Impact of Public- and Private-Sector Maize Breeding Research in Asia, 1966-1997/98

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Chapter 5

Impact of Public- and Private-Sector Maize Research in Nepal

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Agriculture is the largest sector of the Nepalese economy, contributing over 40% of the gross domestic product (GDP), employing more than 80% of the labor force and accounting for the bulk of export earnings. Despite a growth rate of about 4.4% in the second half of the 1980s, real growth in the agricultural sector has remained lower than population growth in the first half of the 1990s. Cereal crops (paddy, maize, wheat, millet and barley) contribute the larger share to the output of the agricultural sector.

Broadly speaking, Nepal is divided into three ecological zones or belts running east to west. In the south, along the border with India, is the Terai (flat plains, less than 1,000 masl). In the middle are steep hills (1,000–3,000 masl) set alongside rivers, small and large. In the north and along the border with Tibet and China are high mountains (≥3,000 masl). The Terai is the most important area for agriculture, followed by the hills and mountains. Maize is the third most important crop in the Terai, after paddy and wheat. In the hills and mountains, maize is the most important crop, both in terms of area planted and production (Annex 1). Thus, maize is the main crop in the more marginal environments. In 1997/98, maize was grown on about 800,000 ha (25%) of the total area planted to cereals. Production was around 1.37 m t, contributing 21% of the total production of cereals in the country. The hill and mountain zones accounted for 40% and 30%, respectively, of these production figures.

Maize cultivation has always been a way of life for most of the hill farmers. It is the traditional crop cultivated as food, feed and fodder, generally by resource-poor farmers using marginal, semi-marginal and sometimes irrigated prime land. Maize is grown mostly under rainfed conditions during the summer season (April-August), either as a single crop or with millet as a relay crop. In the Terai, inner valleys and low-lying river basin areas of the hills where irrigation is available, maize is also grown during the winter (October-February) and spring (March-June).

Systematic maize research in the country started in 1965. Since then several improved maize varieties have been released, promoted and adopted by maize farmers. As Nepal has not yet developed a hybrid maize variety, a significant number of hybrids have been imported from India, but local/traditional varieties still dominate maize production.

This study aims to assess the impact of public and private sector maize research on long-term maize production in Nepal. Specifically, it attempts to collect, collate and document all available information on maize research and development activities in Nepal; analyze the adoption of maize technology by Nepalese farmers; and estimate the impact of improved maize technologies in the fields. This study uses secondary information from several sources, combined with primary information from a survey of public and selected private companies dealing with maize seed in

Nepal and a survey of some maize seed suppliers in India. Before proceeding to the data analysis and discussion, we provide some background on agricultural research and development in Nepal, especially with respect to maize.

Agricultural Research and Development in Nepal

Agricultural research dates back to the establishment of the Department of Agriculture (DOA) in 1924. Since then, several institutional changes were made to focus the agricultural research system on farmers' problems.

Initially agricultural research was conducted at several agriculture stations on a multi-commodity basis to test and modify technologies borrowed from other countries. In 1966, the Ministry of Agriculture (MOA) was reorganized, and the agricultural research paradigm shifted to a discipline-based approach that was later found to be fragmented and uncoordinated. A new and better-coordinated agricultural research initiative began in 1972/73, following the re-organization of the DOA. The research paradigm once again shifted to multidisciplinary research concepts, with coordinated research programs in major crop commodities such as rice, maize, wheat, potato, citrus, pulses, oilseeds, sugarcane and hill crops. Although it was instrumental in developing relevant technologies, this approach failed to address the important needs of farmers. In 1991 the government passed the Nepal Agricultural Research Council (NARC) Act, establishing NARC as an autonomous apex corporate body for agricultural research attached to the MOA.

Charged with formulating, coordinating and implementing agricultural research programs in Nepal, NARC has three organizational levels: central, regional and subregional. Central management functions are performed by the Office of the Executive Director (OED). Regional administration is entrusted to four regional centers, which in turn share the command over all other agricultural research stations and commodity programs. Across regions, the number of subordinate stations (or substations) differs depending upon the regional setup. The on-farm research of these stations is conducted at outreach research sites. The number of such sites varies according to the needs of the area.

In 1972, to strengthen and broaden maize research and boost national production, the National Maize Research Program (NMRP) was established as a full-fledged commodity program under NARC. Located in Rampur, Chitwan, a major maize growing area in the central Terai, NMRP spearheads maize research in close collaboration with other divisions, stations and research farms under NARC and DOA. Maize breeding, production and agronomy research acquired a new momentum. International collaboration with CIMMYT and other agencies soon followed to improve and broaden the germplasm base through local collection and introduction of new varieties. The main objective of NMRP's maize breeding research has been to develop high yielding, stress tolerant, widely stable cultivars and technology packages suitable to the different agro-ecological zones. Two major agro-ecological zones and six production domains have been defined precisely for maize research (Annex 2). Accordingly, work plans have been developed for each of the NMRP's collaborating research facilities, both within NARC and DOA.

