Tropical and Subtropical Maize in Asia

Production Systems, Constraints, and Research Priorities

Roberta V. Gerpacio and
Prabhu L. Pingali

CIMMYT

Tropical and Subtropical Maize in Asia

Production Systems, Constraints, and Research Priorities

Roberta V. Gerpacio and
Prabhu L. Pingali

IFAD

CIMMYT MR

Correct citation: Gerpacio, R.V., and P.L. Pingali. 2007. *Tropical and Subtropical Maize in Asia: Production Systems, Constraints, and Research Priorities*. Mexico, D.F.: CIMMYT.

Abstract: This book examines future technological and policy prospects for the sustainable intensification of rainfed upland maize production in Asia, and derives R&D priorities for specific maize production environments and markets. Village-level and farmer-group surveys were conducted to characterize upland maize production environments and systems in China, India, Indonesia, Nepal, the Philippines, Thailand, and Vietnam. Survey findings, particularly farmer-identified constraints to maize production, complemented with other relevant data, were used in country-level, R&D priority-setting workshops. High on the list of farmer constraints was drought, estimated to affect three production environments that are home to about 48 million rural poor and produce an estimated 16 million tons of maize, and others such as downy mildew, stem borers, soil erosion/landslides, waterlogging, poor agricultural extension/technology transfer services, and poor access to low-interest credit and markets. Farmers felt that socioeconomic and policy-related constraints impact maize productivity more than technical constraints do. It is important to recognize that technology is not the only key to increasing productivity and bettering the conditions of marginal maize farmers in Asia. There is a growing trend towards commercializing and intensifying maize production that is different from the staple food self-sufficiency paradigm that has been the cornerstone of agricultural policy in most developing countries. Appropriate government policies could help alleviate the adverse consequences of commercialization and promote sustainable intensification of maize production, especially in marginal environments inhabited by resource-poor subsistence farmers.

ISBN: 978-970-648-155-9

AGROVOC Descriptors: Maize; Agricultural development; Farming systems; Production policies; Environmental factors; Cropping systems; Research projects; Project management; Asia

AGRIS Category Codes: E10 Agricultural Economics and Policies

Dewey Decimal Classif.: 633.155

Editing: Alma McNab

Layout/design: Eliot Sánchez Pineda

Printed in Mexico.

Contents

Page No.

Tables ..... **v**
Figures ..... **vii**
Annexes ..... **vii**
Executive Summary ..... **viii**

1. Introduction **1**
1.1 Background 1
1.2 Objectives 2
1.3 Key Activities, Methodologies and Partners 2
1.3.1 Detailed characterization of upland maize-based production systems and identification of constraints 2
1.3.2 Country-specific constraint prioritization and maize R&D plans 3
1.3.3 Maize sector policy analysis and identification of key policy and investment options 3
1.4 Organization of this Book 4

2. Maize Sector Policies in Asia **5**
2.1 Brief Overview of Maize Economy Trends 5
2.1.1 Shifts in demand 5
2.1.2 Production response 6
2.1.3 Trends in trade 6
2.2 Maize Policy Development 7
2.2.1 Production policies 7
2.2.2 International trade policies 8
2.2.3 Macroeconomic policies on exchange rate 9
2.3 Impact of Policies on Maize Production 10
2.3.1 NPC analysis using official exchange rates 10
2.3.2 NPC analysis using shadow exchange rates 11
2.3.3 What do they mean? 12

3. Maize Agro-ecosystems in Asia **13**
3.1 Maize Production Environments 13
3.2 Biophysical Environment 14
3.2.1 Rainfall 15
3.2.2 Temperature 16
3.2.3 Types of soil 16
3.3 Institutional Environment 16
3.3.1 Line agencies 16
3.3.2 Farmer cooperatives and user groups 16
3.3.3 Sources of material inputs 17
3.3.4 Credit institutions 17
3.3.5 Input and output prices 18
3.3.6 Input-output price ratios 19

3.4 Infrastructure 20
3.4.1 Accessibility 21
3.4.2 Irrigation 21
3.4.3 Post-harvest facilities 21
3.4.4 Proximity to markets and marketing practices 21
3.5 Socioeconomic Characteristics 22
3.5.1 Households and ethnicity 22
3.5.2 Literacy and level of education 23
3.5.3 Landholdings and land tenure 24
3.5.4 Maize utilization 24
3.5.5 Farmer classification 25

4. Maize Production Systems 27
4.1 Crops, Cropping Calendars, and Cropping Patterns 27
4.2 Maize Varieties Grown and Farmer Preferences 29
4.3 Land Preparation and Crop Management Practices 29
4.4 Labor and Material Input Use 30
4.5 Post-harvest Practices 31
4.6 Yields and Yield Gap 31

5. Maize Production Constraints 33
5.1 Biotic Constraints 33
5.2 Abiotic Constraints 34
5.3 Socioeconomic and Policy-Related Constraints 35

6. Priority Constraints for Maize Research and Development 37
6.1 Methodology for Identifying Priority Constraints 37
6.2 Production-based Priority Constraints 39
6.2.1 Major findings 39
6.2.2 Priorities by maize production environment and market orientation 48
6.3 Area-based Priority Constraints 50
6.3.1 Major findings 50
6.3.2 Priorities by maize production environment and market orientation 58
6.4 Economics of Priority Constraints 60
6.4.1 Production-based priority constraints 60
6.4.2 Area-based priority constraints 61
6.5 Technology Options to Address Priority Constraints 62
6.5.1 Technology interventions to address abiotic constraints 62
6.5.2 Technology interventions to address biotic constraints 66
6.6 Sources of Research and Technology 69
6.6.1 Public and private sectors: delineation of research responsibilities 69
6.6.2 Role of the public sector 69
6.6.3 Role of the private sector 70
6.6.4 Public and private sectors working together 70
6.6.5 Analyzing the challenges 72
6.7 Research and Policy Agenda 72

7. Summary and Conclusions 74
7.1 Maize Production Environments 74
7.2 Maize Production Systems 75
7.3 Important Production Constraints 76
7.4 The Role of Policy 78

References 79

Annexes 83

Tables

Page No.

Table 2.1. Maize utilization, Asia, 2000-2002. 5
Table 2.2. Average maize area, yield, and production, Asia. 6
Table 2.3. Growth (%) in maize area, yield, and production, Asia, 1961-2004. 7
Table 2.4. Maize production and net imports, Asia, 2000-03. 7
Table 2.5. Summary of agricultural input policies, Asia. 8
Table 2.6. Tariff policies for maize, Asia. 8
Table 2.7. Summary of nominal protection coefficients (NPCs) for maize, Asia, 1997-2001. 11
Table 3.1. Major maize mega-environments. 13
Table 3.2. Average prices of the most commonly used maize production inputs and maize output (in PPP $ per unit), Asia. 18
Table 3.3. Input-to-maize grain price ratios for seed, fertilizer, labor, and power, Asia. 20
Table 3.4. Summary of the infrastructure in maize production environments across 265 surveyed locations in Asia. 22
Table 3.5. Selected demographic information from across 265 surveyed locations, Asia. 23
Table 3.6. Selected socioeconomic information from 265 surveyed locations, Asia. 24
Table 3.7. Maize utilization (% of grain produced) across 265 surveyed locations, Asia. 25
Table 3.8. Classification of maize farmers within the community, 265 surveyed locations, Asia. 26
Table 4.1. Major cropping patterns and calendars in maize environments, Asia. 27
Table 4.2. Average use of labor and material inputs, by maize production environments, Asia. 30
Table 4.3. Maize yield by production environment, Asia. 32
Table 6.1. Prioritizing constraints across maize environments and geographic regions. 37
Table 6.2. Classification of by-country geographic regions in the maize environment-production orientation matrix. 39
Table 6.3a. Production, area, number of rural poor, and average yield by maize production environment and market orientation (with and without subtropical/mid-altitude-commercial maize production in India and excluding Southwestern China), Asia. 40
Table 6.3b. Production, area, number of rural poor, and average yield by maize production environment, Southwestern China. 40
Table 6.4a. Top 30 priority constraints to maize production according to the production-based efficiency index, Asia (with and without STMA-commercial maize production in India and excluding Southwest China's maize production systems). 41
Table 6.4b. Top 30 priority constraints to maize production according to the production-based efficiency index, maize production systems of Southwest China. 42
Table 6.5a. Selected indicators of impact for the top 30 priority maize productivity constraints according to the production-based efficiency index in Asia (with STMA-commercial areas of India and excluding Southwest China's maize production systems). 43
Table 6.5b. Selected indicators of impact for the top 30 priority maize productivity constraints according to the production-based efficiency index in Asia (without STMA-commercial areas of India and excluding Southwest China's maize production systems). 44
Table 6.5c. Selected indicators of impact for the top 30 priority maize productivity constraints according to the production-based efficiency index, Southwest China. 44

Table 6.6. Top 30 priority constraints to maize production according to the production-based poverty index, Asia (with and without STMA-commercial maize production in India and excluding Southwest China's low market surplus maize production systems). 45
Table 6.7. Top 30 priority constraints to maize production according to the production-based marginality index, Asia (with and without STMA-commercial maize production in India and excluding Southwest China's low market surplus maize production systems). 47
Table 6.8a. Top 30 priority constraints to maize production according to the production-based combined index, Asia (with STMA-commercial production areas of India and excluding Southwest China's low market surplus maize production s ystems). 48
Table 6.8b. Top 30 priority constraints to maize production according to the production-based combined index, Asia (without STMA-commercial production areas of India and excluding Southwest China's low market surplus maize production systems). 49
Table 6.9. Production-based priority constraints to maize productivity by production environment and market orientation, Asia (with and without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems). 50
Table 6.10. Top 30 priority constraints to maize production according to the area-based efficiency index, Asia (with and without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems). 51
Table 6.11a. Selected indicators of impact of top 30 area-based priority maize productivity constraints in Asia (with STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems). 53
Table 6.11b. Selected indicators of impact of top 30 area-based priority maize productivity constraints in Asia (without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems). 53
Table 6.12. Top 30 priority constraints to maize production according to the area-based poverty index, Asia (with and without STMA-commercial maize production areas of India and excluding China's Southwest low market surplus maize production systems). 54
Table 6.13. Top 30 priority constraints to maize production according to the area-based marginality index, Asia (with and without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems). 55
Table 6.14. Top 30 priority constraints to maize production according to the area-based combined index, Asia (with and without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems). 57
Table 6.15. Area-based priority constraints to maize productivity by production environment and market orientation, Asia (with and without the STMA-commercial maize production areas of India and excluding Southwest China's low market surplus production areas). 59
Table 6.16. Estimated gross income loss in maize production across environments due to the top 30 priority constraints, production-based and area-based combined indices, Asia (PPP $/ha). 60
Table 6.17. Estimated gross income loss in maize production by environment and market orientation across the top 30 priority constraints, using production-based and area-based combined indices, Asia (PPP $/ha). 61
Table 6.18. Technology and socioeconomic/policy-related options for addressing priority constraints to maize production in Asia. 63

Figures

Page No.

Figure 2.1. Mean utilization of maize as food, feed, and seed, Asia, 1961-2002. 5
Figure 2.2. Area and yield contribution to maize production growth in Asia, 1961-2004. 6
Figure 3.1. Long-term rainfall distribution and maize cropping season in Cebu, Eastern Visayas (low market surplus production, top), and Bukidnon, Northern Mindanao (commercial production, bottom), Philippines. 15
Figure 3.2. Monthly rainfall and maize-based cropping patterns in the drylands of Jeneponto, South Sulawesi, Indonesia. 15
Figure 3.3. Seasonal rainfall distribution in China by mega-environment. 15
Figure 4.1. Maize cropping calendars, Asia. 28

Annexes

Annex 1. Survey locations, their number by maize mega-environment and salient characteristics, Asia. 83
Annex 2. Matrix of RRA/PRA survey sites by maize agroecological environment and market orientation of maize production. 85
Annex 3. Summary of agro-climatic features of surveyed locations classified by agroecological region and orientation of maize production, Asia. 86
Annex 4. Types of soil present and their farmer-reported advantages and disadvantages, across surveyed villages, Asia. 87
Annex 5. Maize production and poverty parameters by country and agroecological zone, Asia. 88
Annex 6. List of 286 prioritized maize productivity constraints identified by Asian maize farmers. 89

Executive Summary

Globally, 69% of all cereal areas is rainfed, and accounts for 58% of world cereal production. Rainfed areas include 40% of rice, 66% of wheat, 82% of maize, and 86% of other coarse grains (Rosegrant et al. 2002). This book examines future technological and policy prospects for the sustainable intensification of rainfed upland maize production in Asia, in light of its increasing importance, particularly within the regional food system. Rapid rural appraisal/participatory rural appraisal (RRA/PRA) techniques were used in conducting village-level and farmer-group surveys to obtain a detailed characterization of upland maize production environments and systems in China, India, Indonesia, Nepal, the Philippines, Thailand, and Vietnam. Survey findings, particularly farmer-identified constraints to maize production, complemented with exhaustive literature searches and relevant published and unpublished secondary data, were used in country-level, national maize technology R&D priority-setting workshops. The maize R&D priority-setting methodology developed by Pingali and Pandey (2001) at CIMMYT was applied to derive R&D priorities for specific maize production environments and markets. In each country maize sector policy studies were conducted alongside the characterization surveys and priority-setting workshops.

Across Asia, farmers growing maize in different agroecological environments, for either household use or commercial markets, experience very similar biotic, abiotic, socioeconomic, and policy-related constraints to maize production. Among these constraints, first addressing the problem of drought in the rainfed lowland-commercial, rainfed upland-semi-commercial, and commercial production environments will provide the highest technical returns to maize R&D investments in Asia when contribution to regional maize production and share in regional maize area are considered. Drought is estimated to affect about 6.8 million ha just in these three production environments (53.5% of total regional maize area), where the affected areas produce an estimated 16 million tons of maize, and about 48 million rural poor are located. Alleviating drought in these environments is estimated to improve yield by about 35%, and could have an enormous impact on maize production in Asia. Drought also appears to have the highest economic impact in terms of estimated gross income loss. Semi-commercial and commercial maize farmers in rainfed upland environments are estimated to lose at least PPP$ 450/ha (purchasing power parity, PPP) when drought conditions persist.

Apart from drought, downy mildew, stem borers, leaf blight, stalk rot, soil erosion/landslides, soil micronutrient deficiency, waterlogging, lack of capital, poor agricultural extension/technology transfer services, and poor access to low-interest credit and to input and output markets commonly figured in the priority constraints lists. Socioeconomic and policy-related constraints were estimated to affect up to 180 million of the rural poor across Asia. Alleviating these constraints could improve maize productivity by at least 18%.

While constraints relating to low market surplus and subsistence maize production systems do not appear in the priority lists, continuing to invest (albeit modestly) in subsistence farming research remains important, particularly in Indonesia, Nepal, and the Philippines. In general, the priority constraints list based on combined efficiency, poverty, and marginality indices closely follows the priority list based on a poverty index alone, and reflects the farmers' sentiments that socioeconomic and policy-related constraints impact maize productivity more than technical constraints do.

The public and private sectors each have unique capabilities, resources, and comparative advantages that can contribute to alleviating constraints to maize productivity in Asia, and links between the two sectors appear to be expanding. These include international germplasm exchanges, public-private germplasm transfers, collaborative varietal testing networks, genetic improvement, and crop/resource management; they also exploit mutual advantages that work towards the advancement of maize cultivars. Hence, public/private sector alliances could promote spillovers of research results from high- to low-potential environments and from economically advanced to economically deprived areas.

Finally, it remains important to recognize that technology—from the simple to the advanced—is not the only key to increasing productivity, improving the sustainability of intensified maize production, and bettering the conditions of marginal maize farmers in Asia. No amount of advanced public- or private-sector maize technology research and development will help the most disadvantaged farmers unless substantial parallel investments are made in rural infrastructure, agricultural training and extension, input and output distribution and marketing systems, and harvest and post-harvest facilities. Hence, the growing trend towards commercializing and intensifying maize production requires a paradigm in agricultural policy formulation and research priority setting that is different from the staple food self-sufficiency paradigm that has been the cornerstone of agricultural policy in most developing countries. Appropriate government policies could help alleviate many of the possible adverse consequences of commercialization and promote sustainable intensification of maize production, especially in marginal environments inhabited by resource-poor subsistence farmers, the eternal target beneficiaries of agricultural R&D in Asia.

1. Introduction

1.1 Background

Over the next 20 years, Asian policy-makers will confront unprecedented growth in the demand for maize. Recent projections by the International Food Policy Research Institute (IFPRI) indicate that by 2020 the demand for maize in all developing countries will overtake the demand for wheat and rice, with Asia accounting for nearly 60% of the global demand for maize (IFPRI 2003). Throughout much of the region, rapid economic growth and accelerating urbanization are causing notable changes in food consumption patterns. The trend is most evident in Southeast and East Asia, where traditional rice diets are becoming increasingly diversified, leading to greater consumption of fruits and vegetables, as well as of bread, meat, poultry, and dairy products. Growing demand for the latter is expected, in turn, to generate an explosion in the demand for maize, which will rise from 295 million tons (Mt) in 1997 to 514 million tons in 2020. China alone is expected to experience a 94% increase in demand for maize over this period. According to the report on current trends and future projections of livestock supply and demand, developing countries are in the midst of a demand-driven "Livestock Revolution." Livestock production and consumption of both meat and milk products are expected to grow about four times faster in developing countries than in developed countries up to 2020. By 2020, developing countries will produce 60% of the world's meat products, and Asia, led by China, will account for the major share of the increase in meat demand in developing countries. In fact, China alone will account for 43% (51 million tons) of additional meat demand worldwide between 1997 and 2020 (Delgado et al. 1999).

In some Asian countries, rising export demand may also complement rising domestic demand for maize. In the last decade, maize exports have become more competitive following currency devaluations, particularly in Indonesia and Thailand, where this has placed an additional strain on domestic production capacity.

Projected increases in demand for maize in Asia will have significant implications for the sustainability of agriculture in Asia's rainfed upland environments where maize is largely grown, and for household food security, especially among the poorest of the poor. Future rapid growth in demand for maize, whether to meet domestic food and feed requirements or to satisfy export demand, is expected to lead to crop substitution, intensification of lands already planted to maize, commercialization of existing maize-based production systems, and expansion of maize cultivation into lands not currently farmed. These processes are most likely to be observed in agriculturally disadvantaged areas, including eastern India, the outer islands of Indonesia, the mid-hills of Nepal, the island of Mindanao in the Philippines, northern Thailand, and the Central and Northern Highlands of Vietnam. The response of these areas to future growth in demand for maize needs to be understood in terms of changes in farming systems, evolving land use patterns, and increasingly diversified income growth. The need for a holistic, system-wide understanding of the intensification process is especially important given that marginal upland regions in Asia are frequently home to poor rural communities, many of them ethnic minorities for whom maize is a primary food staple. The food security implications for poor households of the rise in maize demand need to be understood and addressed.

This project was designed to strengthen the capacity of research managers and policy makers to understand and respond to the intensification of maize-based farming systems in the rainfed uplands of seven Asian countries, by providing them with comprehensive, accurate data on the current state of upland maize farming systems, as well as information on the options available for promoting sustainable improvements in maize productivity growth. To date, these systems have received relatively little attention; research and development (R&D) efforts have understandably focused on the irrigated lowland zones where most surplus food is traditionally produced. As the capacity of these more favorable high-potential zones is exhausted, and as diets diversify out of cereals, the rainfed uplands will play an increasingly important role in feeding the region's rapidly growing populations. Given the fragility of many of these rainfed upland systems, it will be important that the intensification process be guided in a way that will not only be sustainable, but that will also improve the incomes and welfare of local populations while protecting the resource base upon which agriculture depends.

1.2 Objectives

The overall goal of this project is to promote the sustainable intensification of maize production systems in the Asian uplands[1] and enhance maize supplies while ensuring income growth and improved food security for poor households that subsist on maize. The study has four specific objectives:

- To develop in-depth knowledge of upland maize-based farming systems, identify constraints to future productivity growth, and anticipate potential environmental consequences likely to result from intensification;
- To conduct country-specific maize technology research, set up development plans for the uplands, and promote their implementation;
- To help IFAD and Asian governments identify priority development projects for the uplands, particularly projects that enhance food security while protecting the environment and reduce poverty by promoting sustainable improvements in maize production practices; and
- To examine and analyze within the context of overall food policies, country-specific macroeconomic and trade policies influencing the maize sector, with the goal of conveying information about key investment opportunities to achieve sustainable and equitable maize productivity growth in the uplands.

1.3 Key Activities, Methodologies, and Partners

Funded by the International Fund for Agricultural Development (IFAD) and managed by the International Maize and Wheat Improvement Center (CIMMYT), the project was implemented through a multi-country, multi-institution, multi-disciplinary collaborative effort involving China, India, Indonesia, Nepal, Philippines, Thailand, and Vietnam. Selected agriculturists and economists from these seven countries were actively involved in the project. Researchers from CIMMYT, IFPRI, and Stanford University provided conceptual and methodological support. Senior officials working in the National Agricultural Research and Extension Systems (NARES) and/or Ministries of Agriculture in these countries strongly supported the project.

Key activities fall into three main components: (1) detailed characterization of upland maize-based production systems and identification of constraints to maize productivity growth in Asia; (2) development of country-specific maize technology research plans and identification of related policy and investment opportunities; and (3) macro- and microeconomic analyses of each country's maize sector. Results of the third component have been included in a separate volume and will not be discussed at length in this publication.

Two other important activities are implicit to the project. First is strengthening of NARES capacity to conduct rapid rural assessment (RRA) and participatory rural appraisal (PRA) surveys and undertake prioritization and policy research, and instructing NARES researchers on the socioeconomic aspects of maize production. Second is the development and maintenance of a powerful database that incorporates farm-level quantitative and qualitative information plus secondary data from nearly 300 locations across the seven participating countries.

1.3.1 Detailed characterization of upland maize-based production systems and identification of constraints

A detailed characterization of upland maize-based production systems across Asia was conducted through a two-stage survey: first, a RRA survey with key village informants and farmer-group respondents; and second, a PRA component, again, with farmer-group respondents. The RRA asked more of the production input-output questions typical of agricultural economic surveys, while the PRA was a semi-structured open discussion, gathering more qualitative than quantitative information. RRA was used as a quick, effective, and low-cost method of collecting data at the village or community level

[1] While generally taken as "high lands, ground elevated above the meadows," "uplands" in this project refers to land that is generally dry. Also, marginal lands usually suffer from insufficient rainfall; some lands are considered marginal for other reasons, e.g. excessive slope or high soil acidity, but lack of water is by far the main cause. A rainfed environment is marginal when the water-limited potential yield of a crop falls to less than 40% of its potential yield (CIMMYT 1989).

about local farming systems, production technologies, constraints to technology adoption and use, product utilization, etc. It was conducted systematically, with multidisciplinary teams interviewing respondent groups in an active, open-ended yet guided question-and-answer forum. Survey respondents included different sub-groups within the community, for example, large farmers, small farmers, landless laborers, and female-headed households.

The PRA discussions elicited information needed for evaluating the potential for and constraints to intensification of maize production systems, anticipating likely consequences of intensification (e.g., declining soil fertility, soil erosion), and identifying technological, institutional, and infrastructural constraints to the sustainable enhancement of maize productivity growth. These discussions also gave a glimpse of farmer-experienced environmental pressures brought about by intensified maize production in major upland environments across Asia.

Many of the upland maize-growing environments are home to large numbers of low-income farmers. Thus, Asian policy makers will have to confront how intensification of maize-based production systems is likely to affect the poor in these environments, particularly with regard to food security. Information regarding maize utilization patterns (food and feed) was also collected, with an eye to identifying food security risks faced by vulnerable groups within the community. To elicit the perspective of farmers from different economic backgrounds and gender, the interviews/surveys were conducted using four groups of farmer-respondents: a mixed social group—one male group and one female group—and a poor-farmer group—one male group and one female group. Information collected using RRA/PRA methods was supplemented by information collected through a detailed review of available published and unpublished literature.

Between November 2000 and February 2002, a total of 265 locations (villages) in primarily marginal upland regions across seven countries were visited, and detailed maize production and resource use information was collected using RRA/PRA techniques. Annex 1 lists the specific study sites in each country. The dataset generated from these field surveys is the first extensive and comprehensive dataset documenting the wide range of maize-based production systems across Asia.

1.3.2 Country-specific constraint prioritization and maize R&D plans

The detailed country-specific maize R&D plans developed emphasize the sustainable intensification of maize production in the uplands, with the objective of alleviating the constraints identified through the RRA/PRA surveys. Country-specific R&D planning mainly involved organizing a national maize research priority-setting workshop, with the participation of senior maize researchers, national maize program directors, and other stakeholders from both the public and private sectors. The workshop allowed the country project teams to present findings from the RRA/PRA surveys; to inventory current and potential technologies for alleviating the identified constraints; as well as to help identify technologies currently not available in a country but that may be brought in from abroad. The workshop ranked the proposed solutions based on their potential for alleviating the identified constraints, and identified policies needed for the rapid promotion and adoption of the proposed solutions.

1.3.3 Maize sector policy analysis and identification of key policy and investment options

Conducted in collaboration with IFPRI and Stanford University, the policy study component used an open economy framework, examining country- and maize sector-specific macroeconomic and trade policies within the context of overall food policies, and the changing global trade environment. For example, given increasing globalization and trade liberalization, it examined the equity implications of opening the country's maize sector and the potential effect of macroeconomic policies (e.g., trade, interest rate, labor policies) on maize supply and prices.

This component identified and prioritized key infrastructure investment opportunities for selected upland locations in Asia. In the context of declining public sector investment, the need and potential for investments in micro-irrigation, transport, storage, and community level seed production systems and for investments in adaptive research and extension efforts, including the potential role of NGOs, were studied. This information will be useful not only for national policy makers, but also for IFAD regional staff and portfolio managers.

1.4 Organization of this Book

This book provides comprehensive and updated documentation on upland maize-based production systems across Asia, and synthesizes characterization and maize R&D prioritization reports from seven countries. (Six country reports containing more detailed country-specific information have been published as separate volumes.) The book's general framework for analysis and discussion is based on a matrix of maize production environments and market orientation, delineating the predominantly commercial and subsistence maize production systems, constraints, and research and development priorities.

Chapter 2 summarizes findings from the country-level maize sector policy studies, beginning with a brief description of the macro-level trends of maize utilization, production, and trade, to provide a perspective of the crop's economic importance in the region. Chapter 3 gives a description of the range of maize production environments in Asia, discussing their respective biophysical, institutional, infrastructure, and socioeconomic characteristics. Chapter 4 discusses the farm-level environment of maize production, from cropping calendar and varieties grown to crop management practices to harvest and post-harvest practices. Chapter 5 synthesizes farmer-identified maize production constraints elicited during the RRA/PRA surveys. These include biotic, abiotic, institutional, and input supply constraints, as well as other socioeconomic and policy-related factors. Chapter 6 discusses the priority constraints systematically elicited at the regional level, and relates these to specific maize production environments and to relevant technology development and dissemination options. All these sections are brought together in a summary and conclusions chapter (Chapter 7), which highlights maize R&D recommendations for widely varying maize production areas, with special emphasis on Asia's marginal uplands.

2. Maize Sector Policies in Asia

This chapter summarizes the findings of country-specific maize sector policy studies (published under one cover; see Gulati and Dixon 2007 for details), and attempts to relate farmer situations, particularly maize production constraints, to various agricultural and trade policies. Each country's maize sector policy report provides an overview of recent trends in maize demand, supply, and trade; analyzes government maize policies; measures incentives for maize producers using nominal protection coefficients (NPCs); and concludes with impacts of trade liberalization on the prevalence of poverty.

2.1 Brief Overview of Maize Economy Trends

2.1.1 Shifts in demand

The impact of Asia's population growth in the past 20 years on food demand has been compounded by income growth and urbanization, which together have shifted consumer preferences towards higher-priced calories and animal products. Statistics show that Asia's per capita consumption of staple grains (such as maize) has declined, while per capita consumption of livestock, fish, and other animal products has increased. Total meat consumption alone in the seven project countries rose by 280% between 1980 and 2000. This in turn rapidly increased domestic meat production, particularly of pork and poultry, whose production grew much faster than the global average. Between 1961 and 2001, Asia's pork production grew nearly 8% annually (compared to 3.3% for the world), and its share in total world production grew from 10% in 1961 to 52% in 2001. In the same period, poultry production increased 7% annually (compared to 5% for the world), and its share in world production doubled from 12% to 24%.

As a consequence, demand for maize as feed grain quadrupled from 39 Mt in 1980 to 93.5 Mt in 2000, at an average growth rate of 6.9% per annum (see Figure 2.1). In Asia as a whole, 62% (up from 47% in 1980) of total maize supply is currently used to feed livestock, about 22% is used as food, and the rest goes to other uses (industrial input, seed). Not surprisingly given its enormous size, China uses more maize than any other Asian country, mainly to feed livestock. During 2000-02 in Asia, feed use of maize was highest in Thailand, where livestock producers used nearly 89% of all maize (Table 2.1).

The use of maize as an industrial input to produce food and non-food products has also increased, although less dramatically. Food use of maize (including industrially processed food maize) rose from 23.0 Mt per year during the 1960s to 39.6 Mt per year during

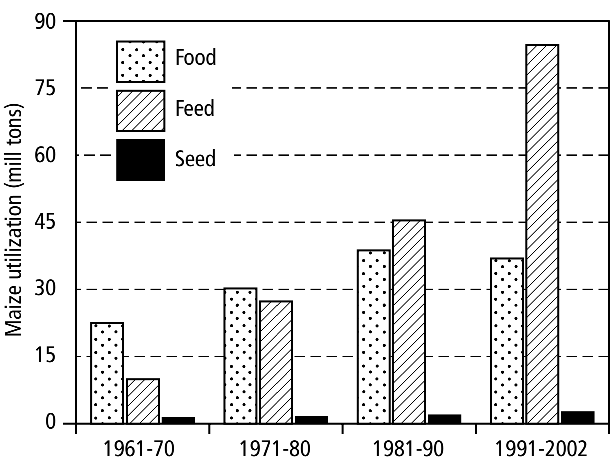


Figure 2.1. Mean utilization of maize as food, feed, and seed, Asia, 1961-2002.
Source: FAOSTAT Database, Utilization Domain, accessed March 2005.

Table 2.1. Maize utilization, Asia, 2000-2002.

	Utilization (Mt)	Human per capita consumption (kg)	Proportion of total supply used for		
			Food	Feed	Other
China	116.6	14.9	16.5	67.7	15.8
India	12.1	4.2	34.2	43.3	22.5
Indonesia	10.7	35.4	68.7	5.2	26.1
Nepal	1.5	42.1	68.4	17.7	13.9
Philippines	4.8	5.2	8.5	79.7	11.8
Thailand	4.3	6.2	9.1	88.8	2.1
Vietnam	2.4	8.2	25.7	66.0	8.3
Asia	152.2	12.1	22.0	61.6	16.4

Source: FAOSTAT Database, Utilization Domain, accessed March 2005.

the 1980s and to 39.8 Mt per year during the 1990s and 2000s (see Figure 2.1); it was highest in Indonesia, where people consumed 68.7% of the maize supply (Table 2.1). More specifically, however, per capita food use of maize in the region declined from 18.5 kg/head in 1980 to 13 kg/head in 2000. The decline in per capita food maize consumption in China, Nepal, and the Philippines outweighed the slight increases registered in India, Indonesia, Thailand, and Vietnam. Although it remains important as a food grain for many rural poor, maize has shifted away from its traditional role as a staple food towards being a commercially traded ingredient in livestock and poultry feed.

From the 1960s to the 1990s and 2000s, the food use of maize grew at 1.6% per year, well below the 7% average annual growth in feed use. Seed use meanwhile doubled from 1.3 Mt during the 1960s to 2.6 Mt during the 1990s and 2000s (Figure 2.1), but its proportion of the total annual maize supply declined from 3.5% to 1.8% between the two periods.

2.1.2 Production response

Worldwide, maize ranks first in terms of production among cereals, just ahead of wheat and significantly ahead of paddy rice. In developing economies, maize ranks first in Latin America and Africa, but third in Asia, after rice and wheat (FAO 2001). Globally, 612 Mt of maize were harvested annually from 2000 to 2003 from about 140 million ha (M ha).[2] During the same period, nearly 160 Mt of maize grain (26% of world production) were harvested in Asian countries from about 43 M ha (about 31% of global maize area). This level of global production represented a 23% increase from 1990-93, when about 497 Mt of maize were produced annually from 133.5 M ha. However, Asia's contribution to worldwide maize production markedly decreased between the two periods (from about 28% to 26%) even though there was a slight increase in its contribution to worldwide harvested maize area (from 29.5% to 31%).

Across Asia, domestic maize production responded to the rapid growth in domestic feed maize demand, mostly through yield improvement rather than area expansion (see Figure 2.2 and Tables 2.2 and 2.3). The area planted to maize increased from 27 M ha during the 1960s to 39 M ha in 1991-2004 (1% average annual growth). During the same period, average maize yields grew at 3.1% per annum from 1.4 t/ha to 3.8 t/ha. Due to the combined effects of area expansion and yield gains, maize production almost quadrupled from 37 Mt in the 1960s to around 145 Mt in 1991-2004 (4.2% average annual growth).

[2] Source: FAOSTAT Database, Production Domain, accessed March 2005.

In 2000-2003, China led Asia in maize production. Chinese farmers produced nearly 118 Mt of maize on 24.3 M ha, achieving average yields of 4.8 t/ha (Table 2.4). India was second after China in maize area harvested and production, followed by Indonesia. Nepal was the smallest maize producer, with Nepalese farmers producing 1.5 Mt of maize on about 825,700 ha and achieving average yields of 1.8 t/ha. Except in China, maize yields in Asia are still significantly lower than the 4.4 t/ha world average. Maize yields are especially low in India, Nepal, and the Philippines at 1.9, 1.8, and 1.8 t/ha, respectively (Table 2.4).

2.1.3 Trends in trade

During 1961-2003, maize exports across the seven Asian countries grew 5.3% per annum, while imports grew faster, 6.6% per annum. Trade moved from net imports of 13.2 Mt in 1995 to net exports of 10.5 Mt in 2003. Across all of Asia, however, maize trade consisted of net imports, growing from an average of 3.7 Mt in the 1960s to 31.8 Mt in the 1990s and 2000s. Furthermore, Asia is projected to be a net importer of at least 60 Mt of maize grain by 2025—an enormous 330% increase from the 1997 net import level (IFPRI 2003).

Table 2.2. Average maize area, yield, and production, Asia.

	Area (M ha)	Yield (t/ha)	Production (Mt)
1961 – 1970	27.0	1.4	37.1
1971 – 1980	31.9	2.0	62.8
1981 – 1990	34.3	2.8	95.4
1991 – 2004	38.7	3.8	145.5
1961 – 2004	33.5	2.7	90.7

Source: FAOSTAT Database, Production Domain, accessed March 2005.
Note: Provisional 2004 data.

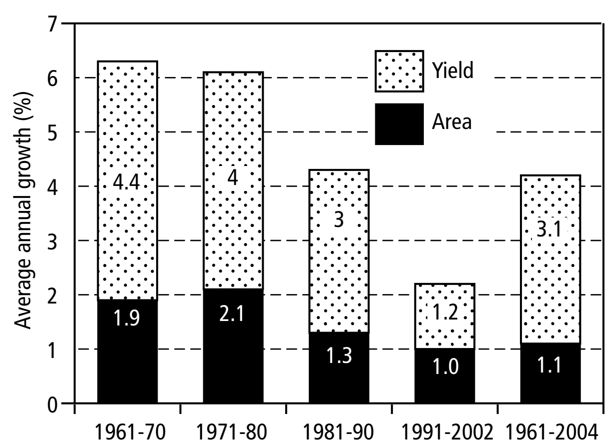


Figure 2.2. Area and yield contribution to maize production growth in Asia, 1961-2004.
Source: FAOSTAT Database, Production Domain, accessed March 2005.

China went from being a major net importer in 1980 (importing 4.6 Mt) to a major net exporter in 2000-03 (exporting 4.8 Mt) and has overtaken Argentina to become the world's second largest maize exporter. Similarly, India moved from being a net importer in the 1990s to being a net exporter in the 2000s. Supported by improved production technologies and favorable agricultural policies (market reforms), the growth in maize production in these two countries exceeded that of domestic utilization and allowed the change in trade status. Thailand was the world's fourth largest maize exporter, exporting 2 Mt annually in the 1990s, but these exports have gradually declined as domestic maize demand has grown. Problems of aflatoxin contamination also hurt Thai maize exports in the mid-1990s (Ekasingh et al. 2004). Indonesia, the Philippines, and Vietnam moved from being more or less self-sufficient to being net importers, as domestic feed maize demand grew. In Nepal, maize trade is not particularly important because self-sufficiency objectives dominate.

Table 2.3. Growth (%) in maize area, yield, and production, Asia, 1961-2004.

	Area harvested	Yield	Production
China	1.3	3.4	4.6
India	0.7	1.8	2.4
Indonesia	0.6	3.2	3.8
Nepal	2.0	(0.2)	1.8
Philippines	0.6	2.6	3.2
Thailand	2.5	1.5	4.0
Vietnam	3.1	2.5	5.6
Asia	1.1	3.1	4.2

Source: FAOSTAT Database, Production Domain, accessed March 2005.
Note: Provisional 2004 data.

Table 2.4. Maize production and net imports, Asia, 2000-2003.

	Area harvested (M ha)	Yield (t/ha)	Production (Mt)	Net trade (000 t)
China	24.3	4.8	117.9	4,844.0
India	6.7	1.9	13.0	147.7
Indonesia	3.3	3.1	10.2	(926.3)
Nepal	0.8	1.8	1.5	(4.6)
Philippines	2.5	1.8	4.6	(249.3)
Thailand	1.2	3.7	4.3	118.7
Vietnam	0.8	2.9	2.4	(165.0)
Asia	39.7	3.9	154.0	4,781.6

Source: FAOSTAT Database, Production Domain, accessed March 2005.
Note: Some columns do not add up due to rounding.

2.2 Maize Policy Development

Following the situation in the United States, European Union, and Mexico,[3] many Asian developing countries have attempted to protect their domestic maize production. This section briefly describes the policy environment under which maize is produced and marketed in Asia, particularly policies on production (output and input), international trade, food, and general macroeconomy.

2.2.1 Production policies

Output policies. Self-sufficiency has in general been the guiding principle for agricultural policy in Asia. However, except in Thailand, maize has been relatively neglected by policy, compared to rice and wheat. This is partly explained by maize's reputation as a poor man's crop (production- and consumption-wise), reflecting an urban bias in policymaking. Only the rise in maize's importance as feed pushed the livestock sector as a major force in maize policy considerations.

Government procurement of crops at a floor price is the most common method of supporting farmers. Except in Thailand (and Indonesia during the 1980s), maize support prices have not played a significant role in Asian maize policy. Floor prices in China and India, the largest producers in the group, were commonly far below actual market prices, and so did not affect producer decisions. China seems to be reversing its trend of non-support for maize farmers in recent years by raising quota procurement prices, although at the expense of halting market reforms (Huang and Rozelle 2005). Support prices in Nepal, the Philippines, and Vietnam have been negligible or nonexistent. Indonesia had a floor and ceiling price program for maize from 1978 until the early 1990s. Thailand employs a limited price support program for maize farmers, but procurement programs for maize have been generally dysfunctional in these countries.

Government support for R&D is an alternative pathway to supporting domestic maize production (see Chapter 2, Gerpacio 2001). Various research, development, and extension programs for maize exist in all the seven countries, with the primary goal of generally promoting the adoption of high-yielding (often hybrid) maize varieties, along with increased fertilizer use. Maize production inputs increasingly involve the private sector, and remain important vehicles for providing support to maize farmers.

[3] In these countries, maize production has historically been heavily subsidized, resulting in domestic prices being twice as high as world prices. If all such market distortions were removed, the world maize price would likely rise, with subsidized countries cutting back output more than others would be able to expand theirs.

Input policies. Fertilizer and seed represent the largest input costs in maize production, and were the focus of most input subsidy programs across Asia in the 1980s to late 1990s (Table 2.5). However, they led to: (1) domestic fertilizer and seed prices being much higher than world market prices; (2) inefficiencies in domestic markets; (3) illegal trading (particularly in Indonesia); and (4) a substantial financial burden in national budgets, especially during the 1997 Asian economic crisis.

Since then, however, input markets in the seven countries have generally been liberalized. A smooth transition to a market-based system saw fertilizer prices gradually decline. Numerous private companies have entered the seed market, and pricing policies have been altered, resulting in the gradual increase of the seed-to-grain price ratio. Particularly in Thailand, input subsidies have continued, but with increased participation of farmer organizations (Ekasingh and Thong-ngam 2005). In Nepal, the government gradually eliminated fertilizer and price subsidies in the late 1990s, but continues to provide transport subsidies for fertilizer and seed sales in areas inaccessible by roads. In 1998, Indonesia abolished fertilizer subsidies immediately following the Asian financial crisis, doubling fertilizer prices. Rice farmers were compensated for the large production cost increase, but maize farmers received no such benefit.

2.2.2 International trade policies

Unlike developed countries, developing countries do not have the fiscal resources to support producers through domestic measures, and most protection occurs at the border. Across the seven countries under study, most maize trade is government arranged, and barriers have historically remained high. However, there has been a general trend towards reducing maize trade barriers under the Uruguay Round Agreements Act (URAA).[4] India, China, Thailand, and the Philippines implemented tariff-rate quotas (TRQs)[5] for maize under World Trade Organization (WTO) commitments. Nepal and Indonesia have tariff-only policies (Table 2.6). Recently, however, depressed international grain prices prompted several governments to reverse the trend towards grain trade liberalization.

Table 2.6. Tariff policies for maize, Asia.

	TRQ (000 tons)	In-quota rate (%)	Over-quota rate (%)	Implementation period
China	7, 200	1	65	2004
India	500	15	60	1999-2003
Indonesia	--	5	--	1998
Nepal	--	10[1]	--	--
Philippines	217	35	50	1995-2000
Thailand	55	20	76-80	1995-2004
Vietnam	n.a.	n.a.	n.a.	n.a.

Source: IFAD-CIMMYT Asia maize sector country studies, WTO as cited in Wada et al. (2005).
[1] Exemption of tariff granted to products from India and Tibet.
n.a. – not available.

[4] The URAA implements the Uruguay Round of the General Agreement on Tariffs and Trade (GATT), which includes an agreement on Trade Related Aspects of Intellectual Property (TRIPS).

[5] A tariff-rate quota is a quota for a volume of imports at a lower tariff. After the quota is reached, a higher tariff (over-quota tariff) is applied on additional imports. In principle, a TRQ provides more market access to imports than a quota. In practice, however, many over-quota tariffs are prohibitively high and effectively exclude imports in excess of the quota (Skully 2001).

Table 2.5. Summary of agricultural input policies, Asia.

Country	Agricultural input policies	Reference
China	Fertilizer production and distribution government controlled. Dual marketing system with in-quota and out-of-quota prices. Fertilizer subsidy at 52-77%. Seed subsidies.	Huang and Rozelle 2005
India	Fertilizer, power, and irrigation subsidies. Restricted seed imports.	Gulati and Narayanan 2005
Indonesia	Subsidized fertilizers for food crops.	Suhariyanto 2005
Nepal	Fertilizer, seed, and fertilizer/seed transport subsidies.	Paudyal 2005
Philippines	Subsidized fertilizers and seed (mostly yellow hybrid maize seed). Import restrictions on both these inputs.	Costales 2005
Thailand	Subsidized production of both hybrid maize seed and inorganic fertilizers. Subsidized 90% of hybrid maize seed cost to farmers during 1994-98.	Ekasingh and Thong-ngam 2005
Vietnam	Subsidized hybrid maize seeds produced by government agencies. Subsidized credit for fertilizer imports.	Khiem et al 2005

A highly restrictive policy regime insulated India's economy from global markets. The Indian government heavily regulated food grains and related products, banned maize exports in the 1960s and 1970s, and in the 1980s allowed maize imports only through the Food Corporation of India. Later, when the demand for poultry feed began to grow, the feed industry was allowed to import maize without license, and maize exports were allowed under a ceiling. In 1999, a TRQ for maize of 15% in-quota and 60% out-of-quota was set (Table 2.6). Trade liberalization remains slow, however, and any move toward liberalizing external trade policy is usually accompanied by measures designed to counter the effects of such a move.

In China, food self-sufficiency goals led policymakers to restrain imports of land-intensive grains. Nearly 20 years of policy reforms gradually changed China's foreign trade regime from a highly centralized, planned, and import substitution-oriented regime to a more decentralized, market-oriented, and export-promoting one. Trade and other policy reforms significantly altered China's trade composition in favor of products for which China has a comparative advantage. China's maize trade liberalization, however, was fairly minimal prior to WTO accession (Huang and Rozelle 2005). Maize imports were limited to those who had licenses and import quotas, and the current maize trading system results in considerable distortions and inefficiency.

China's WTO accession commitments include decreasing overall agricultural import tariffs from about 21% in 2001 to 17% by 2004; a maize in-quota tariff of only 1%, and decreasing the maize out-of-quota tariff to 65%; increasing maize TRQ volumes from 5.7 Mt in 2002 to 7.2 Mt in 2004; and phasing out all maize export subsidies (on average, 34% of the export price) (Huang and Rozelle 2005). After the removal of maize export subsidies, maize prices initially fell by 20%, but exports continued during China's first year as a WTO member.

Thailand's self-sufficiency objective restricted maize exports during 1961-81, but increasing domestic feed maize demand led to re-instituting export quotas from 1992 to date. Following the 1995 WTO minimum access requirements, Thailand implemented TRQs for maize, which actually represented a step backward from liberalization in the early 1990s. The tariff rate is now 20% and 76-80% for in-quota and over-quota maize, respectively (Table 2.6); in-quota rates can be announced on a year-by-year basis.

