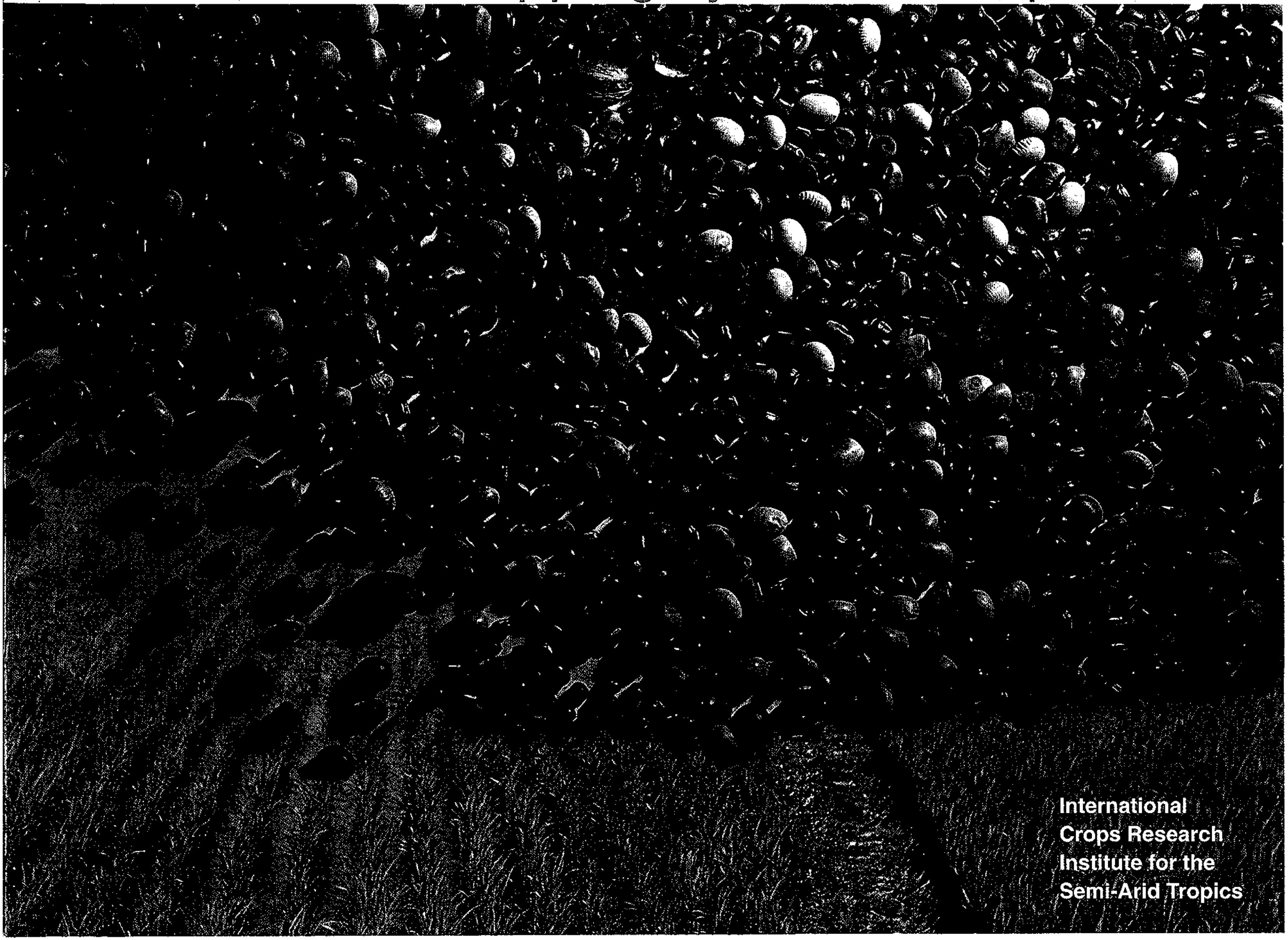
Legumes in rice-based cropping systems in tropical Asia



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Abstract

The beneficial effects of legumes in maintaining and improving soil fertility in different crop production systems are well known. Despite this knowledge, legume cultivation has declined in many agricultural systems, including the rice-based cropping systems in tropical Asia. The decline in legume cultivation was driven by the need for staple cereal—rice—and the policies of the national governments to ensure self-sufficiency in rice production. Most productive areas were used for multiple cropping of rice, and legumes were either not cultivated at all or relegated to marginal lands. As a consequence soil health has deteriorated. Decreased availability and high price has resulted in low per capita consumption of legumes by the poor people, although legumes are major sources of protein to them in many Asian countries. In this book, an attempt has been made to collate and update the database on area, production and productivity of legumes in tropical rice-growing countries in Asia—Cambodia, peninsular India, Indonesia, Myanmar, Philippines, Sri Lanka, Thailand, and Vietnam. Geographic information system (GIS) technologies have been used to map the legume production areas and production constraints.

Analysis of available data indicates that agricultural system productivity is declining or plateauing in the intensive rice monocropping areas of many countries, suggesting possible degradation of rice lands due to crop intensification. A few national programs have initiated programs for crop diversification involving legumes, to widen the food basket and for sustainability of the production system. In addition to grain legumes, legume green manures are reported to have a major role in sustaining soil fertility. Trade liberalization is expected to have a major influence on the market price of legumes. Therefore, countries that have efficient systems (low cost of production) for legumes will have competitive edge over other countries. Conducive national policies will have positive effects on increasing legume production at low production costs. Considering that legumes are low-yielding crops, research efforts are needed to improve the yield potential through ideotype breeding, coupled with incorporation of resistances to major biotic and abiotic constraints in a target environment. On the other hand, efforts should continue to breed short- and extra-short-duration legume varieties to fit into niches in the rice-based cropping system. On-farm participatory research needs to be strengthened in many countries to adapt and adopt high-yield legume technologies (variety + agronomic management). Since availability of good quality seed of improved varieties of legumes is a major constraint to adoption, a concerted collaborative effort is needed by government and non-government organizations, private sector, and farmers to ensure seed supply. A mechanism of levy on legume produce is recommended to support research and development of legumes in Asian countries.

Résumé

Référence: Des légumineuses dans les systèmes de culture à base du riz en Asie tropicale—contraintes et oportunités. Les effets bénéfiques des légumineuses dans le maintien et l'amélioration de la fertilité du sol dans différents systèmes de production agricole sont bien connus. Malgré cela, la culture des légumineuses a baissé dans de nombreux systèmes agricoles, notamment dans les systèmes rizicoles en Asie tropicale. Cette baisse est due au besoin en céréale de base—le riz—et aux politiques des gouvernements nationaux qui visent à garantir l'autosuffisance en ce qui concerne la production du riz. La plupart des zones productives ont été utilisées pour la production du riz et les légumineuses n'étaient pas cultivées ou étaient reléguées aux terres marginales. En conséquence, l'état du sol s'est détérioré. Même si dans de nombreux pays asiatiques, les légumineuses constituent une source majeure de protéines pour les pauvres, sa faible disponibilité et le niveau élevé des prix a entraîné une faible consommation par tête d'habitant de ces cultures par cette couche de la population. Le présent ouvrage tente d'examiner et de mettre à jour la base de données sur la superficie, la production et la productivité des légumineuses dans les pays asiatiques producteurs de riz—le Cambodge, la Péninsule indienne, l'Indonésie, le Myanmar, les Philippines, le Sri Lanka, la Thaïlande et le Vietnam. Les technologies du Système d'Information Géographique (SIG) ont été utilisées pour dresser une carte des zones de production de légumineuses et des contraintes liées à sa production.

L'analyse des données disponibles indique que la productivité du système agricole baisse ou stagne dans les régions de nombreux pays, où le riz est cultivé de manière intensive, en monoculture, suggérant une dégradation possible des terres rizicoles du fait de l'intensification des cultures. Quelques projets nationaux ont lancé des programmes de diversification agricole, comprenant des légumineuses, afin d'élargir la base alimentaire et d'assurer la pérennité du système de production. Outre les légumineuses en grains, il a été signalé que les engrais verts à base de légumineuses jouent un rôle important dans le maintien de la fertilité du sol. On s'attend à ce que la libéralisation du commerce ait une grande influence sur le prix des légumineuses sur le marché. En conséquence, les pays ayant des systèmes efficaces de production des légumineuses (c'est-à-dire à un coût faible) auront un avantage sur les autres. Des politiques nationales favorables auront des effets positifs sur l'augmentation de la production du riz à des faibles coûts de production. Étant donné que les légumineuses sont des cultures à faibles rendements, il convient de déployer des efforts en matière de recherche pour améliorer les rendements potentiels à travers la sélection d'idéotypes, associée à l'incorporation des caractères de résistance aux contraintes biotiques et abiotiques dans un environnement cible. D'autre part, les efforts devraient se poursuivre pour sélectionner des variétés de légumineuses à cycles court et très court correspondant à des créneaux au sein du système de production basée sur le riz. La recherche participative en milieu paysan doit être renforcée dans de nombreux pays pour adapter et adopter des technologies de légumineuses à haut rendement (variété + gestion agronomique). La disponibilité de semences de variétés améliorées de légumineuses de bonne qualité étant la principale contrainte à l'adoption, les institutions du gouvernement, les ONG, le secteur privé et les paysans doivent déployer des efforts concertés pour garantir l'approvisionnement. Il est recommandé qu'un mécanisme de taxes sur les légumineuses soit mis en place pour appuyer la recherche et le développement des légumineuses dans les pays asiatiques.

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Legumes in Rice-based Cropping Systems in Tropical Asia

Constraints and Opportunities

Edited by

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Contents

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1. Introduction and Background

C L L Gowda, A Ramakrishna, O P Rupela, and S P Wani[1]

Introduction

The over utilization of subsistence landholdings and their expansion to new, and often marginal, farming areas, combined with non-adoption of appropriate soil, water, and nutrient management practices, leads to increased vulnerability to soil degradation. Many tropical land-use systems are in the midst of such a downward spiral of nutrient depletion, loss of vegetative cover and soil biota, and soil erosion. The ameliorative effect of crop rotation with legumes in continuous cereal cropping and/or cereal dominated systems has long been known. But legume cultivation has declined due to increased demand for staple cereals, and unstable yields of legumes. This is a consequence of low yield potential of legumes, as compared with cereals [e.g., rice (*Oryza sativa* L.) and maize (*Zea mays* L.)] and susceptibility of legume crops to many biotic and abiotic stresses. However, recent advances in genetic improvement and management techniques for legumes have enhanced the feasibility of their cultivation in cereal dominated systems, so as to increase crop diversification and contribute to system sustainability and income generation.