Organization of the Maize Seed Industry

Nepal's seed industry formally began in 1966/67, when the Agriculture Supply Corporation (presently Agriculture Inputs Corporation, AIC) collected and sold 140 t of paddy and 162 t of wheat seed. Since then, AIC has been the only public-sector entity responsible for producing and marketing improved/certified seed. In the private sector,

several traders handle less bulky, high value seed in comparatively accessible areas, but their contribution to maize seed supply and distribution is limited.

Role of the Public Sector

Among the major responsibilities of NMRP is to maintain the purity of commercially released open-pollinated maize varieties and to produce targeted breeder and foundation seed. Coordinated by NMRP, the latter activity is also carried out in the different Agricultural Research Stations (ARSs) under the supervision of experienced maize scientists.

Breeder seed produced in the research stations is used for research only and not distributed to the private sector. Foundation seed produced by NMRP and the ARSs is sold to AIC, the Department of Agriculture Development (DOAD)/District Agriculture Development Offices (DADOs), NGOs, private trading seed companies and development projects. These entities in turn produce certified seed through progressive contract farmers in different parts of the country.

The certified/improved maize seed produced by AIC contract farmers is bought back at a price about 15% higher than the local market price of grain maize plus a quality premium of up to 15%. Private seed companies, NGOs and development projects buy back maize seed from contract farmers at prices agreed upon at the time of planting. The DADOs usually do not have a budget allocation to procure improved maize seed produced under their seed multiplication program. Instead they assist the farmers to find a market for the seed and promote these with other farmers.

Role of the Private Sector

Maize hybrids are currently being tested at the research stations, but none has been released by the public sector. Farmers are aware of the performance of maize hybrids in India and are willing to adopt the promising cultivars. Realizing this, private seed companies are importing maize hybrids from India and selling them in Nepal.

There are no official records of the number of maize seed traders in Nepal. The Seed Entrepreneurs' Association of Nepal (SEAN), an organization of private seed traders, has 108 members across the country. It is estimated that its membership would be as high as 150 if all seed traders joined the association. About two-thirds of them (100 traders) handle maize seed. Unlike in other Asian countries, in Nepal no private seed company has established a maize research and development program. These companies only import and distribute hybrid maize seed. Some produce seed of improved OPVs through contract farmers. No official data are maintained on the quantity of seed imported, produced and sold by these entrepreneurs. This study found that, in 1997, private traders handled between 10 kg and 24 t of imported hybrid maize seed and between 100 kg and 20 t of improved OPV seed each.

Seed Production and Distribution

Supply Systems

The public-sector wholesaler, AIC, is responsible for supplying fertilizers and seed of cereals, vegetables and cash crops throughout Nepal. These include wheat, paddy, maize, jute, lentils and vegetables. Available data show that AIC produces and sells between 3,000 and 4,000 t of seed of different crops annually. In the past three years, maize seed composed only about 3% of all seed sold by AIC. Rai and Gyawali (1997) estimated that the maize seed traded by AIC was less than 1% of the total national improved maize seed requirement. This study estimates that about 13,750 t of fresh commercial improved maize seed was required in 1997 (Table 1). Probably AIC handled less than 137 t in that year.

The bigger seed companies can also produce improved maize seed through contract growers, with production operations and buy-back prices agreed upon before planting. The companies provide technical services during cultivation through DADO or their own technicians. They buy, process, package and store the harvested seed. The seed is later sold either through dealers or directly to the farmers. Smaller seed companies, in turn, buy from AIC or other private seed companies, as dictated by availability and prices.

All improved open-pollinated maize seed marketed in Nepal is produced in the country. Although some farmers near the Indian border might be importing improved OPV seed, the quantity is estimated to be insignificant. However, all hybrid maize seed used in Nepal comes from India. Seed traders contact the hybrid maize seed producers in India and order the quantity well ahead of the planting season. In most cases, advance payment is required. The specified amount of seed is delivered to the border, where the traders receive and clear the shipment through the Nepalese Plant Quarantine and Customs Office. So far, the government has not restricted maize seed imports from India. However, Indian regulations do not allow export of either seed or grain without proper licensing, so that the smaller traders who import small quantities of seed from the nearby Indian markets have some problems. Nevertheless, once the seed arrives at the Nepalese customs office, it is treated like any other agricultural product and no customs duty is levied.

An advance income tax of 4% of the seed value is charged at the entry point. This amount is considered a deposit and returned to the trader once he clears all his income tax dues. Nepal's plant quarantine regulations do not restrict seed imports, provided these are accompanied by phyto-sanitary certificates issued by the counterpart agency of the country of origin (Gautam 1994). Import permits are not required. An application fee of NRs 10 (US$ 0.17) per consignment, regardless of the total volume imported, is paid to the plant quarantine office at the entry point in Nepal.

