of

PPB research activities, including on-farm seed selection, small-scale seed production, adaptation experiments for hybrids, and adaptation maintenance of landraces. Farmers participated in selection at different stages of the breeding cycle. Over the years the project has expanded to sixteen farming villages in Guangxi, Yunnan and Guizhou, through networking with provincial and regional breeding institutes and local communities. A collaborative partnership had been created among a number of institutes located at different levels in the public sector hierarchy, i.e. Guangxi Maize Research Institute (GMRI), the Institute of Crop Sciences under the Chinese Academy of Agricultural Sciences, and a policy institute, i.e. Centre for Chinese Agricultural Policy under Chinese Academy of Sciences, and between these and farming communities in the three provinces. The breeders from the public institutes showed great interest in both the local landraces and in farmers' seed selection processes.

Based on collective seed selection and mutual sharing of maize genetic resources and knowledge, the project to end-2010 has bred 5 maize varieties, i.e. Xinmo 1, Guinuo 2006, Zhongmo 1, Zhongmo 2 and Guisuzong. More than 100 landraces and new cultivars have been exchanged between farmers and researchers (CCAP, 2009). Farmers' preferences in seed selection, crossing and (re)combination of crop genetic resources favoured a number of traits in addition to productivity and market price, including taste, colour, early maturity, drought resistance and anti-lodging. The specific combinations of trait preferences were closely associated with the specific ecological and cultural contexts in which farmers lived; these could not be fully satisfied by professional breeders working to meet national seed demands. In contrast, the modern cultivars selected by farmers through PVS have been shown to have adequate adaptation to the local environmental diversity, especially in relation to drought and other stresses. Besides maize, farmers had also adopted the methods they had learned through the project to other crops, such as rice, cassava and soybean. Of the five maize varieties developed jointly by the breeders and farmers, one was officially registered as a protected cultivar under the name of the GMRI breeders. The waxy hybrid, Guinuo 2006 spread since 2005 among local communities through small-scale seed production by farmer-owned seed enterprises.

4.3.4 Emergent tensions between levels

The commercially developed niches are driven by opportunities for market profit that have been opened up by the changes in policy and regulation, and they play an increasingly dominant role in seed provision. The domestic commercial seed sector has a strong focus on competitiveness and yield. However, smallholder farmers' interests and the national interest in agro-biodiversity conservation is not fully addressed by the commercial seed market. PPB is a novelty that challenges the regime and the dominant actors by coupling global competition with the goals of conservation and the development of smallholder farmers' livelihoods in disadvantaged areas. The following focuses on the role of the niche development of PPB in regime change as China seeks to balance commer-

cial and public sector interests and smallholder farmers' livelihoods.

As a radical novelty at niche-level, PPB has encountered a number of tensions and mis-matches with the existing regime:

Technical barriers to PPB products

The first PPB variety Xinmo 1, an open-pollinated cultivar performing well in the Guangxi region, failed at the VCU testing stage because it did not perform well in all the six regions demanded by the value for cultivation and use (VCU) protocols in force in 2005. Cultivars derived from any PPB process are unlikely to comply with the formal cultivar release criteria (Louwaars, 2007). The existing seed regulations can recognize and release only those cultivars passing DUS and VCU testing. Cultivars or landraces selected by farmers, directly as the result of the breeding for adaptation to the agro-ecosystem, generally have four distinct features: 1) they are adapted to specific local circumstances; 2) they exhibit a considerable degree of genetic heterogeneity and therefore are more flexible and reactive to changing natural conditions; 3) they are inherently not stable; and 4) they might or might not be regarded as distinct from each other (Visser, 2002). One of the common issues worldwide is how farmer-selected varieties for low-input conditions can be tested under favourable conditions and comply to DUS criteria when their specific abiotic tolerance and cultural values are not valued and included in the testing protocol.

After 'Xinmo 1' was denied registration by the formal seed release system, the OPVs released by the PPB project subsequently were tested and cultivated only in local communities, without official release. The waxy maize hybrid, Guinuo 2006 has been registered in 2004 under the name of the PPB breeder at GMRI There is no regulation or institutional arrangement in place to support farmers as joint breeders, and which can be recognized by the cultivar registration system.

Hybrid seed production is more dependent on the services of public research institutes than improvement of OPVs and landraces. In the case of the hybrid Guinuo 2006 farmers received intensive support from GMRI, which provided parent seed for each season and regular technical training for on-farm hybrid seed production. Regarded so far by officials as a local experiment, such community-based seed production has been protected from IPR and market-related issues, such as PBR transfer agreements, payments for use of protected varieties, the commercial line restriction for non-commercial seed production, and quality control of farmer-produced seed.

In view of difficulties such as these (that have been reported by PPB practitioners from around the world) the existing cultivar testing system has come under increasing scrutiny (Morris and Bellon, 2004; Rey et al., 2008; Ashby, 2009). Increased interest in maintaining diverse farmer-conserved cultivars also has pushed these technical issues onto the policy agenda (de Schutter, 2009), and

the pressures are growing for regime-level change in the DUS gold standard.

Organizational barriers to the PPB process

The project in the southwest has provided a protected space for niche-level experimentation and for protecting the public value in PGRs, through collaboration between the public sector and farmers for the combined purposes of crop improvement, agro-biodiversity conservation and farmers' empowerment. However, the scaling-out of PPB is challenged by the priorities that public institutes set for themselves. When driven by market profit both public and private research shifts toward the most profitable crops and proprietary varieties, and away from the improvement of varieties, such as open-pollinated varieties, that farmers can reproduce easily (Kloppenburg, 2005; Howard, 2009). Public institutes in China used to play an important role in fundamental research (e.g. pre-breeding research on germplasm) and public good research on minor crops and non-commercialized varieties, but over the transition period they have become profit-driven (S. Zhang, CAAS, personal communication, 2008). According to the key informants, the performance of public breeders today is measured by the number of released varieties, published scientific articles and the commercial projects they have conducted. Their contribution to non-commercial activities such as PPB cannot be represented directly in this evaluation framework and this may discourage institute breeders who wish to be involved in PPB (W. Cheng, GMRI, personal communication, 2010). The shifting function of the public sector has challenged their public good role in non-commercial research for smallholder farmers in less-favourable conditions.

Market barriers to PPB varieties

The key informants stressed that it is the DUS and VCU testing and approval criteria and procedures that have limited the promotion of farmer-selected seeds. The current seed legislation impedes the marketing of varieties that do not meet the requirements and therefore cannot be released for commercial sale. On the other hand, there is no provision in current VCU assessments for evaluating varieties for plant traits that add value to PPB varieties in the markets for which they are intended; these traits include both biotic and abiotic traits such as taste and colour. In addition, although China still implements the more permissive UPOV'78 version, under UPOV'91 farmer-selected heterogeneous populations cannot be registered and consequently also not exchanged between farmers or marketed. Further, for the major food crops, it remains illegal in China to produce on-farm any seeds that have not been officially released. Farmers' rights as seed entrepreneurs and breeders, i.e. to sell their seeds and to set up seed businesses, will continue to be restricted unless care is taken to define in the national law such phrases as 'commercial' seed production in ways that allow farmers to contribute to commercial seed flows.

Synthesis

PPB practices have amplified the tensions within current institutional provisions, within and across levels. TRIPS and UPOV focus on protecting PBRs, and are trade-oriented, while CBD and ITPGRFA seek to secure the rights of farmers over PGRs and to recognize their role in conserving biological diversity. Although there are distinctions within each of these frameworks, the basic distinction between them is the extent to which they are oriented to PBR or farmers' rights. International discussions on the issues related to the incompatibility of these overlapping agreements are always controversial. However, the tensions may play a catalytic role in forcing regime-level change. From this perspective, the emphasis on farmers' rights in the CBD and ITPGRFA could be an opportunity for PPB-led innovation. Table 4.3, based on the key informant interviews, presents a synthesis of the various points raised so far in this paper.

4.4. Discussion and conclusions

This study has explored changes in the seed sector from a multi-level perspective, analysed the innovations created by PPB at niche level in response to such changes, and defined the opportunities for PPB in the changing configuration of seed regulation and policy. The findings help to define the opportunities for change at the niche and regime levels; these dynamics are discussed further below.

4.4.1 Emerging opportunities at regime level

The current seed institutions are biased toward the commercial sectors. They limit the space for non-commercial research and development directed to conservation and the livelihoods of smallholders. Nonetheless, there are options for regime change.

Technical options

Niche-level innovation in southwest China demonstrates that PPB varieties contribute to *in-situ* conservation of agro-biodiversity and crop improvement for smallholders These contributions are not yet recognized and valued by the formal seed registration and release system. If a PPB variety fails the DUS test, a number of issues arise: whose PBR needs to be guaranteed, in which way and how to conserve the variety within the public domain. A minimum requirement would be to establish a list of conservation varieties (Li et al., 2008). China also could develop its own Conservation Varieties legislation for protection of conservation values and localized food preferences. Recent legislative developments at European level concerning seed production and marketing open a new way to safeguard biodiversity of interest to agriculture. Regulation for landrace conservation and use (EU Commission Directive 2008/62/EC 20 June 2008) has been commented by Lorenzetti and Negri (2009); these appear to exclude new or improved farmers' varieties (Chable et al., 2009).

Table 4.3. Emerging technical, organizational and market tensions in relation to niche, regime and landscape levels.

	Tensions among three levels		
	Niche	***Regime***	***Landscape***
Technical	**Biodiversity**: PPB focuses on diverse cultivars adapted to specific eco-systems, and agro-biodiversity for farmers & breeders is a genetic insurance; farmers & communities maintain agro-biodiversity through on-farm seed selection, by means such as taste preference, cultural needs, trust and solidarity. **Conservation-oriented breeding**: trait preferences selected through PPB processes are closely associated with the specific ecological and cultural context; it involves a range of stakeholders (especially the end users of the varieties) in the breeding process.	**Uniformity**: breeding for uniformity is necessary for modern farming & enforced by the DUS seed regulation; farmer selected variety from low-input conditions be measured under favourable conditions, in terms of distinctness, uniformity, stability and yield increasing; lack of the evaluation of varieties for specific plant traits that are not regularly observed in VCU. **Commercially-oriented breeding**: breeding activities carried out on-station by professional breeders focus on limited numbers of widely adapted and profitable crops and varieties, have been encouraged by exclusive PBR protection and strict enforcement of PBRs.	Accession to the requirement of TRIPS and UPOV, there is a growing harmonization of seed regulations worldwide, such as DUS&VCU testing systems. TRIPS offer strong enforcement for WTO member countries. Many countries prefer to choose UPOV as their alternative *sui generis* IPR. Trade expansion and food pressures lead to wide adoption of hybrid varieties, resulting in the replacement of local landraces and the decreasing of agro-biodiversity. The expansion of IPR over PGRs in the form of PBR has promoted commercial breeding and market development through protecting monopoly right of breeders and companies on the market.
Organizational	**Public value**: PPB is a way to protect public value over PGRs, through building up farmer-researcher partnership on crop improvement, supporting local seed provision system through small scale seed production and fairly recognising the contribution of PPB stakeholders and sharing the benefit from PPB products. In the case of *Guinuo 2006*, a hybrid maize variety selected via PPB process, its PBR is protected under the name of institute breeders, due to the lack of mechanisms on recognition and benefit sharing among the stakeholders. Further arrangement on ownership and benefit sharing issues can be supported by **ABS-related agreements**.	**Commercial value**: driven by market profit, there is a shift in both public and private research toward the most profitable proprietary crops and varieties, but away from the improvement of varieties that farmers can easily replant; according to farmers' privilege within seed regulations the amount of on-farm seed production should be held 'below the commercial line'. Such commercial value is guaranteed by **exclusive IPRs**, in the forms of PBRs or patent rights.	To better address the public value of PGRs and balance PBR and FR, both CBD and ITPGRFA seek to secure the rights of farmers on PGRs and to recognize their role in conserving biological diversity. CBD emphasizes the sovereign rights of states and local community rights over PGRs and offers three mechanisms – mutual agreed terms (MAT), Prior Informed Consent (PIC) and Access and Benefit Sharing (ABS) - for enforcement of these rights. In practice the mechanisms tend to limit PGRs transfer and exchange because of the high transaction costs involved. ITPGRFA supports FRs, ABS and multilateral systems as mechanisms for the governance of PGRs for the purposes of conservation and sustainable use of PGRs. Both CBD and IT PGRFA are lack of strong enforcement of those mechanisms.
Market	PPB varieties can be supplied on **niche and diverse seed market**; as a complementary of commercial seed market, on-farm selected and produced seed addresses farmers' multiple needs on seed and food, in relation to its ecological and cultural contexts; small scale seed production of PPB varieties can also benefit the vulnerable group.	**Commercial and uniformed seed market**: seed varieties and products recognized by current seed market become uniform with limited space for addressing diverse local needs; for major food crops, it is illegal to produce and sell the seeds without official release.	The protection of FR to save, use exchange and sell their seeds is a way to recognize farmers' contribution on PGRs maintenance and improvement. How to protect FRs within national legal frameworks? And how to negotiate accommodation of PBRs when implementing FRs? The answers to these questions are still unclear.

Source: this research, from key informant interviews, 2010.

In most cases PPB varieties cannot meet the DUS and VCU requirements because the heterogeneous nature of on-farm selected varieties conflicts with the requirement for uniformity. A solution could be to develop a parallel variety registration system to list PPB and conservation varieties. The yield is the dominant feature in the VCU testing standards and this also limits the opportunity for local varieties that typically perform better on other traits. As failing the VCU test prevents entries into the commercial market, it has been proposed to take VCU out of the registration process and to leave quality judgments to localized procedures. For instance, the test could be used simply to provide market actors and farmers with information; in the USA, for instance, seed quality is monitored by market actors and consumers (Louwaars, 2007). Within the European organic sector some countries are experimenting with testing protocols that integrate organic and low-input growing conditions and additional traits such as weed suppression. Austria has adopted a specific VCU system for organic farming systems. However, it is sometimes difficult to gain policy support for such models because of the question who will pay for the extra costs (Rey et al., 2008).

Organizational options

The publicly funded institutes' involvement in the commercial seed market distorts competition. Their public responsibility for crop improvement for smallholder farmers and especially for crops that occupy a small area or are of minor importance to the national economy, and to pre-breeding research, need to be distinguished from their commercial activities. The commercial sector also could benefit from strengthened collaboration in pre-breeding research; the public institutes could provide specific stress tolerance materials, for instance. Policy guidance for reform and development of the seed industry is under formulation by the State Council and the Chinese Ministry of Agriculture. Although the outcome is not yet known the consolidation of the domestic seed industry and the separation of public institutes and the commercial seed industry seem likely to be central elements in the guidance.

The PPB initiative demonstrates the potential for creating mutually-beneficial farmer-researcher partnerships serving local market, conservation and livelihood goals. Public researchers are playing important roles in on-farm experimentation and seed production in ways that balance farmers' rights within the current seed regulation. For PPB varieties with values that do not meet DUS and VCU requirements, the collaboration secures mainly agro-biodiversity conservation and farmer empowerment benefits. For varieties with local or even national commercial value solutions to the ownership and benefit sharing issues that arise are evolving. The PPB hybrid Guinuo 2006 for instance was registered under the name of the institute breeder. Subsequently the institute's breeders agreed to share the benefit informally through supporting community-based seed production. In Nepal a PPB variety that passes VCU testing can be kept within the public domain without applying for PBR protection, and farmers can participate in commercial seed production, as in the case of 'Jethobudho', a rice landrace improved through PPB and formally released for general cultivation under the national seed certi-

fication scheme (Gyawali et al., 2010). In addition, Access and Benefit-sharing mechanisms (formalised for instance in contract law, see Chapter 5) are envisaged under the CBD and ITGPRFA. However, the implementation and enforcement of ABS mechanisms depend on framing of national legislation.

Market options

Concern about the loss of diversity in agriculture is forcing reconsideration of the need to allow farmers to increase genetic diversity on their farms, but current seed legislation worldwide impedes the marketing of non-uniform varieties and this limits access to diversified seed. Options for market innovation are linked to technical considerations because whether or not a variety can be commercialized is determined by varietal testing. If the VCU system were to become non-compulsory or could take more criteria into consideration, this would help open a space for seed markets serving niche needs and more diverse end uses. Farmers and their communities could generate more income by producing seed specialities with added value. A diversified seed market that consumers can recognise also would provide incentives for PPB practitioners to supply on-farm selected and produced seed. Niche markets (that in the Chinese case are not small, given the numbers who will remain based in smallholder farming for decades to come) can address local needs for speciality seed and food, in relation to their specific ecological and cultural contexts. Vulnerable groups that have difficulties in accessing the commercial seed market also would benefit.

4.4.2 Potential for evolution at the landscape level

Trade-related pressure to comply with WTO and UPOV provisions has led to a growing harmonization of seed regulations worldwide. The concentration of intellectual property rights in PGRs has fostered the commercialization of those resources and the development of commercial seed sectors. IPR and seed regulation are evolving under WTO/UPOV as a form of business regulation that plays a powerful role in driving the direction of R&D and in shaping market structure through binding IPR-based market protection (Drahos, 2010). However, the trade-related aspects of IPR, in the form of PBRs and patent rights, tend to conflict with development-related policy priorities, especially in relation to the pubic interests served by plant breeding for agro-biodiversity conservation, crop improvement in less-favourable region. The actors within the system are engaged in a struggle over who will have power and control over the production and supply of food, and how the benefits and risks arising from different activities will be distributed (Tansey, 2008).

At the country level, there is space for exceptions and protection and many countries, especially developing countries, are exploring their sui generis options for balancing FRs and PBRs. What are the possibilities for China to develop a unique seed system that can drive action on the global stage? The seed system in China seems to be evolving towards a two-track framework. On the one hand, governed by international trade rules, the national seed system is

experiencing industrialization and commercialization, drawing support from the both public and private sectors. On the other hand, as a mega-biodiversity country China also is striving to put in place policy support, regulation and practices for agro-biodiversity conservation, in order to safeguard future breeding options and food security under climate change (Xue, 2011). Since most of its PGRs are in the hands of smallholders, Chinese policy-makers recognise that exclusive IPRs will limit farmers' access and reduce the potential for on-farm crop development. For the sake both of farmers' interests and the continuous conservation of agro-biodiversity, China so far maintains the provision of UPOV 1978 (Song, 2010). However, the concept of farmers' rights does not resonate well in the Chinese context and legislation to protect their interests in PGRs, crop breeding and commercialisation lags behind countries such as India. As the public sector shifts its attention to commercial business, the national legal framework does not as yet recognise farmers as the users and stewards of PGRs. The space for farmer organizations also is still underdeveloped and, though numerous, smallholders have weak capacity to express their needs in relation to seed markets and variety development. The PPB initiative provides a dynamic for change for a two-track evolution and this is being actively pursued in a series of policy workshops (see Chapter 4).

4.5. Outlook

This article presents and analyses the rapid evolution of the seed sector in China. Special attention is paid to PPB as a radical novelty that offers a range of advantages in relation to needs such as those of smallholder farmers in the diverse agro-ecosystems of the southwest, biodiversity conservation and food security under unpredictable or adverse climate change. Although there are opportunities for ensuring that PPB becomes a permanent component in seed provision, further effort is required to stabilize this capacity in the evolving regime. Specifically, what is needed includes:

- amendment of existing seed regulations in order to accommodate varieties with heterogeneous characteristics;
- support to public research institutes' role in breeding oriented to smallholders and conservation;
- protection of the public value created by PPB in relation to agro-biodiversity conservation and farmer empowerment through ABS-related agreements, clearly distinguished from the commercial value protected by exclusive IPRs;
- support to farmer-led seed production and marketing, as a complement to commercial markets, in order to widen farmers' seed choices and respond to their multiple needs.

Chapter 5

Contribution of action researching to institutional innovation: a case study of access and benefit sharing (ABS) mechanisms in participatory plant breeding (PPB) in southwest China

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Abstract

This article investigates the contribution of action research to systemic institutional innovation, through a case study of access and benefit sharing (ABS) mechanisms developed in the context of a participatory plant breeding programme in southwest China. The processes of purposeful change are examined as critical events, in eight episodes. Evidence is presented in these episodes of the role of action research in fostering conducive interaction between local innovation and regime level change. The analysis elaborates the value of action research in supporting multi-level institutional evolution and networked governance of seed systems. The importance is highlighted of regime actors in boundary spanning during these processes. The article concludes that although ABS legislation in China is not yet adequately formulated, ABS can still be addressed in local practice in terms of procedural approaches, such as ABS contracts between farmers and breeders and market-based geographical indications because the legal basis for these mechanisms already exists.

Keywords

Action research; institutional innovation; access and benefit sharing (ABS); participatory plant breeding (PPB); southwest China

5.1. Introduction

For thousands of years, producing, saving and maintaining a healthy seed system has been one of farmers' main concerns. In most developing countries, seed became the subject of agricultural policy and regulation only during the Green Revolution, i.e., from the 1960s onward. Seed became seen as an important vehicle for the dissemination of the technology embedded in the seed itself and the technology that accompanied the new genes such as chemical fertilizers and plant protection chemicals (Louwaars, 2002). The growing pace of the agricultural revolution encouraged the emergence of government agencies to supply and support regulated seed provision for commercial farming. However, over the past 30 years, governments have progressively left the seed business to private enterprise, under an increasingly globalized seed regulatory framework. The meaning of seed, variety and their production has changed decisively with the expansion of intellectual property (IP) regimes to agriculture (Phillips and Onwuekwe, 2007), from a 'common heritage' to exclusively protected property. Farmers' rights over seed, in terms of saving, exchanging and selling seeds from their harvest, have been restricted and in consequence their contribution to on-farm breeding, varietal selection and seed production has been weakened.

On the other hand, when it became evident that the Green Revolution and modern varieties preferentially benefitted farmers in relatively favourable and uniform agro-ecological and socio-economical conditions, the impact on poor people in developing countries was questioned. The differential effects on food prices and labour in many cases did not improve the living conditions of the poorest in those societies (Pimbert, 1994; Conway, 1997; Evenson and Gollin, 2003b; Lipton, 2007). In these areas, the diversity of traditional crop varieties has remained one of the few options that farmers have to meet their livelihood needs (Sawadogo et al., 2005). Research over the last two decades has provided substantial evidence that significant crop genetic diversity continues to be maintained in farmers' fields in the form of traditional varieties (Brush et al., 1995; Bellon et al., 1997; Kebebew et al., 2001; Jarvis et al., 2004, 2011; Jarvis and Hodgkin, 2008,; Bezançon et al., 2009; Guzman et al., 2005; Bisht et al., 2007; FAO, 2010).

