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CIMMYT® (www.cimmyt.org) is an internationally funded, not-for-profit organization that conducts research and training related to maize and wheat throughout the developing world. Drawing on strong science and effective partnerships, CIMMYT works to create, share, and use knowledge and technology to increase food security, improve the productivity and profitability of farming systems, and sustain natural resources. Financial support for CIMMYT's work comes from many sources, including the members of the Consultative Group on International Agricultural Research (CGIAR) (www.cgiar.org), national governments, foundations, development banks, and other public and private agencies.

Correct citation: 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 Research Priorities.* Mexico, D.F.: CIMMYT.

Abstract: Maize is the second most important cereal crop in Indonesia after rice. The demand for maize as food and feed has been steadily increasing. Total national maize production has grown at 4.07% per annum in the last three decades, thanks mainly to the adoption of improved production technologies, particularly hybrid seed. This high production, however, still fails to meet domestic demand and has caused a rapid increase in the net import of maize. This study characterized the maize production systems in four major maize-producing provinces in Indonesia, namely Lampung, East Java, West Nusa Tenggara, and South Sulawesi. Important productivity constraints faced by maize farmers were identified and included: low grain prices during harvest; high input prices; large distances between maize production areas, feed mills, and seed industries; lack of promotion of local improved maize varieties (OPVs and hybrids) by government research centers; and lack of farmer capital. Farmers, the Government of Indonesia, and private companies should be encouraged to develop appropriate technology and policies, such as tariffs and credit systems, to overcome some of these constraints.

ISBN: 970-648-114-1

AGROVOC descriptors: Seed production; Maize; Cropping systems; Yields; Marketing; Technology; Agroecosystems; Agricultural resources; Agricultural research; Indonesia.

AGRIS category codes: E16 Production Economics
A50 Agricultural Research

Dewey decimal classification: 338.162

Printed in Mexico.

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Glossary of Terms

AARD	Agency for Agricultural Research and Development
AIAT	Assessment Institute for Agricultural Technology
BULOG	National Food Authority
CASERD	Center for Agro-Socioeconomic Research and Development
CBS	Central Bureau of Statistics
CIMMYT	International Maize and Wheat Improvement Center
CRIFC	Central Research Institute for Food Crops
DG	Director General
DM	Downy mildew
Dokar	Horse traction
DS	Dry season
HYV	High yielding variety
ICERI	Indonesian Cereal Research Institute
IFAD	International Fund for Agricultural Development
Masl	Meters above sea level
NGO	Non-governmental organization
NTB	West Nusa Tenggara
NTT	East Nusa Tenggara
Ojeg	Motorcycle
OPV	Open pollinated variety
Palawija	Secondary crops
PPL	Field extension workers
PRA	Participatory Rural Appraisal
PT	Corporation/incorporated
QPM	Quality Protein Maize
RFLL	Rainfed lowlands
RIMOC	Research Institute for Maize and Other Cereals
RRA	Rapid Rural Appraisal
SRI	Soil Research Institute
Surjan	Raised and sunken beds
Tegalan	Dryland
WS	Wet season

Acknowledgments

This manuscript is taken from the report on rapid rural appraisal (RRA) and participatory rural appraisal (PRA) conducted in 4 provinces, covering 32 villages in 8 districts of Indonesia. Data/information were collected in November 2000-March 2001. In addition, this document covers the constraints to maize production identified during the National Maize Research and Development Prioritization Workshop, held in Malino, South Sulawesi, 15-17 May 2002, and further intensive discussion during the Fifth Annual Workshop of the Asian Maize Socio-Economic Working Group held in Bangkok, Thailand, on 1-4 August 2002.

The authors would like to express their heartfelt gratitude and appreciation to the many people who provided support and encouragement during the production of this manuscript.

We offer sincere thanks to both the Director General of the Agency for Agricultural Research and Development (AARD) of Indonesia and the Director of the Center for Agro-Socioeconomic Research and Development (CASERD), for permitting and facilitating the team to carry out the study. Thanks are also extended to the Directors of Province and District Agricultural Extension Services in four surveyed Provinces and eight Districts, for their contribution in providing secondary data and their guidance in selecting the sites where the survey was carried out.

We also convey our gratitude to Dr. Subandi (senior maize breeder) and Dr. Faisal Kasryno (former Director General of AARD and senior scientist), for their invaluable comments and corrections during the preparation of this manuscript.

Finally, the authors also express their gratitude and appreciation to the CIMMYT Economics Program, for both technical and financial support, without which this study would not have been possible. We also acknowledge the editorial review of this document by Sarah Fennell, consultant, and Alma McNab, senior science writer/editor, as well as the design and formatting services of Eliot Sánchez Pineda, CIMMYT Corporate Communications, Mexico.

1. Introduction

1.1 Background

In Indonesia, maize is the second most important cereal crop after rice, in terms of the percentage area planted to maize relative to the total area for all food crops. Kasryno (2002) reported that during 1970-2000, the area planted to maize was about 19% of the total area planted to food crops. Rice occupied about 61% of the total area planted to food crops over the same time period. Another 20% was planted to other food crops (palawija) such as soybeans, mungbeans, peanuts, cassava, and sweet potato.

The demand for maize, especially for feed, is steadily increasing. Several data sources were used to quantify this level of demand. The food balance sheets data from the Central Bureau of Statistics (CBS) showed that in 1998 about 69% of maize in Indonesia was used for food (direct and manufactured food (CBS 1999)). Using Input-Output Data, Erwidodo and Pribadi (2002) computed that, in 1995, the total use of maize for human consumption was about 63%, while for feed it was about 30.5%. The highest figure was shown by FAOSTAT food balance sheets, where the total use of maize for human consumption in 1995-1997 was about 79% (Aquino et al. 2001). All sources of data cited above showed the major use of maize was for human consumption. In contrast, Kasryno (2002) estimated that in 2001 about three million (metric) tons (43%) of maize were used for food and four million tons (57%) for feed. His estimation may be correct, especially in the future, since the demand for maize by the feed industry is steadily increasing.

In some provinces, such as East Java, East Nusa Tenggara (NTT), North Sulawesi, South-East Sulawesi, and Irian Jaya, maize is consumed as a staple food, as is rice (Bastara 1988; Malian and Djauhari 1988; Subandi and Manwan 1990). As a major component of feed (accounting for 40% to 60%), the demand for maize during 1988-1998 grew at a rate of about 12% per annum (Hutabarat et al. 1993; Subandi 1998; CBS 1990-2000). Kasryno (2002) estimated that during 1987-2000, the demand for maize for feed grew at a rate of at least 8-10% on average per year.

Most maize (about 57%) during the last decade was grown in Java and contributed about 61% to national maize production (CBS 1991-2001). In 2000, there were at least seven provinces (namely North Sumatera, Lampung, Central Java, East Java, West Nusa Tenggara (NTB), NTT, and South Sulawesi) where maize was the main food crop produced. This study took place in four of these provinces, namely Lampung, East Java, NTB, and South Sulawesi, as shown in Appendix 1.

The 2000 data showed that Central Java and East Java contributed about 50% to the total area planted to maize in Indonesia. The largest area was in East Java (33%), followed by Central Java and Lampung, which contributed about 17% and 11%, respectively, as shown in Figure 1.

The contribution of each province to national maize production was largely consistent with their area. As shown in Figure 2, East Java was the major contributor (36%) to national maize production, followed by Central Java and Lampung, which contributed about 17% and 12%, respectively. The other 19 provinces contributed about 15% to total national maize production.

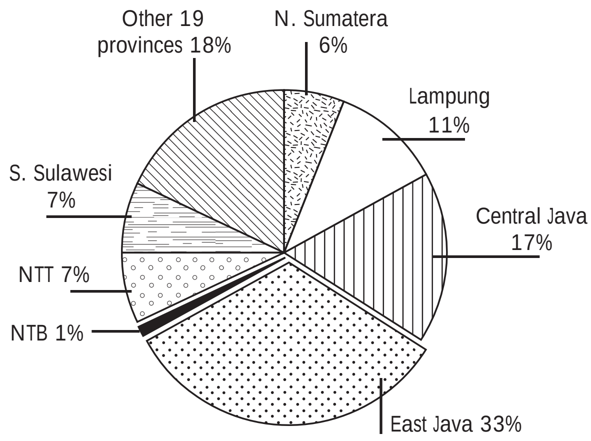


Figure 1. Distribution of maize area in Indonesia, 2000.

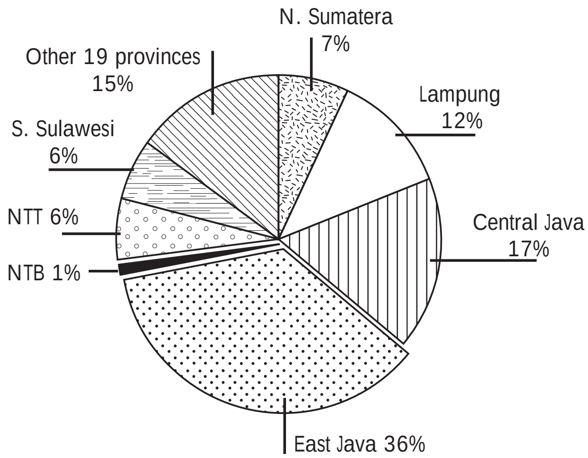


Figure 2. Distribution of maize production in Indonesia, 2000.

During the 1980s, about 79% of maize was grown in dryland areas (Bastara 1988; Subandi and Manwan 1990; Hairunsyah 1993). Subandi (1998) reported that about 89% of maize was grown on rainfed lowlands and dryland areas, with erratic rainfall.

Maize production has shown a substantial increase, from 2.82 million tons in 1970 to 9.34 million tons in 2000, a growth rate of 4.07% per annum (CBS 1971-2001). This production increase was mainly attributed to the adoption of improved technologies, especially improved varieties, including hybrids. Growing hybrid varieties proved to be more profitable than open pollinated and local varieties (Hadi et al. 1993; Suhariyanto 2000).

The considerable production growth of maize, however, failed to meet the domestic demand, causing a rapid increase in its net imports since 1976. During 1969-1975, Indonesia was self sufficient in maize, with sufficiency indices of 1.02 to 1.26 (Adnyana et al. 2001). Since 1976, net imports have increased from 0.05 million tons in 1976 to 0.60 million tons in 1996. A dramatic increase in net imports occurred in 1994 (from about 0.44 million tons in 1993 to 1.09 million tons in 1994).

Price instability at the farm level has discouraged farmers from producing more maize through the use of improved technology, especially in the regions where food and feed industries are not available. The farmers in those regions are faced with a lack of marketing infrastructure. Since farmers have had problems of drying during wet season harvesting, they have been forced to sell their grain at a low price. Only in the regions where feed and food industries exist could maize prices be maintained at a reasonable and quite stable level (Subandi et al. 1998). This condition has led Indonesia to import maize continuously. A study conducted by Timmer (1987) in East Java showed that demand for maize from feed mills is the key to price setting. When feed mills in Jakarta purchased imported maize through BULOG (the National Food Authority) or private importers, at a competitive world price, the local price of maize in East Java decreased to a relatively low level. In addition, although maize producing areas are distributed throughout at least eight provinces, most maize is sold in Java, especially to feed mills. Movement of maize from outer islands to Java led to high transportation costs (Amang 1993).

1.2 Objectives

This study characterizes maize production systems in Indonesia and aims to develop appropriate technology, required by the national research system, to increase maize production in the country. The specific objectives of this study are:

- To identify the characteristics of Indonesian maize production systems including yield, level of technology, marketing, the use of maize, and support systems.
- To identify the constraints to increasing maize production in Indonesia.
- To provide feedback to the national research institute in setting research priorities, based on constraints faced by farmers in each agro-ecosystem.
- To suggest policy alternatives in order to encourage farmers to increase maize production.

1.3 Methodology

1.3.1 Data collection

In order to achieve the objectives outlined above, this study was carried out using the RRA/PRA approach. The data and information collected in this study consisted of primary and secondary data. The primary data were collected using group interviews and discussions with farmers, traders, field extension workers (PPL), and other key informants. Secondary data were collected from sources including the Central Bureau of Statistics (CBS), the General Directorate for Food Crops and Horticulture, the Central Research Institute for Food Crops (CRIFC), the Center for Agro-Socio Economic Research and Development (CASERD), the National Food Authority (BULOG), and the Provincial and District Agricultural Offices. The data collected were:

- Maize production, area, and yield at the regional and national levels.
- Production environment (agro-ecosystem and monthly rainfall).
- Sources of inputs (seeds, fertilizers, and other chemicals).
- Technology applications at the farm level including: cropping patterns; use of varieties (high yielding varieties (HYVs) namely hybrid and improved open pollinated varieties (OPVs), and local varieties); use of inputs such as seeds and fertilizers.
- Maize marketing, including sales and prices.

1.3.2 Location

This study took place in four provinces, namely Lampung, East Java, NTB, and South Sulawesi. In each province two districts were selected, and four villages in each district were chosen. Therefore, 32 villages were selected in the four provinces, as presented in Appendix 2. Three group interviews and discussions were carried out in each village, to obtain detailed information regarding the characteristics of the maize production systems. Intensive discussions, using a participatory approach, were conducted in two or three villages in each province.

1.3.3 Time schedule

This study was conducted in three steps. First, a desk study was carried out using secondary data and related studies published by some institutions. This part was conducted during November-December 2000. Second, the field study using the RRA/PRA approach was carried out during January-March 2001. The reporting of the RRA/PRA part of the study was done in April-May 2001. The report was presented in The Fourth Annual Workshop of the Asian Maize Socio-Economic Working Group in Kathmandu, Nepal, 4-8 June 2001. Thirdly, the National Workshop was conducted in Malino, South Sulawesi, from 15-17 May 2002. The combined report between the Kathmandu and Malino workshops was presented in the Fifth Annual Workshop of the Asian Maize Socio-Economic Working Group held in Bangkok, Thailand, 1-4 August 2002. This manuscript is the combination of these revised reports.

1.3.4 National workshop

For research priority setting, a national workshop was conducted in Malino, South Sulawesi. In this workshop, seven Directors from the Assessment Institute for Agricultural Technology (AIAT) from seven provinces, P.T. BISI (PT Benih Inti Subur Intani), Lampung University, Director of Indonesian Cereal Research Institute (ICERI), Director of Central Research Institute for Food Crops (CRIFC), Director General of the Agency for Agricultural Research and Development (AARD), Director General of Food Crops Production, Governor of South Sulawesi, and some senior scientists were invited. The objective of this workshop was to gather ideas from the participants regarding maize production constraints in their respective regions and research activities needed to overcome the identified constraints.

2. Maize Production

2.1 National Maize Production

During the last decade, most maize (57%) was grown in Java and contributed about 61% to national maize production. In contrast, about 43% of maize was grown outside Java and contributed about 39% to national production (CBS 1971-2001). Although maize continues to be most widely grown in Java, maize area has tended to decline slightly over time, as shown in Figure 3. It decreased from 2.10 million ha in 1970 to 1.97 million ha in 2000, declining at a rate of 0.23% per year (Appendix 3). On the other hand, maize area outside Java grew at a rate of 1.97% per year, during the period of 1970-2000. At a national level, area planted to maize during the same period increased at a rate of 0.55% per year. The growth of area planted to maize in Java, outside Java, and Indonesia as a whole are presented in Figure 3.

For the last three decades (1970-2000), maize production has steadily increased from 2.82 million tons in 1970 to about 9.34 million tons in 2000 (a growth rate of 4.07% per year). This continued growth of production could be mainly attributed to consistent growth in yields, both in Java and outside Java, as shown in Figures 4 and 5.

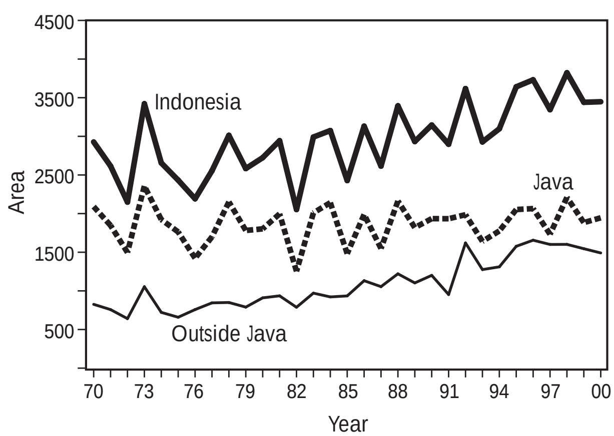


Figure 3. Maize area in Indonesia, 1970-2000.

During 1970-2000, the annual growth of yield was 3.51%, while area growth was 0.55% per year. In 1970-1980, maize production grew at a rate of 3.52% per year, but the peak of production growth occurred in 1980-1990. During this period, maize production grew at a rate of 5.37% per year. The high production growth in this period was mainly attributed to technological progress, shown by substantial yield increases from 1.46 t/ha in 1980 to about 2.13 t/ha in 1990 (a growth rate of 3.85% per year), while the area planted to maize grew at a rate of 1.45% per year. During this period,

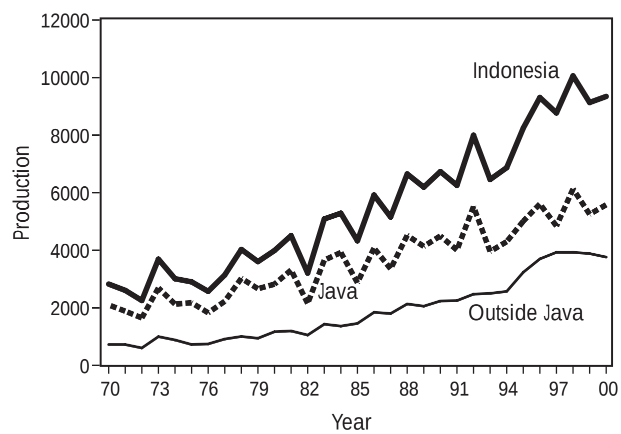


Figure 4. Maize production in Indonesia, 1970-2000.

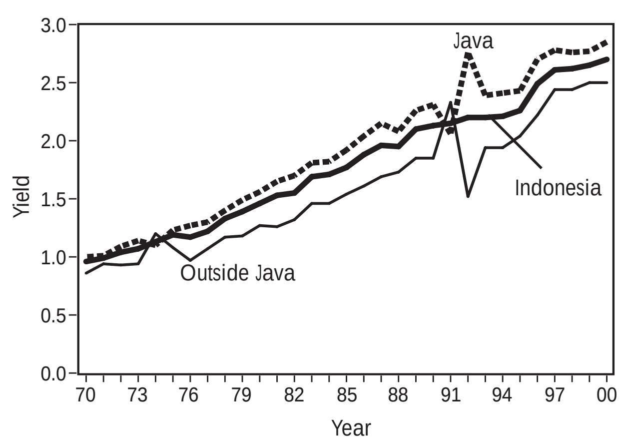


Figure 5. Maize yields in Indonesia, 1970-2000.

intensification of maize production was achieved by the introduction of new high yielding varieties, namely 10 improved OPVs and 5 newly introduced hybrids (C1, C2, CPI1, Pioneer 1 and 2) (Subandi 1998; Maamun et al. 2001).