After opening up its economy considerably since the late 1980s, when it was nearly closed, Vietnam's state agencies still control imports and exports, and tariffs on maize are high. Prior to 2000, quantitative restrictions and licensing requirements controlled maize imports. Under the ASEAN Free Trade Agreement (AFTA), however, Vietnam has committed to reducing tariffs to 20% by 2003 and 5% by 2006. Indonesia too is reducing its tariffs on a number of agricultural products, including maize, to a maximum of 5% under an agreement with the IMF. The WTO agreements on maize in the Philippines meanwhile require that out-of-quota tariffs be reduced to 50% by 2004. The in-quota tariffs are, however, still relatively high at 35%. In Nepal, maize trade is relatively unimportant; hence there are no qualitative restrictions on agricultural trade, and no customs duty is applied to imports from India, Nepal's dominant trading partner (Paudyal 2005).

2.2.3 Macroeconomic policies on exchange rate

Exchange rate policies. Macroeconomic policies can significantly influence overall incentives to agricultural producers. In fact, agriculture may be more sensitive than other sectors to macroeconomic policies (Bautista and Valdes 1993). One of the most important factors influencing maize incentives is the nation's exchange rate policy (Beghin and Fang 2002). Overvalued exchange rates depress incentives to domestic producers of tradable goods, and increase incentives for imports. The real depreciation of domestic currency raises the local currency prices of tradable relative to non-tradable goods, and thus contributes to the price-competitiveness of domestic exports.

The seven Asian governments fixed their exchange rates in the early 1980s, as did most developing countries. There was also a general bias against agriculture, with overvalued exchange rates and higher import controls on industrial products. Since then, there has been a general movement toward floating exchange rates, although applied rates in these countries are, to some degree, still overvalued.

China highly regulated its foreign exchange market through the mid-1990s, and maintained a two-tiered foreign exchange rate system before 1994. While policy determined the official exchange rate, trading at a swap center determined the other rate. In 1994, liberalization united the two exchange rates to create a single managed exchange rate system, resulting in an official devaluation of the yuan of over 50%. This rate has stayed remarkably constant since then, although it has depreciated slightly in recent years. It is widely believed, however, that the domestic currency has gradually become overvalued since 1994, and as such has provided a disincentive to the tradable agricultural sector.

In India, the real exchange rate declined by 53% between 1985 and 1991. A further devaluation in July 1991 accompanied substantial liberalization of the manufacturing sector, and may have significantly reduced the anti-agriculture bias in the country (Narayanan and Gulati 2005). Similar patterns of gradual devaluation were observed in the other Asian countries. The Philippine peso was overvalued prior to having a flexible exchange rate policy after the fall of the Marcos regime in 1986. The official value of the peso depreciated by 274% in 1985-2000, during which a market exchange rate system prevailed, with periodic Central Bank interventions in times of high fluctuation. Similarly, Vietnam's exchange rate policy since 1990 involved making frequent adjustments to the market rate. Nepal switched from a fixed exchange rate system to a floating system in 1983, resulting in substantial devaluation of the Nepali rupee during 1985-2001. Because India is Nepal's largest trading partner, Nepal maintained a special fixed exchange rate with the Indian rupee, and incentives to agricultural producers have remained fairly unaffected by the depreciation of the Nepali rupee relative to other foreign currencies (Paudyal 2005).

The Asian financial crisis. The 1997 Asian financial crisis was a major factor that led to substantial devaluation of most currencies in the region, hitting Thailand and Indonesia especially hard. Prior to the crisis, Thailand had a fixed exchange rate system, and the prevailing rate had been 25 baht/US$ from the late 1980s to 1997. In the 1990s, the overvalued exchange rate led to serious balance of payment deficit and capital outflows, which contributed to the economic crisis (Ekasingh and Thong-ngam 2005). In 2001-2002, Thailand adopted a managed floating exchange rate policy, which devaluated the baht to 40-45 baht/US$.

In Indonesia, the exchange rate was tightly managed and quite stable before the economic crisis. The Asian financial crisis threw the economy into complete disarray, and the value of Indonesian rupiah plummeted upon the adoption of a floating exchange rate in August 1997. Within a year, the rupiah's value fell by over 80%, the largest devaluation in Asia in that period. Prices of tradable commodities soared, resulting in economic hardship and social unrest. The exchange rate has since then fluctuated considerably.

The exchange rates in India and the Philippines were also significantly affected by the Asian financial crisis. During 1997-2001, official exchange rates in those countries depreciated by 30% and 116%, respectively. In contrast, official exchange rates in China, Vietnam, and Nepal were largely unaffected.

2.3 Impact of Policies on Maize Production

The net impact of government policies on maize production (as incentives to maize producers) can be measured by examining the difference between domestic prices and their corresponding international prices (the prices that farmers would have received under a counterfactual free-trade situation), after adjusting for transport and other costs. The *nominal protection coefficient* (NPC) is a straightforward measure of this divergence between domestic and international (or reference) prices, and defined for maize as follows:

$$NPC_{maize} = (P^{d}_{maize} - P^{w}_{maize}E) \,/\, P^{w}_{maize}E$$

where P^{d}_{maize} is the domestic price in local currency;

P^{w}_{maize} is the world reference price in US dollars; and

E is the exchange rate (local currency/US dollar).

If the NPC is larger than 1, the domestic price is greater than the world reference price, implying that maize is protected by domestic policies, and that liberalization would bring greater imports, pushing down the domestic price of maize. If the opposite is true, then maize is implicitly taxed or disprotected, and exports would likely increase with liberalization. An NPC of near 1 implies a neutral protection structure, and producers face domestic prices comparable to border prices.

Nominal protection coefficients are best examined under importable and exportable hypotheses, using official and shadow exchange rates. When domestically produced maize competes with imports (under the importable hypothesis), international transport costs provide a degree of protection for domestic maize producers. In contrast, if maize is an exportable item, the domestic producers' price must be low enough to make their maize competitive in foreign markets after including the cost of transportation to that market.

2.3.1 NPC analysis using official exchange rates

The importable hypothesis is probably most relevant for India, Indonesia, the Philippines, and Vietnam. The Philippines registered the highest NPCs for maize in Asia, ranging from 1.22 in 1988/89 to 1.69 in 1996/97, which implies that government policies have systematically and heavily protected domestic maize producers. In Indonesia NPCs have declined since the 1980s, punctuated by a major fluctuation during the Asian financial crisis (1.22 in 1985/86 to 0.56 in 1997/98). NPCs for maize are presently very near 1 (0.88 in 2000/01), indicating an overall lack of protection, or disprotection, to maize farmers in Indonesia. Government decisions to adopt a floating exchange rate policy, reduce import tariff rates, and abolish the fertilizer subsidy, combined with the decline of maize prices relative to other food crops, proved detrimental to maize farmers. Maize cultivation may hence shift to more marginal low-potential lands, as farmers reserve their productive lands for more profitable crops.

Around 1990, India's NPC for maize under the importable hypothesis dropped to 0.86. In a relatively short time span, maize went from being highly protected (1.47 in 1987/88) to being implicitly taxed. Maize has thus become an efficient import substitute since the end of the 1980s. India's domestic maize producers, however, are non-competitive with regard to exports; Indian maize cannot be exported at current levels of prices and technology. To emerge as an efficient maize exporter, India would need to augment yields, and reduce costs and prices. Higher priority to R&D, and improved seed production and distribution may be the key to achieving this. Nepal is in a similar situation: maize NPCs were below 1 during most of the 1990s under the importable hypothesis, but maize producers have been consistently non-competitive in the export market. Unless substantial investment in maize technology generation and dissemination is made to improve resource productivity, Nepalese maize cannot compete on the export market.

In Thailand, maize producers are competitive under the importable hypothesis, but have consistently been protected under the exportable hypothesis. The government has always set maize price supports and actual import tariff rates to bring domestic prices in line with market (and world) prices. In China, maize has been heavily taxed by procurement quotas, and NPCs for maize under both the importable and exportable hypotheses were much lower than 1 until 1997/98. With the provision of subsidies and the reduction of procurement quotas, China has begun to protect its maize farmers in recent years. Under the exportable hypothesis, only China approaches competitiveness.

Table 2.7 summarizes the NPCs for maize in Asia, calculated using official and shadow exchange rates under both the importable and exportable hypotheses.

2.3.2 NPC analysis using shadow exchange rates

Scenario analyses using social (shadow) exchange rates showed that NPCs for maize are significantly lower than those calculated using official exchange rates–45% lower, on average, in the importable hypothesis. The situation has gradually changed since the early 1990s, as exchange rate regimes have generally moved closer to market determination. Analyses also showed that the overvaluation of domestic currency creates the largest disincentive to domestic maize production in Asia.

In China, the net effect of all policies—including macroeconomic policies—has been heavy implicit taxation to the maize sector under both the importable and exportable hypotheses. Overvaluation of domestic currency in China caused much lower NPCs for maize (calculated under the shadow rate) until 1997, when the impact of overvaluation became fairly small. Exchange rate policy represented a heavy tax on maize producers until this time. With further liberalization of exchange rate policies, maize prices may be expected to increase in China.

Similarly, in India, overvaluation of the rupee resulted in moderately lower NPCs under the shadow exchange rate until the early 1990s. Since then, maize NPCs in India have been between 0.7 and 0.9 for both official and social exchange rates under the importable hypothesis.

Table 2.7. Summary of nominal protection coefficients (NPCs) for maize, Asia, 1997-2001.

	Using official exchange rates		Using shadow exchange rates	
	Importable hypothesis	Exportable hypothesis	Importable hypothesis	Exportable hypothesis
China	Undistorted	Subsidized	Heavily taxed	Taxed
India	Heavily taxed	Subsidized	Heavily taxed	Subsidized
Indonesia	Taxed	Subsidized	n.a.	n.a.
Nepal	Undistorted	Heavily subsidized	Undistorted	Heavily subsidized
Philippines	Heavily subsidized	Heavily subsidized	Heavily subsidized	Heavily subsidized
Thailand	Undistorted	Heavily subsidized	Undistorted	Heavily subsidized
Vietnam	Heavily subsidized	Heavily subsidized	n.a.	n.a.

Undistorted = NPCs between 0.95 and 1.05; Taxed = between 0.80 and 0.94; Heavily taxed = less than 0.80; Subsidized = between 1.06 and 1.20; Heavily subsidized = above 1.20.
n.a. – Data not available.

The Philippine peso, meanwhile, was overvalued before 1996/97, but has been undervalued since then, with significant impacts on production incentive indicators. When the social exchange rate is used, NPCs were on average 18% lower during earlier periods and 51% higher since 1996/97. It remains, however, that the Philippine maize sector has been heavily protected, and that maize prices may decrease if the official exchange rate approaches market equilibrium.

The impact of exchange rates on incentive indicators in Nepal and Thailand was relatively minor compared to the other project countries. The effect in Nepal was consistently small, averaging 4% higher with the social exchange rate during the study period owing to a slightly undervalued domestic currency. In Thailand, the major impact occurred mostly between 1991/92 and 1995/96.

2.3.3 What do they mean?

The policy study indicates that maize producers in the Philippines and Vietnam, of all the Asian countries examined, would be especially hurt by complete market liberalization. These countries, already moderate importers of maize, have protected their domestic producers substantially through a combination of strict import controls and input subsidies. With market liberalization, Filipino and Vietnamese maize producers would be largely unable to compete with cheap imports. Apart from supportive government policies, substantial investment in maize technology generation and dissemination to improve productivity and profitability will be needed to bring down domestic prices of Filipino and Vietnamese maize. In the Vietnamese uplands, where the maize area recently expanded, the challenge will be to improve the marketing system and infrastructure, and to disseminate and promote farmer adoption of sustainable maize-based production systems (Khiem et al. 2005). In the Philippines, substantial improvement of rural roads, particularly in predominantly white maize-producing regions, would simultaneously better farmers' access to markets and institutions, which would, in turn, enhance productivity and competitiveness (Costales 2005).

Indonesia is a maize importer with relatively few market distortions; India and Thailand import and export comparable quantities of maize, resulting in near zero net trade. Domestic maize production in these countries appear to be fairly competitive as an import substitute, but not as an export commodity. As such, it pays for maize production in India to concentrate on domestic markets, especially since demand from the food processing and feed industries is likely to increase dramatically. Given the current framework of self-sufficiency, if all maize demand is to be met through domestic production, then it has to come from yield increases rather than from maize area expansion. Yield increases would have to come from a wide range of improved production technologies as well as a whole gamut of government policies on agricultural production and marketing (Narayanan and Gulati 2005).

Similarly, in Thailand government policies and programs related to agricultural credit, research, and extension services need to be strengthened to be able to address the emerging problems of maize farmers. Government policies have tended to apply mostly to farmers with good access to resources, markets, and information. It is time for resource-poor maize farmers to benefit more from government policies. Meanwhile, Nepal's maize producers have had poor incentives and are competitive as producers of import substitutes (though not as exporters). Since Nepal does not engage in much cross-border trade, and India is nearly its only trading partner, domestic maize producers are unlikely to be affected much by market liberalization, unless the special exchange rate between the Nepalese rupee and the Indian rupee changes significantly.

Domestic producers in China, the world's second-largest maize exporter, would be quite competitive with imports, and nearly competitive in exports, assuming no change in the official exchange rate. The overvalued exchange rate, however, has served as an implicit tax on producers (along with government procurement policies), and devaluation of the yuan would significantly benefit the maize sector.

Given the uncertainties involved, it appears that while some maize producers in Asia may benefit from trade liberalization, numerous others will face stronger competition that may threaten their livelihoods. Food grain self-sufficiency policies have traditionally favored rice and wheat producers. To help alleviate the economic hardship of maize producers, this policy priority must change. Economic liberalization combined with exchange rate reforms, rural infrastructure improvements, better market access for maize producers, and increased investment in research, development, and extension programs would go a long way towards easing the transition of Asian maize producers to a globalized economy.

3. Maize Agro-ecosystems in Asia

3.1 Maize Production Environments

Maize (*Zea mays* L.) is a versatile crop that adapts easily to a wide range of production environments. Maize grows at latitudes ranging from the equator to slightly above 50º North and South, from sea level to over 3,000 meters above sea level (masl), under heavy rainfall and in semi-arid conditions, in temperate and tropical climates. The maize growing cycle can range from three months to more than a year (Dowswell et al. 1996). Maximum grain yields have been recorded in locations where temperatures reach 30-32ºC during the day and drop to 11-18ºC at night, but the crop can tolerate wide deviations from this ideal temperature range (Dayanand 1998).

There is no universally recognized system for classifying maize production environments. CIMMYT, which holds a global mandate for maize improvement in developing countries, has developed a classification system based on the concept of *mega-environments* (CIMMYT Maize Program 1988a, Hartkamp et al. 2000).[6] CIMMYT maize breeders commonly distinguish four major mega-environments: the lowland tropics (or tropical lowlands), tropical highlands, subtropics/mid-altitude zones, and temperate zones (Table 3.1). These classifications do not correspond precisely to geographic definitions of the tropics, subtropics, and temperate regions, but rather are based on agroclimatic criteria that include minimum and maximum mean temperatures during the growing season, elevation, and, to a lesser extent, latitude (Dowswell et al. 1996). Steps are being taken to refine this classification to also consider, among other factors, adaptability of CIMMYT germplasm and incidence of maize insect pests and diseases.

Across all developing countries and in Asia, maize is grown mainly in tropical lowland and temperate environments. However, while tropical lowland production environments are found in all the world's regions and in all Asian countries, temperate production environments are found mostly in East Asia (87%), particularly in northern China (Table 3.1; CIMMYT 1988b as cited in Dowswell et al. 1996; Vasal 1998). Within a given country, maize production may be concentrated within a single mega-environment

Table 3.1. Major maize mega-environments.

	Tropical lowlands	Tropical highlands	Subtropics/mid-altitude zones	Temperate zones
General characteristics				
Latitude	0-25º North and South	0-25º North and South	26º-36º North and South	> 36º North and South
Elevation (masl)	< 1,000	> 1,800	1,000 – 1,500	All elevations
Day length (hours)	11 – 12.5	11 – 12.5	12.5 – 13.4	> 13.4
Mean temperature (ºC)	> 24	< 18	18 – 24	
Description	Largely high humidity, rainfed systems. Includes some winter season regions at higher latitudes.	Equatorial highlands, typically over 2,000 masl.	Typically less than 1,800 masl. Usually rainfed but with large variation in rainfall.	Highest latitude regions where maize production is possible.
% of total maize area, all developing countries in Asia, late 1990s				
Including China	35.4	2.5	11.2	50.8
Excluding China	53.6	3.8	16.9	25.6

Source: Vasal (1998); CIMMYT (1989); Hartkamp et al. (2000).

[6] A mega-environment (ME) is a broad, not necessarily contiguous production area, occurring in more than one country and frequently trans-continental, delineated by certain ecological conditions (e.g., temperature, rainfall, soils), crop characteristics (e.g., maturity cycle, grain color, grain texture), biotic and abiotic constraints, and socio-economic factors (e.g., production systems, cropping patterns, consumer preferences). MEs are also defined as the largest subunits of a crop's growing or target environment within which a particular variety or related practice is useful. Hartkamp et al. (2000) present a GIS-based approach by CIMMYT to defining mega-environments for maize research.

(as in Indonesia, Philippines, and Thailand, where maize is grown mainly in tropical lowland zones), or it may be distributed across several different mega-environments (as in China, where maize is grown in lowland tropical, subtropical/mid-altitude, tropical highland, and temperate zones).

The definition of environments, however, is subjective. For example, "mid-altitude" and "subtropical" are sometimes used interchangeably where germplasm requirements are similar, so results are not easily reproducible, and the two types of mega-environments are not well differentiated (Hartkamp et al. 2000). A similar situation holds for the use of elevation: perceptions of "lowland," "mid-altitude," and "highland" can vary among maize researchers, especially across regions and where countries have established their own classifications. For example, India's "plains" mistakenly give the impression of belonging to a lowland tropical environment, but upon closer scrutiny are more accurately part of a subtropical/mid-altitude environment, whereas the "scarce rainfall zone" and "dry zone" of India do in fact fit into the lowland tropics classification. Unfortunately, updating the definitions of mega-environments has been sketchy for lack of resources to do a more complete, methodical revision.

This book concentrates on maize grown in tropical lowland and subtropical environments in Asia's developing countries, because these are the areas where most maize in the region is grown. It also includes subtropical/mid-altitude maize production areas in the region, as well as large temperate maize production areas in countries such as China. Annex 1 shows the country and mega-environment distribution of villages surveyed in Asia.

This book adapts the Asian paddy production environment classification, wherein tropical lowland environments can be subdivided into three more specific agroecological zones, namely irrigated lowlands, rainfed lowlands, and rainfed uplands (IRRI 1984). In irrigated lowlands crops (usually rice) are grown under irrigation in fields with well-maintained dikes that can hold 30 cm of water. Availability of irrigation water may be year-round or seasonal, and other non-rice crops, particularly high-value crops, may be grown under irrigation in rice-based patterns. In rainfed lowlands rainfed crops are grown on puddled soil in fields bounded by dikes that pond water to about 30 cm. Water depth seldom exceeds 30 cm. Depending on the amount and distribution of rainfall over the year, one or two puddled crops are grown. These areas receive little or no irrigation, and non-rice crops may be grown before or after the rainfed rice crop. Rainfed uplands depend on rainfall for crop production, but are not flooded. The runoff and infiltration of rainwater is so high that water does not accumulate on the land. Most of these are sloping lands or lands with higher elevation than the surrounding areas. Upland rice varieties are grown in fields prepared and seeded under dry conditions, and non-rice upland crops, such as maize, are important and grown in the wet and dry seasons.

At the country level, the districts and villages surveyed had both large maize areas and high volumes of maize produced (i.e., they had a significant share of the district's total maize area and production); also surveyed were districts and villages representing different maize production environments and maize-based production systems. Special attention was given to proper representation of marginal, less favorable maize production environments. Surveyed villages also provided variation in household utilization of maize. For the purpose of the analysis, surveyed villages were classified as low market surplus (or subsistence), semi-commercial, and commercial, based on percentages of household utilization of maize as food, feed, and source of income through sales.[7] Annex 1 shows the salient characteristics of the surveyed villages, and Annex 2 classifies the specific survey sites within the matrix of maize production environments and market orientation on which subsequent discussions in this book are based. The following sections describe and discuss the findings and observations from the RRA/PRA surveys.

3.2 Biophysical Environment

Annex 3 describes the agro-climatic features of the maize growing areas surveyed and demonstrates the versatility of maize, i.e., its ability to flourish in just about any environment. Maize can grow on the flat lands and plains of Indonesia and Vietnam, as well as in the hills and steep slopes (up to 2,500 masl) in Nepal, the Philippines, and Thailand. In India, maize is grown in a wide range of environments, from extreme semi-arid to sub-humid and humid regions, as well as in the low and mid-hills of the western and northeastern regions. Even excluding temperate growing environments, maize growing environments in China vary considerably in terms of rainfall, temperature, and topography over the tropical lowland and subtropical/mid-altitude regions.

7 Low market surplus (or subsistence) villages were defined as those where the majority of households retained 70% or more of maize output for household food and/or feed purposes; semi-commercial villages were defined as those where most households retained between 26% and 69% for household food/feed use; and commercial villages were defined as those where most households retained 0 to 25% for household food/feed use.

3.2.1 Rainfall

In most tropical environments, maize requires 600-700 mm of moisture well distributed over the growing season. Annual rainfall in all study sites (with the exception of some areas of Karnataka and Andhra Pradesh, India) appears to be sufficient for maize production and can support two or three crops per year, but seasonal distribution regulates planting. Maize farmers who are partially or totally dependent on rainfall adjust the cropping calendar to coincide with months when precipitation will be sufficient to supply crop water requirements. Supplementary water sources, such as wells, natural streams, reservoirs, and deep wells, can also be found. Supplementary water, however, is not usually used for irrigating field crops but rather for limited vegetable and cash crop production. As an example, Figures 3.1 and 3.2, respectively, show how Filipino and Indonesian farmers in low market surplus and commercial maize-growing areas time their crop according to long-term rainfall distribution. Rainfall distribution across growing seasons by mega-environment in China is presented in Figure 3.3.

In the tropical rainfed lowland/rainfed upland areas of Nusa Tenggara Barat, Indonesia, Mindoro Occidental, Philippines, and Phichit and Chiang Rai, Thailand, rice is grown during the wet season, followed by a maize planting supported by residual soil moisture and supplementary irrigation, if sowing is timed properly. In these areas, maize is sown in October/November and harvested in March. In tropical lowland environments of China, two (spring and fall) or three (spring, fall, and winter) maize crops are possible, although in many areas drought and competing crops have limited maize production to spring. Spring and summer maize

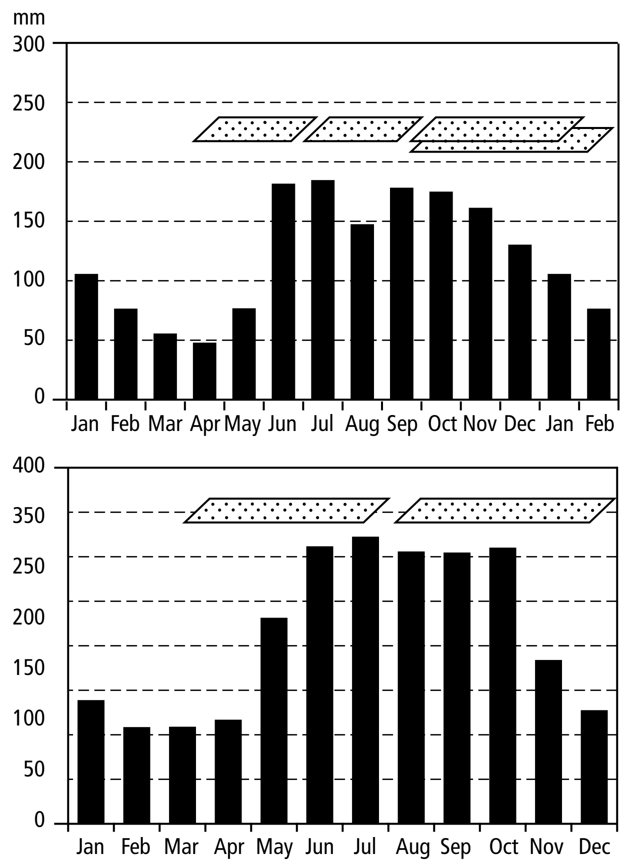


Figure 3.1. Long-term rainfall distribution and maize cropping season in Cebu, Eastern Visayas (low market surplus production, top), and Bukidnon, Northern Mindanao (commercial production, bottom), Philippines.
Rainfall data: Cebu, Eastern Visayas – 1971-2000; Bukidnon, Northern Mindanao – 1961-2000.
Source of rainfall data: PAGASA.

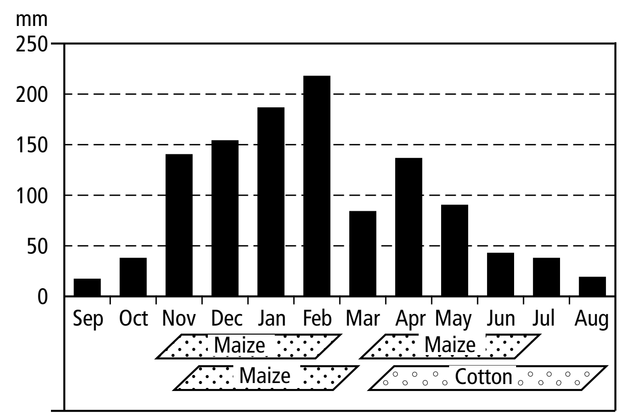


Figure 3.2. Monthly rainfall and maize-based cropping patterns in the drylands of Jeneponto, South Sulawesi, Indonesia.
Source: Swastika et al. (2004).

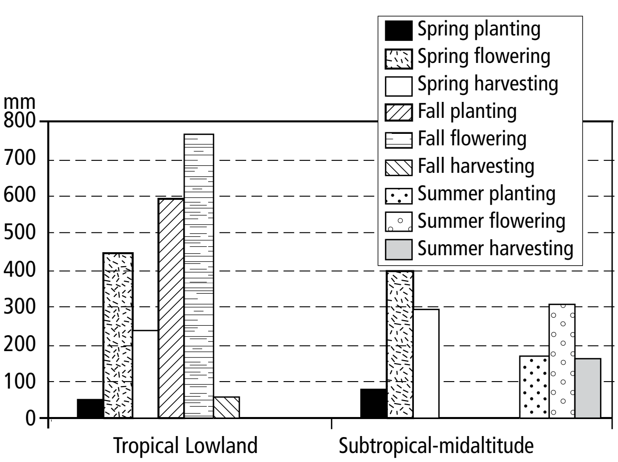


Figure 3.3. Seasonal rainfall distribution in China by mega-environment.
Source: IFAD-CIMMYT-CCAP RRA/PRA surveys, 2001-2002.

crops are possible in some subtropical/mid-altitude growing environments. Meanwhile, annual rainfall in the subtropical/mid-altitude mid- and high-hill environments of Nepal allows only one crop of maize, often sown in late March/early April and harvested in September/October.

Maize can be affected by dry periods at critical growth stages in years when the dry season comes earlier than expected. Karnataka, India, has the lowest annual average rainfall (about 600 mm) among the study sites, and maize is grown only once a year, from May to September. South Cotabato in Mindanao, Philippines, has one of the lowest levels of annual average rainfall reported (916 mm), yet three maize crops are planted. Rainfall in this province/region is lowest during the planting of the first maize crop and highest during the third maize cropping. It helps that tropical storms are a low risk factor in this southern island of the Philippines.

3.2.2 Temperature

A high mean temperature (around 28°C) during the growing season generally characterizes tropical maize growing environments, with a high mean minimum temperature (around 22°C) and a high mean maximum temperature (around 32°C). Across the study sites, the range of air temperatures was widest in India and relatively limited in Indonesia, Philippines, and Thailand. In India, air temperatures can range from 7-36°C (in Bihar and Madhya Pradesh) to 2-46°C (in Rajasthan). Air temperature averaged 24-28°C in the maize growing areas of the Philippines, and 25-27°C in Thailand, with March/April as the hottest months and December/January as the coolest months. Temperatures in China averaged 24.6 °C during the spring maize growing season and 26 °C during the fall growing season. In general, temperature variation during the maize cropping season does not critically affect the maize crop as much as rainfall variation.

3.2.3 Types of soil

Across the survey areas, secondary data describing soil characteristics were in general limited. Parent or origin materials of soil were shown in soil maps, but data on the current status of soil fertility, degradation, or management requirements in research sites were limited. Primary soil data were derived almost entirely from farmer interviews during the RRA/PRA surveys.

In each country, farmer-respondents were asked to describe the soil types in their farms and to assess the advantages and disadvantages of each type based on fertility level, drainage characteristics, susceptibility to erosion, and suitability for crop production or other agricultural uses. The most common soil types in the survey sites are clay, clay loam, and sandy loam soils, consistently described by farmers as the most fertile soils, generally suited to most crops (Annex 4).

Farmer assessments of soils included the following observations:

- Clay soils have good water-holding capacity and soil fertility, but can be wet/muddy and difficult to plow during the wet season;
- Clay loam soils retain water better and are suitable especially for growing cereals, but drain poorly and are prone to soil erosion;
- Sandy loams do not become waterlogged but are more susceptible to drought and have poor soil fertility; and
- Sandy clay loams are good for crop production and pasture, but susceptible to soil erosion.

3.3 Institutional Environment

3.3.1 Line agencies

Across the region, government extension offices, mainly Departments (Ministries) of Agriculture (DA) and Departments of Agricultural Extension (DAE), and private seed companies play a vital role in disseminating technology information to farmers in maize producing villages. Department of Agriculture technicians are responsible for conducting as regularly as possible farmers' field schools and training sessions to provide farmers with updated maize cropping technology. Seed and fertilizer company field technicians also provide information to maize farmers, although generally limited to the products being marketed by the company. Non-government organizations (NGOs), nearby agricultural state universities and colleges (SUCs), neighbors, and other farmers within the community share knowledge and are seen as valuable sources of information. Television and radio programs also provide technology information to farmers in China. In some countries (e.g., the Philippines and Vietnam), however, little or no extension services are provided by SUCs, and NGOs and international agricultural research centers (IARCs) have not yet reached many of the surveyed areas.

3.3.2 Farmer cooperatives and user groups

Farmers in many parts of Asia realize the benefit of working together and have established formal and informal groups for numerous objectives. Informal groups are based on mutual understanding only, community based, belong to the same faith, have specific traditions, and share the same natural resources. Formal user groups, producer/marketing groups, and cooperatives reportedly have also been organized in the surveyed villages with help from government or non-government organizations.

In Nepal's mid- and high–hills, for example, the existence of forest, drinking water, and irrigation user groups was reported. Vegetable and milk producer/marketing groups are also present in relatively accessible villages. In the Philippines, Rural Improvement Councils (RICs) provide technical, financial, and livelihood assistance to their members in the form of livestock dissemination programs, small handiwork business assistance, and help in establishing small consumer (*sari-sari*) stores. In Lampung province, Indonesia, farmers organized themselves into groups of 20-30 members; each group made a common maize cultivation plan covering the varieties to be grown, planting time, and level of fertilizer usage. In Thailand, farmer cooperatives often do not deal with output marketing, because individual farmers sell their production through extensive networks of private merchants. There are several associations that facilitate the management of water storage tanks and irrigation for rice production in tropical lowland environments in China. Farmer associations for transplanting rice seedlings and for coordinated sales of agricultural products such as fruit, ginger, and fish were also described. However, no associations related to maize production or sale were reported.

Across the region, women's, youth, and church organizations are also active in running livelihood, leadership, and religious programs and seminars in their respective communities. During the RRA/PRA surveys, farmer-respondents rated most community organizations as helpful and performing satisfactorily, although several were reported to be ineffective and inactive.

3.3.3 Sources of material inputs

In general maize farmers in Asia obtain material inputs (seeds, fertilizers, and pesticides) from the many agricultural input outlets in the countryside and nearby cities. However, maize farmers are frequently unable to pay cash for production inputs and instead obtain their supplies from private trader-financiers on a charge-to-crop credit arrangement.

Concerned government agencies also play a role in ensuring that maize seed and fertilizers are available to farmers, sometimes free but more often at discounted or subsidized prices through agricultural production intensification programs. When asked about problems related to material inputs, a large number of farmers expressed dissatisfaction with the high prices of seed and fertilizers purchased from private traders, while others complained that maize seeds supplied by government programs often had poor germination, poor field performance, and low yields. Quality problems, including adulteration, were often reported with respect to fertilizers and other chemicals.

3.3.4 Credit institutions

Farmers need not only appropriate agricultural technologies, but also sufficient capital to purchase them. A large percentage of farmer-respondents stated that they lack the resources to support their farm operations and thus depend heavily on borrowed capital. Very few (e.g., 2% in the Philippines and 13% in Thailand) have the money to completely cover their crop production costs. Many farmers are forced to borrow from private moneylenders or trader-financiers on a charge-to-crop scheme with extremely high interest rates (reported to be 3-5% a month in Thailand and 10-20% in the Philippines).

In a charge-to-crop scheme, lenders (often private traders) sell agricultural inputs to farmers on credit but at higher than market prices, and later buy back the harvests at lower than market prices. In this scheme, loans for agricultural inputs, as well as interest due for one cropping season, are deducted from the total value of the harvest sold to the lender. Farmers continue to support this seemingly costly and unfair arrangement because they find using the private trader-financiers more accessible and/or convenient than going to formal credit institutions. These private loans do not require collateral and do not have the same credit limits imposed by many formal credit institutions. Moreover, the process is less time-consuming, and private trader-financiers are generally available at all times. Farmer-respondents also stated that they had to continue using the services of private trader-financiers because the income from a harvest is usually insufficient to pay for loans taken during the previous cropping season.

Formal credit programs are also available from some government and private banks, yet very few farmers take advantage of them because they find the paper work too tedious and the requirements (especially collateral) prohibitive. Utilization of rural credit cooperatives varied across survey sites in China, but funds obtained were not necessarily targeted for agricultural production. An important source of credit across all survey sites was informal credit obtained from relatives, friends, other farmers, women's associations, or farmers' credit groups. Some farmers reported their decision not to take on loans because they anticipated difficulties in repaying them.

3.3.5 Input and output prices

Table 3.2 summarizes the estimated average prices in purchasing power parity (PPP) dollars[8] of the most commonly used maize inputs and of maize grain output in the surveyed maize production environments. Price variations among environments are largely due to differences in transportation and handling facilities provided by suppliers. Seed and fertilizer are the most common material inputs bought by maize farmers. Seeds of local/traditional varieties and improved OPVs are often saved from preceding harvests or purchased from/exchanged with other farmers in the community. If purchased, seed of local/traditional varieties costs anywhere from PPP$ 0.58/kg in the rainfed upland, semi-commercial production areas to PPP$ 0.95/kg in the subtropical/mid-altitude, low market surplus production areas. They were, surprisingly, most expensive in the rainfed upland, low market surplus production areas, at PPP$ 2.19/kg. Asian maize farmers, however, pay a much higher price for hybrid seed, about 10 to 16 times that of local/traditional and improved OPVs. In contrast, hybrid seed costs from PPP$ 5.02/kg in rainfed upland and subtropical/mid-altitude, low market surplus production areas to PPP$ 9.04/kg in the rainfed upland, semi-commercial areas.

Farmer-respondents reported that the most common inorganic fertilizers used in maize production are urea (46-0-0), complete fertilizer (14-14-14 or 15-15-15) and ammonium phosphate (16-20-0). Prices of inorganic fertilizer did not vary much among agroecologies, but were expectedly higher in remote upland areas with poor market access. In the irrigated and rainfed lowlands, ammonium phosphate was the cheapest inorganic fertilizer, and complete fertilizer the most expensive. In the rainfed uplands, urea was the cheapest inorganic source of plant nutrients, and again complete fertilizer the most expensive. Other inorganic fertilizers used in maize production included muriate of potash (0-0-60), diammonium phosphate (18-46-0), and ammonium sulfate (21-0-0). Some farmers applied organic fertilizers such as farmyard manure (FYM) and chicken dung either collected from their own backyards or purchased from input traders. In Nepal, however, manure and stover are normally not traded.

Table 3.2. Average prices of the most commonly used maize production inputs and maize output (in PPP $ per unit), Asia.

	Irrigated lowland	Rainfed lowland			Rainfed upland			Subtropical/ midaltitude		
	Commer-cial	Low market surplus	Semi-commer-cial	Commer-cial	Low market surplus	Semi-commer-cial	Commer-cial	Low market surplus (excluding China)	Low market surplus (China)	Semi-commer-cial
Maize seed (per kg)										
Local	0.76	0.62	0.80	0.71	2.19	0.58	0.59	0.95	0.68	-
Improved OPV	1.05	0.65	1.48	1.26	1.60	0.86	1.23	1.46	0.68	-
Hybrid	7.45	5.06	8.96	8.02	5.02	9.04	8.22	5.02	3.82	4.45
Inorganic fertilizers (per 50 kg)										
Urea	31.55	42.84	36.80	39.81	40.33	35.26	31.15	39.09	40.06	42.61
Complete	42.51	30.76	42.06	40.93	38.30	39.45	39.38	---	30.78	30.70
Ammonium phosphate	21.64	---	27.02	31.23	---	32.26	33.20	---	---	34.09
Labor wage rate (per person-day)										
Male	7.01	9.38	6.97	8.96	5.85	8.46	7.39	5.71	10.82	12.60
Female	5.73	8.93	6.16	8.24	5.13	8.18	6.81	4.65	9.63	9.66
Power rental										
Animal (per day)	15.00	290.70[a]	12.78	13.62	12.76	12.19	13.72	12.95	301.05[a]	340.95[a]
Tractor (per ha)	41.35	291.15	74.39	50.24	---	72.44	52.07	---	---	---
Maize grain price (per kg)										
Farm gate	0.66	0.49	0.57	0.47	0.64	0.49	0.44	0.82	0.48	0.49
Nearest market	0.81	0.51	0.64	0.72	0.73	0.65	0.71	0.92	0.51	0.50

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.
[a] PPP$/ha.

[8] Purchasing power parity (PPP) dollars are computed by converting national currency estimates to a common currency using a PPP conversion factor defined as the number of units of a country's currency needed to buy the same amount of goods and services in the domestic market as a US dollar would buy in the US. The use of PPP conversion allows a balanced comparison (and consolidation) of national currency prices across different countries or locations. The source of conversion factors used in the calculations is 2002 World Development Indicators, World Bank.

Some, but not many, farmers used pesticides in maize production. The most commonly applied chemical pesticides are field herbicides and insecticides. Some farmers also treated their maize seed with chemicals to protect it against storage pests such as weevils.

Across Asia, average daily wages for agricultural farm labor appear to discriminate against women: male labor enjoys a higher average daily wage rate of PPP$ 5.71-8.96/person-day, while female labor receives an average daily wage of PPP$ 4.65-8.24/person-day (Table 3.2). Snacks and/or lunch for farm workers are sometimes provided, especially during planting and harvest operations. In Nepal, most farm operations are done with family and exchange labor, and use of hired labor is not common except during peak times. In the Philippines, groups of farm laborers can be hired for either planting or harvesting maize. The local contract arrangement is called the '*pakyaw*' system, where total labor is normally paid on a per-hectare rate during planting. Harvesters are paid either in cash at a per-sack rate or in kind, with a share of the harvested cobs. The most common harvest-sharing scheme is 10:1, where for every 10 sacks of harvested maize, the owner gets nine sacks and the harvesters get one sack.

For land preparation, some farmers contract two- or four-wheel tractors at a rate ranging from PPP$ 41.35/ha in irrigated lowland-commercial maize areas to PPP$ 74.39/ha in rainfed lowland, semi-commercial areas. Animal power with operators can also be contracted for land preparation, especially in hilly areas, at PPP$ 12.19-15.00/person-animal day. In some areas, farmers can rent draft animals at a daily rental rate.

Maize grain prices varied widely within and across the maize production environments surveyed. Maize grain prices in the nearest markets ranged from PPP$ 0.64 to 0.92/kg and were higher by PPP$ 0.07-0.27/kg than those at the farm gate (PPP$ 0.44-0.82/kg). Subsistence maize farmers in the rainfed upland and subtropical/mid-altitude production areas (e.g., in Nepal's far and midwestern development region and Cebu and Leyte provinces in the Philippines) kept most of their grain for home consumption. Where both are available, yellow maize (usually hybrid) commanded a higher price than white (local/traditional) maize. Farmers expressed that in recent years they have observed that farm input prices tended to increase, while output prices have stayed more or less at the same, if not declining, level.

3.3.6 Input-output price ratios

Using the average of all reported maize seed prices and the average of all reported maize grain prices, the seed-to-grain price ratio across the surveyed areas in Asia was 6.52 using farm-gate and 5.20 using nearest-market grain prices during 2000-2001. This means that Asian maize farmers have to sell, on average, 5.20 kg of maize grain to pay for one kilogram of maize seed. This is much lower than the seed-to-grain price ratio of 11.21 derived in 1997/98 during CIMMYT's Asia maize seed industry study (Gerpacio 2001). As expected across production environments, the seed-to-grain price ratios were lower when farmers grew local/traditional maize or improved OPVs than when they used hybrids (Table 3.3). At farm-gate local/traditional maize grain prices, the seed-to-grain price ratio was lowest at 1.15 in irrigated lowland, commercial areas, and highest at 3.40 in rainfed upland, low market surplus areas. For hybrids, the seed-to-grain price ratio was low at 6.14 and 7.79 in subtropical/mid-altitude, low market surplus and rainfed upland, low market surplus areas, respectively. Ratios were consistently lower when maize grain prices at the nearest market were used in the computation.

To exploit the full genetic potential of modern maize varieties, particularly hybrids, farmers must use complementary inputs, especially fertilizers, and they must perform improved management operations that often require additional labor. The profitability of using complementary inputs and improved management practices depends primarily on their cost. Input-to-grain price ratios can be used to make inter-environment comparisons of the relative costliness of key inputs, which, in turn, can serve as rough indicators of the profitability of adopting modern maize varieties. Table 3.3 also shows the fertilizer-, labor- and power-to-grain price ratios prevailing in the different maize production environments of Asia between late 2000 and early 2002.

Across fertilizer grades, the fertilizer-to-grain price ratio at the farm gate was lowest at 1.08 in irrigated lowland, commercial maize areas and highest at 1.60 in rainfed upland, commercial areas. Ratios were much lower using grain prices at the nearest market, ranging from 0.88 in irrigated lowland, commercial maize areas to between 1.41 and 1.52 in rainfed upland low market surplus and commercial areas in China and throughout Asia and in subtropical/mid-altitude low market surplus and semi-commercial maize production areas in China. Inorganic fertilizers are more expensive in these areas, and farmers must sell more kilograms of maize to compensate for the cost of one kilogram of inorganic fertilizer.

The most expensive input to maize production appears to be mechanization (tractor power), which requires that farmers sell at least 63 kg of maize in irrigated lowland, commercial areas and up to 147 kg in rainfed upland, semi-commercial environments to recover the cost of having one hectare of land mechanically prepared. Animal power is cheaper than mechanization, especially in low market surplus and semi-commercial maize production areas where it is widely used by marginal, resource-poor farmers.

As previously mentioned, input-output price ratios are higher when maize grain farm-gate prices, rather than nearest-market grain prices, are used in the calculations. This indicates that price ratios are relatively more favorable to farmers selling in the nearest market than farmers selling at the farm gate. Farmers accept lower prices due to the convenience and savings in time and labor of having the buyer come to them. Meanwhile, across production environments, farm inputs tend to be cheaper in the irrigated lowland, commercial maize production areas and more expensive in the rainfed upland, semi-commercial and commercial environments. In particular, seed-to-grain price ratios (for local/traditional and improved OP varieties) tend to be highest in rainfed upland, low market surplus maize production environments. This suggests that high (and rising) input prices constrain maize production, especially for marginal, resource-poor farmers who reside mostly in less favorable production environments. Appropriate government programs will be important to address this concern and contribute to alleviating rural poverty in the more marginal areas of rainfed upland environments.

3.4 Infrastructure

A rural community's economic development depends on a number of critical infrastructure components, particularly road and communication systems and post-harvest and marketing facilities. The availability of this type of infrastructure plays an important role in promoting the modernization and commercialization of agriculture—often the backbone sector—in the community. However, most maize producing areas in the tropical lowlands have only poor, inadequate infrastructure to support the expansion of agricultural production.

Table 3.3. Input-to-maize grain price ratios for seed, fertilizer, labor, and power, Asia.

	Irrigated lowland	Rainfed lowland			Rainfed upland			Subtropical/ midaltitude		
	Commercial	Low market surplus	Semi-commercial	Commercial	Low market surplus	Semi-commercial	Commercial	Low market surplus (excluding China)	Low market surplus (China)	Semi-commercial
Input-to-maize grain farm-gate price ratio										
Seed (all)	6.77	6.70	7.45	8.94	3.38	8.77	11.69	1.87	5.60	8.90
Local	1.15	1.27	1.41	1.53	3.40	1.18	1.34	1.17	1.42	-
Improved OPV	1.59	1.33	2.61	2.70	2.48	1.75	2.77	1.79	1.42	-
Hybrid	11.31	10.33	15.81	17.22	7.79	18.38	18.56	6.14	7.96	8.90
Fertilizer (all)	1.08	1.51	1.41	1.49	1.23	1.45	1.60	1.35	1.50	1.48
Urea	0.96	1.75	1.30	1.38	1.25	1.43	1.41	0.96	1.67	1.70
Complete	1.29	1.26	1.48	1.71	1.19	1.60	1.78	---	1.28	1.23
Labor	9.66	18.68	11.59	18.47	8.52	16.96	16.03	6.34	21.30	22.26
Power										
Animal	22.76	28.63	22.54	29.26	19.81	24.78	30.97	15.85	53.00	48.98
Tractor	62.77	44.76	131.22	107.89	---	147.29	117.55	---	---	---
Input-to-maize grain nearest-market price ratio										
Seed (all)	5.53	6.30	6.59	5.81	2.98	6.60	7.30	1.66	5.51	9.08
Local	0.94	1.22	1.24	0.99	2.99	0.89	0.84	1.03	1.33	-
Improved OPV	1.30	1.27	2.30	1.76	2.18	1.32	1.73	1.59	1.33	-
Hybrid	9.24	9.92	13.98	11.20	6.86	13.84	11.59	5.45	7.49	9.08
Fertilizer (all)	0.88	1.45	1.24	1.49	1.08	1.09	1.00	1.20	1.41	1.52
Urea	0.78	1.68	1.15	0.90	1.10	1.21	0.88	0.85	1.57	1.74
Complete	1.05	1.21	1.31	1.11	1.05	1.20	1.11	---	1.21	1.25
Labor	7.89	17.95	10.25	12.01	7.49	12.77	10.01	5.62	20.05	22.71
Power										
Animal	18.58	27.84	19.92	19.03	17.44	18.66	19.34	14.06	50.52	46.69
Tractor	51.24	43.52	115.98	70.16	---	110.91	73.39	---	---	---

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.
--- No data available.