The larger seed companies market imported hybrid maize seed through appointed dealers or their own branches throughout Nepal. The smaller seed traders simply sell from their own shops. As most traders import upon farmers' demand, the traders do not risk being unable to sell expensive imported seed.

Type and Quantity of Seed Traded

In 1997, total maize area in the country was estimated to be 860,000 ha, including winter and spring maize (about 60,000 ha) grown in irrigated lowlands. About 64% (550,000 ha) was planted to improved maize (Agricultural Statistics Division 1998). Commercial seed covers slightly less than 30% of this area while recycled seed produced by the farmers themselves covers the rest. Local landraces or traditional varieties are cultivated on the remaining 310,000 ha of maize area (Table 1).

Table 2 presents the involvement of the public and private sectors in the maize seed market in Nepal in 1997. Of the 3,850 t of commercial maize seed

Table 1. Maize area and seed requirement, Nepal, 1997

	Area (000 ha)	Seed (t)
Total maize	860 [a]	21,500
64% improved varieties, of which	550	13,750
29% commercial seed	157	3,850
71% recycled seed	393	9,900
36% traditional varieties	310	7,750

Source: CIMMYT Maize Impact Survey 1998/99.

[a] Includes an estimated 60,000 ha under winter/spring maize in the Terai/inner Terai, in addition to about 800,000 ha reported by the Central Bureau of Statistics.

Table 2. Quantity (t) of maize seed sold by type of material and organization, Nepal, 1997

	Hybrids	Improved OPVs	Total
NMRP and AIC	–	124	124
NARC research stations[a]	–	86	86
Non-profit organizations (INGOs, NGOs)	–	180	180
Farmer groups collectively producing and selling seed[b]	–	210	210
Individual farmers under DADO seed multiplication program[c]	–	2,535	2,535
Direct import by individual farmers	100	–	100
National private traders	215	400	615
Total	315	3,535	3,850

Source: CIMMYT Maize Impact Survey 1998/99.

[a] The 12 research stations under NARC are located at Surkhet, Nepalgunj, Lumle, Khairenitar, Parwanipur, Kavre, Pakhribas, Hardinath, Nawalpur, Kapurkot, Pokhara and Rampur.

[b] Seed production and marketing are done through the farmer group under the Secondary Crops Development Project.

[c] Includes seed produced by progressive farmers in the Tarai and in mid-hill districts, for which foundation seed is produced and distributed by DADO and its outreach research stations.

sold in Nepal in 1997, around 210 t was distributed by public-sector agencies. Private seed dealers sold about 615 t of maize seed, of which 215 t (35%) was hybrids imported from India and 400 t was improved OPV seed produced locally. Farmer-cooperators of the Secondary Crops Development Project produced and sold another 210 t of improved OPV maize seed. In addition, national and international NGOs and other projects produced about 180 t of OPV maize seed through progressive farmers under their technical supervision. Progressive individual farmer-cooperators in the DADO seed multiplication program (where DADO provides the foundation seed and technical know-how, but farmers are free to sell the seed to any buyer) produced a total of 2,535 t of public OPVs, accounting for about 66% of total maize seed sales.

Seed Quality Control

Seed entrepreneurs, maize farmers, and planning and policy-making authorities are aware of the importance of seed quality and of an efficient seed quality control system in developing a viable seed production and distribution program. In 1988, the Nepal Seed Act was enacted to provide for voluntary seed certification but compulsory labeling of marketed seed (Raut 1997). It also created the National Seed Board (NSB), mainly to formulate national seed policies and set standards for seed quality control. The Seed Development and Quality Control Services Section, under the DOA Division of Crop Science, in turn certifies different crop seeds according to minimum quality standards determined by NSB. The AIC has an in-house seed quality control system. Seed procured from contract farmers is tested by the Internal Quality Control Section, graded and the premium calculated. Processed seed is labeled, stored in good warehouses and sold to grain producing farmers through *sajhas* (cooperatives) and private dealers throughout Nepal.

The Seed Act has not yet been fully implemented owing to the lack of set rules and regulations (Pandey *et al*. 1997). At present, only cereal seed produced by government farms and research stations is certified. Seed produced by other agencies does not require certification and traders can market it without correct labelling. There is no legal provision to make the trader accountable for any misinformation.

Products of the Research and Development System

Improved Open-Pollinated Varieties

As noted, systematic maize improvement work in Nepal began in 1965, when the Division of Agricultural Botany initiated the Coordinated Maize Program. Between 1965 and 1972, four improved OPVs of maize were released: Rampur Yellow for lower elevation areas; Khumal Yellow for the mid-hills; Kakani Yellow for the high hills; and Hetunda Composite for the foothills and inner Terai. Between 1972 and 1985, the NMRP released Janaki and Arun-2 for cultivation in the Terai, inner Terai and the foothills, and Makalu-2 for the hills.