During 1990-2000, the progress in technology was slowing down. Annual yield growth rate was 2.40% per year, while annual area growth rate was 0.92%. Therefore, the growth rate of maize production declined to 3.33% per year. The growth of maize area and production in Indonesia during 1970-2000 are presented in more detail in Table 1.

Table 1. Growth rates of maize area, production, and yield in Indonesia, 1970-2000.

	Growth rate (%/year)		
Period	**Area**	**Production**	**Yield**
1970-1980	-0.72	3.52	4.28
1980-1990	1.45	5.37	3.85
1990-2000	0.92	3.33	2.40
Average 1970-2000	0.55	4.07	3.51

In fact, there were many HYVs available (6 OPVs and 36 hybrids) during 1990-2000. However, there were some constraints to the adoption of new technology (Subandi 1998; Suhariyanto 2000; Maamun et al. 2001; Kasryno 2002):

- Maize is grown mainly (89%) in rainfed and dryland areas, with low soil fertility and erratic rainfall, and is often exposed to drought conditions.
- Maize is grown in less developed or remote areas.
- Farmers are small landholders, have little formal education, lack cash capital, and, therefore, are not able to apply inputs (seed, fertilizers, and chemicals) properly.
- There are no price incentives for the grain, and prices for inputs are high.
- Distances of maize production areas from seed and feed industries can be large.
- Poor management systems make it difficult to ensure good seed quality.
- Improved OPVs and hybrids bred by government research institutes receive little promotion. On the other hand, hybrids bred by private companies are expensive.

These constraints resulted in a low production growth rate, and in-country production was not able to meet the growing domestic demands for maize. The fast growth of domestic livestock and feed industries has contributed to the substantial increase in demand for maize (Sayaka 1995). Subandi (1998) estimated that the demand for maize, as a major component of feed, is increasing at a rate of 12% per year. Consequently, net import of maize has steadily increased from about 0.3 million tons in 1991 to 1.1 million tons in 1997 and about 0.5 million tons in 1999. Based on USDA data (cited by Erwidodo and Pribadi 2002), in 2000 Indonesia imported about 1.3 million tons of maize and exported about 0.3 million tons, the net import being 1.0 million tons.

Despite such constraints, Indonesia has significant potential for increasing maize production in the future. This will be possible mainly due to the increasing role of hybrids in maize production systems. Maamun et al. (2001) estimated that the percentage area planted to hybrids, relative to total area planted to maize, increased from about 1.7% in 1990 to 14.3% in 1998.

During the period 1980-2001, Indonesia introduced about 66 high yielding varieties. Out of these 66 varieties, 47 varieties (71.21%) were hybrids and only 19 varieties (28.79%) were OPVs (Nugraha and Subandi 2002). From 47 hybrid cultivars, only 9 (19%) were bred by public research institutes, while another 36 cultivars (81%) were bred by private companies.

An increasing share of hybrids in the Indonesian seed industry has also been observed. Total seed production in 2000 was 41,600 tons, and about 29,850 tons (72%) of it was hybrid seed (Directorate of Seeds 2000 cited by Nugraha and Subandi 2002). In terms of the institutions that produce hybrid seed, about 95.5% of hybrid seeds were produced by private companies, namely P.T. Bisi, Pioneer, and Monagro Kimia. The government-owned companies, namely Sang Hyang Seri and Pertani, only produced about 1,350 tons (4.52%).

In line with the increasing share of hybrid seed used in maize production systems, the figures indicate that the seed industry is an attractive business proposition. This condition should encourage more participation of the private sector in maize agribusiness and, therefore, maize production could continue to increase at a rapid rate.

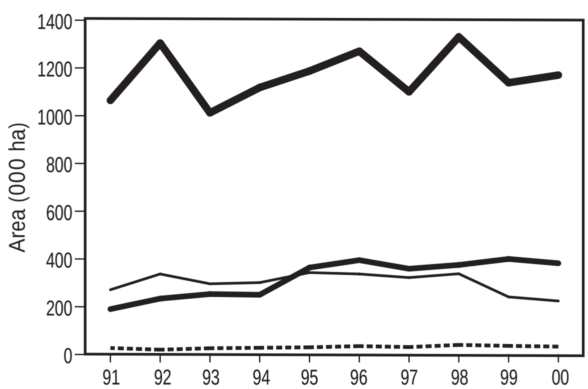
2.2 Regional Maize Production

2.2.1 Maize area

In Lampung, maize is mainly planted on dryland (tegalan) and rainfed lowlands. A small portion is planted on irrigated lowlands. In 2000, the area planted to maize was about 32.4% of the total area planted to food crops, while rice occupied about 42% (Kasryno 2002). This figure indicated that maize is the second most important crop grown in this region, after rice. During the last decade, the area planted to maize fluctuated but, as a whole, it increased from 0.19 million ha in 1991 to 0.38 million ha in 2000 (a growth rate of 8.09% per year).

In East Java, maize is mainly cultivated on dryland and rainfed areas, and some on irrigated lowlands. In 2000, the area planted to maize in East Java was about 31% of the total area planted to food crops, while the area planted to rice was about 47%. Again, in this area, maize is the second most important food crop after rice. Among the four study provinces, East Java had the largest area planted to maize.

As in Lampung, the area planted to maize in East Java fluctuated by year, but in general it increased from about 1.06 million ha in 1991 to 1.17 million ha in 2000 (a growth rate of 1.07% per year). Compared to Lampung, the area planted to maize in East Java was relatively low. This was because of almost no possibility to extend agricultural activities in Java, due to scarcity of suitable land. The trends of area planted to maize in the four study provinces are presented in Figure 6.



	91	92	93	94	95	96	97	98	99	00
Lampung	190	234	253	250	364	395	359	375	400	382
E. Java	1064	1304	1012	1118	1187	1270	1100	1330	1138	1170
NTB	27	20	26	28	30	35	31	40	36	33
S. Sulawesi	271	337	296	301	343	337	322	338	241	224

Figure 6. Area planted to maize in the study areas, 1991-2000.

As in other provinces, most of the maize in NTB is cultivated on dryland, and only a small portion is planted on rainfed lowlands. As shown in Figure 6, among the four study provinces, the area planted to maize in NTB was the smallest. However, the growth in area was significant, increasing from 26,623 ha in 1991 to 32,512 ha in 2000, equivalent to a growth rate of 2.25% per year, during 1991-2000. In 2000, the area planted to maize in NTB was about 7.18% of the total area planted to food crops. It was the third most important crop after rice (71%) and soybeans (14.6%).

In contrast, the area planted to maize in South Sulawesi declined from 0.27 million ha in 1991 to 0.22 million ha in 2000 (a growth rate of –2.11% per year). The decline in area planted to maize was due to price disincentives. During the harvesting season, maize grain price often dropped to a level below the average cost of production. Therefore, some farmers changed from maize to other crops, such as cotton or soybean. Similarly, the proportion of the total area planted to food crops also decreased, from about 30% in 1980 to about 20% in 2000 (Kasryno 2002). During the same period, the proportion of the area planted to rice was about 60% in 1980 and 66% in 2000. So although decreasing in area, maize was still the second most important crop after rice.

2.2.2 Maize production and yield

During the last decade, maize production in Lampung increased from about 0.42 million tons in 1991 to 1.12 million tons in 2000, a growth rate of 11.65% per year. Among the four study provinces, Lampung had the highest growth of production. This growth was attributed both to the large growth in area (8.09%) and yield (3.29%) during this period. This high growth was made possible by the good support of infrastructure and agro-industry. Lampung has good transportation facilities; all roads to the villages are asphalted with good public vehicles. There are also at least five feed mills with a total capacity of about 500,000 tons of feed per year. In addition, another support system is the mutual collaboration that exists between farmers and three companies in this province. PT Tanindo (a seed company) provides farmers with hybrid maize seed on credit, which farmers pay back after harvesting at a price determined prior to the planting season. PT Pertani collaborates with farmers by providing fertilizers and other chemicals through farmers' groups and extension workers (PPL). Again, the repayment occurs after harvesting, with the chairmen of these farmers' groups and extension workers responsible for the collection of repayments from the farmers. In 2001, PT

Darmaniaga collaborated with farmers by providing all inputs (except labor), and farmers paid them with a share of the ear-maize. The share was 5:7, that is 5 portions for Darmaniaga and 7 portions for farmers. These support systems enable farmers to effectively adopt new technologies, especially hybrids.

In East Java, maize production increased from about 2.50 million tons in 1991 to 3.39 million tons in 2000, a growth rate of 3.42% per year. Most of the production growth was contributed by yield growth. Maize yields increased from 2.35 t/ha in 1991 to about 2.90 t/ha in 2000, growing at a rate of 2.36% per year. On the other hand, area grew at a rate of 1.07% annually.

Compared to the other provinces, maize yield in East Java was the highest. This was mainly due to the widespread use of hybrids, especially in rainfed and irrigated lowlands. The high adoption of new technology was achieved by a good support system. East Java has good transportation networks and well developed agro-industry. East Java is also the center of hybrid seed production as well as food and feed industries. Farmers, therefore, have good access to maize seeds and maize grain markets. Farmers grew local varieties for home consumption only, while for commercial purposes they grew hybrids or recycled hybrids. Only a few of them grew improved OPVs.

In more detail, maize production and yields in the four provinces are presented in Figure 7 and 8, while their growth summary is presented in Table 2.

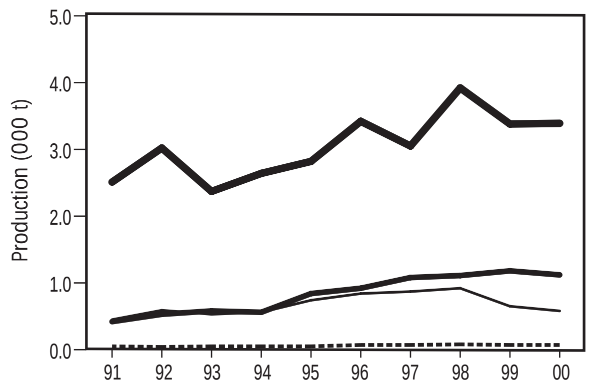
During the same period, maize production in NTB increased from about 51,000 tons in 1991 to about 67,000 tons in 2000, growing at a rate of 3.15% per year. Most of the production growth was attributed to area growth (2.25%/year), and only 0.90% was attributed to yield growth.

The low yield growth indicated slow progress in technological improvement. This was because of farmers' poor access to high quality seeds and the feed industry. Pure hybrid seeds were expensive, while the grain price was low. Most farmers used recycled hybrids, which were much cheaper than pure hybrids, but their yields were much lower. There was no difference in grain price between varieties. Farmers grew local varieties in small plots, for human consumption only.

In South Sulawesi, maize production increased from 0.45 million tons in 1991 to about 0.58 million tons in 2000, (a growth rate of 2.82% per year), although maize area declined by 2.11% per year. This significant positive growth was achieved due to substantial growth in yields. Maize yields increased from 1.66 t/ha in 1991 to 5.07 t/ha in 2000, a substantial growth rate of 5.07% per year.

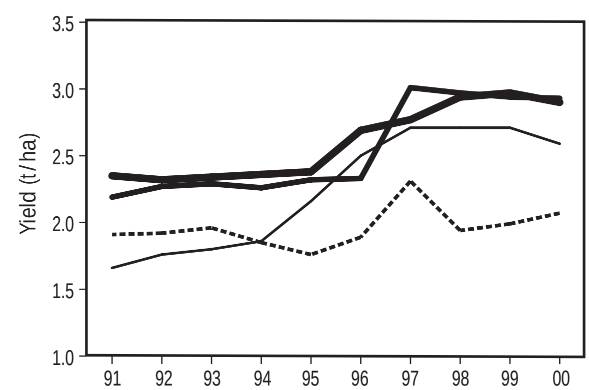
Table 2. Growth rates of maize area, production, and yield in the study areas, 1991-2000.

	Growth rate (%/year)		
Province	**Area**	**Production**	**Yield**
Lampung	8.09	11.65	3.29
East Java	1.07	3.42	2.36
NTB	2.25	3.15	0.90
South Sulawesi	-2.11	2.82	5.07



	91	92	93	94	95	96	97	98	99	00
Lampung	0.42	0.53	0.58	0.56	0.84	0.92	1.08	1.11	1.18	1.12
E. Java	2.51	3.02	2.37	2.64	2.82	3.42	3.05	3.92	3.38	3.39
NTB	0.05	0.04	0.05	0.05	0.05	0.07	0.07	0.08	0.07	0.07
S. Sulawesi	0.45	0.59	0.53	0.56	0.74	0.84	0.87	0.92	0.65	0.58

Figure 7. Maize production in the study areas, 1991-2000.



	91	92	93	94	95	96	97	98	99	00
Lampung	2.19	2.27	2.29	2.26	2.32	2.33	3.01	2.97	2.94	2.93
E. Java	2.35	2.32	2.34	2.36	2.38	2.69	2.77	2.94	2.97	2.90
NTB	1.91	1.92	1.96	1.85	1.76	1.89	2.31	1.94	1.99	2.07
S. Sulawesi	1.66	1.76	1.80	1.86	2.16	2.50	2.71	2.71	2.71	2.59

Figure 8. Maize yields in the study areas, 1991-2000.

3. Characteristics of the Maize Production System

3.1 Biophysical Environment

As mentioned earlier, maize in Lampung is cultivated mainly in dryland areas, where it is the most important crop, followed by cassava. The topography of the drylands in this province is flat to hilly (undulating), with a slope of 0-15%. The elevation of the study area ranges from 115 to 195 meters above sea level (masl). The major soil type is yellow-red podzolic with high acidity (pH<5) and low fertility.

The average annual rainfall from 1989-1999 was about 2455 mm (Appendix 3). Lampung has the highest rainfall of the four provinces. This high rainfall enables farmers to grow maize twice a year. The common cropping patterns are maize-maize and maize-cassava. Although the province has high rainfall, water availability can be a problem. The dry season maize is often faced with drought due to uneven distribution of rainy days. The average yield losses due to drought are reported to be around 30%. In 1997, when El Niño occurred, yield losses were about 70%.

The maize-maize cropping pattern, with maize being grown throughout the year, provides conditions that facilitated the outbreak of downy mildew in 1974-1975. Since then, downy mildew has been the main disease of maize in Lampung, especially when farmers plant late. This disease can reduce yields by 50-70%, although farmers have used Ridomill as a seed treatment.

In East Java, maize is cultivated in drylands, rainfed areas, and irrigated lowlands. Farmers in dryland and rainfed regions classify the soil according to color, namely red or black soil. The local agricultural officers use the term volcanic soil, whereas farmers in irrigated areas describe it as sandy alluvial soil. The topography is flat and hilly (plain-undulating) for dryland and rainfed areas, respectively, while irrigated lowlands are flat.

The elevation of the irrigated lowlands varies from 100 to 300 masl, while dryland and rainfed areas are 120 to 600 masl. Of the four provinces in the study, East Java has the largest range of elevation for maize production. The rainy season starts in November and ends in March, while the dry season occurs from April to October. The average annual rainfall in the study area was 1424 mm in the drylands and rainfed lowlands, and 1563 mm in the irrigated lowlands. The number of rainy days was 51 days in the drylands, and 81 days in the irrigated lowlands. The main cropping patterns in the irrigated areas were rice-maize and rice-chili, while in rainfed lowlands it was rice-maize. In the drylands, the common cropping patterns were maize-chili and maize-cassava.

The significant abiotic stress reported by farmers in East Java was drought, which occurred every four to five years. The worst drought occurred in 1997 and caused a reduction in yield of about 25 to 75%. The important pests attacking maize in the field were rats, stem-borers, and grasshoppers, but yield losses due to these pests were not significant. The known storage pest is the weevil, which attacks grain stored for more than three months. This is the case for local (white) maize, which is stored for more than three months, for home consumption. The losses due to this pest were reported to be less than 5%. None of the respondents stored yellow maize for more than four weeks.

In NTB, maize was cultivated mostly on drylands. None of the respondents knew the name of the soil in their area. The extension workers classified the soil as sandy alluvial. The topography of the land is flat in Sumbawa and hilly or undulating in East Lombok. Elevation is about 10 to 50 masl in Sumbawa and 100 to 360 masl in East Lombok.

The rainy season starts in November and ends in March, while the dry season is from April to October. The average annual rainfall in the study area was about 1479 mm, 1301 mm in East Lombok and 1658 mm in Sumbawa. There were 83 rainy days per year in East Lombok and 124 days in Sumbawa district.

The major cropping pattern in East Lombok was maize-mungbean or maize-fallow. Some rich farmers grew tobacco after maize. In Sumbawa the main cropping pattern was maize-fallow. Only farmers with tube-wells could practice a maize-maize cropping system.

The significant abiotic stress reported by farmers in NTB was drought. The worst drought occurred in 1997 and caused a reduction in yield of about 10 to 25%. Unlike in other provinces, there was no significant pest attacking maize in this area. Although storage weevils were reported, there were no yield losses due to this pest, because farmers usually stored maize for less than four weeks.

In South Sulawesi, maize was mostly cultivated on drylands (Jeneponto), irrigated areas, and rainfed lowlands (Bone). The main soil type is latosol in dryland areas and clay in the irrigated lowlands, with the topography being hilly in the drylands and plain-undulating in irrigated areas. In dryland areas, most of the farmers made terraces to avoid erosion as a soil conservation strategy. The elevation of the study area ranges from 20 to 50 masl in the lowlands to about 130 to 500 masl in the drylands.

In contrast to the other regions of Indonesia, the rainy season in the irrigated area of Bone runs from April to October, while the dry season starts in November and ends in March. The average annual rainfall was 2019 mm/year. In the drylands of Jeneponto, the wet and dry seasons are similar to other regions in Indonesia. The average annual rainfall was about 948 mm/year. Among the four provinces, the annual rainfall in this area is the lowest. To overcome water shortages, farmers practiced zero tillage for dry season maize.

The significant abiotic stress reported by farmers in South Sualwesi was drought. As in all regions of Indonesia, the worst drought occurred in 1997. The most common pests attacking maize in the lowlands were rats, but yield losses due to this pest were not significant. There was no reported pest in the drylands. No significant disease was found in this study area. The storage weevil commonly attacked white-grain maize, which is usually stored for more than 3 months for home consumption. To minimize grain losses, farmers stored maize as un-husked ears. The biophysical environments of maize areas in the study regions are presented in more detail in Appendix 3.

3.2 Infrastructure

Infrastructure is one of the most important factors affecting the performance of maize production systems. In particular, good transportation facilities (road and vehicle) in Lampung have facilitated the buying of inputs and the sale of farmers' products. The most commonly used vehicle for transportation in this province is the minicab. Farmers usually sell their grain soon after harvesting, without post-harvest processing. Because of good transportation facilities, the traders can easily travel to the villages to buy maize grain during the harvesting season. Threshing is carried out at the farmers' houses and drying is done in their respective drying facilities. The traders often provide farmers with some inputs and cash credit at an interest rate of 1.5% per month, similar to the interest rate of commercial banks. If traders do not come to the village, farmers are easily able to get to the nearest market, which is approximately 3 km away, to sell their grain.