3.4.1 Accessibility

Most of the surveyed villages have seasonal/fair-weather roads and fair-to-good asphalted roads that allow motorized vehicles, from motorcycles to small pick-ups and trucks, to pass (Table 3.4). Agricultural extension agents can visit these areas to disseminate updated agricultural technology information to farmers. Sales agents of private input companies can come and promote their new maize seed, fertilizers, or pesticides. Agricultural traders-financiers can also come to collect, buy, and transport farmers' agricultural output in bulk.

Some interior villages in the mountainous areas of northwest Vietnam and in Bukidnon province, Northern Mindanao region, Philippines, reported poor road conditions that were inaccessible to motor vehicles, especially during the rainy season. In most villages, tractors and small trucks are used to transport large loads, while motorcycles are used to transport small amounts of farm inputs and produce. In villages where vehicle access is most difficult, farmers use horses, cattle, and carts for transport. In the mid- and high-hills of Nepal, farmers also carried inputs and produce (and even construction materials) on their shoulders and backs.

In general, semi-commercial and commercial maize-producing areas that are nearer to market or to feed-processing centers were reported to have relatively good road and transportation systems. The villages surveyed in East Lombok, Indonesia, however, are only three kilometers away from the nearest market, but the poor transportation system makes it difficult for farmers to transport their produce. In Vietnam's Mekong River Delta provinces, most transport of agricultural produce is done via the waterways; hence boats are an important means of transportation.

3.4.2 Irrigation

Irrigated maize is grown mainly in lowland ecosystems where tubewells and communal irrigation systems supply water mainly for rice production. In upland environments, farmers largely depend on rainfall, and the main source of irrigation water, if any, is springs and rivers, although irrigation for maize tends to be minimal. One exception was in certain areas of the subtropical/mid-altitude maize environment in China (Sichuan Province), where irrigated spring maize is cultivated. However, irrigation water, when available, is reserved for rice production and cash crops in southwestern China, high-value crops such as vegetables in the Philippines, baby corn and sweet corn in Thailand, and coffee and black pepper in Vietnam.

3.4.3 Post-harvest facilities

There are few drying and no large storage facilities in most of the surveyed maize growing upland villages. Only a few farmer cooperatives have some kind of drying or storage facility for their members' use. In the large commercial maize areas of Vietnam, a limited number of power-operated drying facilities is available to local traders during the rainy season. Farmers usually dry their maize under the sun, on house roofs, flat cement floors or roads, drying baskets, or plastic sheets. In southern Philippines, rice and maize farmers were observed to dry grain on one lane of a two-lane highway over an 11-km stretch. Across Asia, sun-dried maize grain is stored in sheds, storage barns, bamboo baskets, and wooden boxes or in cupboards, urns, or plastic sacks at home. Commercial maize farmers do not store maize for long periods to avoid high storage losses caused by weevils.

Most small Asian farmers shell their maize manually. In the commercial maize growing areas of Vietnam, large maize producers hire shelling machines to reduce labor and time, especially when the crop is harvested under unfavorable weather conditions. In the Philippines, a roving mechanical maize sheller comes to the villages during harvest season, or farmers can have their maize shelled for a fee at a few privately operated stationary shellers. Some farmers across the region also commonly use small electric shelling devices or manually operated maize shellers to process grains intended for home use.

In the hills of Nepal, the presence of power-operated maize-grinding mills in the production areas depends largely on road access, since transportation costs can be prohibitive. Only a few farmers in semi-commercial villages grind their maize, mainly for farm animal feed. Traditional manual grinding stones are also used in remote villages. Maize farmers in the rainfed lowland and semitropical/mid-altitude regions of China usually have access to power-operated milling facilities in their own villages.

3.4.4 Proximity to markets and marketing practices

Most of the lowland villages surveyed have small regular markets within the community. Other villages have only periodical (weekly) markets where agricultural products and livestock are sold. In contrast, farmers in Vietnam's remote villages in the northern uplands and central coast upland areas walk 10-25 km to get to the nearest (primary) market. Similarly, in one upland village in Northern Mindanao, Philippines, people travel up to 57 km to reach the nearest market. Villages in commercial maize production areas of the irrigated lowlands, rainfed lowlands, and rainfed upland environments were, on average, only 20 km away from the nearest market and have better access to markets compared to those in the rainfed uplands (Table 3.4). In commercial maize areas, the marketing system involves small village-based assemblers, commission agents, middlemen, and independent traders. Farmers have observed intense competition among these marketing agents to get the most farm produce to maximize their capital output.

Maize farmers sell their grain and other farm products either directly in public markets or to traders who come to the villages. A barter system also prevails on a limited scale in Nepal. In general, self-financed maize farmers sell their grain at more distant secondary markets, where prices are often higher than at markets closer to the village. Maize farmers with loans from trader-financiers have to sell their grain to the financiers despite the low prices they often get. Trader-financiers come to the villages during harvest and haul the grains in volume. Trucking services (transportation costs) may be charged to the farmers, shouldered by the traders, or shared by both parties. In Thailand and the Philippines, a few farmers sell their output to feed mills in nearby areas. Farmers consider feed mills good market outlets because they pay higher than market prices, and some do not have very strict grain quality standards. Chinese farmers sell maize to government grain outlets to fulfill government grain procurement quotas, but recent policy changes have begun to eliminate this requirement.

In Indonesia, how maize is marketed depends on the type of maize. Yellow maize (mostly hybrid and recycled hybrid) is sold directly to other farmers soon after harvesting. White maize is usually stored as ears with husks after sun-drying. Farmers sell their white maize gradually, and the money it brings in is used to cover daily household expenditures. Part of the white maize harvest is also consumed as a staple food in the household.

In Vietnam's commercial maize areas, farmers with substantial yield prefer to sell freshly shelled maize to local traders right on the field at harvesting. This marketing practice is more popular in the rainy season because farmers do not have sufficient drying and storage facilities. In villages with good road access, local/traditional and improved OPV maize is sold on the field to local traders who harvest and transport it.

3.5 Socioeconomic Characteristics

3.5.1 Households and ethnicity

Total population and number of households varied widely among participating countries, surveyed villages, and maize production environments (Table 3.5). The most densely populated surveyed villages were located in India, in the subtropical/mid-altitude,low market surplus, irrigated lowland-commercial, and rainfed lowland, semi-commercial

Table 3.4. Summary of the infrastructure in maize production environments across 265 surveyed locations in Asia.

Maize production environment and market orientation	Distance to nearest market (km)	Road conditions	Means of transportation available
Irrigated lowland			
Commercial	0 - 5.0	Relatively good to good; good and moderate asphalt; black top gravel; seasonal/gravel	Minicab; pick-up trucks; carts
Rainfed lowland			
Low market surplus	0 – 20	Dirt road	Bus; by foot; bicycle; motorcycle; tractor; 3 wheeled vehicle (cyclecar); ox pulled cart
Semi-commercial	3.0 – 57.0	Poor to fair to good; moderate asphalt and gravel; black top; seasonal/fair-weather gravel road;	Minicab; jeepneys; motorcycles; tricycles; small trucks
Commercial	1.5 – 10.0	Poor; relatively good to good asphalt; moderate gravel	Minicab; jeepneys; tricycles; trucks; pick-up trucks; carts
Rainfed upland			
Low market surplus	4.0 – 25.0	Black top; seasonal/fair-weather road; gravel/asphalted road	Jeepneys; tricycles; motorcycles
Semi-commercial	2.0 – 57.0	Good; gravel/asphalted road; seasonal/fair-weather road;	Motorcycles; jeepneys; tricycles; small trucks; pick-up trucks
Commercial	2.7 – 20.0	Fair to good; good asphalt; moderate gravel	Minicab; jeepneys; tricycles; small trucks; pick-up trucks
Subtropical/mid-altitude			
Low market surplus	0.5 – 25.0	Dirt road; Seasonal/fair-weather road; gravel; black top	Bus; by foot; bicycle; motorcycle; tractor; 3 wheeled vehicle (cyclecar); truck
Semi-commercial Commercial	10	Dirt road	Bus; by foot; boat

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.

maize environments, with a maximum of 21,000, 34,300, and 38,900 people, respectively. No consistent patterns emerged based on production orientation, but villages in rainfed upland maize production areas were generally observed to have the smallest population size.

On the other hand, average household size observed across the surveyed villages and production environments did not vary much, ranging from 3-6 members per household across all sites (Table 3.5). The rainfed upland-semi-commercial and -commercial environments tended to have higher average household sizes of up to 6 members per household as compared to other production environments.

Ethnic grouping is localized in the surveyed regions/provinces. In Vietnam, *Kinh* is the major ethnic group, accounting for nearly 90% of total population; the rest are minor ethnic groups, living mostly in the country's upland areas. In Thailand, most maize farmers are *Thai* and only a small number are members of hill tribes. In the Philippines, ethnic groupings are different in each of the surveyed provinces. The *Ibanag* and *Ilocano* groups are prominent in Isabela Province, while the *Mangyans* predominate in Mindoro Occidental and Camarines Sur. The study areas in Mindanao (Bukidnon, South Cotabato, and Cotabato) had the highest number of ethnic groups, with the *Cebuanos*, *Lumads*, and *T'bolis* being the top three. Although the *Han Chinese* make up the majority ethnic group across China as a whole, the *Zhuang* and *Yao* are very prevalent in the tropical lowland sites of Guangxi Province. The largest group, the *Zhuang*, was the majority ethnic group in many of the survey sites.

Males headed most households across all surveyed villages. However, male and female usually play an equal role in making farm decisions, since agriculture is considered to be a family enterprise. An exception was the surveyed villages in Nepal's eastern mid-hills and terai/inner terai, where the heads of 22% and 15% of households, respectively, were female. These figures indicate that women are highly regarded in these areas, and also that men tend to seek employment outside the villages, e.g., in urban areas. In Mindanao, Philippines, women headed 14% of all households.

3.5.2. Literacy and level of education

Education is a good indicator of farmers' capability to adopt new technologies that will help improve farm production. In general, the literacy rate was highest in the rainfed lowland-commercial and rainfed upland-semi-commercial production environments. The majority of the population across the surveyed villages has attended or completed primary (elementary) education (Table 3.5). A good percentage also attended and/or finished secondary school (high school), particularly in the irrigated lowland-commercial and rainfed upland-low market surplus maize areas.

In the Philippines, most people consider education to be a top priority, and even resource-poor families will strive hard to send their children to school. In Nepal, passing the 'School Leaving Certificate (SLC)' examination is an important indicator of the level of education. Unfortunately, only a minimum number of Nepalese passed the examination in 2000/2001; for this reason, an astounding 30-50% was reported as illiterate in the subtropical/mid-altitude hill maize areas.

Table 3.5. Selected demographic information from across 265 surveyed locations, Asia.

				Educational level (range in %)			
Maize production environment and market orientation	Total population (000)	Number of households	Average household size	Illiterate	Elementary level or graduate	High school level or graduate	College level or graduate
Irrigated lowlands							
Commercial	2.4-34.3	467-3,800	4.0-5.7	0-30	44-57	35-54	5-16
Rainfed lowlands							
Low market surplus	1.0-3.1	250-811	3.8-5.1	0-5	63-94	5-30	1-12
Semi-commercial	0.4-38.9	108-8,000	3.3-5.9	0-30	33–79	17-54	1-25
Commercial	0.9-18.6	159-3,505	4.3-5.7	0–9	44–66	19-46	1-11
Rainfed uplands							
Low market surplus	0.5-9.3	96-1,759	4.3-5.0	8-38	32-48	32-55	6-9
Semi-commercial	1.4-7.1	229-1,419	4.8-5.9	2–3	42-79	17-30	3-25
Commercial	1.2-1.7	211-347	4.9-5.9	2–9	66-79	17-19	3-6
Subtropical/mid-altitude							
Low market surplus	0.9-21.1	209-4,063	3.2-4.2	0-50	57-95	4-20	0-15
Semi-commercial	1.4	359	3.9	20	71	6	1
Commercial							

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.

3.5.3 Landholdings and land tenure

Maize farmers across all production environments in Asia had an average farm size ranging from 0.3 to 20.8 ha (Table 3.6). The range of farm sizes was widest (1.5-20.8 ha) in the rainfed upland-semi-commercial maize areas and narrowest (0.3-1.3 ha) in the irrigated lowland-commercial maize areas. In Thailand, 31% of maize farmers had large farms, averaging about 16 ha. The largest farm size reported was a landholding of 80 ha in Nakorn Ratchaseema Province, Thailand.

With the exception of farmers in China, most maize farmers in surveyed villages across Asia are landowners, with the highest proportion (65-100%) living in the irrigated lowland-commercial production environments (Table 3.6). Tenants/sharecroppers are located mostly (16-64%) in the rainfed upland-low market surplus production environments. Fixed-rent payers are high in the rainfed lowland-semi-commercial (up to 22%) and subtropical/mid-altitude-low market surplus (up to 19%) maize areas. In the rainfed lowland- and rainfed upland-semi-commercial maize production environments, however, up to 92% of maize farmers are landless.

In China, under the household responsibility system (HRS) reform that began in 1979, collective land was allocated to individual households based on household size or a combination of household size and labor. Since private ownership of agricultural land does not officially exist in China, this so-called responsibility land remains collectively owned and subject to periodic reallocation by village leaders. Farmers are supposed to have complete use and income rights over the land during the contract period. Most agricultural lands in surveyed villages in China fall under the category of responsibility land. Villages can also maintain an area of unallocated "contract land," which is leased to households on a short-term basis. Households in all surveyed villages in both rainfed lowland and subtropical/mid-altitude regions were also allocated small amounts of land for household plots largely used to grow vegetables for household consumption.

While most farmers in the lowlands of Vietnam have been provided the red book (land use certification) for the land they own, many farmers in the uplands, particularly those located near forest areas, still do not have legal land use privileges. These farmers do not have access to formal credit sources and have little incentive to invest in land that is not theirs.

3.5.4 Maize utilization

In Asia, maize has become a major component of human diets and the preferred substitute during periods of rice shortage. As expected, however, maize utilization patterns differ depending upon the food habits of the local population. Where livestock, pig, and poultry production is developing rapidly, most maize (particularly hybrid) is grown not for human consumption, but for animal feed (Table 3.7). In semi-commercial and commercial production systems, 40-100% of all maize produced was sold, and up to 60% was fed to barnyard animals. With the exception of surveyed villages in China that predominantly grew hybrids for feed (40-90% of total output), subsistence farmers in the rainfed uplands and subtropical/mid-

Table 3.6. Selected socioeconomic information from 265 surveyed locations, Asia.

Maize production environment and market orientation	Average farm size (ha)	Tenure status of farmers (%)[a]					
		Land-owner	Tenant/ share-cropper	Fixed-rent payer	Landless	Mortgage payer	CLT/part-owners[b]
Irrigated lowlands							
Commercial	0.3-1.3	65-100	15-35	0-6	0-7	0-1	
Rainfed lowlands							
Low market surplus	0.2-0.8						
Semi-commercial	0.7-3.3	0-100	2-28	0-22	0-92	0-16	5-13
Commercial	0.3-15.4	23-99	1-35	0-2	0-10	0-14	3-36
Rainfed uplands							
Low market surplus	0.7-1.8	36-81	16-64		0-3		
Semi-commercial	1.5-20.8	0-88	2-20	2-3	7-92	5-16	3-50
Commercial	0.6-7.2	23-100	1-34	0-2	0-10	0-14	3-38
Subtropical/mid-altitude							
Low market surplus	0.1-2.1	44-92	1-33	0-19	1-4		
Semi-commercial	0.3-2.5						
Commercial	0.5-1.7						

Source: IFADCIMMYT RRA/PRA Surveys 2000-2001.

[a] Tenure status does not include surveyed villages in China, where all crop land is allocated by or contracted from the village.

[b] CLT – Certificate of Land Transfer, issued to agrarian reform beneficiaries in the Philippines.

altitude environments planted mostly local/traditional maize varieties and kept 59-90% and up to 73% of output, respectively, for household consumption. Again, with the exception of subtropical/mid-altitude environments in China, where approximately 20% was retained for feed use, only 1-5% of maize produced in subtropical/mid-altitude-semi-commercial areas was fed to barnyard animals. Although subsistence farmers in rainfed lowland environments reported marketing some of their maize, most of it is used for household consumption and feed.

In predominantly low-market-surplus villages, maize ears are dried with or without husk and stored, and later milled as needed for immediate use. In Bukidnon, Northern Mindanao, Philippines, maize farmers reported that when the harvest is very poor, even yellow maize is processed and consumed as food. Maize farmers in the rainfed uplands-low market surplus production environments retained a significant proportion of their grain for seed. In subtropical/mid-altitude-semi-commercial environments, a portion of the maize grain was allocated for other purposes, e.g., as the main ingredient in brewing the local beverage.

3.5.5 Farmer classification

One exercise conducted during this study was to classify farmers within the community, in accordance with local perceptions of wealth and poverty. Farm households were classified as either poor/small, medium/intermediate, or rich/large farmers, and farmer-respondents were asked to provide descriptions and general characteristics of each group. Respondent-selected parameters most frequently included farm size, income by source, household size, and number of livestock owned.

Farmer groupings were characterized very similarly across production environments, except for slight differences in farm size and proportion of income contributed by maize production (Table 3.8). The poor/small farmer group was characterized as mostly tenants or sharecroppers with large households and little or no education. With the exception of China, where landholding size was believed to be relatively uniform across the different farmer groups, if land was owned, farmers tended to have small farms: 0.5 ha or less in the irrigated lowland-commercial environments and up to 2.0 ha in the rainfed lowland-semi-commercial and all the rainfed uplands maize areas. Poor/small farmers in the rainfed lowland-commercial maize areas tend to have relatively large farms of up to 3.2 ha. Most of their income comes from maize production and other agricultural activities (they often hire themselves out as labor to other farms). Other types of off-farm income opportunities appear to be quite limited. Poor/small farmers in the rainfed lowland-commercial maize areas of the Philippines earn an estimated 59-76% of their income from maize production and none from non-agricultural activities. In South Lampung, Indonesia, poor farmers earn most of their income from non-farming activities. In subtropical/mid-altitude environments, poor farmers often lag behind in adopting new technologies due to lack of capital.

Medium/intermediate farmers, many of whom are landowners, have more sources of income than poor/small farmers. Farm size ranges from 0.5 to 5.0 ha across all environments, except in the rainfed lowland-commercial maize areas, where farms covered 0.8-8.0 ha. Income in this group comes mainly from maize production and other agricultural crops/activities. In Thailand, medium/intermediate farmers earn an average of 50,000-80,000 baht (US$1,250-2,000). In the

Table 3.7. Maize utilization (% of grain produced) across 265 surveyed locations, Asia.

Maize production environment and market orientation	Maize utilization (% of grain produced)				
	Sold	Kept for food	Animal feed	Retained as seed	Other
Irrigated lowlands					
Commercial	40-100	0-41	0-60	0-3	0-9
Rainfed lowlands					
Low market surplus	0-28	1-60	20-94	0-10	0
Semi-commercial	46-100	0-41	0-29	0-30	0-9
Commercial	70-100	0-22	0-29	0.1-2	0-4
Rainfed uplands					
Low market surplus	1-3	59-90	2-34	4-27	
Semi-commercial	62-100	0-20	0-29	0-1	1-3
Commercial	62-100	0-14	0-29	0-2	0-3
Subtropical/mid-altitude					
Low market surplus	0-35	1-73	1-95	0-4	0-24
Semi-commercial	40-52	30-45	1-20	0	0-8
Commercial	60-80	10-30	5-10		4-10

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.

Philippines, maize production provides an estimated 48-65% of this farmer group's total household income, and non-farm activities account for about 6-14%. The typical non-farm income-earning activities for medium/intermediate farmers include buy-and-sell enterprises, driving public vehicles for hire, working in factories or stores in nearby cities, and working as construction laborers within or outside the community.

Farmers in the relatively rich/large farmer group tend to have smaller households and larger farms (at least 5.0 ha) where crop diversification, particularly to cash crops, is more prevalent. These farmers (in China, Philippines, and Thailand) tend to be less economically dependent on maize production and characteristically obtain the highest share of their income from cash crops and non-agricultural activities. In several survey sites in the Philippines and Thailand, the relatively richer/larger farmers have education and skills that allow them or their family members to hold white-collar jobs in bigger cities; some family members may work overseas and send remittances home. In contrast, richer/larger farmers in South Sulawesi, Indonesia, still earn most of their income from producing agricultural commodities (cotton, cocoa, and tobacco) and barnyard livestock raising. In Nepal, rich/large farmers often lead the community towards adoption of new and improved technologies especially those pertaining to maize production.

Table 3.8. Classification of maize farmers within the community, 265 surveyed locations, Asia.

Maize production environment and market orientation	Farmer group/classification		
	Poor/Small	Medium	Rich/Large
	General characteristics, similar across environments		
	Small farm size; large family/household size; little or no education; large portion of income from maize and other agricultural products/activities; lag in adopting new technology	Medium-sized farms; more income sources; income mainly from maize and other agricultural products/activities; easily adopt new agricultural technologies	Large farms growing more than one crop; small family/household size; income mainly from maize and other agricultural products/activities; skills or education allows family members to work in city or abroad; easily adopt new technologies
	Specific characteristics (differences) reported		
Irrigated lowlands			
Commercial	Average farm size up to 0.5 ha	Farms of 0.5-2.0 ha; no income from cash crops/business (Nepal)	Farm size 2.0 ha or more
Rainfed lowlands			
Low market surplus	Large income share from maize (40-100%), small share from non-agricultural sources; less educated household head, older household heads	Income share from maize approximately 30-60%; young to middle-aged household heads	Largest share of income from off-farm work (60-80%), smallest share from maize (7-27%); less maize consumption as food; household head better educated than those of poor/small or medium households; middle-aged household heads
Semi-commercial	Farms up to 2.0 ha; about 59-76% of total income from maize production and none from non-agricultural activities; in East Java, Indonesia, large portion of income from other agricultural products/activities and little from maize	Farm size range 0.5-5.0 ha	Average farm size >5.0 ha; in East Java, Indonesia, large portion of income comes from other agricultural products/activities and little from maize
Commercial	Farms at up to 3.2 ha; in Thailand, income was mostly dependent on wage employment	Farm size range 0.8-8.0 ha	Farm size 1.0-8.0 ha
Rainfed uplands			
Low market surplus	Average farm size 0-2.0 ha	Average farm size 2.0-5.0 ha	Average farm size >5.0 ha; less proportion of income (29-56%) from maize production, and higher from non-agricultural activities
Semi-commercial	Average farm size 0–2.0 ha	Average farm size 2.0-8.0 ha	Average farm size >5.0 ha
Commercial	Average farm size 0–2.0 ha	Average farm size 2.0-5.0 ha	Average farm size >5.0 ha
Subtropical/mid-altitude			
Low market surplus Semi-commercial Commercial	Lag in adoption of new technologies due to lack of capital to buy seed, fertilizer, and other inputs; most income from agricultural production; little or no off-farm income	Less dependent on agricultural income than poor/small farmers	Larger share of income from off-farm employment; household head better educated

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.

4. Maize Production Systems

Crop production was the main agricultural enterprise across the surveyed villages in Asia, most of which grew maize as the primary crop. Cotton, wheat, chili, vegetables, legumes, root crops, and cash crops are also relay-cropped or intercropped with maize, usually on a small percentage of the total cultivated area. Most farm households also engage in small-scale (barnyard) poultry and livestock production to augment their income and supply home needs. In the Philippines, for example, non-farm activities and enterprises such as small-scale trading, small *sari-sari* stores, or driving tricycles and jeepneys also provide additional income in many of the surveyed sites.

Animals commonly raised by maize farmers include cattle, carabaos (water buffaloes), goats, swine, and poultry, with relatively wealthier farmers owning more animal types and units. Besides providing meat, water buffaloes and cattle are kept as work animals, while goats, swine, and poultry are kept to sell as necessary, especially during lean months. In some villages in Indonesia and Nepal, poultry is also kept for home consumption, especially in lower-income farm households. Eggs are a source of both household food and income in China.

4.1 Crops, Cropping Calendars, and Cropping Patterns

Across all surveyed areas, the diversity in number and types of crops is very large, with maize grown either as a main crop or as a second crop after rice or wheat (Table 4.1). In Nepal, where maize is the single most important crop in terms of production and

Table 4.1. Major cropping patterns and calendars in maize environments, Asia.

Country	Major maize cropping patterns	Maize cropping calendar
India	Maize-wheat/sugarcane; paddy/maize-wheat; maize; potato-wheat; maize-potato+coriander-vegetables; maize-mustard-onion; maize-potato-cucumber; maize-chili	Rainy season: June/July-Sep/Oct Winter season: Oct/Nov-Mar
Indonesia	Maize-maize; maize-cassava Rice-maize; maize-chili	Wet season: Oct/Nov-Feb/Mar Dry season: March-July
Nepal	Bari land: Maize+millet; maize+millet-wheat/barley; maize-wheat/barley; maize-pulses/oilseeds	Summer: Mar/Apr-Sep Winter: Sep-Feb
Philippines	Maize-maize-maize; maize+legumes-maize-vegetables; upland rice/maize-vegetables	1st: May-July 2nd: Aug-Nov 3rd: Dec-Mar
Thailand	Maize-mungbean; Maize-sorghum/sunflower	1st: Apr/May-Aug/Sept 2nd: Sept-Dec/Jan 3rd: Jan-Apr
Vietnam	Rice-rice-maize; Maize; Maize-rice-rice	Spring-summer: Jan-May Summer-autumn: May-Sep Autumn-winter: Aug-Dec Winter-spring: Sept-Jan
China (subtropical/ mid-altitude and rainfed tropical lowland)	**Spring maize:** maize-soybean/cassava; maize-sweet potato; maize-rice-sweet potato; maize-maize/sweet potato; maize/vegetable-sweet potato; wheat-maize/soybean; maize-rice-sweet potato; rice-wheat; wheat-maize; wheat-maize/green bean; rape/maize-rice. **Summer maize:** maize/soybean-wheat; wheat-maize; wheat-maize/soybean; maize-soybean; maize/wheat; wheat/vegetable-sweet potato/maize/soybean **Fall maize:** maize-maize; maize/soybean-wheat; maize/sweet potato-soybean; maize/cassava-soybean; maize-sweet potato-soybean; maize-maize/sweet potato	Feb/March-June/July May/June-Sep/Oct July-Oct/Nov

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.

consumption, two main crops of maize are grown per year, mostly on *Bari* land (rainfed uplands). Other crops include millet (the second most important crop), wheat, soybean, and peas, the latter two usually intercropped with maize. Large cardamom, tea, broom grasses, sugarcane, and jute are some of the major cash crops planted in the mid-hills and *terai* of Nepal.

Cropping calendars and cropping patterns differ across maize agroecologies, reflecting variation in environmental conditions such as soil, topography, irrigation, drainage, rainfall, and other climatic factors (Figure 4.1). In India, maize is largely grown under rainfed conditions during the rainy season. The maize crop is sown after the onset of the monsoon in June/July and invariably harvested before the first fortnight of September. In winter, maize is grown in favorable and irrigated environments from November to March. In Thailand, the first maize crop is grown in the wet season from May to August/September. The second maize crop is grown during the dry season from September to December, and gets only a few weeks of rain; hence it is subjected to a high risk of drought. A third season of maize (from January to April) after rice is only possible in irrigated paddy fields. A limited area can be planted with third season maize, with the limited output often commanding a relatively high price. In Indonesia, the first crop (wet season) is planted in October/November and harvested in February/March; the second cropping cycle (dry season) (in Lampung and East Java) is from March to June/July. Lampung maize farmers follow a maize-maize cropping pattern, while others follow a maize-cassava pattern. In East Java, rice is the most important crop, and maize is only planted after rice.

The Philippines and Thailand have two maize cropping seasons, with maize grown either as a main crop or as a dry season crop after transplanted rice. With sufficient rainfall and favorable weather conditions, some areas grow a third crop of maize, usually in paddy fields. Legumes, vegetables, and cash crops such as tobacco, sunflower, and sorghum may also be planted as a relay or intercrop with maize. Maize, however, is second only to rice in Indonesia and Vietnam. It is generally grown once a year, with few farmers planting twice a year. Cassava, chili, sweet potato, beans, tea, fruit trees, groundnut, tobacco, sugarcane, cotton, coffee, rubber, cashew, and black pepper are the other major crops grown in these two countries. In India, maize is most commonly grown in rotation with wheat in Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh (traditional maize areas) and with chickpea in Karnataka and Andhra Pradesh (non-traditional maize areas). Black gram, green gram, or vegetables are commonly intercropped with maize during the rainy season. In the most marginal rainfed environments, farmers customarily fallow their lands after the maize crop.

In China's subtropical/mid-altitude environment, the primary maize production system is rainfed summer maize, although a much smaller irrigated spring maize system can be found in areas of Sichuan Province. A cropping pattern common in the rainfed summer maize system is winter wheat–summer maize–fall vegetable. The duration of summer maize is similar to that of middle season rice, approximately 110 days. In the rainfed tropical lowlands, three cropping seasons per year is common. The predominant maize system is the rainfed spring maize system, but in many

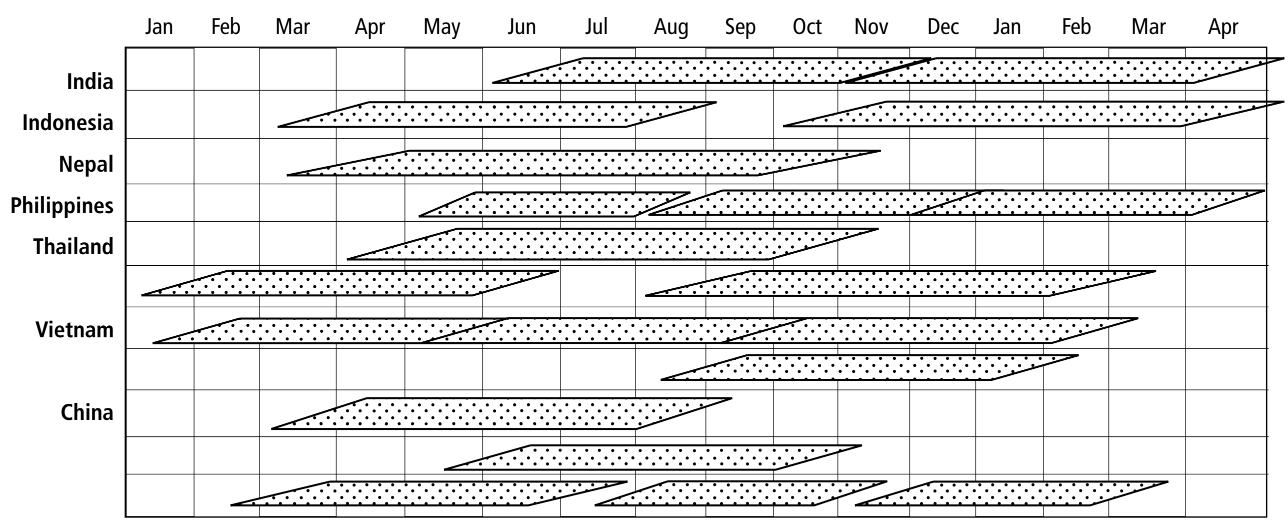


Figure 4.1. Maize cropping calendars, Asia.
Source: IFAD-CIMMYT RRA/PRA Surveys 200-2001.

areas the cultivation of fall and/or winter maize is also possible. The winter maize crop is largely green maize, cultivated and consumed more as a vegetable than as a grain crop. However, the cultivation of fall and winter maize following spring maize has been decreasing due to competition from other crops and to shifts in consumption preferences from maize to rice. In subtropical/mid-altitude and tropical lowland maize regions of China, maize may be planted in rotation with a wide range of crops, including potato, rape, vegetables, melons, and wheat (in subtropical/mid-altitude maize environments).

4.2 Maize Varieties Grown and Farmer Preferences

Maize farmers in Asia grew local/traditional, improved open-pollinated, and hybrid varieties. In much of Asia, local/traditional maize varieties are grown in areas predominantly subsisting on the crop, and modern yellow hybrids are grown in predominantly commercial maize-growing areas. Farmers generally select maize varieties based on intended use. For home food and feed, farmers prefer to grow local/traditional white maize varieties for their good eating quality, low material inputs requirement (especially fertilizers), and low production cost, as the seed can be recycled. If maize is grown purely for cash income, farmers are more likely to grow hybrid varieties, provided they have access to enough capital for material and labor inputs. Farmers are aware these improved varieties will produce higher yields when proper quantities of inputs are supplied.

When choosing hybrid varieties to plant, Asian maize farmers prefer those with high yields, heavy grains, general resistance to pests and diseases, resistance to drought and other climatic stresses, and high shelling recovery. In the mid-hills of Nepal and the central island of Visayas, Philippines, where white maize (mostly local/traditional and improved OPVs) is grown largely for human consumption, farmers prefer maize varieties with early maturity, high milling recovery, good eating quality, and general suitability to marginal soils. Other characteristics that influence farmers' choice of variety are grain weight, level of productivity, maturity period, and quantity and quality of foliage.

In India, the more commercial, non-traditional maize-growing areas of Karnataka and Andhra Pradesh are generally planted to hybrids, for which seed replacement is high (75-90%). Traditional maize growing areas (Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh) are sown to more local/traditional varieties, especially during the rainy season, and seed replacement is very low. Winter maize is gaining importance because it is, subject to less risk under assured irrigation and the best management practices, and gives higher yields than rainy season maize. Indian farmers often sow hybrids or composites during the winter season, and farm-saved seed of local/traditional varieties during the rainy season.

Both subsistence and semi-commercial farmers in the subtropical/mid-altitude maize environments of China cultivate hybrid varieties almost exclusively. Recycling of hybrid seed was reported in some low-market-surplus villages, but they represented only a small share of the total maize area. In rainfed tropical lowland environments, farmers grew hybrids, local/traditional varieties, and improved OPVs. Local/traditional varieties were preferred for cultivation on hilly terrain, for their suitability to marginal soils, and for their consumption qualities. The performance of improved OPVs varied by location, but in sites where they continued to be cultivated, farmers preferred them for their consumption qualities, good ear development, drought tolerance, and earlier maturity. The fact that farmers can save seeds for planting was another advantage of improved OPVs.

Part of the RRA/PRA survey was a researcher-led farmer exercise on ranking desirable characteristics of maize varieties. As expected, farmer-respondents ranked high yield as the most desirable and important characteristic, especially if the crop is grown for cash income. Where maize is grown for food, farmers considered good eating quality as the most important characteristic. Other maize characteristics preferred by Asian maize farmers included pest and disease resistance, heavy grain weight, and full maize ear (Philippines); early maturity, lodging resistance (Nepal); reasonable seed price (Thailand); insect resistance, firm stalks, and large ears (Vietnam); and drought tolerance, insect and disease resistance, lodging resistance, and upright leaf structure for intercropping (China).

4.3 Land Preparation and Crop Management Practices

In general, land preparation for maize production in Asia consists of one or two plowing operations using either machine or animals, or a combination of both, mechanized plowing, and harrowing and furrowing using draft animals. In some remote and sloping villages, land preparation is done either with animals or manually. In Lam Dong and Ka Do provinces, Vietnam, ethnic groups still practice shifting cultivation. Their land preparation begins with slashing and burning forest, bush, or grassland and continues with hand tools. Land preparation is more intensive in commercial maize-producing areas. In the Philippines, land preparation consists of one or two plowing operations, harrowing to level the field and reduce the size of soil clods, and furrowing. These land preparation operations are often done with animal traction, but may be mechanized on level terrain, especially if capital is available to pay for tractor rental. In Thailand, land preparation consisted of land clearing, burning crop residues, and tillage using large tractors. In China's subtropical/mid-altitude environments where maize is often relay-cropped with wheat, no tillage operations are carried out before planting maize. Farmers leave space for maize when sowing wheat, and maize is sown by hand in the spring. In rainfed lowland environments, land is tilled once or twice (once is most common) before sowing.

Maize seeds are commonly sown in plow marks or holes and then covered with soil. Hybrids are sown one to two seeds per hill, with 25-30 cm between hills and 75-80 cm between furrows. Local/traditional and improved OPVs are sown two to three seeds per hill, leaving 60 cm between furrows and 30-40 cm between hills. In Thailand, maize farmers used a higher seed rate when planting manually than when a mechanical seeder is used (normal seed rate is two seeds per hill). Replanting and thinning are done as necessary.

Weeds are commonly controlled twice in a crop season, through combined manual or hand weeding and off-barring and hilling-up (in the Philippines). First weeding is done 25-30 days after sowing (DAS), while the second weeding is done at 50-60 DAS. Across Asia, herbicides are very seldom used in maize production, although Thailand applies pre-emergence herbicides after planting, followed by mechanical weeding. Post-emergence herbicides are also used when weeds are abundant. Fertilizers and other pesticides are also applied but often at rates lower than recommended or than required by the crop, and only when pest infestation is heavy.

Hill farmers in Nepal apply farmyard manure (FYM) at 9-22 t/ha to increase soil fertility. Although farmers have been introduced to integrated pest management (IPM) in maize, its use has been limited. Some Filipino maize farmers have been trained in the use of *Trichogramma ostriniae*, a biological control for Asian corn borer, yet only a few actually apply it, mainly because of its limited availability. Harvesting is done manually at all sites.

4.4 Labor and Material Input Use

Seeds, fertilizers, and farmyard manure are the major material inputs used by Asian maize farmers. The range of seed rate used appears to be widest at 6-60 kg/ha in the subtropical/mid-altitude-low market surplus maize environments, where (except in China) mostly local/traditional and improved OP varieties are grown (Table 4.2). Farmers use high seeding rates to ensure against low germination and pest problems. Meanwhile, in most irrigated lowland, rainfed lowland, and rainfed upland environments, maize is seeded at 13-34 kg/ha. Low market surplus areas in rainfed lowland environments had a somewhat larger range for seeding rate.

Table 4.2. Average use of labor and material inputs, by maize production environments, Asia.

Maize production environment and market orientation	Seed rate (kg/ha)	Total fertilizer use (kg/ha)	Equivalent nutrients			Farmyard manure (kg/ha)	Manual labor		
			N	P	K		Total (person-day/ha)	Male (%)	Female (%)
Irrigated lowlands									
Commercial	18-27	125-810	-	-	-	1125-9000	30-243	47	53
Rainfed lowlands									
Low market surplus	22.5-70	52-641	10.4-382	29-190	13.5-96	0-14611	176-397	47-50	49-53
Semi-commercial	16-24	100-604	49-375	14-128	14-102	0-9000	28-195	47-86	14-53
Commercial	13-24	100-725	42-375	14-128	2-102	0-4000	28-195	55-86	14-45
Rainfed uplands									
Low market surplus	16-34	50-325	30-235	7-135	7-121	0-22000	40-295	38-100	0-62
Semi-commercial	16-24	50-604	30-235	7-135	7-121	0-10000	40-111	55-100	0-45
Commercial	13-24	50-604	20-325	7-135	3-121	0-10000	40-181	55-100	0-45
Subtropical/mid-altitude									
Low market surplus	6-60	43-495	9-199	23-177	12-56	0-20000	65-295	40-53	47-60
Semi-commercial	7-9	25-52	47-373	16-176	10-92	0-10000	172-321	36-49	51-64

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.

Across the region, urea (45-0-0), complete fertilizer (15-15-15), ammonium phosphate (16-20-0), and ammonium sulfate (21-0-0) are the most popular fertilizers used in maize production. The average amount of inorganic fertilizer used varied widely across the surveyed sites, mainly due to differences in specific soil conditions and in farmers' knowledge of the maize plant's basic nutrient requirements. Across all maize production environments surveyed, total inorganic fertilizer applied ranged from a low 22 kg/ha in the subtropical/mid-altitude-low market surplus areas to a high 810 kg/ha in the irrigated lowland-commercial environments (Table 4.2). In general, inorganic fertilizers are applied twice, first during sowing and then 25-30 DAS (in the Philippines) or 45-60 DAS (in Thailand). Subsistence maize farmers in rainfed upland and subtropical/mid-altitude environments tend to apply the most organic fertilizer (farmyard manure) at up to 22 t/ha.

Labor use in maize production was, on average, 28-295 person-days per hectare (PD/ha), with mostly male agricultural labor (Table 4.2). Subsistence maize production in the rainfed uplands and subtropical/mid-altitude areas tended to be labor-intensive using mostly family labor. On average across maize farms in these two environments, 62% of total labor is done by women, who are hired mostly for planting, manual weeding, and harvesting. In Vietnam, maize shelling and drying are also regarded to be a woman's job.

4.5 Post-harvest Practices

In general, maize is harvested manually using family, exchange, and hired labor. Farmers transport the harvested ears home to dry. Sun drying takes place in the yard, on drying pavements at home, or in community areas because mechanical dryers are seldom available in the villages. Shelling is done either manually or by a hired shelling machine. In some cases, maize is first shelled and then sun-dried, before being sold to traders and feed mills. Since many households lack storage facilities, farmers have little choice but to sell their maize grain soon after harvest. Farmers also find it difficult to store maize grain long enough for prices to go up, due to various reasons: weevils attack stored grain and lower its quality; grain that is not dried to optimum moisture content, especially during the wet season, can develop mold; and, in the Philippines, farmers have to sell their harvest immediately to pay back loans from trader-financiers. Better-off farmers bring their grain to commercial maize mills for milling, while poorer farmers use their own wooden or stone mills. Farmers reported that mechanical milling produces maize grits of better quality.

In Thailand, most farmers sold their grain to merchants who provide mechanical mills and hauling services. Milling of maize grain is done in the village immediately after harvesting. The merchants dry and store the milled output in their silos. Large feed mills to whom merchants sell the grain store it in their facilities. In contrast, Indonesian farmers sell their maize unshelled (still on the cob) right after harvesting. Traders dry and shell the maize before selling it to large feed mills.

Local/traditional and improved OP maize harvested for home use is hand-sorted at home; the smaller and "not-so-good" ears are milled, and the good ones are kept for seed. If planting the same variety the next season, farmers select the seed soon after harvest. For seed, farmers choose big, bright-colored grains from clean, pest-free ears with good husk cover. The ears are chosen from maize plants of average height and good stand so that the second-generation crop will be resistant to lodging. The ears are sun-dried with or without husks and stored in dry areas in the house or in a separate storage shed. Farmers report that ears with husks store better because weevils, a common storage pest, do not easily infest them. The ears are shelled manually just before use.

4.6 Yields and Yield Gap

As expected, hybrid varieties yield more than local/traditional and improved OP varieties, with rainfed lowland and rainfed upland environments giving comparable levels of good yields (Table 4.3). Across production environments, hybrid maize yields ranged from 1.6 t/ha in subtropical/mid-altitude-low market surplus areas to 6.5 t/ha in rainfed upland-commercial, and 7.0 t/ha in subtropical/mid-altitude-commercial environments. In contrast, yields of local/traditional maize varieties ranged from a low of 0.9 t/ha in rainfed lowland and subtropical/mid-altitude low market surplus areas to a high of 3.0 t/ha in rainfed lowland low market surplus environments. Recycled hybrids, commonly used in Indonesia, yielded from 2.3 to 4.3 t/ha, which is more than the yield of hybrid maize grown in the subtropical/mid-altitude-semi-commercial areas.

In all surveyed sites, farmers are aware that the productivity of their maize crop can be improved and reported several reasons for the yield gap. First and foremost are the erratic, unpredictable weather conditions that affect crop growth and yields. Tropical storms, such as often occur in the Philippines (Camarines Sur and Leyte), can easily destroy crops. In some areas, weather extremes (heavy rains and flooding early in the maize season and drought in the later stages of crop growth) adversely affect maize production. Second, Asian maize farmers tend to use less than the recommended amounts of fertilizers because they lack the capital to purchase inputs. Farmers cited soil acidity, declining soil fertility, and the continued loss of fertile topsoil due to erosion (particularly in the hills of Nepal) as other probable causes of maize yield gaps in Asia. In India, farmers reported that maize yield gaps are explained by low seed replacement, poor seed quality, and ineffectiveness of recommended agronomic practices. Other causes include pest incidence, poor agricultural extension services that contribute to farmers' insufficient access to improved technology and/or technical information, and poor cultural management practices.

Table 4.3. Maize yield by production environment, Asia.

Maize production environment and market orientation	Range of maize yield (t/ha)			
	Local/ traditional	Improved OPVs	Hybrids	Recycled hybrids
Irrigated lowlands				
Commercial	1.3 – 2.5	2.1 – 3.5	3.8 – 5.5	2.3
Rainfed lowlands				
Low market surplus	0.9 – 3.0	1.9 – 3.0	1.9 – 6.0	-
Semi-commercial	1.3 – 2.3	1.7 – 3.0	3.3 – 5.5	2.3
Commercial	1.2 – 1.7	1.5 – 3.0	3.5 – 5.6	2.5
Rainfed uplands				
Low market surplus	1.3 – 2.2	1.7 – 2.7	3.3 – 4.4	-
Semi-commercial	1.3 – 2.3	1.7 – 2.5	3.3 – 4.8	-
Commercial	1.3 – 2.3	1.7 – 3.5	2.8 – 6.5	3.5 – 4.3
Subtropical/mid-altitude				
Low market surplus	0.9 – 2.4	1.2 – 3.0	1.6 – 4.7	-
Semi-commercial	1.2 – 1.6	1.4 – 1.9	2.0 – 4.5	-
Commercial	1.5 – 2.5	1.9 – 2.9	3.0 – 7.0	-

Source: IFAD-CIMMYT RRA/PRA Survey 2001.
- Not reported.