The continuing *in-situ* conservation of plant genetic resources (PGRs) seemingly will depend on the farmer and the farming community retaining the knowledge, institutions and capacity to evaluate the benefits that agro-biodiversity has for them. The importance of strengthening local institutions to enable farmers to take a greater role in the management of their resources for combined livelihood and conservation purposes has been emphasised (Jarvis et al., 2011). Since the 1980s, participatory plant breeding (PPB) has been developed as a complementary strategy in modern crop improvement. By bringing farmers and breeders together for seed development and varietal selection small scale farmers in the areas neglected by commercial interests receive the benefits of varieties well-adapted to their variable, marginal or complex cropping environ-

ments, livelihood needs, and local market demand. PPB potentially combines breeding purposes with agro-biodiversity enhancement within specific agro-ecological landscapes; PPB practices also foster the integration of farmers' and breeders' skills and knowledge. However, the practitioners and products of PPB have encountered everywhere a series of socio-political and institutional barriers, not least in relation to variety registration and the sharing of the benefits of PPB seed (Ashby, 2009; Almekinders, 2011).

The expansion of IP protection over seed, in the form for instance of plant breeders' rights (PBRs) and patents on traits and varieties, has increased the institutional constraints. Farmers' access to on-farm saved seed is becoming more restricted and their actual and potential contribution to long-term PGRs maintenance and improvement is undervalued by the emergent regime. Although access and benefit sharing (ABS) issues increasingly have been discussed at the international level, and there is strong insistence that the countries, communities and farmers that grant access to their plant genetic resources should share in the benefits that other, commercial users derive from these resources (de Jonge, 2011), there remain numerous institutional uncertainties at the national and local levels.

The uncertainties derive in part from the provisions of different conventions. The Convention on Biological Diversity (CBD) for instance declares that states have sovereign rights over PGRs and introduces a compensation mechanism, as the first example of an ABS model, which requires that developing countries be compensated for the contribution of their biological resources (CBD, 1992; de Jonge, 2011). The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) frames ABS in terms of rights (ITPGRFA, 2001); it asserts among other clauses farmers' rights to save, exchange, and sell farm saved seed, regulated by national legislation. Farmers who contribute to PGRs maintenance and improvement are becoming subject also to national ABS legislation that ignores or integrates the international frameworks to varying degrees (Ghijsen, 2009). Commercial seed businesses for their part have benefited principally from the implementation of IP protection and the evolution of plant breeders' rights (PBRs) under the successive International Union for the Protection of New Varieties of Plants (UPOV) conventions. In UPOV 1991, the scope for protection has been expanded from 'traded reproductive material' (as stated in UPOV 1978) to all materials, including the harvested product and the end product; and farmer-saved seeds in UPOV 1991 have been brought within the scope of PBRs (Ghijsen, 1998).

As the institutional map becomes more complex, and to varying degree contradictory, countries are searching for appropriate mechanisms through which to balance competing interests, and the rights of plant breeders and farmers. The existing modalities include a variety of practices ranging from open seed exchange without or with some upfront payment (usually in the form of a price paid by a buyer), to a formal agreement with or without any benefit sharing

arrangement (Nijar, 2011). The range of mechanisms is making it more, rather than less difficult to frame appropriate legislation that satisfies the interests of all parties. China for instance became a member of the CBD in 1993, signed the 1978 version of UPOV on joining the World Trade Organisation in 1999, and is preparing to join ITPGRFA. Preparation of ABS legislation was initiated in 1995; it is still under negotiation among the different sectors and interests concerned in seed improvement and provision (Qin, 2009).

This study is based on a participatory plant breeding (PPB) programme in maize in Guangxi in southwest China, as the context through which to probe the space for institutional innovation in relation to farmers' access to improved seed, maintaining farmers' roles in PGRs conservation, and the development of benefit-sharing mechanisms. The analysis teases out the evidence, presented in eight episodes, for conducive interactions between local institutional innovation and regime change. The chosen research practice, action research, is positioned as the vehicle for multi-actor learning that mediates the tensions that arise from the multi-level change processes.

5.2. Conceptual framework

5.2.1 A multi-level perspective on system innovation

System innovation concepts provide a framework for analysing technological, ecological and institutional change, that increasingly are applied to agricultural development processes (Hall et al., 2003; Morriss et al., 2006; Spielman et al., 2008; Devaux et al., 2009; Klerkx et al., 2010). The system innovation literature (e.g., Ison, 2008; Knickel et al., 2009) and historical analyses of socio-technical regimes (Rip and Kemp, 1998) that emerge in relation to local level innovations (e.g., Geels and Schot, 2007; Schot and Geels, 2008), provide many useful insights but the processes by which multi-level interaction actually occurs are rarely well-covered. There has been relatively little attention paid to how changes in the interaction between niche and regime levels, which always brings tension and conflict, can be made conducive to achieving the desired institutional outcome.

The multi-level perspective on system innovation distinguishes analytical and heuristic concepts in order to understand system innovations through the frame of a hierarchy of institutional settings at landscape, regime, and niche levels. The macro-level of landscape is taken to consist of slow-changing external relations that provide gradients for pathways of change. The landscape can be described in terms of the external structure of relationships or the embedding context for the interactions of actors between and within the hierarchy of levels. The meso-level of socio-technical regimes, that is, a society's rule set embedded in formalised knowledge, practices, procedures, norms, regulations and organisational arrangements, accounts for relative stability in the application

of technology and 'lock in' to historical pathways of development. The rules enable and constrain activities within social relationships and micro-level niches. The micro-level of niches (as protected experimental spaces) accounts for the generation, testing and development of innovation (Geels, 2002). Novel configurations require a protected space (Rip, 2002) in which a network of actors enact change by working closely together under specially designed conditions to develop, test and disseminate desired changes (Van der Ploeg et al., 2004).

During an innovation process new links are formed among actors and their material world that changes the articulation between what happens within the protected space (niche) and at regime level. Historical choices, current policies and legislation, and dominant technological infrastructures and the interests that depend on them, shape the development of novel configurations. At the same time, the creation of novelties can have profound effects at regime and landscape levels (Hoogma et al., 2002; Roep and Wiskerke, 2004). If a regime is confronted by novelties with the necessity of change, tensions emerge and the dominant linkages in the configuration may begin to 'loosen up' (Geels, 2002). The institutional rule set evolves through dealing with those tensions and introducing new elements in the articulation of levels.

5.2.2 Action research

Action research (AR) is a participatory process of investigation concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a worldview that values the knowledge, skills and capacities of multiple actors. It brings together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people (Reason and Bradbury, 2006), oriented to system development and the improvement of knowing and knowledge (Chisholm, 2001). Emphasis is placed in its practice on collaborative production of knowledge generated inter-subjectively in and through shared actions (Gibson-Graham, 1994; Kesby, 2007; Kindon et al., 2007). AR thus is in principle and practice an apt research approach to system innovation.

In this study, we also stand back from our own practice and examine the role and contribution of action research in developing a novel ABS mechanisms and relationships.

5.3. Methodology

5.3.1 Data generation

The core stakeholders in the study initially were farmers from twelve PPB trial villages in Guangxi, four breeders from Guangxi Maize Research Institute (GMRI),

one breeder from the China Academy of Agricultural Sciences (CAAS), and three policy researchers from the Centre for Chinese Agricultural Policy (CCAP). The network subsequently was expanded as a result of the AR co-learning process to include policy makers from the Chinese Ministry of Agriculture (MoA) and Ministry of Environmental Protection (MoEP), and PPB and ABS experts from institutes outside China. Data were gathered through a range of activities that were designed and re-designed in successive AR cycles:

- At the niche level, a series of institutional experiments have been executed - which has never been attempted before in China – in which 'experiment' was understood as an early stage of an on-going process of institutional development, in which 'proof of the ABS concept' was explored. The institutional experiments on ABS have been tested in three ways, each building on cycles of AR: a) PPB breeding activity from 2000 onward, targeting the improvement of maize landraces and farmers' varieties, locally-adapted hybrid development, and building farmers' capacity; b) community-based seed production of PPB varieties, from 2005 onward, to provide a market-based reward for PPB farmers; and c), from 2008 onward, the development of ABS contracts between the maize breeding institute (GMRI) and 12 farming communities; the first was signed in 2010. The contracts provide formal support to farmers' on-farm PGRs conservation and improvement (including landraces, improved farmers' varieties, and hybrids).
- At regime level, the stakeholders, guided and facilitated by the PPB programme, have entered into dialogue with key actors positioned in higher level institutions responsible for breeding, seed production and ABS within the Chinese national context. Twelve policy workshops and round table discussions have been held at provincial, regional (including the southwest provinces), national and international levels between 2000 and 2010, with the direct and indirect involvement of policy makers from the Ministry of Agriculture, Ministry of Environmental Protection, researchers and breeders from the Chinese Academy of Agricultural Sciences (CAAS), the Guangxi Academy of Agricultural Sciences (GAAS), the Guangxi Maize Research Institute (GMRI), and ABS colleagues from other countries. These meetings have taken up different aspects of regime change, including public breeding policy, agro-biodiversity conservation, smallholder farmers' livelihood improvement, and the details of ABS mechanisms. The meetings have created networked participation in a platform for discussing – and to an extent negotiating - niche-regime interactions, through which additional regime level innovations have been proposed and considered.

Events, decisions and processes were monitored and documented throughout by means of: 1) the documentation of the research practices and the participant observations of the field researchers; 2) joint identification of key episodes, distilled during reflection meetings in the successive AR cycles in the field and at the level of the PPB programme. The episodes were further discussed with farmers and policy stakeholders at provincial (i.e. Guangxi) and Beijing levels;

3) planning and design of further actions, on the basis of the co-learning built around each episode.

5.3.2 Data analysis

Innovation histories based on important events (here a series of related events are treated as 'episodes') allow analysis of the dynamics of innovation processes (Spielman et al., 2009; Klerkx et al., 2010). In order to provide a basis for analysis of the interactions between niche and regime levels, the study traced the timeline of the generation of novelty from 2000 through 2010, documented critical events, interactions and relationships in each of the eight episodes, and identified strategic shifts in action and institutions that resulted in consequence. The structure of innovation history in the analysis focuses on 'events' – what is happening, 'strategic shifts' – why they are critical, and 'process' - the role of action research in building new relationships between niche and regime level actors, information, issues and 'the rule set'.

5.4. Critical events driving the articulation between levels

5.4.1 Episode 1: Formal breeders realize farmers' expertise in seed selection and breeding and accept farmers as valuable partners

At the end of 1990s, an assessment of the impact of international maize and wheat improvement centre (CIMMYT) -released maize varieties on poor farmers in southwest China (Song, 1998) observed the systematic separation of the formal seed system and farmers' seed system. Formally bred and released modern varieties were shown to have poor adaptation in the remote mountainous regions of the southwest and to be only marginally adopted by the farmers in these regions. On the other hand, although the southwest was known to be the centre of maize genetic diversity in China and landraces were intensively distributed in local communities (Yao et al, 2007), the assessment documented for the first time the local diversity of landraces conserved in communities, with more than 80 per cent of farmers' seed being supplied by their own seed systems (Song, 1998). CCAP researchers felt on the basis of this study that it was urgent to utilize local varieties (i.e. farmer improved open-pollinated varieties (OPVs) and landraces) more effectively in formal breeding in order to adapt formally released varieties to local conditions. A pioneering PPB project, funded by the International Development Research Centre (IDRC) and the Ford Foundation, was initiated in 2000 with facilitation provided by the Centre for Chinese Agricultural Policy (CCAP) in Beijing. The project started in Guangxi with the active collaboration of maize breeders from GMRI (the provincial public breeding institute) and CAAS (the national public breeding institute). Project researchers invited the breeders to farmers' fields to discover for themselves farmers' skills, knowledge and expertise in managing genetic diversity. Later on farmers were

invited to bring their varieties to the institute and to share their experience with seed selection. During the exchange visit the breeders discovered that the farmers had conserved and improved Tuxpeño 1, a maize OPV released earlier by International Maize and Wheat Improvement Centre (CIMMYT), and that one farmer, known as Aunt Pan from the Wentan village, had improved a locally important variety that had become widely popular in the surrounding local communities. Breeders from the provincial and national formal breeding institutes started to accept that farmers could be supported to become valuable partners in seed development and improvement. With the assistance of the project researchers they returned to the Wentan village and invited Aunt Pan to join the PPB research team to continue improving Tuxpeño 1. From 2000 to 2004, gradually, the project became a programme (funded in part from Chinese sources), expanding from one village to five and from individual farmers to farmer groups. For both breeders and farmers, PPB became an entry point to explore and identify technological and institutional options to bridge farmers' seed systems and the formal seed system, integrate scientific knowledge and farmers' knowledge in breeding and conservation, and to build mutual respect and understanding among farmers and public breeders.

5.4.2 Episode 2: Whose varieties are they? Challenges encountered in registration of PPB varieties

In 2003, with the support of the PPB team, GMRI breeders entered the first PPB variety, Xinmo 1 (an OPV), into the formal testing procedure for value of the variety for cultivation and use (VCU). There are two levels of VCU testing in China, at both the national and the provincial levels. 'Xinmo 1' was entered into the national testing procedure and in the Northern provinces it did not perform as well as in the trial villages of Guangxi; it finally failed the VCU test. The PPB team reflected on the challenges to the registration of PPB products. They decided that henceforth OPVs would be released only in the trial villages and their neighbouring communities. Another variety, a waxy maize hybrid, Guinuo 2006, that had passed VCU tests successfully in the trial village, was officially released in 2003 at regional level by registration through the GMRI. One of the parental lines of 'Guinuo 2006' was collected from the trial village and later on farmers participated in adaptation trials of this line. The commercialisation of 'Guinuo 2006' by the GMRI-owned seed company subsequently generated significant financial benefit for the breeders because it soon became one of the most popular waxy varieties on regional seed markets.

By the start of 2011, four OPVs had been bred but not officially registered because they cannot meet the requirements of the national VCU tests and the hybrid Guinuo 2006 is the only variety that has been registered. In 2004 the research team started to explore the space for recognizing PPB varieties through other mechanisms than the national VCU procedures. They invited provincial and national policy makers and formal breeders to a policy dialogues to discuss registration and release issues for PPB varieties. The issue of how to recognize

farmers' contribution and create incentives for PPB farmers emerged as an important part of the dialogue. During the meeting the farmers and breeders who had joined in PPB activities, themselves concluded that the current seed regulation left little space for farmer improved varieties because VCU testing admits to the market only those varieties that show 'clear improvement' (especially in the yield) in all its testing regions compared to existing varieties. The performance of PPB varieties, selected from and for low-input conditions, cannot easily be assessed under favourable conditions. On the other hand, given the generally weak awareness of farmers' rights and contribution to PGRs conservation, both in the field and in policy circles, the meeting participants agreed that farmers could not easily be granted benefits as potential (joint) breeders even if a PPB variety could be registered. Moreover, the mandates of public breeding institutes have been changing since the opening up the seed market in 2001, most currently combine breeding, seed multiplication, and seed marketing. The CAAS breeder at the meeting gained the support of the other participants for his view that, in order to support farmers' breeding activities within PPB, it had become necessary to clarify and separate the public interest and commercial roles of these institutes, and ensure that their commercial enterprises compete in the market place on equal terms with private commercial seed enterprises.

5.4.3 Episode 3: Reaching an agreement on sharing benefits at community level

From 2004 onwards 'Guinuo 2006' rapidly penetrated the commercial market. Farmers who had participated in the adaptation testing of 'Guinuo 2006' had appreciated with pride its potential commercial value but they also subsequently became aware of the costs for themselves of purchasing the seed i.e., for accessing it from the commercial market. The PPB team started to realize that it was unfair that the farmers who had contributed to seed development should now have to pay for using it. In order to help farmers save on the seed cost and as a way to re-direct benefits to PPB farmers, the PPB team initiated the community-based seed production of Guinuo 2006 in the trial villages. Unlike OPVs for which farmers can produce seed individually and independently, hybrid seed production needs more intensive technical support, such as provision of parental seeds and development of isolation skills during the flowering stage. Since Guinuo 2006 has been registered and protected, community-based seed production requires prior agreement among GMRI breeders, the GMRI-owned seed company and the seed production villages. The PPB team invited all the stakeholders together for a discussion of the feasibility of reaching an agreement in support of community-based seed production. There was general welcome for the idea and the negotiations resulted in an agreement to share the economic and financial benefits i.e. the breeding institute and the seed company would supply the commercial market while allowing PPB farmers to supply the seed for local niche markets. On the breeders' side, this agreement was based on their desire to continue to build relationships of mutual trust. 'We have collaborated with those PPB farmers for a long time, we trust them as friends; and we would

like to grant them small scale seed production in their communities' (K. Huang, PPB maize breeder from GMRI, July 2005). In 2005, two of the trial villages located in remote mountainous areas were selected for seed production; these locations were chosen because the breeders wanted to reduce the chances that the parental lines of the hybrid variety, which remained protected by their plant breeders' right, would be stolen by rival commercial interests.

5.4.4 Episode 4: Recognizing the potential value of landraces for formal breeding

From the beginning of the collaboration in PPB breeders both in CAAS and GMRI reported that the genetic base of maize hybrids was becoming dangerously narrow and they realized the importance of landraces conserved on-farm as a potential source of valuable new breeding material. Because the PPB team has enabled breeders the opportunity to visit and work with farmers in identifying and collecting farmers' PGRs, the breeders have become increasingly aware of the existing and potential connections between their breeding activity and the plant materials conserved by farmers. In 2008 the PPB team concentrated on on-farm landrace conservation and on extending PPB activity to new communities in Guangxi and into two additional provinces, Yunnan and Guizhou. The new communities were located in the more remote regions of the southwest than the original PPB villages and the farmers in these villages were shown in a survey to conserve an even larger range of PGRs. In collaboration with the MoA's 'Agricultural System Construction' programme (a national public research system reform initiative that started about the same time), the PPB team and their new provincial collaborators and community leaders, intensified their work on PGRs conservation and utilization.

During a field visit to the villages of Luocheng and Yizhou the breeders' awareness and appreciation of farmers' expertise in *in-situ* conservation greatly increased when they discovered that some of the local varieties developed and maintained by the farmers showed better performance and adaptation to the conditions in the farmers' fields. The farmers in Luocheng and Yizhou readily agreed to become a PPB and conservation site. At the same time, the local landraces collected through the initial and follow-up field visits have been trialled on station and their properties investigated in the laboratory, thereby becoming integrated into the routine work of the institutes. In 2009, during another policy dialogue, the CAAS breeders presented the initial findings of simple-sequence repeat (SSR) analysis of 170 landraces and OPVs collected from farmers' fields in the three provinces (unpublished data). Based on the findings, the CCAP researchers and policy makers from MoA and MoEP realized that formal breeding programmes were not taking full advantage of the utilization of local PGRs, that the collaboration between farmers and breeders needed to be strengthened, that more emphasis should be put on *in-situ* conservation, and that mechanisms needed to be developed to provide incentives for farmers to collaborate with the breeders and to continue to conserve local PGRs. It

was proposed by the CAAS breeders that the farmers receive what they called a subsidy whenever PGRs was collected from them and whenever farmers participated in selection and breeding work together with the breeders. However this proposal has not yet been taken into account by the policy makers on the national level.

5.4.5 Episode 5: Recognizing the tensions between local ABS practice and regulatory frameworks

In order to better understand the generic problem of the emergent tensions between local ABS practices and national regulatory frameworks the IDRC organized in Beijing in 2009 an international exchange of the ABS experience in four countries, China, Jordan, Peru, and Nepal. The meeting comprised a workshop in Beijing and a field visit to PPB villages in Guangxi. The close links between ABS issues and national legislation, crop policy, and stakeholders' interests became a focus of discussion at the workshop. Chinese officials working on ABS legislation, from the MoA and MoEP participated in the discussion. They introduced the slow progress with implementation of the CBD and development of ABS legislation in China. The PPB team presented the PPB-related ABS practice in Guangxi and the community-based seed production of 'Guinuo 2006', defined by the team as an ABS experiment at the niche level. They stressed that the further development of the emergent practice required a series of new institutional arrangements, such as procedures for registering a joint plant breeders' right, a joint plant breeders right transfer agreement and mechanisms for payment for use of protected varieties, the introduction of a 'commercial line' restriction for non-commercial seed production, and for quality control of farmer-produced seed. Other ABS initiatives within China were presented, such as ABS arrangements for utilisation of animal genetic resources in the Yunnan-Tibet region and ABS arrangements for use of medicinal traditional knowledge and the related medicinal plants in Guizhou and Inner Mongolia. Chinese participants also learned from the other countries' experience that both public research institutes and local non-governmental organizations play important roles in addressing ABS for smallholder farmers.

The subsequent policy dialogues organized in the AR process continued to raise challenging issues. In China, ultimately the state has sovereign rights over all plant genetic resources and private ownership and PGRs property rights have been vaguely defined, i.e. in law it remains the case that no individual can claim ownership over PGRs. Breeders can receive 100 Yuan from the government [i.e. US$15] for each variety collected for a gene bank, but there is no payment for farmers if seeds are collected from their fields. To compensate farmers for their contribution, CAAS breeders suggested refunding those farmers for the costs of maintaining the designated PGRs in their fields, to the value of 0.3-0.5 per cent of any commercial profit a commercial seed company might derive from that material. Subsequently, the GMRI breeders endorsed this idea, but when they discussed the proposition within their provincial institutes the institutes' com-

mercial branches that are responsible for seed production and marketing, objected. The exposure of the opinions and interests of each stakeholder brought into the open the tensions between benefit-sharing and the public and commercial roles of GMRI breeders. The officials concluded that China lacked a common ABS framework at the national level and that this was creating uncertainty for emergent local practices.

5.4.6 Episode 6: Overcoming problems in mainstreaming PPB – creating incentives for breeders

During the field visit linked to the ABS workshop, the PPB experiment in Guangxi attracted the attention and interest of other PPB practitioners, such as Dr. S. Ceccarelli, an internationally acclaimed PPB practical breeder from the International Centre for Agricultural Research in the Dry Areas (ICARDA). He suggested improvements to how the field experiments were designed and implemented. It was a critical moment for the PPB team because they were at the point of offering a follow-up training for PPB breeders in China. The team recognized the potential and importance of his expertise and invited him to join local breeders during the training, held in January 2010 in Guangxi. Ceccarelli demonstrated and discussed how PPB activity and results can be documented and generate high quality scientific papers. The credibility of the outside expert provided the other participants a stimulus to discuss how to improve their PPB work as a rigorous scientific activity: 'Before this training, I understood PPB is more related to farmer-led field experiment, aiming at improving farmers' livelihood and their capacity building. From this training, I reflect that there is also an institute-led PPB experiment, which can be designed in a more scientific manner' (S. Zhang, CAAS breeder, January 2010). The concept of evolutionary breeding was introduced in support of building the scientific rationale for farmer participation in on-site selection and breeding. The scientific excitement created during the training provided incentives for institute breeders to commit to breeding-oriented experiments with farmers, and the scientific data generation and publication on the basis of PPB, and provided them with the confidence that PPB is a scientifically-recognised and rigorous professional activity.