The success of maize-based farming systems in Lampung was also largely attributable to the farmers' own support systems. As such, farmers were organized into groups, each consisting of 20-30 farmers. Each group made a common plan for maize cultivation covering the varieties to grow, planting time, and level of fertilizer use. The external support systems included government intervention and involvement of the private sector. The local government launched a special intensification program (GEMA PALAGUNG 2001 was launched to attain self-sufficiency by increasing yields in rice and palawija with soybean and maize as secondary crops), in addition to offering credit to farmers, via provincial and district agricultural extension services. The most important sources of information regarding maize technology are the extension workers, followed by seed companies as shown in Appendix 4. Another support system for farmers is good collaboration with private companies, in terms of providing inputs, cash credits, and grain marketing.

In East Java, most of the villages visited have moderate-to-good asphalted roads and moderate gravel roads. Public transport, such as minicabs, pick-ups, and motorcycles (called ojeg), allow easy access to and from the villages. The transportation cost from the villages to the local markets ranged from Rp 500 to Rp 1000 per person or per 100 kg fertilizers or grains, depending on the distance of the market from the village. (In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.) The average distance to the nearest market is 3 km.

The performance of farmers' groups was good in irrigated lowlands, while only fair in dryland areas. In the irrigated lowlands, farmers' groups not only successfully determined which variety, and when, to grow, and how much fertilizer should be applied, but they also provided their members with credit to buy inputs. The cash capital of the group came from the savings of their members. Most inputs were bought from the shops in the sub-district markets. Sources of cash capital were mainly individual farmers and farmers' groups in irrigated areas, while the cash sources in dryland areas were individual farmers and private traders. In irrigated areas, the information about maize technology was mostly provided by extension workers and seed companies, while in the drylands most technology was supplied by extension workers and other farmers.

In NTB, the transportation system is not as good as in Lampung and East Java. Most villages visited in East Lombok have bad-to-moderate gravel roads. Only one village has a good asphalted road. In the study area of Sumbawa, two villages are located on the main provincial (good asphalted) road. Motorcycle (ojeg) is the most popular mode of transportation in East Lombok, whereas minicab, horse traction (called dokar), and ojeg are the most common means of public transport in Sumbawa. Most inputs were bought in the shops in the sub-district markets.

The unfavorable transportation systems (especially in East Lombok) made it very difficult for farmers to sell their maize to the district or sub-district markets, although the nearest market is only 3 km from the village. Most farmers sold their maize grain soon after harvesting, either in the field or at home, at a relatively low price. Most farmers complained about the price they received for their maize but were unable to improve this situation.

Farmers' groups and cooperatives in this region only dealt with planting time and decisions about which varieties to grow. They were not involved with maize marketing or credit. The main source of cash capital was a farmer's own capital and credit from private traders with high interest rates (12.5%/month). The sources of technology-related information were extension workers and other farmers.

In South Sulawesi, most villages in the study area have good asphalted and moderate gravel roads. The main mode of public transport used by farmers was the minicab. Most inputs were bought from shops in the local markets. Sources of cash capital were a farmer's own capital, farmers' groups, and commercial banks. The performance of farmers' groups was good. All respondents reported that farmers' groups were active in providing their members with information about technology. They decided when to grow, which varieties to grow, and how much fertilizer should be applied. Farmers' groups also provided cash credit for their members.

The information about maize technology came mostly from extension workers and farmers' own experiences. Maize marketing was done in two ways, depending on the type of maize grown. Yellow maize (mostly hybrid and its corresponding recycled hybrid) was sold directly to other farmers soon after harvesting. White maize was usually stored as ears with husks, after sun-drying. Farmers sold this maize gradually, and money earned from this sale was used for daily household expenditures. Part of the white maize harvest was consumed as staple food. Details of the infrastructure in the study areas are presented in Appendix 4.

3.3 Farmer Characteristics

The average age of maize farmers in Lampung was 42 years (ranging from 27 to 61 years). In general, most formal education was obtained in elementary school, with an average duration of school attendance of seven years (graduating from elementary school and completing grade one in secondary school). Only a few farmers attended high school. Such limited formal education, however, did not appear to be a serious constraint to farmers adopting modern technologies. Most of them had a high level of understanding of hybrid maize technology. Most farmers in Lampung (95%) have their own land. Landowners usually contract the landless (5%) under a sharecropping arrangement. The average size of the farms was 2.1 ha, with the largest being 4.7 ha (Appendix 5).

In the dryland areas of East Java, farmers had an average age of 39, ranging from 26 to 59 years old. The farmers in irrigated areas were older, ranging from 29 years to 71 years old with an average age of 42 years. Their formal education ranged from 1 to 11 years, with an average of 6 and 7 years, respectively, in the lowlands and dryland areas. This means that the majority of them had only graduated from elementary school. There was a tendency for younger people (20-30 years old and with higher education levels) not to want to work in agriculture. They preferred to work in non-agricultural sectors that promised a higher income. Farm size ranged from 0.2 to 1.8 ha, with an average of 0.7 ha in the drylands and 0.4 ha in the irrigated lowlands, as shown in Appendix 5. However, productivity of the irrigated lowlands was much higher, so that the welfare of farmers in this area was better than their counterparts in the drylands.

As shown in Appendix 5, farmers' age in NTB ranged from 26 to 55 years old, with an average age of 39 years. Farmers mostly attended elementary school for an average of about six years, with many farmers having a low level of formal education. Farm size in this study area ranged from 0.4 to 2.5 ha, with an average of 1.2 ha. About 99% of respondents owned their own land. Renting land was not common in this study area.

In South Sulawesi, there was no significant difference in age across agro-ecosystem. The respondents' ages ranged from 24 to 68 years, with an average age of 45 years. Their levels of formal education were relatively low, ranging from 1 to 11 years (an average of 6 years), again showing that most farmers in South Sulawesi had only received elementary school education. Farm sizes ranged from 0.1 to 1.0 ha in the irrigated lowlands (Bone), with an average of 0.4 ha. In the drylands of Jeneponto, farm size ranged from 0.3 to 1.9 ha, with an average of 0.6 ha. This shows that, in the region as a whole, most farmers own less than 1.0 ha. All respondents in Jeneponto have their own land, while only 65% of respondents in Bone were landowners (Appendix 5).

Farmers were grouped into three categories: poor, medium, and rich. The indicator used for classification of farmers was the level of land ownership.

In Lampung, farmers with less than 0.35 ha were classified as poor farmers, those with 0.35 to 3.0 ha as medium farmers, while those with farms larger than 3.0 ha were classified as rich farmers. All economic classes had the same average family sizes, of five members. The average farm sizes were 0.2 ha, 1.5 ha, and 4.3 ha, respectively, for poor, medium, and rich farmers. The poor and medium farmers generally grew food and horticultural crops. On the other hand, in addition to growing food and horticultural crops, rich farmers also cultivated perennial crops as an extra source of income (Appendix 6).

In the irrigated areas of East Java, farmers with less than 0.5 ha were classified as poor farmers, those with 0.5 to 1.0 ha as medium farmers, and those owning more than 1.0 ha as rich farmers. On the other hand, in dry-land areas, poor farmers were described as those with less than 0.5 ha, medium farmers were those with 0.5 to 2.0 ha, while rich farmers were those with more than 2.0 ha of land. There was a tendency for poor farmers to have larger family sizes. In irrigated areas, the average family size of the poor farmers was 4-7, while the medium and rich farmers had 4-5 and 2-5 members, respectively. The same trend was observed for farmers in dryland areas. There was also a tendency for farmers in irrigated areas to have larger family sizes compared to their counterparts in dryland areas. For example, the medium farmers in irrigated areas had an average family size of 4-5 people, while in dryland areas families had 3-5 members. In irrigated lowland areas, poor farmers grew rice and maize, while medium and rich farmers grew either rice and maize or rice followed by chili. In the drylands, poor and medium farmers grew maize and cassava or chili, while rich farmers tended to grow maize and chili (Appendix 6).

In NTB, farmers with less than 0.75 ha were categorized as poor farmers, those with 0.75 to 1.5 ha were categorized as medium farmers, while farmers who owned more than 1.5 ha were classified as rich farmers. Similar to East Java, there was a tendency in NTB for rich farmers to have the smallest family sizes. All respondents in NTB cultivated food crops, especially maize. Rice was mainly cultivated in a small area of rainfed land. In addition to food crops, some of the medium income and most of the rich farmers in East Lombok also cultivated tobacco, which was very capital intensive. Poor farmers, with limited cash capital, could not grow tobacco.

In the drylands of South Sulawesi, farmers owning less than 0.5 ha of land were categorized as poor farmers, medium farmers were those with 0.5 to 2.0 ha, and farmers with more than 2.0 ha were classified as rich farmers. In the irrigated lowlands, the poor, medium, and rich farmers were those with <0.5 ha, 0.5 to 1.0 ha; and >1.0 ha, respectively. There was no significant difference among categories in terms of family size, which averaged five both in irrigated and dryland areas. The main crops cultivated by farmers in the irrigated lowlands were maize and rice. Rich farmers cultivated cocoa as another source of income. In dryland areas, farmers mainly grew maize and cotton. As in the lowlands, rich farmers in dryland areas also grew cocoa (Appendix 6).

In terms of livestock ownership, there was a tendency in all study areas for rich farmers to have more cattle, compared to medium and poor farmers. This is as expected, because cattle are expensive to rear. On the other hand, the ownership of poultry and goats was not dependent on the economic status of the farmers, except in NTB, where medium and rich farmers had more goats.

Regarding farming decisions, there was no difference between the three categories of farmers in all study areas. All respondents reported that they made farming decisions together with their wives (Appendix 6).

3.4 Use of Maize Grain and Crop Residues

In Lampung, all maize was grown for direct sale. Farmers who usually grew recycled maize during the dry season used less than 0.5% for seed. About 70% of respondents used maize straw for mulching, while only 5% of them used the green leaves for livestock fodder. None of them were using maize straw or cobs for fuel (Appendix 7).

In the drylands of East Java, about 41% of local maize was consumed as a staple food, another 58% was sold, and only 1% was used for seed. In irrigated areas, 100% of maize was sold. In terms of crop residues, most of the respondents (90% in irrigated and 80% in dryland and rainfed areas) used green leaves for feeding cattle. None of the respondents used maize straw for mulching. There were also about 25% of respondents in irrigated areas and 50% in dryland areas that used dry stems, cobs, and husks for fuel. Some farmers (10%) did not use crops residues for any purpose. They let other people take the residues for free.

In NTB, 99% of farmers grew maize to sell. The remaining 1% was used for seed, most commonly practiced by farmers in East Lombok who grew recycled maize. About 56% of respondents used green maize leaves for livestock fodder. None of the respondents used maize straw for mulching. Only 2% of respondents used crop residues for fuel. The remaining farmers burned all crops residues in the field.

In South Sulawesi, about 21% of farmers in the irrigated area of Bone and 14% in the drylands of Jeneponto used maize grain as a staple food. Most of them (77% in Bone and 85% in Jeneponto) grew maize for sale. About 1% was used for seed. In Jeneponto, 72% of respondents used crop residues for mulching and about 20% of them used crop residues for livestock fodder. In Bone, 56% and 22% of farmers used crop residues for mulching and livestock fodder, respectively. None of the respondents in the study area used crop residues for making compost. The details of maize grain and crop residues' utilization are presented in Appendix 7.

3.5 Sources of Income

The differences in crop cultivation, in different regions, resulted in variable sources of income for farmers. Poor farmers in Lampung earned about 62% of their income from non-farming activities. Money earned from maize only contributed about 22% to their income. Another 16% of their income was earned from other agricultural activities. In contrast, 52% of rich farmers' income was earned from maize and 46% from other commodities, especially perennial crops, such as coffee, pepper, and coconuts. Only about 2% of rich farmers' income was earned from non-farm activities (Appendix 8).

In East Java, maize was not a major source of income for any economic class of farmer. Most of the income in irrigated areas came from other crops, namely rice and chili. In the irrigated lowlands, only about 20% of the poor farmers' income, 22% of the medium farmers' income, and 15% of the rich farmers' income came from maize. Most of the income (70% for the poor, 66% for the medium, and 55% for the rich farmers) was earned from other agricultural activities. Similarly, maize in the dryland areas was a minor source of income (22% for the poor and the medium, and 24% for the rich farmers). This contrasted with the situation of rich farmers in Lampung, where maize was the main source of income.

In NTB, maize was a significant source of income. It contributed about 49%, 44%, and 41% of the household income of the poor, medium, and rich farmers, respectively. The smallest source of income for all farmers was non-agricultural activities. The largest source of income for the medium and rich farmers was other agricultural activities, especially tobacco cultivation in East Lombok and livestock in Sumbawa.

In the lowlands of Bone (South Sulawesi), maize contributed about 26%, 39%, and 44% of the income of the poor, medium, and rich farmers, respectively. Most of the income of the poor farmers (41%) was earned from non-agricultural activities. On the other hand, about 49% of the income of the medium farmers and 56% of the income of the rich farmers came from other agricultural commodities, especially cotton and cocoa.

In dryland areas, about 57% of the poor farmers' income came from non-agriculture activities. About 56% of the income of the medium farmers and 65% of the income of the rich farmers came from maize (Appendix 8). These figures show that poor farmers in the study area have to work hard outside the agricultural sector, while the medium and rich farmers received most of their income from agriculture, especially maize cultivation.

4. Level of Technology

4.1 Maize Varieties

In Lampung, most farmers (87.5%) used pure hybrids during the wet season. Only 12.5% of them used recycled hybrids. In contrast, during the dry season only about 23.7% of farmers used pure hybrids, and 76.3% used recycled seeds (selected from previously harvested hybrids).

In East Java, maize varieties used were either local, improved OPVs, or hybrids. The hybrids were pure or recycled. Maize cultivation was different for each agro-ecosystem and season. In the irrigated and rainfed lowlands, maize was generally cultivated after rice. Some farmers grew maize during the wet season, in rainfed lowlands with less rainfall. In the dryland areas, maize was planted in the wet season.

During the wet season, most farmers (47%) in dryland areas grew the local variety, followed by hybrids (29%), recycled hybrids (22%), and improved OPVs (2%). Similarly, most farmers in the rainfed lowlands grew the local variety (40%), recycled hybrids (40%), and hybrids (20%). None of the farmers grew maize in the irrigated lowlands during the wet season.

In the dry season, all respondents in the irrigated lowlands grew hybrids, while about 80% of farmers in rainfed lowlands grew the local variety, followed by recycled hybrids (18%), and only 2% of farmers grew improved OPVs. None of the respondents in the irrigated lowlands cultivated the local variety.

In NTB, during the wet season of 2000/2001, most farmers (55.4%) used recycled hybrids. About 40.6% of them used pure hybrids, 3.7% used improved OPVs, and only 0.3% used the local variety. Farmers in East Lombok, who grew maize during the dry season, used recycled hybrids.

In South Sulawesi, the use of maize varieties also varied. In the drylands of Jeneponto, there were at least four varieties being used. During the dry season, about 59.2% of farmers used hybrids, 31.3% used recycled hybrids, about 7.5% used the local variety, and another 2% used OPVs. In contrast, during the wet season, about 62.5% of respondents used recycled seeds, about 21.7% used hybrids, 8.8% used the local variety, and only 2% grew OPVs.

In the lowlands of Bone, during the dry season, about 93.7% of respondents used local maize and only 6.3% of them used improved OPVs. Local maize was grown mainly for human consumption. The details of maize varieties used in the study area are presented in Table 3.

Farmers grew local maize in the study areas because:

- they use maize as a staple food;
- HYVs seeds are expensive, especially hybrids;

Table 3. Maize varieties grown in the study areas, 2000.

Province/land type	Season	Local (%)	Improved OPV (%)	Hybrids (%)	Recycled hybrid (%)
Lampung:					
Dryland	WS†	-	-	87.50	12.50
	DS‡	-	-	23.75	76.25
East Java:					
Irrigated (Kediri)	WS	-	-	-	-
	DS	-	-	100	-
Dryland (Tuban and Kediri)	WS	47	2	29	22
	DS	-	-	-	-
Rainfed (Tuban)	WS	40	-	20	40
	DS	80	2	-	18
NTB:					
Dryland	WS	0.25	3.75	40.60	55.40
	DS	-	-	-	-
South Sulawesi:					
Dryland (Jeneponto)	DS	7.50	2	59.20	31.30
	WS	8.80	2	21.70	62.50
Irrigated/RFLL§ (Bone)	DS	93.70	6.30	-	-
	WS	-	-	-	-

† Wet season.
‡ Dry season.
§ Rainfed lowlands.

- hybrid maize needs more inputs, resulting in higher costs to farmers; and
- farmers have less experience with hybrids, so that growing a new variety is perceived as risky.

As shown in Table 3, only a few farmers grew improved OPVs. This was due to limited availability of improved OPV seeds in the market. Farmers reported that the private companies collaborated with extension workers, who promoted the hybrids intensively and made hybrid seeds available. In contrast, no one promoted improved OPVs or government-bred hybrids. Therefore, although more expensive, the use of private-bred hybrids was much higher than improved OPVs and government-bred hybrids. The reasons given as to why farmers grew hybrids and recycled hybrids were that they gave high yields and were grown for sale. On the other hand, there were at least two reasons why farmers used recycled seeds (especially F2). First, the yield of F2 plants was still high (about 85-90% of the pure hybrids). Secondly, farmers did not have to spend their limited capital on expensive hybrid seeds.

Some interesting observations can be made from Table 3. First, hybrid maize is more important in the areas where farmers grow maize for sale. Most of the farmers grew hybrids on drylands, during the wet season, except in East Java, and on irrigated lowlands during the dry season, except in South Sulawesi. When farmers grew recycled seeds, they were taken from the previously cultivated hybrids. The role of hybrid maize in the commercial maize production system is becoming more and more important. Secondly, only about 2% of farmers used improved OPVs. This was due to unavailability of seed in the local market.

4.2 Cropping Patterns

4.2.1 Lampung

A long duration of wet months and a high rainfall in Lampung enable farmers to grow maize twice a year. Figure 9 shows the rainfall pattern and common cropping calendar in the drylands of Lampung. Most farmers follow a maize-maize cropping pattern, and some of them practice maize-cassava. The first maize (wet season) is usually planted in early November and harvested in February, while the second maize (dry season) is usually planted in March and harvested in late June or early July.

There were at least two reasons why farmers grew cassava. First, farmers with large farms were not able to cultivate maize twice, because of a lack of labor. Therefore, they grew cassava, which is not as labor and input intensive. Secondly, there are some cassava flour factories in the area which means cassava can be grown and sold directly to the processing factories.