5. Maize Production Constraints

The increasing demand for feed grain from the livestock and poultry industries coupled with the high yielding maize varieties now available on the market give Asian farmers good reason to intensify maize production. However, as with any other agricultural enterprise, maize production is constrained by problems that depress yields and production despite the advance and availability of agricultural technologies. The most commonly reported biotic constraints are downy mildew, Asian corn borers, stem borers, stalk rot, weevils, and weeds. Abiotic constraints include declining soil fertility, soil erosion, and drought. Improper or unbalanced use of fertilizers, lack of capital, and poor technology transfer were other maize production constraints identified.

5.1 Biotic Constraints

Biotic and abiotic constraints are similar across maize production environments and differ only in intensity at each site. Maize downy mildew (*Peronosclerospora* spp.), a major constraint to Asian maize production, can cause crop losses of more than 80%. Plants infected early in the growing season usually die within a month or do not produce any ears, while plants infected later produce very small ears with scattered grains. Downy mildew was reportedly present in all maize-growing provinces of Indonesia, in South Cotabato and Cotabato, Mindanao (Philippines), in the upper north, northeast, and lower north regions of Thailand, in the Central and Western Development Regions of Nepal, and in Uttar Pradesh, Madhya Pradesh, and Rajasthan (India). In 1987, an epidemic of downy mildew in Nepal caused yield losses as high as 50%. In areas of Indonesia where maize follows maize or sugarcane, downy mildew incidence has been increasing. During the 1996 cropping season in Central Lampung, Java downy mildew (*Peronosclerospora maydis)* affected a total of 7,665 ha, of which 2,880 (about 38%) were totally damaged or heavily infected. Epidemics with an incidence of 20-90% are not uncommon, and annual losses average 40% (Dalmacio 2000). In Indonesia, downy mildew is the most important biotic stress affecting maize production; thus, to be commercially released, varieties must possess downy mildew resistance as well as high yield potential.

Asian corn borer (*Ostrinia furcanalis* Guenee) is observed in Isabela, Southern Tagalog, South Cotabato, and Cotabato (Philippines); in the southeastern region, Mekong River Delta, and the central coasts and highlands of Vietnam; in the rainfed summer maize systems of the subtropical/mid-altitude regions of Sichuan and southern Shaanxi Province (China); in the rainfed spring and fall maize systems of the rainfed lowland regions of China; and in the lower north and upper northeast regions of Thailand. In the Philippines, Asian corn borer is considered the most destructive pest of maize (Morallo-Rejesus and Punzalan 2002); its incidence has reportedly increased over the last 10 years, causing yield losses of 30-100%. Significant efforts have been invested in the development of biological controls, especially in the identification and mass rearing of controls for field release. *Trichogramma ostriniae*, an egg parasitoid used to control Asian corn borer, was introduced to maize farmers at a few survey sites in the Philippines. Farmers, however, reported that the limited and unreliable supply of *Trichogramma ostriniae* constrained its adoption and field application.

In Vietnam, farmers reported an upward trend in insect and disease infestation, particularly stem borer and leaf blight. Depending on temperature and climate, leaf blight is incited by *Helminthosporium maydis* in the warmer lowland tropics and *Exerohilum turcicum* in the cooler climates at intermediate elevations and the highlands, and in the winter season in tropical lowlands (Dowswell et al. 1996). Despite using more pesticides on hybrid varieties, farmers reported that these pest and diseases can more than 30% of expected yields to be lost. Stem borers were reportedly present in Indonesia's outer islands; Nepal's terai, as well as its Eastern, Central, and Western Development Regions; India's Karnataka and Andra Pradesh Provinces, and Vietnam's central highlands, central coasts, and southeastern and Mekong River Delta regions. In China, *Turcicum* and maydis leaf blight, as well as banded leaf and sheath blight (BLSB), were reported by farmers as constraints to maize production in surveyed locations in both subtropical/mid-altitude (Sichuan and southern Shaanxi Provinces) and rainfed lowland production (Guangxi Province) regions. The best economical solution to leaf blight is resistant cultivars. Many tropical germplasm complexes have good resistance to leaf blight, and many tropical inbred lines developed at CIMMYT and IITA are highly resistant. Some resistance genes have been cloned and tagged, which has helped the private sector to quickly introduce resistance into susceptible but high-yielding genotypes.

Stalk rots are another serious and widespread group of maize diseases in Asia, and early maturing, highland floury germplasm is highly susceptible to them. Stalk rot is associated with good growing conditions early in the season, followed by stressful conditions later in the season. Foliar diseases, imbalanced soil fertility, and boring injury by various insect pests increase the likelihood of stalk rot. Stalk rot is the decay of the stalk's internal pith tissues, but the term is often used to indicate stalk breakage, stalk lodging, premature plant death and, occasionally, root lodging. Stalk rots are broadly classified into pre-flowering (*Erwinia* and *Pythium*) and post-flowering (*Fusarium*, *Macrophomina*, *Cephalosporium*, etc.) stalk rots (Lal et al. 2000). The nature of stalk rot is often complex, as a number of fungi, nematodes and, sometimes, bacteria are involved in causing the disease. Yield losses due to stalk rots may result from premature plant death or lodging, or ear rot caused when lodged plants come in contact with the soil. Stalk rot was reported in Isabela and Southern and Central Mindanao (Philippines), Eastern Development Region (Nepal), Central Plain (Thailand), Sichuan and Guangxi Provinces (China), and Southeastern and Mekong River Delta regions (Vietnam).

An overriding concern of maize farmers throughout the tropics is grain damage by storage pests, particularly the maize grain weevil (*Sitophilus zeamais*), in areas where maize is used for human consumption. Dent grain genotypes are more vulnerable than flints; the softer endosperm makes it easier for weevils to lay eggs in the grain and for the larvae to damage the kernel (Dowswell et al. 1996). The extent of grain damage, however, may also depend on the duration of storage. Weevils are reported prevalent in Nepal, Cebu, and Leyte (Philippines), in India's Central and Western Uttar Pradesh, Madhya Pradesh, and Rajasthan, and in southwestern China's maize producing regions. Although the ears are thoroughly sun-dried for two to three days prior to storage, weevil infestation is still very common. Tight, undamaged husk covers reduce weevil infestation in the field. Unfortunately, many of the highest-yielding improved tropical maize materials have relatively poor husk cover, making them highly susceptible to weevil damage. CIMMYT has identified source materials that possess resistance to these pests, and is now conducting cellular and DNA studies to single out the mechanisms underlying resistance, with an eye to transferring this trait to elite maize genotypes.

Across Asia, weeds are a substantial problem not only in maize production but in other crops as well. Several species (*A. spinosus*, *C. odorata* and *Ipomoea triloba*) are persistent problems every cropping season, causing yield losses as high as 100% if no hand weeding or herbicide control is used. It is particularly prevalent in the irrigated areas of Indonesia, all surveyed sites in the Philippines, Central and Western Development Regions of Nepal, and in Karnataka, Andhra Pradesh, Eastern Uttar Pradesh, and Bihar, India.

5.2 Abiotic Constraints

Among abiotic constraints, low and declining soil fertility appears to seriously affect maize production in Asia, particularly in Thailand's unfavorable uplands, the Philippines' sloping and hilly areas, Nepal's Central and Western Development Regions, karst-dominated environments in China's Guangxi Province, and Karnataka and Andhra Pradesh, India. Decline in soil fertility is often a result of soil erosion due to intensified land use and rapid decline in fallow periods, coupled with the extension of agriculture into marginal lands (Pingali and Pandey 2001). In the hilly areas of Bukidnon and South Cotabato, Philippines, farmers are keenly aware of the loss of fertile topsoil due to erosion, yet techniques and technologies to reduce erosion are not widely practiced. Some farmers in Leyte, also in the Philippines, establish rock walls and follow contour plowing, but the adoption of contour hedgerow technology is often not sustained because of the intensive labor required and the farmers' perception that shading may affect their maize crop. In Thailand, most maize farmers use single-cross hybrids, yet yields were still low because of poor soil fertility. Some farmers cannot afford to apply appropriate fertilizer levels, which also results in poor maize yields. Because labor is scarce, the crop is not cared for adequately.

Using high-quality data spanning 38 years (1961-98) and collected at 91 stations in 15 countries, Manton et al. (2001) found that the number of rainy days (at least 2 mm of rain) has decreased significantly throughout Southeast Asia (and the western and central South Pacific), and that the annual number of hot days and warm nights has significantly increased. This climatic trend was felt in the surveyed villages, and drought was widely considered the most important abiotic constraint to maize production. Drought at any crop development stage affects production, but maximum damage is inflicted when it occurs around flowering. Farmers may respond to drought at the seedling stage by replanting their crop, and some yield may be salvaged when drought occurs at later crop stages, but drought at flowering can be mitigated only by irrigation (Pingali and Pandey 2001). Drought was experienced in Indonesia, Philippines, Nepal, China, some parts of Thailand and Vietnam, as well as in Karnataka and Andhra Pradesh, India. In Vietnam, the second maize crop (planted at the end of the rainy season) is usually affected by drought if the rains stop early. Similarly, the area planted to fall maize in China has declined partly due to problems with drought. In in rainfed regions of India, the problem is drought during the summer and waterlogging in times of excess rainfall. In the Philippines, a severe drought was brought on by the El Niño phenomenon in 1997, and some crops, including maize, were severely damaged.

5.3 Socioeconomic and Policy-Related Constraints

As is the case with biotic and abiotic stresses, socioeconomic and policy-related constraints to maize production are similar across environments and include poor technology transfer; high input prices, and low output prices, as well as farmers' inadequate investment in inputs such as fertilizers, lack of capital or of low-interest credit sources, lack of information on crop management, lack of appropriate varieties, and lack of post-harvest facilities.

Maize farmers across production environments commonly reported poor technology transfer services or insufficient agricultural extension assistance from local government agencies. In the Philippines, Thailand, Nepal, and Vietnam, only a few local extension workers are available to serve big farming communities and large numbers of farmers, and, as a result, some are not reached at all. In remote areas, poor transportation systems and difficult working conditions combined with low salaries lead to ineffective service and lack of motivation among extension workers. There is also concern that government agricultural technicians need to be better trained to address specific production problems and provide better, up-to-date information. Farmers commented that the inability of extension services to provide adequate information on agricultural technologies contributes to poor farm productivity. In Indonesia, public extension agencies have been reorganized and now consist of researchers and extension personnel working together to better serve the farmers. Reorganization and policy changes have also occurred in China, but policies allowing research/extension organizations to market seed and inputs, combined with policies requiring those same organizations to finance their own activities have often resulted in conflicting priorities and objectives. In Nepal, some non-government organizations (NGOs) provide updated and improved agricultural technologies, but tend to be more concerned about social awareness; thus farmers still rely on extension workers for new maize production technologies. Vietnamese farmers, realizing the lack of extension workers to inform them of new technologies, rely on their interpersonal network of co-farmers, friends, and relatives.

Farmers' nutrient management practices (e.g., inefficient fertilizer applications, imbalance in nutrients provided) are serious concerns in the maize-growing areas of Asia. Often due to lack of capital, farmers apply fertilizers at lower-than-recommended rates and do not practice regular soil testing and monitoring. The use of organic fertilizers such as farmyard manure is decreasing because of time and labor requirements and diminishing availability. Some farmers also perceive them to be less effective than chemical fertilizers. Meanwhile, incorporation of crop residues is practiced only where land preparation is mechanized. In Indonesia, farmers apply large amounts of fertilizers to realize the full potential of high yielding maize varieties; however, the practice leads to soil acidity in the long run. In recent years in Vietnam, many useful agricultural extension activities have focused on crops, animals, and integrated pest management (IPM), but hardly any have addressed fertilizers and soil improvement technologies. People are worried that if soil quality improvement is not addressed soon, it may be difficult to ensure future food self-sufficiency, especially in remote upland communities.

Asian farmers reported that prices of maize production inputs such as seed, fertilizer, tractor rental, and hired labor have been increasing through the years, while output prices have either remained the same or decreased, resulting in lower profits especially for farmers living in remote areas. In the Philippines, although material inputs are always available, most farmer-respondents reported they have insufficient capital to purchase inputs directly, and instead obtain them from private trader-financiers who provide inputs on loan, at high interest rates. This arrangement does not always allow farmers much choice of materials within the available supply of fertilizers, pesticides, or even maize seed. With private traders, material inputs are often priced higher than the prevailing market retail price. Farmers who use recycled seed may have less financial stress, and the lack of capital at planting time may not seriously hamper their planting schedule. However, they are aware that much lower yields are obtained from recycled seed, especially if no fertilizer is applied. Farmer cooperatives are the best source of production inputs, but few are successful enough to adequately supply the needs of their members. In Nepal, farmers complained that the improved maize varieties available are not well-suited to their environments or their tastes.

Farmers, especially those in remote areas, have had a perennial problem with low output prices. Because markets are so distant, these farmers—served more by private trader-financiers—tend to pay more for their inputs and receive less for their products. The poorer and more marginal among them are likely to be forced to stop maize cultivation as a result of accumulated losses at the end of the crop season. Others who depend on maize for household food security and animal feed continue to cultivate maize, but at low levels of productivity and profitability.

6. Priority Constraints for Maize Research and Development

6.1 Methodology for Identifying Priority Constraints

Given the many constraints reported in each country and maize production environment, a way had to be found of combining and comparing constraints across the region to put together a prioritized agenda for maize R&D in Asia. This study used a modified version of the methodology developed by CIMMYT (Pingali and Pandey 2001) to prioritize maize productivity constraints that farmer-respondents identified during the country RRA/PRA surveys. Three criteria were used for prioritizing the list of farmer-identified constraints: efficiency, extent of rural poverty, and extent of marginality of the maize agro-environment. Details of how each index was created and the weights used for deriving a composite index that included all three criteria are found in Table 6.1.

The *efficiency index* prioritizes constraints in terms of getting the biggest "bang for the research buck" (i.e., the highest return on the investment) and estimates the expected production gain associated with alleviating the constraint. In contrast to the country-level, prioritization-exercise efficiency index, which was based on actual volume of maize production, the regional maize R&D prioritization efficiency index uses a particular maize environment's market orientation and contribution (share) to total regional maize production (or maize area),[9] to determine the importance of the typology in the region. The risk inherent to research investments is quantified in terms of the probability of success in finding a technological or policy solution that will alleviate the constraint, based on the maize scientists' knowledge of the solution.

Even where appropriate technologies are available, their adoption by farmers is not guaranteed. To quantify the probability that farmers in a particular location will adopt a technology, CIMMYT drew on farmer history of technology adoption and patterns of adoption for that location. At the country-level national maize R&D priority-setting workshops, this information was drawn from both historical data and the most informed knowledge of maize scientists participating in the exercise.

The *poverty index* redirects the focus of the efficiency criteria by targeting investments to areas where rural poverty is highest. The commonly accepted measure of absolute poverty is the proportion of the population living below the poverty line, measured as the lowest annual income level required for a citizen to have the basic necessities: food, housing, and clothing. Secondary data on by-country, regional,

Table 6.1. Prioritizing constraints across maize environments and geographic regions.

Efficiency index is a product of:	Poverty index is a product of:	Marginality index is a product of:	Combined index is equal to:
- Importance of constraint in the particular ecology and geographic region - Yield gain associated with constraint alleviation - Share of the particular ecology and geographic region in the region's total maize production (or area) - Probability of success in finding a solution to the constraint - Adoption history (% farmers that have adopted new technologies in the past)	- The efficiency index and share of the rural population living below the poverty line in the particular ecology and geographic region to the region's total number of rural poor	- The efficiency index and inverse of the average maize yield in the particular ecology and geographic region, as obtained from the RRA/PRA surveys	0.5*Efficiency index + 0.3*Poverty index + 0.2*Marginality index

Source: Modified from Pingali and Pandey (2001).

9 This project used production-based and area-based indices in determining priority constraints to maize production in Asia.

rural-urban poverty was used to estimate the number of rural poor in Asia and calculate the poverty index. The *marginality index* modifies the efficiency index by targeting investments toward more marginal production areas, on the assumption that more commercial areas are being served by the private sector. The inverse of the estimated average maize yield obtained in a particular maize-producing geographic region or ecology during the by-country RRA/PRA surveys was used as a measure of marginality index.

At the country level, the constraints identified from the RRA/PRA surveys were ranked across all maize ecologies and geographic regions using the above three indices and a composite index. The weights used in computing the composite index may vary depending on the relative importance of each index and on the mission and perspective of the user. As the objective of this international study was to delineate research and development guidelines, efficiency was used as the primary determining factor in allocating scarce public (and perhaps even private sector) resources, with important consideration given to the extent of poverty and marginality of environment within the ecology and geographic region (see detailed discussion in the next section).

The country-level planning process took place in a national maize R&D priority-setting workshop, with the participation of senior maize researchers from the public and private sectors, regional maize program directors, and other stakeholders. The three-to-four-day national maize workshops presented findings from the RRA/PRA work, inventoried current and potential technologies for alleviating the identified constraints, and identified technologies currently not available in the country, but that could be brought in from abroad. The in-country workshop ranked the proposed solutions based on potential for alleviating the constraints, and identified country-level policies needed for the rapid promotion, deployment, and adoption of the proposed solutions.

The regional priority-setting exercise: (a) classified the by-country geographic regions into the production environment-market orientation matrix; (b) combined the by-country farmer-identified maize productivity constraints; (c) combined similar constraints and calculated appropriate parameters for each constraint in each cell of the production environment-market orientation matrix, and (d) calculated the production (or area)-based indices and ranked the constraints according to the computed indices.

The approach taken in two countries, India and China, were somewhat different from those taken in the other countries included in the regional study. Due to the magnitude of production levels in India, each set of proritized constraints was analyzed with and without those from the subtropical/mid-altitude-commercial maize production systems of India to isolate the impact of these high-production, high rural poverty environments on regional maize R&D priorities.

Issues of great magnitude in both maize production and area relative to other countries present even more of a consideration for the inclusion of China in regional priorities. Furthermore, although the emphasis of the broader seven-country project was primarily on tropical lowlands and, to a lesser extent, semitropical/mid-altitude maize production environments, such a focus in China would have limited the analysis to a relatively small percentage of total Chinese maize area in southwestern China. While maize production and utilization as food, feed, and income source are indeed important to farmer livelihoods in this region, the limited focus would have precluded the discussion of maize research priorities on a national level. To better represent the overall range of maize production in the country and expand maize characterization in China to include major maize production systems, the China team broadened the scope of its research to include temperate maize production environments. Therefore, much of the Chinese maize is grown in environments very different from most maize environments investigated in the other six countries, to which only the tropical and subtropical/mid-altitude environments in southwestern China are similar. Moreover, although it is possible to reclassify the geographic regions used in China based on the production environment-market orientation matrix, it was not possible to reclassify and re-rank priority constraints discussed by farmers and maize scientists in the same way. Results of prioritization of maize production constraints in the Southwest region of China, where the tropical lowland and semitropical/mid-altitude growing environments are located, will therefore be presented parallel to those of the larger synthesis.

Table 6.2 presents the geographic regions and environments by country as classified in the maize production environment-market orientation matrix used as the framework of analysis in this book. Tables 6.3a and 6.3b present the key parameters used in prioritizing regional constraints, respectively, with and without subtropical/mid-altitude-commercial maize production systems in India and Southwestern China. (Annex 5 presents the key maize production and rural poverty parameters by country and agroecological zone that were used as the basis of parameters shown in Tables 6.3a and 6.3b.) All analyses are presented, compared, and contrasted in the discussion below.

Annex 6 shows the full list of 286 prioritized maize production constraints identified by farmers in the different maize production environments surveyed. It is important to note that the constraints given priority may vary depending on the index used.

6.2 Production-based Priority Constraints

6.2.1 Major findings

Based on the efficiency index. Tables 6.4a and 6.4b show the top 30 constraints, associated by maize environment and market orientation, according to the production-based efficiency index, with and without subtropical/mid-altitude (STMA)-commercial maize production in India and the Southwest region of China, respectively. The numbers of priority constraints in the different maize production and market orientation areas are similar with and without India's STMA-commercial lists. Sixteen of the top thirty production-based priority constraints were reported by farmers as prevalent in rainfed upland (semi-commercial and commercial) maize production environments (Table 6.4a). Ten to eleven constraints from the rainfed lowland (semi-commercial and commercial) systems, and two to three constraints from the irrigated commercial areas were included in the list. All of the highest ranked production-based constraints in China's Southwest region pertained to the low-market–surplus, rainfed spring maize production system in rainfed upland environments (Table 6.4b).

Interestingly, nine of the top ten priority constraints in each list, with and without STMA-commercial maize production in India, are exactly the same. These results indicate that, based on the efficiency index

Table 6.2. Classification of by-country geographic regions in the maize environment-production orientation matrix.

Maize production environment	Market orientation of maize production		
	Low market surplus	**Semi-commercial**	**Commercial**
Irrigated	*China*: Sichuan Province (corresponds to irrigated spring maize system in China's Southwest maize agroecological region)		*Indonesia*: All irrigated areas *Thailand:* Irrigated lowland areas in the upper north region *Vietnam*: Lowland areas of central and coastal highland, northern, and southeastern and Mekong Delta regions
Rainfed lowland	*China*: Guangxi Province (corresponds to rainfed spring maize system in China's Southwest maize agroecological region)	*Indonesia*: Java and Bali and outer islands *Nepal*: Terai area of all regions *Philippines*: Upland plains of Southern Tagalog, Bicol, and Central Mindanao *Vietnam*: Upland areas of northern region	*Indonesia*: Rainfed lowland areas of outer islands *Philippines*: Broad plain and hilly areas of Cagayan Valley *Thailand*: Favorable upland in the central, lower north, lower northeast, upper north, upper northeast regions *Vietnam*: Upland areas of central and coastal highland, and southeastern and Mekong Delta regions
Rainfed upland	Philippines: Rolling to hilly and upland areas of Central and Eastern Visayas	*Indonesia*: Dryland areas of Java and Bali, and some outer islands *Philippines*: Rolling to hilly areas of Bicol, all areas in Southern Mindanao, upland, rolling to hilly and upland areas of Northern Mindanao *Thailand*: Unfavorable uplands in the central region and hilly areas in the upper northeast region	*India*: All areas of Karnataka and Andhra Pradesh *Indonesia*: Dryland areas of outer islands *Philippines*: Hilly areas of Cagayan Valley *Thailand*: Hilly or unfavorable upland areas in the lower north, lower northeast, and upper north regions
Subtropical/ mid-altitude	*Nepal*: Mid-hills of Central and Western, Eastern, and Far-Midwestern Development Regions; high hills of all development regions *China*: Sichuan and southern Shaanxi Provinces (corresponds to rainfed summer maize system in China's Southwest maize agroecological region)	*India*: Low rainfall areas of Central and Western Uttar Pradesh, Madhya Pradesh, and Rajasthan	*India*: Medium to high rainfall areas of Central and Western Uttar Pradesh, Madhya Pradesh, and Rajasthan; all regions of Eastern Uttar Pradesh and Bihar

Table 6.3a. Production, area, number of rural poor, and average yield by maize production environment and market orientation (with and without subtropical/mid-altitude-commercial maize production in India and excluding Southwestern China), Asia.

Market orientation of maize production	Maize production environment: Irrigated	Rainfed lowland	Rainfed upland	Subtropical/mid-altitude
	Maize production (000 tons)			
Low market surplus	---	---	201.5	1,031.9
			(0.8)	(4.0)
			(0.9)	*(4.8)*
Semi-commercial	---	2,378.0	5,836.2	---
		(9.2)	(22.6)	
		(11.0)	*(26.9)*	
Commercial	2,318.3	5,317.2	4,610.1	4,184.2
	(9.0)	(20.5)	(17.8)	(16.2)
	(10.7)	*(24.5)*	*(21.2)*	*(0.0)*
	Maize area (000 ha)			
Low market surplus	---	---	316.1	598.2
			(2.5)	(4.7)
			(3.4)	*(6.5)*
Semi-commercial	---	1,594.3	3,065.4	---
		(12.6)	(24.2)	
		(17.3)	*(33.3)*	
Commercial	764.9	1,420.0	1,436.0	3,465.2
	(6.0)	(11.2)	(11.3)	(27.4)
	(8.3)	*(15.4)*	*(15.6)*	*(0.0)*
	Number of rural poor (millions)			
Low market surplus	---	---	5.6	7.5
			(2.7)	(3.5)
			(6.0)	*(8.0)*
Semi-commercial	---	19.9	6.2	---
		(9.4)	(3.0)	
		(21.2)	*(6.7)*	
Commercial	21.4	6.6	26.6	118.3
	(10.1)	(3.1)	(12.5)	(55.8)
	(22.8)	*(7.0)*	*(28.3)*	*(0.0)*
	Average maize yield (t/ha)			
Low market surplus	---	---	0.70	1.70
Semi-commercial	---	1.80	2.82	---
Commercial	2.78	3.78	3.42	1.03

Source: IFAD-CIMMYT country-level maize R&D prioritization workshops 2001-2002.
Note: Figures in parentheses are shares of regional totals. Italicized proportions are for without STMA-commercial maize production in India.

Table 6.3b. Production, area, number of rural poor, and average yield by maize production environment, Southwestern China.

Maize production environment	Rainfed spring maize	Rainfed summer maize	Rainfed fall maize
Maize production (000 tons)	13,904.6	624.9	1,093.6
Maize area (000 ha)	3,550.4	159.6	279.2
No. of rural poor (millions)	7.3	3.9	[a]
Average maize yield (t/ha)	3.96	3.60	2.64

Source: IFAD-CIMMYT country-level maize R&D prioritization workshops 2001-2002.
[a] Rainfed fall maize production system overlaps with rainfed spring maize production system.

Table 6.4a. Top 30 priority constraints to maize production according to the production-based efficiency index, Asia (with and without STMA-commercial maize production in India and excluding Southwest China's maize production systems).

	With STMA-commercialproduction, India		Without STMA-commercial production, India	
Constraint ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Maize production environment and market orientation	Farmer-identified maize production constraint
1	RFLL-commercial	Drought	RFLL-commercial	Drought
2	RFUP-semi-commercial	Drought	RFUP-semi-commercial	Drought
3	RFUP-commercial	Drought	RFUP-commercial	Drought
4	RFUP-semi-commercial	Inappropriate fertilizer use	RFUP-semi-commercial	Inappropriate fertilizer use
5	RFUP-commercial	Poor availability of quality seed	RFUP-commercial	Poor availability of quality seed
6	RFLL-commercial	Corn borers (ear/stem borers)	RFLL-commercial	Corn borers (ear/stem borers)
7	RFUP-semi-commercial	Lack of appropriate variety	RFUP-semi-commercial	Lack of appropriate variety
8	RFUP-commercial	Weeds and weed management	RFUP-commercial	Weeds and weed management
9	RFUP-semi-commercial	Soil erosion and landslides	RFLL-commercial	Rust
10	RFLL-commercial	Rust	RFUP-commercial	Downy mildew
11	RFUP-commercial	Downy mildew	RFLL-commercial	Waterlogging
12	RFLL-commercial	Waterlogging	RFUP-commercial	Stem borers
13	RFUP-commercial	Stem borers	RFUP-commercial	Soil erosion
14	RFUP-commercial	Soil erosion	RFUP-semi-commercial	Soil erosion/landslides
15	RFUP-commercial	Soil infertility	RFUP-commercial	Soil infertility
16	RFUP-semi-commercial	Soil infertility and acidity	RFUP-semi-commercial	Low output prices
17	RFUP-semi-commercial	Low output prices	RFUP-semi-commercial	Downy mildew
18	RFUP-semi-commercial	Downy mildew	RFUP-semi-commercial	Lack of post-harvest facilities
19	RFUP-semi-commercial	Lack of post-harvest facilities	RFUP-semi-commercial	Soil infertility and acidity
20	RFLL-commercial	Soil infertility	RFLL-commercial	Soil infertility
21	STMA-commercial	Post-flowering stalk rot	RFLL-commercial	Lack of capital
22	RFLL-semi-commercial	Lack of capital/low interest credit sources (inadequate credit support)	RFLL-commercial	Banded leaf and sheath blight
23	RFLL-semi-commercial	Drought	Irrigated commercial	Lack of capital
24	RFLL-commercial	Lack of capital	Irrigated commercial	Undeveloped irrigation system / water shortage
25	RFUP-semi-commercial	Limited capital / access to credit	RFLL-commercial	Lack of post-harvest facilities
26	RFLL-commercial	Banded leaf and sheath blight	Irrigated commercial	Inefficient fertilizer use/inappropriate fertilizer application
27	STMA-commercial	Lack of quality seed	RFLL-semi-commercial	Drought
28	Irrigated commercial	Lack of capital	RFLL-commercial	Rodents
29	Irrigated commercial	Undeveloped irrigation system / water shortage	RFUP-commercial	Post-flowering stalk rot
30	RFLL-commercial	Lack of postharvest facilities	RFLL-commercial	Flooding
	By production environment and market orientation	**Frequency count (no. of priority constraints)**	**By production environment and market orientation**	**Frequency count (no. of priority constraints)**
	Irrigated-commercial	2	Irrigated-commercial	3
	RFLL-semi-commercial	2	RFLL-semi-commercial	1
	RFLL-commercial	8	RFLL-commercial	10
	RFUP-semi-commercial	9	RFUP-semi-commercial	8
	RFUP-commercial	7	RFUP-commercial	8
	STMA-commercial	2		
	By type of constraint		**By type of constraint**	
	Drought	4	Drought	4
	Biotic	8	Biotic	9
	Abiotic	6	Abiotic	7
	Socioeconomic	12	Socioeconomic	10

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

alone, first addressing the problem of drought in the rainfed lowland-commercial, rainfed upland-semi-commercial, and commercial production environments would provide the highest returns to maize R&D investments in Asia. Drought is estimated to affect about 6.8 M ha in these three production environments alone (53.5% of the total regional maize area), and the alleviation of this particular constraint has enormous potential impact on maize production. Drought-prone areas include the rainfed lowland areas of Cagayan Valley and Central Mindanao in the Philippines, the southeastern region and Mekong River Delta of Vietnam, and the rainfed upland areas of Java (Indonesia), Southern Mindanao (Philippines) and the upper and lower northeast and central regions of Thailand. In the rainfed upland-low market surplus production environments of Southwest China, alleviation of production constraints caused by drought is also the top priority (Table 6.4b).

Next on the list of priority constraints are inappropriate fertilizer use in the rainfed upland-semi-commercial areas, poor availability of appropriate varieties and quality seed in the rainfed upland-commercial maize areas, and ear and stem borers in the rainfed lowland-commercial environments (Table 6.4a). Other maize production constraints included biotic constraints such as rust,

Table 6.4b. Top 30 priority constraints to maize production according to the production-based efficiency index, maize production systems of Southwest China.

Constraint ranking	Maize production environment and market orientation	Farmer-identified maize production constraint
1	Rainfed spring maize (subsistence)	Drought
2	Rainfed spring maize (subsistence)	Low soil fertility
3	Rainfed spring maize (subsistence)	Cultivated varieties susceptible to insects and diseases
4	Rainfed spring maize (subsistence)	Low level of investment in inputs
5	Rainfed spring maize (subsistence)	Difficulties in purchasing seed of desired varieties (few available outlets)
6	Rainfed spring maize (subsistence)	Poor grain quality
7	Rainfed spring maize (subsistence)	Few opportunities for farmers to sell maize due to undeveloped market
8	Rainfed spring maize (subsistence)	Banded leaf and sheath blight
9	Rainfed spring maize (subsistence)	Poor knowledge of cultivation techniques and crop management
10	Rainfed spring maize (subsistence)	Corn borer
11	Rainfed spring maize (subsistence)	Lack of functioning dissemination system for information on new varieties
12	Rainfed spring maize (subsistence)	Lodging caused by high winds
13	Rainfed spring maize (subsistence)	*Maydis* leaf disease
14	Rainfed spring maize (subsistence)	*Turcicum* leaf blight
15	Rainfed spring maize (subsistence)	Small production scale (low per capita land)
16	Rainfed spring maize (subsistence)	Low seed quality
17	Rainfed spring maize (subsistence)	Soil erosion
18	Rainfed spring maize (subsistence)	Low-quality or fake fertilizers
19	Rainfed spring maize (subsistence)	Storage rodents
20	Rainfed spring maize (subsistence)	Ear rot
21	Rainfed spring maize (subsistence)	Flooding
22	Rainfed spring maize (subsistence)	Low maize price
23	Rainfed spring maize (subsistence)	High seed price
24	Rainfed spring maize (subsistence)	Grain weevils
25	Rainfed spring maize (subsistence)	Mineral deficiencies in soil
26	Rainfed spring maize (subsistence)	Poor transportation infrastructure
27	Rainfed spring maize (subsistence)	Fake or low-quality seed
28	Rainfed spring maize (subsistence)	Cutworm
29	Rainfed spring maize (subsistence)	Labor shortage
30	Rainfed spring maize (subsistence)	Field rodents
	By production environment and market orientation	**Frequency count (no. of priority constraints)**
	Rainfed spring maize (subsistence)	30
	By type of constraint	
	Drought	1
	Biotic	10
	Abiotic	5
	Socioeconomic	14

downy mildew, post-flowering stalk rot (PFSR), and banded leaf and sheath blight (BLSB), and abiotic constraints such as soil erosion/landslides, waterlogging, soil infertility, and soil acidity (each group listed in order of priority). The list of priorities also included socioeconomic and policy-related constraints such as low output prices, lack of postharvest facilities, lack of capital, poor access to low-interest credit sources, and difficulties in marketing maize.

Among the top 30 priority constraints in all Asia according to the production-based efficiency index alone, abiotic constraints are estimated to affect about 5.1 M ha, biotic constraints (pests and diseases) 8.5 M ha, and socioeconomic and policy-related constraints 10.4 M ha (Table 6.5a). Excluding the STMA-commercial areas of India and Southwest China's maize production systems, these constraints affect 5.6, 5.3, and 5.1 M ha, respectively, in Asia (Table 6.5b). In both cases, drought alone affects about 47.7 M rural poor people in maize-growing areas across Asia; thus alleviating this top-priority constraint could potentially add another 35% to maize yields in the region. Including the drought-prone areas of rainfed upland maize environments in China, the area affected by drought increases by an additional 3.6 M ha. Biotic constraints and, particularly, socioeconomic, infrastructural, and policy-related constraints in China's Southwest region, however, also contribute significantly to reduced maize yields and productivity (Table 6.5c).

Based on the poverty index. According to the production-based poverty index alone, post-flowering stalk rot received the highest ranking in the STMA-commercial maize areas (Table 6.6), including the medium-to-high rainfall areas of India's Uttar Pradesh, Madhya Pradesh, Rajasthan, and Bihar. Maize production needs in the STMA-commercial environments, reflected in 12 constraints, dominated the top 30 priority constraints. The rural poor population in this environment totals about 118.3 million, or 55.8% of the total rural poor population across all environments surveyed in Asia (see Table 6.3).

Analysis without STMA-commercial India shows that drought received top priority in the rainfed upland-commercial areas (Table 6.6). These areas include drylands in Indonesia's outer islands, the unfavorable uplands of Thailand's Lop Buri in the Central Plains and Phetchabun in the Lower North region, and India's Karnataka and Andhra Pradesh. Constraints from the rainfed upland-semi- and commercial maize production areas dominated the top 30 priority list.

Table 6.5a. Selected indicators of impact for the top 30 priority maize productivity constraints according to the production-based efficiency index in Asia (with STMA-commercial areas of India and excluding Southwest China's maize production systems).

	Farmer-identified maize productivity constraints				Farmer-identified maize productivity constraints			
Impact indicators	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeco-nomic/policy-related	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeco-nomic/policy-related
	Based on efficiency index				Based on poverty index			
Effective total area affected (000 ha)	6,767.4	5,098.8	8,542.1	10,438.6	7,482.0	---	3,449.3	6,596.8
Estimated maize production across areas affected (000 t)	16,344.7	12,851.1	17,637.6	20,187.7	15,474.3	---	11,827.2	12,639.4
Average yield gain when constraint is alleviated (%)	35.0	28.8	14.1	31.2	31.9	---	11.9	18.8
Estimated no. of rural poor affected (millions)	47.7	15.3	155.0	185.0	162.1	---	76.1	179.4
	Based on marginality index				Based on combined index			
Effective total area affected (000 ha)	6,767.4	3,934.7	9,702.6	9,339.9	5,335.0	6,335.2	6,255.3	4,776.4
Estimated maize production across areas affected (000 t)	16,344.7	8,426.1	18,521.8	16,515.6	14,130.6	9,260.3	14,154.2	8,527.7
Average yield gain when constraint is alleviated (%)	35.0	37.6	15.6	37.5	34.2	24.4	11.9	18.1
Estimated no. of rural poor affected (millions)	47.7	10.5	168.1	166.3	37.0	124.5	171.9	162.3

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.

Note: The geographic regions and environments where specific constraints (except drought) under each of the above groups are reported are not necessarily mutually exclusive. However, careful calculations were made to avoid double counting in the above parameters.

In contrast to priorities based on the efficiency index, those according to the production-based poverty index generally consisted of biotic constraints. These constraints include downy mildew, stem borers, and banded leaf and sheath blight in the rainfed upland-commercial areas, and *Turcicum* leaf blight, stem borers, and *Maydis* leaf blight in the STMA-commercial production areas. These biotic constraints were estimated to affect 3.4-4.9 M ha across Asia; thus their alleviation could improve maize production in the region by an estimated 12% (Tables 6.5a and 6.5b).

Looking more closely at the list including STMA-commercial India in Table 6.6, only 12 of the 30 priority constraints according to the production-based efficiency index alone are included in the priority constraint list based on the poverty index alone, while 18 constraints ranked well below 30 based on the efficiency index were recently added to the top 30 poverty-based priority constraints. These new entrants are constraints reported mostly from the STMA- and the rainfed upland-commercial environments, which together are estimated to

Table 6.5b. Selected indicators of impact for the top 30 priority maize productivity constraints according to the production-based efficiency index in Asia (without STMA-commercial areas of India and excluding Southwest China's maize production systems).

	Farmer-identified maize productivity constraints				Farmer-identified maize productivity constraints			
Impact indicators	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeconomic/policy-related	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeconomic/policy-related
	Based on efficiency index				Based on poverty index			
Effective total area affected (000 ha)	6,767.4	5,608.1	5,264.4	5,100.9	6,767.4	4,679.6	4,874.1	3,711.6
Estimated maize production across areas affected (000 t)	16,344.7	14,540.3	13,947.2	13,453.4	16,344.7	10,838.6	13,701.2	8,981.6
Average yield gain when constraint is alleviated (%)	35.0	26.8	15.0	26.7	35.0	27.4	12.5	24.4
Estimated no. of rural poor affected (millions)	47.7	19.2	36.7	54.8	47.7	29.0	83.4	67.8
	Based on marginality index				Based on combined index			
Effective total area affected (000 ha)	6,767.4	7,101.6	7,050.7	6,155.0	6,767.4	4,791.1	4,697.7	3,711.6
Estimated maize production across areas affected (000 t)	16,344.7	12,851.1	16,491.0	12,449.5	16,344.7	11,185.1	12,805.1	8,981.6
Average yield gain when constraint is alleviated (%)	35.0	28.8	19.7	36.1	35.0	31.1	12.5	24.1
Estimated no. of rural poor affected (millions)	47.7	15.3	56.9	52.8	47.7	29.1	67.6	67.8

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: The geographic regions and environments where specific constraints (except drought) under each of the above groups are reported are not necessarily mutually exclusive. However, careful calculations were made to avoid double counting in the above parameters.

Table 6.5c. Selected indicators of impact for the top 30 priority maize productivity constraints according to the production-based efficiency index, Southwest China.

	Farmer-identified maize productivity constraints			
Impact indicators	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeconomic/policy-related
	Based on efficiency index			
Effective total area affected (000 ha)	3,550.4	3,550.4	3,550.4	3,550.4
Estimated maize production across areas affected (000 t)	13,904.6	13,904.6	13,904.6	13,904.6
No. of rural poor (millions)	7.3	7.3	7.3	7.3
Average yield gain when constraint is alleviated (%)	28.0	20.0	39.5	48.5

Table 6.6. Top 30 priority constraints to maize production according to the production-based poverty index, Asia (with and without STMA-commercial maize production in India and excluding Southwest China's low market surplus maize production systems).

	With STMA-commercial production, India			Without STMA-commercial production, India		
Constraint poverty ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Efficiency ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Efficiency ranking
1	STMA-commercial	Post-flowering stalk rot	21	RFUP-commercial	Drought	3
2	STMA-commercial	Lack of quality seed	27	RFUP-commercial	Poor availability of quality seed	5
3	STMA-commercial	Improper use of fertilizers	53	RFUP-commercial	Weeds and weed management	8
4	STMA-commercial	Post-harvest losses (due to weevils in storage)	58	RFUP-commercial	Downy mildew	10
5	STMA-commercial	Improper cropping systems	64	RFUP-commercial	Stem borers	12
6	RFUP-commercial	Drought	3	RFUP-commercial	Post-flowering stalk rot	29
7	RFUP-commercial	Poor availability of quality seed	5	Irrigated-commercial	Lack of capital	23
8	RFUP-commercial	Weeds and weed management	8	Irrigated-commercial	Inefficient/inappropriate fertilizer application	26
9	RFUP-commercial	Downy mildew	11	RFUP-commercial	Storage pests	33
10	STMA-commercial	Transplanting maize under late sown conditions	45	RFUP-commercial	Turcicum leaf blight	36
11	STMA-commercial	Turcicum leaf blight	46	RFLL-commercial	Drought	1
12	RFUP-commercial	Stem borers	13	RFUP-commercial	Banded leaf and sheath blight	38
13	STMA-commercial	Moisture stress (drought)	129	Irrigated-commercial	Undeveloped irrigation system (water shortage)	24
14	STMA-commercial	Lack of appropriate maturity varieties	130	Irrigated-commercial	Rodents	39
15	STMA-commercial	Stem borer	134	Irrigated-commercial	High production costs/input prices	35
16	STMA-commercial	Maydis leaf blight	139	RFLL-commercial	Corn borers (ear/stem borers)	6
17	RFUP-commercial	Post-flowering stalk rot	34	RFLL-semi-commercial	Lack of capital/low interest credit, inadequate credit support	31
18	Irrigated-commercial	Lack of capital	28	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	32
19	Irrigated-commercial	Inefficient/inappropriate fertilizer application	31	Irrigated-commercial	Waterlogging during crop establishment	46
20	RFUP-commercial	Storage pests	40	RFUP-semi-commercial	Soil erosion/landslides	14
21	RFUP-commercial	Turcicum leaf blight	42	RFUP- commercial	Soil erosion	13
22	RFLL-commercial	Drought	1	RFUP-semi-commercial	Drought	2
23	RFUP-commercial	Banded leaf and sheath blight	44	RFLL-semi-commercial	Drought	27
24	Irrigated-commercial	Undeveloped irrigation system (water shortage)	29	Irrigated-commercial	Lack of labor	53
25	STMA-commercial	Inappropriate crop establishment method	119	Irrigated-commercial	Downy mildew	56
26	Irrigated-commercial	Rodents	47	Irrigated-commercial	Leaf blight/rust (foliar diseases)	59
27	Irrigated-commercial	High production costs/ input prices	41	RFLL-semi-commercial	Rodents	45
28	RFLL-commercial	Corn borers (ear/stem borers)	6	RFUP-semi-commercial	Soil infertility and acidity	19
29	RFLL-semi-commercial	Drought	23	RFLL-semi-commercial	Inadequate post-harvest technologies/facilities	65
30	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	39	RFLL-semi-commercial	Poor marketing system, input/ output market access and undeveloped transport system	49

By maize production environment and market orientation	Frequency count (no. of priority constraints)	By maize production environment and market orientation	Frequency count (no. of priority constraints)
Irrigated-commercial	5	Irrigated-commercial	9
RFLL-semi-commercial	2	RFLL-semi-commercial	6
RFLL-commercial	2	RFLL-commercial	2
RFUP-semi-commercial	0	RFUP-semi-commercial	3
RFUP-commercial	9	RFUP-commercial	10
STMA-commercial	12		
By type of constraint		**By type of constraint**	
Drought	4	Drought	4
Biotic	14	Biotic	12
Abiotic	0	Abiotic	4
Socioeconomic/policy	12	Socioeconomic/policy	10

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

support about 144.9 million (68.3%) of Asia's rural poor people. Meanwhile, 14 constraints ranked below 30 based on the efficiency index were included in the list of poverty-based priorities without STMA-commercial India. The new entrants mostly came from the irrigated-commercial and rainfed lowland-semi-commercial production areas where about 41.3 million rural poor are located.

Based on the marginality index. Including India's STMA-commercial production areas, 17 of the 30 top priority constraints according to the production-based marginality index alone are those reportedly prevalent in the rainfed upland semi-commercial and commercial areas, and nine are from rainfed lowland areas (Table 6.7). Similar to results using the efficiency index, drought in the rainfed lowland and rainfed upland semi-commercial and commercial maize environments ranked within the top five priority constraints based on the marginality index alone. These areas included Indonesia's drylands, Philippines' Cagayan Valley and Southern Mindanao regions, and Vietnam's central coastal highlands and southeastern Mekong River Delta areas. Other top priorities included abiotic constraints (soil erosion, infertility, and acidity problems) and socioeconomic and policy-related constraints (lack of quality seed and post-harvest facilities, limited access to technical information, low adoption of improved technologies, and low output prices). All together, the marginality-based priority abiotic constraints (excluding drought) impact an effective total maize area of 3.9 M ha, which produces about 8.4 M tons of maize. Alleviation of this group of constraints could add an average of almost 38% to maize grain yield. However, it appears that, among the priority constraints based on the marginality of maize environments, biotic constraints (pests and diseases, plus weeds) impact a high number of rural poor (about 168 million), yet once alleviated would contribute the least average gain to yield (15.6%) (see Table 6.5a).