5.4.7 Episode 7: Developing ambitions to create incentives for farmers in relation to agro-biodiversity enhancement

In order to map the distributional changes in maize varieties in farmers' fields over the past 10 years, a CCAP researcher conducted a survey in 2009 that recorded farmers' adoption of hybrids and the persistence on landraces in the three southwest provinces, Guangxi, Yunnan and Guizhou (Li et al., 2011). Analysis of the results showed that there had been a rapid loss of landraces. Some landraces even in the PPB trial villages had disappeared. If there is no one to plant those varieties, there is a lack of seed; if there is no seed, there is no exchange and no further access and the actual and potential public good value of the local PGRs is lost for ever. On average the percentage of the growing area

planted to landraces has declined from 77 per cent in 1998 to 21 per cent in 2008 (Li et al. 2011). In Guangxi a single hybrid, 'ZD 619', covered 44.9 per cent of the maize area in the survey region by 2008 (Li et al. 2011). Such findings astonished both farmers and breeders and in consequence the team re-defined its priority, i.e. to develop and test effective incentives for *in-situ* conservation and PPB breeding. Given the recognition by researchers, professional breeders and officials in the policy dialogues that legislation on biodiversity, farmers' rights and ABS lag behind in China, the team realized the urgency of creating workable mechanisms at the niche practice level.

5.4.8 Episode 8: Making an ABS agreement among PPB stakeholders

The team scoped possible mechanisms for ABS through a series of policy dialogues and round table discussions with policy makers and officials, breeders, institute managers and farmers. Two property regimes for PGRs i.e. as common property and exclusive property (based on plant breeders' rights), were discussed and the implications of each for how farmers might benefit from them. The researchers showed how under a common property regime, farmers as resource stewards can benefit from public subsidy while under a PBR regime, farmers can benefit from the royalty on new varieties if they are recognised as contributing to the breeding of the registered variety. It emerged in the discussions that according to the current Plant Variety Protection (PVP) regulation (1997) in China, farmers can be recognized as the joint breeders through a contracting arrangement. However, such an agreement is difficult to achieve in practice because the development of the public breeders' commercial interests has created a competing stake in PGRs between farmers and the public institutes, and farmers' rights can rarely be claimed through PVP law. Meanwhile , the passing of the Science and Technology Progress Law in 2008, that was sponsored by the Ministry of Science and Technology (MoST), allows the products of public investment in breeding to be privatized by the public institute, in the form of exclusive IPR (these issues are discussed in Chapter 4). During the 2nd Regional Inter-governmental ABS conference held in Nanjing in April 2010, members of the Association of Southeast Asian Nations (ASEAN) exchanged their experience with IPR implementation, ABS legislation, and how to balance farmers' right (FR) and plant breeders' right (PBR) within their national seed regulatory frameworks. India for instance has integrated FR and PBR into a comprehensive national seed law, i.e. The Protection of Plant Varieties and Farmers' Rights Act (2001), which defines a farmer as i) conserver of crop diversity and genetic resources, ii) breeder of farmers' own varieties; and iii), cultivator and producer enjoying a traditional right to sow, re-sow, sell or barter farm-saved seed. Thailand has built into its national framework four scenarios for PVP implementation, by distinguishing the protection of 1) new plant varieties, 2) general domestic plant varieties, 3) wild plant varieties, and 4), local domestic plant varieties (ASEAN, 2010).

At a policy dialogue organised in Beijing following the ASEAN meeting (which was attended by one of the team's researchers) the participants were inspired

by a presentation of an ABS contract model that has been developed in Taiwan. This requires recognition by name of any farmer contribution, and an enforceable fair benefit arrangement agreed by all the named parties, before a license for seed release is granted. It provides an alternative to arrangements based on exclusive rights, and compels the balancing of interests among stakeholders in the public sector, commercial sector and farming communities. Of particular interest to mainland China's policy makers was the model's reliance on procedural law because this approach to law-making is already well-established in the institutions governing commerce. Given that contracts are well established in commercial practice and are enforceable in law, CCAP researchers started to negotiate an ABS contract together with its stakeholders. In order to distinguish two potential purposes for a contract, i.e. to encourage *in-situ* conservation (for breeding and agro-biodiversity enhancement) on the one hand, and to share fairly the commercial benefit from market exploitation on the other, two types of contract were developed in parallel. The former addressed the urgent need for PGRs maintenance; the latter addressed the fair sharing of benefits from commercialisation with both farmers and institute breeders protected by PBRs. These two contracts were signed by three public research institutes (including one policy institute and two breeding institutes) and 12 farming communities, in Guangxi in June 2010.

In July 2010, the team reported the contract process to MoEP and MoA officials, and discussed the feasibility of scaling out the practice at national level. MoEP officials proposed to integrate the PPB team's case experience into the national ABS discussion. MoA officials realized the necessity for setting up a national PGRs and landrace registration system as the basic step required for international recognition of national ABS law. They also suggested Geographical Indication (GI) protection as an alternative form of protection for PPB products. Although experience with GIs in China is limited so far, GIs already have opened new markets for traditional agricultural products and have been used as a form of collective IP by all those who produce that product in a given area (Nagarajan, 2007; Ilbert and Petit, 2009). Since the early 1990s, China has developed three modalities of GI protection for raw agricultural products and the final product, respectively under the supervision of the State Administration for Industry and Commerce (SAIC), the General Administration of Quality Supervision Inspection and Quarantine (AQSIQ), and the Ministry of Agriculture (MoA) (Wang, 2009). All three modalities already allow recognition of and reward for farmers' contributions. If the seed of PPB varieties and its products can be protected by the GI system, farmers in southwest China will have a strong opportunity to enter into the market and share the benefit from their conservation, production, and value-adding efforts.

5.5. Analysis and Discussion

5.5.1 Niche-Regime interactions foster institutional innovation

The eight episodes show a series of adjustments that arose in the AR process as the team and broader circles of stakeholders engaged in joint learning. Each shift revealed an outcome of niche-regime interactions that have been called into existence as a result of the PPB team's efforts. Institutional innovation in the end is dependent on the extent to which these interactions build enduring relationships, networks of interest and procedural or other arrangements. The implication is that institutional innovation is a highly unpredictable process (Klerkx et al., 2010). Some shifts bring tensions openly into discussion, others initiate new spaces for change. Table 5.1 compares the eight episodes in terms of niche-regime interaction, strategic shifts, the role played by action research, and the institutional change achieved.

Positive interactions bring opportunities and widen the space for further innovation, while negative interactions may cause conflict and tensions between niche level practices and regimes, as can be seen in episodes 2 and 7 in which diagnosis of the challenges for PPB varieties and agro-biodiversity respectively was seen as confronting to existing interests. Table 5.1 also shows how the emerging practices and discourse continually shifted the focus of AR. Armitage et al. (2007a) argue that an emergent outcome may represent an important innovation under conditions of change, uncertainty, and complexity. Table 5.1 further reveals how learning at one level or among one set of stakeholders was progressively shared with others, allowing actors to plan and design new actions and address emerging issues and options. Sometimes the planned activity was adjusted to accommodate a new situation, e.g. the design of the PPB training carried out in episode 6 was initiated during the field visit carried out in episode 5.

Seen as a whole, the processes covered in this article can be seen as both bounded by well-defined concerns, yet sufficiently open for new elements and actors to enter as new information and knowledge was introduced and networking created new relationships among those hitherto widely separated from each other. By creating space and time for new meaning and practices to emerge among actors positioned at different levels, around concrete experiments, the learning at niche level is enabled to penetrate the regime level (Steyaert and Jiggins, 2007).

Table 5.1 in addition allows analysis of AR as an evolving process that integrates practice and reflection, re-design and planning, and accommodates contrasting perspectives and draws in actors from different levels. For instance, episodes 1, 3 and 8 are more practice-oriented, in which PPB, community-based seed production and the ABS contract have been initiated and achieved. Episodes 2, 5 and 7 are more reflection-oriented, in which the team defines the constraints to ABS

Table 5.1. Highlights of eight episodes in a participatory maize breeding project in southwest China, in relation to 'niche-regime interaction', 'strategic shift', 'role of action research' and 'institutional change' of each.

Episode (year)	**Critical events (Niche-regime interaction happens)**	**Strategic shifts**	**Role of action research**	**Institutional change achieved (as results and outcomes)**
1 (2000)	Formal breeders begin to realize farmers' expertise on breeding and recognize farmers as valuable partners	PPB started with farmer improved varieties in Guangxi	Networking farmers and breeders in breeding, facilitating mutual understanding and respect relationship between farmers and breeders	Farmer-breeder collaboration in PPB; trust building during PPB
2 (2003)	PPB varieties face challenges in seed regulation: OPV failed VCU testing, hybrid was registered by breeders; farmers are excluded from PBR and market incentive; the commercial role of public institute was realized	Reflecting on registration challenges and taking ABS issues into consideration	Defining institutional challenges of PPB products, organizing reflection and bringing negative situation into discussion	(emerging mis-matches between PPB varieties and seed regulations)
3 (2005)	Farmers are excluded from commercial market of *Guinuo* 2006, the project proposed to refund PPB farmers through community-based seed production, breeders and seed company allowing PPB farmers supply the seed for local niche market	Reaching an agreement of sharing benefit at community level through seed production	Facilitating interaction and negotiation on seed production, balancing the request from both breeders and farmers (i.e. balancing PBR and FR) and enhancing the collaboration during seed production	Agreement on seed production
4 (2008)	Formal breeders realized the narrowed genetic base in hybrid breeding and the potential value of landraces in future breeding, a collaboration with national programme on PGRs conservation and utilization in three SW provinces started, formal breeding institutes become more aware of genetic diversity existing in SW	Recognizing the potential value of landraces for formal breeding, and scaling out PPB to SW region	Introducing farmer conserved PGRs to formal breeding institutes; and enhancing trust-building and knowledge sharing during PGRs collection	(strengthening the importance of in-situ conservation in the southwest)
5 (2009)	IDRC experience exchange and policy dialogue on ABS; discussing PPB-ABS issues/practices within Chinese context and defining the alternatives for the project	CAAS breeders propose the refund for farmers, objected by GMRI breeder	Bringing PPB-ABS practice/issues into policy discussion, and vice versa	(gap between ABS practice and national legislation)
6 (2010)	Mainstreaming PPB through a training, PPB methods shift into breeders' daily work through creating incentives for breeders	PPB experiment becomes more systematic and scientific-oriented	Bringing outside expert into the project, in order to make PPB more convincing for breeders; creating incentives for institute breeders, in terms of scientific experiment and publications	Mainstreaming PPB method in public breeding institute in the southwest provinces
7 (2010)	Reflecting on the loss of agro-biodiversity in SW, the team seeks for incentives for farmers; sharing the survey findings with national and SW-provincial institutes to increase their awareness on PGRs conservation	Developing ambitions to create the incentives for farmers on agro-biodiversity enhancement	Conducting survey and sharing the findings with PPB team and breeding institutes, facilitating the reflection on PGRs maintenance	(seeking for incentives for farmers' in-situ conservation)
8 (2010)	Searching for feasible options to balance PBR and FR within regulatory framework; making ABS agreement among PPB stakeholders, combining both landrace maintenance and hybrid breeding	Inspired by ABS contract model of Taiwan, ABS contract has been signed by breeders and farmers.	Defining ABS alternatives within national context, facilitating stakeholders making agreement on ABS contract, bridging local practice and policy forum into dialogue	ABS contract

Notes: ABS = access and benefit sharing; CAAS = Chinese Academy of Agricultural Sciences; FR = farmer's rights; IDRC = International Development Research Centre; OPV = open-pollinating variety; PBR = plant breeder's rights; PGRs = plant genetic resources; PPB = participatory plant breeding; VCU = value for cultivation and use.
Source: this research.

and PGRs maintenance, and seeks alternative spaces in the regime which might be induced to support the emergent niche-level innovations. In episode 4 we see that change in the AR's focus was not driven by farmers at the grassroots' level but was based on the concerns expressed by regime-level stakeholders about the potential value of landraces. The shifts illustrated in episode 6 are related to building the capacity and scientific understanding of formal breeders with regard to PPB. The eight episodes together encompass institutional innovation as the result of creating new ways for niche and regime level actors to interact and build mutually useful relationships, driven by critical moments that have led either to strategic changes in practice or to an expansion of what was taken into account in formulating appropriate frameworks in China for PPB, seed registration and release, ABS, and PGRs. Some strategic shifts have happened gradually and slowly (e.g. episode 4), while others were caused by a sudden change or surprise opportunity (e.g. episode 6, initiated by a field visit).

Within each episode, action researchers play different roles, such as network broker (Wenger, 1998, 2000; Klerkx et al., 2010) in episodes 1, 3, 5, 8, discovering the boundaries of the issues at stake together with the stakeholders (Steyaert and Jiggins, 2007), or by bringing in new elements or knowledge and broadening the horizon of practice as in episodes 2, 7, 8, or by creating capacity for adaptive management and situated learning from experiments (Steyaert and Jiggins, 2007) in episodes 3, 4, 6, 7, 8. Sometimes, proposals that are considered and then rejected, or actions that fail to deliver their intended promise, none the less help define the issues in a situation that is complex. For example in episode 5, the proposal to refund farmers' efforts to maintain resources was rejected by the GMRI-owned seed company, thereby bringing into open discourse the conflicting interests of the public interest and commercial branches of GMRI.

A number of institutional changes (i.e. changes at the regime level) has resulted from the niche-regime interaction, such as the development of a framework and procedures for PPB collaboration and the contractual agreement on seed production and ABS and PGRs. In other instances, the interaction did not lead directly to institutional change but rather made visible or even created tensions and 'mis-matches' in the articulation of interests and institutional arrangements, in turn building pressure for further change.

5.5.2 Action Research and 'adaptive co-management'

Action research provides a general approach for developing the institutional governance of systemic relationships in which the research team usually has primary responsibility for proposing designs and facilitating the process. The specific roles of researchers in AR include designing and facilitating meetings, collecting and feeding back information, monitoring and helping manage the overall network development process, and creating ways for members to learn from the process (Chisholm, 2001). In such a way, action research plays an im-

portant role in mediating learning processes and relationships among people, and between people and their material world. In this study, CCAP researchers acted as the main facilitators driven by the motivation to create among PPB stakeholders an understanding of and capacity to deliver a workable ABS mechanism. AR in this case, as shown in the eight episodes, created a platform for mutual understanding, knowledge creation and social learning. The feedback provided to stakeholders by means of the distillation and joint consideration of each of the eight episodes through time clearly served to support the enlargement of the space for action and the participants' commitment to shared learning as the basis of institutional adaptation (Leeuwis, 2004).

The findings presented here indicate that in this case AR enabled processes and outcomes that parallel those reported in the adaptive co-management literature (for instance, in Armitage et al., 2007b). The key features of adaptive co-management include a focus on learning-by-doing, integration of knowledge systems, collaboration and power sharing among community, regional, and national levels, and management flexibility (Olsson et al., 2004). Adaptive co-management seeks to provide evolving and place-specific governance that responds to feedback (both social and ecological) and places coupled social-ecological systems on sustainable trajectories (Dietz et al., 2003). The PPB-related ABS exploration for instance can be seen as a form of adaptive co-management evolving in a dynamic and non-linear fashion over the eight episodes.

Adaptive co-management calls for transitions in governance 'at all levels' that involve state, public sector, private and civil society actors. According to Berkes (2007), flexible, multi-level institutions and cross-level learning networks are important for building adaptive capacity in a world characterized by rapid rates of change and abrupt transformations. Transitions in governance rarely happen by themselves and everywhere seem to demand careful facilitation as new relationships of trust are created and spaces for well-informed negotiation among stakeholders are developed. The experiences reported in the eight episodes further show that because the outcome – workable ABS mechanisms – cannot be defined in advance, debate, uncertainty, and difficult choices, struggles and the risk of serious disappointment, are all part of the process (Meadowcroft et al., 2005).

5.5.3 Networked (regime) actors in action research

The research process analysed here influenced the relationship among farmers, breeders, policy makers and outside experts, through structuring a learning network and supporting all actors to enter into new spaces for discussion. Beginning from a simple professional collaboration between researchers, breeders and farmers around crop breeding and varietal selection, based on their complementary knowledge and experience, as mutual understanding and trust accumulated, new issues emerged and were explored together, and these chal-

lenged everyone's accepted boundaries of understanding and action. Meanwhile, new issues arose from the actions taken and new elements and actors entered into the discourse as higher level officials and other policy makers, as well as outside experts contributed new information and considerations. The existing boundaries of knowledge began to open up and discussions both broadened and deepened. The network itself became 'knowledgeable' and increasingly empowered to act on the basis of the members' shared understanding of each other's values and interests, representing a form of 'distributed cognition' (Röling, 2002).

The position of the researchers was especially important in these processes. They had sufficient PPB expertise to be accepted as colleagues by the breeders; they had sufficient social and academic standing to be accepted as credible and legitimate authorities by provincial and central officials; and yet they also, by their long term presence in the field, and the respect and value they gave to farmers' knowledge and skills, were accepted as trusted and comfortable partners of the communities they worked in. Such boundary spanning actors (Wenger, 1998, 2000; Klerkx et al., 2010) have been identified in other settings as essential to regime change. When there are tensions between niche and regime, or agent and structure, the boundary spanner plays an important role in mediating relationships at the interface. In this study the CCAP researchers created opportunities to link niche level practice directly with policy actors and to mobilize a boundary-spanning network in relation to policy and regulation. The breeders from CAAS and GMRI similarly each began to link niche practice and outputs within their technical and scientific fields with the related regime context.

5.5.4 Institutional change in relation to ABS

This paper has discussed ABS issues within the context of PPB, where farmers and breeders interact in relation to the breeding activity and on-farm PGRs maintenance. From 2005 to 2010, a number of institutional changes in relation to ABS have been accomplished through and as a result of the interaction. These are an informal mechanism in the form of an agreement on seed production, a formal mechanism in the form of a legally enforceable contract, new procedures for and commitments to local level capacity building in relation to PPB, ABS, and PGRs conservation, identification of new options (such as GI and procedural law), and influence on the still evolving policy environment. In China, rights-based approaches to seed management, and ABS legislation, are still under negotiation among diverse interests and sectors. At the practice level, change in the incentive structures (Williamson, 2000; Slangen et al., 2008) has been shown to be effective in bringing about institutional innovation, and this experience is being closely followed by Chinese policy makers. The major constraints to PPB-related ABS exist in the seed regime in relation to VCU and DUS (distinction, uniformity and stability) testing, exclusive IP protection, and the vacuum in national legislation with respect to ABS. Given there is no body

of national ABS law in place, niche level practices have been created that offer a range of practical options for policy makers to consider. In particular, since the role of contract law already is well established in commercial practice and the contracts are enforceable in law, this study's policy dialogue participants have expressed strong interest in pursuing ABS through the procedural law governing contracts, learning from the experience of the draft model law in Taiwan. However, the wider application of this option depends on a willingness to allow farmers' organisations to become registered as legal entities. Another kind of procedural approach to ABS is already achievable, under the three modalities described in this paper for registering Geographical Indications (GIs). All three modalities already allow recognition of and reward for farmers' contributions to the development of raw agricultural materials and food products. GIs are expected therefore to provide additional windows of opportunity in the near future for sharing the market benefits of PPB products.

5.6. Conclusions

This paper demonstrates the contribution of action research to building conducive interactions between niche practice and regime. The value of action research in fostering institutional innovation has been shown by detailed study of the processes of change with respect to PPB-related ABS mechanisms. The analysis of eight critical events uncover the strategic shifts that have occurred in a research practice that has evolved as shared learning accumulated among niche- and regime-level actors. Each episode details the twists and turns in the iteration between practice and reflection, through which stakeholders jointly discover the issues and make new accommodations. The results offer legislators and policy-makers in China in the on-going formulation of ABS policy and law a number of tested options for sharing access and benefits in crop breeding, varietal selection and plant genetic resource conservation. These novelties, emerging from PPB practice in a programme niche that has attracted international, national, provincial and community level support, offer ways for China to balance interests while respecting its obligations under international law and accommodating competitive market pressures.

Chapter 6

Expressing the public value of plant genetic resources by organising novel relationships: the contribution of selected participatory plant breeding and market-based arrangements

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Abstract

This article explores the experience of expressing the public value of farmers' cultivars through organizing novel relationships among public and private actors, by means of participatory plant breeding (PPB) programmes and market-based arrangements. The concepts of public and private interest and value are examined from a public administration perspective in relation to the direct, indirect and option value of the plant genetic resources (PGRs) represented by farmers' cultivars. Seven organizational options from selected countries are examined in relation to their role in (i) creating indirect and options values; (ii) sustaining the legitimacy of and support for related practices; and (iii) developing operational capacity of the associated organizations and actors. The three main findings are (a) innovations in breeding and conservation developed through PPB are key factors in the management by smallholders of the indirect and option value of agro-biodiversity; (b) market-based arrangements and the creation of new sets of property rights in the products developed from farmers-bred cultivars legitimize and support for PPB and PGRs conservation; and (c), the organization of the indirect and option value of farmer-bred cultivars calls for the integration of the joint efforts of producers, consumers, market actors and public sector agencies in networked governance, that can take a variety of forms. Lessons are drawn from and for China, where legal and regulatory practices in the seed sector are still under development and smallholders still maintain crop and varietal diversity by their agricultural practices.

Keywords

Community-supported agriculture; farmer-bred cultivars; geographical indications; intellectual property rights; China

6.1. Introduction

It is increasingly recognised that valuable, dynamically evolving germplasm resources are disappearing from production at the very time they are needed for developing sustainable agriculture in the context of climate change (Newton et al., 2010). There has been considerable debate in the literature and policy circles about how to value these resources. Recent research has discussed valuation issues from a range of perspectives. Some studies investigate the public and private valuation of crop genetic resources from an agricultural economic perspective (Smale, 2006) that pinpoints locations in harsh environments, and where markets function imperfectly, as offering the least-cost opportunity for biodiversity conservation in terms of public investments and effective subsidies. Payments for Agro-biodiversity Conservation services (PACs) may have a role in creating incentives for on-farm agro-biodiversity conservation in such locations (Narloch et al., 2009). They point also to a category problem that affects the design of effective policy responses, that is, agro-biodiversity is an impure public good. In so far as agro-biodiversity has private value (Smale et al., 2004) farmers may incur not only one-off costs in learning how to manage modern agriculture for conservation, but also opportunity costs. Others emphasise the 'development opportunity' that commercially under-valued agro-biodiversity represents for smallholders and rural communities (GFAR, 2012) or the future benefits for crop breeders and wider society (Bellon, 2008). Ostrom (2009) suggests another way forward. She argues that the value of agricultural biodiversity is evidenced by communities' willingness to engage in self-organization and collective action to sustain the social-ecological systems that conserve agro-biodiversity. The contributors to Pilgrim and Pretty (2010) explore how likely it is that such efforts are sufficient, unaided by public policy support, to halt or reverse the potential loss of the genetic resources managed by farmers in the 'agricultural commons' that typify many local agro-ecosystems. They provide much evidence for pessimism but also some hope that initiatives such as community-conserved areas will prove effective.

The debate is of urgent practical concern because most countries are experiencing a rapid transition in their seed systems, with power to control the commercial seed development and supply of all major crops passing to the commercial seed sector at both the global and national levels (Renwick et al., 2012). The production and utilization of genetic resources that have commercial value only in local markets is not a priority for private commercial breeders and the expansion of intellectual property rights (IPR) into agriculture, in the form of patent and plant variety protection, has accelerated the development of the commercial seed sector (Phillips and Onwuekwe, 2007; Renwick et al., 2012). The economic growth of the commercial seed sector in practice has diminished the public interest in agro-biodiversity and the actual and potential contribution of smallholder farmers' seed enterprises to agricultural modernization and trade.