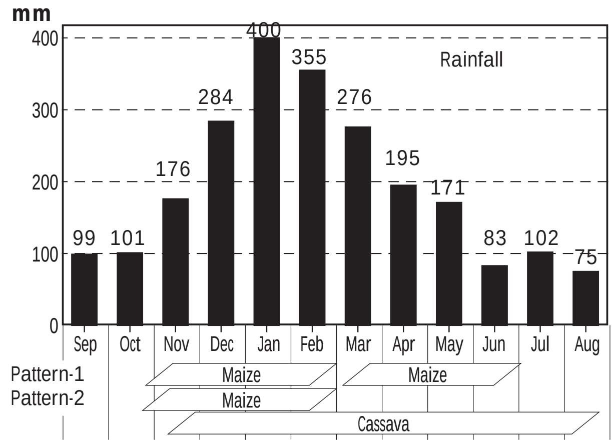


Figure 9. Monthly rainfall and maize-based cropping pattern in Lampung.

4.2.2 East Java

Cropping patterns in East Java were considerably different across agro-ecosystems. In general, cropping patterns in this province are shown in Figures 10 and 11. In irrigated lowlands, maize was planted in late March or early April (after harvesting rice), and harvested in July, as shown in Figure 10. The cropping pattern in the rainfed lowlands was similar to that in the irrigated lowlands. In this area, maize was also mainly planted after rice. Only a few respondents reported that they grew wet season maize in rainfed areas. In the irrigated and rainfed lowlands, rice was the most important crop. As long as water is sufficient for rice, farmers will grow rice. Only in the dryland areas does maize become the first priority crop during the wet season, as shown in Figure 11.

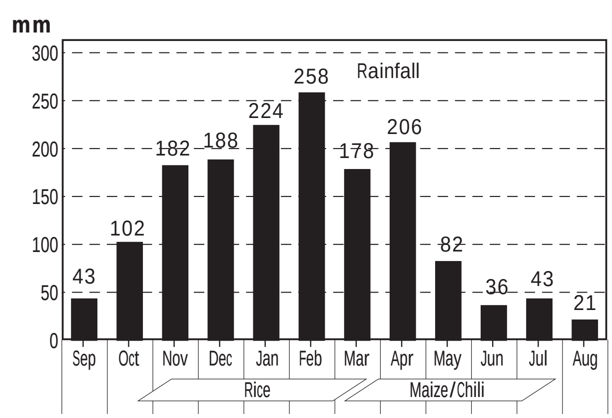


Figure 10. Monthly rainfall and cropping pattern in irrigated and rainfed lowlands of East Java.

4.2.3 NTB

In East Lombok, the main cropping pattern was maize-mungbean. The rich, and some of the medium, farmers grew tobacco (instead of mungbean) after maize. Tobacco is a very capital-intensive crop and, therefore, unaffordable for poor farmers. In Sumbawa, the main cropping pattern was maize-fallow. Only a few farmers (in a small area) followed a maize-maize cropping pattern and this was especially in areas where a water pump was available.

Maize is usually planted in November and harvested in March, while mungbean is planted in April and harvested in July. The maize-based cropping patterns in NTB are presented in more detail in Figure 12.

4.2.4 South Sulawesi

The irrigated area of Bone, in South Sulawesi, has a different climate compared to the other regions of Indonesia. The rainy season starts in March and ends in August, while the dry season is from September to February. Therefore, if we use October as a starting point, the cropping pattern in the lowlands was maize-rice, as shown in Figure 13. On the other hand, the wet and dry seasons in Jeneponto are similar to other regions of Indonesia and, therefore, the Jeneponto region has different cropping patterns to Bone. In this area there are two cropping patterns: maize-maize and maize-cotton, as presented in Figure 14.

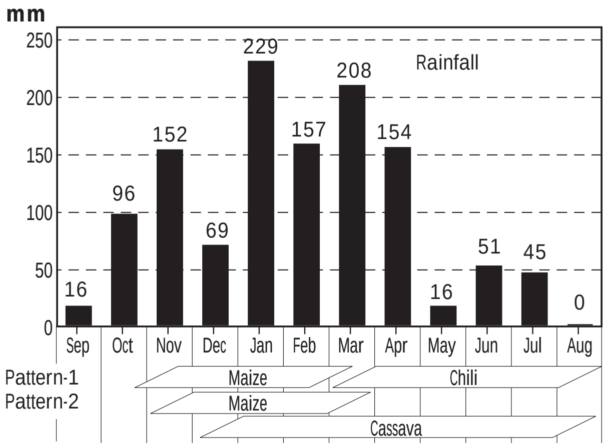


Figure 11. Monthly rainfall and cropping pattern in the drylands of East Java.

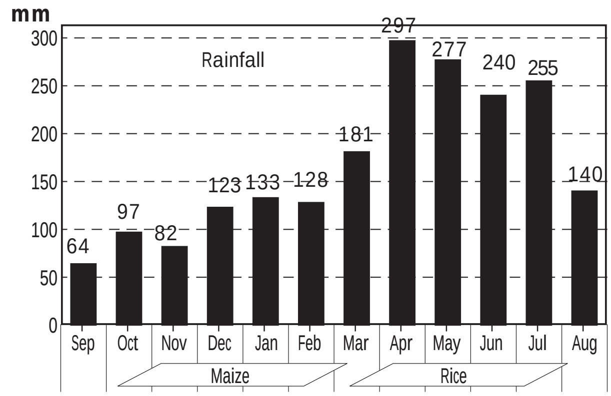


Figure 13. Monthly rainfall and cropping pattern in the irrigated and rainfed areas of Bone, South Sulawesi.

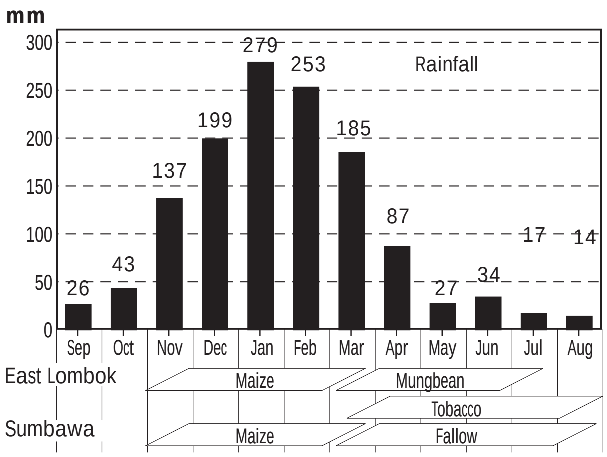


Figure 12. Monthly rainfall and cropping patterns in NTB.

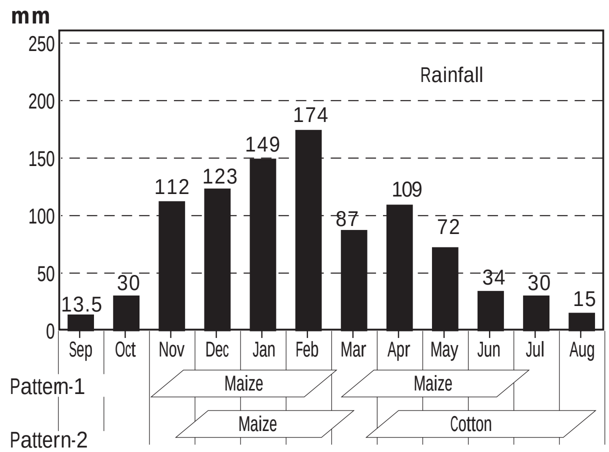


Figure 14. Monthly rainfall and maize-based cropping pattern in the drylands of Jeneponto, South Sulawesi.

4.3 Land Preparation and Crop Management

Crop management for maize cultivation in Lampung was similar across seasons; the only difference was land preparation. During the wet season, land preparation was done intensively (plowing twice and harrowing once), while for the dry season, land preparation was less intensive (plowing once and harrowing once). About 75% of respondents used animal power and about 23% used tractors for land preparation. Only 2% of respondents did land preparation manually, as shown in Table 4. Most of the respondents reported that using a tractor for land preparation was faster than animal power. Unfortunately, the number of tractors in each village was not sufficient to fulfill the need for all areas.

In East Java, land preparation was done differently depending on the agro-ecosystem. In the drylands, most farmers (80%) used animal traction for land preparation and about 20% used a tractor. For rainfed areas, about 70% of farmers used animal power and the rest used a tractor. In the irrigated lowlands, about 51% of farmers used a tractor and another 49% used animal power. None of the respondents prepared the land manually (Table 4).

In NTB, most of the farmers (86%) (in East Lombok) used animal power for land preparation. Only 8% of them did land preparation manually, and 6% used tractors. In Sumbawa, about 63% of respondents used a tractor, and the rest (37%) used animal power for land preparation.

Most farmers in South Sulawesi used animal power for land preparation. During the first (dry) season, about 93.7% of respondents in the drylands of Jeneponto and 75% of respondents in the wetlands of Bone used animal power. Only 6.3% of them in Jeneponto and 25% in Bone did land preparation manually. During the second or wet season, about 32.5% of farmers did land preparation by minimum tillage manually, and most of them (67.5%) practiced zero tillage, as presented in Table 4.

Table 4. Land preparation practices for maize production in the study areas, 2000.

Province/land type		Land preparation (%)			
		Zero tillage	Manual	Using animals	Using tractors
Lampung:	Dryland	-	2.12	75	23
East Java:	Irrigated	-	-	49	51
	Dry land	-	-	80	20
	Rainfed	-	-	70	30
West NT:	East Lombok	-	8	86	6
	Sumbawa	-	-	37	63
South Sulawesi:					
Dryland:	DS[†]	-	6.3	93.7	-
	WS[‡]	67.5	32.5	-	-
Irrigated/RFLL[§]:	DS	-	25	75	-

[†] Dry season.
[‡] Wet season.
[§] Rainfed lowlands.

In terms of maize planting, about 87% of respondents in Lampung used animals to prepare the rows by plowing. Only 13% of respondents planted maize manually. Crop spacing was about 75 cm between rows, and 25 cm within the rows, with one seed per hole. Animal power was also used for weeding by 43% of farmers in Lampung. About 31% of them used human labor and another 26% used herbicides, as shown in Table 5.

In East Java, almost all of the respondents (99%) reported that they planted maize manually. Only a few farmers in the drylands and rainfed lowlands used animals for planting maize. There was no significant difference between irrigated and non-irrigated areas in terms of the planting practices for maize. For weeding, there was considerable variation between irrigated area and non-irrigated areas. All farmers in the irrigated areas used manual weeding, while in the drylands and rainfed lowlands the numbers of farmers who used manual and animal power were almost equal (Table 5). The main reason for using animal power was the scarcity of human labor.

Weeding was generally done twice. Farmers used cattle for weeding between rows, while weeding within the row was done by hand. The first weeding was done about three weeks after planting and usually done together with fertilizer application. The second weeding was done about five to six weeks after planting.

All of the respondents in East Lombok reported that they planted maize manually, while in Sumbawa 45% of farmers planted maize manually and 55% used animal power. In terms of weeding, about 55% of farmers in both East Lombok and Sumbawa did weeding manually and about 45% of them used animal power, as shown in Table 5.

Most of the respondents (62.5%) in Jeneponto, during the dry season, used animals for maize planting, while about 37.5% of them planted maize manually. Crop spacing was about 75 cm between rows, 25 cm within the row, and one seed per hole. In Bone, 56% of respondents used animals and another 44% of them used human labor for maize planting. Crop spacing was 75 cm between rows and 50 cm within the row, with two seeds per hole. The difference in crop spacing was mainly due to the difference in varieties. In contrast, during the wet season, about 67.5% of respondents planted maize manually and only 32.5% used animal power. This was because most of them were practicing zero tillage, so that planting had to be done manually.

Animal power was also used for weeding in Jeneponto, both during the first and the second seasons (50% of respondents). About 37% of them did hand weeding and the rest used animals. In contrast, all of the respondents in Bone did hand weeding. Crop management practices in the study areas are presented in more detail in Table 5.

4.4 Input Use

4.4.1 Lampung

In Lampung, inputs used for maize cultivation consisted of seeds, fertilizers, manure, insecticides, and herbicides. There was no significant difference in the use of seeds between East and South Lampung. During the wet season, farmers used about 15 kg maize seeds per hectare, in both East and South Lampung, while in the dry season they used 21 kg/ha and 22 kg/ha seeds, respectively, in East and South Lampung. The amounts of seeds used in both areas were almost identical because farmers in these two districts used hybrids.

All farmers used urea at an average dosage of 200 kg/ha in East Lampung and 217 kg/ha in South Lampung, during the wet season. In the dry season, farmers used a lower level of urea, 187.5 kg/ha on average in East Lampung and 143.7 kg/ha in South Lampung. The lower use of urea during the dry season was due to some farmers using recycled seeds. Urea was usually applied twice, together with the first and second weeding. Phosphate fertilizer, in the form of SP36, was commonly used in both districts and both seasons. During the wet season, farmers used 75 kg/ha and 150 kg/ha of SP36 per hectare, respectively, in East and South Lampung. In the dry season, they used 81.2 kg/ha and 100 kg/ha SP36 on average, respectively, in East and South Lampung. Potassium in the form of KCl was used at a low rate. Farmers in East Lampung used only about 12.5 kg/ha of KCl, during both the wet and dry seasons. In South Lampung, farmers used KCl at a rate of 37.5 kg/ha and 25 kg/ha, respectively, during the wet and dry seasons. In addition to inorganic fertilizers, farmers also applied manure, about 300 kg/ha during the wet season and only 62.5 kg/ha during the dry season.

Farmers reported that none of them used pesticides because there were no significant pests infesting maize in the field. The only biotic stress was downy mildew. Therefore, they only used seed treatment for recycled seeds and herbicide for weeding. The details of material input use in Lampung are presented in Table 6.

Table 5. Crop management practices for maize production in the study areas, 2000.

Province/land type		Planting (%) Manual	Planting (%) Using animals	Weeding (%) Manual	Weeding (%) Using animals	Weeding (%) Using herbicide
Lampung:	Dryland	13	87	30.6	43.1	26.3
East Java:	Irrigated	100	-	100	-	-
	Dryland	99	1	52	48	-
	Rainfed	99	1	50	50	-
West NT:	East Lombok	100	-	55	45	-
	Sumbawa	45	55	55	45	-
South Sulawesi:						
Dryland:	DS†	37.5	62.5	37.5	50	12.5
	WS‡	67.5	32.5	37.5	50	12.5
Irrigated:	DS	43.7	56.3	100	-	-

† Dry season.
‡ Wet season.

Table 6. Material input use per hectare by districts and seasons, Lampung, 2000.

Item	Wet Season East Lampung Quantity	Wet Season East Lampung Cost (†Rp000/ha)	Wet Season South Lampung Quantity	Wet Season South Lampung Cost (†Rp000/ha)	Dry Season East Lampung Quantity	Dry Season East Lampung Cost (†Rp000/ha)	Dry Season South Lampung Quantity	Dry Season South Lampung Cost (†Rp000/ha)
Seeds (kg/ha)	15	231.7	15	270	21	23.125	22	22
Fertilizer (kg/ha)								
Urea	200	240	217	253.7	187.5	215.0	143.7	191.9
ZA	-	-	-	-	-	-	-	-
SP-36	75	143.7	150	207.5	81.2	133.1	100	147.5
KCl	12.5	21.2	37.5	68.7	12.5	21.2	25	26.1
Manure (kg/ha)	300	26.5	350	52.2	62.5	6.2	-	-
Pesticides (l/ha)	-	-	-	-	-	12.5	-	7.5
Herbicides (l/ha)	2.5	107.7	3.25	123	1.5	60.7	1.3	51.7
Total	**-**	**771**	**-**	**975**	**-**	**472**	**-**	**447**

† In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.

Labor was generally needed for land preparation, planting, weeding, fertilizer application, harvesting, shelling, and transportation. An average of Rp 1.22 million and Rp 1.15 million/ha were spent on labor costs, respectively, during wet and dry seasons. Men and women participated equally in most farm activities, except in land preparation, where only the men were involved. Women were slightly more involved than men in planting, while men participated more in weeding. For fertilizer application and harvesting, they participated equally, both during the wet and dry seasons. The detail of labor use in Lampung is presented in Table 7.

4.4.2 East Java

Levels of input use in East Java were dependent on both the agro-ecosystem and the season. Farmers used about 20 kg maize seeds/ha for local, recycled, and pure hybrid varieties. Planting was done by hand, either in holes made by sticks or by the plow furrow. Crop spacing varied from 75 x 30 cm to 100 x 40 cm, depending on the variety and individual practices.

Similar to Lampung, all farmers in East Java used urea at an average rate of 100 kg/ha in the rainfed lowlands, 150 kg/ha in the drylands, and 393 kg/ha in irrigated areas. These values are equivalent to 45 kg N/ha in rainfed, 67.5 kg N/ha in dryland, and 175 kg N/ha in irrigated areas. Urea was usually applied twice, together with the first and second weedings. Another form of nitrogen used by farmers in the irrigated lowlands was ZA (N with S). Phosphate fertilizer, in the form of SP36, was commonly used in irrigated areas, but relatively few farmers used it in the rainfed lowlands. The average use of SP36 in rainfed areas was 25 kg/ha, while in irrigated areas it was 150 kg/ha. Potassium (in the form of KCl) was only used by farmers in irrigated areas at an average rate of 52 kg/ha. Farmers in dryland and rainfed areas did not apply potassium. In addition, most of the farmers in the study area applied manure. In fact, farmers applied manure ranging from 1500 kg to 7500 kg/ha. Farmers in irrigated areas applied much more manure than farmers in dryland and rainfed lowlands. The total cost of inputs used by farmers in East Java was about Rp 1.46 million/ha in irrigated areas and about Rp 0.23 million/ha, in both dryland and rainfed lowlands. The summary of material input use is presented in Table 8.

Table 7. Labor use per hectare by activity, Lampung, 2000.

Item	Wet Season		Dry Season	
	Quantity (days)[†]	Cost ([‡]Rp000/ha)	Quantity (days)[†]	Cost ([‡]Rp000/ha)
Land preparation				
Manual	4.5	51.7	13	149.5
Animal	-	193.5	-	148.1
Tractor	-	80.5	-	-
Planting				
Men	7	80.5	8	92
Women	8	84	8.5	89.2
Animal	3	45	3	45
Weeding				
Men	6	69	14.5	86.2
Women	5.5	57.7	5	52.5
Animal	6	90	6.5	97.5
Fertilizer applic.				
Men	6	69	5.5	63.2
Women	6	63	5.5	57.7
Harvesting				
Men	11.5	132.2	9.5	109.2
Women	11.5	120.7	9.5	99.7
Shelling	-	-	-	-
Transportation	-	78.7	-	63.7
TOTAL	**-**	**1,216.0**	**-**	**1,154.0**

[†] Days are interpreted as "person-days" for human labor, "animal-days" for animals, and "machine-days" for tractors and other machinery.
[‡] In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.

Regarding crop protection, farmers did not use pesticides or herbicides. In this study area, white grubs often infested maize in the early stages of growth. A major factor causing this infestation was late planting of maize. Late planting during the rainy season was usually due to uneven distribution of early rains and competition for labor with other wet season crops, especially rice in rainfed areas.