Similarly, in the list without India's STMA-commercial production constraints, 19 of the 30 top priority constraints came from the rainfed upland semi-commercial and commercial areas; drought ranked as the first priority constraint that maize R&D in Asia should address. More constraints reported from the rainfed lowland-commercial production environments, as well as more abiotic constraints, made it to this priority list. These abiotic constraints are estimated to affect about 7.1 M ha, on which nearly 13 M tons of maize are produced. Alleviating those contraints could add an average of about 29% to maize grain yields (Table 6.5b).

Table 6.7 also shows that more farmer-identified maize production constraints that ranked lower based on the efficiency and poverty indices ranked higher based on the marginality index. For example, soil erosion/landslides in rainfed upland-semi-commercial environments ranked second based on the marginality index, ninth based on the efficiency index, and thirty-first based on the poverty index. Similarly, low adoption of improved technology was number 27 in rainfed lowland-semi-commercial areas based on the marginality index, number 57 based on the efficiency index, and number 74 based on the poverty index. Moreover, only 13 and 20, respectively, of the top 30 priority constraints based on efficiency and poverty alone were included in the priority list based on marginality alone. All these observations show that priorities will depend on the parameter (efficiency, poverty, marginality of environment) that is perceived to need more emphasis, according to the overall goals and objectives of the prioritization exercise.

Based on the combined index. Aggregating the above three indices (criteria) generated a production-based composite index and ranking using a set of arbitrary weights: 50% for efficiency, 30% for poverty, and 20% for marginality of the environment (see Table 6.1). The top 30 priority constraints, according to the production-based combined index, that should be addressed by R&D are shown in Tables 6.8a and 6.8b. Of the 30 priority constraints, including those from India's STMA-commercial production areas, 11 are specific to the rainfed upland environments, 2 to the rainfed lowlands, 5 to the irrigated (commercial) lowlands, and 12 to STMA (commercial) environments (Table 6.8a). On the other hand, the top 30 priority constraints list, excluding India's STMA-commercial production areas, consists of 14 from the rainfed uplands, 7 from the rainfed lowlands, and 9 from the irrigated-commercial areas (Table 6.8b). Moreover, while biotic and abiotic constraints dominate the list in Table 6.8a, biotic constraints and socioeconomic and policy-related constraints dominate the list in Table 6.8b.

Maize area and production in low market surplus farming environments are relatively low across Asia; consequently, this maize production system does not appear in priority listings based on the combined index (nor in any of the priority listings based on efficiency, poverty, and marginality). The two top 30 constraints priority listings according to the production-based combined index closely follow the priority listing based on the poverty index, which in turn is strongly linked to the number of rural poor by geographic region and production environment. Low market surplus farming nonetheless remains important at the country level, particularly in Indonesia, Nepal, and the Philippines. It is therefore important for these countries to continue investing (even if modestly) in low market surplus farming research. As such, mechanisms to promote spillovers from research on more commercial areas to low market surplus farming environments ought to be established and encouraged.

Table 6.7. Top 30 priority constraints to maize production according to the production-based marginality index, Asia (with and without STMA-commercial maize production in India and excluding Southwest China's low market surplus maize production systems).

	With STMA-commercial production in India			Without STMA-commercial production in India		
Constraint marginality ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Efficiency ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Efficiency ranking
1	RFUP-semi-commercial	Drought	2	RFUP-semi-commercial	Drought	2
2	RFUP-semi-commercial	Soil erosion/landslides	9	RFUP-semi-commercial	Soil erosion/landslides	14
3	STMA-commercial	Post-flowering stalk rot	21	RFUP-commercial	Drought	3
4	RFUP-commercial	Drought	3	RFLL-semi-commercial	Drought	1
5	RFLL-commercial	Drought	1	RFUP-semi-commercial	Low output prices	16
6	RFUP-semi-commercial	Low output prices	17	RFUP-semi-commercial	Inappropriate fertilizer use	4
7	RFUP-semi-commercial	Inappropriate fertilizer use	4	RFUP-semi-commercial	Lack of post-harvest facilities	18
8	STMA-commercial	Lack of quality seed	27	RFUP-commercial	Poor availability of quality seed	5
9	RFLL-semi-commercial	Lack of capital/low interest credit, inadequate credit support	22	RFUP-semi-commercial	Downy mildew	17
10	RFUP-semi-commercial	Downy mildew	18	RFUP-semi-commercial	Weeds	37
11	RFUP-semi-commercial	Lack of post-harvest facilities	19	RFLL-commercial	Corn borers (ear/stem borers)	6
12	RFUP-commercial	Poor availability of quality seed	5	RFUP-commercial	Downy mildew	10
13	RFUP-semi-commercial	Weeds	37	RFUP-commercial	Stem borers	12
14	RFUP-semi-commercial	Soil infertility and acidity	16	RFUP-commercial	Weeds and weed management	8
15	RFLL-semi-commercial	Drought	23	RFLL-semi-commercial	Lack of capital/low interest credit, inadequate credit support	31
16	RFLL-commercial	Corn borers (ear/stem borers)	6	RFUP-commercial	Soil infertility	15
17	RFUP-commercial	Downy mildew	11	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	32
18	RFUP-commercial	Stem borers	13	RFUP-semi-commercial	Soil infertility and acidity	19
19	RFUP-commercial	Weeds and weed management	8	RFLL-semi-commercial	Drought	27
20	RFUP-semi-commercial	Limited capital/access to credit	25	RFUP-commercial	Soil erosion	13
21	RFUP-commercial	Soil infertility	15	RFLL-commercial	Rust	9
22	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	39	RFUP-semi-commercial	Limited capital/access to credit	34
23	RFLL-semi-commercial	Rodents	43	RFLL-commercial	Waterlogging	11
24	RFLL-semi-commercial	Post-harvest pests and diseases	49	RFLL-semi-commercial	Poor marketing system, input/ output market access and undeveloped transport system	49
25	STMA-commercial	Improper/inadequate use of fertilizers	53	RFLL-semi-commercial	Rodents	45
26	RFUP-semi-commercial	High price of inputs (including seed, transport)	36	RFUP-semi-commercial	High price of inputs (including seed, transport)	40
27	RFLL-semi-commercial	Low technology adoption	57	RFUP-semi-commercial	Limited farmer access to information and technology due to poor extension	41
28	STMA-commercial	Post-harvest losses (weevils during storage)	58	RFLL-semi-commercial	Post-harvest pests and diseases	61
29	RFLL-semi-commercial	Low fertilizer use	61	RFUP-semi-commercial	Stalk rot	43
30	RFUP-semi-commercial	Limited farmer access to information and technology due to poor extension	38	RFLL-commercial	Soil infertility	20

By maize production environment and market orientation	Frequency count (no. of priority constraints)	By maize production environment and market orientation	Frequency count (no. of priority constraints)
Irrigated-commercial	0	Irrigated-commercial	0
RFLL-semi-commercial	7	RFLL-semi-commercial	6
RFLL-commercial	2	RFLL-commercial	5
RFUP-semi-commercial	11	RFUP-semi-commercial	12
RFUP-commercial	6	RFUP-commercial	7
STMA-commercial	4		
By type of constraint		**By type of constraint**	
Drought	4	Drought	4
Biotic	10	Biotic	10
Abiotic	3	Abiotic	6
Socioeconomic/policy	13	Socioeconomic/policy	10

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

6.2.2 Priorities by maize production environment and market orientation

To gain a better picture of priority constraints by maize production environment and market orientation across Asia, the list of top 30 priority constraints according to a production-based combined index was augmented with a few selected lower-priority constraints reported prevalent in the other maize production and market orientation areas. These lower-priority constraints were intentionally selected to show the type and extent of specific constraints experienced by Asian maize farmers. Table 6.9 shows the supplemented list of priority maize constraints; constraints not included among the top 30 regional priorities have their regional ranking according to a production-based combined index indicated in parenthesis. Constraints that entered

Table 6.8a. Top 30 priority constraints to maize production according to the production-based combined index, Asia (with STMA-commercial production areas of India and excluding Southwest China's low market surplus maize production systems).

Maize production environment and market orientation	Farmer-identified maize production constraint	Ranking by index used			
		Efficiency	Poverty	Marginality	Combined
STMA-commercial	Post-flowering stalk rot (PFSR)	21	1	3	1
STMA-commercial	Lack of quality seed	27	2	8	2
STMA-commercial	Imbalanced/improper/inadequate fertilizer use	53	3	25	3
RFUP-commercial	Drought	3	6	4	4
STMA-commercial	Post-harvest losses (due to weevils during storage)	58	4	28	5
STMA-commercial	Improper cropping systems (mixed cropping/intercropping)	64	5	36	6
RFUP-commercial	Poor availability of appropriate varieties and quality seed	5	7	12	7
RFUP-commercial	Weeds and weed management	8	8	19	8
RFUP-commercial	Downy mildew	11	9	17	9
RFUP-commercial	Stem borers	13	12	18	10
STMA-commercial	Transplanting maize under late sown condition	45	10	34	11
STMA-commercial	*Turcicum* leaf blight	46	11	35	12
STMA-commercial	Moisture stress (drought)	129	13	83	13
RFLL-commercial	Drought	1	22	5	14
STMA-commercial	Lack of appropriate maturity varieties	130	14	86	15
STMA-commercial	Stem borers	134	15	95	16
STMA-commercial	*Maydis* leaf blight	139	16	107	17
RFUP-commercial	Post-flowering stalk rot (PFSR)	34	17	49	18
Irrigated-commercial	Lack of capital	28	18	43	19
Irrigated-commercial	Inefficient fertilizer use/inappropriate fertilizer application	31	19	45	20
RFUP-commercial	Storage pests	40	20	53	21
RFUP-semi-commercial	Drought	2	33	1	22
RFUP-commercial	*Turcicum* leaf blight	42	21	55	23
Irrigated-commercial	Undeveloped irrigation system (water shortage)	29	24	52	24
RFLL-commercial	Corn borers (ear/stem borers)	6	28	16	25
RFUP-commercial	Banded leaf and sheath blight	44	23	62	26
RFUP-semi-commercial	Soil erosion/landslides	9	31	2	27
Irrigated-commercial	Rodents	47	26	65	28
Irrigated-commercial	High production costs/input prices	41	27	59	29
STMA-commercial	Inappropriate crop establishment method	119	25	138	30

By maize production environment and market orientation	Frequency count (no. of priority constraints)
Irrigated-commercial	5
RFLL-semi-commercial	0
RFLL-commercial	2
RFUP-semi-commercial	2
RFUP-commercial	9
STMA-commercial	12
By type of constraint	
Drought	3
Biotic	14
Abiotic	11
Socioeconomic/policy	2

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

the priority list that did not include India's STMA-commercial maize production areas are listed in italics. Some of the specific constraints added may already have been on the regional priority constraints list, but associated with a different production environment or market orientation. For example, poor quality of hybrid seed was added to the rainfed upland-semi-commercial environment, but its equivalent—poor availability of quality seed—was already listed as a priority constraint in the rainfed upland-commercial areas. Noticeably, important constraints, such as poor farm-to-market roads in rainfed upland-low market surplus areas and nematodes in STMA-semi-commercial environments, were close to the bottom of the full priority list based on the combined index.

Table 6.8b. Top 30 priority constraints to maize production according to the production-based combined index, Asia (without STMA-commercial production areas of India and excluding Southwest China's low market surplus maize production systems).

Maize production environment and market orientation	Farmer-identified maize production constraint	Ranking by index used			
		Efficiency	Poverty	Marginality	Combined
RFUP-commercial	Drought	3	1	3	1
RFUP-commercial	Poor availability of appropriate varieties and quality seed	3	5	2	2
RFUP-commercial	Weeds and weed management	8	3	14	3
RFUP-commercial	Downy mildew	10	4	12	4
RFUP-commercial	Stem borers	12	5	13	5
RFLL-commercial	Drought	1	11	4	6
RFUP-commercial	Post-flowering stalk rot (PFSR)	29	6	36	7
Irrigated-commercial	Lack of capital	23	7	31	8
Irrigated-commercial	Inefficient fertilizer use/inappropriate fertilizer application	26	8	33	9
RFUP-commercial	Storage pests	33	9	40	10
RFUP-commercial	*Turcicum* leaf blight	36	10	42	11
Irrigated-commercial	Undeveloped irrigation system (water shortage)	24	13	39	12
RFUP-commercial	Banded leaf and sheath blight	38	12	46	13
RFLL-commercial	Corn borers (ear/stem borers)	6	16	11	14
Irrigated-commercial	Rodents	39	14	52	15
RFUP-semi-commercial	Drought	2	22	1	16
Irrigated-commercial	High production costs/input prices	35	15	44	17
RFUP-semi-commercial	Soil erosion/landslides	14	20	2	18
RFUP-commercial	Soil erosion	13	21	20	19
RFLL-semi-commercial	Lack of capital/low interest credit, inadequate credit support	31	17	15	20
RFLL-semi-commercial	Lack of suitable (hybrid) varieties	32	18	17	21
RFLL-semi-commercial	Drought	27	23	19	22
RFUP-semi-commercial	Soil infertility and acidity	19	28	18	23
Irrigated-commercial	Waterlogging	46	19	65	24
Irrigated-commercial	Lack of labor	53	24	70	25
Irrigated-commercial	Downy mildew	56	25	117	26
RFUP-commercial	Soil infertility	15	31	16	27
RFLL-semi-commercial	Rodents	45	27	25	28
Irrigated-commercial	Leaf blight/rust (foliar diseases)	59	26	79	29
RFLL-semi-commercial	Inadequate post-harvest technologies/facilities	65	29	34	30

By maize production environment and market orientation	Frequency count (no. of priority constraints)
Irrigated-commercial	9
RFLL-semi-commercial	5
RFLL-commercial	2
RFUP-semi-commercial	3
RFUP-commercial	11
By type of constraint	
Drought	4
Biotic	12
Abiotic	5
Socioeconomic/policy	9

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.

Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

6.3 Area-based Priority Constraints

6.3.1 Major findings

Based on the efficiency index. Table 6.10 shows the top 30 regional constraints, associated by maize production environment and market orientation, according to an area-based efficiency index. In both priority lists (with and without India's STMA-commercial maize production areas), most of the top 30 area-based priority constraints were reported by farmers to be prevalent in the rainfed upland (semi-commercial and commercial) maize production environments. Both lists are dominated by biotic constraints, as well as socioeconomic and policy-related constraints to maize production.

Table 6.9. Production-based priority constraints to maize productivity by production environment and market orientation, Asia (with and without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems).

Maize production environment	Market orientation of maize production		
	Low market surplus	Semi-commercial	Commercial
Irrigated			Lack of capital Inefficient fertilizer use Undeveloped irrigation system (water shortage) Rodents High production costs/input prices *Waterlogging* *Lack of labor* *Downy mildew* *Leaf blight and rust (foliar diseases)* Waterlogging/crop establishment (37) Stem borers (94) Lack of post-harvest facilities (158)
Rainfed lowland		*Lack of capital/low interest credit, inadequate credit support* *Drought* *Rodents* *Inadequate post-harvest technologies and facilities* Lack of suitable (hybrid) varieties (34) Poor marketing system (50) Low technology adoption (72) Poor technology transfer system (81)	Drought Corn borers (ear/stem borers) Rust (42) Soil infertility (58)
Rainfed upland	Ineffective financial scheme (190) Low soil fertility (194) Poor farm-to-market roads (195)	Drought Soil erosion/landslides *Soil infertility and acidity* Poor quality of hybrid seeds (91) Rodents (99) Poor farm-to-market roads (102) Leaf blight (120)	Drought Poor availability of appropriate varieties and quality seed Weeds and weed management Downy mildew Stem borers Post-flowering stalk rot Storage pests *Turcicum* leaf blight Banded leaf and sheath blight *Soil erosion* *Soil infertility*
Subtropical/ mid-altitude	Declining soil fertility (108) Lack of suitable improved varieties (116) Termite/white grubs (138) Soil acidity (152)	Inadequate availability of quality seeds (218) Stem borers (222) Improper maize-based intercropping system (225) Nematodes (231)	Post-flowering stalk rot Lack of quality seed Imbalanced use of fertilizers Post-harvest losses Improper cropping systems Transplanting maize under late sown conditions *Turcicum* leaf blight Moisture stress (drought) Lack of appropriate maturity varieties Stem borers *Maydis* leaf blight Inappropriate crop establishment method

Note: In the above table, constraints when including India's STMA-commercial maize production areas are listed in regular font; those in the scenario excluding these production areas are listed in italics.

Table 6.10. Top 30 priority constraints to maize production according to the area-based efficiency index, Asia (with and without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems).

Area-based efficiency ranking	With STMA-commercial production in India			Without STMA-commercial production in India		
	Maize production environment and market orientation	Farmer-identified maize production constraint	Production-based efficiency ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Production-based efficiency ranking
1	RFUP-semi-commercial	Drought	2	RFUP-semi-commercial	Drought	2
2	RFUP-semi-commercial	Inappropriate fertilizer use	4	RFUP-semi-commercial	Inappropriate fertilizer use	4
3	RFUP-semi-commercial	Lack of appropriate variety	7	RFUP-semi-commercial	Lack of appropriate variety	7
4	STMA-commercial	Post-flowering stalk rot (PFSR)	21	RFUP-semi-commercial	Soil erosion and landslides	14
5	RFUP-semi-commercial	Soil erosion and landslides	9	RFUP-semi-commercial	Downy mildew	17
6	STMA-commercial	Lack of quality seed	27	RFUP-commercial	Drought	3
7	RFUP-semi-commercial	Downy mildew	18	RFUP-semi-commercial	Low output prices	16
8	RFUP-commercial	Drought	3	RFLL-commercial	Drought	1
9	RFUP-semi-commercial	Low output prices	17	RFUP-semi-commercial	Soil infertility and acidity	19
10	RFLL-commercial	Drought	1	RFUP-semi-commercial	Lack of post-harvest facilities	18
11	RFUP-semi-commercial	Soil infertility and acidity	16	RFUP-commercial	Poor availability of quality seed	5
12	RFUP-semi-commercial	Lack of post-harvest facilities	19	RFLL-semi-commercial	Lack of capital/low interest credit source (inadequate credit support)	31
13	RFUP-commercial	Poor availability of quality seed	5	RFLL-semi-commercial	Drought	27
14	RFLL-semi-commercial	Lack of capital/low interest credit source (inadequate credit support)	22	RFUP-commercial	Weeds and weed management	8
15	RFLL-semi-commercial	Drought	23	RFUP-commercial	Downy mildew	10
16	RFUP-commercial	Weeds and weed management	8	RFLL-commercial	Corn borers (ear/stem borers)	6
17	RFUP-commercial	Downy mildew	11	RFUP-semi-commercial	Limited capital / access to credit	34
18	RFLL-commercial	Corn borers (ear/stem borers)	6	RFUP-commercial	Soil erosion	13
19	RFUP-semi-commercial	Limited capital / access to credit	25	RFUP-commercial	Soil infertility	15
20	RFUP-commercial	Soil erosion	14	RFUP-commercial	Stem borers	12
21	RFUP-commercial	Soil infertility	15	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	32
22	RFUP-commercial	Stem borers	13	RFUP-semi-commercial	High input prices (especially seed, transport)	40
23	STMA-commercial	Imbalanced/improper/ inadequate use of fertilizers	53	RFUP-semi-commercial	Weeds	37
24	STMA-commercial	Post-harvest losses (due to weevils during storage)	58	RFUP-semi-commercial	Farmers' limited access to information and technology due to poor extension	41
25	RFUP-semi-commercial	Pests and diseases (ear rot, stalk rot)	32	RFLL-semi-commercial	Rodents	45
26	STMA-commercial	Inadequate cropping systems (mixed cropping/ intercropping)	64	RFLL-commercial	Rust	9
27	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	39	RFUP-semi-commercial	Stalk rot	43
28	RFUP-semi-commercial	High input prices (especially seed, transport)	36	RFLL-commercial	Waterlogging	11
29	RFUP-semi-commercial	Weeds	37	RFLL-semi-commercial	Post-harvest pests and diseases	61
30	RFUP-semi-commercial	Farmers' limited access to information and technology due to poor extension	38	RFLL-semi-commercial	Sloping land and soil erosion	62

By maize production environment and market orientation	Frequency count (no. of constraints)	By maize production environment and market orientation	Frequency count (no. of constraints)
Irrigated-commercial	0	Irrigated-commercial	0
RFLL-semi-commercial	3	RFLL-semi-commercial	6
RFLL-commercial	2	RFLL-commercial	4
RFUP-semi-commercial	13	RFUP-semi-commercial	13
RFUP-commercial	7	RFUP-commercial	7
STMA-commercial	5		
By type of constraint		**By type of constraint**	
Drought	4	Drought	4
Biotic	9	Biotic	10
Abiotic	4	Abiotic	6
Socioeconomic/policy	13	Socioeconomic/policy	10

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

A similar exercise was carried out for maize systems in China's Southwest agroecological region. Due to the similarity of the information and magnitudes conveyed by area and production data across maize systems, there was no difference in efficiency rankings between the production-based priority ranking results presented in Table 6.4b and the results of area-based prioritization. The top 30 constraints in China's Southwest all pertained to drought and to biotic constraints and socioeconomic and policy-related problems in the rainfed upland low market surplus spring maize production system.

For the rest of Asia, area-based prioritization indicated that addressing the problem of drought in the rainfed upland-semi-commercial environments first will provide the highest returns to maize R&D in Asia. Alleviating the drought problem will impact a maize area of around 3 M ha (24% of the regional total), with an average maize yield of 2.8 t/ha, that supports an estimated 6.25 million rural poor in Asia. These environments cover the drylands of Java and Bali (Indonesia), the upland, rolling-to-hilly areas of Southern Mindanao (Philippines), and the unfavorable uplands in the lower northeast region of Thailand. Other maize production constraints included in the priority list were biotic constraints such as post-flowering stalk rot, downy mildew, weeds and stem borers, and abiotic constraints such as soil erosion/landslides and soil infertility and acidity. Socioeconomic and policy-related constraints, however, dominated the priority lists and included, among others, lack of quality seed, low output prices, lack of post-harvest facilities, lack of capital or of low-interest credit, and inadequate credit support from the government.

A closer look reveals that eight to ten constraints not included in the priority list according to the production-based efficiency index (discussed in section 6.2.1) are included in Table 6.10. The new entrants are mostly socioeconomic and policy-related constraints from the rainfed upland-semi-commercial and STMA maize environments. They range from lack of suitable (hybrid) varieties to inappropriate cropping systems and farmers' limited access to information and technology, all of which reflect inadequate or poor agricultural extension services to maize farmers in these areas.

Of the top 30 priority constraints in Asia (including India's STMA-commercial maize areas and excluding Southwest China's rainfed upland low market surplus areas) according to the area-based efficiency index alone, socioeconomic and policy-related constraints are estimated to impact 9.3 M ha (73.8% of the regional total) and about 78.3% of Asia's rural poor. The set of biotic constraints in the priority list comes next, affecting 8.9 M ha and 161.7 million rural poor Table 6.11a). However, without India's STMA-commercial maize production environments and Southwest China's rainfed upland low market surplus areas, the set of biotic constraints appear to have the highest estimated impacts, affecting about 7 M ha (76.7% of the total maize area) and 56.9 million rural poor (43.4% of the regional total). It is estimated that alleviating that set of biotic constraints would improve maize yields by an average of nearly 20% (Table 6.11b).

Based on the poverty index. When included, constraints reported from Asia's STMA-commercial maize production environments composed the top 10 priority constraints based on the poverty index alone (Table 6.12), led by post-flowering stalk rot, lack of quality seed, and imbalanced or inadequate fertilizer use. These environments include all maize production zones in India's Uttar Pradesh, Madhya Pradesh, Rajasthan, and Bihar, and account for about 16% of Asia's maize production, grown on 27% of the maize area. However, nearly 56% of the region's rural poor live in these environments, where average maize yields are barely 1.03 t/ha (see Table 6.3).

In contrast to priorities determined using the area-based efficiency index, which were dominated by socioeconomic and policy-related constraints, those based on the poverty index consisted mostly of biotic constraints (15 in all) such as post-flowering stalk rot, *Turcicum* leaf blight, stem borers, *Maydis* leaf blight, and downy mildew. These biotic constraints were estimated to affect about 6 M ha of maize area (47.8% of the regional total) and 171.2 million rural poor (nearly 81% of the regional total) (Table 6.11a). Noticeably, 17 of the priority constraints in Table 6.12 are new entrants that received lower priority according to the area-based efficiency index. Most (14) of these new entrants are constraints reported from the STMA-commercial maize production environments of Asia.

Meanwhile, 21 of the constraints on the priority list according to the production-based poverty index are included in Table 6.12, and again most (seven) of the nine new entrants are prevalent in the STMA-commercial maize production environments. The new entrants are mostly biotic constraints (banded leaf and sheath blight, brown stripe downy mildew, termites, and nematodes). These results consistently show the influence on the poverty-based priority constraints lists of the STMA-commercial production environments' share in the regional number of rural poor.

Without India's STMA-commercial maize production environments, constraints from the rainfed upland-commercial maize production environments dominated the top 30 priority list, led by drought, poor availability of quality seed, and weeds. These constraints were reportedly prevalent in the low to high rainfall zones of Karnataka and Andhra Pradesh

Table 6.11a. Selected indicators of impact of top 30 area-based priority maize productivity constraints in Asia (with STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems).

	Farmer-identified maize productivity constraints				Farmer-identified maize productivity constraints			
Impact indicators	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeconomic/policy-related	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeconomic/policy-related
	Based on efficiency index				Based on poverty index			
Effective total area affected (000 ha)	6,767.4	4,253.9	8,876.0	9,339.9	2,730.4	6,255.3	6,056.8	6,484.4
Estimated maize production across areas affected (000 t)	16,344.7	9,513.4	17,817.8	16,515.7	6,350.3	9,260.3	12,533.1	12,283.8
Average yield gain when constraint is alleviated (%)	35.0	33.7	17.1	31.0	38.8	24.4	8.8	18.8
Estimated no. of rural poor affected (millions)	47.7	12.6	161.7	166.3	37.3	124.5	171.2	178.1
	Based on marginality index				Based on combined index			
Effective total area affected (000 ha)	5,432.7	3,904.3	7,780.5	7,987.5	6,767.4	6,482.2	6,188.0	6,943.9
Estimated maize production across areas affected (000 t)	11,387.9	6,960.8	11,415.9	12,230.2	16,344.7	10,003.6	10,495.2	12,692.2
Average yield gain when constraint is alleviated (%)	37.6	29.5	16.8	33.5	35.0	29.9	10.2	21.1
Estimated no. of rural poor affected (millions)	41.2	14.5	142.2	139.8	47.7	124.8	158.1	180.0

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: The geographic regions and environments where specific constraints (except drought) under each of the above groups are reported are not necessarily mutually exclusive. However, careful calculations were made to avoid double counting in the above parameters.

Table 6.11b. Selected indicators of impact of top 30 area-based priority maize productivity constraints in Asia (without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems).

	Farmer-identified maize productivity constraints				Farmer-identified maize productivity constraints			
Impact indicators	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeconomic/policy-related	Drought	Other abiotic problems	Biotic (pests and diseases)	Socioeconomic/policy-related
	Based on efficiency index				Based on poverty index			
Effective total area affected (000 ha)	6,767.4	5,937.9	7,050.7	5,995.2	6,767.4	4,679.6	6,902.0	4,649.1
Estimated maize production across areas affected (000 t)	16,344.7	13,975.5	16,491.0	12,449.5	16,344.7	10,838.6	16,386.7	10,405.8
Average yield gain when constraint is alleviated (%)	35.0	28.8	19.7	35.7	35.0	27.4	15.8	28.3
Estimated no. of rural poor affected (millions)	47.7	23.3	56.9	52.8	47.7	29.0	74.9	73.8
	Based on marginality index				Based on combined index			
Effective total area affected (000 ha)	6,767.4	4,773.7	7,617.0	5,995.2	6,767.4	4,142.4	6,918.8	6,550.1
Estimated maize production across areas affected (000 t)	16,344.7	9,550.5	15,202.9	12,449.5	16,344.7	9,166.9	16,437.0	14,074.6
Average yield gain when constraint is alleviated (%)	35.0	33.5	22.3	38.9	35.0	29.7	15.5	30.4
Estimated no. of rural poor affected (millions)	47.7	18.5	50.6	52.8	47.7	12.5	74.8	74.0

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: The geographic regions and environments where specific constraints (except drought) under each of the above groups are reported are not necessarily mutually exclusive. However, careful calculations were made to avoid double counting in the above parameters.

Table 6.12. Top 30 priority constraints to maize production according to the area-based poverty index, Asia (with and without STMA-commercial maize production areas of India and excluding China's Southwest low market surplus maize production systems).

	With STMA-commercial production, India				Without STMA-commercial production, India			
Area-based poverty ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Prod'n-based poverty rank	Area-based efficiency rank	Maize production environment and market orientation	Farmer-identified maize production constraint	Prod'n-based poverty rank	Area-based efficiency rank
1	STMA-commercial	Post-flowering stalk rot	1	4	RFUP-commercial	Drought	1	6
2	STMA-commercial	Lack of quality seed	2	6	RFUP-commercial	Poor availability of quality seed	2	11
3	STMA-commercial	Imbalanced /improper/ inadequate use of fertilizers	3	23	RFUP-commercial	Weeds and weed management	3	14
4	STMA-commercial	Post-harvest losses (due to weevils during storage)	4	24	RFUP-commercial	Downy mildew	4	15
5	STMA-commercial	Improper cropping systems (mixed cropping/intercropping)	5	26	RFUP-commercial	Stem borers	5	20
6	STMA-commercial	Transplanting maize under late sown conditions	10	33	RFLL-semi-commercial	Lack of capital/low interest credit, inadequate credit support	17	12
7	STMA-commercial	Turcicum leaf blight	11	34	Irrigated-commercial	Lack of capital	7	36
8	STMA-commercial	Moisture stress (drought)	13	72	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	18	21
9	STMA-commercial	Lack of appropriate maturity varieties	14	75	RFLL-semi-commercial	Drought	23	13
10	STMA-commercial	Stem borers	15	84	Irrigated-commercial	Inefficient fertilizer use	8	38
11	RFUP-commercial	Drought	6	8	RFLL-semi-commercial	Rodents	27	25
12	STMA-commercial	Maydis leaf blight	16	90	RFUP-commercial	Post-flowering stalk rot	6	49
13	RFUP-commercial	Poor availability of quality seed	7	13	RFUP-semi-commercial	Soil erosion/landslides	20	4
14	RFUP-commercial	Weeds and weed management	8	16	Irrigated-commercial	Undeveloped irrigation system (water shortage)	13	39
15	RFUP-commercial	Downy mildew	9	17	RFUP-commercial	Storage pests	9	54
16	RFUP-commercial	Stemborers	12	22	RFUP-semi-commercial	Drought	22	1
17	STMA-commercial	Inappropriate crop establishment method	25	105	RFUP-commercial	Turcicum leaf blight	10	55
18	STMA-commercial	Lack of location-specific transfer of technology for rainfed conditions, esp for farm women	42	117	RFUP-commercial	Banded leaf and sheath blight	12	57
19	STMA-commercial	Banded leaf and sheath blight	43	119	RFLL-commercial	Drought	11	8
20	STMA-commercial	Broadleaf and grassy weeds	44	120	Irrigated-commercial	High production costs/input prices	15	46
21	STMA-commercial	Brown stripe downy mildew	46	124	RFUP-semi-commercial	Soil infertility and acidity	28	9
22	Irrigated-commercial	Lack of capital	18	43	RFLL-semi-commercial	Inadequate postharvest technologies/facilities	29	51
23	STMA-commercial	Rodents	48	125	RFLL-semi-commercial	Poor marketing system, input/ output market access and undeveloped transport system	30	31
24	STMA-commercial	Termites	49	126	Irrigated-commercial	Rodents	14	68
25	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	30	27	RFUP-semi-commercial	Weeds	32	23
26	RFLL-semi-commercial	Drought	29	15	RFLL-commercial	Corn borers (ear/stem borers)	16	16
27	Irrigated-commercial	Inefficient fertilizer use	19	45	Irrigated-commercial	Waterlogging	19	59
28	STMA-commercial	Nematodes	50	130	RFUP-semi-commercial	Limited capital/access to credit	38	17
29	RFLL-semi-commercial	Rodents	32	31	RFUP-commercial	Soil erosion	21	18
30	RFUP-semi-commercial	Soil erosion/landslides	31	5	Irrigated-commercial	Lack of labor	24	70

By maize production environment and market orientation	Frequency count (no. of priority constraints)	By maize production environment and market orientation	Frequency count (no. of priority constraints)
Irrigated-commercial	2	Irrigated-commercial	7
RFLL-semi-commercial	3	RFLL-semi-commercial	6
RFLL-commercial	0	RFLL-commercial	2
RFUP-semi-commercial	1	RFUP-semi-commercial	5
RFUP-commercial	5	RFUP-commercial	10
STMA-commercial	19		
By type of constraint		**By type of constraint**	
Drought	2	Drought	4
Biotic	15	Biotic	11
Abiotic	2	Abiotic	4
Socioeconomic/policy	11	Socioeconomic/policy	11

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

states of India and in the drylands of Indonesia's outer islands. Biotic as well as socioeconomic and policy-related constraints dominated this priority scenario. These groups of constraints impact an estimated 74.9 and 73.8 million rural poor, respectively, and their alleviation would improve maize yields by about 16% and 28%, respectively (Table 6.11b).

Based on the marginality index. Including India's STMA-commercial areas, the 30 top priority constraints based on the marginality index alone come almost equally from rainfed lowland- and rainfed upland-semi-commercial production environments, and are mostly (16) socioeconomic and policy-related constraints (Table 6.13). All together, the marginality-based priority socioeconomic and policy-related constraints impact an estimated total maize area of nearly 8 M ha, whose average maize yield is only about 1.9 t/ha, and an estimated 140 million rural poor people, or nearly 66% of Asia's rural poor population (Table 6.11a).

Similar to results using the poverty index, post-flowering stalk rot and lack of quality seed in the STMA-commercial maize areas were the top two priority constraints that maize R&D in Asia ought to address based on the marginality index alone. Also similar to area-based priorities according to the efficiency index, the top 30 marginality-based productivity constraints included mostly socioeconomic and policy-related constraints such as lack of capital or of low-interest credit and low technology adoption in rainfed lowland-semi-commercial areas, and low output prices in rainfed upland-semi-commercial areas. Other top priorities included abiotic (drought, soil erosion, and landslides) and biotic constraints (downy mildew, weevils during storage, weeds, and rodents).

Interestingly, the above general trend in constraint prioritization remains even when the STMA-commercial maize production environments of India are excluded from the analysis. That is, constraints

Table 6.13. Top 30 priority constraints to maize production according to the area-based marginality index, Asia (with and without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems).

	With STMA-commercial production, India				Without STMA-commercial production, India			
Area-based marginality ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Prod'n-based marginality rank	Area-based efficiency rank	Maize production environment and market orientation	Farmer-identified maize production constraint	Prod'n-based marginality rank	Area-based efficiency rank
1	STMA-commercial	Post-flowering stalk rot	3	4	RFUP-semi-commercial	Drought	1	1
2	STMA-commercial	Lack of quality seed	8	6	RFUP-semi-commercial	Soil erosion/landslides	2	4
3	RFUP-semi-commercial	Drought	1	1	RFLL-semi-commercial	Lack of capital/low interest credit source (inadequate credit support)	15	12
4	RFUP-semi-commercial	Soil erosion/landslides	2	5	RFUP-semi-commercial	Downy mildew	9	5
5	RFLL-semi-commercial	Lack of capital/low interest credit, inadequate credit support	9	14	RFUP-semi-commercial	Low output prices	5	7
6	STMA-commercial	Inadequate fertilizer use	25	23	RFUP-semi-commercial	Inappropriate fertilizer use	6	2
7	RFUP-semi-commercial	Downy mildew	10	7	RFUP-semi-commercial	Lack of post-harvest facilities	7	10
8	RFUP-semi-commercial	Low output prices	6	9	RFUP-semi-commercial	Weeds	10	23
9	STMA-commercial	Post-harvest losses (weevils during storage)	28	24	RFLL-semi-commercial	Drought	19	13
10	STMA-commercial	Inappropriate cropping systems (mixed cropping/inter-cropping)	36	26	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	17	21
11	RFUP-semi-commercial	Inappropriate fertilizer use	7	2	RFLL-semi-commercial	Post-harvest pests and diseases	28	29
12	RFUP-semi-commercial	Lack of post-harvest facilities	11	12	RFUP-semi-commercial	Limited capital / access to credit	22	17
13	RFUP-semi-commercial	Weeds	13	29	RFLL-semi-commercial	Rodents	25	25
14	RFLL-semi-commercial	Drought	15	15	RFUP-semi-commercial	Soil infertility and acidity	18	9
15	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	22	27	RFLL-semi-commercial	Low technology adoption	47	32
16	RFLL-semi-commercial	Post-harvest pests and diseases	24	36	RFUP-semi-commercial	High input prices (including seed, transport)	26	22
17	RFUP-semi-commercial	Limited capital/access to credit	20	19	RFLL-semi-commercial	Low fertilizer use	51	33
18	RFLL-semi-commercial	Rodents	23	31	RFUP-semi-commercial	Farmers' limited access to information and technology due to poor extension	27	24
19	RFUP-semi-commercial	Soil infertility and acidity	14	11	RFLL-semi-commercial	Poor marketing system, input/output market access and undeveloped transport system	24	31

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

Table 6.13. Top 30 priority constraints to cont'd....

	With STMA-commercial production, India				Without STMA-commercial production, India			
Area-based marginality ranking	Maize production environment and market orientation	Farmer-identified maize production constraint	Prod'n-based marginality rank	Area-based efficiency rank	Maize production environment and market orientation	Farmer-identified maize production constraint	Prod'n-based marginality rank	Area-based efficiency rank
20	RFLL-semi-commercial	Low technology adoption	27		RFUP-commercial	Drought	3	6
21	STMA-commercial	Transplanting maize under late sown conditions	34	33	RFUP-semi-commercial	Stalk rot	29	27
22	STMA-commercial	Turcicum leaf blight	35	34	RFLL-semi-commercial	Sloping land and soil erosion	32	30
23	RFUP-semi-commercial	High input prices (including seed, transport)	26	28	RFLL-semi-commercial	High input prices (including transport, credit)	63	45
24	RFLL-semi-commercial	Low fertilizer use	29	40	RFUP-commercial	Poor availability of quality seed	8	11
25	RFUP-semi-commercial	Limited access to information and technology at farmers' level due to poor extension	30	30	RFLL-commercial	Drought	4	8
26	RFLL-semi-commercial	Poor marketing system, input/output market access and undeveloped transport system	39	38	RFLL-semi-commercial	Weeds (sedges and broad-leaf)	67	48
27	RFUP-commercial	Drought	4	8	RFUP-commercial	Soil infertility	16	19
28	RFLL-semi-commercial	Sloping land and soil erosion	32	37	RFUP-commercial	Downy mildew	12	15
29	RFUP-semi-commercial	Pests and diseases (ear rot, stalk rot)	38	25	RFUP-commercial	Stem borers	13	20
30	RFUP-semi-commercial	High input prices (including seed, transport)	40	51	RFUP-commercial	Weeds and weed management	14	14

By maize production environment and market orientation	Frequency count (no. of constraints)	By maize production environment and market orientation	Frequency count (no. of constraints)
Irrigated-commercial	0	Irrigated-commercial	0
RFLL-semi-commercial	10	RFLL-semi-commercial	11
RFLL-commercial	0	RFLL-commercial	1
RFUP-semi-commercial	12	RFUP-semi-commercial	12
RFUP-commercial	1	RFUP-commercial	6
STMA-commercial	7		
By type of constraint		**By type of constraint**	
Drought	3	Drought	4
Biotic	8	Biotic	9
Abiotic	3	Abiotic	4
Socioeconomic/policy	16	Socioeconomic/policy	13

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

reported from the semi-commercial maize production areas of Asia's rainfed lowlands and rainfed uplands, and those related to socioeconomics and policy dominate the top 30 priorities in this scenario (Table 6.13). Included in these production areas are the drylands in Java and Bali, Indonesia, the upland to rolling to hilly areas in Northern and Southern Mindanao, the Philippines, and the rolling to hilly areas of Thailand's lower north region. Drought and soil erosion/landslides in the rainfed upland-semi-commercial production areas are the top two constraints to be addressed when marginality of the production environment is emphasized. Drought alone impacts about 3.9 million rural poor spread across 2.7 M ha that, on average, yield about 2.6 t/ha. Drought alleviation could add an estimated 35% to maize yields in these areas.

Except for five to seven new entrants, the set of marginality-based priority constraints using share of regional maize area is the same as that based on contribution to regional maize production (Table 6.13). This indicates results are consistent regardless of the parameter used in prioritizing maize R&D based on marginality of the maize production environment.

Based on the combined index. Table 6.14 shows the top 30 priority constraints that, based on the combined index using share of regional maize area, ought to be addressed by maize R&D in Asia. The table also shows how the constraints ranked when contribution to regional maize production was used in prioritization. Nine of the top ten priority constraints were reported

Table 6.14. Top 30 priority constraints to maize production according to the area-based combined index, Asia (with and without STMA-commercial maize production areas of India and excluding Southwest China's low market surplus maize production systems).

Area-based combined index ranking	With STMA commercial production, India: Maize production environment and market orientation	Farmer-identified maize production constraint	Production-based ranking	Without STMA commercial production, India: Maize production environment and market orientation	Farmer-identified maize production constraint	Production-based ranking
1	STMA-commercial	Post-flowering stalk rot	1	RFUP-commercial	Drought	1
2	STMA-commercial	Lack of quality seed	2	RFUP-commercial	Poor availability of appropriate varieties and quality seed	2
3	STMA-commercial	Imbalanced/improper/inadequate use of fertilizers	3	RFUP-commercial	Weeds and weed management	3
4	STMA-commercial	Post-harvest losses (due to weevils during storage)	5	RFUP-commercial	Downy mildew	4
5	STMA-commercial	Improper cropping systems (mixed cropping/ intercropping)	6	RFUP-commercial	Stem borers	5
6	STMA-commercial	Transplanting maize under late sown conditions	11	RFLL-semi-commercial	Lack of capital/low-interest credit, inadequate credit support	20
7	STMA-commercial	Turcicum leaf blight	12	RFUP-semi-commercial	Drought	16
8	STMA-commercial	Moisture stress (drought)	13	RFUP-semi-commercial	Soil erosion/landslides	18
9	STMA-commercial	Lack of appropriate maturity varieties	15	RFLL-semi-commercial	Drought	22
10	RFUP-commercial	Drought	4	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	21
11	STMA-commercial	Stem borers	16	Irrigated-commercial	Lack of capital	8
12	STMA-commercial	Maydis leaf blight	17	RFLL-semi-commercial	Rodents	28
13	RFUP-commercial	Poor availability of appropriate varieties and quality seed	7	Irrigated-commercial	Inefficient fertilizer use/inappropriate fertilizer application	9
14	RFUP-commercial	Weeds and weed management	8	RFLL-commercial	Drought	6
15	RFUP-commercial	Downy mildew	9	RFUP-semi-commercial	Soil infertility and acidity	23
16	RFUP-commercial	Stem borers	10	RFUP-commercial	Post-flowering stalk rot	7
17	RFUP-semi-commercial	Drought	22	Irrigated-commercial	Undeveloped irrigation system (water shortage)	12
18	STMA-commercial	Inappropriate crop establishment method	30	RFUP-commercial	Storage pests	10
19	RFUP-semi-commercial	Soil erosion/landslides	27	RFUP-commercial	Turcicum leaf blight	11
20	RFLL-semi-commercial	Drought	31	RFUP-commercial	Banded leaf and sheath blight	13
21	RFLL-semi-commercial	Lack of suitable (hybrid) varieties	34	Irrigated-commercial	High production costs (input prices)	17
22	RFLL-semi-commercial	Lack of capital/low-interest credit, inadequate credit support	35	RFLL-semi-commercial	Inadequate post-harvest technologies/ facilities	30
23	RFLL-semi-commercial	Rodents	36	RFUP-semi-commercial	Weeds	34
24	RFLL-commercial	Drought	14	RFLL-semi-commercial	Poor marketing system, input/output market access and undeveloped transport system	35
25	Irrigated-commercial	Lack of capital	19	RFUP-semi-commercial	Downy mildew	32
26	RFUP-semi-commercial	Soil infertility and acidity	33	RFLL-commercial	Corn borers (ear/stem borers)	14
27	STMA-commercial	Lack of location-specific technology transfer for rainfed conditions, especially for farm women	60	RFUP-semi-commercial	Limited capital/access to credit	39
28	Irrigated-commercial	Inefficient fertilizer use/inappropriate fertilizer application	20	RFUP-commercial	Soil erosion	19
29	STMA-commercial	Banded leaf and sheath blight	64	Irrigated-commercial	Rodents	15
30	STMA-commercial	Broadleaf and grassy weeds	65	RFUP-semi-commercial	Low output prices	36

By maize production environment and market orientation	Frequency count (no. of constraints)	By maize production environment and market orientation	Frequency count (no. of constraints)
Irrigated-commercial	2	Irrigated-commercial	5
RFLL-semi-commercial	4	RFLL-semi-commercial	6
RFLL-commercial	1	RFLL-commercial	2
RFUP-semi-commercial	3	RFUP-semi-commercial	7
RFUP-commercial	5	RFUP-commercial	10
STMA-commercial	15		
By type of constraint		**By type of constraint**	
Drought	4	Drought	4
Biotic	11	Biotic	12
Abiotic	3	Abiotic	3
Socioeconomic/policy	12	Socioeconomic/policy	11

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001 and country-level maize R&D prioritization workshops 2001-2002.
Note: RFLL – rainfed lowland; RFUP – rainfed upland; STMA – subtropical/mid-altitude.

from the STMA-commercial maize production environments in the Indian states of Uttar Pradesh, Madhya Pradesh, Rajasthan, and Bihar, and are led by post-flowering stalk rot, lack of quality seed, and imbalanced/inadequate fertilizer use. Of the top 30 priority constraints, 15 are specific to the STMA-commercial environments, 8 to the rainfed uplands, 5 to the rainfed lowlands, and 2 to irrigated-commercial environments. Most of these priority constraints are socioeconomic and policy-related problems and biotic constraints. Together, these socioeconomic and policy-related constraints are reported to impact an estimated 6.9 M ha and 180 million rural poor, which represent 55% and 85% of regional totals, respectively (Table 6.11a). Alleviating these constraints could contribute 21% to maize yields in the region. Biotic constraints, meanwhile, impact about 54% of the regional maize area and 22.5% of Asia's rural poor, and it is estimated their alleviation would improve maize yields by 10%. These results confirm that addressing socioeconomic and policy-related constraints would significantly impact maize productivity much more than technology.