On the other hand, the majority of the world's smallholder farmers continue to source their seed from their own harvests and from informal seed markets and exchange networks. The attention and efforts of some parts of the public sector and non-governmental organization (NGO) community are turning towards neglected and underutilized crops or varieties, on various grounds, including conservation, nutrition, power, and climate change concerns (Bellon and Risopoulos, 2001; Gruere et al., 2007; Van Dusen et al., 2007). This paper examines selected examples of novel arrangements that seek to harmonise rather than make trade-offs among these goals, and relates these to opportunities in China. China is the world's second largest economy but still has millions of smallholder farmers who are dependent on informal seed systems, and as yet the policy, legal and regulatory provisions in its seed sector are under development. Thus the lessons of recent experience, from novel arrangements developed inside China and from elsewhere, may have significant impact on the choices policy makers might yet make. At the same time, China is recognized as retaining globally important agro-biodiversity in smallholder' farming systems, particularly in the southwest provinces where the majority of poor farmers live. Although in recent years these farmers have adopted modern maize hybrids they continue to maintain – especially in the karst mountain areas – their own farmers' varieties and landraces (Li et al., 2011).

The opening up of China's domestic seed market in the 1990s and China's entry into the global trading system has brought about new tensions between agricultural modernization and agro-biodiversity conservation. The transition has been accompanied by changes in seed regulation in order to bring China into compliance with international agreements, leading to the rapid emergence and expansion of the commercial seed sector and changes in the functions of public research institutes as they too expand the scope of their work into commercial seed development and marketing enterprises. However, policy-makers recognize that the market-driven demand for crop varieties that suit dominant market actors' interests cannot fully represent smallholder farmers' needs. In China's more remote mountainous regions, local seed systems and farmer conserved plant genetic resources (PGRs) still play an important role in farmers' livelihoods (Li et al., 2011). The government and the public sector are seeking ways to protect on-farm conserved PGRs and smallholder farmers' interests, within the frame of rapid commercial development of agriculture and food systems. The diverse, competing and intensifying claims on-farmer-maintained agro-biodiversity underscore the importance to global science and technology of retaining such resources in the public domain (Smale and Day-Rubenstein, 2002), yet the problem remains of designing an effective policy and operational response. The aim of this paper is to contribute to resolving the problem through an examination of the cases. We frame our evidence, analysis and discussion in terms of concepts drawn from public administration.

6.2. The concept of value

We begin by unpacking the concept of value in order to dissolve the private-public dichotomy. Brush (2000) distinguishes three different types of value for crop genetic resources: direct, indirect and an option value. Direct values are derived from the non-commercial (e.g., on-farmer own-consumption) and commercial (e.g., marketed surpluses) benefits derived from production, and the benefits (e.g., utility, happiness, nourishment, sustenance, etc.) derived from consumption. Indirect values refer to the environmental services rendered by genetic resources and to the benefits that result from biological resources irrespective of harvest and consumption. For *in-situ* conservation, the most important asset of local varieties is their indirect value in maintaining crop evolutionary relationships. Option values are derived from the future use of a resource that may be expressed as the desire to bequeath a specific or more general cultural patrimony to future generations or as the potential of a variety to meet future demands or conditions of production. Farmers are most likely to be interested in the direct values exemplified by the consumption or income benefits associated with enhanced productivity, e.g., higher or less volatile yields, lower costs of production per unit area, greater nutritional or consumption value. Farmers tend to be less sensitive to indirect and option values; these represent the public value of crop genetic resources for humankind as a whole or for particular societies. Public investments typically are needed to sustain or enhance indirect and option values, with private actors showing little willingness to take these values into account unless rewarded by subsidy (for instance, for landscape management) or by special market arrangements. Private actors in recent years have been seeking to capture the potential commercial value of farmer-bred cultivars, and to remove this potential also from the public domain by bringing farmers' varieties under exclusive intellectual property rights. The expansion of intellectual property regimes into agriculture is restricting the common good nature of PGRs. At the same time, public actors have been developing new mechanisms for maintaining or enhancing the public interest, particularly in option values.

Conservation of varieties is considered a particularly important option value. Veteläinen et al. (2009) argue that this implies utilization in ways that reconcile or harmonise private and public benefits. Participatory plant breeding (PPB) is recognized as one among other strategies for achieving such a balance of interests. PPB in fact has a three-fold purpose that mirrors Brush's (2000) distinctions: increasing the direct value of local generic resource for smallholder farmers, strengthening the indirect value of these resources within specific eco-systems, and conserving the option value of crop bio-diversity for future breeding. As we shall see, China is evolving a novel inter-organisational arrangement under the PPB umbrella that seeks to harmonise all three value categories. Other arrangements are emerging, based on forming networks among those willing to take into account – and pay for – the environmental, health and social aspects of seeds and food systems (Pascual and Perrings, 2007). Not all of these

arrangements rely on public subsidy; a range of market-related initiatives are being explored to produce change in the modes of connectivity between the producers and consumers of food, generally through reconnecting food to the social, cultural and environmental context of its production (e.g. Hinrichs, 2003; Kirwan, 2004).

6.2.1 Public interest and public value

We distinguish in our analysis between public interest and public value. The concept of public interest refers to the outcomes in any context that best serve the long-run survival and well-being of a social collective construed as a 'public'. The public interest focus is on the public as a whole rather than its constituent parts, and on the collective good. The concept is close to the related concept of public value but draws attention to the questions of 'for whom is something of value?', 'who speaks for their interest?' and the reasons or reference points by which people value things.

A clear definition of public value remains elusive. People may be said to value something because it is in their interest (Bozeman, 2007) but this is an inexact and somewhat circular relationship that can, moreover, shift over time. Public value has been described as a multi-dimensional construct, a reflection of the politically-mediated expression of collectively determined preferences consumed by the citizenry (O'Flynn, 2007). Anything related to collective action requires relationships of trust and fairness. Trust and fairness are norms created in interaction; they can be generated not just through outcomes but also through procedural processes for reward and sanction, and enforceable principles.

Bozeman (2007) suggests that society's public values are those providing normative consensus about (a) the rights, benefits, and prerogatives to which citizens should (and should not) be entitled; (b) the obligations of citizens to society, the state, and one another; and (c) the principles on which governments and policies should be based. Given that global market demand is not able to articulate such a normative consensus - to be exact, it does not distinguish between farmer-maintained landraces, local varieties, and commercially bred varieties (Eyzaguirre and Dennis, 2007), the full range of public values that are latent in farmers' PGRs and its management and development cannot be adequately expressed through current market processes (Donahue, 1991).

6.2.2 Determining preferences

The expression of public values also may be read as public preferences. The question then arises as to whether public preference is sufficiently captured in the monetized choices of consumers or requires some alternative or complementary process.

Economic analysts recognize that public preferences are 'bounded' i.e. they cannot be derived from models of human behaviour that position individuals as autonomous and rational decision-makers. It has been robustly established that individuals' choices are co-dependent on others' behaviour and preferences and that choices are thus conditional and relational rather than purely rational. Stoker (2006), for instance, shows how people's choices are motivated by the relationships they build in networks and partnerships, that is, relationships formed for a common purpose that are grounded in mutual respect and shared learning. The determination of public value in this view becomes a collective judgment realized through actions chosen in a reflexive manner, taking into account the internal capacity of the network and the enabling environment. The socio-economic and technical potential of PPB in the derivation of public preferences thus may be said to relate to the ways in which plant breeders and market actors inter-act with farmers' PGRs and its management by farmers.

A second consideration is the role of public agencies in actively shaping preferences, through enabling new experiences and evidence to be co-generated among diverse interests. Given that public value can be produced by a variety of entities, including private firms, non-profit or voluntary organizations, service-users, it cannot be argued that public value rests on the identity of those who produce the value. Rather, indirect and option values are a matter of who forms and consumes the value of that which is valued as an expression of a collective public interest. Public agencies nonetheless may be uniquely placed in some contexts to support the emergence of networks that can develop and exploit the values that lie beyond the individualism of the market and the monetization of value. Networked governance based on novel relationships and inter-organisational arrangements across the public-private boundary may encourage and supports citizens to participate in such judgments and, even as consumers, to bring new values to the marketplace. Thirdly, because there is a lack in the public domain of an equivalent to market-based pricing mechanisms that aggregate the preferences of individuals, it becomes part of the function or responsibility of public agencies to actively seek to understand and identify aggregated preferences and how these change over time. We return to this issue in the discussion section.

6.2.3 Framing questions

We derive from these preliminary clarifications a series of questions that serve to focus attention in the cross-case analysis on four inter-dependent issues:

1. What is the important public value each organization seeks to produce and whose interests are taken into account, what values are accommodated, and in which way values are derived?
2. What sources of legitimacy and support are relied upon to authorize an organization to take action and provide the resources necessary to sustain the effort to create public value? This idea on the one hand

refers to material and financial support, measured by such as the willingness of customers to pay for the products and services derived from the identified value; on the other hand, it concerns social and political legitimacy.

3. What operational capabilities does an organization rely on (or needs to develop)? How did the organizations in the study create organizational capabilities to generate public value from PGRs? How were interests balanced or harmonized to deliver the desired results?
4. How was the process of valuation organized so as to capture the values desired by different publics? We explore this question specifically in relation to PPB, which is positioned in this article as the organization of the breeding process in a way that helps to define the public interest over PGRs, and as the mechanism for value articulation and aggregation.

We use these questions to interrogate in the remainder of this paper, by means of cross-case comparisons of instances drawn from selected countries, how indirect and option values have been created, strengthened and rewarded through novel arrangements organised through PPB, and through developing related market-based relationships. Lessons are drawn concerning the options for establishing the public interest and assigning value by means of such arrangements and, in the Chinese context, for reconciling or harmonizing private and public interests and how public value can be better created and protected in the future in China. The article concludes by reflecting what can be learnt from innovations within China itself that may be relevant to other countries.

6.3. Methodology

6.3.1 Approach

The seven cases selected in this study were purposefully selected to represent a range of options for PPB in relation both to innovative institutional arrangements and to alternative market systems, and for their potential relevance to China. The cases are as yet rare examples within dominant agriculture and food systems and they do not drive policy-making - although they may prove to have the potential to do so.

Four of the cases are embedded in contrasting production contexts: 1) PPB for organic potato development in The Netherlands, linked directly with commercial breeding companies, under strong plant variety protection; 2) a locally-initiated multi-stakeholder seed production group, that plays an important role in supplying PPB seed in Nepal; 3) PPB products that are registered and commercialized by a farmer co-operative in Nicaragua; and 4) capacity building for benefit-sharing of PPB varieties among public institutes and farmers in southwest China.

These cases were presented and analysed at an international workshop (IDRC, 2009). The participants noted how the public value of PGRs may trigger a re-design of the market, so that market actors can obtain the direct benefit (i.e. cash value) of crop genetic resources, and consumers' willingness to pay more for the public value is encouraged. Three additional cases were then selected to analyse this potential: 1) PPB varieties and local agro-biodiversity products that are valued and marketed by community-supported agriculture (CSA) associated with a restaurant, in southwest China; 2) the application in China of an appellation label or brand-certification system based on Geographical Indication (GI); 3) the stimulation of conservation and marketing of local crop genetic resources in the EU through setting up a separate conservation regulation mechanism for landraces.

6.3.2 Data generation and analysis

The selection, compilation and analysis of the cases is based primarily on 13 workshops and policy roundtables organized for PPB practitioners and researchers in the context of a larger study (see Chapter 4 and Chapter 5). Academic articles, project reports and government documents have been reviewed during complementary desk research. The Chinese PPB case and related CSA experience are generated from participatory observation of and process documentation over a four-year period (2007-2011), and 12 key informant interviews with public breeders, CSA staff, farmers, policy makers and policy researchers. The research on GI development and distribution in China is built from the database of the Chinese State Administration for Industry and Commerce (SQIC).

6.4. Main findings

The examples under 6.4.1 demonstrate a range of novel arrangements, driven by PPB, for linking breeding activity, the organisation of seed sales, and capacity development, in ways that give varying emphasis to the direct, indirect and option value of farmers' landraces and varieties. The examples under 6.4.2 are driven by market-based arrangements that serve to link farmers' maintenance of agro-biodiversity to consumers.

6.4.1 Securing direct, indirect and options values through contrasting PPB-led arrangements

Industry-led, contract-based PPB serving the organic potato market, The Netherlands

The Dutch potato industry is highly competitive; it has been well-served for many years by breeding efforts devoted largely to enhancing the direct value of germplasm for growers and commercial companies along the potato value chain. Although the organic potato growers are driven in part by non-commer-

cial values they too need to survive in a market where they compete with other organic growers but also with the non-organic sector (Lammerts van Bueren et al., 2009). Technically, Dutch organic potato growers need appropriate varieties to deal with the constraints of low-input organic farming systems and the pressure of late blight, for which no effective organic fungicide is permitted in The Netherlands. Conventional breeding programmes do not generate a sufficient number of such varieties, and for commercial breeding companies it is inefficient to set up a separate breeding programme only to serve the limited area of organic potato production in The Netherlands itself. The Dutch organic potato sector therefore in 2008 started a joint public breeding programme, to develop better adapted and late blight resistant varieties, with financial support from the Dutch government. The government's interest was to make investments in the organic niche market because of the potential spin-off also for the conventional potato sector (for instance, in reducing the need to apply crop protection chemicals). The collaboration was organized through a network among six potato breeding companies, 12 organic farmers, and scientists working for the organic sector's research service, the Louis Bolk Institute, and at Wageningen University.

The collaborative breeding process involves three years of visual selection by farmer-breeders among progenies (clones) of crossings made by breeders. The farmer-breeders then return the selected clones to one of the involved breeding companies for further testing and selection for a range of additional traits and selection through to final variety registration and marketing. The farmer-breeders' main motivation is to secure appropriate varieties as quickly as possible in the short term. On the other hand, all the collaborators recognize that there is also a need for a long-term pre-breeding effort in order to produce a continuing flow of new potential crossing parents and therefore introduce into the breeding programme commercially important plant material such as new sources of resistance from wild potato relatives.

The ownership of the genetic resources and the sharing of the royalties between the breeding companies and farmer-breeders, is arranged by a legally-enforceable contract. When a selection effort results in a marketable variety, it is registered under the name of the farmer-breeder and the company who represents the variety in the market and maintains the quality of the variety. Royalties usually are shared on a 50:50 basis. This programme builds on a long tradition of collaboration in the potato sector in The Netherlands and has proved to be effective, generating about 50% of the conventionally-grown potato cultivars released in the country (Lammerts van Bueren and Van Loon, 2011).

NGO-led multi-stakeholder seed production and network-based seed sales, linked to rice Participatory Varietal Selection (PVS), Nepal

This example is based on Gyawali et al. (2007) and Sthapit and Rao (2009). Since the late 1990s a Nepali NGO, the Local Initiative for Biodiversity Research and Development (LI-BIRD) has been practising and leading Participatory Varietal Selection (PVS) in the hill regions of Nepal, in order to develop the breeding value of the genes and genetic traits in farmers' cultivars (Sthapit and Rao, 2009).

'Jethobudho' is a farmer-bred aromatic rice landrace of the Pokhara valley in the mid-hills where it is valued for its superior cooking qualities and its superior milling recovery. Consumers are willing to pay a higher purchase price for it. However, a significant quality variation and poor access to quality seed has limited the competitiveness of 'Jethobudho' in relation to other high quality rice varieties. National variety release requirements and the lack of any organized system for quality seed production for landraces, further limit its market potential.

Successive cycles of participatory variety selection were carried out in farmers' fields to compare the overall performance of a strain of 'Jethobudho' improved by breeders from the national rice breeding institute who were collaborating with LI-BIRD, with the farmers' own Jethobudho, using the farmers' own evaluation criteria. It took in the end eight years, from 1998 to 2006, to improve specific market-preferred traits in the Jethobudho rice landrace, from the initial joint setting of breeding goals to registration and release by the National Seed Board of Nepal for general cultivation under the national seed certification scheme. Its formal registration in the catalogue of commercialized cultivars has allowed farmer groups in its place of origin in Pokhara to develop a new income stream, by producing and selling farmer-certified 'Pokhareli Jethobudho' seeds. A farmer, association or company are allowed to produce and sell the seeds if they maintain the certified quality.

The development of market incentives and mechanisms for equitable sharing of benefits from the use of local landraces has generated monetary benefit for the farmers who participated in the PVS work (Gyawali et al., 2010). Community-based seed production groups have been supported by LI-BIRD to form a seed network, led by the Fewa Seed Production Group. The network is facilitated by a collaborative group of researchers from the Nepal Agricultural Research Council, Bioversity International, and LI-BIRD. The network has strengthened farmer-to-farmer seed systems and linked community-based seed producers with local seed entrepreneurs. The Fewa Seed Production Group also provides regular training, organizational support and other services for the farmers (Gyawali et al., 2007).

NGO-led PPB catalyses development of seed sales by a farmer co-operative, Nicaragua

Almekinders (2011) provides the information for this example. In Nicaragua Golden Mosaic Virus (GMV) is a major problem for growers of the common bean. Severe attacks could devastate the crop. In 1998 the incidence of GMV was particularly high; none of the commonly grown bean varieties showed an acceptable level of resistance and farmers in northern Nicaragua experienced increasing difficulty in growing the crop at all. At that moment, a local NGO, CIPRES proposed a PPB project in order to develop a GMV-resistant variety. The project team consisted of a breeder from the national research programme, a technician working for the NGO and 45 farmers from local villages. Five farmer-breeders located in different micro-climates from 1999 onwards agreed to host a trial on their land and collect data on emergence, flowering, GMV resistance, and yield of successive selections, guided by the breeder who regularly visited the fields and participated in community meetings. During these meetings explanation and advice were provided on the farmers' planting, evaluation and selection practices and the lay-out of plots. The NGO technician facilitated and coordinated the entire process. In 2002, each of the five farmers provided seed from their best GMV-resistant line, selected also on environmental criteria, taste preferences and compatibility with local farming practices.

In order to be allowed to produce and sell the seed of the selected varieties on the national market, performance data for the selected seed had to be generated on a wider scale. This was organized through networks of farmer groups. Subsequently, one of the five farmer-bred and selected varieties, labelled in the trial as 'JM-12.7', was found to be the most stable, and to have the widest adaptation and largest commercial potential of the five. The farmer-breeder named this variety to convey information about his village, his name and his trial (Almekinders, 2011).

Up to 2004 two of the bean varieties were launched informally by distributing handfuls of the seeds at regional agricultural fairs without cost to interested farmers. The farmers in the trial areas subsequently decided to meet the demand by establishing a co-operative as a legal entity so they that could formally register the cultivars in their name and derive a direct benefit from seed sales. According to national seed law both the variety and the co-operative have to be registered, and the co-operative has to register as a seed producer and demonstrate that it has expertise in variety maintenance. The 'JM-12.7' was registered in 2007 by the national authority and since then the co-operative has produced 'JM-12.7' seed for the commercial market. The co-operative now has 82 members and a full-time administrator to manage the seed business, together with a technician and an accountant. In order to meet the rising demand for the seed the farmer-members complement their own production with production contracted from other farmers and co-operatives in the region (Almekinders, 2011).

Multi-stakeholder capacity building for sharing the benefits of PPB, southwest China

This example is based on Song and Jiggins (2003), Song et al. (2006), Song et al. (2012) and also Chapter 3. China's first participatory breeding project was started in 2000 in Guangxi, in the southwest, a recognized centre of indigenous maize diversity in China. It built on previous research on the systematic separation between the centrally-organized public seed system and local farmers' seed systems, and the lack of incentives for formal breeders in the public system to develop maize cultivars adapted to the karst landscape of the southwest, and to local livelihoods, consumer preferences and seed markets (Song and Jiggins, 2003; Song et al., 2006). PPB was adopted as a means for bridging this gap, and subsequently has been adopted for additional crops in three provinces, coordinated by the Centre for Chinese Agricultural Policy (CCAP) with financial and technical support from the International Development Research Centre of Canada. Researchers from the CCAP and breeders from Guangxi Maize Research Institute (GMRI) and the Chinese Academy of Agricultural Sciences in Guangxi today are collaborating with farmers from 12 villages and one farmer group from one of the villages.

After 10 years of collaboration, more than 100 open-pollinated and hybrid maize varieties have been tested in Guangxi and five farmer-preferred maize varieties have been released in the trial villages, i.e. Xinmo 1, Zhongmo 1, Zhongmo 2, Guisuzong and Guinuo 2006. PPB farmers and breeders have tried to register them in the national catalogue so that they launch larger scale production but the first PPB variety Xinmo 1, an open-pollinated variety (OPV), failed the Value for Cultivation and Use (VCU) test in 2003 because it did not perform well in all the six regions demanded by the VCU protocols. After 'Xinmo 1' was rejected by the formal variety registration system, the selected OPVs were tested for local release only and cultivated in the local communities without official registration. However, the hybrid 'Guinuo 2006' has been officially registered and subsequently, in 2003, it was commercialized by the GMRI breeders.

Based on the trust built during PPB process, an agreement about how to exploit the potential benefit of community-based hybrid seed production of 'Guinuo 2006' was reached in 2005 between PPB breeders and farmers. Under the agreement, the breeding institute and its own seed company may supply the commercial market with 'Guinuo 2006' seed and the PPB farmers may supply the seed for local niche markets. The breeders are providing technical and training support to the community's seed enterprise.

The project also initiated and developed access and benefit sharing contract between public breeding/research institutes and the farming communities, with two distinct purposes i.e. to encourage *in-situ* conservation of option values for future breeding and for agro-biodiversity enhancement; and to share fairly any commercial benefit from market exploitation. The contracts have been signed by three public research institutes (including one policy institute and two breed-

ing institutes) and 12 farming communities in Guangxi in June 2010. It strengthens the contribution of both PPB farmers and their genetic resources during the breeding process, and regulate the way to share the benefit, in terms of a right to name the variety, share the ownership (via joint PBR) and royalties, and obtain subsidies for landrace conservation and experiment risks.

6.4.2 PGRs conservation in farmers' fields: options related to novel marketing and trading arrangements

Market and use potential are important components of the value of local genetic resources in farming practice; farmers do not conserve diversity for the sake of conservation alone if they do not see any cash or use values (Sthapit et al., 2006). There are a number of novel marketing and trading arrangements that create and increase the public and private value of local crop genetic resources, for instance by developing the visibility on the market for local produce labels that signal the special value of the contents, for which higher prices might be demanded, and by creating exclusive intellectual property in PGRs in ways that allow farmers to control supply for a given price. Here we present three such marketing and trading arrangements.