The study presented in this book results from the project "Legume-based technologies for rice and wheat production systems in South and Southeast Asia" funded by the Asian Development Bank (ADB), Philippines and being implemented by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India and the national agricultural research systems (NARS) in Bangladesh, India, Indonesia, Nepal, Pakistan, Sri Lanka, Thailand, and Vietnam. The overall objectives of the project are to:

- Quantify the scope for greater inclusion of legumes in rice and wheat (*Triticum aestivum* L.) cropping systems (RWCS);
- Develop technological options (management and genetic) for reducing the major biotic and abiotic constraints to adoption of legumes in RWCS;
- Evaluate improved technologies in farmers' fields to catalyze adoption and elicit feedback on further research needs and adoption constraints; and
- Assess adoption and quantify the impact of improved legume-based technologies for RWCS.

The overall aim of the project is to address issues related to sustainability of cereal dominated agricultural production systems in South and Southeast Asia, and to explore options for greater inclusion of legumes for improving the agricultural systems productivity, and long-term sustainability. The project focused on two broad production systems of Asia: (1) the Indo-Gangetic Plain region of South Asia, where both rice and wheat are grown, often in rotation with other crops, as the region is in subtropical latitudes; and (2) tropical South and Southeast Asia where rice-based cropping systems are predominant. A study of the constraints and opportunities in the RWCS in the Indo-Gangetic Plains (Bangladesh, India, Nepal, and Pakistan) was done previously and has been published (Johansen et al. 2000).

This study focuses on the tropical rice-growing areas of Cambodia (Kampuchea), peninsular India, Indonesia, Myanmar, Philippines, Sri Lanka, Thailand, and Vietnam. Although Cambodia and Myanmar are not involved in the ADB-funded project, we included these in the study for covering the major rice-growing countries in Southeast Asia.

Objectives of the Study

The overall aim of the study was to update and compile database of crops grown in the target regions of South and Southeast Asia to assess the current situation, and analyze trends and factors influencing those trends. This will assist the scientists and policy makers in planning appropriate research and development programs and for providing a baseline against which to measure future technology adoption and assess impact. Although information for the required databases exist in different forms and places, they need to be assembled and documented properly for making the information user-friendly. New tools such as computerized databases and geographic information system (GIS) make this task more feasible and provide opportunities for a more comprehensive analysis of existing databases. Therefore, the specific objectives of the study were to:

- Update the databases on area, production, and yields of the major legumes (including grain, oilseed, green manure, and fodder legumes) grown in tropical rice-based cropping systems of Asia;
- Use GIS technology to relate area and yields of these legumes, and their time trends, vis-à-vis influence of factors of the physical environment, biotic stresses, alternative cropping options, and socioeconomic considerations;

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- Interpret these data in terms of prospects for increased use and production of these legumes in the Asian tropical rice-based cropping systems; and
- Present the resultant information and recommendations in user-friendly hard copy and also in an electronic format to facilitate easier access and utilization by scientists and policy makers in Asia and elsewhere.

The Procedure Followed

ICRISAT, in collaboration with national programs, has been involved in characterizing the production systems in Asia to help scientists and policy makers in prioritizing research and development. The first attempt by ICRISAT and NARS partners in cropping systems analysis for its mandate legume crops was carried out under the Asian Grain Legumes Network (now Cereals and Legumes Asia Network) and published as a research bulletin (Virmani et al. 1991). All maps were hand drawn, which is laborious and error-prone. The data in this bulletin were from mid- to late 1980s. Despite its drawbacks, this publication has proved to be a valuable guide to the status, problems, and prospects of the ICRISAT mandate legumes in Asia through the 1990s. However, with the availability of GIS technologies, ICRISAT and the International Center for Agricultural Research in the Dry Areas (ICARDA), Syria attempted an agroclimatic analysis of chickpea (*Cicer arietinum* L.) in West Asia and North Africa region. GIS was used to prepare colored maps which were published in a book (Saxena et al. 1996). This volume provided valuable insights into chickpea in the target regions for scientists and policy makers.

Considering that many national and international institutes were embarking on use of GIS related to agricultural research, ICRISAT organized a GIS harmonization workshop in 1997 to update on GIS software options, discuss database requirements, availability, storage, exchange and output options, and develop recommendations for optimizing interaction in the use of GIS for cropping systems analysis in the Asia region. GIS specialists from the Centro Internacional de Agricultura Tropical (CIAT), International Center for Integrated Mountain Development (ICIMOD), Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), International Rice Research Institute (IRRI), Cornell University (USA), International Programs Division, Natural Resource Conservation Services (USA), Asian NARS, and ICRISAT reviewed the state-of-the-art in using GIS as a research tool for characterization of target production systems. The participants also agreed on standardized databases and formats so that these can be exchanged among the partners. The proceedings of the workshop were published (Pande et al. 1999). Training was also provided at ICRISAT for NARS scientists in use of GIS for cropping systems analysis. Subsequently, the case studies using GIS for analysis of cropping systems were compiled and published (Pande et al. 2000).

Plans for organizing this study were made in mid-1997 by asking senior scientists in the target countries to compile the needed information and data, and prepare country papers emphasizing the scope and opportunities for legume cultivation in tropical rice-based cropping systems. We also commissioned experts to prepare regional outlook papers on role and importance of pulses, oilseeds, and green manures in sustainability of RWCS. A workshop on "Legumes in tropical rice-based cropping systems of Asia: Constraints and opportunities" was held at ICRISAT, Patancheru, India during 18–20 January 1999. The regional outlook and country papers were presented and discussed. Need for further data and finalization of papers was also agreed by the participants. Participants formulated future research and development strategies to promote legumes production in the tropical rice-based cropping systems. A list of legumes referred in this book are in Table 1.1.

Table 1.1. Legumes grown in tropical rice-based cropping systems of Asia.

Common name	Botanical name
Black gram, urd bean	*Vigna mungo* (L.) Hepper
Butter bean, lima bean	*Phaseolus lunatus* L.
Chickpea	*Cicer arietinum* L.
Cowpea	*Vigna unguiculata* (L.) Walp.
Groundnut	*Arachis hypogaea* L.
Horse gram	*Macrotyloma uniflorum* (Lam.) Verdc.
Khesari, lathyrus, grass pea	*Lathyrus sativus* L.
Kidney bean, common bean	*Phaseolus vulgaris* L.
Lablab bean	*Lablab purpureus* (L.) Sweet
Lentil	*Lens culinaris* Medic.
Mung bean, green gram	*Vigna radiata* (L.) Wilczek
Pea	*Pisum sativum* L.
Pigeonpea	*Cajanus cajan* (L.) Millsp.
Pillipesara, jungli moth	*Vigna trilobata* (L.) Verdc.
Soybean	*Glycine max* (L.) Merr.

Based on the discussion during the workshop, the authors were asked to update the country papers to ensure that missing data and information were included in the final versions. Despite this, we could not ensure uniformity of data and presentation across different countries. This was because of the non-availability of information and data in some countries, and different formats used by national programs for GIS. But, the editors have made their best efforts to put these together in this book, and hope that this will be useful to the target audience.

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2. Legumes in Tropical Rice-based Cropping Systems in Cambodia: Constraints and Opportunities

Mak Soeun[1]

Abstract

Mung bean, soybean, and groundnut are the major legumes in Cambodia (Kampuchea), occupying 57,000 ha in 1998/99. Legumes are essentially concentrated in a narrow belt of the country starting from the northwestern border of the country and extending to the southeastern border. This belt receives rainfall between 1250 mm and 1750 mm annually, and length of growing period ranges from 150 days to 209 days. The favorable part of the growing period obviously goes to rice. The legumes are presently concentrated around Kampong Cham province. Increase in area under legumes seems possible in Takeo, and parts of Pursat and Kampong Tham. Legumes are generally grown on alluvial soils along rivers, on Latosols and on slopy lands, on residual moisture after rice harvest. Legumes account for 5% of the gross national product. Much of the soybean is exported. Export of other legumes, mung bean in particular, is restricted due to poor seed quality. High humidity (60% to 80%) throughout the year and high temperatures of 21°C to 35°C (40°C during April–May) encourage diseases and insect pests, that are a major threat to crop production.

Varietal development to address local constraints is an immediate necessity. Other factors that can enhance legumes production in the country include diversifing rice-rice cropping system, cropping systems that can help reduce soil erosion on slopy lands, legume varieties that can fit in rotation with rice, and linking food crops to processing industry to create demand for legumes and provide cash income to farmers.

Introduction

Cambodia (Kampuchea) is located between 102–108° E and 10–15° N, bordering Thailand in the northwest, Laos in the north, Vietnam in the east, and the southern province having access to the Gulf of Siam (Fig. 2.1). Cambodia is physically divided into three portions by rivers and lakes. The Mekong river flows into the country from Laos and out into Vietnam. Cambodia covers a geographic area of 181,035 km , about 74% of which is under forest, 17% under cultivation, and 3% under pasture land. In 1967, the cultivated area was approximately 3 million ha, but in 1997–98, it was about 2.5 million ha including rubber (*Hevea brasiliensis* Muell.) plantation. Of this, approximately 2.2 million ha is planted to rice (*Oryza sativa* L.), 46,000 ha to vegetables, 10,000 ha to fruit trees, and 180,000 ha to other field crops (MAFF 1995, 1997, 1998).

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Physical Environment

Climate

Cambodia's tropical climate has distinct wet and dry seasons. Rain commences in late April or early May and continues through November. Much of the legume growing area is in the zone with average rainfall of 1250–1750 mm (Fig. 2.2). Mountainous and coastal areas receive 2500–4000 mm of rain per annum.

Daily temperatures fluctuate between 21°C and 35°C. However, at the peak of the hot season (April–May), temperatures are around 40°C. The temperatures are coolest during October–January. The relative humidity in Cambodia fluctuates between 60% and 80% throughout the year. The least humid days are during April, before the onset of rains. Although the maximum daily humidity remains reasonably constant, the difference between maximum and minimum humidity decreases considerably during peak rainfall in September and October. High humidity induces plant diseases and provides an ideal environment for insects. However, it also reduces evaporation from water storage areas.

Evaporation is greatest (250 mm per month) during March and April, when maximum temperatures are high and minimum humidity is at its lowest. Annual evaporation expected from a free standing surface is almost double that of the annual rainfall. Evaporation in Cambodia is not related to the seasonal winds. The maximum wind measurements tend to be of momentary gusts, many of which precede rainstorms. Cambodia is not in the typhoon belt.