In the early 1980s, germplasm improvement was formally initiated to develop varieties suitable for the different ecological regions of Nepal. All available local and exotic elite genetic materials in the country were classified into seven groups based on maturity, grain color, adaptability and other desirable characteristics (Misra *et al*. 1980). Using materials from these populations, breeders improved the yield potential, earliness and plant height of Rampur Yellow, Khumal Yellow, Kakani Yellow, Rampur Composite and Hetunda Composite. Breeding work on these populations produced six varieties, i.e., Ganesh-2, Manakamana-1, Rampur-1, Rampur-2 and Arun-1, which were released for commercialization in the late 1980s and early 1990s. Annex 3 lists improved varieties released in Nepal and their basic characteristics.

Hybrids

Hybrid maize research began in 1978 with efforts to develop conventional hybrids by inbreeding plants from well-adapted improved populations. In the first half of the 1980s, promising hybrids of the Pioneer series were imported from Thailand and India and were evaluated. Their performance, however, was not consistent and was inferior to that of Rampur Composite during the rainy seasons (Rajbhandary 1982). In the 1980s, pure lines of maize were introduced from the International Institute of Tropical Agriculture to fulfill the demand for hybrid maize in suitable areas. A few single-cross varieties were made out of those superior lines and evaluated. The results were not significantly superior to Rampur Composite and the Indian hybrid Deccan-103 already being grown in eastern Nepal (Lal *et al.* 1987). Crossbreeding between pure lines, development of non-conventional hybrids and simultaneous improvement and evaluation efforts continue at the NMRP station in Rampur. As in other developing countries, facilities and resources are not adequate to vigorously pursue full-fledged inbreeding/test crossing in Nepal.

Adoption and Impact of Improved Maize

Adoption

Since 1955/56, when exotic materials were first introduced, 15 maize varieties have been developed and released for cultivation in the different agro-ecological zones of Nepal. Variety-specific adoption in farmers' fields is not known precisely, but available aggregate data indicate that, in 1993/94, about 30% of all maize area in Nepal was planted to "fresh" improved varieties (i.e., varieties that farmers have recycled for no more than one to three years) and the rest to local/traditional varieties (Table 3). The proportion of maize area under fresh improved varieties increased to about 40% in 1997/98. Although hybrid maize seed has been imported from India in the last few years, this seed is not officially recorded as it is sold to local farmers without prior testing and certification from Nepalese government agencies.

Among the three ecological zones, the Terai has more irrigated land under improved maize than the hills and mountains. In 1993/94, 84% of the Terai maize area was planted to improved varieties compared to 46% of the maize area in the hills and about 39% in the mountains. By 1997/98 these proportions had increased significantly (Table 3). Adoption of improved maize varieties is more widespread in the Terai because of better access, irrigation and climate, all of which make it more profitable to invest in improved seed. However, maize farmers in the hills and mountains are also gradually shifting to improved maize because of its higher yield potential. Farmers are introduced to seed of improved OPVs either by other farmers or by AIC and private seed distributors.

Impact

Annex 3 shows the yield potential of improved maize released in Nepal. The yield potential of cultivars released for the Terai, inner Terai and foothills ranged from 2.2 t/ha (Arun-2) to 6.5 t/ha (Janaki). Janaki is the only variety released for winter cultivation in this zone. Winter cultivation is more favorable and produces a higher yield for maize because of lower pest and disease incidence. In the hills, yield potential ranged from 3.9 t/ha (Ganesh-2) to 4.9 t/ha (Khumal Yellow). Varieties used in the high hills can yield 3-5 t/ha. These yield potentials far exceed the mean yield obtained from local varieties planted during the monsoon (1.75 t/ha) and winter (1.96 t/ha) (NMRP 1997).

In 1993/94 and 1997/98, improved maize varieties had consistently higher yields of 400-600 kg/ha more than the local/traditional varieties in all ecological regions (Table 4). Over the same periods, yields of improved maize either increased slightly or remained constant, while yields of local varieties declined. This indicates that the maximum potential yield levels of currently available improved maize varieties were probably achieved, either because there was not much

Table 3. Area planted to improved and local maize varieties, Nepal, 1993/94 and 1997/98

	1993/94		1997/98	
Location	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)
Mountains				
Local	36,438	61.4	30,944	48.6
Improved	22,952	38.6	32,762	51.4
Total	59,390	100.0	63,706	100.0
Hills				
Local	283,608	53.9	241,999	43.2
Improved	242,640	46.1	317,610	56.8
Total	526,248	100.0	559,609	100.0
Terai				
Local	27,828	16.5	14,719	8.4
Improved	140,663	83.5	161,026	91.6
Total	168,461	100.0	175,745	100.0
Nepal				
Local	347,874	46.1	287,662	36.0
Improved	406,225	53.9	511,398	64.0
Total	754,099	100.0	799,060	100.0

Source: Agricultural Statistics Division (1995, 1997).