When constraints from STMA-commercial environments are excluded from the analysis, constraints reported from the rainfed upland-semi-commercial and commercial maize production environments dominated the list of top 30 priority constraints. Drought is the first priority that should be addressed, followed by poor availability of appropriate varieties and quality seed, then by three biotic constraints—weeds and weed management, downy mildew, and stem borers (Table 6.14). All top five priority constraints were reportedly prevalent in rainfed upland-commercial maize production areas. In this scenario, biotic and socioeconomic and policy-related constraints were estimated to impact 6.9 and 6.5 M ha of maize area, respectively, and about 74-75 million rural poor people. Similarly, it appears that addressing socioeconomic and policy-related constraints could have a greater impact (30%) than addressing biotic constraints only (16%) (Table 6.11b).

Table 6.14 also shows that most of the area-based top 30 priority constraints also appear in the production-based top 30 list. Including India's STMA-commercial areas, eight constraints that were not on the production-based top 30 list made it to the area-based list. Most of these new entrants are socioeconomic and policy-related constraints reported from the rainfed lowland-semi-commercial maize production environments, including the rainfed lowlands of Java and Bali in Indonesia, the *terai* region of Nepal, and the upland plains of Southern Tagalog, Bicol, and Mindanao in the Philippines. Meanwhile, without India's STMA-commercial areas in the analysis, five constraints that ranked lower based on contribution to regional maize production made it to the area-based top 30 priority constraints list. Most of these new entrants were, again, socioeconomic and policy-related constraints reported this time from Asia's rainfed upland-semi-commercial maize production areas. Classified in these environments are the drylands of Java and Bali in Indonesia, the upland, rolling to hilly areas of Bicol and Northern Mindanao in the Philippines, and the northern region of Vietnam.

6.3.2 Priorities by maize production environment and market orientation

Table 6.15 shows the area-based priority constraints across Asia by maize production environment and market orientation, both with and without India's STMA-commercial maize areas, excluding Southwest China's low market surplus production areas, and with the addition of a few selected lower-priority constraints reported in the other maize production environments. Constraints that entered the priority list when India's STMA-commercial maize production areas were included are in regular font; the priority constraints when these production areas have been excluded are in italics. As in the production-based set shown in Table 6.9, some of the specific lower-priority constraints added may already appear on the regional priority constraints list, but associated with different maize production environment and market orientation. In this case, stem borers in the rainfed upland-commercial maize production environments was among the top 30 priority constraints with and without India's STMA-commercial maize production areas, but the same constraint reported in the irrigated-commercial areas ranked only 68 in the latter scenario.

Discussions in Sections 6.2 and 6.3 show that: (a) research prioritization (in this case, of maize productivity constraints) can be done systematically on a scientific basis; (b) priorities for Asian maize R&D can vary depending on the production parameter emphasized; and (c) the top priority constraints to be addressed by Asian maize R&D are similar, whether prioritization was done based on contribution to regional maize production or on share of regional maize area. Results presented here, however, are not intended to be recommendations written in stone; the overall picture has been presented to help guide Asian maize researchers and policymakers. It is also acknowledged that regional and national maize R&D coffers are not unlimited, so all priority constraints cannot be addressed at the same time, and that local politics could revise the priority constraints "recommended" to receive early attention and alleviation.

Table 6.15. Area-based priority constraints to maize productivity by production environment and market orientation, Asia (with and without the STMA-commercial maize production areas of India and excluding Southwest China's low market surplus production areas).

Maize production environment	Market orientation of maize production		
	Low market surplus	Semi-commercial	Commercial
Irrigated			Lack of capital Inefficient fertilizer use *Undeveloped irrigation system (water shortage)* *High production costs/input prices* *Rodents* Downy mildew (42) Stem borers (68) Lack of short-cycle (winter-crop) varieties (114)
Rainfed lowland		Drought Lack of suitable (hybrid) varieties Lack of capital/low interest credit, inadequate credit support Rodents *Inadequate post-harvest technologies and facilities* *Poor marketing system, input/output market access and undeveloped transport system* Low technology adoption 44)	Drought *Corn borers (ear/stem borers)* Waterlogging (51) Flooding (61) Cutworms/armyworms (85)
Rainfed upland	Limited knowledge of proper crop management (132) High production and post-harvest pest incidence (149)	Drought Soil erosion/landslides Soil infertility and acidity *Weeds* *Downy mildew* *Limited capital/access to credit* *Low output prices* Poor farm-to-market roads (80) Lack of labor (125) Waterlogging (160)	Drought Poor availability of appropriate varieties and quality seed Weeds and weed management Downy mildew Stem borers Post-flowering stalk rot Storage pests *Turcicum* leaf blight Banded leaf and sheath blight *Soil erosion* Zinc/micronutrient deficiency (66) Low quality land preparation (166)
Subtropical/ mid-altitude	Lack of suitable improved varieties (86) Soil erosion (95) Soil acidity (117)		Post-flowering stalk rot Lack of quality seed Imbalanced use of fertilizers Post-harvest losses (weevils in storage) Inadequate cropping systems Transplanting maize under late sown conditions *Turcicum* leaf blight Moisture stress (drought) Lack of appropriate maturity varieties Stem borer *Maydis* leaf blight Inappropriate crop establishment method Lack of location-specific technology transfer, especially for farm women Banded leaf and sheath blight Broadleaf and grassy weeds

Note: In the above table, constraints when including India's STMA-commercial maize production areas are listed in regular font; those in the scenario excluding these production areas are listed in italics.

6.4 Economics of Priority Constraints

6.4.1 Production-based priority constraints

Table 6.16 shows the estimated economic value (in PPP dollars) of addressing the top 30 regional priority constraints and constraint groups identified using the combined indices and the top 30 priority constraints for Southwest China using the efficiency-based measure. Both with and without India's STMA-commercial areas, drought appeared to have the highest economic impact on maize production (in terms of estimated gross income loss), i.e., at least PPP$ 503/ha using farm-gate maize grain prices. When India's STMA-commercial areas were included, socioeconomic and policy-related constraints caused the next highest gross income loss; other abiotic constraints came in second when India's STMA-commercial areas were excluded. Biotic constraints (pests and diseases) appear to have the least economic impact among the farmer-identified maize productivity constraints in both scenarios.

Including India's STMA-commercial areas, maize farmers in rainfed upland-semi-commercial and -commercial areas were estimated to lose about PPP$ 450/ha and PPP$ 588/ha, respectively, when drought conditions persist. Among the maize areas affected by drought, the highest economic impact of the constraint is felt in the rainfed upland-commercial areas of Indonesia's outer islands, India's Karnataka and Andhra Pradesh states, and in the upper and lower north regions of Thailand. Looking at more specific production constraints, irrigated-commercial maize farmers, particularly in Vietnam's southeastern region and Mekong River Delta, tend to lose the most income (about PPP$ 708/ha) due to limited capital and/or poor access to low-interest credit. These farmers perceive that they lose as much as 35% of their gross income from maize production due to this constraint, which keeps them from applying needed farm inputs such as fertilizers. *Turcicum* leaf blight in low-to-high rainfall zones of Karnataka and Andhra Pradesh (India) has the least economic impact on maize production, PPP$ 135/ha based on farm-gate grain prices.

In China's Southwest region, the economic impact on maize production of drought alone may range between PPP$ 499/ha and PPP$ 510/ha. Aggregate effects of biotic constraints together with socioeconomic and policy-related constraints have a significant economic impact in terms of estimated gross income losses, PPP$ 704-720/ha and PPP$ 864-883/ha, respectively.

At the environment and market orientation level, the top 30 priority constraints appear to have the highest combined economic impact on maize production in Asia's irrigated-commercial areas including India's STMA-commercial maize environments, and in the rainfed upland-semi-commercial areas when those environments are excluded. Using farm-gate maize prices, commercial maize farmers in irrigated areas can lose about PPP$ 447/ha (Table 6.17) due to all 30 top priority constraints in their area—downy mildew, foliar diseases, rodents, waterlogging,, and inefficient/inappropriate fertilizer application, among them. Rainfed upland-semi-commercial maize farmers, meanwhile, can lose about PPP$ 411/ha,

Table 6.16. Estimated gross income loss in maize production across environments due to the top 30 priority constraints, production-based and area-based combined indices, Asia (PPP $/ha).

	Gross income loss estimates (PPP $/ha)			
	Production-based		Area-based	
Priority constraint/ constraint groups	Using farm-gate prices	Using nearest-market prices	Using farm-gate prices	Using nearest-market prices
With STMA-commercial areas of India				
Drought	511.78	760.36	440.22	607.81
Other abiotic constraints	199.05	264.04	339.03	449.74
Biotic constraints (pests and diseases)	156.41	241.49	176.61	258.84
Socioeconomic and policy-related constraints	284.30	364.60	221.39	275.59
Without STMA-commercial areas of India				
Drought	503.36	694.99	503.36	694.99
Other abiotic constraints	487.27	682.57	415.91	588.72
Biotic constraints (pests and diseases)	174.71	250.89	186.88	273.83
Socioeconomic and policy-related constraints	372.02	455.98	431.21	531.19
Southwest China's maize production systems				
Drought	498.96	510.05	a	a
Other abiotic constraints	356.40	364.32	a	a
Biotic constraints (pests and diseases)	703.89	719.53	a	a
Socioeconomic and policy-related constraints	864.27	883.48	a	a

[a] Identical to corresponding production-based results.

primarily due to abiotic constraints led by drought, soil erosion, and soil infertility and acidity. The latter areas include Java and Bali in Indonesia, Northern and Southern Mindanao Provinces in the Philippines, and the central, upper, and lower northeast regions in Thailand.

6.4.2 Area-based priority constraints

Similar to production-based priority constraints, drought has the highest economic impact on maize production, causing gross income losses of at least PPP$ 440/ha using farm-gate maize grain prices (Table 6.16). The next highest loss in gross income is caused by all other abiotic constraints if the STMA-commercial areas of India are included, and by socioeconomic and policy-related constraints if those environments are excluded. Abiotic constraints include mainly soil erosion, infertility, and acidity, while socioeconomic and policy-related constraints include lack of capital or low-interest credit, lack of quality seed, and poor technology transfer, among others. Biotic constraints (e.g., downy mildew, stem borers, and post-flowering stalk rot) again appear to cause the lowest economic losses of gross income obtained from maize production. These biotic constraints were reported from the drylands of Indonesia's outer islands and from Uttar Pradesh, Madhya Pradesh, Rajasthan, and Bihar, the non-traditional maize-growing states of India.

Table 6.17. Estimated gross income loss in maize production by environment and market orientation across the top 30 priority constraints, using production-based and area-based combined indices, Asia (PPP $/ha).

Maize production environment and market orientation	Estimated income loss using maize farm-gate price		Estimated income loss using maize price at nearest market	
	Production-based	Area-based	Production-based	Area-based
With STMA-commercial areas of India				
Irrigated lowland				
Commercial	447.49	661.84	549.20	812.26
Rainfed lowland				
Semi-commercial	---	291.19	---	326.95
Commercial	361.78	485.12	554.21	743.16
Rainfed upland				
Low market surplus	---	---	---	---
Semi-commercial	348.36	411.25	462.11	545.53
Commercial	259.86	293.76	419.32	474.03
Subtropical/mid-altitude				
Low market surplus	---	---	---	---
Semi-commercial	---	---	---	---
Commercial	*	*	*	*
Without STMA-commercial areas of India				
Irrigated lowland				
Commercial	385.27	447.49	472.83	549.20
Rainfed lowland				
Semi-commercial	260.61	256.13	292.61	287.58
Commercial	361.78	361.78	554.21	554.21
Rainfed upland				
Low market surplus	---	---	---	---
Semi-commercial	411.25	370.58	545.53	491.59
Commercial	301.18	270.01	485.99	435.70
Subtropical/mid-altitude				
Low market surplus	---	---	---	---
Semi-commercial	---	---	---	---
Commercial	•	•	•	•
China's Southwest maize production systems (gain by addressing all top 30 priority constraints in each production system)				
Rainfed spring maize (low market surplus)	2,423.52	**	2,477.38	**
Rainfed summer maize (low market surplus)	2,086.56	**	2,136.24	**
Rainfed fall maize (low market surplus)	1,478.72	**	1,512.32	**

--- Not computed; no constraint from this environment and production system was included in the top 30.
* Not computed; price data not available.
• Not computed; excluded from the analysis.
** Same as corresponding production-based results.

At the production environment and market orientation level, the top 30 priority constraints appear to have the highest combined economic impact on maize production in Asia's irrigated-commercial areas, both with and without India's STMA-commercial maize areas. At farm-gate prices, commercial maize farmers in the irrigated areas could lose at least PPP$ 447/ha (Table 6.17) due to the combined effect of the top 30 priority constraints. Irrigated-commercial maize production areas include the irrigated environments of Indonesia and the lowland areas of Vietnam's southeastern region and Mekong River Delta.

Estimated losses of maize production gross income due to the various constraints are even higher when nearest-market grain prices are used in the calculations. This confirms the earlier observation that Asian maize farmers may lose more income when they sell their products at the farm gate, and not at the nearest market, where they can get better prices.

6.5 Technology Options to Address Priority Constraints

The country-level national maize R&D prioritization workshops each identified technological as well as socioeconomic and policy-related options to address priority constraints. The workshops also identified suppliers with a comparative advantage in delivering a particular research product. The country-level technology and policy-related options identified have been consolidated into one regional list for this report (Table 6.18). The sub-sections below discuss technological options for alleviating abiotic and biotic constraints. Country-level maize sector policies and policy-related options for alleviating the socioeconomic constraints of Asian maize farmers are summarized and discussed in a separate chapter (see Chapter 2).

6.5.1 Technology interventions to address abiotic constraints

Drought/moisture stress. Most yield losses due to drought are caused by moisture stress during flowering and grain-filling, and the rest by pre-flowering stress. Maize is unusually susceptible to drought at flowering, when it depresses yield potential by irreversibly limiting the number of kernels and ears that develop; if stress is severe, yields may be reduced nearly to zero. At this stage in crop development, it is too late for farmers to adjust management practices because fertilizers and/or pesticides have already been applied, and the season is far too advanced to consider replanting (Edmeades et al. 1994). In this study, drought was reported as prevalent in the rainfed lowland and rainfed upland environments surveyed. Technologies that reduce the effects of drought include small-scale irrigation, rainwater harvesting, cultivars that either escape or tolerate the stress, and better crop and water management strategies such as conservation (zero/minimum) tillage.

Small-scale irrigation/water harvesting. In India, water has been harvested since antiquity, when the art of water management was perfected. In the face of adversity, communities have revived or created new water harvesting systems. Water harvesting structures and water conveyance systems specific to the ecological region and culture have been developed. Raindrops are harvested directly, and checkdams, called *johads*,[10] and other structures have been built to harvest water that runs off the soil. Water from rooftops is collected and stored in tanks built in the courtyards. Rain from open community lands is collected and stored in artificial wells. Monsoon runoff is harvested by catching water from swollen streams and flooding rivers and stored it in various kinds of reservoirs. Traditional and contemporary technologies allow water harvesting in both rural and urban areas. In many locations in India these technologies have helped people withstand recurring drought, and thus look promising for adaptation and promotion in other parts of Asia.

Although many water harvesting case studies have shown increases in yield and water use efficiency, it is not clear that the widespread use of these technologies is feasible (Rosegrant et al. 2002). The high initial cost of building the water harvesting structure often provides a disincentive for adoption. These structures are usually built during the dry season when labor is cheaper, but also scarce due to worker migration. Maintenance costs, on the other hand, often occur in the rainy season, when labor costs are higher due to competition with conventional agriculture. Thus while many case studies show positive results, water harvesting methods have yet to be widely adopted by farmers.

In the Philippines, the government's Bureau of Soils and Water Management (BSWM) carried out a 10-year small-scale irrigation project (official title: Small Water Impounding Project or SWIP) that covered the construction of rainwater harvesting structures, small diversion dams, small farm reservoirs, and shallow tubewells. Under SWIP, structures were built across

[10] *Johads*, traditionally used in Rajasthan, India, are small earthen check dams or crescent-shaped bunds, built across a sloping catchment to capture and conserve surface runoff. Water accumulating in the *johad* percolates into the soil and augments the groundwater. See www.rainwater-harvesting.org for the full list of water harvesting structures and conveyance systems in India.

narrow depressions or valleys to hold back water, and reservoirs were created to store rainfall and runoff during the rainy season. SWIP usually works in partnership with local government units (LGUs) that have the technical capability to implement such projects. In most cases, the LGUs provide matching funds and, as a result, both national and local governments are held accountable for the project. Small diversion dams are concrete or rockfill structures constructed across a channel or river with continuous flow to raise the water level and divert the water by gravity from the source to the point of use. Primarily intended for supplemental irrigation, diversion dams serve farmers who cultivate areas adjacent to small rivers or creeks. A small farm reservoir (SFR) is a smaller version of SWIP structures, designed to collect and store rainfall and runoff for use on a single farm, for which water is delivered to the canals through siphons. A shallow tubewell (STW) is a tube or pipe vertically set into the ground to a depth of 20-60 feet

Table 6.18. Technology and socioeconomic/policy-related options for addressing priority constraints to maize production in Asia.

		Technology supplier				
Priority constraints	Options identified to alleviate priority constraint	Concerned government agencies	IARCs	Private sector	Local universities	NGOs
Abiotic constraints						
Drought	Small-scale irrigation	*	•			•
	Rainwater harvesting	•	*			•
	Tolerant maize variety	•	*	*		
	Early maturing maize variety	•	*	*		
	Conservation tillage (zero/minimum tillage)	•	*	*	•	•
Soil acidity	Soil amelioration (organic matter/lime)	*	•		•	•
	Balanced fertilization	*	•	•		•
	Tolerant maize variety	•	*	*		
Soil erosion	Sloping agricultural land technology	*	*		•	•
	Conservation tillage (zero/minimum tillage)	*	*		•	•
Biotic constraints						
Corn/ear/stem borers	Biological control	*	*	•		
	Tolerant/resistant maize variety	•	*	*		
	Integrated pest management	*	*			•
	Biotechnology	•	*	*		
Downy mildew	Tolerant maize variety	•	*	*		
	Judicious pesticide application	*	•		•	
Weeds	Judicious herbicide application	*	•		•	
	Weed control management practices (proper land preparation)	*	•			•
Post-flowering stalk rot	Tolerant/resistant maize variety	•	*	*		
	Integrated pest management (IPM)	*	•		•	•
Socioeconomic/policy-related constraints						
Limited access to technical information	Conduct of farmer field schools (FFS) / on-farm research / other farmer training	*	•		•	•
	Develop and promote school-on-the-air programs	*			•	•
	Production and distribution of agricultural information materials	*	•	•	•	•
Lack of post-harvest facilities	Investment in appropriate, low-cost post-harvest facilities and technologies	*				•
	Promotion/deployment of available post-harvest technologies	*	•		•	•
Lack of capital/ inadequate credit support	Improved/increased access to formal credit	*				•
	Train farmers to become entrepreneurs	*			•	•
Inadequate farm-to-market transport system	Investment in rural transport facilities	*				•
Poor access to input and output markets / inadequate marketing opportunities	Market matching	*		•		•
	Develop appropriate marketing network	*		•		•
	Investment in / development of maize processing industry and livestock industry	*		•		

Source: IFAD-CIMMYT country-level National Maize R&D Priority-Setting Workshops, 2001-2002.
Note: * - principal actor; • - secondary actor.

(6-18 meters) to raise water by suction from shallow aquifers. Such small-scale irrigation systems consist of one or more fully developed STWs equipped with a centrifugal pump powered by a 5-10 hp diesel engine or electric motor that can serve a contiguous area of 3-5 ha. The system is designed for supplemental irrigation and as an irrigation water augmentation source at the end of existing systems. As of December 2003, 53,800 of these four small scale irrigation projects had been constructed, with a total service area of about 176,500 ha and 130,000 farmer-beneficiaries (http://bswm.da.gov.ph/swip.html, accessed 7 October 2004).

Early maturing cultivars for drought avoidance. In Asia, 63% and 76% of maize varieties released by public and private maize breeding programs, respectively, by late 1998/early 1999 were extra-early (<100 days) and early (100-110 days) maturing cultivars (Gerpacio 2001). Short-cycle varieties offer both technical and economic advantages: they can be accommodated more easily into intensive cropping patterns including two or more crops a year, and they escape drought in areas where the rainy season is reliable but too brief to support late-maturing varieties; they also shorten the "hungry season" by providing food well before other food sources become available. Compared to full-season varieties, however, early-maturing cultivars tend to yield less and are more susceptible to diseases and insects. The challenge for maize breeders has been to develop short-cycle varieties that combine high yield potential with adequate levels of disease and insect resistance.

Several national maize programs in Asia and Africa are working with CIMMYT and IITA to develop germplasm that combines early maturity and high yield potential. The best early maturing germplasm complexes thus far are more correctly termed intermediate-to-early maturing. These elite populations have a maturity period of 90-100 days, a yield potential of 4-5 t/ha, and resistance to several important diseases (Dowswell et al. 1996).

Drought tolerance. For drought tolerance, matching crop development to rainfall pattern is the single most important breeding goal in rainfed environments (Edmeades et al. 1997a). Maize breeding at CIMMYT and elsewhere has concentrated on developing later maturing cultivars that stabilize yield by reducing the effect of drought on grain number and size. A network of national programs (India, Brazil, China, Ghana, Burkina Faso, Cote d'Ivoire), CIMMYT, and IITA is collaborating to develop elite maize populations with enhanced drought tolerance. The objective is to produce germplasm that has improved seed set under moisture stress but produces high yield under more favorable growing conditions (Dowswell et al. 1996). So far, research results show yield gains under drought are accompanied by significant increases under well-watered conditions. These results also appear to hold quite generally for OPVs commonly grown in drought-prone areas, and will most likely apply to hybrids as well. For selection, conventional breeding has depended on plant performance criteria such as yield or secondary traits highly associated with yield under drought (e.g., antithesis silking interval, or ASI). A long ASI is generally equated with drought susceptibility, and selection for reduced ASI has been successfully used to increase yield under drought in maize (Banzinger et al. 2000). In this vein, much effort has been devoted to sharply reducing ASI, and yield gains associated with success in this area have been around 100 kg/ha/year (5% per annum) in tropical lowland germplasm (Edmeades et al. 1997b). Also, grain yield heterosis—the superior performance of crosses relative to their parents—is high in maize, and greater under drought stress than under optimal conditions. Therefore, identification and development of heterotic groups of elite inbreds can contribute to hybrid performance under drought. However, in water-limited environments, conventional breeding for improved yields has been slow due to year-to-year variation in rainfall and within-season variation in rainfall distribution in the drylands.

Recently, scientists at the Indian Agricultural Research Institute (IARI) Division of Genetics, New Delhi, developed a high-yielding and drought-tolerant maize variety that does well in the country's northern plains (The Hindu, 2 December 2004, New Delhi). Commercially released as 'Pusa Composite 3', the new maize variety has an average yield potential of 4.4 t/ha, is of intermediate maturity, resistant to lodging, and tolerant to stalk borer and major foliar diseases. The stalks of the new varitey are of excellent forage quality because of their stay-green character. The ears are long, with yellow flint grains. The composite does well under low-input and moisture-stress conditions, hence promising wide acceptance by the farming community.

Better farm-level crop and water management strategies. Integrated drought management includes, among other things, farm-level crop and water management strategies to reduce water stress, such as planting on the optimum date to align critical plant development stages with rainfall; tillage to promote greater rooting depth, better water infiltration and storage in the soil, and reduced competition from weeds; and mulching to reduce water loss. Crop and water management strategies, however, are environment and location specific, and as such can be costly to develop and disseminate.

Soil acidity. Most tropical soils are acidic, and aluminum toxicity is the main reason for crop failure in such soils. Approximately 43% of the world's tropical lands is classified as acidic, and 38% of those lands are in Asia. The area of acid soils planted to maize in Asia was estimated to be around 2.5 M ha (de Leon et al. 2000). Acid uplands cover from 33% of total land area in Indonesia and the Philippines to as high as 66% in Laos (Garrity 2000). The excess Al in acid soils interferes with root cell division, increases cell wall rigidity, fixes P in less available forms in the soil and on root surfaces, decreases root respiration, and interferes with the uptake, transport, and use of essential elements. Roots in acid soil become inefficient at absorbing and utilizing water and nutrients, even when the root zone is moist, quickly developing wilting and nutrient deficiency symptoms (Pandey et al. 1994). Soil acidity, often due to long-term application of inorganic fertilizers, was widely reported by farmer-respondents from the rainfed upland environments of Karnataka and Andhra Pradesh (India) and Northern and Central Mindanao (Philippines). The options identified to help alleviate this priority constraint included soil amelioration with organic matter or lime, balanced fertilizer application, and the use of tolerant maize varieties. In general, applying adequate amounts of lime to increase soil pH to approximately 5.5 is recommended. Very few of the surveyed villages practiced liming, which needs to be repeated every few years and is too expensive for resource-poor maize farmers. Moreover, liming subsoils deeper than 30 cm is difficult and also incompatible with the current trend towards conservation tillage on sloping lands (Pandey et al. 1994).

The development and use of germplasm tolerant to both high Al toxicity and low P levels would provide a less expensive, permanent solution. Acid tolerant cultivars would, for example, help minimize the amount of amendments (lime) applied to the soil. Tolerant varieties also offer an ecologically clean, cost-effective way to increase maize yields in affected areas. They would allow sustainable maize cropping systems to be established on less-utilized acid hillsides, thus reducing the pressure on more fragile lands. CIMMYT researchers have found that acid tolerance is present both in germplasm materials that originated in acid areas and in those that have never been grown in acid soils. Also, yield in acid environments was found to be positively correlated with yield in non-stress environments, so that it is possible to develop a variety that would yield well in both acid and normal soils. Tolerance to soil acidity does not necessarily mean lower performance under high management conditions (Pandey et al. 1994). The national programs of Indonesia and Colombia, two countries with extensive acid soil problems, have released varieties derived from CIMMYT Maize Program materials: Antasena in Indonesia and Sikuani in Colombia (de Leon et al. 2000).

Soil erosion. Sloping uplands cover about 60-90% of the total land area of each country in Southeast Asia (Garrity and Sajise 1993). Soil erosion, as estimated by river sediment load per hectare of watershed, is much more serious in Southeast Asia than in any other region of the world (Milliman and Meade 1983). The densest populations in the world are transforming these watersheds at a tremendous rate, and exacerbating their degradation.

Soil erosion in the rainfed upland environments surveyed (particularly in Cagayan Valley, Philippines, and the outer islands of Indonesia) can be substantially reduced by the adoption of sloping agricultural land technologies (SALT) and/or of conservation (zero or minimum) tillage systems. SALT is a package of soil conservation and food production technologies that integrates several soil conservation measures in just one setting. With SALT field and permanent crops are grown in 3-to-5-meter-wide bands between contoured rows of nitrogen fixing trees, to minimize soil erosion and maintain soil fertility. The trees are thickly planted in double rows to make hedgerows. When a hedge is 1.5 to 2.0 meters tall, it is cut down to about 75 cm, and the cuttings (tops) are placed in alley-ways to serve as organic fertilizer.

A simple, easily applied, low-cost, and timely method of farming uplands, SALT was developed for Asian farmers that have few tools, limited capital, and little training in agriculture. With the SALT system, farmers can grow familiar crop varieties and use traditional farming patterns. If farmers leave the SALT farm, as some tribal groups do, the nitrogen fixing trees and shrubs (NFTS) will continue to grow and overshadow the cropping area. By the time the land is cultivated again, the soil has been enriched by the large amount of NFTS leaves, and there is no erosion to contend with. The trees may also be harvested for firewood or charcoal (ARLDF 1997). Extensive data from the IBSRAM Sloping Lands Network trials in six countries have confirmed that annual soil loss with hedgerow systems is typically reduced by 70-99% (Sajjapongse and Syers 1995).

Unfortunately, farmer adoption of these systems is still very low. Constraints include the tendency for perennials to compete for growth resources, thereby reducing yields of associated annual crops and the inadequate amounts of phosphorus that are cycled to the crop in the prunings. The major problem is the extra labor needed to prune and maintain the hedgerows. Farmers' labor investment to prune and maintain the hedgerows was about 31 days per hectare, or 124 days of annual labor for four prunings, which increased labor for a maize crop by 90% (ICRAF 1996). Such an increase in production costs was seldom rewarded by a commensurate increase in returns.

Conservation tillage (CT) involves minimal soil disturbance and maintains at least 30% of crop residues on the soil surface at planting time (CTIC 1994). The residue cover helps minimize wind and soil erosion, preserve soil structure, and conserve water by reducing runoff. Four specific tillage systems can be classified as CT: no-till (zero tillage), ridge till, mulch till, and minimum/reduced tillage systems (Monsanto 2004). The no-till or zero tillage system involves no seedbed preparation other than opening the soil (a slit or punched hole) to place seed at the intended depth. In the ridge till system, row crops may be planted on the ridge top, in the furrow, or along both sides of the furrow as a way to manage soil moisture. The mulch till system retains crop residues on the soil surface, providing a protective cover. The minimum/reduced tillage system involves minimal soil disturbance for crop production, and minimal use of conventional tillage equipment.

A primary advantage of CT is that no additional investment in land conservation measures such as terraces, contour bunds, or soil conservation barriers is required, making the technology equally accessible to small- and large-scale farmers. The technology also offers (a) easier land preparation and weeding operations, (b) substantial savings by reducing mechanical power and labor requirements, (c) improved soil quality and moisture retention, (d) reduced soil erosion, and (e) increased yields. Conservation tillage systems, however, are not universally applicable. They are adapted for use in areas with sandy to clay loam soil types, in flat to hilly and slightly rolling terrain, and in areas with no conventional tillage implements. Adoption of reduced tillage systems is limited by two factors: competition for crop residues and input availability (Pingali and Pandey 2001). Where crop residues are important for livestock feed, it is difficult for farmers to leave even a part of those residues on the soil. Herbicides and machinery are crucial to CT, and limited access to these inputs can constrain adoption in remote low market surplus production systems.

6.5.2 Technology interventions to address biotic constraints

Stem and corn borers. Stem borer resistance has been developed through conventional breeding and genetic engineering. Entomology research at CIMMYT has aided in identifying inbred lines that possess tolerance to fall armyworm and maize stem borers. In the field, on-farm tests of CIMMYT's insect resistant maize populations have shown that, in addition to high yields, the populations have better grain quality because they avoid *Stenocarpella maydis* ear rot. One area that warrants further research is germplasm that resists "second-generation" attack, i.e., larvae that attack during flowering. Selection for resistance at flowering has been slow because borers feed on diverse plant tissues at this time. Historically, selection focused on increasing stalk strength to withstand tunneling, thereby facilitating mechanical harvesting. To reduce second generation damage, researchers are now screening plants for reduced feeding damage in the tissues first fed upon by larvae, specifically the sheath, husk, and ear.

In eastern, western, and central Africa, where farmers can lose 15-45% of their annual maize harvest to stem borers (equivalent to at least 400,000 tons of maize, valued at US$ 90 million) CIMMYT's Africa Maize Stress (AMS) Project helped the Kenya Agricultural Research Institute (KARI) to identify insect-resistant maize and develop testing sites where thousands of borer larvae are reared and applied each crop cycle. Maize that resists one or more borer species has been identified and is being made available to farmers. Leaf toughness, a trait identified at CIMMYT, has been used to screen maize for insect resistance without having to infest plants in the field. Leaf toughness has been observed to lower insect feeding and is not negatively correlated with yield. Molecular research at CIMMYT has found five markers that account for nearly two-fifths of the phenotypic variation for leaf toughness. In western and central Africa, intercropping maize with cassava or cowpeas has been found to reduce yield losses from stem borers.

In 1984, Taiwan's Council of Agriculture launched a program to biologically control the Asian corn borer, *Ostrinia furnacalis* Guenee, on both field corn and sweet corn using an egg parasitoid, *Trichogramma ostriniae*. For higher effectivity in controlling the Asian corn borer, *T. ostriniae* was combined with two or three insecticide treatments on field corn, and with three treatments of *Bacillus thuringiensis* and one low-toxicity insecticide for sweet corn. This system of integrated control significantly reduced the proportion of damaged plants and increased grain yield of field corn by 11%. The long-term mass release of *T. ostriniae* also showed an accumulative effect in suppressing corn borer population density (Tseng 2000).

More recently, genetic engineering has been used to incorporate genes derived from *Bacillus thuringiensis* (*Bt*) into maize, which could provide effective inherent control of stem and corn borers, allowing maize to be grown using fewer chemical pesticides. The use of biotechnology crop varieties has also been documented to increase fertilizer efficiency, provide more flexible weed control, promote conservation tillage, protect water quality, and aid in soil conservation (Phillips 2001). By 2004/2005, *Bt* maize had been adopted by 12 countries (US, Canada, Spain, Germany, Argentina, Honduras, South Africa, Uruguay, Portugal, France, Czech Republic, and the Philippines) (ISAAA 2005), that cover nearly 20 M ha, which is equivalent to 13.6% of the global maize area of 146.8 M ha (FAOSTAT Production Domain, accessed 13 December 2006). There is also significant potential for *Bt* maize in India, Indonesia, and Thailand, where Asiatic corn borers, spotted stem borers, Asian pink stem borers, and armyworms are important pests. In China, early field trials indicate that *Bt* maize can increase yields by over 15%, which is significant because China has around 25 M ha of maize. Prior to commercialization in the Philippines, significant increases in productivity of 25% in the dry season and 40% in the wet season have been reported from *Bt* maize field trials (ISAAA 2004).

As early as 2001, Monsanto Philippines reported an average 40% yield advantage for Yieldgard®, its *Bt*-protected maize variety, over traditional hybrid maize based on results of their multi-location trials across the Philippines (Monsanto Philippines 2001). Extensive research on Yieldgard® in the US also showed that it is nutritionally equivalent and performs comparably to conventional varieties for livestock and poultry feed; it is also effective for controlling targeted insect pests without harming humans, fish, wildlife, and beneficial insects, and has improved grain quality, thus enhancing food and feed safety (Monsanto 2001). A year after commercialization in the Philippines (with approximately 20,000 ha planted in 2003), Yorobe (2004) reported that *Bt* maize yielded 37% more than conventional maize crops. Although its production costs were higher (due to more expensive seed), *Bt* maize also generated a higher net income. Filipino farmers who planted *Bt* maize saved PhP 168/ha (about US$ 3/ha) on pesticide and earned an additional PhP 10,132/ha (about US$ 170/ha).

However, this technology does raise a major concern: the development of *Bt* resistant insects. Effective insect resistance management (IRM) strategies must be established to counter this natural adaptation. Refugia are needed to maintain populations of susceptible insects that will mate with resistant insects and delay the development of *Bt* resistance (Pingali and Pandey 2001). Refugia are a central component of a broader IRM strategy that includes integrated pest management and the combination of multiple sources of insect resistance in the maize plant. Stacking or pyramiding *Bt* genes to ensure that multiple toxins are expressed in plants will also prolong resistance, which may be further enhanced through the incorporation of conventional resistance.

The application of DNA markers has the potential to improve selection efficiency and accelerate the development of germplasm with good agronomic performance and adequate levels of host plant resistance. Restriction fragment length polymorphism (RFLP) markers are being used to identify chromosomal regions that control quantitative trait loci (QTL) affecting insect resistance. Cost-savings and efficiency gains are expected if RFLP markers can be used in practical breeding to facilitate the incorporation of insect resistance into elite germplasm (Dowswell et al. 1996).

Downy mildew. Several strategies are available for the management of downy mildew diseases of maize. Cultural practices have been suggested, including roguing or eliminating diseased plants and planting a wide area within two weeks to eliminate the continuous presence of inoculum. These practices, while practical and economical, require perfect timing, early monitoring, and prompt destruction of infected seedlings. Seed dressing with a metalaxyl slurry has been the standard treatment to control downy mildew for more than two decades. Metalaxyl, also known as Apron, SD, and Ridomil™, is a systemic fungicide capable of protecting maize crops from downy mildew infection. Complete reliance on metalaxyl is, however, not a sound practice; should a metalaxyl-resistant strain of the downy mildew fungus arise, all gains achieved through maize breeding could be wasted. The chemical has actually begun to show signs of declining efficacy based on observations of plants from treated seed lots (Raymundo 2000).

A broad range of high-yielding germplasm with adequate downy mildew resistance is now available for most areas where the disease is prevalent. Maize research institutions in Thailand and the Philippines significantly contributed to the development of these materials. International germplasm exchange in Asia and cooperative testing for downy mildew resistance has led to the rapid development and deployment of resistant varieties, including Thailand's Suwan 1 (released in 1973), the DMR (downy mildew resistant) composite series released in the Philippines in the 1970s, Indonesia's Penjalinan, Ganjah Kretek, and Arjuna, and India's Ganga 5 (Raymundo 2000). ADB-CIMMYT's Asian Maize Biotechnology Network (AMBIONET) Project used molecular markers to accelerate breeding for traits of interest, including downy mildew resistance. CIMMYT's now-defunct Asian Regional Maize Program (ARMP) used to work with national systems in the region to develop and disseminate high yielding varieties and hybrids, with special emphasis on resistance to downy mildew, a regionally important maize disease.[11] In addition to adapting germplasm from CIMMYT-Mexico for use in Asia, the ARMP developed several broad-based,

[11] The Thailand-based Asian Regional Maize Program (ARMP) no longer exists. Today a few CIMMYT scientists are stationed in the region (India, Nepal, Bangladesh), but none of them works specifically on downy mildew.

downy mildew-resistant populations to meet a range of local needs. It also pyramided genes conferring resistance to other types of stress (such as corn borers, acid soils, and waterlogging) into germplasm that already possessed downy mildew resistance.

The private sector has been selling, in mildew-prone areas, seed of commercial cultivars treated with Ridomil™, a systemic fungicide; it has also began to develop resistant cultivars. Seed treated with Ridomil™ is, however, too expensive for resource-poor farmers. While the public sector has been relatively successful in developing resistant cultivars through traditional breeding (de Leon and Lothrop 1994), many such cultivars are unfortunately not reaching farmers due to insufficient seed production and distribution.

Stalk rots.[12] Considerable research has been done on factors that influence stalk rots, the most important of which is the inherent susceptibility of the cultivar, which may be altered by weather conditions, moisture availability, grain fill and kernel number, cultural practices, plant densities, leaf disease damage, cloud cover, and insect damage. In general, stalk rot is most severe and incidence is greater with increased fertility. Several studies suggest that a balanced, continuous supply of nitrogen throughout the maize growing season helps reduce stalk rot incidence, and that when adequate potassium is present, stalk rot severity is reduced. Tillage practices have also been related to the occurrence of stalk rot diseases. In the absence of leaf blights, reduced tillage has been shown to actually diminish most stalk rot diseases, possibly because it decreases soil moisture evaporation and results in less stress.

A systematic and comprehensive breeding program on stalk rot resistance began in India (Delhi, Ludhiana, Hyderabad) in the early 1990s, and in Thailand (Farm Suwan) in 1993, in collaboration with CIMMYT's ARMP. During the last 30 years, a wide collection of maize has been screened at research stations covering most disease-prone agro-climatic regions in India. Early maturing composites developed in the 1970s and early 1980s in Pantnagar have shown high levels of resistance to both downy mildew and stalk rot. 'Rudrapur local' contributed resistance to *Erwinia* and *Pythium* (pre-flowering) stalk rots to the highly resistant hybrid Ganga Safed-2. Pioneer Hi-Bred Inc. has apparently found resistance to *Pythium* stalk rot and is using it in breeding its materials in Egypt (Dowswell et al. 1996). However, when there is severe environmental stress and disease pressure, stalk rots can affect even the most resistant germplasm (De Leon and Pandey 1989).

Since there are few sources of resistance to stalk rot complexes in maize, breeders have been examining related species and genera such as *Zea diploperennis*, *Z. mexicana*, *Z. perennis*, *Z. luxurians*, *Tripsacum* spp., *Coix, Chlonachne*, and others for the presence of genes conferring resistance to stalk rots. Teosinte, for example, has excellent resistance to many of the stalk rot pathogens. Research is still needed, however, in the following areas (a) inoculation techniques to distinguish resistant plants from escapes; (b) studies on appropriate inoculum loads for individual pathogens; and (c) genetic studies on resistance to different pathogens.

Post-harvest (storage) pests. Damage from insects and diseases that attack stored grain commonly causes losses of more than 20% of harvested grain in least developed countries (LDCs), where tropical conditions allow insects and disease pathogens to reproduce rapidly and colonize unprotected grain (Meikle et al. 1999, as cited in Bergvinson and Garcia-Lara 2004). Among the important storage insect pests of maize in developing countries are the maize weevil (*Sitophilus zeamais*), larger grain borer (*Prostephanus truncatus*), and red flour beetle (*Tribolium castaneum*). Control of storage pests has largely focused on hygiene and includes thorough cleaning of the storage area, removing old grain from the area, repairing storage structures, filling cracks where insects can hide, and applying recommended insecticides to storage walls and ceilings (especially if infested) (Bergvinson 2001a). One of the most successful means of preventing post-harvest pests is good husk cover, the result of farmer selection over time (Dobie 1977, as cited in Bergvinson 2001a) and seed hardness (Ransom 2001). Selecting hard grain types and types known to slow the buildup of insects may reduce losses due to insects. However, for kernel hardness to be effective, grain moisture content must be below 16% for the existing resistant sources (Bergvinson 2001b).

To capitalize on genetic diversity for storage pest resistance, researchers have made significant progress in understanding the biochemical, biophysical, and genetic bases of host plant resistance to ensure that the traits being selected meet consumer demands. A new approach called "targeted allele introgression" using marker-assisted selection (genetic engineering) is being used to introduce storage pest and disease resistance into farmers' varieties, while preserving their food and processing qualities and enhancing their genetic diversity. The impact of this technology will be felt most in LDCs because it is packaged in the seed and being designed to ensure that farmers have the option to recycle seed, a common practice among subsistence farmers (Bergvinson and Garcia-Lara 2004).

[12] This section draws heavily from Lal et al. (2000).

6.6 Sources of Research and Technology[13]

This section discusses the roles and responsibilities of the public and private sectors (including, among others, IARCs, such as CIMMYT, NARESs, and national and multinational companies) that supply research and technology products. Each of these players has unique capabilities, resources, and comparative advantages that can help alleviate maize production constraints in Asia.

6.6.1 Public and private sectors: delineation of research responsibilities

When prioritizing future public sector maize research, it is important to accurately anticipate prospective private sector activities in order to avoid duplicating efforts and identify potential areas of collaboration. The private sector has been active in maize research, development, and dissemination since the 1930s and 1940s. The private sector has been active in tropical maize systems that support commercial production, developing and selling hybrids adapted to particular geographic and ecological regions. It has been well acknowledged that the private sector is far more effective than the public sector in providing seed to farmers in most developing countries (see Morris 1998 and Gerpacio 2001).

During the past decade, private sector investment in tropical maize has increased substantially, mainly due to four factors:

1) The rapid growth in feed maize demand and consequent commercialization of maize production systems have provided an impetus for private sector investment;

2) Global amalgamation of agribusiness has brought significant resources to bear on the problems of tropical maize systems;

3) The emergence of biotechnology as a strategic force in developing agricultural technology and enormous private sector investments in exploiting this technology; and

4) The increased use of intellectual property rights (IPR), which allows developers of a technology to appropriate the profits it generates.

6.6.2 Role of the public sector

When national research systems are initially formed, state-sponsored organizations almost always play a dominant role in organizing the development and dissemination of improved technologies. Over time, however, the role of the public sector typically declines, and its functions are gradually taken over by the private sector. In Asia today, public sector dominance of agricultural R&D is largely a thing of the past. Only China and India retain sizeable public agricultural research and extension systems. In Southeast Asia today, public maize breeding research is carried out only in two or three organizations per country.

Nevertheless, a key role of national and international public sectors has been training and human resource development, which, by lowering the costs of learning and capacity building, has encouraged private companies to become involved in R&D. The public sector will continue to enjoy a strong comparative advantage in human resource development, especially in the developing world.

Many national and international public sectors also opt to move upstream in the germplasm development process, for example, by concentrating on genetic resource conservation and management and pre-breeding activities designed to produce basic germplasm that can be used as source materials by commercial breeding programs. Public sector efforts in the collection, characterization, and preservation of genetic resources have resulted in significant social and private sector benefits. Social benefits are gained in terms of conserving the rich genetic heritage of landraces and wild relatives of maize (and other crops) that are in danger of disappearing from developing country farming systems. Private sector benefits accrue in terms of free access to genetic resource collections that private companies can use to enhance their crop breeding activities. Pre-breeding research to produce elite breeding materials that can be used to develop locally adapted varieties will remain an important public sector activity. Although some believe that it will become obsolete if anticipated advances in genomics are achieved, pre-breeding will remain an important component of maize research in developing countries for the next 5 to 20 years.

Within the realm of genomics and biotechnology, advanced national research institutes (such as those of China and India) and multinational companies will probably maintain their dominance in basic and applied research. Nevertheless, the international public sector could act as a conduit that provides access to these technologies by training developing country scientists in their use.

[13] This section draws heavily from Pingali and Pandey (2001) and Gerpacio (2001).