Soil

There are 11 types of soils present in Cambodia (Fig. 2.3). These soil types together constitute 95% of the cropping area of the country. About 50% of the wet season rice is grown in infertile soil types. The more fertile soil types, however, dominate in the other rice ecosystems with about 60% of the dry season rice. Deep water rice is grown on alluvial soils and lacustrine alluvial soils (Nesbitt 1997). The moderately fertile soils occur on about 5–10% of the rice area in each ecosystem, while only 5% of shallow water wet season and deep water rice and 1% of the shallow water dry season rice are grown on acid-problem soils. Vegetable and horticultural crops dominate alluvial soils, but with a significant proportion of horticultural plantations occurring on the Rhodic Ferralsols (Latosols). Rubber production dominates on the Rhodic Ferralsols (Latosols) and forests dominate on the acid and basic Lithosols.

As the Cambodian economy develops there will be increasing demands on the soil resources in the country (Tichit 1981). There is a pressing need for a better understanding of the soil to avoid adverse environmental consequences caused by the inappropriate use of soils. More data needs to be collected about the soil, and soils should be classified in terms of their limitations and uses rather than relying solely on taxonomic soil classification systems.

Land Use

Based on soil, rainfall, and evapotranspiration, the length of growing period is shown in Figure 2.4. Inadequate water supply is often cited as one of the serious problems facing agricultural development in Cambodia. Lack of irrigation water means that it is only possible to produce one rice crop a year resulting in food shortages for 2–4 months of the year in many areas. Wherever possible, supplementary irrigation is provided during periods of low rainfall. To date, groundwater potential for large-scale irrigation has not been identified. Use of groundwater for irrigation is thus likely to be restricted to small-scale vegetable and fruit gardens, especially those cropped in the dry seasons. Improved irrigation facilities are badly needed.

A recent inventory of irrigation systems listed 841 schemes totaling 310,000 ha. Supplementary irrigation is often provided to the rainfed rice crops, particularly during periods of low rainfall. In

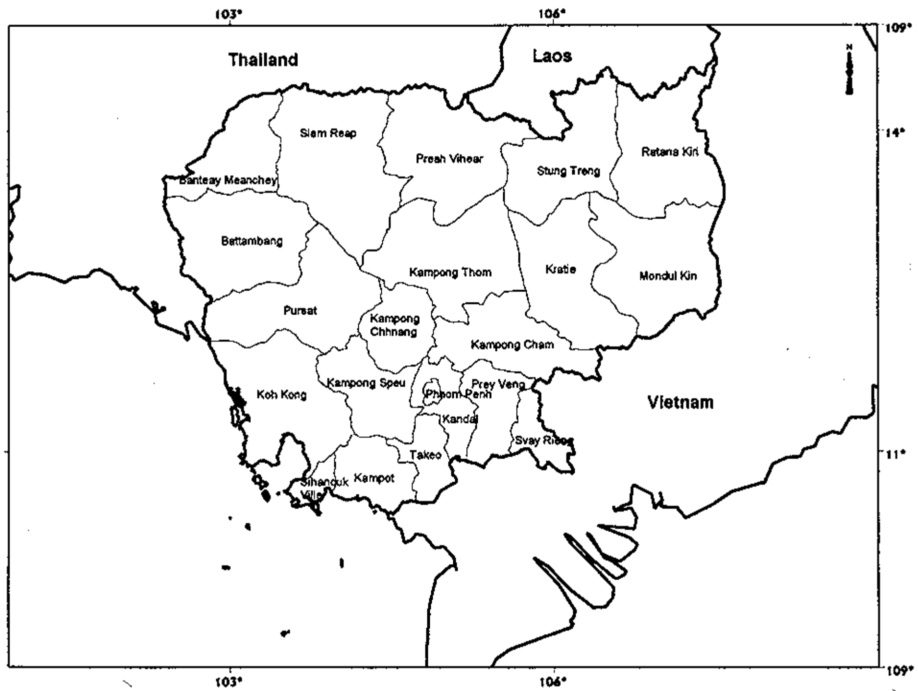

Figure 2.1. Administrative divisions of Cambodia.

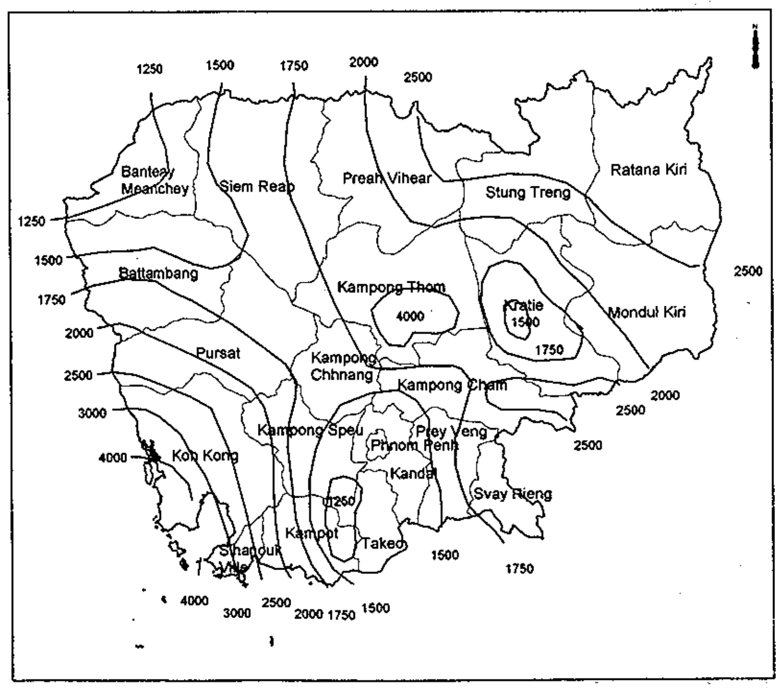

Figure 2.2. Rainfall map of Cambodia.

the wet season, supplementary irrigation may be through direct runoff, river diversion, pumping, or by release of stored water.

Area, Production, and Yield of Legumes

Legume crops include mung bean (*Vigna radiata* (L.) Wilczek), soybean (*Glycine max* L.), groundnut (*Arachis hypogaea* L.), cowpea (*Vigna unguiculata* (L.) Walp.), and other minor grain and vegetable legumes. Legume crops account for >5% of the gross domestic product (GDP). Most legume crops are grown for domestic market and export on alluvial soils along the rivers and red soils, or under irrigation after rice. Mung bean, cowpea, and groundnut are grown as intercrops with upland rice (DOA 1998). These crops are also grown in the rainfed lowland areas before wet season rice or after rice, under residual soil moisture.

Trends in area, production, and productivity of the three major legumes, soybean, mung bean, and groundnut are shown in Figure 2.5. Area and production of legumes show wide variation across years. Area and production in the late 1990s has increased substantially for soybean, and slightly for groundnut, while that of mung bean declined compared to that in the mid-

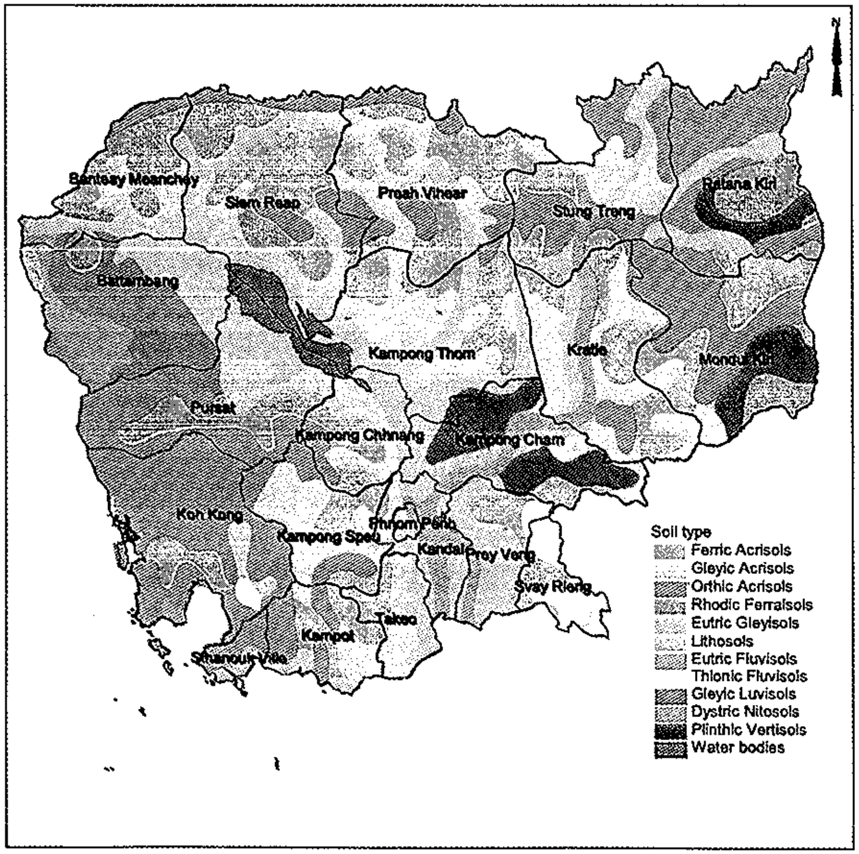

Figure 2.3. Soils in Cambodia (Source: FAO 1995).

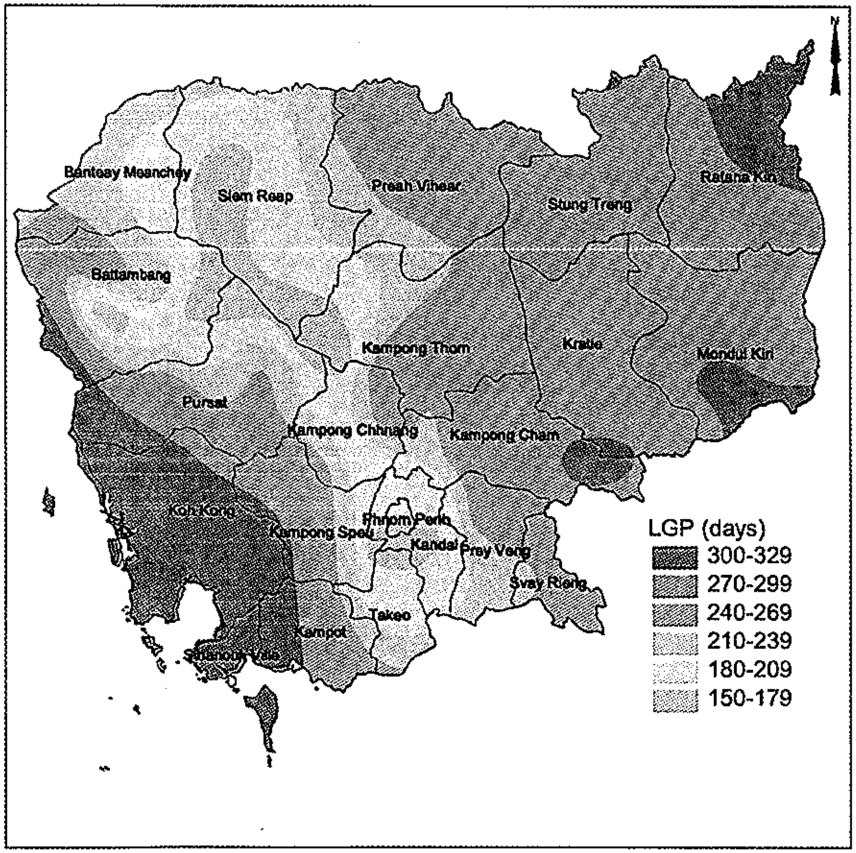

Figure 2.4. Length of growing period (LGP) in Cambodia (Source: FAO 1995).