As in Lampung, labor in East Java was also needed for land preparation, planting, weeding, fertilizer application, harvesting, shelling, and transportation, as shown in Table 9. Land preparation was completely done by men. In irrigated areas, for planting and harvesting, men and women contributed equally. Weeding and fertilizer application were mostly done by men. Total labor costs for maize cultivation were about Rp 1.25 million/ha in irrigated areas, about Rp 0.57 million/ha in dryland areas, and Rp 0.76 million/ha in the rainfed lowlands.

4.4.3 NTB

Unlike in East Java, none of the farmers in NTB used manure for maize cultivation, although many of them had cattle. Farmers in this province only used inorganic fertilizers, urea and SP36. They used, on average, 20 kg maize seeds/ha, in both East Lombok and Sumbawa. Crop spacing commonly used by farmers was 75 x 40 cm for both hybrids and recycled maize.

Farmers in East Lombok used urea at an average rate of 150 and 175 kg/ha, respectively, for recycled and pure hybrids. The average uses of SP36 were 50 and 62.5 kg/ha, respectively, for recycled and pure hybrids. Farmers in Sumbawa used more urea than farmers in

Table 8. Material input use per hectare, by agro-ecosystem in East Java, 2000.

	Land Type					
	Irrigated		Dryland		Rainfed	
Item	Quantity	Cost (†Rp000/ha)	Quantity	Cost (†Rp000/ha)	Quantity	Cost (†Rp000/ha)
Seeds (kg/ha)	20	350	20	30	20	30
Fertilizer (kg/ha)						
Urea	392.5	451.4	150	172.5	100	115
ZA	112.5	135	0	0	0	
SP-36	150	270	0	0	25	45
KCl	52	104	0	0	0	-
Manure (kg/ha)	7,500	150	1,500	30	2.3	45
Pesticides (l/ha)	-	-	-	-	-	-
Herbicides (l/ha)	-	-	-	-	-	-
Total		**1,460.4**		**232.5**		**235**

† In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.

Table 9. Labor use per hectare for maize production in East Java, 2000.

	Land Type					
	Irrigated		Dryland		Rainfed	
Item	Quantity (days)†	Cost (‡Rp000/ha)	Quantity (days)†	Cost (‡Rp000/ha)	Quantity (days)†	Cost (‡Rp000/ha)
Land preparation						
Manual	4	60	3	45	3	45
Animal power	7	245§	6	270	6	270
Tractor	2	350§	-	-	-	-
Planting						
Men	10	125	-	-	6	86
Women	10	90	6	60.8	6.75	71.2
Weeding						
Men	17.5	136.5	3	41.8	2.75	40.7
Women	9.5	104.5	2	15	2.75	30.5
Fertilizer Appl.						
Men	3.5	56	2	27	3	40.5
Women	-	-	1	13.3	2	22
Harvesting						
Men	10.5	108.5	9	43	11	64.5
Women	10.5	87.5	7	32	8	33
Shelling						
Men		42	2	9	2	13.5
Women	-		1	3	1	4.5
Transportation	-	142	-	7	-	37.5
Total		**1,249.5**		**566.9**		**758.9**

† Days are interpreted as "person-days" for human labor, "animal-days" for animals, and "machine-days" for tractors and other machinery.
‡ In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.
§ Farmers were either using animal power or tractor.

East Lombok, but they did not use SP36, as shown in Table 10. The low and imbalanced use of fertilizer (especially in Sumbawa), together with the common use of recycled hybrids (particularly in East Lombok), were thought to be the factors causing low yields of maize in NTB. The total costs of inputs were about Rp 317,500 and Rp 666,250/ha, respectively, for recycled and pure hybrids in East Lombok, and about Rp 685,000/ha for hybrids in Sumbawa.

Manual labor used in NTB was mostly done by men. It was only during planting that women were more involved than men. In East Lombok, fertilizer application and harvesting were done by men and women together. For other activities, men generally participated more than the women did, especially in Sumbawa. The total labor costs to farmers were Rp 1.30 million/ha and Rp 2.12 million/ha, respectively, in East Lombok and Sumbawa. The details of labor use and their costs in NTB are presented in Table 11.

4.4.4 South Sulawesi

During the dry season, farmers in Jeneponto used about 16 kg maize seeds/ha, while in the wet season they used 18 kg/ha. In Bone, farmers used about 24 kg seeds/ha. The fact that more seeds were used in Bone compared to Jeneponto was due to the use of local maize in Bone, while in Jeneponto most farmers used hybrids. Local maize was usually

Table 10. Material input use per hectare, by district in NTB, 2000.

	Seeds		Urea		SP36		Material cost
Location	Quantity (kg/ha)	Cost (†Rp000/ha)	Quantity (kg/ha)	Cost (†Rp000/ha)	Quantity (kg/ha)	Cost (†Rp000/ha)	(†Rp000/ha)
E. Lombok							
Recycled maize	20	55	150	192.5	50	70	317.5
Hybrids	20	345	175	222.5	62.5	98.8	666.3
Sumbawa							
Hybrids	20	355	275	330	0	0	685

† In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.

planted 2-3 seeds per hole, while hybrids were mostly planted at a density of 1 seed per hole, although some farmers planted 2 seeds per hole. In terms of costs for seed, farmers in Jeneponto who used hybrids spent much more than farmers in Bone who used local maize.

Fertilizer use was indicative of the level of technology application. Farmers in Jeneponto used urea at an average rate of 175 kg/ha during the dry season and about 160 kg/ha in the wet season. In contrast, farmers in Bone used on average only 75 kg/ha. Another nitrogen fertilizer used by farmers was ZA. Farmers in Jeneponto also used SP36 and KCl, while farmers in Bone did not use either of these two fertilizers. In addition to inorganic fertilizers, farmers also applied manure at an average of 1,250 kg/ha and 1,125 kg/ha, respectively, in Jeneponto and Bone, during the dry season.

Table 11. Labor use per hectare for maize production in NTB, 2000.

Activities	East Lombok		Sumbawa	
	Quantity (days)†	Cost (‡Rp000/ha)	Quantity (days)†	Cost (‡Rp000/ha)
Land preparation				
- Manual	0	0	0	0
- Animal	7	280.0	10	400§
- Tractor	0	0	4	450§
Planting				
- Men	5	90.6	0	0
- Women	7	85.0	4	40.0
- Animal	0	0	6	262.5
Weeding				
- Men	12	201.2	12	180.0
- Women	9	119.0	10	118.7
- Animal	2	72.5	4	150.0
Fertilizing				
- Men	2	35.0	0	0
- Women	2	25.5	0	0
- Animal	0	0	0	0
Harvesting				
- Men	10	150.0	18	275
- Women	10	125.0	8	89.0
Shelling				
- Men	0	0	0	0
- Women	0	0	0	0
Transportation	8	120	10	150
Total †Rp 000/ha		**1,303.8**		**2,115.2**

† Days are interpreted as "person-days" for human labor, "animal-days" for animals, and "machine-days" for tractors and other machinery.
‡ In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.
§ Farmers were either using animal power or tractor.

Farmers reported that there were no significant pests attacking maize in the field. Therefore, none of them used pesticides. They only used herbicides for weeding, as shown in Table 12. In Jeneponto, the total cost of inputs for maize cultivation was about Rp 1.05 and Rp 0.67 million/ha, respectively, during the dry and wet seasons. In contrast, farmers who used local maize in Bone spent only Rp 0.24 million/ha, during the dry season.

The role of women and men in the activities of maize production in Jeneponto were equal, both in the dry and wet seasons. In contrast, men carried out most maize production activities in Bone. Women were only involved in harvesting. The total labor costs (including animal power) in Jeneponto were Rp 1.23 million/ha during the first season, and Rp. 0.79 million/ha in the second season. The relatively low labor costs for the second season in Jeneponto were mainly due to the application of zero tillage. In Bone, labor costs were Rp 0.88 million/ha, as shown in Table 13.

Table 12. Material input use per hectare, South Sulawesi, 2000.

Item	Dry Season				Wet Season	
	Jeneponto		Bone		Jeneponto	
	Quantity	Cost (†Rp000/ha)	Quantity	Cost (†Rp000/ha)	Quantity	Cost (†Rp000/ha)
Seeds (kg/ha)	16	266.5	24	24.0	18	299.8
Fertilizer (kg/ha)						
Urea	175	210.0	75	90.0	160	192.0
ZA	117	140.0	50	60.0	95	113.7
SP 36	138	220.0	-	-	123	196.0
KCl	50	100.0	-	-	50	100.0
Manure (kg/ha)	1,250	-	1,125	-	-	-
Pesticide (l/ha)	-	-	-	-	-	-
Herbicide (l/ha)	1.4	70.0	0.5	30.0	1.0	50
TOTAL		**1,050.2**		**243.4**		**669.7**

† In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.

4.5 Yield Levels

The average yield of hybrid maize per hectare in Lampung was 4.75 t (in the wet season) and ranged from 3.0 to 7.5 t/ha. In the dry season, the average yield was 4.3 t/ha (a range of 3.0 to 5.0 t/ha). The maximum yields obtained by farmers were 7.5 t/ha in the wet season and 5.0 t/ha in the dry season, as presented in Table 14. This shows that the yield potential of hybrid maize in Lampung is high.

The average yield of recycled maize in the wet season was 3.5 t/ha (a range of 3.0 to 4.5 t/ha), while in the dry season it was 3.5 t/ha (a range of 2.0 to 4.5 t/ha). Based on the maximum yield, the yield potential of recycled maize is 4.5 t/ha in both wet and dry seasons. The yield of recycled maize in the wet season was 26%, and in the dry season 16%, below that of the hybrids.

Based on the yield potential of hybrids or recycled maize, there is an opportunity to increase maize yields at the farm level, both in the wet and dry seasons. Farmers reported that the main reason for the observed yield gap was input use, especially fertilizer application and planting time.

In the study area of East Java, the yields obtained by farmers in irrigated areas (6.35 t/ha) were much higher than in dryland (1.53 t/ha) and rainfed areas (1.61 t/ha). These differences in yield were mainly due to three factors: (1) pure hybrids with high inputs were grown in irrigated lowlands, as compared to local and recycled maize with low inputs grown in dryland and rainfed lowlands (Table 8); (2) soil fertility in the irrigated lowlands is higher than in rainfed and dryland areas; (3) during the wet season, farmers in the irrigated lowlands planted rice with high inputs, especially fertilizers. The residual effect of slow release fertilizer, especially SP-36, enhances maize yields when it is grown after rice in such a system.

Table 13. Labor use per hectare for maize production, South Sulawesi, 2000.

	Dry Season				Wet Season	
	Jeneponto		Bone		Jeneponto	
	Quantity (days)†	Cost (‡Rp000/ha)	Quantity (days)†	Cost‡Rp (‡Rp000/ha)	Quantity (days)†	Cost‡Rp (‡Rp000/ha)
Land preparation						
- Manual	7	70	5	50	-	-
- Animal	12	300	15	300	-	-
- Tractor	-	-	-	-	-	-
Planting						
- Men	-	-	4	40	-	-
- Women	5	40	-	-	5	40
- Animal	5	125	5	125	5	125
Weeding						
- Men	7	70	12	120	5	50
- Women	8	64	-	-	5	40
- Animal	4	100	5	100	4	100
Fertilizing						
- Men	3	30	3	30	3	30
- Women	3	24	-	-	3	24
- Animal	-	-	-	-	-	-
Harvesting						
- Men	10	100	3	30	10	100
- Women	10	80	3	30	10	80
Shelling						
- Men	-	-	-	-	-	-
- Women	-	-	-	-	-	-
Transportation						
- Men	-	225	-	54	-	200
Total ‡Rp(000)	**-**	**1,228**	**-**	**879**	**-**	**789**

† Days are interpreted as "person-days" for human labor, "animal-days" for animals, and "machine-days" for tractors and other machinery.
‡ In January-March 2001, US$ 1.0 was equivalent to Rp 8,500.

As shown in Table 14, yield levels from recycled maize, obtained by farmers in East Lombok, ranged from 1.5 to 3.6 t/ha, with the average yield being 2.5 t/ha. The yield from pure hybrids ranged from 2.5 to 4.5 t/ha, with an average yield of 3.5 t/ha (1 t/ha higher than the yield of recycled maize). In Sumbawa, the yield of hybrids ranged from 2.5 to 6.0 t/ha, with an average yield of 3.3 t/ha. None of the farmers in the study area of Sumbawa used recycled hybrids in the wet seasons of 1999/2000 or 2000/2001.

In South Sulawesi, the average yield of the local variety grown in dryland areas was 2.0 t/ha during the dry season and 1.8 t/ha during the wet season (a range of 1.0 to 3.0 t/ha). The average yield of OPVs was 3.5 t/ha, with a range of 3.0 to 4.0 t/ha. The average yields of hybrids

Table 14. Maize yields in the study areas, 2000.

Province/land type/season			Local (t/ha)		Improved OPV (t/ha)		Hybrids (t/ha)		Recycled hybrid (t/ha)	
			Average	Range	Average	Range	Average	Range	Average	Range
Lampung:		WS†	-	-	-	-	4.75	3–7.5	3.49	3–4.5
		DS‡	-	-	-	-	4.32	3–5	3.46	2–4.5
East Java:	Irrigated		-	-	-	-	6.35	5.4–7.7	-	-
	Dryland		1.53	0.8–2.6	-	-	-	-	2.32	1.5-3.7
	Rainfed		1.61	1.0–2.5	-	-	-	-	-	-
NTB:	East Lombok		-	-	-	-	3.5	2.5–4.5	2.5	1.5–3.6
	Sumbawa		-	-	-	-	3.3	2.5–6.0	-	-
South Sulawesi :										
	Dryland:	DS	2.0	1–3	3.5	3–4	5.4	3–8	4.6	2–6
		WS	1.8	1–3	3.5	3–4	5.3	3–8	4.0	3–6
	Irrigated		1.8	0.5–2.5	2.5	2–4	-	-	-	-

† Wet season.
‡ Dry season.

and recycled maize were relatively high compared to those obtained by local and improved OPVs.

The yield of hybrids in the drylands ranged from 3.0 to 8.0 t/ha, with average yields being 5.4 t/ha and 5.3 t/ha, respectively, during dry and wet seasons. Hence, there is a significant opportunity for increasing maize yields at the farm level, to get closer to the potential yield of 8 t/ha. To achieve that objective, factors that caused yield gaps need to be investigated, so that the appropriate technology can be transferred to farmers. The yields of recycled maize were 4.6 t/ha and 4.0 t/ha, respectively, during dry and wet seasons. These yields were higher than those of improved OPVs and local maize.

In the lowland area of Bone, the average yield of local maize was 1.8 t/ha, and the range of yield was 0.5 to 2.5 t/ha, as shown in Table 14. The average yield of the improved OPV being grown was 2.5 t/ha, with a range of 2 to 4 t/ha. This yield was higher than that of the local variety. Since farmers are still growing the local variety, the opportunity to increase maize yields is limited and more progress could be made by changing to improved OPVs or hybrids.

From Table 14, one can observe that, in all study areas and in all agro-ecosystems, yields of hybrids were the highest, followed by recycled hybrids, improved OPVs, and then the local maize.

4.6 Post-Harvest Practices and Maize Sale

Maize farmers in Lampung usually harvested manually. The husks were removed before handling and the ears were piled up in their own houses. Farmers reported that they had never dried ears before selling them.

Maize, in the form of ears, was sold from the farmers' houses, immediately after harvesting. Traders who each had their own thresher usually did the threshing. The maize was usually paid for 3 to 7 days after the transaction. Traders came to the villages every harvesting season. Farmers who grew recycled maize selected seeds for the next planting soon after harvesting. This was done by selecting big, healthy and brightly colored ears. The husked ears were thoroughly sun-dried and stored for the next season.

In East Java, farmers harvested maize 120–130 days after planting, depending on the variety, and harvesting was done manually. Some farmers sold maize directly in the field soon after harvesting, and some carried their maize (particularly local maize) to the house, where it was sun-dried for several days. After drying and shelling, the moisture content of the grain was 17-20%. The local (white) maize was usually stored for home consumption and sold gradually in small quantities. Farmers stored yellow maize (the hybrid or its corresponding recycled hybrid) for a limited period (1-4 weeks), until they could get a better price.

Seeds for the next planting were mostly selected from the last harvest and stored above the cooking place (stove) to prevent infestation by storage pests, particularly weevils. Only a few farmers in the dryland and rainfed lowlands bought new seeds after the original purchase of a new variety. Only farmers in irrigated areas bought new pure hybrids.

About 80% of farmers in dryland and 90% in irrigated areas used green leaves for livestock fodder. About 50% of farmers in the drylands and 25% in irrigated areas used dry stems, dry cobs, and husks for fuel, and about 10% of farmers in both areas did not use crop residues for any purpose.

As in East Java, harvesting in NTB was done manually. Most farmers sold their maize directly in the field soon after harvesting. The traders did the drying and threshing. Only a few of the farmers carried the maize to their houses for sun-drying and storage for a few weeks, while they waited for a better price. Farmers who grew recycled hybrids selected seeds from the last harvest and stored them above the traditional stove to prevent the infestation by storage pests. In East Lombok, about 80% of farmers used crop residues for cattle feeding and another 20% did not use crop residues for any purpose. In Sumbawa, only about 32.5% of farmers used crop residues for fodder, about 5% of them used crop residues for fuel, and about 67% of them did not use crop residues at all.

In South Sulawesi farmers also harvested their maize by hand. The husks of yellow maize were removed before hauling, while for white maize ears with husks were brought to their houses. For yellow maize, the ears were piled up in the house where shelling was usually done by hand with a simple implement made of wood. The grains were immediately sold (without sun-drying) to the trader for cash. For the white maize, the husked ears were sun-dried thoroughly for 5-7 days by spreading them on the floor. After drying, the husked ears were tied in bunches consisting of about 20 ears per bunch. The maize was stored in this way for about 6-12 months, unless some maize was required for consumption or was sold to the local market to meet daily expenses.

5. Constraints to Increasing Maize Productivity

The production system adopted by maize farmers in Indonesia depends on the geographical area, the cropping system, and management choices. Due to the significant variation between the different agro-ecological zones that make up the country's maize growing areas, there is a broad spectrum of production constraints. Subandi (1998) concluded that the low level of national maize productivity is attributed to many interacting factors:

- low or poor soil fertility;
- resource-poor farmers;
- limited or no specific technologies;
- low adoption of improved technologies;
- inappropriate or poor post-harvest handling, especially for wet season maize;
- grain price uncertainty during harvest time.

Major constraints to maize production have been examined and the solution to address the problems has been identified several times (Subandi et al. 1988; Subandi and Manwan 1990). Despite the increasing trend of maize yields during the last two decades, the current national yield of 2.8 t/ha is still low considering that most recently released cultivars have high yield potential (6 to 9 t/ha). The constraints found during the RRA/PRA study were discussed, clarified, and elaborated during the country workshop held in S. Sulawesi in May 2002. These findings will be presented in this chapter along with a prioritization of the constraints. For this section of the report, maize production constraints were identified by reviewing available information, interviewing farmers, and directly observing maize fields. The problems associated with maize production were identified and grouped into socio-economic constraints, biotic and abiotic constraints, and institutional constraints.