Table 4. Yield performance of improved and local maize varieties, Nepal, 1993/94 and 1997/98

	Yield (t/ha)	
Location	1993/94	1997/98
Mountains	1.53	1.57
Local	1.36	1.33
Improved	1.79	1.80
Hills	1.60	1.66
Local	1.42	1.36
Improved	1.82	1.89
Terai	1.90	1.92
Local	1.60	1.38
Improved	1.96	1.97
Nepal	1.67	1.71
Local	1.43	1.36
Improved	1.87	1.91

Source: Agricultural Statistics Division (1995, 1997).

varietal turnover (so there was no gain in yield potential) or there was not much increase in the use of purchased inputs. Further increases were possible only through an integrated nutrient and pest management approach, both of which are currently at their lowest level. Declining yields of local maize varieties have been observed throughout Nepal since the early 1970s and are attributed mainly to declining soil fertility and varietal degeneration.

In general, the impact of improved maize technology (which is almost synonymous with the use of improved cultivars) has been an increase in production. The full impact of the new technology, however, has yet to be realized in the absence of achieving the complete adoption and realizing the full yield potential of these varieties. Varietal technology has always been the dominant component of improved maize technology, but its impact will be more significant once improved seed is adopted in tandem with recommended agronomic practices.

Key Issues

Regulations and Policies

Following the creation of NARC in 1991, the Ninth Five-Year Development Plan clearly spelled out agricultural research policies consistent with priority inputs and outputs set forth in the Agricultural Perspective Plan (APP). (The APP is the basic planning document for the long-term development of Nepal's agriculture sector.) Important elements of the policy are provisions to attract the participation of private and non-governmental sectors in agricultural research; the promotion of client-based competitive research by contracting out research; and the incorporation of environmental and gender dimensions in agricultural research. As clearly pointed out by APP, several policy issues in Nepal's agricultural research system need to be addressed properly.

The first issue is the balance between adaptive and basic research. It has often been argued that Nepal can easily borrow agricultural technologies from India. This is possible if the agricultural research system in the border states of India is strong and Nepal has a strong adaptive research system of its own. Indian technology, however, may not be applicable to all of Nepal's ecological zones, so that the extent of transfer needs to be evaluated critically. It is thus imperative for Nepal to develop a clear vision and mandate for adaptive and basic research.

The second issue is that of returns to investments in agriculture research. Sharma (1983) and Morris *et al*. (1991) have shown that returns to investment in rice, maize and wheat research in Nepal, ranging from 33% to over 80%, have been high and comparable to those in neighboring countries. Although individual farmers in favorable pockets may have benefited substantially, most farmers have yet to enjoy the products of agricultural research. This situation calls for investment to expand research recommendation domains through complementary investments in infrastructure and other production inputs.

The third issue is the appropriate level of expenditure on agriculture research. Should ex ante analysis suggest that returns to research investments are likely to be high, spending more on agricultural research is justifiable, as additional investment is likely to have high returns. Determining the appropriate level of research expenditure is difficult in the absence of long-term disaggregated data. Although the World Bank and Food and Agriculture Organization (FAO) of the United Nations have recommended spending between 1-2% of agricultural gross domestic product on agricultural research, NARC has to develop alternative research spending scenarios that will support the realization of APP growth targets.

Intellectual Property Rights

Nepal is considered a small seed market in Asia and private investments on maize research and development may not be attractive. To attract private and non-governmental organizations to Nepal's agricultural research sector, a set of policy measures targeting individual researchers and research organizations and focusing mainly on providing incentives and a better research environment were adopted. These measures include the provision of adequate research facilities; recognition of outstanding research achievements (with monetary awards); naming new technologies after the researcher; providing patent rights to original research outputs; and providing scholarships and research grants to outstanding researchers. Appropriate legislative measures that will provide researchers and research organizations exclusive ownership rights, or property rights, to their innovations and findings, as well as guarantee the transferability and enforceability of such rights, are also required. A key issue is protecting the intellectual property of importers of technology, since the private sector brings in updated technology from India. Although it has been discussed frequently, the issue of intellectual property rights in agricultural research has yet to receive legal recognition in Nepal.

Equity Issues

Given the government policy of regionally balanced development and poverty alleviation, equity considerations in agricultural research in general, and maize research and development in particular, are gaining importance. National resources need to be allocated to regional maize research needs, based on each region's contribution to national maize production and on the size of the population dependent on maize.