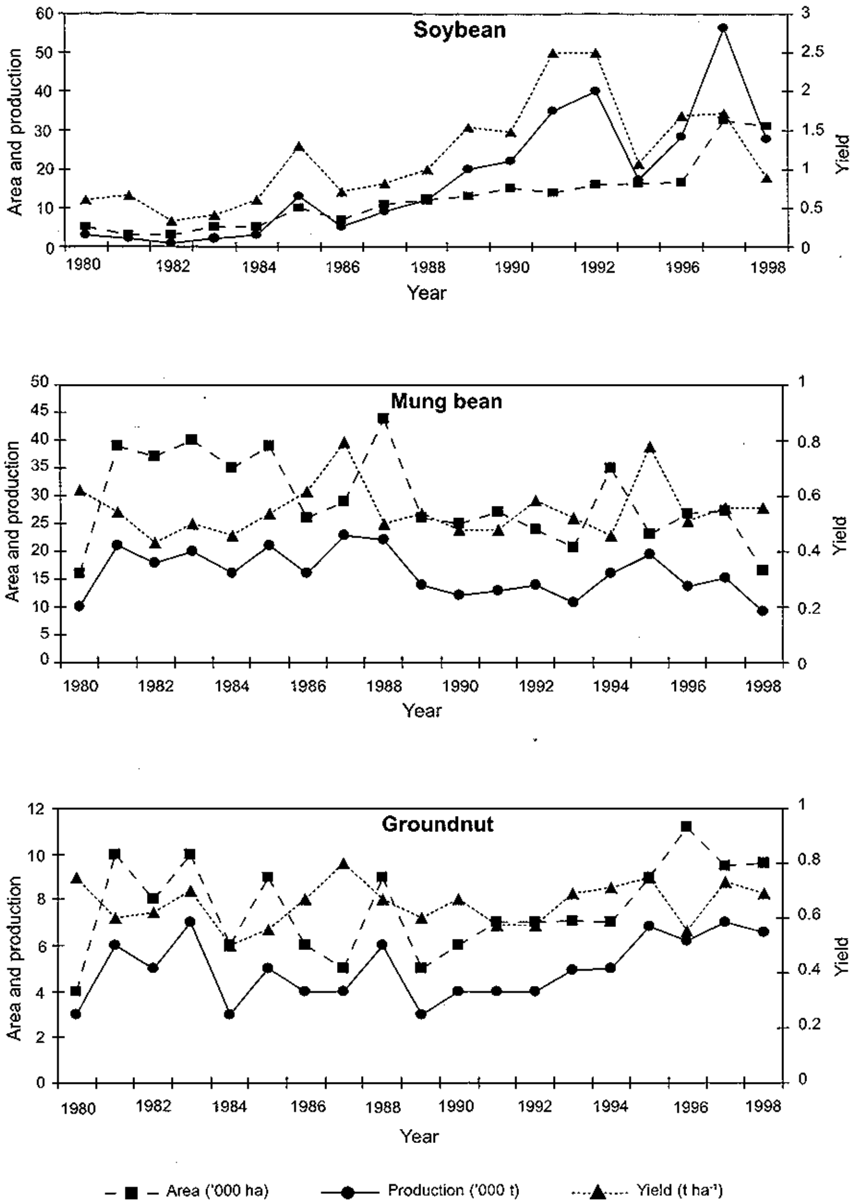

Figure 2.5. Area, production, and yield of major legumes in Cambodia.

and late 1980s. Productivity of soybean has shown increase, while mung bean and groundnut yields have stagnated.

Soybean

Soybean is usually grown during the rainy season as a rainfed crop, on alluvial and red soils on sloping lands. Soybean cultivation is concentrated in two provinces (Kampong Thom and Kampong Cham), with limited area in few others (Fig. 2.6). Limited soybean area is also reported in the dry season under fertile alluvial and black soils, sometimes with supplemental irrigation.

Mung bean

Mung bean is grown on alluvial, red, silt, and sandy clay loams along river banks as a rainfed crop, usually before or after rice crop in the dry season. During the rainy season, it is grown on sloping uplands. Cultivation of mung bean is spread across many provinces, but concentrated in five provinces (Fig. 2.7).

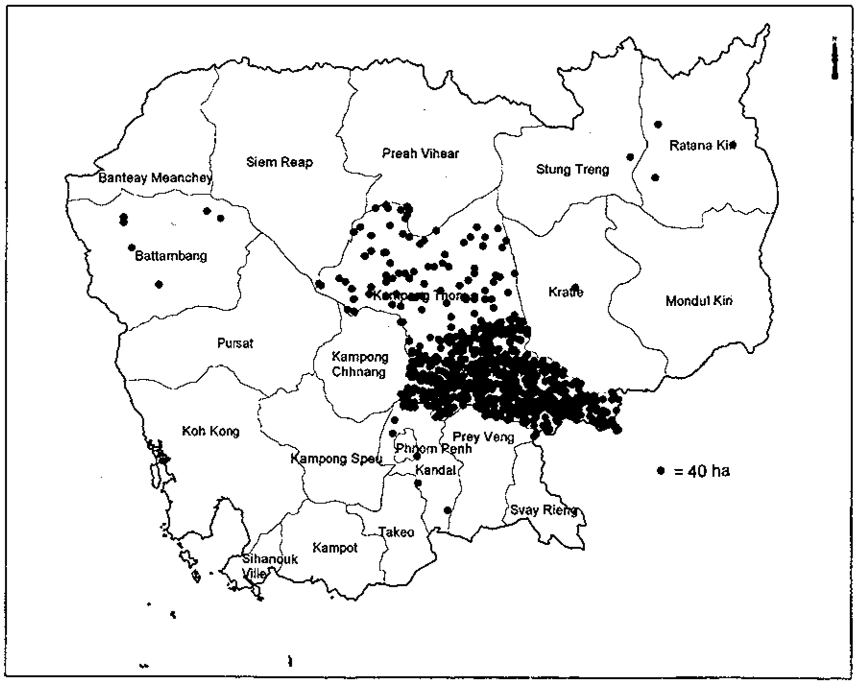

Figure 2.6. Distribution of soybean in Cambodia, 1998/99.

Groundnut

Groundnut is usually grown as a rainfed crop on alluvial soils along river banks and sandy loam and red soils in sloping areas. Cultivation of groundnut in the rice-based system is minimal, and is concentrated only in four provinces (Fig. 2.8).

The soil and agronomic requirements of the legume crops mean that they compete for better land with rice and vegetable production. It is likely that as rice yields improve and household rice security is attained, diversification into crops with a high potential for cash income and returns will occur. The 1993 Agricultural Development Options Review (ADOR) determined that Cambodia has a comparative advantage for export of soybean and mung bean at then prevailing prices and yields.

Marketing and Processing

Majority of the soybean produced is exported. Some soybean is used in locally produced livestock feed. There is no oil extraction plant in Cambodia. Mung bean is generally grown for domestic markets and for home consumption, with a relatively low proportion exported. The quality of mung bean is an issue for exports.

A private feed processing mill with a capacity of 500,000 t has been built near Phnom Penh, Cambodia. Currently it processes around 100,000 t. Excess capacity is likely to encourage additional areas of maize (*Zea mays* L.) and soybean, especially in red soils where high yields are achieved. There may also be some opportunities for contract soybean and maize production.

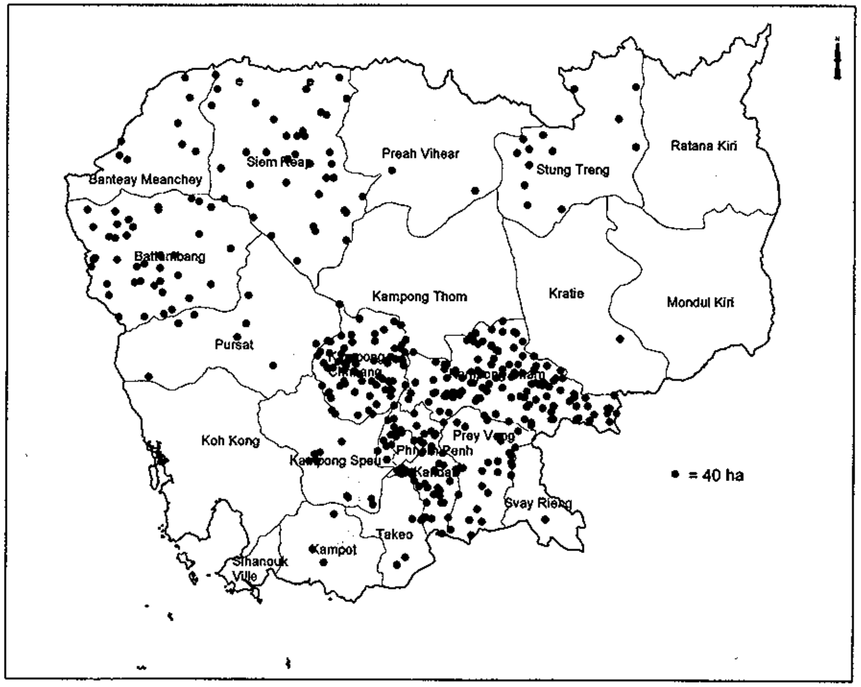

Figure 2.7. Distribution of mung bean in Cambodia, 1998/99.