5.1 Biotic and Abiotic Constraints

A wide array of diseases and pests have been known to attack maize plants throughout their life cycles and during storage (Sudjadi 1988; Baco et al. 2000). However, only a few of these biotic stresses cause damage of economic importance. In 2001, a panel of ICERI maize researchers reviewed the documented list of maize production constraints. Attempts were made to determine solutions to the problems highlighted and to set up research programs (Table 15).

Table 15. Main constraints limiting production in all major maize production areas and their relative importance for research and development priorities.

Constraints	East Java	Central Java	Lampung	South Sulawesi	North Sumatra	East Nusa Tenggara	North Sulawesi	New Opened area[†]
Yield potential	****	****	****	****	****	****	****	****
Soil problems	*****	*****	****	*****	****	*****	*****	*****
Early maturity	***	***	*	***	*	****	***	**
Drought	***	***	***	***	*	*****	***	****
Waterlogging	**	**	**	***	***	*	*	***
Downy mildew	****	****	*****	****	****	****	****	****
Leaf blight	***	***	***	***	***	***	***	***
Stem borer	***	***	****	***	***	***	***	***
Storage insects	**	**	**	***	****	****	***	****
Seed system	*	**	**	***	**	***	**	**

Source: Subandi et al. (1988) and re-evaluated in 2001 by ICERI.
* Low priority for research and development.
***** High priority for research and development.
† Includes transmigration area.

Downy mildew (DM) is the most important biotic stress affecting maize production in Indonesia, and poor soil quality is the predominant abiotic limiting factor. Other important diseases often found, but causing less damage, include leaf blights (*Helminthosporium* spp.), leaf spots (*Curvularia* spp.), rusts (*Puccinia polysora*), stalk and ear rots (*Fusarium* spp., *Diplodia* spp.), and banded leaf and sheath blight (BLSB) (*Rhizoctonia solani).* A report by a private seed company pathologist familiar with the region confirmed that DM, leaf blights, BLSB, southern rusts, stalk/root rots, and *Diplodia* ear rots were important diseases in Indonesia (Dalmacio 2000). BLSB is prevalent in many of the maize producing areas in Indonesia but no yield losses have been recorded to date. Recently, a serious attack of gray leaf spot (*Cercospora* leaf spot) was reported to affect hybrid cultivars in farmers' fields located in the high altitude area of Tanah Karo (North Sumatra), but no information was available regarding the extent of these yield losses.

Downy mildew disease affecting maize in Java and Sumatra is believed to be caused by *Peronosclerospora maydis,* which has spherical shaped conidia. The DM pathogen commonly found in Sulawesi has elongated shaped conidia, and resembles *Peronosclerospora philippinensis*. This fungus has been identified as the causal organism of the serious damage observed in major maize production centers in East, Central, and West Java, S. Sulawesi, Lampung, and North Sumatra. Because downy mildew is the most important maize disease in the region, the committee for variety release requires that any promising variety must possess DM resistance as well as having high yield potential. Despite the DM resistance conferred by the released varieties, farmers still usually apply Ridomil, an expensive and non-environmentally friendly fungicide. Recent research conducted by an ICERI pathologist in South Sulawesi indicated that most of the released varieties showed susceptibility to DM when grown under high disease pressure (Wakman 1999).

The important insect pests of maize are shoot flies (*Atherigona* sp.), Asian corn borers (*Ostrinia furnacalis*), and weevils (*Sitophilus* sp.). Shoot flies can cause severe damage if maize is seeded late in the rainy season (Dahlan 1994). Other than these, the Directorate of Plant Protection of the Department of Agriculture (1996) reported that army worm (*Mythimna* sp.), corn ear worm (*Helicoverpa* sp.), rats, and wild pigs were also important pests.

Weevils are important in areas where humans consume maize. The extent of grain damage depends on the duration of storage. In the areas covered by the current study, it was observed that most harvested maize was sold directly by farmers to the traders. Only a few farmers carried the harvested ears to their houses, to be sun-dried and stored for a few weeks, as they waited for a better price. Some portion of their maize, especially the white type, is stored for their own consumption. In the drier areas of eastern Indonesia, such as East Nusa Tenggara and some part of Sulawesi, farmers usually store their dried maize ears for longer periods (6-12 months). Hence, despite thoroughly sun-drying the ears before storage, weevil infestation is very common.

In general, yield losses due to borers and shoot flies were not significant. But there were instances where in a few areas, borers and grasshoppers caused significant yield losses. In 1987 borer infestation was recorded as attacking 9,100 ha of maize fields, but the figure was only 1,300 ha in 1996 (Directorate of Plant Protection 1996).

5.2 Socio-Economic Constraints

Several socio-economic constraints relating to maize productivity were identified during the field study and include: the high price of inputs particularly hybrid seed and fertilizers; the low price of outputs; and lack of cash capital. The high price of hybrid seeds has forced some farmers to use recycled hybrids, with lower yields than the pure hybrids. At present, the main factor causing high price of seeds is the distance between farmers and the seed industry, especially hybrids bred by private companies.

In the dry land ecology of outer Java (except Lampung), poor infrastructure and low purchasing power of farmers are also associated with low maize productivity. The low price of outputs is mainly due to poor access of farmers to the market. This condition is common in the areas where no big feed mill industries exist. The situation is often worst during the wet season harvest time, when the farmers have no choice but to sell their grain (sometimes as harvested ears) because no appropriate drying or storage facility is available.

The high price of quality seeds, especially of hybrid cultivars, is the main reason why improved germplasm is not widely adopted. It is not surprising to observe farmers growing advanced generations of the hybrids, resulting in lower yields. Farmers who do not have enough capital at the start of the growing season commonly grow recycled materials. The public maize research institute has released hybrid cultivars, and these seeds can be sold at a reduced price. However, since the maize seed production and distribution systems of the publicly bred cultivars is not yet established, the dissemination and adoption of their research products are not well developed. There are no strong, or regularly managed, maize seed production agencies available for publicly bred cultivars. In none of the surveyed sites did we find seeds of any improved publicly bred OPVs (Arjuna, Bisma, Wisanggeni, Lagaligo) or hybrids (Semar 1 up to Semar 9) that were being sold by agro-input shops at the local markets.

Application of fertilizers is recognized as an important factor influencing increased productivity, especially for farmers who grow hybrid maize. But the price of fertilizers has increased due to a reduction in the level of government subsidy provided. The high price of fertilizers coupled with a lack of purchasing capacity have led farmers to reduce the dose and rate of fertilizer application. The exception to this situation is that observed in irrigated and other favorable maize production areas in East Java, where farmers still applied fertilizers at a relatively high rate because they expect larger profits from their high yielding hybrid maize.

The low price of maize grain is mainly associated with farmers' poor access to the market. Except for areas near the feed mill industry in East Java and Lampung, most dryland maize farmers, especially in remote areas, do not have strong bargaining power when selling their grains.

5.3 Institutional Constraints

Low adoption of improved technology is, to some extent, related to poor technology dissemination and distribution mechanisms. This is particularly true for publicly generated technologies. The national maize research institute–recently renamed the Indonesian Cereal Research Institute (ICERI)–has released a number of OPVs and hybrid cultivars. Under the Indonesian system, ICERI is responsible for producing breeder's seeds (coming directly from research programs) of the released cultivars. Foundation seed (coming from breeder's seed) is handled by provincial seed centers, and seed growers commonly do the mass production of extension (or commercial) seed. Most commonly, the seed growers sell seed directly to farmers or cooperatives. But sometimes their seed is packaged and marketed by public corporations such as Sang Hyang Seri and Pertani.

The system lacks effective promotion of quality seed, and uncertainties exist about the timely distribution of seed. No organization is yet available nor fully committed to regular management and promotion of the ICERI germplasm products. There have been occasional links between ICERI and the two public corporations but the desired and sustainable partnerships between the companies and the public research institute are not yet well established. Ironically there has been a growing interest among national private sector companies to become ICERI partners in promoting maize cultivars. Presently the national AARD does not have a strong or clear policy on releasing or commercializing hybrid cultivars.

Lack of promotion of appropriate technology is also associated with weak research-extension linkages. During the last decade, there has been a decline in the role and impact of public extension agencies. Agricultural extension workers have not received enough effective training, and contacts with research institutes from where they could acquire new technology and information are weak. Under such circumstances, reorganization and reorientation of research and development took place in 1995. In each province,under the AARD system, the AIATs were established. The ideal AIAT consists of researchers and extension personel working together in the assessment of research products developed by commodity research institutes, as well as testing and promotion of the selected technology packages.

Another institutional constraint is the marketing system for maize grain and other products. In our study, farmer groups and cooperatives were not found to be marketing any agricultural products. The cooperatives did not even provide credit for their members. Therefore, farmers generally borrowed cash from traders, at high interest rates.

Most of the feed industries that buy maize grains are located in East Java, Lampung, and N. Sumatra. The large distances between the maize buyers in these areas and other major producing areas such as Sulawesi, Nusa Tenggara, and Central Java mean that farmers incur high transportation costs. As a result of these high costs, farmers receive a lower price for their maize grain at the farm gate. Price uncertainty is even more common for the wet season harvest, when most farmers do not have appropriate shelling, drying, or storage facilities.

5.4 Other Constraints

Other constraints causing low productivity of maize are poor soil and crop management. The majority of corn is grown on dryland areas either once or twice per year. Survey results have shown that almost 60% of these drylands have low productivity (Mink et al. 1987) largely due to acidity of soils such as ultisol, oxisols, and histosols. The two most important environmental stresses affecting maize production are poor soils and lack of water. Other factors limiting maize production under acid dryland conditions are: low nutrient content of the soils; low levels of organic matter; aluminum and manganese toxicities; and lack of high yielding varieties adapted to stressed environments. Maize is usually poorly adapted to strongly acidic soils. Root growth of acid-stressed maize is inhibited, resulting in inefficient absorption of nutrients. Nitrogen and phosphorus have been the major nutrients found to be deficient in the soils of most maize production centers in Indonesia. There is very limited improved germplasm available for acid soils and drought-stressed environments. The yield of most potentially high yielding maize varieties, grown under conditions of low availability of nutrients, can be reduced even more by quite minor water deficits during the growing season, since the root systems are not well developed.

Since the majority of maize is grown in the rainfed dryland regions, the crop is commonly sown with the first rains. Once the crop is established, there may be an unpredictable and erratic moisture supply from rainfall. Early drought stress may begin after only a few days without rain, resulting in poor plant stand. Drought stress during the flowering and grain filling stages can cause significant yield loss (Lafitte 2000).

Subsistence crop maintenance practices are still common in remote areas. Farmers usually burn plant residues, hand hoe the land, sow the seed manually after making the holes with wooden sticks, remove weeds with hand hoes or by hand. The practice of hand weeding is common even in highly productive maize areas of Java, since labor is cheap there. Minimum tillage and weed control using herbicides are common practices in Lampung, where there is a shortage of labor.

In irrigated and rainfed lowland areas, where maize is usually grown during the late wet season, excess moisture can often be a problem if high rainfall occurs late in the season. Waterlogging generally occurs on heavy soils with poor drainage where a hardpan, due to previous rice planting, restricts the vertical movement of water.

6. Priority Constraints for Research

6.1 Methodology for Identifying Priority Constraints

The main constraints to maize production were identified during the field survey in 2000/01, conducted in four provinces. The first draft of the study report was presented at the Annual Meeting of the Socio-Economic Working Group held in Nepal in June 2001. Later in May 2002, a country workshop was held in S. Sulawesi to discuss the RRA/PRA findings, to clarify and identify more constraints, and to set up priorities for research and development to address some of these problems.

The workshop was attended by senior NARS scientists, policy makers, extension personnel, and seed corporations engaged in maize development in different parts of the country. Senior CIMMYT scientists facilitated discussions directed at establishing priorities.

The plenary session of the workshop on the first day included presentations on:

- An overview of Indonesia's National Maize Production Program, by the DG, Directorate of Food Crop Production;
- The National Maize R&D Program, by the Director of ICERI;
- Private Sector Maize R&D Program, PT Benih Inti Subur Intani; and
- RRA/PRA results from the International Fund for Agricultural Development (IFAD)-CIMMYT study in Indonesia, presented by the country team.

After a general discussion of the topics during the plenary session, the participants were divided into four working groups. The four groups further clarified and elaborated the constraints based on four maize ecosystems: drylands, irrigated lowlands, rainfed lowlands, and swampy areas. Each group considered the yield gain that could be achieved if the particular constraints were alleviated. The working group presented their findings in the following session, which were further discussed, validated, and conclusions presented.

The second part of the workshop involved discussion on technology/policy options for constraints alleviation. Efficiency indices for each specific constraint were estimated considering the following factors: the importance of the constraint; the yield gain associated with alleviation of the constraint; the total production of maize in each specific agro-ecosystem; the probability of finding a solution to the constraint; and the adoption history (percentage of farmers who have adopted the new technology).

Given the many constraints reported in each agro-ecozone, one must find a way to combine and compare the constraints across agro-ecozones to obtain some idea of a prioritized agenda for maize research and development in Indonesia. This study used the methodology that CIMMYT developed (Pingali and Pandey 2001) to help prioritize maize productivity constraints across maize ecologies and geographic regions for tropical maize systems. Three criteria are used for prioritizing public research: efficiency, the extent of poverty, and the extent of marginality of the production agro-environment. Efficiency index estimates the returns a given research investment would yield, or the biggest bang for the research buck. It approximates how the alleviation of constraints, by either research or extension-cum-research, would most likely contribute to total production gains. Poverty index modifies the efficiency index to give some weight to poor farmers and their food security situation. With a higher proportion of poor people, the poverty index associated with the constraint is higher. Constraint ranking based on a poverty index should be closely looked at when poverty alleviation is a major concern for researchers and policymakers.

The marginality index modifies the efficiency index by targeting investments toward the more marginal agro-environmental areas, with the presumption that more commercial areas are being, or will be, served by the private sector. The inverse of the estimated average maize yield in a particular maize-producing geographic region or ecology was used as a measure of the marginality index. Weights of 0.5, 0.3 and 0.2 were given to efficiency, poverty, and marginality indices, respectively. The combined index is, therefore, calculated by adding the products of 0.50 x efficiency index, 0.30 x poverty index and 0.20 x marginality index.

6.2 Priority Constraints

In early sessions of the working group the maize eco-zones were divided into four: Java and Bali, Sumatra, Sulawesi and Nusa Tenggara, and Kalimantan. The calculation of indices based on islands did not give satisfactory results. The participants of the workshop agreed on grouping the region into two: Java and Bali and outer islands. In total there were 98 constraints covering Java and Bali and outer islands (outside Java and Bali) across four ecosystems. Based on the data gathered from the Central Bureau of Statistics, efficiency, poverty, marginality, and combined indices were calculated. Finally, 20 constraints across all regions and agro-ecosystems were established. These constraints are more or less similar in ranking regardless of which index is applied (Table 16). The priority constraints for each agro-ecology are discussed in the following paragraphs.

6.2.1 The dryland ecology of Outer Islands

The dryland maize production system in outer islands is mainly characterized by poor farmers living either in relatively wet environments (Kalimantan) or dry climates (NTT and NTB). In most of Sulawesi, maize is grown by poor farmers in relatively dry environments, often on acid soils with low inherent fertility and productivity. Food maize is important in these regions. However, areas in the higher altitude region of North Sumatra and the low altitude area of Lampung consist of high productivity drylands where more commercial maize farming is carried out. Hybrids are the main varieties used in these two provinces.

Weeds are a constraint in outer islands, where a lack of labor causes this biological problem to become more important. Drought is a problem particularly in the eastern and drier part of the country. On the acid soils of Sumatra and Kalimantan, which have a higher annual rainfall, a few rainless days during the maize growing season may cause drought stress, due to poor root growth related to toxic aluminum sub-soils. In general, the maize production system in dryland areas outside Java and Bali is associated with unfavorable environments, except in the highland areas of North Sumatra and the dryland/rainfed lowland areas of Lampung.

Post-harvest problems, caused by weevils attacking maize where it has been poorly dried and stored, lead to low quality grain and yield losses. These constraints are associated with low input purchasing power, poor

Table 16. Priority ranking of major biophysical and institutional maize production constraints in Indonesia.

Eco-zone	Region	Constraint	Efficiency rank	Poverty rank	Marginality rank	Combined rank
Dryland	Outer islands	Acid soils	1	1	1	1
Dryland	Outer islands	Weeds	2	2	2	2
Dryland	Outer islands	Drought	3	3	3	3
Dryland	Outer islands	Post-harvest	4	4	4	4
Dryland	Outer islands	Low soil fertility	5	5	5	5
Dryland	Outer islands	Infrastructure	6	6	6	6
Dryland	Outer islands	Downy mildew	7	7	8	7
Dryland	Outer islands	Low price of output	8	8	10	8
Dryland	Outer islands	Seed availability	9	9	12	9
Dryland	Outer islands	Lack of labor	10	12	14	10
Dryland	Outer islands	Poor purchasing power	11	14	15	11
Dryland	Java and Bali	Drought	14	11	7	12
Irrigated	Java and Bali	Inappropriate fertilizer application	12	10	33	13
Dryland	Java and Bali	Weeds	15	13	9	14
Dryland	Outer islands	Soil erosion	13	18	21	15
Dryland	Java and Bali	Low nitrogen	18	17	11	16
Irrigated	Java and Bali	Lack of capital	16	15	36	17
Irrigated	Java and Bali	Waterlogging/ crop establishment	17	16	37	18
Dryland	Java and Bali	Soil erosion	21	20	13	19
Dryland	Outer islands	Stem borers	19	24	25	20

bargaining position of farmers when selling their outputs, as well as unavailability of quality seeds. Although many pest and disease constraints were identified, downy mildew was the only important biotic stress.

6.2.2 The dryland ecology of Java and Bali

Similar to most of the drylands in outer islands, the drylands of Java and Bali are characterized by low productivity, where farmers are generally poor and only apply technology to a limited extent. Drought, soil erosion, and low nitrogen are the main physical constraints, while weeds are the notable biological problem. These constraints, along with low cash capital, have caused low maize yields. Therefore, more effort is needed to increase maize yields in this agro-ecosystem.

6.2.3 The irrigated areas of Java and Bali

This maize area is characterized by high productivity, and maize farmers are generally advanced in adopting technology. But the use of fertilizer is inappropriately high, up to 650 kg/ha. Lack of capital is a constraint especially at the start of the growing season when farmers need to purchase expensive seeds (usually hybrids) and fertilizers. Among the important constraints, waterlogging is the most important problem when unexpectedly high rainfall occurs during the dry season.

7. An Agenda for Maize Research and Development in Indonesia

Public research institutes remain important sources of maize technology. During recent years, multinational seed companies have had an increasing impact, especially on hybrid maize technology. However, the private sector generally serves commercial maize farmers. Considering a wide array of constraints, the fact that less emphasis has been given to research targeting subsistence and traditional maize producing areas, and the low and declining financial support experienced by the public sector, the research agenda for country maize must be addressed.