Community-supported agriculture: PPB cultivars and derived local products linked to an urban restaurant, in Guangxi, southwest China

Value addition is in part a strategy for stimulating consumers' awareness of and increasing market demand for a product; this example illustrates how effort to improve the processing, packaging and promotion of the ecological value of products derived from the PPB efforts in Guangxi, have been linked to urban consumers – a form of community-supported agriculture (CSA). This in turn has encouraged the farmers to increase the area under local crops and varieties. The growing academic literature on CSA provides numerous examples (see, for instance, Wilson, 2008) that identify CSA as a worthwhile option for deriving higher public and private value from local PGRs, based on the development of direct partnerships between farmers and local consumers and explicit agreement about how the risks, costs and products will be shared along the value chain (Fieldhouse, 1996). Usually producers and consumers commit to each other through an informal, short-term CSA agreement. CSA has shown to encourage and support ecologically-sensitive forms of food production, contribute to building social capital in local communities, and educate consumers and others about the value of farmers' varieties and local food products of high cultural worth (Feagan and Henderson, 2009). In China in recent years a challenging situation has arisen with regard to food safety, after a series of widely-publicized contamination events that have impacted negatively both domestic and international food trade. The trust between food producers and consumers locked into the modern food value chain has been weakened. At the same time Chinese authorities are becoming alarmed at the speed with which the emergent highly commercialized food system and industrialized food processing are driv-

ing out products based on local genetic resources of plants and animals (Xue, 2011). From 2000 onward CSA practitioners in China have been encouraged to introduce and test CSA models in practice based on different forms of direct-marketing mechanisms.

The following example is based on the main author's research. An entrepreneur based in the capital city of Guangxi province, looking for ways to support the growth of a sustainable local food system, got in touch with a local NGO, Farmers' Friend, which supported his idea of opening a restaurant as a showcase and outlet for local food products. The NGO helped the entrepreneur to identify farmers who were interested in producing the local varieties suited for high-value local food products. The NGO mobilized funding to help the entrepreneur start up in 2005; since then his business has boomed and he is planning to open a second restaurant. For the farmers, the restaurant is becoming a major buyer of their output, that shares the risks of farming, places regular orders, and pays a set price (usually a quarter to a third higher than the regular market price) for the products delivered. For the restaurant's customers, the restaurant is becoming the food supplier of choice, selling not only a range of tasty meals and local wines but also packages of a growing range of products. Farmers' Friend staff support these developments both in the farmers' fields and in the restaurant, where they display and share information and exchange feedback from farmers and consumers about how to improve and grow the concept of protecting the public value of local genetic resources through consumer recognition and a market return.

The collaboration between the restaurant and the PPB initiative started in 2008. Fresh maize cobs of the PPB hybrid 'Guinuo 2006' were first sold in the restaurant in the spring of 2010 and soon were in demand by the customers. Today, in seven of the PPB villages the farmers and the restaurant have negotiated a formal, long term supply contract and the farmers have established suppliers' cooperatives to serve the restaurant. The products supplied are based on local varieties of maize, rice, soybean, vegetable, meat, and herbs, and include also home-made spirits and noodles.

Area-based value addition through Geographic Indication arrangements in China

Geographical Indications (GIs) offer the potential to conserve farmers' agro-biodiversity on an area-wide basis. This may have some advantages over farm-based options in so far as the integrity between crop genetic resources, mosaics of farming systems at landscape scale, and ecosystem functioning can be maintained as the products derived from these resources are brought into new relationships with markets. It is proving easier to register the products derived from PPB materials under GI arrangements than to register PPB varieties through the official variety testing and registration procedures. It is the GI label that then provides a traceable connection between farmers' conservation of varieties and landraces (an indirect and option value) and market-based benefits from prod-

uct sales (a direct private benefit).

GIs are defined as 'indications which identify goods as originating in the territory of a Member, or a region or locality in that territory, where a given quality, reputation, or other characteristic of the good is essentially attributable to its geographical origin' (TRIPs Agreement under WTO, Art. 22-1). Today, GIs have acquired an international reputation as a form of intellectual property that can contribute to maintaining biological and cultural diversity (Bérard and Marchenay, 2006; Bowen, 2010). GIs in agriculture not only provide good information for consumers regarding the characteristics of the products sold under a GI regime, they also express the cultural dimension of farming and traditional foodstuffs within a territory (and thus offer an alternative to community-conserved areas, i.e. CCAs – see Robson and Berkes, 2010). Another advantage is that because they establish common intellectual property (a so-called soft IPR regime) they have wide potential applicability in areas where farmers' varieties and traditional foods are either unique and rare or still highly diverse and abundant. Whereas commercial trademarks usually are owned by individual economic agents (who thereby obtain a monopoly over their use), GI arrangements can be applied by all economic agents in a specific geographical area. In current discussion on the relationship between the Convention on Biological Diversity (CBD) and intellectual property in World Trade Organization (WTO) and the World Intellectual Property Organization (WIPO) , GIs have been mentioned as having the potential to safeguard and promote biodiversity-related products, reduce misappropriation, and share the public and private value of PGRs more fairly.

The following draws on Wang (2009) and the authors' recent research. The institutional arrangements relating to GIs in China are complex. China has established that authority to control the commercial exploitation of traditional knowledge and resources by means of GIs (Wang 2009) is vested in three public bodies: the Department of Industry and Trade, the Department of Health and Quality, and the Ministry of Agriculture:

- Department of Industry and Trade: GIs have been regulated since 1994 by the Trademark Law that includes a specific regulation for Collective and Certification Marks issued by the State Administration for Industry and Commerce (SAIC). From April 2003 additional measures for the Regulation and Administration of Industry and Commerce have come into force. Another set of measures for 'special signs on geographical indications' became effective in 2007 in order to strengthen the link between a GI and the elementary design of the special sign (i.e. a brand image or label). Inspection and supervisory power is vested in the Administration for Industry and Commerce.
- The Department of Health and Quality: Quality control is provided by the service for the Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), which was created in 2004 and enacted on 15 July 2005. The AQSIQ is responsible for quality management, import and ex-

port control, quarantine and registration of GI recognition and control. It provides procedures for the declaration, examination, follow-up and control of GIs, as well as for standardization (control of specifications).

- The Ministry of Agriculture: arrangements for a third GI system has been established in 2008 by the Ministry of Agriculture (MoA), oriented towards raw agricultural products.

A comparison of these three systems of GI protection in China is presented in Table 6.1. Each system has its own authority and has been implemented independently; this confers some advantages that offer applicants a choice among the options that best suit their purpose and by allowing a considerable degree of flexibility in interpretation. However, in some respects the arrangements overlap, while in others they are incompatible, and this causes a degree of market confusion and legal uncertainty (Wang, 2009).

Each system maintains its own list of GI products. The SAIC list is the longest-established and lists up to 31 December 2009 662 GIs. It is interesting to note that 31 of the listed products have been registered by parties based outside China. The other GIs are filed either by product associations, product federations, or by research centres, local industries and other public authorities; only 2% have been granted to farmer cooperatives and associations. Raw agricultural products protected under SAIC are connected to the MoA's own list, of GIs registered with the MoA. GI applicants in all three systems include industrial and commercial associations, government-affiliated agencies, research agencies and institutes, private enterprises, and farmer cooperatives and associations (see Table 6.2).

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[4] **The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) has been introduced as the requirement for WTO Members to have plant variety protection and extend patentability to micro-organisms. It is the first international instrument to introduce minimum standards for intellectual property protection at the global level. WIPO also plays a key role in the dynamic of the shifting and cross-cutting negotiation of IP issues in a variety of for a. It is closely linked to the implementation of the TRIPS Agreement. The expansion of intellectual property into the biological sphere and the reactions to that have overshadowed at times and helped shape the types of international agreements affecting IP and biodiversity. The negotiations of CBD have focused on five areas: access to genetic resources and benefit sharing; traditional knowledge innovations and practices; technology transfer; agricultural biodiversity; and implementation, compliance and enforcement. Much of the work on agricultural biodiversity under the CBD has been carried out in collaboration with the International Treaty on Plant Genetic Resources for Food and Agriculture under FAO. It strengthens the value of agricultural biodiversity and the rights of farmers and local communities (see Tansey and Rajotte, 2008).**

Table 6.1. Three types of legal system already operating in China for the protection of traditional and origin-linked food products

	AQSIQ[1]	SAIC[2]	MoA[3]
Role and principal functions	In charge of national quality, entry/exit commodity inspection, health quarantine, animals and plants quarantine, food safety, certification and accreditation, standardization, and administration law enforcement at national and local levels	In charge of market supervision and regulation, protecting the legitimate rights and interests of business and consumers by carrying out the regulations in the fields of enterprise competition. Assist in the implementation of international conventions and rules and facilitates the international exchanges of the trademarks.	Regulate and enforce the use of chemicals, pollutants and pesticides in farms; it is also responsible for animal health.
GI definition	Grown products, livestock and aquatic products come from the defined area. The raw materials are originated entirely or partially within this defined zone, and then processed in this area into compliance with the specifications.	GI product is from a specific region with its quality reputation and other features that are determined by natural or cultural elements of the region.	The GI agricultural products are named after a geographical area indicating it is produced within a particular area and their quality and characteristics depend on natural historical and cultural factors.
Level of protection	Decree N. 78, based on the 'Product Quality Law' and 'Standardization Law'	Trademark law, regulation and measures, GI's protection is made compatible with TRIPS.	Administrative measures. Go into effect Feb 1, 2008.
Type of protection	Special system dedicated to GI products	The GI can be registered by SAIC as a certification mark or a collective mark.	Dedicated to the raw agricultural products

Notes: [1]AQSIQ – Administration of Quality Supervision, Inspection and Quarantine; [2]SAIC – State Administration for Industry and Commerce; [3]MoA - Ministry of Agriculture.

Source: Wang (2009).

Table 6.2. Structure of GI applications in China

GI applicants in China	% of total applications
Industry and commerce associations	64
Government-affiliated agencies	24
Research agencies /institutes	7
Enterprises	3
Farmer cooperatives and associations	2

Source: compiled from State Administration for Industry and Commerce database (till 31 December 2009)

Establishing a regulation for landrace conservation and marketing: the EU case

This example is based on Serpolay et al. (2011a, 2011b) and Chable et al. (2009). Recent legislative developments at the European level (i.e. Commission Directive 2008/62/EC 20 June 2008) with regard to seed production and marketing have opened a new way to utilize the biodiversity of interest for agriculture (Lorenzetti and Negri, 2009). They provide procedures for legal recognition and registration of so-called 'conservation varieties' so as to be able to bring to market older, formally non-registered landraces and locally adapted varieties threatened by genetic erosion (Newton et al., 2010).

Farm Seed Opportunities (FSO), a research project funded by the European Union (EU) research programme, was designed to support the implementation of this new regulation (Chable et al., 2009). Partners in the project included public research institutes, farmers' seed networks and organic farmers' associations concerned with the conservation and use of farmers' varieties that do not fit the DUS (Distinctiveness, Uniformity and Stability) performance criteria of the current seed regulations that govern assessment and release of commercial seed to the market. FSO partners carried out a survey of European innovations in seed maintenance practice that supported the project's purpose, resulting in a list of 68 initiatives in 17 European countries, including participatory plant breeding projects in organic or low-input agriculture (Chable et al., 2009). Based on the insights generated by the survey the project organized field trials in organic or low-input farms to generate data over three years from successive generations of local cultivars of wheat, maize, spinach and beans, through the European network of partners in Italy, France and The Netherlands. The experimental data produced by the FSO project has been used as a reference for recommending modification of the current regulations and/or to suggest a new mechanism for governing for these types of cultivars alongside the current regulations (Serpolay et al., 2011a, 2011b). FSO research also examined the potential of niche markets for the products of local varieties (e.g. geographical indications, private labels or certification), in order to contribute to the enlargement of the market for local varieties.

Although the new European directive aims at enhancing biodiversity by offering possibilities to utilize historical conservation varieties, it does not provide options for farmers to improve landraces or breed for new locally adapted varieties. Such newly bred varieties can be marketed only when they comply with the regular DUS criteria. Debate continues within the EU concerning the relationship between the conservation, utilization and improvement of landraces (Chable et al., 2009).

6.5. Analysis and discussion

First, the various arrangements presented above for creating or recognizing the public value of farmers' agro-biodiversity are assessed by means of the four sets of questions posed in the introduction of this chapter. Briefly: (1) what is the important public value protected or promoted? Whose interests are taken into account? 2) who or what legitimizes the arrangements? (3) on what operational capabilities do the arrangements rely? who or how were these capabilities created? (4) how is the process of valuation organized? A cross-case analysis follows these questions, summarized in Table 6.3.

6.5.1 The importance of public values

Each of the examined examples, under both 6.4.1 and 6.4.2, starts with an intervention to create and define public value but the mix of direct, indirect and option values in focus vary considerably. PPB, at least potentially, ensures that option values become available to other breeders in the 'wider societal interest' but also importantly that, as this happens, the involved farmers' and communities' contributions are established and recognised in novel network relationships or by contract. In some of the cases the development of indirect values still rests on local-level initiatives that restrict the public benefits to relatively small publics; further exploration in implementation practice is needed in these cases to test their wider value for larger publics. In other cases the indirect and option value already has been taken into either or both market arrangements and public policy.

The novel relationships and arrangements have been initiated and promoted by a variety of public and private entities, including public research institutes, commercial enterprises, voluntary organizations (e.g. NGO) and various government agencies. Public sector agencies and NGOs may be said nonetheless to have played particularly important roles in facilitating and supporting the development and management of these, and it is their 'power to convene' that has ensured that a plurality of interests are able to jointly consider the derivation of the collective public interest.

Private interests have been expressed by taking into consideration such direct values as entrepreneurial reward, farmers' preferences in variety development and opportunity to participate in seed sales, and consumers' preferences in food purchases. Farmers benefit from growing locally-appropriate varieties and rewarded as breeders or stewards of local varieties; consumers access to high quality and traceable food products of high cultural value; and market actors obtain economic benefit from producing and trading these resources. Notably, the expression of private interest in PGRs has been linked in these cases to incentives for private actors to join in the creation of public value. These options for PGRs maintained for the public good purposes of conservation and the option value of future utilization have attracted the attention of both public and private

actors, demonstrating that the public interest can be harmonized with private interests if appropriate institutional arrangements can be developed and enforced. As the benefit-sharing arrangements specified in Table 6.3 illustrate, the implication is that while continuing investment in the option value by public authorities is needed it is possible to make arrangements that allow public authorities to cover some of the cost through harmonizing direct, indirect, and option values.

6.5.2 Legitimacy and support

Given the public goods nature of PGRs and the collectively developed process of PPB, some of our cases adopt or create a common property instrument for PPB products. It seems that this attention to questions of access and benefit-sharing has been important in legitimising the work. When the ownership or the enjoyment of PGRs and the products derived from them are openly shared within a group of defined members such as a farmers' cooperative, the signatories to a contract or within a definable territory, conservation goals clearly are supported. Unusually, the Dutch potato case combines the private protection conferred by plant breeders' rights and an additional private agreement on royalty-sharing among the stakeholders. On the other hand, while the three market mechanisms presented under (b) all grant non-exclusive rights in the marketing of products derived from farmers' varieties, two of the three create a strict boundary around the right holders, such as the proposed EU regulation on Conservation Varieties and GI labels. The third, the CSA restaurant example, applies less strict and more flexible boundary definitions. Taken as a whole the cases suggest that in the creation of public value, forms of collective ownership can be developed creatively to counter-balance the privatisation of public goods.

However, the creation of public value in PGRs clearly requires a forum and a procedure that allows reflection by those drawn into the novel relationship, such as farmers, other members of civil society, public agencies, and entrepreneurs, on the core values a society wishes to conserve, support, and use (Bozeman, 2007). That is to say, the additional costs generated by investing in the development of a forum and a procedure for determining value, do need to be paid, either by the government, citizens, private commercial participants and/or consumers. The economic feasibility of public value is determined by whether any or a combination of these social categories is willing to pay more for the public value.

The cases illustrate various ways this challenge has been met. In the Dutch potato case, the royalty-sharing agreement for the products of the PPB activity, that has been operationalized by commercial breeding companies, and self-selecting customers in the organic market, spreads the costs among public agencies, consumers, and entrepreneurs. The implementation costs of establishing the public value of farmers' agro-biodiversity through PPB in the Nepal and China cases have been met largely by grants or subsidies from government agencies and

national or international NGOs but the costs of sustaining the novel relationships are recovered, at least in part, by seed sales. The CSA restaurant in Guangxi spreads the costs among the PPB programme, an entrepreneur, and consumers. All of the three GI systems in China balance consumers' willingness to pay in return for a formal procedure to guarantee the appellation, and the products' quality and authenticity. The European Directive on Conservation Varieties on the other hand, driven both by public policy and market demand, spreads the costs between regulatory agencies and private actors.

6.5.3 Balancing interests and benefits

Each case (Table 6.3) evidently has developed an internal capacity to balance the interests of different stakeholders, whether by means of a contract, procedural law, or an intermediary organization. However, each does so in a unique fashion:

- In the Dutch potato case within the potato sector in The Netherlands, a prior history of private-public collaboration seems to have played an important role, in so far as it provided a familiar and effective way of acting within the potato sector when the organic stakeholders created the capacity to carry out contract-based PPB in the commercial sector.
- In the Chinese maize case, the development of contract-based arrangements for the exploitation and sharing of the commercial benefits of PPB products, in this case was based on a history of years of farmer-scientist involvement in PPB It has allowed farmers for the first time to share the commercial benefit with breeding companies and/or public breeding institutes.
- Individual farmers in the Nepal rice case shared in the direct benefit through participating in community-based seed production and sale. In the Nicaragua common bean case, this is organised collectively through a farmer co-operative, registered as a seed producer that organised the commercial benefit on behalf of its members. In both cases the new arrangements have been catalysed by an NGO.
- In the CSA restaurant case it was the development of a new relationship between an individual entrepreneur and farmers working with a PPB programme that facilitated a new market-based connection between consumers and farmers. Consumers paid more for quality food traceable to a food culture and named communities, and the public interest was secured from the conservation of local resources and related traditional knowledge and food products.
- The GI case showed how a soft IPR arrangement that offers product protection can be designed to combine protection of crop genetic resources (from forces that otherwise might appropriate or erode the public value of farmer-conserved crop genetic resources) and enjoyment of the benefits derived of those resources direct value, by individuals in a specified geographical area.

- The market for conservation varieties in the EU is developing also as a kind of area-based a niche marketing arrangement, for products of local varieties conserved by farmers, which are processed in the 'region of origin' of those genetic resources. Here, it is government-led policy intervention that is catalysing the novel relationships and market arrangements.

6.5.4 Innovations in breeding

On the evidence of the cases public actors have 'become important agents in helping to discover and define what it would be valuable to do' (Moore, 1995) with respect to the conservation of PGRs in smallholder farming by means of innovations in the organisation of breeding. A number of studies have shown that formal breeding and seed systems do not always have the capacity to supply the variability needed in low input farming systems in harsh environments, nor to meet the need for locally adapted varieties (Jarvis et al., 2011).

Three responses are considered here. PPB aims to develop crops and varieties that are better adapted to farmers' local environmental and management conditions and to give more attention to the diverse traits that farmers and consumers value in their specific localities (Sthapit et al., 2006). The PPB cases considered in this chapter combine genetic resource conservation with further crop improvement and utilization. However, new varieties developed through PPB usually, but not necessarily, lack uniformity and thus tend to be excluded by variety registration and seed certification regulations and procedures (Visser, 2002). This limits the opportunities for farmers to obtain revenue, restricts the genetic diversity available in the market, and ultimately may threaten on-farm diversity (Louwaars, 2000). Notably, in the EU case, it is proposed that conservation of landraces is separated from crop improvement, with the consequence that landraces adapted to local and regional conditions and threatened by genetic erosion can be registered for commercialization only under certain conditions and only within the region of origin (Chable et al., 2009). Options such as CSA and GI arrangements on the other hand recognise and protect the value of farmers' landraces and varieties by linking their special quality and locality to consumers and the market. To a great extent, the creation of such market-based arrangements is an important source of legitimacy and support for the PGRs in question. By coupling CSA, GI and PPB the scope and adaptability of all three could be further enhanced.

6.5.5 The development of a combination of property rights regimes

We have noted that in determining the public value of farmers' varieties the costs of maintaining them are difficult to calculate and that bureaucratic or market arrangements for compensating the farmers who produce and maintain them, and manage the conditions in which the material continues to evolve, are

Table 6.3. Cross-case comparison on 'public value creation', 'legitimacy and support' and 'operational capabilities'

		The Netherlands	Nepal	Nicaragua	China-PPB	China-CSA	China-GIs	EU-FSO
The organizations involved		Farmer-breeders linked to commercial companies and public breeding sector	Multi-holder seed production group, formed through rice PPB	PPB products linked to market through farmers' co-operative	Building capacity for benefit-sharing of PPB varieties, among public institute and farmers	CSA restaurant linked to PPB varieties and local agricultural products	Value added to PGRs products through GI-brand and labelling; traditional food linked to its cultural dimension and promotion of biodiversity-related products	Design of separate conservation regulation for landraces in EU; enlarging the market for local varieties
Whose interests are taken into account?	**1. Public interest** (what is the important public interest protected or promoted?)	Breeding for sustainable and low-input agriculture	Discovering the breeding value of landraces	Releasing widely adapted disease-resistant varieties in local region	Providing access to appropriate improved seed by smallholder farmers in areas not served by private sector	Obtaining quality and diverse food; adding market value for local genetic resources	Providing good information with cultural expression and potential function on biodiversity enhancement; reducing negative impacts caused by homogenous food system	Encouraging on-farm conservation, improvement and management of agricultural biodiversity; strengthening the role of farmers in conservation and breeding
	2. Private interest	Developing appropriate varieties for organic potato growers, sharing royalties among farmers and companies	Generating economic benefit for local farmers; providing quality rice variety for consumers	Distributing appropriate seed to smallholder farmers	Creating incentives for PPB farmers	Benefit CSA farmers and local consumers	Benefit producers within geographical areas; creating diverse market choices for consumers	Benefit growers, consumers and other market actors of EU conservation varieties
Values of PGRs desired	- Direct V	Niche organic market;	Supplying local seed market;	Marketing PPB varieties by farmer co-operative;	Mainly for HH consumption	Niche CSA market;	GI market of products, incl. seed and food.	EU market for local varieties;
	- Indirect V	High-biodiversity in breeding	High-biodiversity and landrace enhancement;	Selecting locally adapted varieties;	High-biodiversity & PGRs conservation	High-biodiversity of food and culture	High-diversity of food and culture	Landrace conservation in its place of origin
	- Option V	Adaptive capacity	Adaptive capacity of farming communities	Improved breeding and organization capacities	Adaptive capacity and rural dev. of marginal areas	Conservation	Conservation	Conservation

Who or what legitimizes and supports the arrangements?		Initiated by the organic potato sector, with support from Dutch government and public researchers of Louis Bolk Institute and Wageningen University	Initiated by local NGO (LI-BIRD), with collaboration of researchers from national agricultural research centre and Bioversity International	Initiated by local NGO (CIPRES), with support from national breeding programme	Initiated by public policy research institute, with technical support from public breeding institutes	Advocated by local NGO (Farmers' Friend) and a restaurant	Facilitated by the government and steered by market	Advocated by EU regulatory authorities, with the support from public research institutes and farmers' seed networks
The operational capabilities created	**1. Intellectual Property instrument** (by which means are public values of PGRs legitimately created and protected?)	Private property of farmer-breeders with agreement on royalty sharing	Common property recognition for farmers in Pokhara region	Common property recognition for farmer co-operative (registered as seed producer)	Common property recognition with contract on benefit sharing	Common property recognition with vague definition of 'local' and 'origin'	Common property recognition within a certified region	Mixed instruments, GIs, private label, or certification
	2. Market linkage (through what linkages do the consumers/ others pay more for public value?)	Linking to organic seed market	Linking to regional seed supply system	Linking to local commercial seed market	Supplying seed within local communities	Linking local food products to consumers through restaurant	Linking market through GI-brand and labelling	Marketing local varieties from region of origin
	3. Benefit-sharing arrangement (how to share the benefits derived from PGRs products?)	Variety registered under the name of the farmer-breeder and the breeding company, the companies represent the variety in the market; farmer-breeders, companies and project share royalties, based on contract	Community-based seed production based on local seed system, i.e. Fewa Seed Production Group; others within this region are allowed to produce and sell the seeds	A farmer co-operative established for variety registration; co-operative supplies commercial market under contractual production by others in the region	Breeders register and supply PPB varieties to commercial market; PPB farmers benefit from community-based seed production and future breeding, based on agreements	Entrepreneur connects consumers and farmers directly, valuing local resources, traditional knowledge and organic farming, providing market space for PPB products	GIs are instruments that can be used by all economic agents in a specific geographical area, combining 'protecting (from outsider)' and 'sharing (with insider)'	Focusing on the potential in niche markets for products from local varieties; the development of seed quality standards more suited to local varieties

Source: this research.

the exception. The ability to claim and protect intellectual property in genetic resources is considered by Brush (2000) to be necessary to increase the direct and option values of local crops and farmers' varieties. Property rights that link markets to farmers' varieties may create an incentive that can influence strongly the use of crop diversity and farmers' livelihoods (Eyzaguirre and Dennis, 2007).