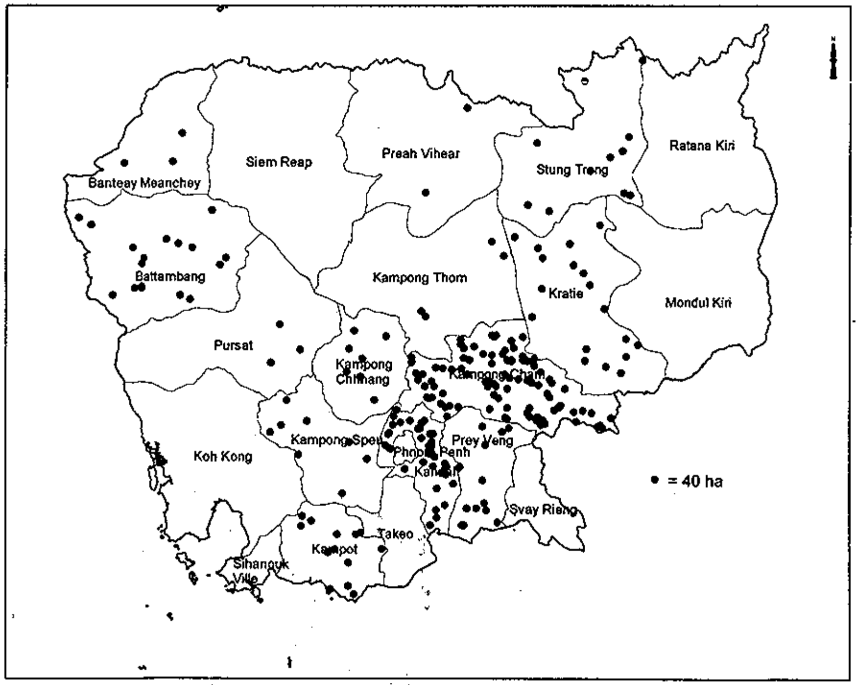

Figure 2.8. Distribution of groundnut in Cambodia, 1998/99.

Key Issues of Legumes Production

Legume crops require proper variety and management conditions that are currently lacking in Cambodia. There is likely to be competition with rice. Improved food security through increased rice yield is likely to develop opportunities for diversification into legume crops (DOA 1998). Erosion is a problem on sloping soils, but may be reduced by intercropping with legumes. Legumes as part of crop rotations have the potential to improve soil fertility. Labor costs are low and development of contract production will increase the demand for mechanization. Intensive crop production and processing may increase employment opportunities.

Horizontal and vertical integration is more likely to occur in cash cropping industries and this may lead to contract production where processors and market organizations supply inputs and credit requirements. However, slow market development is likely to reduce prices for the commodities, but increase input and market costs. Variability in prices particularly for legume crops is likely to discourage farmers to diversify.

Constraints to Legumes Production

There are several factors that contribute to the concentration of agriculture and the failure to expand particularly in recent years. Lack of security discourages farmers from settling in large areas. Labor shortage exists in the provinces. Additional labor and draft power is also required to expand the cultivated area. Labor is a constraint in some provinces with the greatest potential for area expansion. Much of unused land is situated away from roads and villages. Besides being exposed to extortion activities of terrorists and bandits, the people in the villages are isolated because the land is far from schools and other facilities. The infrastructure needs to be improved. Construction of roads and schools and installation of irrigation and drainage facilities may speed up expansion of cultivated area.

Cambodia lacks human resource in legumes research and development. Soil infertility is one of the most serious constraints to crop yield improvement in Cambodia. The soils in many areas also exhibit characteristics of iron toxicity, acidity, and high salt concentrations. Fertilizer consumption is extremely low, approximately 15–20 kg ha^{-1}. Some other constraints to legumes production and development in Cambodia are described below.

Biotic and Abiotic Constraints

Insect pests, including stored grain pests, and diseases are the major constraints to legumes production in Cambodia (Table 2.1). Cutworm (*Spodoptera litura*), horn worm (*Agrius convolvuli*), leaf miner (*Aproaerema modicella*), aphids (*Aphis craccivora*), pod borer *(Maruca vitrata*), and flea beetle (*Etiella zinckenella*) cause severe damage to mung bean and soybean. Leaf rollers (*Lamprosema indicata*), aphids, and pod borers *(Helicoverpa armigera*) are major pests, which cause damage on groundnut. Cercospora leaf spot (*Cercospora cruenta*) and yellow mosaic on mung bean; soybean mosaic on soybean; early leaf spot (*Cercospora arachidicola*), stem rot (*Sclerotium rolfsii*), and root rot (*Rhizoctonia solani*) on groundnut are important diseases causing economic losses. *Callosobruchus chinensis* and *C. maculatus* are the most serious storage pests. Climate risk from drought and flooding, and poor soil fertility are important abiotic constraints.

Socioeconomic Constraints

- Farmers' knowledge, experience, and skill in legumes production is low. Hence, low yield in traditional production systems may discourage cultivation.
- Availability of credit is poor and market infrastructure is inadequate.
- High quality seed, inputs, and extension and research services are not available.
- Processing and storage facilities and marketing systems are lacking.
- Regulations and quality assurance of inputs (such as seed, fertilizer, and pesticides) are absent.

Opportunities for Increasing Legumes Production

There are many opportunities to improve legumes production and development in Cambodia:

- Investment in research is likely to develop opportunities for productivity improvement.
- Development of research-extension-farmer linkages.
- Soybean, cowpea, and other legume crops have high potential of export.
- Improved water management systems will reduce risks and increase yield.
- Development of private sector processing and marketing organizations.
- Availability of improved quality seed of high-yielding varieties will increase yields.
- Improved distribution and marketing systems will improve returns and income to farmers.
- Linkages with commerce and industry should be established for development of agro-processing industry.

Table 2.1. Major diseases and pests of grain legumes in Cambodia.

Crop	Disease (Pathogen)	Insects
Mung bean	Cercospora leaf spot (*Cercospora cruenta* Sacc.) Yellow mosaic (mung bean yellow mosaic virus)	Flea beetle (*Etiella zinckenella* Treitschke) Pod borer (*Maruca vitrata* Gey.) Leaf miner (*Aproaerema modicella* Dev.) Horn worm (*Agrius convolvuli* L.) Aphids (*Aphis craccivora* Koch) Bruchids (*Callosobruchus chinensis* L., *C. maculatus* F.) Cutworm (*Spodoptera litura* F.)
Soybean	Soybean mosaic (soybean mosaic virus)	Pod borer (*Maruca vitrata* Gey.) Leaf miner (*Stomopteryx subsecipvella* Zell.) Cutworm (*Spodoptera litura* F.) Flea beetle (*Etiella zinckenella* Treitschke) Aphids (*Aphis glycines* Mats.) Bruchids (*Callosobruchus chinensis* L.)
Groundnut	Early leaf spot (*Cercospora arachidicola* Hori) Stem rot (*Sclerotium rolfsii* Sacc.) Root rot (*Rhizoctonia solani* Kühn)	Leaf roller (*Lamprosema indicata* F.) Pod borer (*Helicoverpa armigera* Hübner) Aphids (*Aphis craccivora* Koch) Bruchids (*Callosobruchus chinensis* L., *C. maculatus* F.)

- Improved postharvest technology, and storage and processing facilities, and greater involvement of private sector in provision of inputs and other services.

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3. Legumes in Tropical Rice-based Cropping Systems in Peninsular India

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Abstract

Rice yields in peninsular India are stagnating in recent years due to continuous monocropping. Of the total 12.12 million ha of rice in peninsular India, area sown to legumes in rice-based cropping system (RBCS) is only about 10–12% of rice area. In addition to meeting the growing demand for pulses, legumes have to be introduced in RBCS in rice monocropping areas in peninsular India either as preceding or as post-rice crop to sustain and improve rice productivity. Among the legumes grown, black gram and mung bean are the major crops in RBCS. The constraints to legumes production in RBCS, such as soil compaction, excessive moisture at the time of sowing, poor plant stand, low water-holding capacity of soils leading to terminal stress, weeds, and soilborne diseases are discussed in depth to identify opportunities and suitable genotypes of legumes for RBCS. A more decentralized breeding work to improve grain legumes for adaptation to specific locations under RBCS, will play a significant role towards sustainability of RBCS and global agriculture. Strategies for improving legumes production in RBCS in peninsular India including management options, genetic options, and policy issues are discussed.

Introduction

Legumes contribute to sustainability of global food production systems by enriching the soil through biological nitrogen fixation and improving soil physical conditions. Grain legumes are the major source of dietary protein in the vegetarian rich diets of Indians. Judicious inclusion of legumes in the cropping systems by Indian farmers through the ages is responsible for maintaining soil productivity in this part of the world. Therefore, grain legumes are rightly called "unique jewels of Indian crop husbandry". India is a major legumes (pulses) producing country in the world sharing 35% area and 28% production with annual production around 14 million t from 24 million ha of land.

Peninsular India (Fig. 3.1) comprising Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, and Kerala states are characterized by semi-arid tropical climate, except in parts of Kerala and coastal Karnataka that are humid tropics. All these states have a long coastal line, with occasional cyclonic threats. Almost all the crops grown in the tropical belt of the world are grown in peninsular India.

The area under rice (*Oryza sativa* L.) has increased since 1947, with the development of irrigation projects, both major and minor. Total area under crops in peninsular India during 1994 was around 12.12 million ha. The traditional coarse cereals + grain legumes cropping systems have been replaced to a great extent by monocropping with rice. Modern agriculture in this area is also evident as monocropping of commercial crops such as cotton (*Gossypium* sp) and tobacco (*Nicotiana tabacum* L.) is practiced. At the same time, the productivity of rice is stagnating due to continuous monocropping and excessive dependence on chemical fertilizers. The total area sown to rice in tropical India (12.12 million ha) compared to the area sown to legumes (6.1 million ha) is presented in Figure 3.2. The total legumes area includes crops grown both in rice-based as well as in other cropping systems; thus vast areas of rice monocropping still exist. To sustain and improve rice productivity, legumes have to be introduced in rice-based cropping systems (RBCS) in different rice-growing areas in peninsular India.