During the last session of the country workshop, the participants tried to estimate the probability of success in eliminating each of the 20 priority constraints in each agro-eco zone and the probability of farmers adapting the new technology. Based on an index that combined these criteria, research approaches were ranked. The most effective approaches for dealing with the identified priority constraints and the likelihood of producing an impact to eliminate the constraints are summarized in Table 17. The higher the likelihood index the more likely it is that the constraint to maize production can be overcome.

Appendix 9 gives details on the probability of success, adoption, and potential suppliers of the technologies.

7.1 Major Findings

The prioritization exercises indicated that top priority should be given to the dryland agro-ecosystem of outer Java, where acid soils, weeds, and drought problems are the main constraints. Because there are many constraints to maize production on poor, dry, acid soils, more emphasis should be placed on developing early maturing varieties tolerant to stressed environments. Another related problem that needs to be addressed concerns the low availability of quality seed of released tolerant varieties.

In Java and Bali, the main constraints are inappropriate fertilizer application, drought, weeds, waterlogging, soil erosion, and lack of capital. In irrigated areas of this region, maize is largely grown by commercial farmers in favorable environments. Private companies in this agro-ecosystem are active as providers of agro-input products and as traders of maize grains. Higher productivity is expected to increase national production, especially through better adoption of hybrid technology. The issue of a lack of capital should be addressed by changing policies to improve access to credit.

To address the problem of inappropriate fertilizer application, research should include detailed studies on fertilizer use efficiency, such as rate and timing, for each soil type. It is hoped that maize farmers will be able to reduce the level of fertilizer application, while maintaining productivity levels. Downy mildew is considered an important limiting factor in all ecosystems.

7.2 Recommendations for Future Action

The public maize institutes should focus their research and development efforts on the acid soil and drought-stressed areas of outer islands, because this is where the majority of poor maize farmers live and where maize is a major staple food. In addition, the private sector does not focus on these environments. The geographical area covered by the national maize research institute is large and includes a wide variety of agro-ecosystems. Considering these circumstances, it is recommended that resources should be allocated in such a way that they can address the needs of the different agro-ecologies, maize farmers, and maize consumers. The major areas that need to be addressed can be divided into three categories:

- technology development (including varietal development and research into cropping systems, soil fertility, and pest control),
- technology dissemination, and
- supply of inputs and marketing of outputs.

Table 17. Research approaches ranked by the likelihood of eliminating constraints to maize production.

Constraints	Research approaches	Rank	Likelihood index
	Agro-ecology: Dryland (Outer Islands)		
Acid soils	Development of tolerant variety	1	0.71
	Soil amelioration	2	0.50
Weeds	Conventional	1	0.70
	Development of herbicide tolerant variety	2	0.60
	Appropriate machinery	3	0.24
Drought	Use of early maturing variety	1	0.76
	Development of tolerant variety	2	0.71
	Zero / minimum tillage	3	0.32
	Small-scale irrigation	4	0.24
	Mulching	5	0.24
	Rainwater harvest	6	0.20
Post-harvest	Improved drying techniques	1	0.63
	Development of good husk cover,	2	0.54
	Development of weevil tolerant variety	3	0.54
	Improved storage	4	0.12
	On time harvest	5	0.12
Low soil fertility	Fertilizer application management.	1	0.71
	Development of low-N tolerant variety	2	0.45
	Organic matter management	3	0.25
Infrastructure	Communication by private sector	1	0.24
	Public investment on transport facilities	2	0.20
Downy mildew	Development of DM resistance varieties.	1	0.81
	Fungicide	2	0.57
	Cultural practices	3	0.21
Low price of output	Post-harvest facilities		
	a. Collective dryer	1	0.13
	b. Collective storage	2	0.13
	Import limitation (tariff)	3	0.06
	Contract farming	4	0.05
Seed availability	Improvement of seed production system	1	0.05
Lack of labor	Herbicide	1	0.60
	Farm machinery	2	0.20
	Minimum tillage	3	0.15
	Draft animal	4	0.05
Purchasing power	Credit	1	0.36
	Farmer cooperative	2	0.16
	Farmer association	3	0.10
	Corporate farming	4	0.06
Soil erosion	Zero tillage / minimum tillage	1	0.54
	Conservation systems	2	0.45
	Cover crop	3	0.16
Stem borer	Integrated pest mgt / early observation	1	0.25
	Agro-ecology: Irrigated and dryland in Java and Bali		
Inappropriate fertilizer application	Improved fertilizer technology		
	- Rate, time	1	0.70
	- Utilization of organic matter	2	0.32
Drought	Use of early maturing varieties	1	0.30
	Development of tolerant varieties	2	0.20
Weeds	Conventional weeding	1	0.70
	Use of herbicide with minimum tillage	2	0.40
Low nitrogen	Development of low N tolerant varieties	1	0.20
	Nitrogen fertility management	2	0.70
Lack of capital	Increase accessibility to credit	1	0.60
	Develop corporate farming, farming	2	0.08
	Develop micro finance institution	3	0.06
	Develop partnership with private sector	4	0.13
Waterlogging / crop establishment	Drainage technique	1	0.27
	Surjan[†] system	2	0.09
	Tolerant variety	3	0.40
	Transplanting technique	4	0.08
Soil erosion	Cultural practices (mulching, minimum tillage, slope cropping)	2	0.40

[†] A specialized tidal swamp maize production system found mainly in newly-opened land outside Java. On this type of land, maize is grown using the *surjan* system (raised and sunken beds). Rice is commonly grown in standing water in the sunken beds, and maize and / or other *palawija* (secondary crops such as soybean, peanuts, cassava) are grown on the raised beds. Farmers in these production areas grow maize as one component of the farming system and, depending on the market demand, maize be harvested for grain or as a green crop.

7.2.1 Varietal development

Ideally farmers should grow a few widely adapted improved varieties. However, because of the diversity in agro-ecologies, it will be necessary to develop many improved cultivars adapted to the specific cropping system conditions faced by farmers in each area. The three most important traits that should be incorporated into improved germplasm are earliness, high yield potential, and tolerance to stressed environments. These traits may be combined in one variety by employing recurrent selection schemes in appropriate testing sites. Early maturing cultivars are particularly important for the target drought-stressed environments and for the increasing areas of maize grown on rainfed and irrigated lowlands. The latest study by Kasryno (2002) showed that maize was grown during the dry season, following the rice harvest, in the traditional rice areas of East and Central Java, Lampung, and North Sumatra.

The national maize research institute has been working on improving germplasm targeted to acid soils and drought-stressed environments. However, the testing and evaluation of genetic materials associated with these traits have been limited due to a lack of resources and appropriate testing sites. Since these abiotic stresses (acid soils, low fertility, and drought) are interrelated and will provide important challenges as maize areas expand in the future, research and development for this target environment should be well planned and nationally coordinated to provide a network of appropriate activities.

The increasing trend has been for the government of Indonesia to import rice as a staple food for its population. This has forced the policy makers and agricultural officials to explore maize-based food as an alternative, with the aim of reducing dependency on rice alone. Maize-based food is not new and has been an important part of peoples' diets in most parts of Sulawesi, the Islands of Nusa Tenggara, Madura, and some parts of East and Central Java. In most of these areas white maize is prevalent, and the common cultivars are based on local germplasm. However, in East Nusa Tenggara, where maize is a staple food, yellow maize is more important. To some extent this is due to the unavailability of quality seeds of improved white maize. Unfortunately, research and development on white maize seems to have lagged behind that for yellow maize. During the last three decades only two white maize cultivars were released. In addition, there has been almost no government program related to the development and promotion of white maize. Since food maize is becoming increasingly important, development of high yielding white maize is needed. One important trait to be incorporated into improved germplasm is resistance to storage pests, such as weevils.

Farmers and consumers could benefit from the availability of nutrient-enriched maize (QPM or quality protein maize) for food and feed purposes, if national programs start to significantly utilize this material. Preliminary evaluations of CIMMYT-introduced QPM populations started in 2002. As research and development of QPM is not easy or cheap, its applications for Indonesia should be undertaken as part of an integrated approach, on a long-term basis. In the short term, the elite and advanced QPM materials, for the CIMMYT Asian region, can be further evaluated in specific target environments, and promotion of QPM can start with involvement of the national private sector. In the long term, conventional breeding approaches could be complemented by molecular-assisted selection programs for conversion or improvement of national germplasm for enhanced protein quality.

As previously stated, maize production in more favorable areas is dominated by privately bred hybrid cultivars, for animal feed and commercial farming. The private sector is not involved in maize breeding research in Indonesia; their research is done abroad but they have extensive testing programs in their target areas. The public research institutes should, therefore, continue to conduct hybrid-related research, for example, development of heterotic populations. Population improvement through the development of lines, OPVs, and hybrids is a continuous process and should be well organized. Public research institutions should not compete with the private sector in promoting hybrid-related technologies and instead should work in partnership with them. ICERI could avoid duplication of efforts by concentrating its research in areas and environments where technology is needed and not where the private sector is already doing a good job. In the past, hybrid breeding has not been targeted to less favorable environments due to poor yields of hybrids under such conditions and the limited business prospect of hybrid seed development in this area. Seed production systems are usually weak in the public sector, and without a feasible system it is difficult for hybrid technology to be efficiently adopted. Since future maize expansion will very much rely on the dryland ecologies of outer islands, hybrid-oriented breeding programs for low-productivity or stressed environments should be initiated.

Incorporating resistance to downy mildew is another important breeding goal. Screening for DM resistance and incorporation of DM resistance genes should be carried out as standard components of the germplasm improvement process. Resistance to storage pests, such as weevils, is also desirable, particularly for food and/or white maize. Regarding kernel color type, it is recommended that yellow and white maize get the same attention. Flint and semi-flint types are both priorities but work will also be initiated on floury maize, as demand also exists for this maize type.

7.2.2 Resources and crop management

Until 1995, public sector maize research was carried out at six locations distributed throughout the major maize production regions of Indonesia. These were Banjarbaru (South Kalimantan), Bogor (West Java), Malang (East Java), Maros (South Sulawesi), Sukamandi (West Java), and Sukarami (West Sumatra). These Food Crops Research Institute maize stations covered all maize growing regions. Considerably greater attention was given to maize research for favorable environments, largely located in non-traditional maize areas growing commercial maize for animal feed. Almost no attention was given to maize research for marginal environments and resource poor farmers in traditional maize areas.

Maize improvement and agronomy research in Indonesia is now mainly carried out by ICERI. The institute was formerly known as the Research Institute for Maize and Other Cereals (RIMOC) and although the name has changed, the mandate remains the same. ICERI is located in South Sulawesi, which is a traditional maize area, where maize is largely grown for human consumption. Resource poor farmers grow maize in this marginal environment, where little maize improvement has been done, and where the private sector will probably have little involvement. As a central maize research institute, ICERI lacks adequate testing sites for targeting of improved technology to specific environments and farmers needs. The main ICERI stations are all located in South Sulawesi.

One important lesson learned from the RRA/PRA study was that improved varieties, bred by public research institutes, make little or no impact in farmers' fields due to poor, or no, availability of these seeds. The same findings were noted by a renowned international scientist who, in 2001, reviewed national maize research programs and their organization. He also observed that none of the varieties or hybrids, developed and released by ICERI after its establishment in 1994/95, were apparent in the farmers' fields nor in the production pipeline. In contrast, private sector hybrids were better known by both extension workers and farmers. As may be expected, the private sector does a good job of seed production as well as providing a network for dissemination of information on their products.

The ICERI mandate includes a large geographical area covering a variety of agro-ecological zones. It is unlikely that ICERI will be successful in development of superior technology, adaptable and acceptable to farmers, without an active collaborative program. The Assessment Institute for Agricultural Technology (AIAT) provides collaborators in each province. AIAT takes a proactive role in testing and identifying superior varieties and hybrids for the region/province served by them. To some extent, ICERI has been working together with AIAT's staff despite the absence of a formal network. Perhaps official assignment of one or two agronomists from each AIAT is needed, in the provinces where maize is important, whose responsibility would be to work on collaborative projects with ICERI. Last year five of AIAT's staff undertook maize improvement training at CIMMYT, Mexico. It would be good in the future if they could work with ICERI programs involved in maize testing and development. ICERI has proposed establishment of a network for collaboration with the AIAT institutions. Equally important is the training of AIAT agronomists who are responsible for testing ICERI germplasm and technology in various environments represented at the stations, as well as assessing performance in farmers' fields. In addition ICERI should take advantage of the existence of the faculties of agriculture in some Indonesian universities, some of which train students up to Ph.D. level while others are involved in maize research. ICERI should establish collaborative maize research activities with these universities, as it would be mutually beneficial. Research on post-harvest technology, including storage facilities and weevil and aflatoxin infestations, would probably be an area where ICERI could develop collaborative programs with universities. Similarly, ICERI should build up links with NGOs that are actively disseminating improved and adapted technology to farmers. NGOs can also be a good source of feedback to public maize institutes.

8. Bibliography

Adnyana, M.O., D. S. Swastika, and R. Kustiari. 2001. Dinamika dan Antisipasi Pengembangan Komoditas Tanaman Pangan (The Dynamics and Anticipation of Food Crops Development). In Rustastra, I.W., P.U.Hadi, A.R. Nurmanaf, E. Jamal, and A. Syam (eds), *Proceedings of the National Seminar on Perspective of Agricultural and Forestry Development 2001 and Future*. Bogor, 9-10 November 2001.

Amang, B. 1993. *Ekonomi Perberasan, Jagung, dan Minyak Sawit di Indonesia (Economy of Rice, Corn, and Palm Oil in Indonesia).* PT Dharma Karsa Utama. Jakarta.

Aquino, P., F. Carrion, R. Calvo, and D. Flores. 2001. Selected Maize Statistics. In P.L. Pingali (ed), *CIMMYT 1999-2000 World Maize Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector*. Mexico, D.F.:CIMMYT.

Baco, D., J. Tandiabang, and W. Wakman. 2000. Pests and Diseases of Maize in Indonesia: Status and Research Needs. In Vasal et al. (eds), *Proceedings of the Seventh Asian Regional Maize Workshop*. PCARRD, Los Banos, Philippines, February 23-27, 1998.

Bastara, T. 1988. The Development Program of Corn in Indonesia. In *Corn*. Central Research Institute for Food Crops (CRIFC). Bogor.

Central Bureau of Statistics (CBS). 1970-1999. Food Balance Sheet. Jakarta, Indonesia:CBS.

——.1971-2001. Indonesian Statistical Year Book. Jakarta, Indonesia:CBS.

Dahlan, M.M. 1994. Research and Development of MARIF. *Proceedings of the Asian Regional Maize Research Planning and Coordination Meeting*. Farm Suwan, Thailand, Oct. 24-27, 1994. A CIMMYT-Asian Regional Maize Program Special Report.

Dalmacio, S.C. 2000. Importance of and growing concerns for maize diseases in the Asian Region. In Vasal et al. (eds), *Proceedings of the Seventh Asian Regional Maize Workshop*. PCARRD, Los Banos, Philippines, February 23-27, 1998.

Directorate of Plant Protection. 1996. Data Luas Serangan Hama dan Penyakit Jagung di Indonesia. (Unpublished data).

Erwidodo and N. Pribadi, 2002. Produksi dan Permintaan Jagung di Indonesia: Perkembangan dan Proyeksi. (Production and Demand for Maize in Indonesia: The Progress and Projection). Presented at the Panel Discussion on "The Potential of Maize for Alternative Food, held by the Agency for Food Security, Ministry of Agriculture, 25 April 2002.

Hadi, P., Waluyo, and Sugiarto. 1993. *Penelitian Agribisnis. (Agribusiness Research, Book II: Corn)*. Technical Report. Center for Agro-Socio-economic Research. Bogor.

Hairunsyah, 1993. The Research Program of Corn in Banjarbaru Research Institute for Food Crops (BARIF). In Hairunsyah, I. Noor, D.I. Saderi, and R. Galib (eds), *Proceedings on Corn Research Seminar*. BARIF. Banjarbaru.

Hutabarat, B., Y. Yusdja, E. Basuno, A. Subekti, I. Sadikin, dan V. Siagian. 1993. The Regional Trade Pattem of Corn Commodity in Indonesia. Research Report. Center for Agro-Socio Economic Research (CASER). Bogor.

Kasryno, F. 2002. Perkembangan Produksi dan Konsumsi Jagung Dunia Selama Empat Dekade Yang Lalu dan Implikasinya Bagi Indonesia. (The Progress of World Maize Production and Consumption for the Last Four Decades, and Its Implication to Indonesia). Presented at a one day seminar on Maize Agribusines. Bogor, 24 June 2002. AARD.

Lafitte, H.R. 2000. Tropical Maize Physiology. In Paliwal et al. (eds), *Tropical Maize Improvement and production*. FAO Plant Production and Protection Series. No. 28.

Maamun, M.Y., O. Suherman, D.J. Baco, M. Dahlan and Subandi. 2001. Impact of Breeding Research on Maize Production and Distribution in Indonesia. In Gerpacio, R.V. (ed), *Impact of Public and Private Sector Maize Breeding Research in Asia, 1966-1997/98*. Mexico, D.F. CIMMYT.

Malian, H., and A. Djauhari. 1988. The Farm Budget Analysis of Corn. In Subandi, M. Syam, and A. Widjono (eds), *Corn*. Central Research Institute for Food Crops (CRIFC). Bogor.

Mink, S.D., P.A. Dorosh, and D.H. Perry. 1987. Com Production Systems. In C.P. Timmer (ed.), *The Corn Economy of Indonesia*. Pp. 62-87.

Nugraha, U.S., and Subandi. 2002. Perkembangan Teknologi Budidaya dan Industri Benih. (The Progress of Maize Production Technology and Seeds Industry. Presented at a one day seminar on Maize Agribusiness. Bogor, 24 June 2002. AARD.

Sayaka, B. 1995. The total factor productivity measurement of corn in Java, 1972-1992. *Jurnal Agro Ekonomi* (Agricultural Economics Journal) 14(1): 39-49.

Subandi. 1998. Corn Varietal Improvement in Indonesia: Progress and Future Strategies. *IARD Journal*, Vol. 20 (1). Agency for Agricultural Research and Development. Jakarta.

Subandi, Ibraim,M, A. Blumenschein. 1988. National Coordinated Research Program on Corn. Central Research Institute for Food Crops. Agency for Agricultural Research and Development.

Subandi, and I. Manwan, 1990. Penelitian dan Teknologi Peningkatan Produksi Jagung di Indonesia. (The Research and Technology to Improve Corn Production in Indonesia). Special Report Pus/04/90. Central Research Institute for Food Crops (CRIFC). Bogor.

Subandi, I. G. Ismail, and Hermanto. 1998. *Corn: The Technology of Production and Post-harvest*. Central Research Institute for Food Crops (CRIFC). Bogor.