Environment, Health and Safety Issues

New and modern agricultural production technologies that involve chemical fertilizers and pesticides, both in research trials and in the fields, have significant environmental implications. To internalize environmental protection concerns in all development activities, a National Environmental Impact Assessment (EIA) guideline was prepared in 1993 by the National Planning Commission in collaboration with IUCN (The World Conservation Union). Guidelines covering forestry (1995), industry (1995), roads (1996) and power and irrigation (1999) have been prepared and are in different stages of implementation. Similarly, the Environmental Protection Act (1996) and Environmental Conservation Rule (1997) were enacted, adopting the rules of conducting EIAs for all types of development plans/activities. However, the EIA guidelines drafted by the Ministry of Agriculture in 1996 for the agricultural sector have yet to be finalized and approved. The Pesticide Act (1991), designed for the judicious use of harmful pesticides and for adopting precautionary measures to safeguard the health and safety of the general public, is yet to be effectively implemented. For now, maize is unlikely to attract the application of a lot of pesticides, particularly in the hills and mid-hills. If labor becomes scarce, the use of pesticides (especially herbicides) could become an issue.

The legislative framework required to protect the environment and general public from the harmful effects of pesticides has been prepared. The pertinent issue is how effectively these legislative measures will be implemented, particularly when the agricultural intensification programs recommended by APP are underway. Given the limited implementation capacity of the stakeholders, the extent to which the legislation will be internalized into the agricultural research system is a question with no definite answer.

Summary, Conclusions and Recommendations

Maize is one of the most important cereals in Nepal, but despite the high yield potential of improved maize cultivars, their adoption and yield performance in farmers' fields appear to be far from satisfactory. Improved cultivars occupied about 40% of the maize area, but farmers' yields of improved maize still remain lower than potential yields. One reason for this yield gap is that farmers do not regularly replace seed; another is that farmers apply minimum or no modern inputs, especially chemical fertilizers, because of the difficulty of accessing and transporting inputs to the farm.

The National Maize Development Project (NMDP) is the only government institution responsible for supporting the country's maize seed industry, including the maintenance and production of breeder and foundation seed. However, it has yet to officially release a hybrid maize variety in Nepal. Because farmers have shown their willingness to adopt hybrid maize, the private sector fulfills this need by importing hybrids from India. Recently, the Nepalese government adopted a liberalization policy under which the private sector can supply agricultural inputs on an equal footing with AIC, a government agency. This new policy has attracted traders to the seed trade. Today, about 60% of all agro-veterinary traders in Nepal also trade maize seed.

Unfortunately, no systematic effort has been made to obtain reliable estimates of the total effective demand for improved maize seed in Nepal, which hampers the growth and development of the local maize seed industry. In addition, the public sector's dominance of Nepal's seed industry has discouraged stronger private sector participation. Private seed companies see the seed business as risky because of unwarranted and sudden government policy shifts.

The area planted to maize (around 860,000 ha) requires around 16,000 t of certified seed, 80 t of foundation seed and 400 kg of breeder seed. Fulfilling this seed demand requires a well-coordinated and decentralized seed production system. Such a system has yet to evolve in Nepal. The government's capacity to produce breeder and foundation seed is constrained by limited resources and facilities. The production of quality certified seed by either public agencies or private companies is also constrained by limited information on effective demand as well as by inconsistencies in government policies affecting the seed industry.

Given the above situation, several important recommendations are in order. First, NARC should initiate a detailed study of maize agro-ecological zones and production domains to understand conditions in the field and incorporate socioeconomic and systems perspectives into the national maize research program. Second, government facilities for seed research and production should be improved for NARC and NMDP to implement their mandates effectively. Third, quality seed of improved maize varieties needs to be made more accessible and available to farmers through a decentralization of the seed supply system. Fourth, public-sector dominance in the seed industry should be completely removed, to allow the more efficient and effective private sector to become more active in producing better quality commercial seed. The government's role should be confined to the production and distribution of breeder and foundation seed and to regulate the quality of improved maize cultivars imported into Nepal.

It is clear that the demand for hybrid maize seed is growing fast in the country, though the exact size of the potential market is not known. The quantity of hybrid maize seed imported annually from India is unknown, as the trade is mainly informal. Although a systematic effort to coordinate imports

is imperative, establishing the feasibility of a hybrid maize seed program in the country by estimating potential demand is most urgent.

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Annex 1

Maize Area (ha), Production (t) and Yield (t/ha) by Ecological Zone, Nepal, 1974/75 to 1997/98