Agroecological Features

Based on rainfall, soil, mean annual temperature, and length of growing period, the region has been classified into eight agroecological zones (AEZs) (Fig. 3.3). The zones are:

- Karnataka plateau – hot arid ecoregion (AEZ 3)
- Deccan plateau – hot semi-arid ecoregion (AEZ 6)
- Deccan plateau (Telangana) and Eastern Ghats – hot semi-arid ecoregion (AEZ 7)
- Eastern Ghats and Tamil Nadu uplands and Deccan plateau (Karnataka) – hot semi-arid ecoregion (AEZ 8)
- Moderately to gently sloping, hot and moist/dry sub-humid ecoregion (AEZ 11)
- Eastern plateau (Chotanagpur) and Eastern Ghats – hot sub-humid ecoregion (AEZ 12)
- Eastern coastal plain – hot sub-humid to semi-arid ecoregion (AEZ 18)
- Western Ghats and coastal plain – hot humid/pre-humid ecoregion (AEZ 19)

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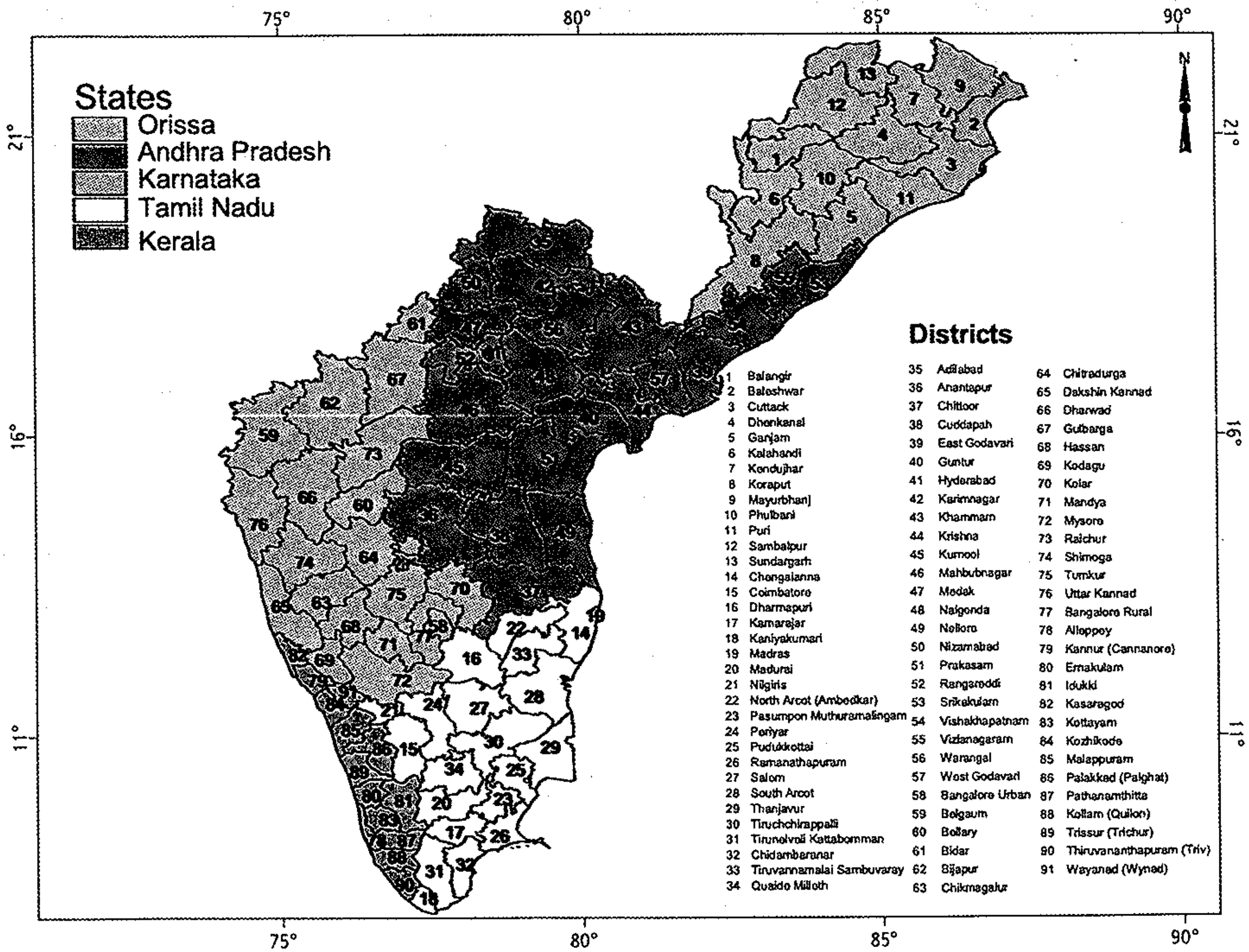


Figure 3.1. Administrative map of peninsular India.

Peninsular India is characterized by hot, semi-arid tropics with east coastal area having hot sub-humid climate, while the west coastal area has hot humid/pre-humid ecoregions. This region receives rainfall both from Southwest monsoons (rainy season) and Northeast monsoons (winter) with occasional cyclones. The rainfall received varies from very high (3343 mm) in Kerala to low (747 mm) in the southern parts of the Deccan Plateau in Andhra Pradesh and Tamil Nadu (Fig. 3.4). Most of the central region (Deccan Plateau) is considered as an area with erratic and low rainfall, wherein crops suffer from both soil and atmospheric drought.

The soil types in peninsular India are presented in Figure 3.5. Though varied soil types exist, deltaic alluviums are predominant in coastal areas where lowland rice is grown traditionally (Godavari, Krishna, and Cauveri deltas). The soils in other command areas vary from light soils in Orissa state and Telangana in Andhra Pradesh to Vertisols in Andhra Pradesh and Karnataka states.

The mean annual temperatures in peninsular India vary from 14°C to 28°C (Fig. 3.6). Although mean temperatures are moderate

(24–26°C), the day temperatures in peninsular India are usually high with >40°C in summer (March–May). The night temperatures in winter (November–January) are mild (around 15°C) which permits cultivation of legumes such as mung bean (*Vigna radiata* (L.) Wilczek) and black gram (*Vigna mungo* (L.) Hepper) round the year. There are areas, according to elevation and latitude, where winter temperatures are <15°C, enabling cultivation of chickpea (*Cicer arietinum* L.), a winter crop.

The length of growing period varies from 74 days to >329 days in the different regions in peninsular India (Fig. 3.7). However, most areas have 90–179 days permitting cultivation of at least one crop a year. The growing season of legumes in RBCS in different areas and seasons is usually between 65 days and 95 days.

The river waters from Mahanadi in Orissa; Vamsadhara, Godavari, Krishna, and Penna in Andhra Pradesh; Cauveri in Tamil Nadu; and Cauveri, Krishna, and Tungabhadra in Karnataka are utilized for irrigation through river valley projects. In addition to the traditional rice bowls in the delta regions of Mahanadi in Orissa, Godavari and Krishna in Andhra Pradesh, and Cauveri in Tamil Nadu, rice crop has been introduced, whenever a new irrigation potential was created. Thus, rice has become the major food crop in peninsular India replacing traditional rainfed sorghum (*Sorghum bicolor* (L.) Moench)/millets + legume cropping systems in the semi-arid tropics, and has relegated legumes to further marginal lands.

Unlike the perennial rivers in northern India, the rivers in peninsular India flow fully during rainy season only and the release of water in irrigation canals depends on the monsoons. Depending on the availability of irrigation water, the cultivation of rice varies from single crop to three crops a year in different command areas. Thus, not only monocropping but also cultivation of rice more than once on the same piece of land has become a practice. The yields of rice are therefore, stagnating in recent years. Introduction of a legume crop in rotation with rice offers promise to achieve sustainable high yields of rice in addition to meeting the growing demand for pulses.

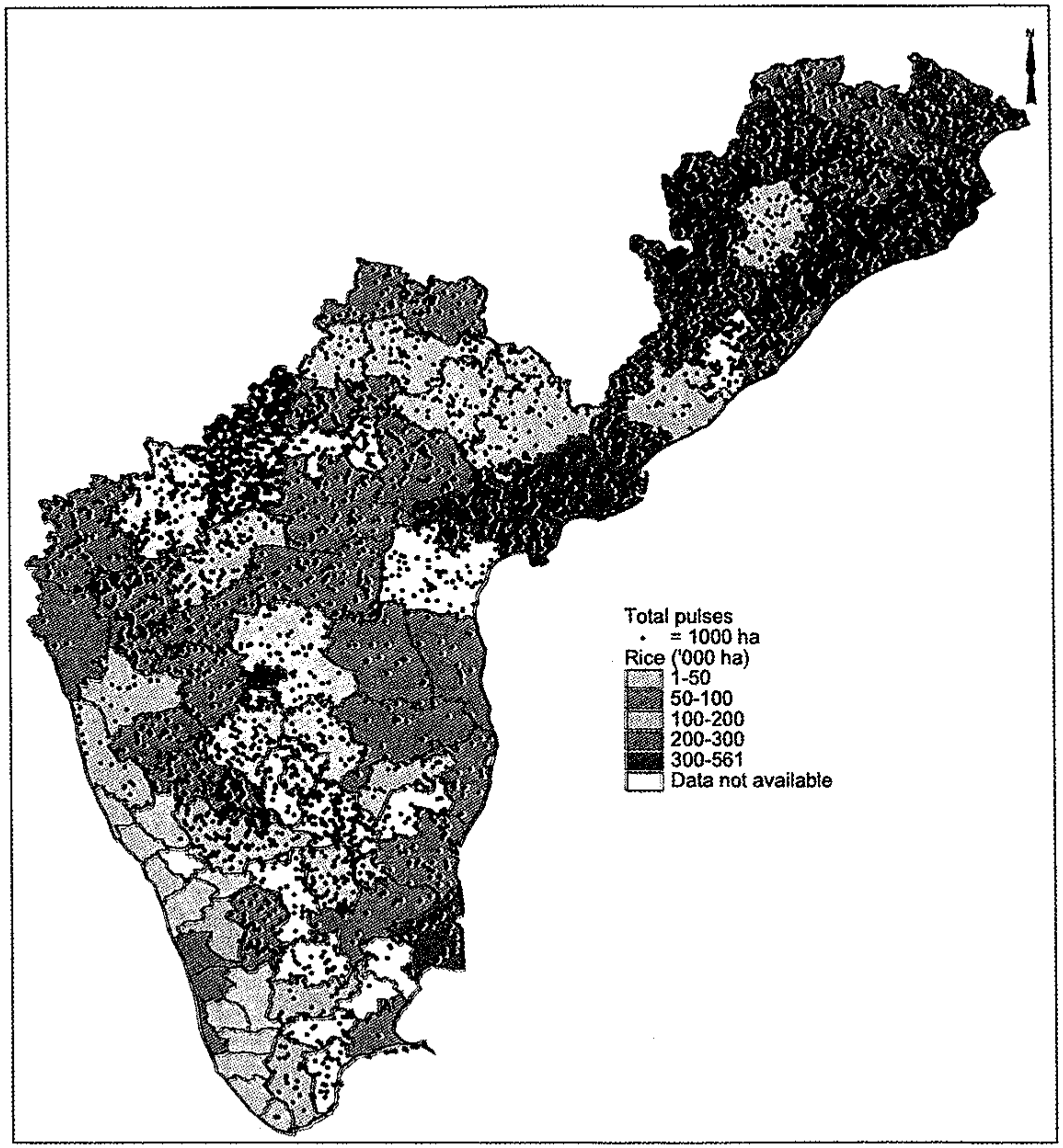
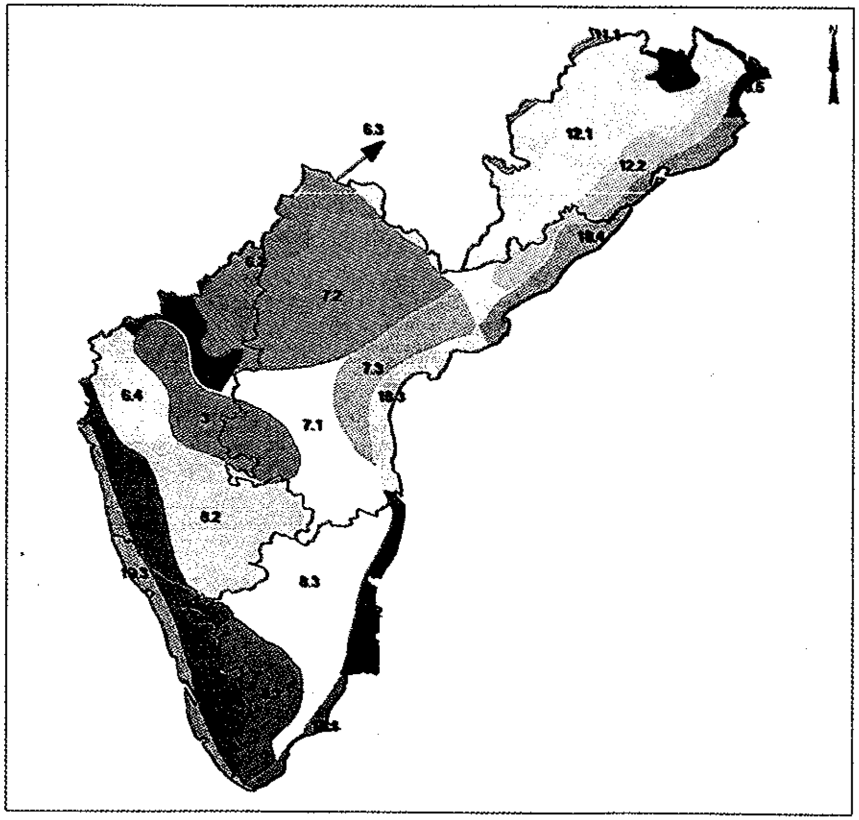