Perhaps most important to the world's poorest farmers and communities, the public sector will continue to be the sole source of research and technology (particularly developing and evaluating varieties) for geographic areas that the private sector considers unprofitable. These include predominantly low market surplus production areas with low market potential or that are marginal in terms of crop production (e.g., drought-prone environments). For these environments, a few public agencies produce maize seed and distribute it through agricultural extension services, especially in less favorable areas where maize is an important crop. One may expect private sector involvement to be relatively low in the Central and Eastern Visayas regions of the Philippines and some parts of South Asia. Hence, rather than producing hybrid seed in direct competition with private companies, many public seed agencies concentrate on promoting informal seed production and distribution systems (Dowswell et al. 1996).

6.6.3 Role of the private sector

Private sector participation in maize R&D in Asia has grown steadily since the early 1990s, when a wave of policy reforms broke up what had effectively been state monopolies in many countries. At that time, governments began framing new policies to encourage the growth of national private seed companies, and provide a better business environment for multinationals. Most multinational companies have strong maize R&D and seed production and distribution infrastructure, which allows them to operate efficiently in major maize production zones. The private sector began to invest more in breeding maize hybrids (and varieties in some instances) for developing countries, particularly tropical maize production systems and areas where secure profits can be realized. Maize R&D activities pursued by the private sector in Asia vary depending on the size of the company and the volume of maize seed it sells. Generally speaking, the larger the company, the greater its ability to establish its own breeding program. Many smaller seed companies that lack in-house research capacity contract public research programs and sometimes even large private companies to multiply and distribute seeds of improved OPVs and hybrids developed by others. Most multinationals operating in Asia are large enough to have ventured into biotechnology research.

The private sector will continue to be the dominant player in genomics and biotechnology, both in terms of investment and as a source of technology and bioinformation. Through consortia and alliances, these resources will be made available to national and multinational companies in the developing world.

Having developed transgenic maize, the private sector promises to provide maize cultivars that tolerate or resist a wide range of stresses and offer improved nutritional quality. This could broaden the range of environmental conditions under which maize can be grown and increase its productivity and stability. Developing world maize farmers and consumers, however, are just beginning to reap the full benefits of these technologies (for example, through the recent commercialization of *Bt* maize in some Asian countries) because the private sector, in light of inadequate IPR protection, farmers' inability to afford the product, and biosafety concerns, has moved cautiously and slowly in extending these technologies to the developing world.

The private sector also dominates the growing fields of genomics and proteomics, research areas that allow identifying and studying a multitude of individual genes, their interaction and expression under diverse environmental conditions. In addition, the discovery of syntenies among species promises to revolutionize plant breeding by allowing scientists to capitalize on the basic similarity across all cereal genomes to quickly apply advances in one species to all the others. Coupled with the ability to transfer genes of interest through genetic engineering, advances in these fields will undoubtedly change the pace and scope of agricultural research and development.

6.6.4 Public and private sectors working together

International maize R&D is carried out by a complex system made up of diverse organizations, large and small, public and private, national and multinational. Many of the organizations that participate in the global maize breeding system are linked through the exchange of products, services, or information. How are these linkages playing out in the Asian context? Collaborative activities discussed below illustrate how public-private sector linkages are growing in Asia.

International germplasm exchange. The establishment of the Consultative Group on International Agricultural Research (CGIAR) in 1969 provided a formal system or mechanism through which the global breeding community could access research products from public institutions. In Asia, maize germplasm is made available by CIMMYT (a CGIAR center), which also facilitates international germplasm exchange, wherein any bonafide maize breeder can request samples of experimental materials (provided free of charge) for use in his or her breeding program. Today, most public and private breeding programs have received, and are using, germplasm materials from CIMMYT. New infusions of CIMMYT germplasm remain important to them as a source of genetic diversity and new traits (e.g., stress tolerance), but only new or emerging programs rely heavily on direct requests of CIMMYT germplasm.

Public-private germplasm transfer. To reduce government expenditures, many Asian countries have scaled back investments in seed production and distribution, activities that are readily assumed by private companies because they offer clear profit opportunities. Hence, to move improved materials into farmers' fields, public breeding programs have made their germplasm products available to private seed companies, often on a commercial basis. To illustrate, Thailand's two main public breeding programs (at Kasetsart University and the Department of Agriculture) provide elite breeding lines to multinational and domestic private companies for use in developing commercial hybrids (see Ekasingh et al. 2001). Traditionally, these lines were provided free of charge, but beginning in the mid-1990s, Kasetsart University started collecting royalties from private-sector recipients, who, in turn, are assured exclusive use of the germplasm.

Genetic improvement. Strategic alliances in several areas of genetic improvement—those that do not require the proprietary protection associated with genetic engineering—would be beneficial to both the public and private sectors. One example is the development of early maturing maize varieties and hybrids to fit the intensive cropping systems in the tropical lowlands of Asia. Both the public and private sectors are particularly keen to develop hybrids for the feed industry in the lowlands of Southeast Asia; the public sector is also interested in OPVs that could enhance food supplies and food security in Asia. The public and private sectors could also play mutually supportive roles in the development of maize that is resistant to economically important pests and diseases (such as downy mildew and borers) or tolerant to abiotic constraints such as drought, acid soils, and waterlogging.

Crop/resource management. Public/private sector alliances are also possible in the realm of crop and resource management technologies. For example, public sector interest in promoting sustainable land use, together with private sector interest in promoting RoundUp™, an effective, safe, and inexpensive herbicide, gave rise to a very successful partnership aimed at developing and promoting zero tillage systems in Argentina and Brazil (Ekboir 2000; Ekboir and Parellada 2000, as cited in Pingali and Pandey 2001). Clearly, it would be constructive to explore similar win-win alliances in the geographic areas and agroecologies of Asia. A multi-sector, multi-actor alliance similar to the Rice-Wheat Consortium in the Indo-Gangetic Plains (covering Bangladesh, India, Nepal, and Pakistan; see www.rwc.cgiar.org for details) can be explored for maize in Asia. Within its nutrient management objectives, the Consortium aims to: (a) develop a better understanding of the extent of yield declines, stagnating yields, and/or factor productivity declines in the rice-wheat systems; (b) gain a better understanding of changes in soil biological activity and physical properties in intensive rice-wheat production systems; and (c) develop effective soil nutrient supply assays/tests that would lead to more effective fertilizer recommendations/practices for rice-wheat systems.

Mutual advantages. Public/private sector alliances would help narrow the science/technology gap between rich and poor nations and also help deliver new technologies to farmers. For the private sector, participation in such alliances would accelerate the progress of subsistence farmers towards commercialization and increase their client base. The public sector would benefit by gaining easier access to private sector technologies and more sophisticated networks and techniques for technology dissemination.

At the research level, the relative strength of the private sector in biotechnology and genomics, and of the public sector in germplasm (especially information and expertise related to desirable traits and germplasm improvement for developing countries) could provide a strong basis and considerable impetus for the creation of alliances.

In low market surplus maize production areas, the public sector will continue to be the leading source of technology, although the need for private sector support will increase. Public/private sector alliances could promote spillover of research results from high potential to low potential environments and from economically advanced to economically deprived areas. Private sector innovations for more favorable areas could be shared with (or licensed to) the public sector for use in less favorable areas. Such arrangements could provide the private sector opportunities to contribute to the social good and promote the long-term commercialization of less favorable low market surplus environments.

In the high-potential commercial maize production areas, the public sector can actively complement the activities of the private sector. Pre-breeding research and the provision of source germplasm would reduce the cost of private sector development of hybrids suited to particular ecological and geographic niches. Public sector research aimed at developing maize with improved tolerance and resistance to abiotic and biotic stresses for low-potential agroecological zones could also provide considerable benefits to high-potential environments. Similarly, the public sector could play a crucial complementary role to the private sector in developing appropriate crop and resource management technologies for high-potential environments. Indeed, it would be beneficial for the private sector to fund such efforts.

6.6.5 Analyzing the challenges

Spielman and von Grebner (2004) assessed the opportunities for, and challenges to, creating and sustaining public-private partnerships between the IARCs and leading multinational, research-based agribusiness companies, and tentatively concluded that public-private partnerships are significantly constrained by insufficient accounting of the actual and hidden costs of partnership; persistent negative perceptions across sectors; undue competition for financial and intellectual resources; and a lack of working models from which to draw lessons and experiences. Despite these constraints, however, there is sufficient common space in which to generate greater opportunities for public-private partnerships in pro-poor agricultural research. To create an environment more conducive to public-private partnerships, the following steps can be taken:

a) Compile and maintain an analytical inventory/ database of public-private partnerships in the IARCs and, more generally, in developing country NARSs from which lessons may be learned.

b) Identify feasible research problems and opportunities that require research inputs from both the public and private sectors and are immediately relevant to small-scale, resource-poor farmers and other vulnerable agents in developing countries.

c) Increase the frequency and technicality of dialogue between the sectors to reduce negative perceptions and foster understanding of potential research opportunities; make the dialogues attractive and constructive for decision-makers from both sectors.

d) Improve the quality of cost-benefit analyses of partnerships and make available information on terms and conditions included in agreements to manage risk and liability.

e) Explore the creative use of third-party brokers and other mechanisms to separate research priority-setting and financing from research execution.

f) Engage in multi-stakeholder discussion on public-private partnerships and agricultural biotechnology research with a wider audience, despite the controversy and conflict that such interactions may cause.

Spielman and von Grebner (2004) concluded that if public- and private-sector actors are willing and able to take these steps, both may realize the potentially significant benefits of greater intersectoral collaboration, including improved access to scientific and financial resources, new synergies in research, access to new and emerging markets, and greater capacity to solve problems that cannot be addressed by a single actor. Most important, greater public-private partnership may contribute to the improvement of livelihoods for small-scale, resource-poor farmers, food-insecure urban and rural households, and other vulnerable individuals and households in developing countries.

6.7 Research and Policy Agenda

In Chapters 2, 5, and 6 we identified and prioritized technical and socioeconomic constraints to maize production, discussed possible solutions to alleviate those constraints, and presented the country-specific policy environments in which players in the maize industry are embedded. The primary objective of maize research, development, and extension systems in Asia is to generate new and improved technologies that will increase maize productivity and maize farmers' incomes as well as promote longer-term production resource sustainability. Appropriate investments in research, technology generation, and policy reforms could help alleviate many maize productivity constraints and improve maize farmers' livelihoods. In responding to commercialization trends in maize production, however, research and policy should not emphasize just one technology or technology aspect. The focus of research should be to provide maize farmers the flexibility to make decisions across technology choices (and perhaps even across crop choices), amidst supportive agricultural policies.

Both substantial crop-specific and system-level research efforts will be important in providing maize farmers the flexibility to make these choices. Crop-specific research includes increases in yield potential, shorter-cycle cultivars, improved quality characteristics, and greater tolerance to biotic and abiotic stresses. System-level research would include land management and tillage systems, farm-level input management, and post-harvest technologies. Also important is research on the impacts of intensification in terms of buildup and incidence of pest populations and soil degradation (depletion of soil nutrients, soil acidity). Including households, communities, and markets in the system, research should study the impacts of intensification on household and community dynamics, on labor markets and availability, as well as on output marketing and distribution.

Given growing populations and income-induced demand for increased consumption, there continues to be a strong need to achieve higher productivity levels for the staple cereals. The more high-potential, favorable areas are diverted to non-cereal production, the higher the need for increasing productivity of cereals, including maize. The question to ask is: to what extent should the research system be concerned with technological developments in marginal, less favorable environments, where maize often is grown by resource-poor farmers? In large countries, such as India and China, with high domestic demand for cereals, the answer is relatively clear: investments in marginal environments are absolutely essential for ensuring food security, even if the country is integrated into the global economy (Pingali 2004). Cost-effective research investments would occur in areas where spillover benefits from favorable environments are high. Identifying strategies for diversifying the income and livelihood base of farm households in these environments should also be an important area for research and policy.

Commercialization trends require a paradigm shift in agricultural policy formulation and research priority setting, as presented earlier. The paradigm of staple food self-sufficiency that has been the cornerstone of agricultural policy in most developing countries needs to be updated given changing economic scenarios. Asian governments are facing a challenging task: to assure continued food security for ever-increasing populations on the one hand, and to diversify research and infrastructural investments out of the primary staples, on the other. Appropriate government policies can alleviate many potentially adverse consequences of commercialization and promote sustainable intensification of maize production, especially in relatively marginal, less favorable environments. Long-term strategies include investment in rural markets; transportation and communication infrastructure to facilitate integration of the rural economy; investment in crop improvement research to increase productivity, and crop management and extension to increase farmers' flexibility and reduce possible environmental problems from high input use; and establishment of secure rights to land and water to reduce farmers' risk and provide incentives for investment in sustaining long-term productivity.

7. Summary and Conclusions

7.1 Maize Production Environments

- Maize (*Zea mays* L.) is a versatile crop that is adapted to a wide range of production environments.

Maize grows in diverse agroecological conditions—in areas from 30 to 2,500 m above sea level, with annual rainfall of as little as 500 mm to as much as 2,600 mm, air temperatures as cool as 2ºC to as hot as 36ºC, and a growing cycle ranging from three months to more than a year. High grain yields have been recorded in locations with extreme temperatures. The most common soil types where maize is planted are clay, clay loam, and sandy loam, which have been consistently described by farmers as well suited to grow most crops.

- Most maize farmers in Asia are landowners or tenants/sharecroppers who have attended or completed primary education and whose farms average 0.3-20.8 ha in size.

Across the surveyed locations, maize farm sizes were larger in rainfed upland-semi-commercial areas and smaller in irrigated lowlands-commercial areas. In Thailand, 31% of maize farmers had large farms that averaged about 16 ha. Most landowners are located in irrigated lowlands-commercial areas, while most tenants/sharecroppers live in rainfed uplands-low market surplus production environments. Up to 92% of maize farmers in the rainfed upland-semi-commercial areas were landless laborers. In Vietnam, many upland farmers do not have legal land use privileges, and hence do not have access to formal credit sources nor incentives to invest in the land they till. This indicates that land use or land reform policies may help improve maize productivity and sustainability in the Asian uplands.

- Most maize-producing upland villages are wanting in terms of better infrastructure (transport systems, irrigation, markets), post-harvest facilities, and sources of capital/credit.

Most maize-producing upland villages have only seasonal/fair-weather or fair-to-good weather asphalted roads. Small vehicles such as motorcycles and pickup trucks in accessible areas, and animal-drawn carts in more remote villages, are used for farm transport. Relatively better roads and transportation systems are found in semi-commercial and commercial maize-producing areas that are closer to markets or to livestock feed processing centers.

Lowland villages have small regular markets within the community, while other villages only have once-a-week markets. In Vietnam and the Philippines, some farmers travel 15-57 km to reach the nearest primary market. In Nepal, a barter system prevails on a limited scale. Irrigation, drying, and storage facilities for maize are not common, and farmers consider this an important constraint to improved maize production in Asia.

Most Asian maize farmers reported they did not have enough capital and depended heavily on high-interest credit provided by informal sources in a charge-to-crop scheme. In this lending scheme, trader-financiers sell agricultural inputs to farmers at higher than market prices, and later buy back their harvests at lower than market value. Loans and interest are deducted from the total value of the harvest. Farmers tended to patronize these informal credit sources because they find them more reliable, accessible, and convenient than formal credit institutions.

- Across the region, government extension offices, private seed companies, and formal and informal farmers' organizations play a vital role in disseminating updated technology and information to maize farmers.

Mainly government extension agencies are responsible for conducting farmers' field schools and training sessions. Seed and fertilizer companies also provide technology information to maize farmers, but it is generally limited to the product being sold. Farmer cooperatives and informal organizations give farmers technical information, in addition to acting as sources of capital and material inputs, and outlets for farm output. Youth and women's organizations present in the communities are also channels for disseminating updated agricultural and other information. All these channels, however, need to be improved, and the agricultural extension system could be better organized. SUCs, NGOs, and IARCs are minimally involved in local agricultural extension.

- Asian maize farmers pay much higher prices for hybrid seed, about 9-16 times that of local/traditional and improved OP varieties.

Farmers often recycle or exchange seed of local/traditional and improved OP varieties with other farmers within the community. If puchased, seed of local/traditional maize varieties was priced at PPP$ 0.58-0.95/kg, and hybrids at PPP$ 5.02-9.04/kg. Surprisingly, maize seed was most expensive in rainfed uplands-low market surplus and semi-commercial production areas. Transportation and handling charges accounted for most variation in maize seed prices between production environments. Improvement in transport infrastructure and marketing systems may help close the seed price gaps (as well as those of other inputs), in favor of smallholder maize farmers in the rainfed uplands.

- Average daily wages for farm labor in the Asian uplands favor men over women.

Male laborers earn, on average, PPP$ 0.72-1.06/person-day more than female laborers. Men commonly perform land preparation, planting, fertilizer application, and harvesting. Female labor is used for planting, weeding, harvesting, and post-harvest operations such as shelling and drying. In Nepal, most farm operations are done by family and exchange labor, and use of hired labor is not common, except during peak periods within the crop season. In such instances, the development and promotion of small farm implements, specifically designed for use in the rainfed uplands, could help alleviate the drudgery of farm operations for all agricultural labor.

- Seed-to-grain price ratios are lower with local/traditional or improved OPV maize than in the case of hybrids, and are higher when calculated based on farm-gate prices, rather than nearest-market prices. Seed-to-grain price ratios were highest in rainfed uplands-low market surplus maize production environments.

Based on averages of all reported maize seed and all reported maize grain prices, the seed-to-grain price ratio was 6.52 and 5.20 across Asia during 2000-2001, using farm-gate and nearest-market grain prices, respectively. This indicates that Asian maize farmers have to sell, on average, 5.2 kg of maize grain to pay for one kilogram of maize seed. More specifically, seed-to-grain price ratios ranged from 1.15 to 3.40 for local/traditional and improved OPV maize, and from 6.14 to 18.56 for hybrids.

The computed input-to-grain price ratios were lower when using nearest-market grain prices than when using farm-gate grain prices, indicating that Asian maize farmers receive better prices for their grain if they sell at the nearest market than at the farm gate. On average, farmers received PPP$ 0.44-0.82/kg of maize grain at the farm gate, compared to PPP$ 0.64-0.92/kg at the nearest market. Where both are available, yellow maize (usually hybrids) commanded a higher market price than white (local/traditional) maize.

Across maize production environments, average prices of farm inputs were higher in the rainfed upland areas than in the irrigated lowlands, to the disadvantage of marginal resource-poor farmers in less favorable areas. Appropriate government agricultural support programs will be important to address this concern and alleviate rural poverty in marginal rainfed upland environments.

- Maize has become a major component of people's diets and the preferred substitute during periods of rice shortage.

Subsistence farmers in the rainfed uplands and subtropical/mid-altitude environments kept as much as 90% of their maize for household consumption. Maize utilization, however, differs from one location to another, depending on people's food habits. Where livestock and poultry production is booming, maize (mostly hybrids) is grown to sell to feed mill industries, while in predominantly low market surplus areas, maize (mostly local/traditional varieties) is grown for household consumption.

7.2 Maize Production Systems

- Asian maize farmers choose varieties depending on intended use.

For home food and animal feed, farmers prefer to grow local/traditional white maize varieties for their good eating quality, low input requirements, and low production costs. If maize is grown purely for cash income, farmers are more likely to grow hybrids, as long as they have access to capital to pay for material and labor inputs. Farmers are aware that higher yields can be expected from improved varieties if adequate amounts of inputs are supplied.

When selecting hybrids, maize farmers prefer those having high yields, heavy grains, general resistance to pests and diseases, tolerance to drought and other climatic stresses, and high shelling recovery. When selecting white maize (mostly local/traditional and improved OPVs), grown largely for human consumption, farmers prefer varieties with early maturity, high milling recovery, good eating quality, and general suitability to marginal soils. Other characteristics that influence farmers' choice of variety are grain weight, level of productivity, maturity period, and quantity and quality of foliage.

- Farming households in the Asian uplands follow traditional maize production practices.

Asian farmers grow maize as the main crop and intercrop or relay crop vegetables, root crops, legumes, or cash crops. They augment their income with small-scale livestock and poultry production. Maize is generally grown twice a year, with the first crop usually planted after the first rain. Land preparation consists of one or two plowing operations, and maize seeds are generally sown manually. Weeds are commonly controlled twice in the crop season, through a combination of hand-weeding, off-barring, and hilling-up. Fertilizers are also applied twice in a crop season but often at rates lower than recommended. Pesticides are used only when infestation is heavy. Harvesting is done manually, and most farmers tend to sell yellow maize right after harvest, while local/traditional and improved OPVs are sun-dried and stored mainly for home use. Grains consumed at home are shelled and milled as need arises. Maize yield gaps can be due to erratic and unpredictable weather conditions, lack of fertilizers, pest incidence, poor extension services, and poor management practices.

- Levels of agricultural input use and maize output did not vary significantly across the four maize production environments identified in this study.

Maize seeding rate ranged from 13-24 kg/ha in the irrigated lowlands, rainfed lowlands, and rainfed uplands to 6-60 kg/ha in the subtropical/mid-altitude (STMA) environments. Total fertilizer use was lowest in the STMA areas (22-142 kg/ha), and highest in the irrigated lowlands (125-810 kg/ha). Total labor used ranged from 28 to 295 person-days/ha, with the lowest level used in the irrigated lowlands and the highest in the uplands, reflecting the labor intensity of maize production in more marginal environments. Female farmers provided anywhere from 53% of farm labor in the irrigated and rainfed lowlands to 62% in the STMA environments. The development of small farm machinery for maize-producing areas could help ease tasks often performed by female laborers. Hybrids yielded 3.3-5.6 t/ha in irrigated and rainfed environments, and up to 7 t/ha in the STMA areas. Local/traditional and improved OPV maize yielded 1.3-3.5 t/ha across irrigated and rainfed environments.

7.3 Important Production Constraints

- Maize farmers in different production environments across Asia experience very similar biotic, abiotic, and socioeconomic and policy-related constraints to maize production.

The important biotic constraints identified were downy mildew, Asian corn borers, stem borers, leaf blights, and stalk rots in the field, and weevils during storage. Weeds (*A. spinosus, C. odorata*, and *Ipomoea triloba*) are persistent problems every cropping season, causing yield losses as high as 100% if no hand weeding or herbicide control is used. Drought, soil acidity, and declining soil fertility were the important abiotic constraints identified. Soil fertility decline is due to intensified land use and rapid decline in fallow periods, while soil acidity is often caused by inappropriate nutrient management practices.

Poor technology transfer, inappropriate fertilizer use, lack of capital or low-interest credit, lack of appropriate varieties, lack of post-harvest facilities, high input prices, and low output prices were among the socioeconomic and policy-related maize production constraints identified by Asian farmers, who considered them perennial problems hindering improved agricultural productivity.

- Addressing the problem of drought in the rainfed lowland-commercial, rainfed upland-semi-commercial, and commercial production environments first would provide the highest technical returns to maize R&D investments in Asia, when contribution to regional maize production and share in regional maize area are considered.

Drought is estimated to affect about 6.8 M ha in the three above-mentioned production environments (53.5% of the total regional maize area), where an estimated 16 Mt of maize are produced and about 48 million rural poor are located. Alleviating drought in these environments could improve yield by an estimated 35%, which would have an enormous impact on maize production in Asia.

Apart from drought, other abiotic constraints and socioeconomic and policy-related constraints dominated the priority lists. These included soil erosion/landslides, soil micronutrient deficiency, waterlogging, lack of capital or poor access to low interest credit, poor agricultural extension/technology transfer services, and poor access to input and output markets. Socioeconomic and policy constraints were estimated to affect up to 180 million rural poor people across the region (including the STMA commercial areas of India), and alleviating them could improve maize productivity by at least 18%.

- Constraints reported from STMA (commercial) environments tend to dominate the top 30 priority constraints based on the combined index; when STMA environments are excluded from the analysis, constraints reported from rainfed upland (semi-commercial and commercial) environments dominated the constraint priority lists for Asia.

The top 30 priority constraints based on the combined index focus more on semi-commercial and commercial maize areas. Due to low maize production, the low market surplus (subsistence) system does not appear on any of the priority lists. Subsistence farming, however, remains important, particularly in Indonesia, Nepal, and the Philippines and, consequently, it is important to continue investing (relatively modestly) in subsistence farming research. Mechanisms that promote research spillovers from more commercial areas to subsistence farming environments ought to be established.

- Drought appears to have the highest economic impact in terms of estimated gross income loss, followed by socioeconomic and policy-related constraints, and other abiotic constraints. Biotic constraints (pests and diseases) have the least economic impact of the identified maize productivity constraints.

Semi-commercial and commercial maize farmers in rainfed upland environments were estimated to lose at least PPP$ 450/ha when drought conditions persist. Irrigated lowland-commercial maize farmers perceive that they lose the most income in maize production due to limited capital and/or poor access to low-interest credit.

The top 30 priority constraints have the highest combined economic impact on maize production in Asia's irrigated lowland-commercial areas if India's STMA commercial maize areas are included, and in the rainfed upland-semi-commercial areas if those environments are excluded.

- A wide range of technology options that address priority constraints to maize productivity was identified across Asia.

Technologies identified to address drought included small-scale irrigation, rainwater harvesting, resistant or tolerant cultivars, and better crop and water management strategies (e.g., conservation tillage). Soil amelioration with organic matter or lime, balanced fertilizer application, and the use of tolerant maize varieties were suggested to help alleviate soil acidity, while SALT and/or conservation tillage systems were named to address soil erosion. In promoting these technologies, however, compatibility with production environment, location, farming system, and farmer resources and management capabilities need to be considered, given that technologies can be costly to develop and disseminate to farmers.

Strategies to help alleviate biotic constraints range from the use of varieties developed through conventional breeding and genetic engineering to chemical pesticide application and biological control. Cultural practices (e.g., elimination of diseased plants, synchronization of planting, reduced tillage) have also been suggested. These practices, while practical and economical, require perfect timing, early monitoring, and prompt destruction of infected seedlings. In addition, many resistant maize cultivars developed through traditional breeding are unfortunately not reaching farmers due to lack of seed production and distribution.

- The public and private sectors have unique capabilities, resources, and comparative advantages that could contribute to alleviating constraints to maize productivity in Asia, and links between the two sectors appear to be expanding.

Hoping to avoid wasteful competition with the private sector, the public sector in general has begun to concentrate on activities and geographic areas that are unappealing to profit-oriented firms (e.g., genetic resource conservation, pre-breeding, population improvement, OPV development, as well as subsistence production areas and marginal environments), while also continuing to advance their hybrid maize research. National and international public sectors enjoy a strong comparative advantage in training and human resource development, which lower the costs of learning and capacity building for private sector research and development.

The private sector, meanwhile, has emphasized inbreeding, hybrid development, hybrid seed production, marketing, and distribution. It has also recently become the dominant player in genomics and biotechnology. On the heels of transgenic maize, modern stress tolerant/resistant cultivars from the private sector promise to broaden the range of environmental conditions under which maize can be grown and increase its productivity and stability. Despite this increasing specialization, however, public and private sectors working on maize continue to be linked through various types of collaborative activities. In Asia, these include international germplasm exchange, public-private germplasm transfer, genetic improvement, crop/resource management, and mutual advantages that work towards the advancement of maize cultivars. Hence, public/private sector alliances could promote spillover of research results from high potential to low potential environments and from economically advanced to economically deprived areas.

7.4 The Role of Policy

The growing trend towards commercialization and intensification of maize production requires a paradigm shift in agricultural policy formulation and research priority setting, different from the staple food self-sufficiency paradigm that has been the cornerstone of agricultural policy in most developing countries. Appropriate government policies can alleviate many of the possible adverse consequences of commercialization and promote sustainable intensification of maize production, especially in marginal environments. Long-term government strategies address a wide range of activities from investments in rural infrastructure and agricultural extension to providing farmers with secure rights to land and water, as well as incentives to invest in sustaining long-term productivity.

As Rosegrant et al. (2002) aptly stated, emerging evidence shows that the right kind of investment can boost agricultural productivity far more effectively than previously thought in many less-favored lands (in the case of maize). Increased public investment in these areas has the potential to generate more competitive, if not greater, agricultural growth on the margin than comparable investments in many high-potential areas, and could have greater impact on poverty and environmental problems in less-favored areas. Although rainfed areas differ greatly from region to region depending on biophysical characteristics, certain development strategies may work equally well in many rainfed areas. Key strategies include improving technology and farming systems; ensuring equitable, secure access to natural resources; promoting effective risk management; investing in rural infrastructure; providing a policy environment that does not discriminate against rainfed areas (and/or against maize); and improving coordination among stakeholders: farmers, NGOs, and public institutions.

Finally, it remains important to recognize that technology—both simple and advanced—is not the only key to increasing productivity, improving the sustainability of intensified maize production, and improving the conditions of marginal maize farmers in Asia. No amount of advanced public- or private-sector maize R&D will help the most disadvantaged farmers, unless substantial parallel investments are made in rural infrastructure, agricultural training and extension, input and output distribution and marketing systems, and harvest and post-harvest facilities. The returns to farmer investments in high-yielding varieties will not be maximized if farm inputs cannot be applied and outputs cannot be marketed because of poor rural transport and market systems. Sustainability-promoting technologies will not be attractive to farmers who have no incentive to adopt them because they do not own the lands they till. Improved technologies will remain on the R&D shelves if the agricultural extension system has no resources to effectively conduct its work and disseminate research products to targeted end-users. In the end, appropriate government policies play a bigger role and have greater impact than technology alone does, a fact that has always been perceived by resource-poor farmers, the eternal target beneficiaries of agricultural R&D in Asia.

References

ARLDF (Asian Rural Life Development Foundation). 1997. *How to Series (1)*. Kinuskusan, Bansalan, Davao del Sur, Philippines. 20 p.

Banzinger, M., S. Mugo, and G.O. Edmeades. 2000. Breeding for drought tolerance in tropical maize: Conventional approaches and challenges to molecular approaches. In J.M. Ribaut and D. Poland (eds.), *Molecular Approaches for the Genetic Improvement of Cereals for Stable Production in Water-Limited Environments*. A Strategic Planning Workshop held at CIMMYT, El Batan, Mexico, 21-25 June 1999. Mexico, D.F.: CIMMYT.

Bautista, R.M., and A. Valdes. 1993. *The Bias Against Agriculture: Trade and Macroeconomic Policies in Developing Countries*. Institute for Contemporary Studies Press, San Francisco, CA.

Beghin, J., and C. Fang. 2002. Protection and trade liberalization under incomplete market integration. *American Journal of Agricultural Economics* 84:3.

Bergvinson, D. 2001a. Global post-harvest losses in maize: An overview. In D.N. Manandhar, J.K. Ransom, and N.P. Rajbhandari (eds.). *Developing and Disseminating Technology to Reduce Post-harvest Losses in Maize*. Proceedings of a Working Group Meeting of the Hill Maize Research Project held in Khumaltar, Lalitpur, Nepal, on 25-27 September 2000. Nepal Agricultural Research Council (NARC) and CIMMYT, Kathmandu, Nepal.

Bergvinson, D. 2001b. Advances in post-harvest research at CIMMYT. In D.N. Manandhar, J.K. Ransom, and N.P. Rajbhandari (eds.). *Developing and Disseminating Technology to Reduce Post-harvest Losses in Maize*. Proceedings of a Working Group Meeting of the Hill Maize Research Project held in Khumaltar, Lalitpur, Nepal, on 25-27 September 2000. Nepal Agricultural Research Council (NARC) and CIMMYT, Kathmandu, Nepal.

Bergvinson, D., and S. Garcia-Lara. 2004. Genetic approaches to reducing losses of stored grain to insects and diseases. *Current Opinion in Plant Biology* 2004, 7: 480-485.

CIMMYT Maize Program. 1988a. Maize production regions in developing countries. (Internal document). International Maize and Wheat Improvement Center, Mexico, D.F.

CIMMYT (International Maize and Wheat Improvement Center). 1988b. *Recent Advances in the Conservation and Utilization of Genetic Resources*. Mexico, D.F.

CIMMYT (International Maize and Wheat Improvement Center). 1989. *Toward the 21st Century: CIMMYT's Strategy*. Mexico, D.F.

Costales, A.C. 2004. Changes in the incentives, infrastructural and institutional environments impacting on maize cultivators in the Philippines. In N.C. Wada, C. Fang, and A. Gulati (eds). *Maize in Asia: Changing Markets and Incentives*. IFAD/CIMMYT/IFPRI, CIMMYT, Mexico D.F.

Crawford, I.M. 1997. Rapid rural appraisal. In *Marketing Research and Information Systems (Marketing and Agribusiness Texts 4)*. Rome: Food and Agriculture Organization of the United Nations. Retrieved 30 June 2004 from www.fao.org/docrep/W3241E/w3241e00.htm

CTIC (Conservation Technology Information Center). 1994. Definition of conservation tillage. *Conservation Impact* 12 (11): 6.

Dalmacio, S. 2000. Importance of and growing concerns for maize diseases in the Asian region. In S.K. Vasal, F. Gonzalez Ceniceros, and Fan XingMing (eds.). *Proceedings of the Seventh Asian Regional Maize Workshop*, PCARRD, Los Baños, Philippines (February 23-27, 1998), pp. 267-276.

Dayanand. 1998. Principles governing maize cultivation during rainy season. *Indian Farming* 48 (1): 84-87 (April).

De Leon, C., and J. E. Lothrop. 1994. Lowland tropical germplasm development in Asia with emphasis on selection for downy mildew. In S. K. Vasal and S. McLean (eds.). *The Lowland Tropical Maize Subprogram. Maize Program Special Report*. Mexico, D.F.: CIMMYT. pp 30-45.

De Leon, C., and S. Pandey. 1989. Improvement of resistance to ear and stalk rot and agronomic traits in tropical maize gene pools. *Crop Science* 29: 12-7.

De Leon, C., S. Pandey, and L. Narro. 2000. Development of acid soil tolerant maize germplasm. In S.K. Vasal, F. Gonzalez Ceniceros, and Fan XingMing (eds). *Proceedings of the Seventh Asian Regional Maize Workshop*, PCARRD, Los Baños, Philippines (February 23-27, 1998), pp. 240-248.

Delgado, C.L., M.W. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois. 1999. *Livestock to 2020: The next food revolution*. Food, Agriculture and the Environment. Discussion Paper No. 28. IFPRI, Washington, D.C.

Dobie, P. 1977. The contribution of the Tropical Stored Products Centre to the study of insect resistance in stored maize. *Trop. Stored Prod. Inf.* 34:7-22.

Dowswell, C.R., R.L. Paliwal, and R.P. Cantrell. 1996. *Maize in the Third World*. Westview Press, Boulder, Colorado.

Edmeades, G., J. Bolaños, and S.C. Chapman. 1997a. Value of secondary traits in selecting for drought tolerance in tropical maize. In G. Edmeades, M. Banzinger, H.R. Mickelson, and C.B. Peña-Valdivia (eds.). *Developing Drought- and Low N-Tolerant Maize. Proceedings of a Symposium*, March 25-29, 1996, CIMMYT, El Batan, Mexico. CIMMYT/UNDP, Mexico, D.F.

Edmeades, G., M. Banzinger, J. Bolaños, S.C. Chapman, A. Ortega C., H.R. Laffite, K.S. Fischer, and S. Pandey. 1997b. Recurrent selection under managed drought stress improves grain yields in tropical maize. In G. Edmeades, M. Banzinger, H.R. Mickelson, and C.B. Peña-Valdivia (eds.). *Developing Drought- and Low N-Tolerant Maize. Proceedings of a Symposium*, March 25-29, 1996, CIMMYT, El Batan, Mexico. CIMMYT/UNDP, Mexico D.F. pp 263-273.

Edmeades, G., H.R. Lafitte, J. Bolanos, S. Chapman, M. Banziger, and J. Deustch. 1994. Developing maize that tolerates drought or low nitrogen conditions. In G. Edmeades and J. Deutsch (eds.). *Stress Tolerance Breeding: Maize that Resists Insects, Drought, Low Nitrogen, and Acid Soils*. Mexico, D.F.: CIMMYT.

Ekasingh, B., P. Gypmantasiri, K. Thong-ngam, and P. Grudloyma. 2004. *Maize Production Potentials and Constraints, Research and Development Prioritization: The Case of Thailand*. Mexico, D.F.: CIMMYT.

Ekasingh, B., and K. Thong-ngam. 2004. Maize policies in Thailand. In N.C. Wada, C. Fang, and A. Gulati (eds). *Maize in Asia: Changing Markets and Incentives*. Mexico, D.F.: IFAD/CIMMYT/IFPRI.

Ekasingh, B.S., P. Gypmantasiri, and K. Thong-ngam. 2001. Impact of maize breeding research in Thailand. In R.V. Gerpacio (ed.). *Impact of Public-and Private-Sector Maize Breeding Research in Asia, 1966-1997/98*. Mexico, D.F.: CIMMYT.

Ekboir, J. 2000. Innovation systems and technology policy: Zero tillage in MERCOSUR. Paper presented at the XXIV Conference of the International Association of Agricultural Economists. *Tomorrow's Agriculture: Incentives, Institutions, Infrastructure and Innovations*. August 13-18, 2000, Berlin, Germany.

Ekboir, J., and G. Parellada. 2000. Continuous complex innovation processes: public-private interactions and technology policy. Paper presented at the XXIV Conference of the International Association of Agricultural Economists. *Tomorrow's Agriculture: Incentives, Institutions, Infrastructure and Innovations*. August 13-18, 2000, Berlin, Germany.

FAO (Food and Agriculture Organization of the United Nations). 2001. FAOSTAT Database. Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). 2004. FAOSTAT Database. Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). 2006. FAOSTAT Database. Rome, Italy.

Garrity, D.P. 2000. *The farmer-driven landcare movement: an institutional innovation with implications for extension and research.* World Agroforestry Center, Nairobi, Kenya.

Garrity, D.P., and P. Sajise. 1993. Sustainable land use systems research in Southeast Asia: A regional assessment. In *Proceedings of a Workshop on Sustainable Land Use Systems Research*. p. 59-72. Rodale Institute, Kutztown, Penn., USA.

Gerpacio, R.V. (ed.). 2001. *Impact of Public-and Private-Sector Maize Breeding Research in Asia, 1966-1997/98*. Mexico, D.F.: CIMMYT.

Gerpacio, R.V., J.D. Labios, R.V. Labios, and E.I. Diangkinay. 2004. *Maize Production Systems in the Philippines: Constraints and Priorities for Research*. Mexico, D.F.: CIMMYT.

Gulati, A., and S. Narayanan. 2003. *Subsidy Syndrome in Indian Agriculture*. Oxford University Press, New Delhi.

Gulati, A., and Dixon, J. 2007 *Maize in Asia: Changing Markets and Incentives*. IFAD/CIMMYT/IFPRI, CIMMYT, Mexico D.F.

Ha, D.T., T.D. Thao, N.T. Khiem, M.X. Trieu, R.V. Gerpacio, and P.L. Pingali. 2004. *Maize Production Systems in Vietnam: Constraints and Priorities for Research*. Mexico, D.F.: CIMMYT.

Hartkamp, A.D., J.W. White, A. Rodriguez Aguilar, M. Banzinger, G. Srinivasan, G. Granados, and J. Crossa. 2000. *Maize Production Environments Revisited: A GIS-based Approach*. Mexico, D.F.: CIMMYT.

Huang, J., and S. Rozelle. 2004. China's maize economy and policy. In N.C. Wada, C. Fang, and A. Gulati (eds). *Maize in Asia: Changing Markets and Incentives*. IFAD/CIMMYT/IFPRI, CIMMYT, Mexico D.F.

Huang, J., and S. Rozelle. 2002. *The nature of distortions to agricultural incentives in China and implications of WTO accession*. Paper presented at the final project meeting on WTO Accession, Policy Reform, and Poverty in China, World Bank and the Development Research Center, Beijing, 28-29 June 2002.

ICRAF (International Center for Research on Agroforestry). 1996. *Annual Report for 1995*. Nairobi, Kenya: ICRAF.

IFPRI (International Food Policy Research Institute). 2003. *2025 Projections, International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) Special Project: Global Trends in Food Supply and Demand*. IFPRI, Washington D.C.

IFPRI (International Food Policy Research Institute). 2002. *2025 Projections, International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) Special Project: Global Trends in Food Supply and Demand*. IFPRI, Washington D.C.

IRRI (International Rice Research Institute). 1984. *Cropping Systems in Asia: On-Farm Research and Management.* IRRI, Los Banos, Laguna, Philippines.

ISAAA (International Service for the Acquisition of Agri-biotech Applications). 2004. *Global Adoption of Bt Maize, 1996-2003*. Global Knowledge Center on Crop Biotechnology, ISAAA c/o IRRI, Los Banos, Laguna, Philippines.

ISAAA (International Service for the Acquisition of Agri-biotech Applications). 2005. *Global Area of Biotech Crops, by Crop, 1996-2005*. Available online at http://www.isaaa.org/kc/CBTNews/press_release/images/briefs34/figures/hectares/by%20crop_hectares.jpg.

Joshi, P.K., N.P. Singh, N.N. Singh, R.V. Gerpacio, and P.L. Pingali. 2004. *Maize in India: Production Systems, Constraints, and Priorities for Research*. Mexico, D.F.: CIMMYT.

Khiem, N.T., M.X. Trieu, T.D. Thao, and D.T. Ha. 2004. Policy analysis of maize in Vietnam. In N.C. Wada, C. Fang, and A. Gulati (eds). *Maize in Asia: Changing Markets and Incentives*. IFAD/CIMMYT/IFPRI, CIMMYT, Mexico D.F.

Lal, S., C. De Leon, V. K. Saxena, S. B. Singh, N. N. Singh, and S. K. Vasal. 2000. Maize stalk rot complexes: Innovative breeding approaches. In S.K. Vasal, F. Gonzalez Ceniceros, and Fan XingMing (eds). *Proceedings of the Seventh Asian Regional Maize Workshop*, PCARRD, Los Baños, Philippines (February 23-27, 1998). pp. 290-306.

Manton, M.J., P.M. Della-Marta, M.R. Haylock, K.J. Hennessy, N. Nicholls, L.E. Chambers, D.A. Collins, G. Daw, A. Finet, D. Gunawan, K. Inape, H. Isobe, T.S. Kestin, P. Lefale, C.H. Leyu, T. Lwin, L. Maitrepierre, N. Ouprasitwong, C.M. Page, J. Pahalad, N. Plummer, M.J. Salinger, R. Suppiah, V.L. Tran, B. Trewin, I. Tibig, and D. Yee. 2001. Trends in extreme daily rainfall and temperature in Southeast Asia and the South Pacific: 1961-1998. *International Journal of Climatology* 21: 269-284.

Meikle, W.G., N. Holst, and R.H. Markham. 1999. Population simulation model of *Sitophilus zeamais* (Coleoptera: Curculionidae) in grain stores in West Africa. *Environmental Entomology* 1999, 28: 836-844.

Milliman, J. D., and R. H. Meade. 1983. World-delivery of river sediment to the oceans. *Journal of Geology* 91:1-21.

Monsanto. 2004. *Conservation Tillage*. (Internet accessed information from Monsanto Company – http://212.100.230.153/reports/brochure/index.html)

Monsanto. 2001. *Monsanto reveals results of field trials.* Agri Asia Yearender.

Monsanto. 2001. *YieldGard® corn: food and feed safety*. Biotechnology Insight.

Morallo-Rejesus, B., and E. M. Punzalan. 2002. Mass Rearing and Field Augmentation of the Earwig, *Euborollia annulata*, Against Asian Corn Borer. Terminal report, Department of Entemology, University of the Philippines Los Baños, College, Laguna, Philippines. pp 1-19.

Morris, M.L. 1998. *Maize Seed Industries in Developing Countries*. Boulder, Colorado: Lynne Rienner Publishers, Inc. and Mexico, D.F.: CIMMYT.

Narayanan, S. and A. Gulati. 2004. The corn economy of India. In N.C. Wada, C. Fang, and A. Gulati (eds.). *Maize in Asia: Changing Markets and Incentives*. IFAD/CIMMYT/IFPRI, CIMMYT, Mexico D.F.

PAGASA – Philippine Atmospheric, Geophysical and Astronomical Services Administration. Monthly total and annual climatic data. Agham Road, Diliman, Quezon City.

Pandey, S., H. Ceballos, and G. Granados. 1994. Development and improvement of lowland maize populations by CIMMYT's South American regional maize program. In S.K. Vasal and S. McLean (eds.). *The Lowland Tropical Maize Subprogram. Maize Program Special Report*. Mexico, D.F.: CIMMYT.

Paudyal, K. 2004. Policy environment of maize production and trade in Nepal. In N.C. Wada, C. Fang, and A. Gulati (eds.). *Maize in Asia: Changing Markets and Incentives*. IFAD/CIMMYT/IFPRI, CIMMYT, Mexico D.F.

Paudyal, K.R., J.K. Ransom, N.P. Rajbhandari, K. Adhikari, R.V. Gerpacio, and P.L. Pingali. 2001. *Maize in Nepal: Production Systems, Constraints, and Priorities for Research*. NARC and CIMMYT, Kathmandu, Nepal.

Phillips, M.J. 2001. *The Future of Agricultural Biotechnology.* Paper delivered at the 2001 D.W. Brooks Lecture, College of Agriculture and Environmental Science, University of Georgia. Biotechnology Industry Organization (BIO). (October 1).

Pingali, P.L. 2004. *Westernization of Asian Diets and the Transformation of Food Systems: Implications for Research and Policy*. ESA Working Paper No. 04-17, Agricultural and Development Economics Division, FAO of the United Nations, Rome, Italy. (September).

Pingali, P.L. and S. Pandey. 2001. Meeting world maize needs: Technological opportunities and priorities for the public sector. In P.L. Pingali (ed.). *CIMMYT 1999-2000 World Maize Facts and Trends*. Mexico, D.F.: CIMMYT.

Ransom, J.K. 2001. Factors affecting post-harvest losses in maize. In D.N. Manandhar, J.K. Ransom, and N.P. Rajbhandari (eds.). *Developing and Disseminating Technology to Reduce Post-harvest Losses in Maize*. Proceedings of a Working Group Meeting of the Hill Maize Research Project held in Khumaltar, Lalitpur, Nepal on 25-27 September 2000. Nepal Agricultural Research Council (NARC) and CIMMYT, Kathmandu, Nepal.