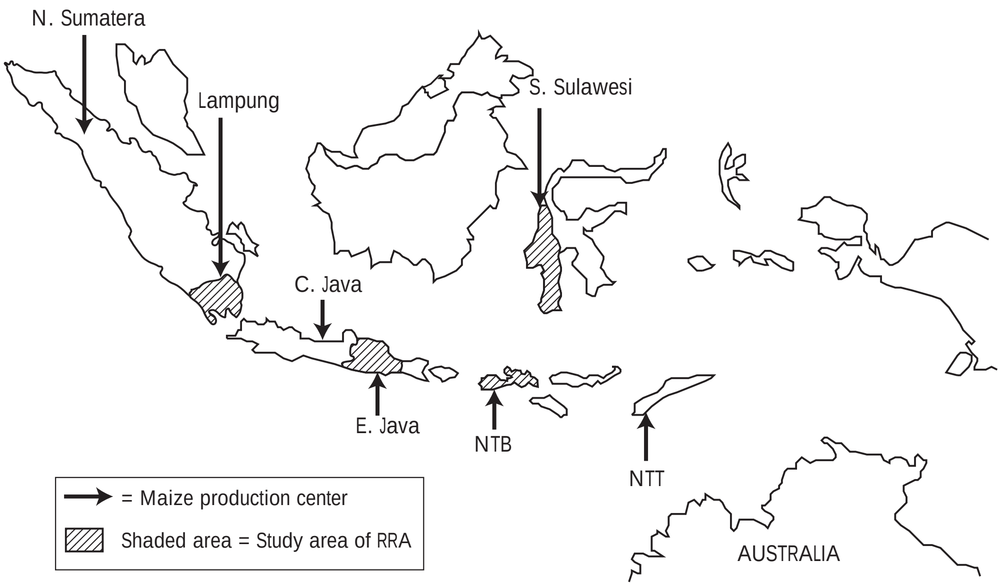
Sudjadi, M.S. 1988. Penyakit Jagung dan Pengendaliannya (Maize Diseases and their Control). In Subandi et al. (eds.), *Jagung* (Maize). Central Research Institute for Food Crops (CRIFC). Bogor.

Suhariyanto, K. 2000. Maize Production and Cost Structure in Indonesia. Presented at the Third Annual Workshop of the Asian Maize Socio Economics Working Group, in Ho Chi Minh City, Vietnam, 26-29 June 2000.

Timmer, C.P. 1987. Corn Marketing. In C.P. Timmer (ed.), *The Corn Economy of Indonesia*. Cornell University Press. New York. pp.201- 234

Wakman, S. R., dan M.S. Kontong. 1999. Kehilangan hasil 12 varietas jagung unggul akibat penyakit bulai. Technical Report. Presented at Weekly Intern Seminar, RIMOC/BALITJAS, 29 May1999.

Appendix 1. Maize production centers in Indonesia.



Appendix 2. The location of RRA/PRA maize production sites in Indonesia, 2001.

Provinces	Districts	Sub-districts	Villages	Agro-ecosystem
Lampung	1. South Lampung	1. Jati Agung	1. Sumber Jaya	Dryland
			2. Rejo Mulyo	Dryland
			3. Sidoharjo	Dryland
			4. Karang Rejo	Dryland
	2. East Lampung	2. Marga Tiga	5. Tanjung Harapan	Dryland
			6. Sukadana Baru	Dryland
			7. Negeri Tua	Dryland
			8. Negeri Katon	Dryland
	3. Kediri	3. Plemahan	9. Plemahan	Irrigated
			10. Mojo Ayu	Irrigated
		4. Kepung	11. Kebon Rejo	Dryland
			12. Kampung Baru	Dryland
East Java	4. Tuban	5. Kerek	13. Margorejo	Dryland & RFLL[†]
			14. Hargoretno	Dryland & RFLL
			15. Padasan	Dryland & RFLL
			16. Temayang	Dryland & RFLL
NTB	5. Sumbawa	6. Alas Barat	17. Mapin Baru	Dryland
			18. Sanggrahan	Dryland
			19. Aijati	Dryland
			20. Saketong	Dryland
	6. East Lombok	7. Pringgabaya	21. Suela	Dryland & RFLL
			22. Suntalangu	Dryland & RFLL
			23. Selaparang	Dryland
			24. Labuhan Lombok	Dryland
South Sulawesi	7. Jeneponto	8. Klara	25. Rumbia	Dryland
			26. Tolo Utara	Dryland
		9. Bangkala	27. Bero Angin	Dryland
			28. Palantikan	Dryland
	8. Bone	10. Ulaweng	29. Palawaruka	Irrigated
			30. Ulaweng Cinong	Irrigated
		11. Kajuara	31. Gona	RFLL
			32. Bulu Tanah	Dryland

† RFLL = Rainfed lowland.

Appendix 3. Biophysical environments of maize production systems in Indonesia.

Province	Agro-ecozone	Elevation (masl)	Topography	Soil type/ description	Rainfall (mm/ year)	Maize based cropping system	Existing abiotic stress	Important pests and diseases		Important storage pest
								Pests	Diseases	
Lampung	Dryland	115-195	Plain/ undulating	Yellow red podsol	2,455	Maize-maize; maize-cassava	Drought	None	D.mildew	None
East Java	Irrigated	100-300	Plain	Sandy alluvial	1,563	Rice-maize; rice-chili	Drought	Stem borer, rat, grasshopper	D.mildew	None
	Dryland/ RFLL[†]	120-600	Plain/ undulating	Volcanic	1,424	Maize-cassava; rice-chili	Drought	Stem borer, rat	D.mildew	Weevil
NTB	Dryland	10-360	Plain/ undulating	Sandy alluvial	1,479	Maize-mungbean; maize-fallow	Drought	None	None	None
S.Sulawesi	Dryland	130-500	Hilly	Latosol	948	Maize-cotton; maize-maize	Drought	None	None	Weevil
	Irrigated/ RFLL	20-50	Plain/ undulating	Clay soil	2,019	Maize - rice	Drought	Rat	None	Weevil

[†] RFLL = Rainfed lowland.

Appendix 4. Infrastructure and institutional environment of maize production systems in Indonesia.

Province	Agro-ecozone	Farmer organization	Input source	Cash capital source	Source of farm technology information	Nearest market (km)	Road condition	Transportation
Lampung	Dryland	Good	Shop	Private company and own capital	Extension workers and seed company	2.69	A1, B2	Minicab
East Java	Irrigated	Good	Shop	Own capital and farmer group	Extension workers and seed company	3	A1, A2	Minicab, Ojeg
	Dryland/ RFLL[†]	Fair	Shop	Own capital and private traders	Extension workers and other farmers	3	A2, B2	Minicab, Pickup, Ojeg
NTB	Dryland	Fair	Shop	Own capital and private traders	Extension workers and other farmers	5.38	A1, B2	Minicab, Dokar, Ojeg
S.Sulawesi	Dryland	Good	Shop	Farmer groups and own capital	Extension workers and other farmers	3	A1, B2	Minicab
	Irrigated/ RFLL[†]	Good	Shop	Farmer groups and own capital	Extension workers and other farmers	1.5	A1, B2	Minicab

[†] RFLL = Rainfed lowland.

Notes: A1 = Good asphalt; A2 = Moderate asphalt; B1 = Good gravel; B2 = Moderate gravel; B3 = Poor gravel.

Appendix 5. Characteristics of maize farmers in four provinces of Indonesia.

Province	Agro-ecozone	Age (years)			Education (years)			Farm size (ha)			Landowner (%)	Sharecropper (%)
		Min	Max	Average	Min	Max	Average	Min	Max	Average		
Lampung	Dryland	27.3	61.5	42.4	2.8	11.1	7.0	0.2	4.7	2.1	95.3	4.7
East Java	Irrigated	29.0	70.5	41.6	1.0	9.5	6.0	0.2	0.9	0.4	100	0
	Dryland/RFLL†	25.7	59.2	39.2	2.8	10.7	6.7	0.2	1.8	0.7	100	0
NTB	Dryland	26.3	54.6	39.2	1.0	11.0	6.4	0.4	2.5	1.2	99.3	0.7
S.Sulawesi	Dryland	24.3	67.8	45.5	1.3	10.8	5.5	0.3	1.9	0.6	100	0
	Irrigated/RFLL†	24.5	63.3	45.0	2.8	10.0	6.5	0.1	1.0	0.4	65	35

† RFLL = Rainfed lowland.

Appendix 6. Characteristics of maize farmers by class, in Indonesia.

Province	Agro-ecozone	Family size (number of people)			Land ownership (ha)			Crop cultivated		
		Poor	Medium	Rich	Poor	Medium	Rich	Poor	Medium	Rich
Lampung	Dryland	4.8	4.8	4.9	0.2	1.5	4.3	Food crops	Food and horticultural crops	Food and horticultural crops, Perennial crops
East Java	Irrigated	4·7	4·5	2·5	<0.5	0.5·1.0	>1	Rice, maize	Rice, maize, chili	Rice, maize, chili
	Dryland/RFLL†	4·6	3·5	2·4	<0.5	0.5·2.0	>2.0	Maize, chili, cassava	Maize, chili, cassava,	Maize, chili
NTB	Dryland	3·6	3·6	2·6	<0.75	0.75·1.5	>1.5	Food crops	Food crops	Food crops, tobacco
S.Sulawesi	Dryland	5.5	5.0	5.0	0.1	1.1	3.3	Maize, cotton	Maize, cotton	Maize, cotton, cacao
	Irrigated/RFLL†	5.3	5.0	5.0	0.1	0.6	1.6	Rice, maize	Rice, maize	Rice, maize, cacao

† RFLL = Rainfed lowland.

Appendix 6. Characteristics of maize farmers by class, in Indonesia (continued).

Province	Agro-Ecozone	Farming decisions			Number of poultry			Number of goats			Number of cattle		
		Poor	Medium	Rich	Poor	Medium	Rich	Poor	Medium	Rich	Poor	Medium	Rich
Lampung	Dryland	Farmer and wife	Farmer and wife	Farmer and wife	6.0	7.9	8.4	1.9	1.8	2.0	-	1.8	3.6
East Java	Irrigated	Farmer and wife	Farmer and wife	Farmer and wife	5.0	5.0	5.0	2.0	4.0	0.0	0.0	2.0	3.0
	Dryland/RFLL†	Farmer and wife	Farmer and wife	Farmer and wife	4.2	3.5	4.8	2.0	2.2	5.2	0.8	2.0	4.8
NTB	Dryland	Farmer and wife	Farmer and wife	Farmer and wife	8.5	9.8	9.8	1.5	1.5	1.5	3.6	3.6	5.0
S.Sulawesi	Dryland	Farmer and wife	Farmer and wife	Farmer and wife	9.5	9.0	7.5	0.8	1.0	1.3	0.0	1.0	3.5
	Irrigated/RFLL†	Farmer and wife	Farmer and wife	Farmer and wife	7.0	7.8	8.0	0.3	1.0	0.0	0.0	0.5	2.3

† RFLL = Rainfed lowland.

Appendix 7. Utilization of maize grain and crop residues in Indonesia.

Province	Agro-ecozone	Maize grain used (%)				Crop residues used (%)				
		Food	Feed	Sold	Seed	Compost	Mulching	Fodder	Fuel	Not used
Lampung	Dryland	0	0	100	0	0	70	5.125	0	27.5
East Java	Irrigated	0	0	100	0	0	0	90	25	10
	Dryland / RFLL†	41.3	0	57.7	1	0	0	80	50	10
NTB	Dryland	0	0	99.1	0.9	0	0	56.25	2.5	43.75
S.Sulawesi	Dryland	13.6	0	85.4	1	0.00	71.8	20	0	8.2
	Irrigated / RFLL†	21.5	0	77.5	1	0.00	56.25	22.50	0.00	18.75

† RFLL = Rainfed lowland.

Appendix 8. Farmers sources of income in four provinces of Indonesia.

Province	Agro-ecozone	Poor Farmers (%)			Medium Farmers (%)			Rich Farmers (%)		
		Maize sales	Other agric'l	Non agriculture	Maize sales	Other agric'l	Non agriculture	Maize sales	Other agric'l	Non agriculture
Lampung	Dryland	21.9	15.6	62.5	35.6	39.4	25	51.9	45.6	2.5
East Java	Irrigated	20	70	10	22.5	66.5	11	15	55	30
	Dryland / RFLL†	22	56.3	21.7	22.5	52.5	25	24	32.5	43.5
NTB	Dryland	48.8	40	11.2	44.4	45.6	10	40.6	50.6	8.8
S.Sulawesi	Dryland	27.5	15	57.5	56.2	36.3	7.5	65	35	0
	Irrigated / RFLL†	26.2	32.5	41.3	38.7	48.8	12.5	43.8	56.2	0.0

† RFLL = Rainfed lowland.

Appendix 9. Technology options for main constraints affecting maize production systems in Indonesia.

Constraints	Technology options	Prob of success (%)	Prob of adoption (%)	Rank	Suppliers	ICERI	AIAT	CGIAR	SRI	UNIV	HAR	PS
Agro-ecology: Outer Islands-Dryland												
Acid Soil	1 Tolerant variety	75	95	1	CIMMYT, NARS	***	*	*		*		**
	2 Soil ammelioration	100	50	2	NARS	*	***		**			*
Weeds	1 Variety tolerant to herbicide	100	60	2	Private sector	**	*	**				***
	2 Machinery	60	40	3	NARS, NGO	*	*					**
	3 Conventional	100	70	1	NARS, Farmers		*					
Drought	1 Tolerant variety	75	95	2	CIMMYT, NARS	***	*	*				**
	2 Early maturity	80	95	1	CIMMYT, NARS	***	*	*				**
	3 Zero/minimum tillage	40	80	3	NARS	*	***			*		**
	4 Mulching	60	40	5	NARS		*		*			
	5 Small-scale irrigation	95	25	4	NARS	*	*				**	*
	6 Rainwater harvest	80	25	6	NARS, ICRISAT	*	*				**	*
Post-harvest	1 Appropriate variety/ husk cover, drooping ears	60	90	2	NARS, CIMMYT, and private sector	***	*	*				**
	2 Tolerant variety (weevil)	60	90	3	NARS, CIMMYT	***	*	*				**
	3 Drying	90	70	1	NARS, PS	*	**					***
	4 Harvest on time	40	30	5	NARS		**					
	5 Storage (proper)	40	30	4	NARS, PS	*	**					***
Low soil fertility	1 Tolerant variety (Low-N)	50	90	2	NARS, CIMMYT	***	*	*		*		**
	2 Fertilizer application	95	75	1	NARS	*	***	*	*			*
	3 Organic matter	50	50	3	NARS	*	***	*	*			*
Infrastructure	1 Public investment in transportation facilites	25	80	1	GOI							
	2 Communication by private sector	40	60	2	Private sector							
Downy mildew	1 Tolerant varieties	90	90	1	NARS, CIMMYT	***	*	*		*		**
	2 Fungicide	95	60	2	NARS		*					**
	3 Cultural practices	70	30	3	NARS		***					
Low price of output	1 Post harvest facilities											
	a. Collective dryer	25	50	1	Farmers groups		*		*	*	***	
	b. Collective storage	25	50	2	Farmers groups		*		*	*	***	
	2 Import limitation (tariff)	15	40	3	GOI							
	3 Contract farming	20	25	4	Farmers groups,		*		*	*	***	**
	Increase efficiency				private sector,AIAT	*	***			*	*	
Seed availability		–	–	–		–	–	–	–	–	–	–
Lack of labor	1 Minimum tillage	60	25	3	Farmers groups	*	***				**	
	2 Farm machinery	25	80	2	Private sector	*	***				**	
	3 Draft animal	15	30	4	Farmers groups	*	***				**	
	4 Herbicide	70	85	1	Private sector	*	***				**	
Purchasing power	1 Corporate farming	20	30	4	Farmer		***		*	*	*	
	2 Famer cooperative	35	45	2	Farmer		***		*	*	*	
	3 Farmer association	50	20	3	Farmer		***		*	*	*	
	4 Credit	60	60	1	GOI/PS						***	
Soil erosion	1 Zero/minimum tillage	90	60	1	NARS, CIMMYT		***		*	*		**
	2 Conservation systems	90	50	2	NARS, CIMMYT		***		*		*	*
	3 Cover crop	40	40	3	NARS		***		*		*	*

Notes: ICERI: Indonesian Cereal Research Institute; AIAT: Assessment Institute for Agricultural Technology; CGIAR: Consultative Group on International Agricultural Research; SRI: Soil Research Institute; Univ: Universities; HAR: agencies outside NARS; PS: Private sector; CIMMYT: International Maize and Wheat Improvement Center; NARS: national agricultural research system; NGO: non-governmental organization; ICRISAT: International Crops Research Institute for the Semi-Arid Tropics; GOI, GOVT: Government of Indonesia.

***** Low level of involvement; ****** medium level of involvement; ******* high level of involvement.

Appendix 9. Technology options for main constraints affecting maize production systems in Indonesia (continued).

Constraints	Technology options	Prob of success (%)	Prob of adoption (%)	Rank	Suppliers	ICERI	AIAT	CGIAR	SRI	UNIV	HAR	PS
Agro-ecology: Java Bali- Irrigated												
Inapproriate fertilizer application	1 Appropriate fertizer technology					*	***	*	*	*		*
	- Rate, time - Method, kind	100	70	1	NARS, AIAT, UNIV, Private sector	**	***		*	*		
	2 Utilize organic matter	80	40	2	NARS, AIAT, UNIV, Private sector	**	***		*	*		
Lack of capital	1 Increase accessibility to credit	80	75	1	Bank Informal credit Private sector						**	
	2 Develop partnership with private sector	25	50	4	Bank Informal credit Private sector		**				*	
	3 Develop corporate farming, farming cooperative	30	25	2	Bank Informal credit Private sector		**		*		***	
	4 Develop micro-finance institutions	10	60	3	Bank Informal credit Private sector		**		*		***	
Water logging / crop establishment	1 Drainage technique	90	30	1	GOVT, AIAT, UNIV	*	**				***	
	2 Surjan system	90	10	2	GOVT, AIAT, UNIV		**					
	3 Tolerant variety	50	80	3	NARS, AIAT, UNIV	***	*	*		*		**
	4 Transplanting technique	80	10	4	AIAT, UNIV		**					
Water shortage	1 Small-scale irrigation	80	60	1	GOVT, AIAT, UNIV.	*	**			*	***	*
	2 Cultural practices (Mulching, min. tillage, time of planting)	100	40	2	Key Famer, AIAT	*	***					*
	3 Early maturity varieties	60	50	3	NARS, AIAT	***	*	*		*		**
	4 Tolerant varieties	40	50	4	NARS, GOVT, AIAT	***	*	*		*		**
	5 Water harvest	80	60			*	**			*	***	*

Notes: ICERI: Indonesian Cereal Research Institute; AIAT: Assessment Institute for Agricultural Technology; CGIAR: Consultative Group on International Agricultural Research; SRI: Soil Research Institute; Univ: Universities; HAR: agencies outside NARS; PS: Private sector; CIMMYT: International Maize and Wheat Improvement Center; NARS: national agricultural research system; NGO: non-governmental organization; ICRISAT: International Crops Research Institute for the Semi-Arid Tropics; GOI, GOVT: Government of Indonesia.

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ISBN: 970-648-108-7

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