Figure 3.2. Comparison of total pulses and rice distribution in peninsular India, 1994.

A common feature of most lowland rice-growing areas is that legumes can be introduced either preceding or succeeding the rice crop. The sowing of legume crop depends on the sowing and harvest of rice crop, which in turn depends on the water released in canals. Rice is sown almost round the year in some parts of peninsular India. For example, the main season rice (rainy season) alone in Andhra Pradesh is sown right from June in East Godavari district to October in Prakasam and Nellore districts. Thus, introduction of a legume crop in RBCS and the management and varietal requirements vary in different regions due to location specificity. Some possibilities are given in Table 3.1. The legume crop grown in RBCS is usually a grain legume, occasionally with a fodder or green manure crop grown in summer or early season.



Agroecological subregions in Peninsular India

3 - Karnataka plateau, hot arid eco-subregion (ESR) with deep, loamy and clayey, mixed red and black soils, low to medium available water capacity (AWC), and length of growing period (LGP) 60-90 days.

6.1 - South western Maharashtra and North Karnataka plateau, hot dry semi-arid ESR with shallow and medium, loamy black soils, medium to high AWC, and LGP 90-120 days.

6.2 - Central and western Maharashtra plateau and North Karnataka plateau and North western Telengana plateau, hot moist semi-arid ESR with shallow and medium, loamy to clayey black soils, medium to high AWC, and LGP 120-150days .

6.3 - Eastern Maharashtra plateau, hot moist semi-arid ESR with medium and deep clayey black soils, medium to high AWC, and LGP 120-150 days.

6.4 - Moderately to gently sloping North Sahyadris and western Karnataka plateau, hot dry sub-humid ESR with shallow and medium, loamy and clayey black soils, medium to high AWC, and LGP 150-180 days.

7.1 - South Telangana plateau and Eastern Ghat, hot dry semi-arid ESR with deep loamy to clayey mixed red and black soils, medium AWC, and LGP 150-180 days.

7.2 - North Telangana plateau, hot moist semi-arid ESR with deep loamy and clayey mixed red and black soils, medium to very high AWC, and LGP 120-150 days.

7.3 - Eastern Ghats, hot moist semi-arid/dry sub-humid ESR with medium to deep, loamy to clayey mixed red and black soils, medium AWC, and LGP 150-180 days.

8.1 - Tamil Nadu uplands and leewards flanks of Sahyadris, hot dry semi-arid ESR with moderately deep to deep, loamy to clayey, mixed red and black soils, medium AWC, and LGP 90-120 days.

8.2 - Central Karnataka plateau, hot moist semi-arid ESR with medium to deep, red loamy soils, low AWC, and LGP 120-150 days.

8.3 - Tamil Nadu uplands and plains, hot moist semi-arid ESR with deep, red loamy soils, low AWC, and LGP 120-150 days.

11.1 Moderately to gently sloping Chattisgarh/Mahanadi basin, hot moist/dry sub-humid transitional ESR with deep, loamy to clayey, red and yellow soils, medium AWC, and LGP 150-180 days.

12.1 - Garjat Hills Dandakaranya and Eastern Ghats, hot moist sub-humid ESR with deep loamy, red and lateritic soils, low to medium AWC, and LGP 180-210 days.

12.2 - Eastern Ghats, hot moist sub-humid ESR with medium to deep loamy, red and lateritic soils, medium AWC, and LGP 180-210 days.

12.3 - Chhotanagpur plateau and Garjat Hills, hot, dry sub-humid ESR with moderately deep to deep, loamy to clayey, red and lateritic soils, medium AWC, and LGP 150-180 days.

18.1 - South Tamil Nadu plains, hot dry semi-arid ESR with deep, loamy to clayey, alkaline coastal and deltaic alluvium-derived soils, medium AWC, and LGP 90-120 days.

18.2 - North Tamil Nadu plains, hot moist semi-arid ESR with deep, clayey, cracking coastal and deltaic alluvium-derived soils, high AWC, and LGP 120-150 days.

18.3 - Andhra plains, hot dry sub-humid ESR with deep, clayey, coastal and deltaic alluvium-derived soils, low to medium AWC, and LGP 150-180 days.

18.4 - Utkal plain and East Godavari delta, hot dry sub-humid ESR with deep, loamy to clayey, coastal and deltaic alluvium-derived soils, medium AWC, and LGP 180-210 days.

18.5 - Gangetic delta, hot moist sub-humid to humid ESR with deep, loamy to clayey, coastal and deltaic alluvium-derived soils, medium AWC, and LGP 240-270 days.

19.1 - North Sahyadris and Konkan coast, hot humid ESR with medium to deep, loamy to clayey, mixed red and black soils, medium to high AWC, and LGP 210-240 days.

19.3 - Konkan, Karnataka and Kerala coastal plain, hot humid to per-humid transitional ESR with deep, clayey to loamy, acidic, coastal alluvium-derived soils, low AWC, and LGP 240-270 days.

Figure 3.3. Agroecological subregions in peninsular India (Source: NBSS & LUP, India).

Table 3.1. Possibilities of introducing legumes in rice-based cropping systems in peninsular India.

Cropping system	Region
Pre-rice	
Legume-rice-legume (summer)	Andhra Pradesh (AP), Karnataka (in all command areas, where irrigation water isreleased late during rainy season and in tank-fed rice areas)
Post-rice	
Rice-legume (winter)	AP (Krishna delta), Orissa
Rice-legume (late winter)	AP (Penna delta), Tamil Nadu (Cauveri Delta)
Rice-rice-legume (summer)	AP (Godavari delta), Tamil Nadu (Cauveri delta)

Legumes in Peninsular India

Legumes cultivated in peninsular India are mung bean, black gram, pigeonpea (*Cajanus cajan* (L.) Millsp.), chickpea, soybean (*Glycine max* (L.) Merr.), cowpea (*Vigna unguiculata* (L.) Walp.), horse gram (*Macrotyloma uniflorum* (Lam.) Verdc.), groundnut (*Arachis hypogaea* L.), lablab bean (*Lablab purpureus* (L.) Sweet), and forage legumes such as (*Vigna trilobata* (L.) Verdc.), *Crotalaria juncea* L., and *Sesbania rostrata* Brem.

Among the legumes (or pulses, as they are popularly known) grown, black gram and mung bean are the major crops in RBCS, while groundnut is

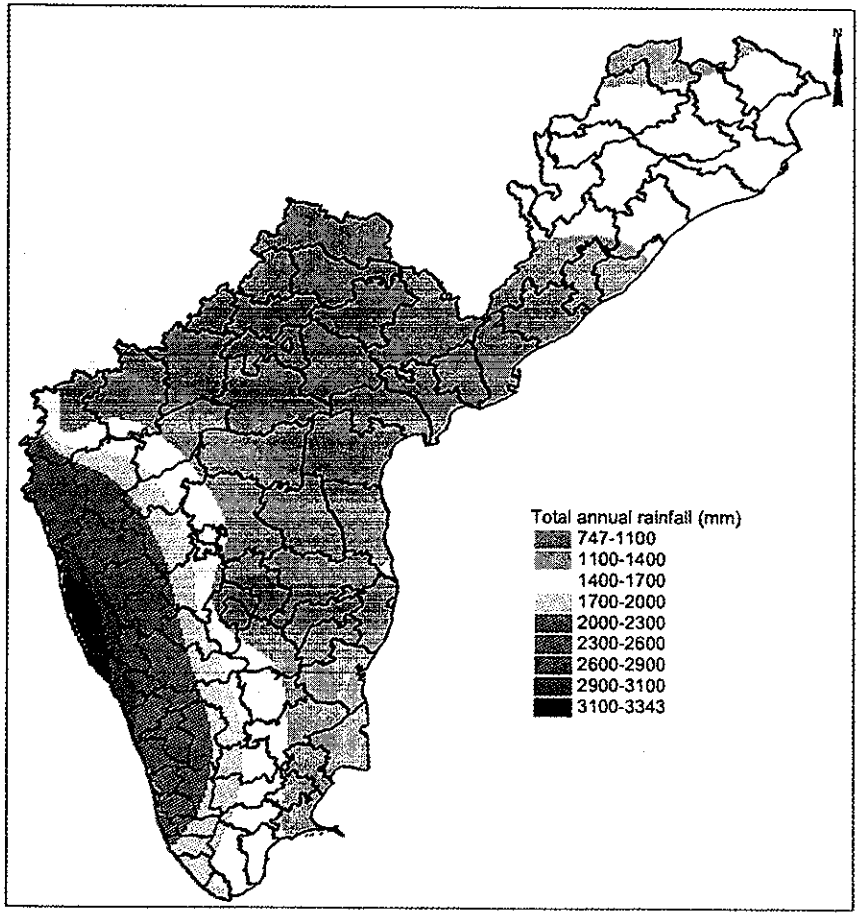


Figure 3.4. Rainfall distribution in peninsular India (Source: IWMI, Sri Lanka).