The evidence considered in this study challenges the dominant property rights regime in agriculture and food systems. Bromley (1991) distinguishes four possible property regimes: 1) government property regimes – control over the entire bundle of property rights is in the hands of government; 2) private property regimes – private actors have the legal and socially permitted right to exclude others; 3) common property regimes – a form of private property for a group of co-owners; they can be organized as a collective group property or a corporate group property; and 4) non-property regimes – i.e. open access regimes where there is no ownership, only occupation or use rights. However, plant genetic resources and related traditional knowledge conventionally have been collected and used under the principle of common heritage. This principle defines genetic resources as public domain goods. Public domain goods are defined by the quality of non-competitiveness – one person's use of elements within the public domain does not deprive use to others. However, they can be removed from the public domain by the assertion of an intellectual property right (Brush 2000). The property rights regimes governing PGRs have evolved in recent decades from a non-property regime (i.e. as the common heritage of mankind PGRs can be freely used and shared) (FAO, 1983), to a government property regime (i.e. by asserting the sovereign rights of nations, as under the CBD), and most recently to a private property regime (i.e. PGRs can be patented, and protected under PBRs, creating exclusive enjoyment that abstracts the resource from the public domain). The evidence of this study is that a combination of property rights regimes can be developed that balance public and private interests.

6.5.6 Networked governance

The analysis indicates that where it is accepted that PGRs are public goods, the governance of PGRs is becoming networked. By networked governance we mean a form of governance of PGRs that involves a role for citizens, private and public agents and NGOs that are recognized as having a legitimate stake in the PGRs in question and are involved in discovering, defining and producing the public value of the material (Stoker, 2006). We did not set out to study this phenomenon and thus can offer only some very preliminary observations that raise rather than answer questions. First, we discern in our cases the emergence of novel relationships structured in diverse institutional forms, that are nonetheless distinguishable from the hierarchical relationships of the state and the temporally limited exchange relationships organized by markets. Secondly, structural analysis of the cases might suggest that that their capability is constituted by the degree and nature of the inter-connectivity among network members, related to the position of each member in the network. Thirdly, by

shifting the focus to the actors, we see that the connections are defined by mutual exchange of benefits and that each network's capability is constituted in purposeful action taken to advance the collective interest. Fourthly, we point to indications that the decision to join any of the networks has involved more than a calculation of narrow interest or the direct benefits of membership. For instance, by being connected in a network the members have gained access to opportunities for learning. What our analysis does not reveal is the degree to which the networks - taken singly or as an emergent class – can sustain the balancing of private and public values. How might they adapt to increasing market pressures? How widely can they cast their net to conserve the indirect and option values of farmers' landraces and varieties, the agro-ecosystems in which they are embedded, and the food products of high cultural value that are derived from them?

6.6. Conclusion

This study has explored different options for creating and protecting the public value of plant genetic resources. It was shown that public interest can be harmonized with private interests if appropriate institutional arrangements, such as a combination of right regimes can be developed and enforced and the additional costs generated by investing in the development of a forum and a procedure for determining value, can be paid, either by the government, citizens, private commercial participants and/or consumers. By networked governance, private and public agents and NGOs are recognized as having a legitimate stake in the PGRs in question and are involved in discovering, defining and producing the public value of the material. To a great extent, the creation of such market-based arrangements is an important source of legitimacy and support for the PGRs in question.

The options that China might find especially valuable as it struggles to balance public and private interests in its unique PGRs, to determine the public value of PGRs, and to link this value to market opportunity are: 1) the EU provision for the separate registration and marketing of conservation varieties; and the identified need to amend the existing DUS regulations in order to accommodate varieties with more heterogeneous characteristics; 2) the Dutch potato case, in which commercial breeding and seed companies are linked under commercial contract law with farmer-breeders and public breeders, and royalty-sharing arrangements clearly define the rights and responsibilities of each party; 3) the cases of Nepal rice and Nicaragua common bean, which farmer-led seed production and seed provision have been supported and enhanced through organizational development.

Chapter 7

Discussion and conclusion

7.1. Introduction

Participatory plant breeding (PPB) has been accepted as a complementary strategy in modern agricultural research (Witcombe et al., 2005); however, the further development of this strategy encounters significant institutional challenges as it extends and expands into different socio-technical contexts. The main objective of this thesis therefore has been to understand these challenges and induce supportive multi-level institutional change through and for participatory plant breeding in the Guangxi province in southwest China. To achieve this objective, we have investigated (i) the incentives and options for strengthening the relation between communities' and farmers' plant genetic resources (PGRs) management, conservation and plant breeding in Guangxi, and (ii) the institutional options at different levels for formalising and rewarding PGRs management and conservation by farmers and communities. In this final chapter, Section 7.2. gives an overview of the main findings. A discussion of the practical, theoretical, policy and methodological contributions is presented in Section 7.3. The chapter ends in Section 7.4 with a prospective outlook on the most promising transitions, to which this study has contributed in various ways detailed in this thesis.

7.2. Overview of main findings

The results of this study indicate that although hybrids have been promoted and pushed rather heavily by the state and private organizations remarkably few farmers in the southwest actually have felt pressured to adopt such seeds; adoption has been motivated by farmers' perceptions of the advantages and expanding market opportunities. In the Guangxi, Yunnan and Guizhou provinces maize hybrids rapidly became dominant over the period 1998 to 2008, especially in Guangxi where the area under hybrids has reached 93% of the maize area. The data reveal that farmers experienced several economic and many agronomic advantages for using hybrids, indicating that they are indeed internally motivated to use hybrids (Chapter 2). The most important advantages that the surveyed farmers perceived were higher yields and lodging resistance. However, the farmers also associated hybrids with a large number of disadvantages, especially poor adaptability and inadequate service provision in relation to seed quality control, availability of cultivar information and the accessibility of seed. Moreover, a considerable proportion of farmers still reserved a portion of their land for landraces and farmers' varieties even if hybrids dominated their cropping. The farmers stressed that these materials have several advantages over hybrids, especially regarding their adaptability to local conditions, the taste, and the relatively ease of gaining access to seed. The farmers also expressed a range of functional preferences for landraces and farmers' varieties, related to food culture, land quality and economic infrastructure. Even so, it was found that the expansion of hybrids had led to a sharp reduction in the number and area grown under landraces and farmers' varieties in farmers' fields, and that

their interest in and care for local genetic resources seemed to have dwindled. However, in the seed systems of poor and vulnerable farmers especially, this study shows that these materials still play an important role, since such farmers often cannot afford the seed costs of hybrids and/or accommodate the agronomic and economic risks associated with them. Overall, despite the large scale adoption of hybrids, there is still considerable scope for improving the quality and adaptability of landraces, farmers' varieties and hybrids. This calls for local hybrid cultivar improvement, including strategies such as on-farm cultivar testing, demonstration and evaluation.

PPB activity in southwest China started in 2000, specifically targeting the improvement of landraces and farmers' varieties, locally adapted hybrid development and farmers' capacity building. The PPB process has been documented over the period 2000 till end 2011, including the efforts of breeders of the Guangxi Maize Research Institute, thirteen communities, and more than 100 farmers. We have examined the potential of including smallholders in the hybrid development which has not yet be discussed in the literatures (Chapter 3). We have developed a conceptual model for fruitful procedures, based on five assumptions a) the hybrids are bred for adaptation to local needs and preferences, b) the dependence on and need for genetic diversity is taken into account, c) breeders collaborate closely with farmers also in the initial stages of the breeding programme i.e. in establishing the breeding goals by identifying the desired traits and preferred local populations as (one of the) crossing parents, d) hybrid seed production can be integrated into the farmers' local seed system, and e) farmers and breeders can agree intellectual property rights, access and benefit sharing in a fair and transparent way. The case of the Guangxi PPB maize programme illustrated how farmers and breeders can both benefit from close collaboration in early stages of the breeding programme and can design an agreement on sharing access, benefits and market.

In addition, in order to understand the institutional changes in the organization of seed supply in China, we adopted a multi-level perspective taken from system innovation studies, which links niche-level practices with the dynamics of regime-level change and landscape-level trends. We show in Chapter 4 that PPB practices have amplified the tensions within current seed-related institutional provisions in China, within and across levels. China has been progressively drawn into international negotiations over seed, bringing further tensions. International discussions of the issues relate to the incompatibility of overlapping agreements are always controversial: TRIPS and UPOV for instance focus on protecting plant breeders' rights and are trade-oriented, while the CBD and ITPGRFA seek to secure the rights of farmers over PGRs and to recognize their role in conserving biological diversity. However, the tensions may play a catalytic role in forcing regime-level change. From this perspective, we show in our analysis that the emphasis on-farmers' rights in the CBD and ITPGRFA opens an opportunity for PPB-led innovation in China.

The contribution of action researching to institutional innovation has been examined in relation to developing access and benefit sharing mechanisms in the context of the participatory plant breeding programme in southwest China. We adopted action researching and the multi-level perspective as analytic concepts through which to explore and demonstrate the contribution of action research to building conducive interactions between niche practice and regime (Chapter 5). The value of action research in fostering systemic institutional innovation has been shown by detailed study of the processes of change with respect to PPB-related access and benefit sharing (ABS) mechanisms. The analysis of eight critical events uncovered the strategic shifts that have occurred in research practices, that have evolved as shared learning accumulated among niche- and regime-level actors. Analysis of each episode details the twists and turns in the iteration between practice and reflection, through which stakeholders jointly discovered the issues and made new accommodations. The results offer legislators and policy-makers in China in the on-going formulation of ABS policy and law a number of tested options for sharing access and benefits in crop breeding, varietal selection and plant genetic resource conservation. These novelties, emerging from PPB practice in a programme niche that has attracted international, national, provincial and community level support, offer ways for China to balance interests while respecting its obligations under international law and accommodating competitive market pressures.

In Chapter 6 we also explored recent efforts to determine and assert the public value of plant genetic resources through participatory plant breeding as well as a range of options for balancing public and private interests in conservation of agro-biodiversity and in bringing to market the products of PPB, and farmers' varieties and crops. The findings and analysis demonstrate that the creation of public value calls for the integration of innovations in the value chain that recognize the joint efforts of producers, consumers, market actors and the public sector. Further development of public value requires additional study of the economic feasibility and explicit supportive public policies for the options identified. Further experimentation with the most promising options for China is needed to test their legitimacy and support within the embedded institutional regime and enhance their internal operational capacity.

7.3. Discussion and conclusions

7.3.1 From an unbalanced to an integrated and harmonised breeding research, conservation and seed supply system

Genetic resources for modern breeding will not survive if local landraces, farmers' varieties and seed systems do not survive. Landraces, farmers' varieties and seed systems will not survive if there is no way for farmers to receive market advantage from maintaining these. The expansion of hybrids has influenced

agro-biodiversity in farmers' field and farmers' access to landraces. Smallholder farmers in the mountainous regions of southwest China have become more vulnerable within their agronomic and market conditions because they are cultivating on average less than 0.2 hectares (Li and Song, 2010) in resource-constrained remote upland areas that are agro-ecologically diverse and risk-prone. The vulnerability of the smallholder farming sector is a significant concern in China; in 2010 the country as a whole had about 750 million-farmers cultivating less than 120 million hectares of arable land. Most of these farmers are smallholders. Under the modernization trends occurring in rural China, local genetic resources and associated traditional farming knowledge are disappearing, and smallholder farmers have become more dependent on the market; output and livelihoods can be easily affected by the price of food and seed.

Farmers' landraces and varieties have been marginalized by the implementation of the new seed policies and the development of commercial seed markets. Moreover, the reduction in landraces and varieties maintained on-farm challenges future breeding activity because it reduces the type and amount of primary material available to breeders. The need for the development of breeding strategies and support mechanisms based on-farmers' reasoning and experiences, and for combining and integrating yield potential with local preferences (both bio-physical and socio-economic), has been identified in this study. However, current breeding and seed policies place little emphasis on the maintenance and improvement of landraces or farmers' varieties. The utilization of such materials in modern breeding has been minimal in China so far, contributing to a narrowing of the genetic base of the hybrid seed that is commercially available to farmers (Liu et al., 2004; Yao et al., 2007).

With a growing awareness of the public value of agro-biodiversity among public agencies, civil society and some consumers in China, some attention has been paid by these stakeholders in recent years to farmer maintained and improved cultivars and related market initiatives. It has been robustly demonstrated worldwide that PPB can address smallholder farmers' needs as well as combine conservation and crop improvement objectives for landraces, farmers' varieties and hybrids (Sthapit et al., 2006).This study confirms that PPB in China also can develop crops and cultivars that are better adapted to farmers' local environmental and management conditions and that give more attention to the diverse traits that farmers' and consumers' value in their specific localities.

This study further shows that there need not be a mutually exclusive trade-off between public, commercial and farmers' crop improvement and seed systems (Figure 7.1a); they can be harmonised if suitable institutional arrangements can be put in place (Figure 7.1b). Appropriate regulatory and support provisions can encourage complementarity instead of competition in seed systems. This study shows that, in the right conditions, they can be designed to address both the commercial value and public value of plant genetic resources, i.e. promote market diversification and varied agro-ecological landscapes, in order to meet diverse social and conservation needs.

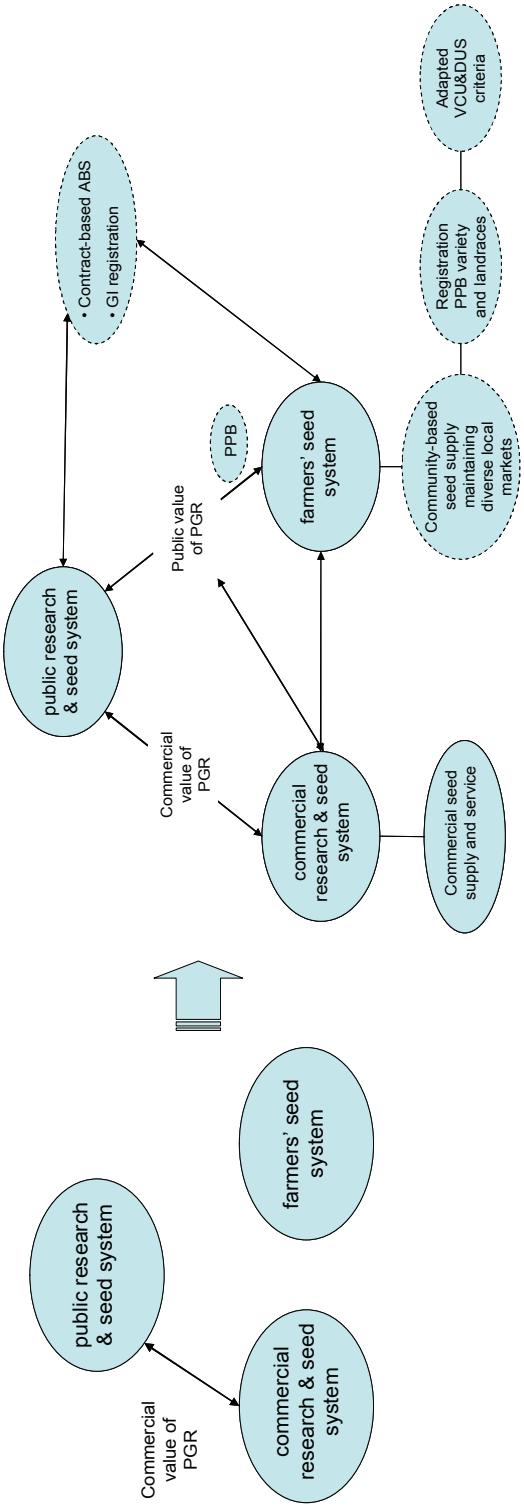

Figure 7.1a. The inter-linkage of public and commercial research and seed systems in pursuit of competition

Figure 7.1b. The inter-linkage of public, commercial and farmers' seed systems in pursuit of complementarity

Source: this thesis.

Further integration of the formal and commercial seed systems and farmers' seed systems needs to take into account the inter-linkages of (a) public research and the public seed system, (b) commercial research and the commercial seed systems, and (c) farmers' seed system (Figure 7.1b). We have identified in this thesis a range of options for integrating public research and the public seed system, commercial research and the commercial seed system, and farmers' crop improvement, in demonstration of the potential to create integrated breeding research, conservation and seed supply system in China. However, we also show that collaboration among the different seed systems and actors requires appropriate procedural mechanisms and institutions, such as contracts for access and benefit sharing (ABS), registration of geographical indications (GI), community-based seed supply and participatory plant breeding (PPB).

7.3.2 Institutional innovation in breeding and seed supply in China

The breeding and seed supply systems in China are in transition. The multi-level perspective adopted in this thesis has provided a frame for analysis of regime change in the organization of the seed supply system over the last decade in China. At the landscape level the implications for China of the regulation of plant genetic resources through various international treaties and conventions are under review by policy actors in the light of the evolution of the global seed industry. At the regime level, there is on-going transition in the Chinese context towards a market-based seed supply. Seed supply at the niche level offers a range of options for the development of radical novelty in variety development and seed provision for and by smallholder farmers. However, a series of technical, organizational and market 'mismatches' still exists within the current seed regime that hinder further expansion of these options. Although this study shows that there are opportunities for ensuring that PPB for instance becomes a permanent component in seed provision, further effort is required to stabilize this capacity in the evolving regime. Specifically, what is needed includes:

- amendment of existing seed regulations in order to accommodate varieties with more heterogeneous characteristics;
- support to public research institutes' role in breeding that is oriented to smallholders and conservation;
- protection of the public value created by PPB in relation to agro-biodiversity conservation and farmer empowerment through ABS-related agreements, clearly distinguished from the commercial value protected by exclusive intellectual property rights (IPRs);
- support to farmer-led seed production and marketing, as a complement to commercial markets, in order to widen farmers' seed choices and respond to their multiple needs.

7.3.3 Policy options for pursuing China's ambitions to modernise crop development whilst conserving plant genetic resources and improving smallholder farmers' livelihoods

Seed diversity

The mountainous regions in southwest China have been identified as a 'biodiversity hotspot'. This study reveals that the expansion of hybrids has reduced agro-biodiversity in farmers' field and farmers' access to landraces. Farmers have switched to commercial hybrids and give less attention to landraces and farmers' varieties because they gain little commercial advantage from them at present, resulting in considerable degradation in their quality, and this in turn motivates further abandonment. The erosion of locally adapted landraces and farmers' varieties is experienced by farmers as increasing crop vulnerability to insect pests and diseases and accelerating the loss of local knowledge about diversity. The rate of replacement of landraces and farmers' varieties by hybrids is increasing and local seed provision is eroding; both trends limit farmers' access to local genetic resources and could lead to the situation that in the long run farmers have no choice but to adopt the hybrids the market offers, unless other interventions in crop breeding and seed provisioning are supported by combined public and market-oriented support. However, few farmers seem concerned to accept responsibility for the loss of biodiversity and the loss of biodiversity seems to be of little concern to most farmers of the current generation. It thus becomes an urgent matter (a) for government and public research institutes to conserve and utilize genetic resources as a safeguard against an unpredictable future (Bragdon et al., 2009; Newton et al., 2010); (b) for support to be given to multi-actor engagement in the further development of the commercial options for utilization of farmers' PGRs that are identified in this thesis.

On the other hand, the advantages of currently commercially released hybrids have not yet been convincingly demonstrated to farmers in the southwest. There is a need to investigate how these might be improved and adapted to local agronomic and socio-economic contexts. In order to move forward on both conservation of farmers' PGRs and hybrid improvement, there are various, complementary approaches that might be considered: the *ex-situ* (genebank) approach, the *in-situ* (on-farm) approach and the participative approach to crop breeding (Pimbert, 2011; Morris and Bellon, 2004; Jarvis and Hodgkin, 2008). The Guangxi PPB programme has demonstrated the potential by producing both hybrids and OPVs, in collaboration with GMRI's and CAAS's genebanks.

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[5] **See the Conservation International Website for Biodiversity Hotspots, Mountains of Southwest China, www.biodiversityhotspot.org/xp/Hotspots/china**

Regulation: a two-track approach?

Meanwhile, trade-related pressure to comply with WTO and UPOV provisions is leading to a growing harmonization of seed regulations worldwide. The concentration of intellectual property rights in PGRs has fostered the commercialization of those resources and the development of commercial seed sectors. IPR and seed regulation are evolving under WTO/UPOV as a form of business regulation that plays a powerful role in driving the direction of research and development and in shaping market structure through binding IPR-based market protection (Drahos, 2010). However, the trade-related aspects of IPR, in the form of plant breeders' rights and patent rights, tend to conflict with development-related policy priorities, especially in relation to the public interests served by plant breeding for agro-biodiversity conservation and crop improvement in less-favourable regions. It has been argued that the actors within the system are engaged in a struggle over who will have power and control over the production and supply of food, and how the benefits and risks arising from different activities will be distributed (Tansey, 2008). At the country level, there is space for exceptions and protection in the on-going struggles and many countries, especially developing countries, are exploring their sui generis options for balancing farmers' rights and plant breeders' rights. What are the possibilities for China to develop a unique seed system that can drive action on the global stage?