	Mountain			Hills			Terai			Nepal		
Year	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
1974/75	57,178	105,503	1.85	504,612	945,598	1.87	153,310	243,501	1.59	715,100	1,294,602	1.81
1975/76	57,085	103,483	1.81	503,670	898,932	1.78	152,364	193,280	1.27	713,119	1,195,695	1.68
1976/77	57,081	103,830	1.82	503,032	935,695	1.86	155,283	245,314	1.58	715,396	1,284,839	1.80
1977/78	57,304	92,127	1.61	505,747	841,090	1.66	154,299	246,772	1.60	717,350	1,179,989	1.64
1978/79	57,643	95,871	1.66	509,390	828,788	1.63	154,228	240,908	1.56	721,261	1,165,567	1.62
1979/80	56,886	78,345	1.38	505,413	648,355	1.28	153,769	208,807	1.36	716,068	935,507	1.31
1980/81	57,337	89,767	1.57	511,026	808,527	1.58	156,964	259,014	1.65	725,327	1,157,308	1.60
1981/82	57,702	91,197	1.58	511,767	788,109	1.54	156,586	253,772	1.62	726,055	1,133,078	1.56
1982/83	58,015	82,847	1.43	515,988	699,718	1.36	156,966	247,097	1.57	730,969	1,029,662	1.41
1983/84	58,346	86,132	1.48	517,757	706,251	1.36	155,677	278,388	1.79	731,780	1,070,771	1.46
1984/85	57,816	91,533	1.58	519,506	683,314	1.32	156,290	249,339	1.59	733,612	1,024,186	1.39
1985/86	57,866	85,012	1.47	521,437	709,475	1.36	156,077	244,718	1.57	735,380	1,039,205	1.41
1986/87	58,261	87,092	1.50	523,496	688,590	1.32	157,385	245,065	1.56	739,142	1,020,747	1.38
1987/88	59,310	80,409	1.36	531,471	683,636	1.29	159,078	239,368	1.50	749,859	1,003,413	1.34
1988/89	58,205	80,873	1.39	536,107	769,362	1.44	160,779	272,125	1.69	755,091	1,122,360	1.49
1989/90	58,828	82,711	1.41	529,900	823,034	1.55	162,502	295,703	1.82	751,230	1,201,448	1.60
1990/91	58,415	88,095	1.51	535,730	843,854	1.58	161,937	296,478	1.83	756,082	1,228,427	1.62
1991/92	57,700	86,679	1.50	535,800	825,983	1.54	160,590	292,023	1.82	754,090	1,204,685	1.60
1992/93	59,950	90,370	1.51	546,880	874,740	1.60	168,400	308,670	1.83	775,230	1,273,780	1.64
1993/94	51,920	84,930	1.64	526,810	812,140	1.54	172,420	312,800	1.81	751,150	1,209,870	1.61
1994/95	58,870	90,130	1.53	536,600	853,420	1.59	175,870	331,250	1.88	771,340	1,274,800	1.65
1995/96	61,270	93,020	1.52	556,960	905,190	1.62	173,470	332,850	1.92	791,700	1,331,060	1.68
1996/97	62,210	96,080	1.54	556,040	886,370	1.59	174,750	329,760	1.89	793,000	1,312,210	1.66
1997/98	63,706	100,116	1.57	559,609	929,163	1.66	175,745	338,061	1.92	799,060	1,367,340	1.71
Growth rate (%)	0.24	-0.29	-0.53	0.45	0.21	-0.23	0.62	1.86	1.22	0.47	0.53	0.05

Source: Agricultural Statistics Division, *Statistical Information on Nepalese Agriculture* (various issues).

Annex 2

Production Domains and Trends in Maize Production

Major Production Domains

For research and development, Nepal is divided into two major agro-ecological zones: (1) the Mid- and High Hills Zone and (2) the Terai, Inner Terai and Foothill Valleys Zone. These zones and their subzones show different responses to cultivars and other maize production technology and are briefly described below.

Production Domains in the Mid-and High Hills Zone

In this zone, altitude ranges between 900-2,500 m above sea level (masl), climate varies from warm to cool temperate depending upon altitude, and various micro-climatic regions prevail depending upon aspect. Soil temperature regimes also vary from thermic in the low-lying areas to mesic in high areas.

The first subzone of this agro-ecology is the *Dry Eco-Zone* of the mid- and far-western hills, spanning areas west of Dhaulagiri/Karnali and Rapti River System watersheds. It is characterized by late, low-intensity and short-duration monsoon rains. The major production domain in this sub-zone is summer monocropped maize on *bari* land, with maize-wheat-fallow, maize-barley-fallow, maize-potato or maize-fallow cropping systems. Crops are mainly rainfed, grown without chemical fertilizers but with farmyard manure (FYM).

The second subzone, the *Wet Eco-Zone* of the western, central and eastern hills, spans areas east of Dhaulagiri/Gandaki and Koshi River System watersheds and is characterized by early, higher intensity and longer duration monsoon rains. The two production domains in this subzone are summer relay maize on *bari* land and spring monocropped maize on *khet* land. In the first production domain, cropping systems include maize-millet-fallow, maize-potato or maize/millet-mustard or maize/millet-wheat or maize-buckwheat or maize+soybean-mustard. These crops are mainly rainfed, grown without chemical fertilizers but with FYM. In the second production domain, the maize-paddy-fallow system is followed either with or without fertilizer and with FYM.

Production Domains in the Terai, Inner Terai and Foothill Valley Zone

In this zone, altitudes range between 100-1,000 masl, climate is mostly subtropical with narrow variations on N-S and E-W microclimates, and soil temperature varies from hyperthermic in the low-lying areas to thermic in high elevations. Within this zone are three major maize production domains: summer monocropped maize on *bari* land, spring monocropped maize on *khet* land, and winter monocropped maize on *bari*/*khet* land.