Raymundo, A.D. 2000. Downy mildew of maize in Asia: New perspective in resistance breeding. In S.K. Vasal, F. Gonzalez Ceniceros, and Fan XingMing (eds.). *Proceedings of the Seventh Asian Regional Maize Workshop*. PCARRD, Los Baños, Philippines (February 23-27, 1998). pp. 277-283.

Rosegrant, M.W., X. Cai, S. Cline, and N. Nakagawa. 2002. The role of rainfed agriculture in the future of global food production. EPTD Discussion Paper No. 90 (February). Environment and Production Technology Division, International Food Policy Research Institute (IFPRI), Washington, D.C. USA.

Sajjapongse, A., and K. Syers. 1995. Tangible outcomes and impacts from ASIALAND management of sloping land network. In *Proceedings of the International Workshop on Conservation Farming for Sloping Lands in Southeast Asia: Challenges, Opportunities and Prospects*. Manila, 20-26 Nov. 1994. Proceedings No. 14, Bangkok, Thailand: IBSRAM.

Skully, D. 2001. *AoA issues series: Tariff-rate quota administration*. Economic Research Service, US Department of Agriculture (ERS-USDA). (http://www.ers.usda.gov/briefing/WTO/TRQ.htm)

Spielman, D.J., and K. von Grebner. 2004. *Public-private partnerships in agricultural research: An analysis of challenges facing industry and the Consultative Group on International Agricultural Research*. EPTD Discussion Paper No. 113 (January). Environment and Production Technology Division, International Food Policy Research Institute (IFPRI), Washington, D.C. USA.

Suhariyanto, K. 2004. Maize production and policy issues in Indonesia. In N.C. Wada, C. Fang, and A. Gulati (eds.). *Maize in Asia: Changing Markets and Incentives*. IFAD/CIMMYT/IFPRI, CIMMYT, Mexico D.F.

Swastika, D.K.S., F. Kasim, K. Suhariyanto, W. Sudana, R. Hendayana, R.V. Gerpacio, and P.L. Pingali. 2004. *Maize in Indonesia: Production Systems, Constraints, and Priorities for Research*. Mexico, D.F.: CIMMYT.

Tseng, C.T. 2000. Use of *Trichogramma ostriniae* (Hymenoptera Trichogrammidae), to control the Asian corn borer, *Ostrinia furnacalis* (Lepidoptera Pyralidae). In S.K. Vasal, F. Gonzalez Ceniceros, and Fan XingMing (eds.). *Proceedings of the Seventh Asian Regional Maize Workshop*. PCARRD, Los Baños, Philippines (February 23-27, 1998). pp. 339-356.

Vasal, S.K. 1998. *Hybrid Maize in Asia-Pacific*. Paper presented at the Fifth Annual Conference, Asian Seed '98, Manila, Philippines (23-25 September).

Yorobe, J.M. 2004. *Economic Impact of Bt Corn in the Philippines*. Paper presented at the 45th National PAEDA Convention, 12-13 October 2004, Bureau of Soils and Water Management (BSWM), Diliman, Quezon City, Philippines.

Internet info: www.rainwaterharvesting.org, http://bswm.da.gov.ph/swip.html.

Annexes

Annex 1. Survey locations, their number by maize mega-environment and salient characteristics, Asia.

	China	India	Indonesia	Nepal	Philippines	Thailand	Vietnam	Total	% Total
Locations of sites	Sichuan: Bazhong, Guangan, Lezhi, Shehong, Xuanhan Guangxi: Debao, Duan, Longan, Tiane, Wuming Shanxi: Hongtong, Lingshi, Lishi, Qingxu, Shouyang Shaanxi: Ankang-hanbing, Luochuan, Shen-mu, Yanan, Ziyang Jilin: Changling, Gongshuling Shandong: Jiaxiang, Ningjing, Zhucheng	Bihar: Begusarai, Munger, and Siwan M. P.: Chhindwara, Jhabua, and Mandsaur Rajasthan: Banswara, Bhilwara and Udaipur U. P.: Behraich, Bulandshar, and Hardoi A.P.: Mahboobnagar, Karimnagar, Nizamabad Karnataka: Chitradurga, Belgaum, Dharwad	Lampung: Marga Tiga (Central Lampung) and Jati Agung (South Lampung) East Java: Kerek (Tuban) and Plemahan and Kepung (Kediri) West Nusa Tenggara: Pringgabaya (East Lombok) and Alas Barat (Sumbawa) South Sulawesi: Klara and Bangkala (Jeneponto) and Ulaweng and Kajuara (Bone)	High hills: Sankhuwasabha, Sindhupalchok, and Bajhang Mid-hills: Panchthar, Nuwakot, Lamjung, Baglung, Pyuthan, Salyan, Dailekh, Achham, and Baitadi Terai/inner terai: Jhapa, Udayapur, Bara, Dang, and Bardiya	Cagayan Valley: Isabela Southern Tagalog: Mindoro Occidental Bicol: Camarines Sur Central Visayas: Cebu Eastern Visayas: Leyte Northern Mindanao: Bukidnon Southern Mindanao: South Cotabato Central Mindanao: North Cotabato	Upper north: Chiang Rai, Tak and Chiang Mai Lower north: Nakorn Sawan, Phetchabun, Kamphangphet, Pichit and Uthai Thani Upper NE: Loei Lower NE: Nakorn Ratchaseema Central plain: Lopburi and Sra Kaew	Northwest: Son La and Vinh Phuc Northeast: Ha Giang, Bac Giang and Phu Tho Red River Delta: Ha Tay Northern central coast: Thanh Hoa Southern central coast: Quang Nam Central highland: Dak Lak, Lam Dong and Gia Lai Southeast: Dong Nai Mekong Delta: Soc Trang	47 provinces/ states/ regions	
No. of villages and provinces	Two villages each from two to five counties per province Total of 50 villages across six provinces	Two villages each, from two sub-districts blocks) from each (district Total of 72 villages across 18 districts	Four villages each, from two districts in each province Total of 32 villages across four provinces	Three village development committees (VDCs) from each district in the high and mid hills and two VDCs from each terai/ inner terai district Total of 46 villages across 17 districts	Three villages (barangays) per region, with each village representing a different maize production eco-zone Total of 24 villages across eight geographical regions	Two to three sub-districts each from one to two districts from each province Total of 32 sub-districts (tambons) across 18 districts in 12 provinces	One to three villages each from one to two districts from each province Total of 19 villages across 13 provinces	265 villages across 84 counties/ districts	

cont'd.....

Annex 1. Survey locations, Cont'd...

No. of villages by CIMMYT maize mega-environment	China	India	Indonesia	Nepal	Philippines	Thailand	Vietnam	Total	% Total
Tropical lowlands	10	36	32	10	24	32	19	163	61
Tropical highlands	0	0	0	0	0	0	0	0	0
Subtropical/ mid-altitude	14	36	0	22	0	0	0	72	26
Temperate	26	0	0	9	0	0	0	35	13
Total	50	72	32	46	24	32	19	275	100
% Total	18	26	12	13	9	12	7	100	
Salient characteristics									
Predominant environment	Rainfed upland[a]	Upland plain	Undulating upland	Mid-hills	Rainfed upland	Rainfed upland	Rainfed upland		
Predominant market orientation	Low market surplus[a]	Semi-commercial	Semi-commercial	Low market surplus[a]	Semi-commercial	Commercial	Semi-commercial		
% Maize area planted to MVs	80.0[a]	51.0	70.0	64.0	36.0	99.7	55.5		
Mean farm size (ha)	0.29[a]	1.91	1.03	0.78	1.00	7.30	1.09		
Mean maize yield (t/ha)	3.1[a]	1.4	2.9	1.7	1.6	3.7	2.5		

Source: IFAD-CIMMYT RRA/PRA Surveys, 2000-2001.

Note: Proportions may not add up to 100% due to rounding.

[a] Although sites located in temperate environments predominated in the China survey, for the purposes of the Asian synthesis, we focus only on survey sites located in tropical lowland and subtropics/mid-altitude environments.

Annex 2. Matrix of RRA/PRA survey sites by maize agroecological environment and market orientation of maize production.

Agroecological environment	Market orientation of maize production		
	Low market surplus	Semi-commercial	Commercial
Irrigated lowlands			Indonesia: Kediri and Tuban (East Java); Bone (South Sulawesi) Thailand: Pichit (Lower North) Vietnam: Ha Tay (Red River Delta); Quang Nam (Southern Central Coast); Soc Trang (Mekong Delta)
Rainfed lowlands		Indonesia: Tuban (East Java) Nepal: Dang and Bardiya (MWDR); Bara (CDR); Jhapa and Udayapur (EDR) Philippines: Sablayan, Sta. Cruz and Abra de Ilog (Mindoro Occidental); Tigaon (Camarines Sur); Kadingilan and Talakag (Bukidnon); Tampakan (South Cotabato); Carmen, M'lang and Tulunan (Cotabato) Vietnam: Ha Giang and Phu Tho (Northeast); Thanh Hoa (Northern Central Coast); Quang Nam (Southern Central Coast); Lam Dong (Central Highland)	India: Mahboobnagar and Karimnagar (Andhra Pradesh) Indonesia: East Lombok (NTB); Bone (South Sulawesi) Philippines: Tumauini and San Mariano (Isabela) Thailand: Sra Kaew (Central Plain); Chiang Rai and Tak (Upper North); Loei (Upper Northeast); Nakorn Sawan, Phetchabun, Kamphangphet, Uthai Thani (Lower North); Nakorn Ratchaseema (Lower Northeast) Vietnam: Dak Lak and Gia Lai (Central Highland); Dong Nai (Southeast)
Rainfed uplands	Nepal: Lamjung (WDR) Philippines: San Remigio, Sibonga and Toledo City (Cebu); Mahaplag, Matalom and Tabango (Leyte) China: Debao, Duan, Longan, Tiane, and Wuming (Guangxi)	Indonesia: Tuban (East Java) Philippines: Iriga City and Buhi (Camarines Sur); Malaybalay City (Bukidnon); T'Boli and Surallah (South Cotabato) Thailand: Lop Buri (Central Plain); Nakorn Ratchaseema (Lower Northeast); Chiang Mai (Upper North) Vietnam: Vinh Phuc (Northwest) India: Nizamabad (Andhra Pradesh); Chitradurga, Dharwad and Belgaum (Karnataka)	Indonesia: South Lampung; East Lampung; Kediri (East Java); Sumbawa (NTB); Jeneponto (South Sulawesi) Philippines: Benito Soliven (Isabela) Thailand: Chiang Rai (Upper North); Loei (Upper Northeast); Phetchabun (Lower North) Vietnam: Son La (Northwest)
Subtropical/mid-altitude	India: Jhabua (Madhya Pradesh); Bhilwara (Rajasthan) Nepal: Bajhang, Achham, Baitadi (FWDR); Pyuthan, Salyan and Dailekh (MWDR); Baglung (WDR); Sindhupalchok and Nuwakot (CDR); Sankhuwasabha and Panchthar (EDR) China: Ankanghanbing, Ziyang (Shaanxi); Bazhong, Guangan, Lezhi, Shehong, Xuanhan (Sichuan)	India: Chindwara and Mandsaur (Madhya Pradesh); Udaipur (Rajasthan) China: Ankanghanbing (Shaanxi)	India: Munger, Siwan and Begusarai (Bihar); Banswara (Rajasthan); Behraich, Hardoi and Bulandshar (Uttar Pradesh)

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.

Annex 3. Summary of agro-climatic features of surveyed locations classified by agroecological region and orientation of maize production, Asia.

Predominant agroecological region and production orientation	Elevation (masl)	Range of annual rainfall (mm)	Range of annual average temperature (ºC)	Topography	Soil types present
Irrigated lowland					
Commercial		1,200 – 1,885	25 - 28	Relatively flat to flat with wet lands, plains, and meadows	Sandy loam with good drainage; sandy alluvial
Rainfed lowland					
Semi-commercial	17 - 1,500	916.5 – 2,556.3	17 – 29	Upland plain; plain undulating; rolling to hilly	Clay, loam, clay loam, sandy loam, sandy clay loam, volcanic
Commercial	34 – 1,500	900 – 2,019	24 – 32	Upland plain; plain undulating; hilly; hill plains; highland plateau; medium to high slopes loam, alluvial soil	Clay, clay loam, sandy soil, sandy
Rainfed uplands					
Low market surplus	35 – 823	1,300 – 1,776.6	19.5 – 28	Rolling to hilly areas; mid-hills; steep slopes	Clay, clay loam, sandy loam, calcareous
Semi-commercial	30 – 1,350	966 – 2,028	22 – 32	Highland plateau, rolling to hilly areas, steep slopes	Clay, clay loam, sandy, sandy loam
Commercial	35 – 2,000	500 – 2,455	24 – 28	Plain and hill plains, rolling to hilly, undulating land, sloping hillside, ridges, steep slopes	Clay, clay loam, red loam, sandy soil, alluvial soil, sandy alluvial, latosol
Subtropical/mid-altitude					
Low market surplus	360 – 2,500	600 – 1,546	14.7 -17.6	Mid-hills, hill	Sandy, sandy loam, sandy clay, alluvial
Semi-commercial		700 – 1,400	2 – 36	Plateaus, hills	Clay, clay loam, sandy, sandy loam, loam, alluvial
Commercial		700 – 1, 400	3 – 33	Diara belt, Doab (India)[a]	Clay, clay loam, sandy loam, loam, alluvial

Source: IFAD-CIMMYT RRA/PRA Surveys in Asia, 1999-2001.

[a] Diara belt is a shallow riverbed that is submerged during the rainy season; crop cultivation is done only when rainwater recedes. Doab area is the land between the Ganga and the Yamuna rivers in Uttar Pradesh.

Annex 4. Types of soil present and their farmer-reported advantages and disadvantages, across surveyed villages, Asia.

Soil type	Advantages	Disadvantages
Clay	Good/high water-holding capacity/water retention; good soil fertility; less fertilizer requirement; more soil nutrients; good maize yield; good for contour farming and has potential to support forest trees; generally suitable for growing many crops; suitable for pasture	Difficult to plow; poor drainage; prone to soil erosion; wet/muddy in the rainy season causing poor yield; less porous soil making it difficult to plow and lumpy in the rainy season; tend to lose moisture rapidly when there is no rain; needs proper soil fertility management practices
Clay loam	Suitable for growing any crop, especially cereal crops; good water-holding capacity; fair soil fertility; easy to plow moisture for crops	Poor drainage; low soil fertility; difficult to plow; wet/muddy in the rainy season; prone to soil erosion; limited source of
Clay + lateritic soil	Good yield if there is no drought; can grow cassava with big roots and good weight; easy harvesting	Poor water holding capacity; requires much chemical fertilizer; drought-prone; low percentage of starch in cassava yield; difficult to plow
Sand	No hard pan; easy to plow; minimal soil clodding; good drainage	Poor water holding capacity; not suitable for maize; poor soil fertility
Sandy loam	Easy to plow; good soil if there is enough rain; seeds germinate quickly; good drainage; suitable for paddy rice, maize, legumes, and vegetables; does not become waterlogged	Poor water holding capacity, especially in the dry season; poor soil fertility; poor crop yield; requires much fertilizer; poor drainage; requires organic fertilizers; susceptible to drought
Sandy clay	Suitable for growing maize; low soil erosion; good maize yield; easy for seed planting; allows rapid seed germination	Holds too much water and waterlogs during rainy season, making maize crop prone to stem rot disease; prone to drought in the dry season
Sandy clay loam	Good for crop production and pasture	Slightly susceptible to soil erosion
Loam	Easy plowing; suitable for growing maize, mungbean, and ground nut; allows easy harvesting of ground nut	Poor water-holding capacity in the dry season; much weevil; poor groundnut yield (poor weight)

Source: IFAD-CIMMYT RRA/PRA Surveys 2000-2001.

Annex 5. Maize production and poverty parameters by country and agroecological zone, Asia.

		Maize production (000 t)		Maize area (000 ha)		RRA/PRA	Rural poverty	
Geographical region	Agroecological zone	Production	% Country total	Area	% Country total	average maize yield (t/ha)	No. of rural poor (million)	% Country total
INDIA								
C&W Uttar Pradesh, Madhya Pradesh, Rajasthan	Low rainfall	16.9		48.4		0.3	57.1	21.2
C&W Uttar Pradesh, Madhya Pradesh, Rajasthan	Medium to high rainfall	2,652.1		2,535.4		1.0		
Eastern Uttar Pradesh and Bihar	High (kharif)/medium (kharif)/ spring/winter (irrigated)	1,515.2		881.4		1.7	61.2	22.7
Karnataka	High rainfall	1,363.3		391.6		3.5	22.5	8.4
Karnataka	Medium rainfall	473.9		138.0		3.4		
Karnataka	Low rainfall	3.0		1.3		2.3		
INDONESIA								
Java and Bali	Dryland	3,668.8		1,901.0		1.9	0.2	0.6
Outer islands	Dryland	2,243.2		757.8		3.0	3.9	13.3
Java and Bali	Irrigated	896.1		176.4		5.1	15.8	54.1
Outer islands	Irrigated	775.6		360.7		2.2	0.6	2.1
Java and Bali	Rainfed lowland	817.0		507.5		1.6	0.5	1.7
Outer islands	Rainfed lowland	523.3		210.2		2.5	2.1	7.2
NEPAL								
All regions	High hills	104.4		66.1		1.6	1.2	8.5
Central and western	Mid-hills	530.9		301.7		1.8	3.2	22.9
Eastern DR	Mid-hills	212.5		122.1		1.7	1.3	8.9
Far and mid-western DR	Mid-hills	184.1		108.3		1.7	1.8	13.1
All regions	Terai	335.4		175.6		1.9	6.6	46.6
PHILIPPINES								
Reg. 2-Cagayan Valley	Upland plains to hilly	907.2		283.5		3.2	2.1	3.5
Reg. 4-Southern Tagalog	Rainfed lowland	101.1		72.2		1.4	4.9	9.8
Reg. 5-Bicol	Upland plains to hilly	62.8		89.7		0.7	4.3	13.7
Reg. 7-Central Visayas	Rolling to hilly	154.0		256.7		0.6	3.0	8.1
Reg. 8-Eastern Visayas	Rolling to hilly	47.5		59.4		0.8	2.6	7.1
Reg. 10-Northern Mindanao	Rolling to hilly	798.7		363.1		2.2	2.6	7.6
Reg. 11-Southern Mindanao	Upland plains to hilly	919.0		574.4		1.6	3.4	8.6
Reg. 12-Central Mindanao	Upland plains	919.0		459.5		2.0	1.9	5.4
THAILAND								
Upper north	Irrigated lowland	76.0		19.5		3.9	0.08	6.9
Upper north	Favorable upland	507.5		107.3		4.7	0.13	11.6
Upper north	Unfavorable upland	202.0		63.7		3.2	0.08	7.7
Upper northeast	Favorable upland	183.3		46.1		4.0	0.16	14.6
Upper northeast	Hilly	50.3		16.8		3.0	0.03	2.3
Lower north	Favorable upland	1,763.1		396.2		4.5	0.20	18.3
Lower north	Unfavorable upland	144.5		47.8		3.0	0.03	2.7
Lower north	Hilly	180.2		35.8		5.0	0.04	3.9
Lower northeast	Favorable upland	290.4		65.7		4.4	0.06	5.3
Lower northeast	Unfavorable upland	295.8		87.5		3.4	0.22	19.8
Central	Favorable upland	360.4		85.2		4.2	0.04	3.4
Central	Unfavorable upland	397.2		122.6		3.2	0.04	3.4
VIETNAM								
Central coast and highlands	Lowland commercial	239.2		96.4		2.5	2.1	25.3
Central coast and highlands	Upland commercial	380.1		103.0		3.7	1.3	15.7
North	Lowland commercial	279.6		92.9		3.0	1.2	13.8
North	Upland semi-commercial	653.3		289.8		2.3	1.8	21.6
Southeast and Mekong River Delta	Lowland commercial	51.8		19.0		2.7	1.6	18.6
Southeast and Mekong River Delta	Upland commercial	401.9		122.8		3.3	0.4	5.0
CHINA								
Southwest							11.2	38.2
Southwest	Rainfed spring maize	13,904.6	11.5	3,550.4	14.4	3.96		
Southwest	Rainfed fall maize	1,093.6	0.9	279.2	1.1	3.60		
Southwest	Rainfed summer maize	624.9	0.5	159.6	0.6	2.64		

Source: IFAD-CIMMYT country-level RRA/PRA surveys and National Maize R&D Priority-Setting Workshops, 2001-2002.

Annex 6. List of 286 prioritized maize productivity constraints identified by Asian maize farmers.

Region	Ecozone	Farmer-identified constraint
UP,MP,Rajasthan,Bihar	Medium-high rainfall/winter	Post-flowering stalk rot
UP,MP,Rajasthan,Bihar	Medium-high/winter/spring	Lack of quality seed
UP,MP,Rajasthan,Bihar	All ecozones	Imbalanced/improper/inadequate use of fertilizers
UP,MP,Rajasthan,Bihar	All ecozones	Postharvest losses (weevils during storage)
UP,MP,Rajasthan,Bihar	Medium-high/winter/spring	Improper cropping systems (mixed cropping/ intercropping)
EUP & Bihar	Winter (irrigated)	Transplanting maize under late sown conditions
EUP & Bihar	Winter (irrigated)	Turcicum leaf blight
UP,MP,Rajasthan,Bihar	Medium-high rainfall	Moisture stress (drought)
UP,MP,Rajasthan,Bihar	Medium-high rainfall	Lack of appropriate maturity varieties
Outer islands/KAP/EC367	Dryland/Unfavorable upland	Drought
UP,MP,Rajasthan,Bihar	All ecozones	Stem borer
UP,MP,Rajasthan,Bihar	Medium-high rainfall/spring	Maydis leaf blight
KAP/Outer islands/EC3	Low-high rainfall/dryland/ unfavorable upland	Poor availability of quality seed
KAP/Outer islands	Medium-high rainfall/dryland	Weeds and weed management
Outer islands/EC3/KAP	Dryland/Unfavorable upland	Downy mildew
KAP/Outer islands	Low-high rainfall/dryland	Stem borers
J+B/RP11/EC91113	Dryland/PURHM/Unfavorable upland	Drought
EUP and Bihar	All ecozones	Inappropriate crop establishment method
J+B/RP1011	Dryland/PURHM/rolling to hilly	Soil erosion/landslides
All Nepal/RP12/J+B/North	TR/Upland plains/ RFLL/UPSC	Drought
J+B/All Nepal/RP5/North	RFLL/TR/Upland plain/UPSC	Lack of suitable (hybrid) varieties
RP4512/J+B/North	RFLL/Upland plains/ UPSC	Lack of capital/low interest credit, inadequate credit support
North/RP4512/J+B	UPSC/RFLL/Upland plains	Rats
RP2/CCH/SEMK/ Outer islands/EC25810	Broadplains and hilly/ UPC/RFLL/Favorable upland	Drought
All Indonesia/SEMK/CCH	Irrigated/LWC	Lack of capital
RP1011/EC91113	PURHM/rolling to hilly/ Unfavorable upland	Soil infertility and acidity
C&W UP,MP, Rajasthan	Medium-high rainfall	Lack of location-specific TOT for rainfed conditions, esp for farm women
All Indonesia/CCH/SEMK	Irrigated/LWC	Inefficient fertilizer use/inappropriate fertilizer application
C&W UP, MP, Rajasthan	Medium-high rainfall	Banded leaf and sheath blight
C&W UP, MP, Rajasthan	Medium-high rainfall	Broadleaf and grassy weeds
C&W UP, MP, Rajasthan	Medium-high rainfall	Brown stripe downy mildew
C&W UP, MP, Rajasthan	Medium-high rainfall	Rats
C&W UP, MP, Rajasthan	Medium-high rainfall	Termites
C&W UP, MP, Rajasthan	Medium-high rainfall	Nematodes
KAP	Low-high rainfall	Post-flowering stalk rot
All Indonesia/EC1/North	Irrigated/LWC	Undeveloped irrigation system/water shortage
KAP	Low-high rainfall	Storage pests
RP11/J+B/EC9	PURHM/Dryland/Hilly	Downy mildew
KAP	Low-high rainfall	Turcicum leaf blight
RP511/J+B	PURHM/Dryland	Weeds
KAP	High rainfall	Banded leaf and sheath blight
All Indonesia/North	Irrigated/LWC	High production costs/input prices
RP2/CCH/SEMK/ Outer islands/EC58	UP,BP&hilly/UPC/RFLL/ favorable upland	Corn borers (ear/stem borers)
J+B/RP45/North	RFLL/Upland plain/UPSC	Poor marketing system, input/output market access and undeveloped transport system
RP45/All Nepal/North	RFLL/Upland plain/ TR/UPSC	Inadequate post-harvest technologies/facilities
RP1011	PURHM/rolling to hilly	Limited capital/access to credit
RP2/EC7/Outer islands	Hilly/dryland	Soil erosion
J+B/RP10	Dryland/rolling to hilly	Low price of output
RP1011/EC9	Hilly/PURHM	Pests and diseases (ear rot, stalk rot)
J+B/RP10	Dryland/rolling to hilly	Lack of post-harvest facilities
RP1011	PURHM/rolling to hilly	High price of inputs (including seed, transport)
RP1011	PURHM/rolling to hilly	Limited access to information and technology at farmers level due to poor extension
North/EC1/CCH/J+B/SEMK	Irrigated/LWC	Rats
J+B/RP512	RFLL/Upland plains	Post-harvest pest and diseases (weevils)
North/RP512	UPSC/Upland plains	Sloping land and soil erosion
J+B/EC1113	Dryland/Unfavorable upland	Inappropriate fertilizer use
EC36/Outer islands	Unfavorable upland/dryland	Soil infertility
All Indonesia	Irrigated	Waterlogging/crop establishment
All Nepal/RP412	TR/RFLL/Upland plain	Stem borers/corn borer
J+B/EC1113	Dryland/Unfavorable upland	Lack of appropriate variety

Annex 6. List of 286 ....cont'd.

Region	Ecozone	Farmer-identified constraint
All Indonesia	Irrigated	Lack of labor
All Indonesia	Irrigated	Downy mildew
RP4512	RFLL/Upland plains	Soil acidity/poor soil fertility
Region	Ecozone	Farmer-identified constraint
RP512	Upland plains	Low adoption of technology
RP4512	RFLL/Upland plains	Weeds (sedges and broad leaves)
RP512	Upland plains	Misuse of fertilizer/low fertilizer use
All Indonesia	Irrigated	Leaf blight / rust (foliar diseases)
EUP & Bihar	Medium-high rainfall (kharif)	Weed problems
EUP & Bihar	High (kharif)	Excess water (waterlogging)
EUP & Bihar	High-medium (kharif)	Bacterial stalk rot
RP512	Upland plains	High costs of inputs (including transport, credit)
CCH/SEMK/Outer islands/RP2	UPC/RFLL/BP&hilly	Rats
Outer islands/EC25810	RFLL/Favorable upland	Rust
Outer islands/EC25812	RFLL/Favorable upland	Waterlogging
RP12/North	Upland plains/UPSC	Poor technology transfer system
RP11/EC9	PURHM/Hilly	Poor quality of hybrid seeds
CCH/SEMK/RP2	UPC/broad plains and hilly	Lack of capital
EC212/CCH/SEMK/ Outer islands	Favorable upland/UPC/RFLL	Banded leaf and sheath blight
CCH/SEMK/RP2	UPC/ broad plains and hilly	Lack of post-harvest facilities
Outer islands/EC25	RFLL/Favorable upland	Soil infertility
RP2/CCH/SEMK	BP, UPC	Flooding
RP11/EC9	PURHM/Hilly	Corn borer
RP11/EC9	PURHM/Hilly	Rats
KAP	Medium rainfall	Early maturing hybrids (irrigated environment)
RP12/J+B	RFLL/Upland plain	Downy mildew
Outer islands	Dryland	Post-harvest
CCH/Outer islands/SEMK	Irrigated/LWC	Stem borers
Outer islands	Dryland	Acid soils
Outer islands	Dryland	Purchasing power
S. Mindanao	PURHM	Flash floods
S. Mindanao	PURHM	Limited support from DA-LGUs
Outer islands	Dryland	Infrastructure
Outer islands	Dryland	Low price
KAP	Low-medium rainfall	Zn/micronutrient deficiency
RP2/Outer islands	UP,BP&hilly/RFLL	Weeds
Outer islands	Dryland	Lack of labor
S. Mindanao	PURHM	Strong winds
RP5/J+B	Rolling to hilly/Dryland	Accessibility to input & output markets (poor farm-to-market roads)
All Nepal	Mid- and high-hills	Declining soil fertility
S. Mindanao	PURHM	Poor grain quality
S. Mindanao	PURHM	Whorl maggot
Outer islands/RP2	RFLL/UP,BP&hilly	Cutworms/armyworms
S. Mindanao	PURHM	Banded leaf and sheath blight
S. Mindanao	PURHM	Leaf blight
All Nepal	Mid- and high-hills	Ear rot
ALL Nepal/CWDR/EDR/FMW	Mid- and high-hills	Lack of suitable improved varieties (HYVs, food maize, fodder, varieties for maize/millet, potato+maize system)
S. Mindanao	PURHM	Armyworm
S. Mindanao	PURHM	Rust
RP2/EC12	UP,BP&hilly/Favorable upland	Stalk rot
ALL Nepal/CWDR/EDR/FMW	Mid- and high-hills	Turcicum leaf blight
RP45	RFLL/Upland plain	Unstable price of corn (lack of price support)
Cagayan Valley	BP & hilly	Absence of pricing policy for input and output
RP45	RFLL/Upland plain	Bad weather, flooding, siltation
C. Mindanao	Upland plains	Weeds
EC28/Outer is	Favorable upland/RFLL	Downy mildew
ALL Nepal/CWDR/FMW	Mid- and high-hills	Soil erosion
North/RP4	UPSC/RFLL	Insufficient technical know-how of cultural practices (pest/nutrient management, sowing distance)
C. Mindanao	Upland plains	Limited support of DA-LGU
C. Mindanao	Upland plains	Use of poor quality seeds

Annex 6. List of 286 ....cont'd.

Region	Ecozone	Farmer-identified constraint
ALL Nepal	Terai	Inadequate crop management technologies
RP45	RFLL/Upland plain	Absence of strong farmers organization (coops)
ALLCWDR/EDR/ FMW	Mid- and high-hills	Termites/white grubs
Cagayan Valley	UP, BP & hilly	Aphids
ALL Nepal	Terai	Lack of seed supply
CWDR	Mid-hills	Low plant population
CCH/EC1012	UPC/Favorable upland	Lack of appropriate varieties
ALL Nepal/CWDR/EDR	Mid- and high-hills	Stem borers
Region	Ecozone	Farmer-identified constraint
C. Mindanao	Upland plains	Ear rot
C. Mindanao	Upland plains	Poor grain quality
C. Mindanao	Upland plains	Stalk rot
C. Mindanao	Upland plains	Whorl maggots
CWDR	Mid-hills	Weeds
Java+Bali	Dryland	Low purchasing power
CCH/EC1012	UPC/Favorable upland	Inefficient/inappropriate use of fertilizers & pesticides
C. Mindanao	Upland plains	Egg blight
Outer islands/CCH	RFLL/UPC	Poor access to input & output markets (undeveloped infrastructure)
CCH/North	LWC	Lack of short-duration (winter-crop) varieties
CCH/North	LWC	Wind, typhoons, floods
Java+Bali	Dryland	Lack of labor
Java+Bali	Dryland	Post-harvest diseases and insects
ALL Nepal/CWDR	Mid- and high-hills	Soil acidity
Outer islands/SEMK	RFLL/UPC	Lack of labor
CCH/SEMK	UPC	Declining soil fertility
CCH/SEMK	UPC	Lack of information on technology & markets
Java+Bali	Dryland	Foliar diseases
Java+Bali	Dryland	Seedling fly
Java+Bali	Dryland	White grub
Bicol Region	Upland plains	Limited farm work/job opportunities
CCH	UPC	Typhoons/westerly winds (dry, high temp winds)
CCH/SEMK	UPC	Lack of draft power
Bicol Region	Upland plain	Poor farming systems
Java+Bali	RFLL	Waterlogging
EC1113	Unfavorable upland	Inappropriate land preparation
RP78	Rolling-hilly, uplands	Ineffective financial scheme
CCH/SEMK	LWC	Flooding
Java+Bali	RFLL	Foliar diseases
EC81012	Favorable upland	Aflatoxin
Outer islands	Irrigated	Ear rots
Outer islands	Irrigated	Late supply of inputs
Outer islands	Irrigated	Shoot fly
CCH/SEMK	LWC	Lack of information on technology and markets
Outer islands	Irrigated	Weeds
Outer islands	Irrigated	Armyworm
RP78	Rolling-Hilly, Uplands	Limited knowledge on proper crop management (fertilization, variety use, planting density)
RP78	Rolling-Hilly, Uplands	Low price
RP78	Rolling-Hilly, Uplands	Low soil fertility
RP78	Rolling-Hilly, Uplands	Poor farm-to-market roads/limited access to market outlets
CCH/SEMK	LWC	Lack of post-harvest facilities
CCH/EC1	Irrigated/LWC	Lack of draft power
CCH/SEMK	LWC	Blight
CCH/SEMK	LWC	Ear borers
RP78	Rolling-Hilly, Uplands	High production and post-harvest pest incidence
RP78	Rolling-Hilly, Uplands	Lack of improved post-harvest facilities/equipment
EC1/CCH	Irrigated lowland/LWC	Insects
EC28	Favorable upland	Poor seed quality
EC1012	Favorable upland	Inappropriate land preparation
EC1012	Favorable upland	Plant density too high
Central EC13	Unfavorable upland	Insect at seedling time
Central EC13	Unfavorable upland	Plant density too high

Annex 6. List of 286 ....cont'd.

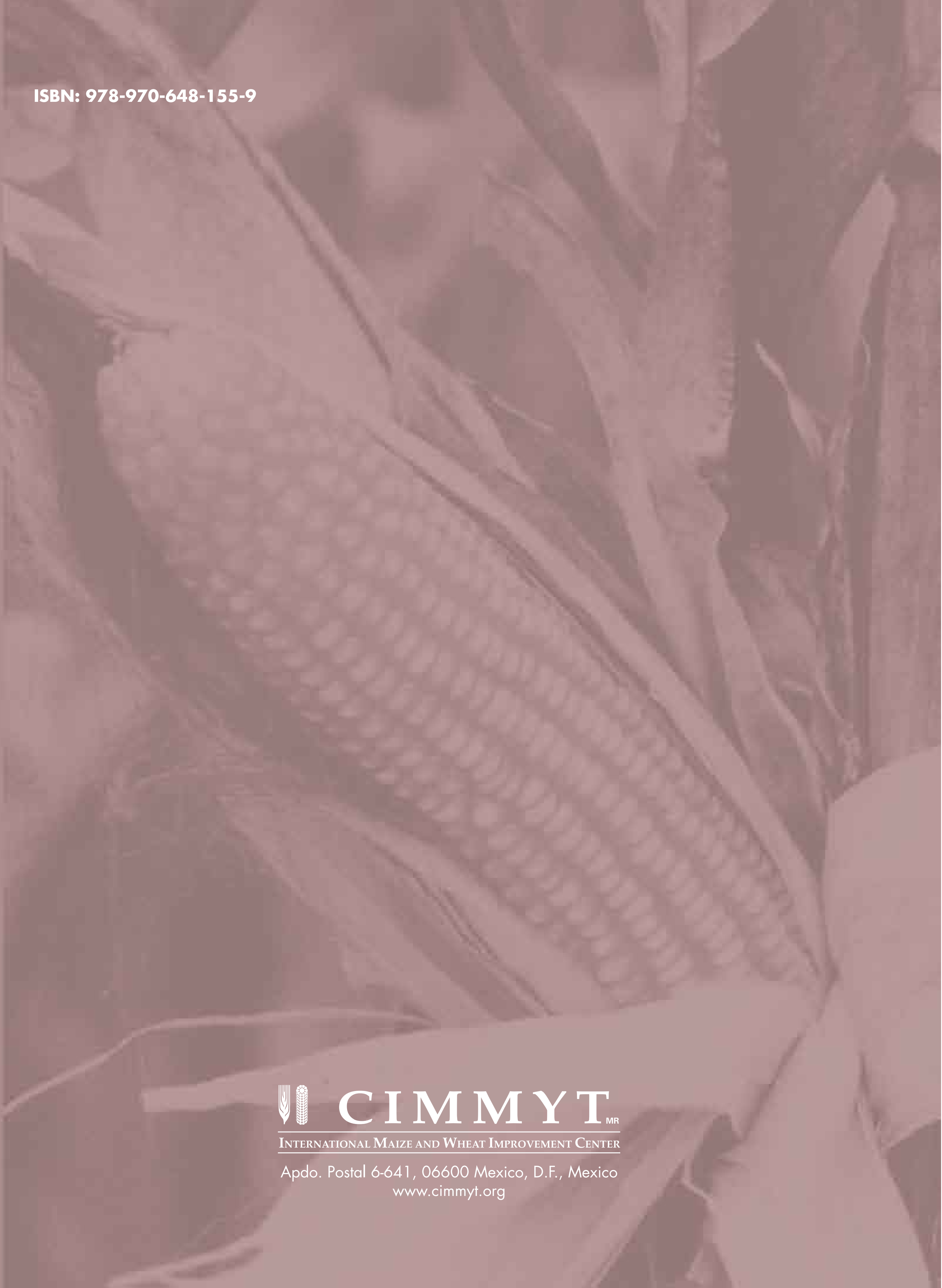
Region	Ecozone	Farmer-identified constraint
Central EC13	Unfavorable upland	Waterlogging
Upper north EC2	Favorable upland	Lodging
CCH	UPC	Lack of inputs
Central EC13	Unfavorable upland	Aflatoxin
EC67	Unfavorable upland/hilly	Rust
EC37	Unfavorable upland/Hilly	Poor land preparation
North	LWC	Lack of technology to plant maize on wet soil
North	LWC	No land available
Upper north EC2	Favorable upland	Termites
Outer islands	RFLL	Acid soils
All Nepal/EDR	Mid- and high-hills	Storage grain loss (due to moths and weevils)
Central EC12	Favorable upland	Ear rot
Outer islands	RFLL	Weevils
Outer islands	RFLL	Poor extension
Region	Ecozone	Farmer-identified constraint
Outer islands	RFLL	Grasshoppers
Outer islands	RFLL	Wild pigs
Lower NE EC10	Favorable upland	Lack of soil improvement
S. Tagalog	Rainfed lowland	Insufficient water supply
Upper north EC3	Unfavorable upland	Ear rot
C&W UP,MP, Rajasthan	Low	Moisture stress (drought)
ALL Nepal/EDR	Mid- and high-hills	Lack of tech. know-how (husbandry, seed maintenance)
S. Tagalog	Rainfed lowland	Trader monopoly
ALL Nepal/EDR	Mid- and high-hills	Human drudgery (lack of improvement in local implements)
C&W UP,MP, Rajasthan	Low	Inadequate availability of quality seeds
S. Tagalog	Rainfed lowland	Sandy soils
EDR	Mid-hills	Labor shortage for first weeding
C&W UP,MP, Rajasthan	Low	Imbalanced/improper use of fertilizers
C&W UP,MP, Rajasthan	Low	Lack of early maturing varieties
ALL Nepal/EDR	Mid- and high-hills	Loose husk cover
All Nepal/EDR	Mid- and high-hills	Stalk rot
ALL Nepal/EDR	Mid- and high-hills	Field crickets
C&W UP,MP, Rajasthan	Low	Chilo partellus (stem borer)
C&W UP,MP, Rajasthan	Low	Lack of package for sloping & eroded lands
C&W UP,MP, Rajasthan	Low	Post-flowering stalk rot
C&W UP,MP, Rajasthan	Low	Improper maize-based intercropping system
C&W UP,MP, Rajasthan	Low	Broadleaf and grassy weeds
C&W UP,MP, Rajasthan	Low	Brown stripe downy mildew
C&W UP,MP, Rajasthan	Low	Lack of location-specific TOT for rainfed conditions, especially for farm women
C&W UP,MP, Rajasthan	Low	Maydis leaf blight
C&W UP,MP, Rajasthan	Low	Termites
C&W UP,MP, Rajasthan	Low	Nematodes
C&W UP,MP, Rajasthan	Low	Weevils during storage
EDR	Mid-hills	Silk beetles
EDR	Mid-hills	Aphids
C&W UP,MP, Rajasthan	Low	Ear borer (Helicoverpa armigera)
C&W UP,MP, Rajasthan	Low	Rats
EDR	Mid-hills	Lack of market and good price
Upper north EC1	Irrigated lowland	Poor seed quality
SEMK	LWC	Drought
SEMK	LWC	Poor soil
SEMK	LWC	Stalk rot
Upper north EC1	Irrigated lowland	Lodging/strong wind
Upper north EC1	Irrigated lowland	Post-harvest fungus
Upper north EC1	Irrigated lowland	Thrips
ALL Nepal	High hills	Lodging
KAP	Low	Improper nutrient management
ALL Nepal	High hills	Lack of post-harvest technology
ALL Nepal	High hills	Seed not available
Southwest	Rainfed spring, summer, fall	Drought
Southwest	Rainfed spring, summer, fall	Low soil fertility
Southwest	Rainfed spring, summer	Strong wind

Annex 6. List of 286 ....cont'd.

Region	Ecozone	Farmer-identified constraint
Southwest	Rainfed spring, summer, fall	Soil erosion
Southwest	Rainfed spring, summer, fall	Flooding
Southwest	Rainfed spring	Lack of soil micronutrients (such as Cu, Zn)
Southwest	Rainfed spring, summer	Hail
Southwest	Rainfed spring, summer, fall	Banded leaf and sheath blight
Southwest	Rainfed spring, summer, fall	Corn borer
Southwest	Rainfed spring, summer, fall	Turcicum and Maydis leaf blight
Southwest	Rainfed spring, summer	Ear rot
Southwest	Rainfed spring, summer	Cutworms
Southwest	Rainfed spring, summer	Southern rust
Southwest	Rainfed spring, summer, fall	Armyworms
Southwest	Rainfed spring, summer	Stalk rot
Southwest	Rainfed spring	Aphids
Southwest	Rainfed spring	Head smut
Southwest	Rainfed spring, summer, fall	Corn silkworm
Southwest	Rainfed spring, summer	Locusts
Southwest	Rainfed spring	Weevils
Southwest	Rainfed spring, summer	Rodents
Southwest	Rainfed spring, summer	Storage moths
Southwest	Rainfed spring, fall	Cultivated varieties susceptible to insects and diseases
Region	Ecozone	Farmer-identified constraint
Southwest	Rainfed spring, summer, fall	Poor grain quality
Southwest	Rainfed spring, fall	Low seed germination rate
Southwest	Rainfed spring	Poor fertilizer quality
Southwest	Rainfed spring, summer, fall	Lack of suitable production technology
Southwest	Rainfed spring, fall	OPV degradation
Southwest	Rainfed spring, summer	Lack of machinery suitable for hillside plots
Southwest	Rainfed spring, summer	Lack of knowledge to distinguish quality fertilizers and pesticides
Southwest	Rainfed spring	Lodging
Southwest	Rainfed spring, summer, fall	Lack of desirable varieties (e.g., suitable for high density planting, early maturing, etc.)
Southwest	Rainfed spring, summer, fall	Low level of investment in inputs
Southwest	Rainfed spring	Low purchasing power
Southwest	Rainfed spring, fall	Problems with maize marketing
Southwest	Rainfed spring, summer, fall	Lack of well functioning dissemination system
Southwest	Rainfed spring, fall	Low maize price
Southwest	Rainfed spring, summer	High seed cost
Southwest	Rainfed spring, summer, fall	Low per capita land – scale of production too small
Southwest	Rainfed spring, summer, fall	Poor road network
Southwest	Rainfed spring, summer, fall	Labor shortages
Southwest	Rainfed spring, summer	Fake seed and pesticide
Southwest	Rainfed spring, fall	High cost of shelling machine
Southwest	Rainfed spring, fall	Few outlets to purchase seed
Southwest	Rainfed spring	Limited time period to purchase seed
Southwest	Rained spring	High deposit required for seed purchase
Southwest	Rainfed fall	Low temperatures
Southwest	Rainfed summer	Shortage of animal traction due to lack of grass
Southwest	Rainfed summer	High fertilizer price relative to maize price

Regions:

India–Bihar, Madhya Pradesh (MP), Rajasthan, Uttar Pradesh (UP), Karnataka (K), Andhra Pradesh (AP), Central and western UP (C&W UP), Eastern UP (EUP).
Indonesia–Outer islands, Java and Bali (J+B).
Nepal development regions–Eastern (EDR), western (WDR), far and mid-western (FMW), central (CDR), terai.
Philippines–Cagayan Valley (Region 2), Southern Tagalog (Region 4), Bicol (Region 5), Central Visayas (Region 7), Eastern Visayas (Region 8), Northern Mindanao (Region 10), Southern Mindanao (Region 11), Central Mindanao (Region 12).
Thailand–Irrigated lowland Chiang Rai (EC1), rainfed upland favorable Chiang Rai and Tak (EC2), rainfed upland unfavorable Chiang Rai and Chiang Mai (EC3), irrigated lowland Phichit (EC4), rainfed upland favorable Nakorn Sawan, Phetchabun, Kamphangphet and Uthai Thani (EC5), rainfed upland unfavorable Phetchabun (EC6), Hilly land Phetchabun (EC7), rainfed upland favorable Loei (EC8), hilly land Loei (EC9), rainfed upland favorable Nakorn Ratchaseema (EC10), rainfed upland unfavorable Nakorn Ratchaseema (EC11), rainfed upland favorable Sra Kaew (EC12), rainfed upland unfavorable Lop Buri (EC13).
Vietnam–Coastal and central highlands (CCH), Southeastern and Mekong River Delta (SEMK), northwest/northeast and Red River Delta (north).
China–Southwest rainfed spring maize system, Southwest rainfed summer maize system, Southwest rainfed fall maize system.



ISBN: 978-970-648-155-9

CIMMYT MR
INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER
Apdo. Postal 6-641, 06600 Mexico, D.F., Mexico
www.cimmyt.org