The seed system in China seems to be evolving towards a two-track framework. On the one hand, governed by the trade rules, the national seed system is experiencing industrialization and commercialization, drawing support from the both public and private sectors. On the other hand, as a mega-biodiversity country China also is striving to put in place policy support, regulation and practices for agro-biodiversity conservation, in order to safeguard future breeding options and food security under climate change. Since most of its PGRs are in the hands of smallholders, Chinese policy-makers recognise that exclusive IPRs will limit farmers' access and reduce the potential for on-farm crop development.

There is no small matter in a country as vast as China; realistically speaking, many millions will remain based in small-scale farming over the next several decades (IAASTD, 2009; de Schutter, 2009). There is thus both a need and, as this study shows, also potential to support their need for improved seed. For the sake of both farmers' interests and the continuous conservation of agro-biodiversity China thus so far maintains the provisions of UPOV 1978, instead of moving on towards UPOV 1991 (Song, 2010). However, the concept of farmers' rights does not resonate well in the Chinese context and legislation to protect their interests in PGRs, crop breeding, and commercialisation lags behind countries such as India. The public sector is shifting its attention to commercial business but the national legal framework does not as yet recognise farmers as the users and stewards of PGRs. The space for farmer organizations also is still underdeveloped and, though numerous, smallholders have weak capacity to express their needs in relation to seed markets and variety development. This study shows that none the less there are options for developing market-oriented reward for

farmers' on-farm conservation and improvement of their landraces and varieties, and these also deserve policy support.

7.3.4 Challenges, difficulties, and opportunities revealed by the study

Re-directing the role of public research institutes during the transition period

The PPB project has provided a protected space for niche-level experimentation and for protecting the public value of PGRs, through collaboration between the public sector and farmers for the combined purposes of crop improvement, agro-biodiversity conservation and farmers' empowerment. However, the scaling-out of PPB is challenged by the priorities that public institutes set for themselves. As in other countries, when driven by market profit both public and private research is shifting toward the most profitable crops and proprietary varieties, and away from the improvement of varieties, such as open-pollinated varieties, that farmers can reproduce easily (Kloppenburg, 2005; Howard, 2009). Public institutes in China used to play an important role in fundamental research (e.g. pre-breeding research) and in public good research on minor crops and non-commercialized varieties but over the transition period they have become profit-driven (S. Zhang, CAAS, personal communication, 2008). According to the key informants, the performance of public breeders today is measured by the number of released varieties, published scientific articles and the commercial projects they have conducted. Their contribution to non-commercial activities such as PPB cannot be represented directly in this evaluation framework and this may discourage institute breeders who wish to be involved in PPB (W. Cheng, GMRI, personal communication, 2010). The shifting function of the public sector has challenged their public good role in non-commercial research for smallholder farmers in less-favourable conditions.

On the other hand, the publicly funded institutes' involvement in the commercial seed market distorts competition. Their public responsibility for crop improvement for smallholder farmers and especially for crops that occupy a small area or are of minor importance to the national economy, and to pre-breeding research, need to be distinguished from their commercial activities. The commercial sector also could benefit from strengthened collaboration in pre-breeding research; the public institutes could provide specific stress tolerant plant materials (i.e. genitors), for instance.

Policy guidance for reform and development of the seed industry is under formulation by the State Council and the Ministry of Agriculture. Although the outcome is not yet known the consolidation of the domestic seed industry and the separation of the public institutes and the commercial seed industry seem likely to be central elements in the guidance. This study demonstrates that, public, commercial and farmers' seed systems can strengthen each other's roles and contribute to diverse but distinct markets, representing complementarity instead of merely competition.

- Implications for China of the proposed ABS legislative agenda

We have discussed ABS issues within the context of an ongoing PPB programme, where farmers and breeders interact in relation to the breeding activity and on-farm PGRs maintenance. From 2005 to 2010, a number of institutional changes in relation to ABS have been accomplished through and as a result of the interaction. They have resulted in (a) an informal mechanism in the form of an agreement on seed production that allows breeders to sell seed to commercial market and the PPB farmers to sell into niche markets, (b) a formal mechanism in the form of a legally enforceable contract, (c) new procedures for and commitments to local level capacity building in relation to PPB, ABS, and PGRs conservation, (d) identification of new options (such as GI and procedural law), and (e) influence on the still evolving policy environment. In China, rights-based approaches to seed management and ABS legislation began in 1995 and are still under negotiation among diverse interests and sectors. At the practice level, this study shows that change in the incentive structures can be effective in bringing about institutional innovation, and this experience is being closely followed by Chinese policy makers. There has been a range of policy discussions, workshops and conferences through which we have delivered the research findings into the ABS-related policy dialogue (Song et al., 2012).

The major constraints to PPB-related ABS exist in the seed regime in relation to VCU (value for cultivation and use) and DUS (distinctiveness, uniformity and stability) testing, exclusive IP protection, and the vacuum in national legislation with respect to ABS. Given that there is no body of national ABS law in place, niche level practices (a) to (e) above have been created that offer a range of practical options for policy makers to consider. In particular, since the role of contract law already is well established in commercial practice and the contracts are enforceable in law, this study's policy dialogue participants have expressed strong interest in pursuing ABS through the procedural law governing contracts, learning from the experience of the draft model law in Taiwan (the detailed process has been described in Chapter 5). However, the wider application of this option depends on a willingness to allow farmers' organisations to become registered as legal entities. Another kind of procedural approach to ABS is already achievable, under the three modalities described in Chapter 6 for registering Geographical Indications. All three modalities already allow recognition of and reward for farmers' contributions to the development of raw agricultural materials and food products. GIs are expected therefore to provide additional windows of opportunity in the near future for sharing the market benefits of PPB products.

7.3.5 Discussion of methodological issues encountered in this study

Role of action researching and its contribution to driving system innovation

Action research in this study was adopted as a research strategy that links to both the methodology and the analysis. It provides a perspective through which to understand the dynamic of change in niche-regime interactions. Because the research is associated with activities in which the actors are seeking to learn their way toward new scientific and policy practices appropriate to China's development needs, action research has offered an appropriate framework and strategy also for the policy-related aspects of the study, as Reason and Bradbury (2006) have addressed.

We have discussed that action researching contributes to systemic institutional innovation, through a case study of the ABS mechanisms developed in the context of the PPB programme in southwest China. We analyse that the processes of purposeful change do require concerted effort among individuals and organizations located at different levels. It is a relatively new mode of researching in the Chinese context; we describe how action researching allows knowledge, information and organizational capacity to be mobilised to build shared purpose and mutual benefits.

- Cross-disciplinary research

The current study encompasses and integrates technical and social science research. From the technical point of view, we have traced the changes of farmers' adoption of maize hybrids and the persistence of landraces in three southwest provinces, from 1998-2008; and we have analysed the technical (but also collaborative) aspects of including farmers in a technically more complicated processes of hybrid development and hybrid seed production. From the institutional point of view, we have examined the seed-related regulatory framework as well as the diverse seed market and we identify the adjustments required to support initiatives that address the public value of plant genetic resources. We show that both regulation and market mechanisms are needed to protect the public value of plant genetic resources, and to balance private interests and public interests. The action researching process connected these disciplines. We argue that optimizing the technical aspects has institutional consequences; conversely, inappropriate or unbalanced institutions may limit or distort technical potentials. It is therefore necessary to strengthen through our research practice the interactions of actors involved in both the technical and institutional aspects.

In this study, such integration can be seen as the result of inter-personal and inter-organizational collaboration, i.e. the development of networks of relationships and understanding among the plant breeding sciences and social sciences, and among scientific knowledge and farmers' knowledge on breeding. It has also strengthened the local level organizational and decision-making ca-

pacity of farmers and local practitioners. The research team from the Centre for Chinese Agricultural Policy (CCAP) played the role of facilitators during the action researching processes. The facilitation was driven by their motivation to develop ABS capacity at niche and regime levels. We note that the network developed over time, through dialogue and practice rather than by prior design, in ways that allowed mutual understanding and respect to evolve, supported by appropriate facilitation, communication and feedback delivery. Through our study, a greater range of actors have become involved in the food and seed related network, including farmers, breeders, as well as consumers and regional conservation interest groups who are working together on the co-development of regional products derived from local PGRs. It is likely that they would not have encountered each other to generate new breeding knowledge and understanding of the value chain without facilitation by the networked members.

Questions of power and status could not be avoided in our research: the fact is that the national breeding institute leads the national agricultural research system, which is organized on the basis of a clearly defined hierarchy of powers. Further, the recognition and valuation of farmers' knowledge through iterative communication and joint practices was significantly influenced by the direct involvement and support of leading breeders and Beijing-based CCAP senior researchers. At the same time recognition of the contribution of national and local social scientists to the PPB processes also proved crucial; breeding used to be regarded as the task solely of professional breeders. Unlike any single discipline research study or one confined to the level of the niche, the action research allowed breeding science to be combined with the social sciences, and interactions to be facilitated across the bureaucratic power structure to form a networked relationship among stakeholders located at different levels, each bringing complementary experience and knowledge. The PPB initiative has opened the window for further collaboration, not only for farmers but also for social scientists. It has been realized that there are distinctive roles for the breeders and social scientists in PPB initiatives – the former put more emphasis on crop improvement while the latter strengthen farmers' empowerment and local capacity building.

This multi-disciplinary collaboration has combined sociological, technical and policy studies in the context of PPB and ABS, through which 'the social distribution of knowledge production' has been practised. According to Gibbons et al. (1994), mode 1 science is embedded in an academic context, with a distinctive disciplinary, homogeneous research team, clearly defined academic quality control, and accountability to science; while mode 2 science is application-oriented and trans-disciplinary, conducted by heterogeneous teams; a wider set of criteria are used in quality measurement, and the practitioners are accountable to both science and society. The programme PPB in southwest China has experienced a transition from mode 1 science to mode 2 science. There have been a series of 'break-through' moments as described in Chapter 5, which brought interaction and negotiation among actors with different knowledge backgrounds, and resulted in new knowledge production, that could not have been created through

single discipline research or professional practice.

The author has been present in the situation addressed in this thesis since 2004, which means that we could take advantage of events and evolving process of learning in ways that short term research could hardly achieve. Such embeddedness and long-term involvement have made it easier for the researchers to understand the situation and changes over the time in the research context. However, long-term engagement also tends to blur the distinction between the scientist as an actor in the situation and as an uninvolved observer.

Multi-level perspective on system innovation and the dynamics of change

Louwaars (2007) has analysed the common disconnections in the process of evolving seed policy, in three domains: 1) lack of effective debate among stakeholders within a policy sector, 2) insufficient communication and understanding among sectors, and 3) poor linkages between local, national and international policy levels. Such disconnections are widely present in many countries. How these disconnections are bridged, and how the interests among sectors are balanced, will drive future directions in the development of the seed sector.

The dynamic of the changing situation in China's seed systems is complex. The key changes are impacting different levels simultaneously but not necessarily in concert. The multi-level perspective as an analytical tool has been developed and used in innovation studies (e.g. Geels and Schot, 2007). It has not previously been applied in the analysis of seed systems in China. We have explored the potential of the multi-level perspective to understand the seed system dynamic, particularly taking into account the tensions and opportunities for niche developments oriented toward smallholders. We have demonstrated that within the current institutional arrangements the further expansion of PPB is challenged by cultivar testing procedures required for cultivar registration and the organizational arrangements between public institutes and market actors. These call for institutional innovation at the local level and also for changes in existing institutions at higher levels. The policy-oriented action researching components of this study have begun to open up opportunity for system innovation in relation both to PPB and ABS mechanisms.

The design of purposeful interaction between niche and regime levels clearly can help foster institutional innovation, through either bringing tensions openly into discussion, or by initiating new spaces for change. Our study shows that the multi-level action research can be an effective strategy to work towards institutional change. However, policy processes at regime levels usually take time to motivate before regime change is institutionalised. Klerkx et al. (2010) argue that institutional innovation seems to be a highly unpredictable process, and some strategic shifts may happen gradually and slowly, while others may be caused by a sudden change or surprise opportunity.

7.4. Outlook

The scope of this research targets mainly southwest China, with special focus on conservation and smallholder farmer-oriented breeding and public service provision. The PPB programme started in Guangxi with maize in 2000, and has expanded to an increasing range of crops and other southwest provinces in recent years, thereby demonstrating the need, the opportunities and the legitimacy of PPB in other parts of China. The findings of this study might provide references for other regions within and outside China.

This study has contributed to increasing the awareness and debate on intellectual property systems in agriculture in China. Chinese policy makers have realized that an appropriate IP system might provide both incentives for inventors and reasonable equity for the whole society. A National Agricultural Intellectual Property Strategy (referred to as 'Strategy') has been introduced, and implemented by the Ministry of Agriculture of China from June 2010. This guidance from the national level aims to fulfil three objectives over the coming ten years (i.e. 2010-2020): 1) to improve the efficiency of plant variety protection law through for instance amending the existing DUS test system; 2) to foster the institutionalization of geographical indication protection on agricultural products; and 3) to set up a management system with clear, defined ownership and benefit-sharing arrangements over agricultural genetic resources. The Strategy strengthens the importance of both new variety development and on-farm maintained agricultural genetic resources. It also, notably, places equal emphasis on new variety protection and geographical indication protection, in order to balance breeders' and farmers' interests in the evolving agricultural IP system. Meanwhile, the 2nd regional ABS conference among Asian countries held in April 2010 in China signalled movement toward formalizing ABS mechanisms at the country and regional levels (ASEAN, 2010).

This study provides tested options for Chinese policy makers to consider as the seed sector evolves. The options are enriching informed discussion at policy levels during China's preparations for the Rio+20 United Nations Conference on Sustainable Development, to be held in 2012. A number of issues derived from and discussed through this study, such as how to balance the commercial and public value of plant genetic resources, how to ensure appropriate benefit sharing among diverse interests in pursuing these values, how to strengthen diverse social and market needs for seed and food products, are all being taken into consideration during the PGRs-related policy-making process.

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Summary

The expansion of modern hybrid varieties in maize (*Zea mays* L.) in China has caused the rapid loss of local varieties, including farmer maintained varieties and landraces. With growing international recognition of the importance of agro-biodiversity conservation and on-farm crop improvement, participatory plant breeding has been accepted as a complementary strategy in modern agricultural research. Participatory plant breeding has been conducted in Guangxi province in the Southwest China since 2000. It has introduced technical options to the formal breeding programme as well as institutional options at a range of levels, including new, formalised benefit sharing arrangement among stakeholders. This study seeks to understand these challenges and, through action research to induce supportive multi-level institutional change through and for participatory plant breeding within the local socio-technical context.

The core research questions of this study are:

- What were the changes in the distribution of maize landraces and hybrids from 1998 to 2008 in the three southwest provinces, Guangxi, Yunnan and Guizhou?
- What are the potentials of participatory plant breeding for maize hybrid improvement in this context?
- How do the institutional changes in the organization of the seed supply system in China influence small holder-oriented seed supply?
- What is the contribution of action researching to institutional innovation in the case of developing access and benefit sharing mechanisms in the context of the participatory plant breeding programme in southwest China?
- How has public value been created, strengthened and rewarded through participatory plant breeding and related market mechanisms in selected cases?

Chapter 2, 'Farmers' adoption of maize hybrids and the persistence of landraces in southwest China: implications for policy and breeding', was based on a survey, which specifically aimed to examine the changes in the distribution of maize landraces and hybrids from 1998 to 2008 in Guangxi, Yunnan and Guizhou, and to explore the extent to which farmers have adopted hybrids and conserve landraces, for what reasons. The results of this study indicate that, although hybrids have been promoted and pushed rather heavily by the state and private organizations, few farmers in the southwest actually have felt pressured to adopt such seeds; adoption has been motivated by farmers' perceptions of the advantages and expanding market opportunities. In Guangxi, Yunnan and Guizhou provinces maize hybrids rapidly became dominant over the period 1998 to 2008, especially in Guangxi where the area under hybrids has reached 93% of the maize area. Our survey data reveal that farmers see several economic and many agronomic advantages in using hybrids, indicating that they are indeed internally motivated to use hybrids. The most important advantages that the surveyed farmers perceive are higher yields and lodging resistance. However, the farmers also associate hybrids with a large number of disadvan-

tages, especially poor adaptability and inadequate service provision in relation to seed quality control, availability of cultivar information and the accessibility of seed. Moreover, a considerable proportion of farmers still reserve a portion of their land for landraces and farmers' varieties even if hybrids dominate their cropping. The farmers stress that these materials have several advantages over hybrids, especially regarding their adaptability to local harsh conditions, the taste, and the relatively ease of gaining access to seed. The farmers also express a range of functional preferences for landraces and farmers' varieties, related to food culture, land quality and economic infrastructure. Even so, it was found that the expansion of hybrids had led to a sharp reduction in the number and area grown under landraces and farmers' varieties in farmers' fields, and that their interest in and care for local genetic resources seems to have dwindled. However, in the seed systems of poor and vulnerable farmers especially, this study shows that these materials still play an important role, since such farmers often cannot afford the seed costs of hybrids and/or accommodate the agronomic and economic risks associated with them. Overall, we show that despite the large scale adoption of hybrids, there is still considerable scope for improving the quality and adaptability of landraces, farmers' varieties and hybrids. This calls for local hybrid cultivar improvement, using strategies such as on-farm cultivar testing, and farmer-based demonstration and evaluation. The chapter concludes by assessing the implications for national policies in relation to seed production, breeding and conservation. The main issues drawn are that there is opportunity to enhance the utilization of landraces in modern breeding in China, taking into account smallholder farmers' needs on the one hand, and the need for the development of breeding strategies and support mechanisms that combine and integrate yield potential with local preferences (both biophysical and socio-economic) on the other.

Chapter 3, 'The potential of participatory hybrid breeding', discusses the potential of involving smallholder farmers in hybrid development for resource poor farming systems. The methodology and practices of participatory maize hybrid breeding, as well as landrace enhancement are explored in the case of the participatory plant breeding (PPB) programme in Guangxi in southwest China (2000-2012). We address the argument that hybrid development can serve smallholder farmers in marginal, resource poor farming systems under certain conditions, by considering the following technical, social and institutional aspects: a) PPB hybrids are bred for yield stability and adaptation to local needs and preferences, b) dependence on and need for genetic diversity is taken into account, c) breeders collaborate closely with farmers not only in the last stages but also in the initial stages of the breeding programme, d) PPB hybrid seed production can be integrated into farmers' local seed system, and e) farmers and breeders can agree on issues dealing with intellectual property (IPR) and access and benefit sharing (ABS) in a fair and transparent way. The obstacles for both farmers and breeders, including related institutional aspects are analysed in reference to the applied breeding process and seed production, and a number of outstanding challenges.

In order to understand the institutional changes in the organization of seed supply in China, we adopt a multi-level perspective taken from system innovation studies, which links niche-level practices with the dynamics of regime-level change and landscape-level trends. Chapter 4, 'Towards a regime change in the organization of the seed supply system in China', explores recent changes in seed supply from this multi-level perspective, and analyses the innovations brought about by PPB at niche level in response to such changes. We then analyse and discuss how PPB practices have amplified the tensions within current seed-related institutional provisions in China. China has been progressively drawn into international negotiations over seed, bringing further tensions, relating to the incompatibility of overlapping agreements. The TRIPS agreement and the UPOV convention for instance focus on protecting plant breeders' rights and are trade-oriented, while the CBD convention and the ITPGRFA treaty seek to secure the rights of farmers over plant genetic resources (PGRs) and to recognize their role in conserving biological diversity. The institutional tensions and opportunities identified for further expansion of PPB in the changing configuration of the seed supply system in the Chinese context are: i) If a PPB variety fails the DUS test, a number of issues arise: whose PBR needs to be guaranteed, in which way and how to conserve the variety within the public domain; ii) the publicly-funded institutes' involvement in the commercial seed market distorts competition. The PPB initiative demonstrates the potential for creating mutually-beneficial farmer-researcher partnerships serving local markets, as well as conservation and livelihood goals; iii) current seed legislation worldwide impedes the marketing of non-uniform varieties and this limits access to diversified seed. However, a diversified seed market that consumers can recognise would provide incentives for PPB practitioners to supply on-farm selected and produced seed. We show that these tensions may play a catalytic role in forcing regime-level change in Chinese seed systems and breeding policy. From this perspective, we show in our analysis that the emphasis on-farmers' rights in the CBD and ITPGRFA opens an opportunity for PPB-led innovation in China.

In Chapter 5, the contribution of action researching to institutional innovation is examined in relation to developing access and benefit sharing mechanisms in the context of the participatory plant breeding programme. We adopt action researching and a multi-level perspective as analytic concepts through which to explore and demonstrate the contribution of action research to building conducive interactions between niche practice and regime. The value of action research in fostering systemic institutional innovation is shown by detailed study of the processes of change with respect to PPB-related access and benefit sharing (ABS) mechanisms. The analysis of eight critical events uncovers the strategic shifts that have occurred in research practices that evolved as shared learning accumulated among niche- and regime-level actors. Analysis of each episode details the twists and turns in the iteration between practice and reflection, through which stakeholders jointly discovered the issues and made new accommodations. The results offer legislators and policy-makers in China, in the ongoing formulation of ABS policy and law, a number of tested options for shar-

ing access and benefits in crop breeding, varietal selection and plant genetic resource conservation. These novelties, emerging from PPB practice in a programme niche that has attracted international, national, provincial and community level support, offer ways for China to balance interests while respecting its obligations under international law and accommodating competitive market pressures. The chosen research practice, action research, is positioned as the vehicle for multi-actor learning that mediates the tensions that arise from the multi-level change processes.

Chapter 6, 'Expressing the public value of plant genetic resources by organising novel relationships: the contribution of selected participatory plant breeding and market-based arrangements', explores recent efforts to determine and assert the public value of plant genetic resources through participatory plant breeding, as well as a range of options for balancing public and private interests in conservation of agro-biodiversity and in bringing to market the products of PPB, and farmers' varieties and crops. Lessons are drawn concerning the options for establishing public interest and assigning value, and for reconciling or harmonizing private and public interests. The findings and analysis demonstrate, for instance, that the creation of public value calls for the integration of innovations in the value chain that recognizes the joint efforts of producers, consumers, market actors and the public sector. Further development of public value requires additional study of the economic feasibility and explicit supportive public policies for the options identified. The article concludes by discussing what can be learnt from such innovations within China itself, that may be relevant to other countries also, and how public value in PGRs can be better created and protected in the future in China. We argue that further experimentation with the most promising options for China is needed to test the legitimacy of the identified options within the embedded institutional regime and to enhance their internal operational capacity.