The first production domain in this zone is characterized by highly accessible areas but lacks irrigation facilities. Maize is grown as a rainfed crop either with or without fertilizer but with some FYM. Major cropping systems include maize-mustard-fallow, maize-upland paddy-fallow, maize-millet-fallow and maize+upland paddy-blackgram. In the second domain, characterized by drought stress and rainfed conditions, the main cropping systems are maize-paddy-fallow, maize-paddy+legume and maize-paddy-buckwheat. The third domain, characterized by highly accessible and irrigated conditions, has maize-paddy-fallow, maize-maize-fallow and maize-paddy+pea as the main cropping systems.

Trends in Maize Area and Production

Trends in maize area, production and yield by ecological zone are presented in Annex Table 2.1. Maize area increased from about 715,000 ha in 1974 to about 734,000 ha in 1984/85, and 799,000 ha in 1997/98. This shows that maize area in Nepal grew by 0.47% per year, partly as a result of bringing more forest land under maize cultivation and to expansion of winter and spring maize in the Terai, inner Terai and river basins in the hills and the mountains. Despite a moderate rate of growth in maize area, production between 1974/75 and 1997/98 increased by only about 0.53% because of very low growth (0.05%) in productivity.

Annex Table 2.1. Annual growth (%) in maize area, production and yield by ecological zone, Nepal, 1974/75 to 1997/98

Ecological zone and period	Area	Production	Yield
Mountains			
1974/75-1997/98	0.24	-0.29	-0.53
1975/76-1979/80	0.03	-6.16	-6.15
1980/81-1984/85	0.28	-0.18	-0.53
1985/86-1989/90	0.32	-1.28	-1.58
1990/91-1994/95	-0.90	0.25	1.16
1995/96-1997/98	1.97	3.74	1.63
Hills			
1974/75-1997/98	0.45	0.21	-0.23
1975/76-1979/80	0.19	-7.46	-7.61
1980/81-1984/85	0.45	-4.36	-4.72
1985/86-1989/90	0.56	4.16	3.55
1990/91-1994/95	-0.14	0.06	0.13
1995/96-1997/98	0.24	1.32	1.23
Terai			
1974/75-1997/98	0.62	1.86	1.22
1975/76-1979/80	0.12	1.37	1.25
1980/81-1984/85	-0.14	0.16	0.26
1985/86-1989/90	1.03	4.95	3.83
1990/91-1994/95	2.39	2.95	0.49
1995/96-1997/98	0.65	0.78	0.00
Nepal			
1974/75-1997/98	0.47	0.53	0.05
1975/76-1979/80	0.16	-5.71	-5.85
1980/81-1984/85	0.31	-2.96	-3.42
1985/86-1989/90	0.64	3.93	3.35
1990/91-1994/95	0.36	0.79	0.43
1995/96-1997/98	0.46	1.35	0.89

Source: Agricultural Statistics Division, *Statistical Information on Nepalese Agriculture* (various issues).

Annex 3

Improved Maize Varieties Released in Nepal

Zone and variety	Year released	Source	Parentage	Grain color	Days to maturity	Average yield potential (t/ha)
Terai, Inner Terai and Foothills Zone						
1 Rampur Yellow	1966	IACP	Composite J1	Yellow	105	4.70
2 Hetunda Composite	1972	–	Local landraces	Yellow	115	4.30
3 Rampur Composite	1975	IACP	Thai Composite-1*Suwan-1	Orange	108	4.40
4 Sarlahi Seto	1978	IACP	Phil. DMR 2	White	115	4.10
5 Janaki	1978	CIMMYT	Rampur 7434*Blanco Subtropical	White	155	6.50
6 Arun-2	1982	CIMMYT	Uncac 242*Phil DMR Subtropical	Yellow	85	2.20
7 Rampur-2	1989	CIMMYT	Local*Exotic	Yellow	108	4.00
8 Arun-1	1995	CIMMYT	Local*Exotic	White	100	4.00
9 Rampur-1	1995	CIMMYT	Local*Exotic	White	115	3.80
Hills Zone						
1 Khumal Yellow	1966	IACP	AntiguaG2D*Guatemala	Yellow	125	4.90
2 Manakamana-1	1986	CIMMYT	Local*Exotic	White	125	4.00
3 Makalu-2	1989	CIMMYT	Amarillo del Bajio	White	145	4.00
4 Ganesh-2	1989	CIMMYT	Local*Exotic	Yellow	165	3.50
High Hills Zone						
1 Kakani Yellow	1966	IACP	AntiguaG2D*Guatemala	Orange	195	3.00
2 Ganesh-1	1997	CIMMYT	Pool 9A	White	175	5.00

Source: Adhikari *et al.* (eds.) 1998.