Chapter 7 draws together the conclusions. First, a synthesis is made of the evidence presented in this thesis in order to assess the current institutional context and prospects for PPB and farmer' varieties in China. The most important features of the context are, i) small holder farmers living in resource poor farming system need improved varieties, which can satisfy bio-physical conditions as well as local socio-economic preferences; ii) the Guangxi PPB programme in maize has shown its potential in both open-pollinated variety improvement and hybrid development. During this process, public breeding institutes play important roles in training and facilitating farmers in relation to breeding and seed production, through which the knowledge from each actor has been exchanged and generated; iii) however, varieties developed from PPB process cannot be easily recognized by national PVP laws and therefore are impeded by the commercial market, and this has discouraged both public breeders and farmers from becoming involved in PPB. Secondly, the policy options for pursuing China's ambitions to modernise crop development whilst conserving PGRs and improving small farmers' livelihoods are presented and discussed. The principal opportu-

nity identified is to build up an integrated and harmonised seed research, conservation and supply system, in order to conserve and utilize genetic resources as a safeguard against an unpredictable future and to support multi-actor engagement in the further development of the commercial options for utilization of farmers' PGRs. Thirdly, the specific role of action researching and its contribution to driving the identified changes is discussed. The advantages (and disadvantages) of conducting and integrating technical, policy-related and social science studies in action research mode are examined in the light of the experiences presented in the thesis. A lesson drawn from this action research is that, the processes of purposeful change require concerted effort among individuals and organizations located at different levels through allowing knowledge, information and organizational capacity to be mobilised to build shared purpose and mutual benefits. Fourthly, the desirability of protecting the public value of plant genetic resources in China through public policy and new market mechanisms is emphasized. The policies and mechanisms that appear to be specifically required are the adjustments in the seed-related regulatory framework, as well as to maintain a diverse seed market: a participatory breeding mechanism, Geographical Indication branding and labelling, community-supported agriculture, or creating a separate conservation regulation mechanism for landrace conservation and marketing.

Samenvatting

De toename in het gebruik van moderne hybride maïsrassen heeft tot een snelle teruggang van lokale rassen geleid waaronder de door boeren in stand gehouden variëteiten en landrassen. Met de groeiende, internationale erkenning van het belang van het in standhouden van agro-biodiversiteit en gewasverbetering door boeren, heeft men participatieve veredeling geaccepteerd als een aanvullende strategie in modern landbouwonderzoek. Participatieve veredeling vindt plaats in Guangxi, een provincie in zuidwest China, sinds 2000. Daarmee zijn zowel technische aanpassingen voor het formele veredelingsprogramma geïntroduceerd als ook institutionele veranderingen op velerlei niveaus, waaronder nieuwe, geformaliseerde overeenkomsten over eerlijke verdeling van opbrengsten van genetische bronnen tussen de belanghebbenden. Deze studie probeert zicht te krijgen op deze uitdagingen en poogt door middel van actieonderzoek op verschillende niveaus ondersteunende institutionele verandering op gang te brengen door en voor participatieve plantenveredeling in de lokale sociaal-technische context.

De belangrijkste onderzoeksvragen zijn:

- Welke veranderingen hebben in de maïsteelt plaatsgevonden met betrekking tot de verdeling tussen landrassen en hybriden van 1998 tot 2008 in drie provincies van zuidwest China: Guangxi, Yunnan en Guizhou?
- Wat zijn de mogelijkheden van participatieve maïshybride veredeling binnen deze context?
- Op welke manier beïnvloeden de institutionele veranderingen in de organisatie van het formele zaadvoorzieningssysteem in China de zaadvoorziening van de kleine boeren?
- Wat is de bijdrage van actieonderzoek geweest aan institutionele veranderingen in de sfeer van instrumenten voor toegang tot en eerlijke verdeling van opbrengsten van genetische bronnen in de context van het participatieve veredelingsprogramma in zuidwest China?
- Op welke wijze is publieke waarde gecreëerd, versterkt en beloond door middel van participatieve plantenveredeling en marktgerelateerde mechanismen in geselecteerde casussen?

Hoofdstuk 2 getiteld 'Gebruik van maïs (*Zea mays* L.) hybriden door boeren en het voortbestaan van landrassen in zuidwest China: gevolgen voor beleid en veredeling', is gebaseerd op een onderzoek dat specifiek gericht was op het in kaart brengen van veranderingen in verhouding in maïs tussen landrassen en hybriden tussen 1998 en 2008 in Guangxi, Yunnan en Guizhou, en beoogde tevens om te na te gaan in hoeverre de boeren hybriden gebruiken en tevens landrassen in stand houden, en waarom. De resultaten van deze studie tonen aan dat ondanks het feit dat hybriden nogal sterk zijn gepromoot en naar voren zijn geschoven door de overheid en private organisaties, weinig boeren in

zuidwest China het gevoel gehad hebben gedwongen te zijn zulke zaden te accepteren; het gebruik er van blijkt vooral ingegeven door veronderstelde werd voordelen en kansen van marktuitbreiding. In de provincies Guangxi, Yunnan en Guizhou hebben in de periode 1998-2008 maïshybriden snel de overhand gekregen, met name in Guangxi waar hybriden op circa 93% van het maïsareaal gebruik werden. Onze inventarisatie liet zien dat boeren verschillende economische en vele agronomische voordelen in het gebruik van hybriden zagen, hetgeen aannemelijk maakt dat zij inderdaad intern gemotiveerd waren om hybriden te gebruiken. De belangrijkste voordelen die de geïnterviewde boeren zagen, waren hogere opbrengsten en resistentie tegen legeren. Echter, boeren associeerden hybriden ook met een groot aantal nadelen, met name slechte adaptatie en inadequate dienstverlening met betrekking tot zaadkwaliteitscontrole, beschikbaarheid van informatie over rassen en toegang tot zaad. Daarnaast bleken een aanzienlijk aantal boeren een deel van hun land te reserveren voor landrassen en boerenrassen, ook al domineerden de hybriden op hun land. De boeren benadrukten dat de landrassen verschillende voordelen hebben in vergelijking tot hybriden, met name de aanpassing aan lokale, stressvolle omstandigheden, de smaak en de relatief makkelijke verkrijgbaarheid van zaad. De boeren gaven ook uiting aan een reeks van functionele voorkeuren voor landrassen en boerenrassen met betrekking tot de voedselcultuur, landkwaliteit en economische infrastructuur. Daarnaast, werd duidelijk dat de uitbreiding met hybriden tot een scherpe daling van aantal en areaal landrassen en boerenrassen leidde, en dat de belangstelling en zorg voor lokale genetische bronnen leek te verminderen. Echter, deze studie liet ook zien dat specifiek in de zaadsystemen van kleine en kwetsbare boeren, deze landrassen en boerenrassen nog steeds een belangrijke rol spelen, omdat deze boeren zich dikwijls niet de kosten van hybridezaad kunnen veroorloven en zich de daarmee verbonden teelt en economisch risico's niet kunnen permitteren. Al met al, laten we zien dat ondanks het op grote schaal in gebruik nemen van hybriden, er nog een aanzienlijk scala aan mogelijkheden zijn om de kwaliteit en adaptatievermogen van zowel landrassen, boerenrassen als hybriden te verbeteren. Dit vraagt om bijvoorbeeld om de ontwikkeling van lokale hybriderassen via bijvoorbeeld rassenonderzoek op boerenvelden, en rassendemonstraties en evaluaties door boeren zelf. Dit hoofdstuk eindigt met het aangeven van de implicaties voor nationaal beleid met betrekking tot zaadproductie, veredeling en instandhouding. De belangrijkste aspecten die naar voren kwamen zijn de kansen om het gebruik van landrassen in moderne veredeling in China te stimuleren, met het oog op enerzijds de behoeften van de kleine boeren, en anderzijds de noodzaak voor het ontwikkelen van veredelingsstrategieën en het ondersteunen van mechanismen die opbrengstpotentie combineren en integreren met lokale voorkeuren (zowel biofysich als sociaal-economisch).

Hoofdstuk 3 getiteld 'De potentie van participatieve hybride-veredeling' bespreekt de mogelijkheden om kleine boeren te betrekken bij hybride-ontwikkeling voor landbouwsystemen met beperkte toegang tot hulpbronnen. De methoden en praktijken van participatieve hybride-veredeling in maïs alsook

landrasontwikkeling zijn verkend met betrekking tot de participatieve veredelingsprogramma in Guangxi in zuidwest China (2000-2012). We beargumenteren dat hybride-veredeling kleine boeren in marginale bedrijfssystemen kan dienen wanneer de volgende technische, sociale en institutionele aspecten meegenomen worden: a. hybriden uit participatieve programma's dienen veredeld te worden voor opbrengststabiliteit en aangepast zijn aan lokale behoeften en voorkeuren, b. de afhankelijkheid van en noodzaak voor genetische diversiteit dient in acht te wordt genomen, c. veredelaars zouden nauw moeten samenwerken met de boeren, niet alleen in het laatste stadium maar ook in de initiële fasen van het veredelingsprogramma, d. de zaadproductie van participatief verkregen hybriderassen zou geïntegreerd kunnen worden in de lokale boerenzaadsystemen, en e. boeren en veredelaars zouden het eens moeten worden over zaken als intellectueel eigendomsrechten en een een eerlijke en transparante verdeling van de opbrengsten van gebruik van genetische bronnen. De knelpunten en de uitdagingen voor zowel boeren als veredelaars, met inbegrip van institutionele aspecten zijn geanalyseerd in relatie tot het toegepaste veredelingsproces en de gebruikte vorm van zaadproductie.

Om een goed begrip te krijgen van de institutionele veranderingen in de organisatie van de zaadvoorziening in China, hebben we gebruik gemaakt van een multi-niveau perspectief zoals gebruikelijk is in studies over systeem-innovatie, waarin praktijken op het niveau van niches worden beschouwd tegen de achtergrond van de dynamiek op het niveau van het socio-technische regime en veranderingen en trends op landschap-niveau. Hoofdstuk 4 getiteld 'Naar een regime verandering in de organisatie van de zaadvoorziening in China', verkent de recente veranderingen in de zaadvoorziening vanuit dit multi-niveau perspectief, en analyseert de innovaties die, in reactie op deze veranderingen, teweeg werden gebracht door het participatieve veredelingsprogramma op niche niveau. Vervolgens analyseren en bediscussiëren we hoe participatieve veredelingspraktijken de spanningen binnen het huidige zaadgerelateerde institutionele voorzieningen in China hebben vergroot. China is in toenemende mate betrokken bij internationale onderhandelingen over zaad dat eveneens spanningen met zich meebrengt rond de onverenigbaarheid van overlappende regelingen. TRIPS en UPOV bijvoorbeeld zijn gericht op het beschermen van de rechten van veredelaars en zijn gericht op handel, terwijl CBD en ITPGRFA poogt de rechten van boeren te beschermen met betrekking tot plantaardige genetische bronnen en om hun rol bij de instandhouding van biologische diversiteit te erkennen. De geïdentificeerde institutionele spanningen en kansen voor verdere uitbreiding van participatieve veredeling in de veranderende configuratie van het zaadvoorzieningssyteem in de Chinese context zijn: i) als een ras uit een participatief programma niet voldoet aan de DUS test, rijzen een aantal vragen op: wiens kwekersrechten moeten worden beschermd en op welke wijze kan een ras behouden blijven in het publieke domein?; ii) de betrokkenheid van publiek gefinancierde instituten in de commerciële zaadmarkt verstoort de competitie. Het participatieve veredelingsprogramma laat de potentie zien van wederzijdse boer-veredelaar partnerschappen in het bedienen

van lokale markten maar dient ook de instandhouding van biodiversiteit en het levensonderhoud van boeren; iii) de huidige regelgeving voor zaad verhinderen wereldwijd het vermarkten van niet-uniforme rassen en dit blokkeert toegang to zaad diversiteit. Echter, een diverse zaadmarkt die tegemoet komt aan de wensen van de consument zou de weg kunnen openen voor participatieve veredeling om te voorzien in door boeren geselecteerde en geproduceerde rassen. We laten zien dat dit spanningsveld mogelijk een rol kan spelen in het afdwingen van een verandering in de Chinese zaadsystemen en veredelingsbeleid op het nivo van het socio-technische regime. Vanuit dit gezichtspunt laten we in onze analyse zien dat de nadruk op rechten van de boer in het CBD en IT-PGRFA een kans biedt voor door participatieve veredelings gestuurde innovatie in China.

In hoofdstuk 5 wordt de bijdrage van actieonderzoek aan institutionele verandering bestudeerd in relatie tot het ontwikkelen van toegang tot en eerlijke verdelingsmechanismen van opbrengsten in de context van participatieve veredelingsprogramma's. We gebruiken actieonderzoeken het multi-niveau perspectief als analytische concepten om de bijdrage van actieonderzoek aan het bevorderen van vruchtbare interactie tussen de niche praktijk en het socio-technische regime te exploreren en zichtbaar te maken. De waarde van actieonderzoek aan de totstandkoming van institutionele innovatie is aangetoond door een gedetailleerde studie van het veranderingsproces met betrekking tot participatieve veredelingsgerelateerde mechanismen van toegang tot en verdeling van opbrengsten. De analyse van acht cruciale gebeurtenissen onthult de strategische verschuiving die heeft plaatsgevonden in het onderzoeksproces dat zich ontwikkelde tot een gedeeld leerproces in het netwerk van actoren op het niveau van niche en regime. Analyse van elke episode laat gedetailleerd de bewegingen zien in het iteratieve proces tussen praktijkervaring en reflectie waarin de deelnemers gezamenlijk de sleutelpunten ontdekten en nader tot elkaar kwamen. Deze resultaten bieden de wetgevers en beleidsmakers in China in het nog lopende proces van formuleren van beleid en wetgeving voor toegang tot en veredeling van opbrengsten, een aantal beproefde opties voor deze kwestie en de daarmee verbonden zaken als de selectie van rassen en de instandhouding van plantaardige genetische bronnen. Deze vernieuwingen die ontstaan zijn in de niche van het participatieve veredelingsprogramma, en het internationale, nationale, provinciale en lokale draagvlak dat daaromheen is ontstaan, biedt China wegen om verschillende belangen in balans te brengen en tegelijkertijd zijn internationale wettelijke verplichtingen te respecteren en te reageren op de druk van de competitieve markt. De gekozen onderzoeksmethode van actieonderzoek heeft zich bewezen als een instrument dat het leerproces tussen verschillende actoren bevordert en daarmee de spanningen overbrugt in the veranderingsproces dat op verschillende niveaus plaatsvindt.

Hoofdstuk 6 getiteld 'Het toekennen van publieke waarde van plantaardige genetische bronnen door het organiseren van nieuwe relaties: de bijdrage van select gekozen participatieve veredelings- en markt arrangementen', onderzoekt

recente inspanningen om de publieke waarde van plantaardige genetische bronnen vast te stellen en toe te kennen, als ook een reeks van opties om publieke en private belangen in evenwicht te brengen bij het instandhouden van agro-biodiversiteit, en het op de markt brengen van producten van participatieve veredeling, boerenrassen en gewassen. Er worden lessen getrokken met betrekking tot de opties voor het vaststellen van publieke belangen en het toekennen van waarde, en voor het bijeenbrengen of in evenwicht brengen van publieke en private belangen. De bevindingen en de analyse laten bijvoorbeeld zien dat het creëren van waarde vraagt om integratie van innovaties in de keten die recht doen aan de gezamenlijke inspanningen van producenten, consumenten, marktpartijen en de publieke sector. Verdere ontwikkeling van publieke waarde vereist aanvullend onderzoek naar de economische haalbaarheid van de aangegeven opties en expliciet ondersteunend beleid van de overheid. Het artikel besluit met de discussie rond de vraag wat men in China kan leren van zulke innovaties, wellicht ook met relevantie voor andere landen, en hoe publieke waarde van plantaardige genetische bronnen beter kan worden benut en in de toekomst kan worden beschermd in China. We beargumenteren dat verder experimenteren met de meest belovende opties voor China nodig is om de geldigheid van de geïdentificeerde mogelijkheden te testen binnen het bestaande institutionele regime, en ook om de eigen operationele capaciteit te bevorderen.

Hoofdstuk 7 brengt alle conclusies samen. Allereerst wordt een synthese gemaakt van het bewijs dat in dit proefschrift is geleverd om de huidige institutionele context en de perspectieven voor participatieve veredeling en boerenrassen in China te beoordelen. De meest belangrijke uitkomsten zijn: i) kleine boeren met weinig hulpbronnen hebben verbeterde rassen nodig die passen bij de lokale biofysische omgeving als ook bij de locale socio-economische voorkeuren; ii) het in Guangxi uitgevoerde participatieve veredelingsprogramma in maïs heeft zijn kracht getoond in de veredeling van zowel zaadvaste als hybriderassen. In dit proces spelen publieke veredelingsinstituten een belangrijke rol in de training en ondersteuning van boeren met betrekking tot veredeling en zaadproductie, waardoor de kennis van elke deelnemer wordt ontwikkeld en uitgewisseld; iii) echter, de rassen uit participatieve veredeling worden niet makkelijk erkend door de nationale regelgeving voor rassentoelating en hebben daardoor geen toegang tot de commerciële markten. Dit heeft zowel publieke veredelaars als boeren ontmoedigd om bij participatieve veredeling betrokken te zijn. Ten tweede zijn de beleidopties verkend om China's ambities te volgen in het moderniseren van de veredeling en tegelijkertijd de plantaardige genetische bronnen te beschermen en het bestaansniveau van kleine boeren te verbeteren. De belangrijkste kans die gevonden is zit in het opbouwen van een geïntegreerd en evenwichtig systeem van rassenonderzoek, instandhouding en zaadvoorziening, om genetische bronnen in stand te houden en te benutten als een verzekering tegen een onvoorspelbare toekomst, en om de betrokkenheid van diverse partijen te stimuleren in de verdere ontwikkeling van commerciële mogelijkheden om de door boeren in stand gehouden

plantaardige genetische bronnen te benutten. Ten derde, is de specifieke rol en bijdrage van actieonderzoek aan het bevorderen van de beoogde innovaties besproken. De voordelen (en nadelen) van het integreren en uitvoeren van technisch, beleidsgerelateerd en sociale wetenschappelijk actieonderzoek zijn bestudeerd tegen het licht van de ervaringen met deze studie. Een les die uit het actieonderzoek getrokken kan worden is dat de processen van gerichte verandering om een gezamenlijke inspanning vragen van individuen en organisaties op verschillende niveaus om kennis, informatie en organisatorische capaciteit te mobiliseren om vorm te geven aan een gezamenlijk doel en nut. Ten vierde, is de wenselijkheid aangegeven van het beschermen van de publieke waarde van plantaardige genetische bronnen in China door overheidsbeleid en nieuwe marktmechanismen. De beoogde beleid en marktmechanismen zijn de aanpassingen in de zaadgerelateerde regelgeving als ook diversificatie van zaadmarkten: participatieve veredeling, handels- en keurmerken voor geografische indicatie, door consumenten gesteunde boerenbedrijfssystemen, of het creëren van een aparte regelgeving voor de instandhouding en vermarkting van landrassen.

About the author

Curriculum Vitae

Jingsong Li was born in Xuzhou, Jiangsu province, China, 29th of June 1980. She lived in her hometown until she went to China Agricultural University in Beijing in 1998. She majored in sociology and obtained her bachelor's degree in 2002. Before graduating from the university, she got an opportunity to apply the Master programme at Wageningen University, the Netherlands. From 2002-2004, she studied Urban Environmental Management at Wageningen University and she did her thesis on environmental sociology with the Environmental Policy group. In 2004 she obtained a Master degree at Wageningen University. Her thesis dealt with a case study of environmental improvements in the cafeteria of Chinese Universities. Shortly after graduation, she was appointed as research assistant by the Centre for Chinese Agricultural Policy, Chinese Academy of Sciences. From then on, she switched her research interest to food and agriculture, with specific focus on smallholder farmer-oriented agricultural research, such as participatory plant breeding, traditional knowledge protection and community-based natural resource management. After working as research assistant for three years, she went back Wageningen University in September 2007, and started her PhD study under the supervision of the Communication and Innovation Studies group and the Plant Breeding group. From 2007-2012, she conducted this PhD research on multi-level institutional change through participatory plant breeding in southwest China, integrated in an on-going project on participatory plant breeding of her home institute.

Publications

Peer reviewed publications

Li, J., Lammerts van Bueren, E.T., Jiggins, J. and Leeuwis, C. (2011) Farmers' adoption of maize (*Zea mays* L.) hybrids and the persistence of landraces in southwest China: implications for policy and breeding. Genetic Resources and Crop Evolution. DOI: 10.1007/s10722-011-9750-1.

Li, J., Jiggins, J. with Song, Y. (Forthcoming) Changing the system from within: experiences with Participatory Plant Breeding and Access and Benefit Sharing in China (accepted by Participatory Learning and Action)

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tionships: the contribution of selected participatory plant breeding and market-based arrangements (resubmitted with revisions to Agricultural and Human Values);

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Song, Y., **Li, J.** and Vernooy, R. (2012) China: Designing policies and laws to ensure fair access and benefit sharing of genetic resources and participatory plant breeding products. In The custodians of biodiversity: sharing access to and benefits of genetic resources, M. Ruiz, R. Vernooy (eds.), 94-120. Abington: Earthscan.

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Education certificate

PE&RC and WASS joint PhD Education Certificate: Jingsong Li

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) and Wageningen School of Social Sciences (WASS) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities).

Name of the activity	Organizers	Year	ECTS
A. General			
- PE&RC Day	PE&RC	2007	0.3
- PE&RC Weekend	PE&RC	2008	0.9
- Review of literature	WUR	2007	6
- Writing of project proposal	WUR	2008	4.5
B. Courses			
- Basic statistics	WUR	2007	1.5
- Research methodology – from topic to proposal	WUR	2008	1.5
- Organic plant breeding and seed production	WUR	2008	3
C. Laboratory training and working visits			
- Regional maize breeding and germplasm conservation; Guangxi Maize Research Institute (GMRI), Guangxi, China	GMRI	2011	4.5
D. Competence strengthening / skills courses			
- PhD Competence assessment	WUR	2007	0.3
- Wageningen UR digital library introduction	WUR	2008	0.3
- Working Endnote X	WUR	2008	0.3
- How to write a world-class paper	WUR	2010	0.3
E. Discussion groups / local seminars / other scientific meetings			
- Stakeholder participation in research	PE&RC, WUR	2008	1.5
- 'Communication and Space for Change' Seminar series of communication science	COM, WUR	2008 2011	3
- Series of seminars on Chinese agricultural policy at Centre for Chinese Agricultural Policy (CCAP), Beijing	CCAP	2009 2010	3
F. International symposia, workshops and conferences			
- Presentation at the Exchange workshop on Participatory Plant Breeding and UPOV 91 in China	WUR	2008	1.3
- Presentation at the 9th meeting of the Conference of the Parties (COP 9) of the Convention on Biological Diversity (CBD), Side-event on Biodiversity and Farmers' Initiative	CBD	2008	1.5
- Presentation at the 1st International IFOAM Conference on Organic Animal and Plant Breeding: breeding diversity	IFOAM	2009	1.9
- Presentation at EUCARPIA 2nd Conference of the 'Organic and Low-Input Agriculture' Section	EUCARPIA	2010	1.9
- Presentation 'Contribution of action researching to institutional innovation', during the 'Communication and Space for Change 'Seminar Series of Communication Science	COM, WUR	2011	1.3
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