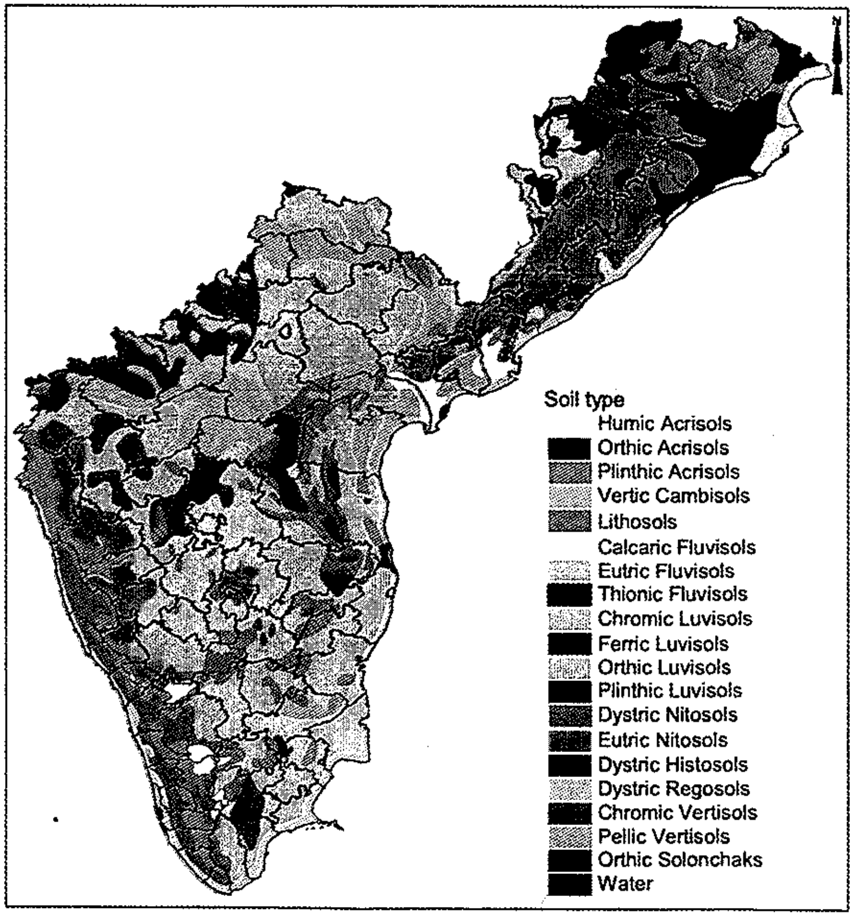


Figure 3.5. Soil map of peninsular India (Source: FAO, Rome, Italy).

grown after rice on coastal sandy soils during winter. Cowpea and horse gram are other grain legumes, occasionally cultivated in RBCS. Pigeonpea and chickpea are also major pulse crops of peninsular India, but are not grown extensively in RBCS at present. However, pigeonpea has great potential as a crop on rice field-bunds.

The area and production of major grain legumes (Fig. 3.8) have remained nearly stagnant over the past three decades. With increase in population, during the same period, the per capita availability (38 g capita^{-1} day^{-1}) is far from the desired norms of the requirement (80 g capita^{-1} day^{-1}). Trends in area, production, and yield of mung bean, black gram, pigeonpea, and chickpea in different states in peninsular India are given in Figures 3.9, 3.10, 3.11, and 3.12. Area and production of mung bean in peninsular India have decreased substantially. Area has decreased from 1.65 million ha in 1990 to 0.8 million ha in 1994, mainly due to decreased area and production in Karnataka (Fig. 3.9). Area under black gram has reduced from about 1.0 million ha to 0.8 million ha, with proportionate reduction in production

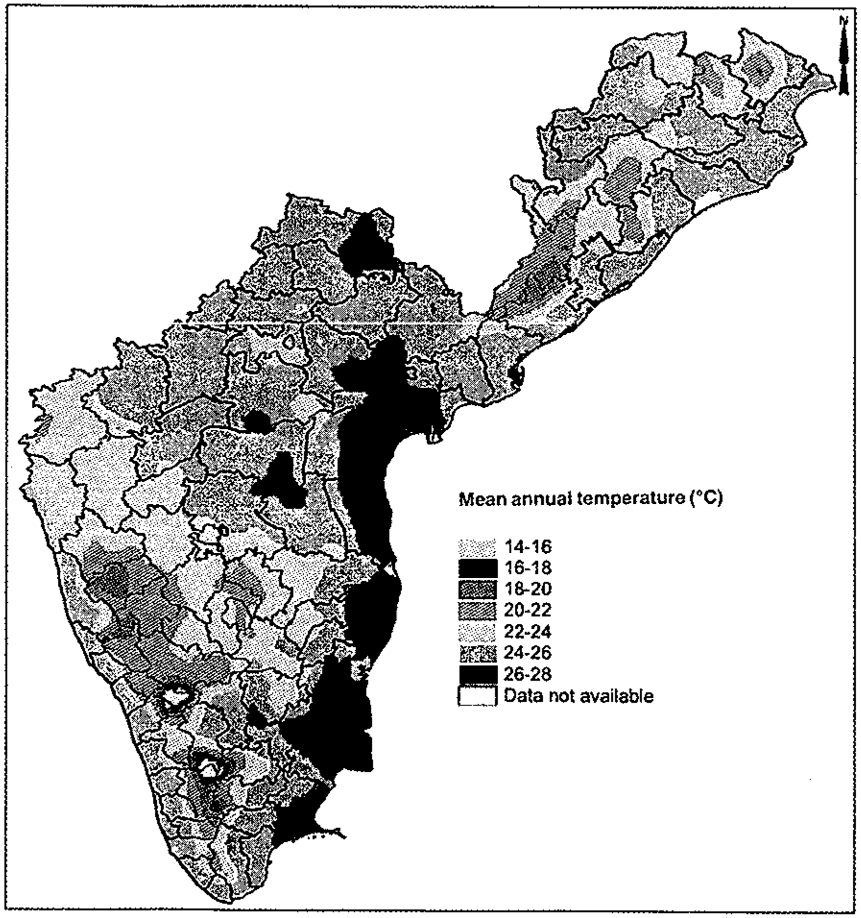


Figure 3.6. Mean annual temperature in peninsular India (Source: IWMI, Sri Lanka).

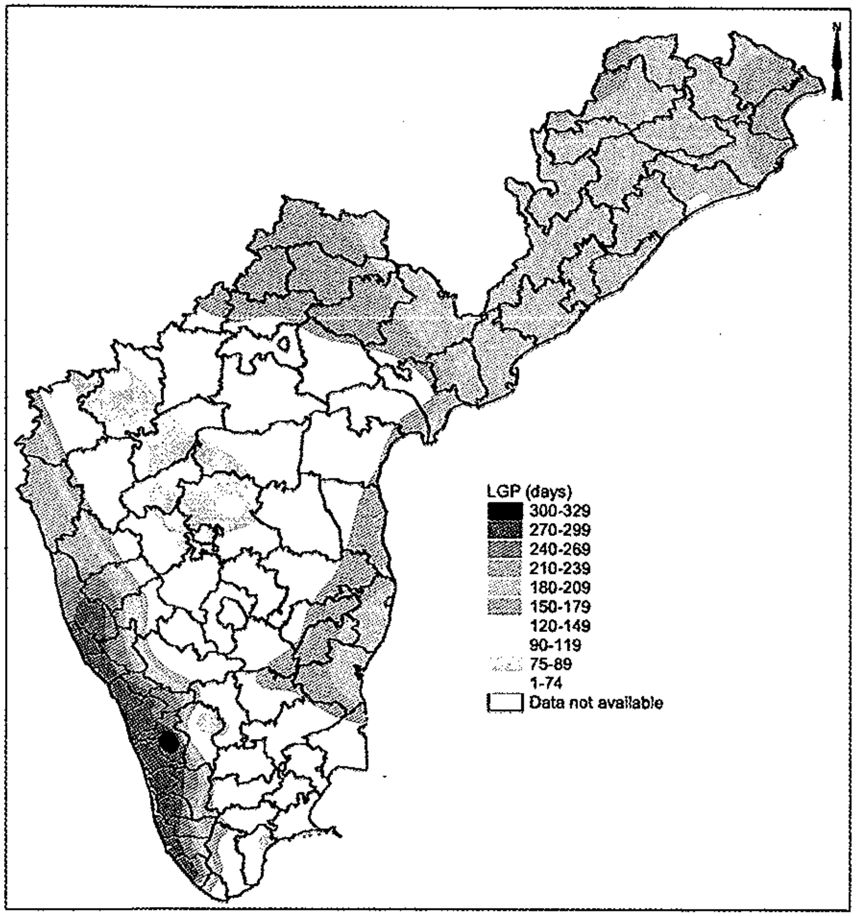


Figure 3.7. Length of growing period (LGP) in peninsular India (Source: IWMI, Sri Lanka).

(Fig. 3.10). Although area under black gram increased until 1992, there was reduction in Andhra Pradesh after 1997, while a moderate increase was observed in Karnataka.

Pigeonpea has shown substantial increase in area, production, and yield in peninsular India (Fig. 3.11), due to increase (although to varying degrees) in all states, except in Karnataka where there has been a reduction in yield. Area, production, and yield of chickpea show increasing trends in peninsular India (Fig. 3.12). This increase is mostly due to increases in Andhra Pradesh and Karnataka, while there was marginal decrease in Tamil Nadu and Orissa. The

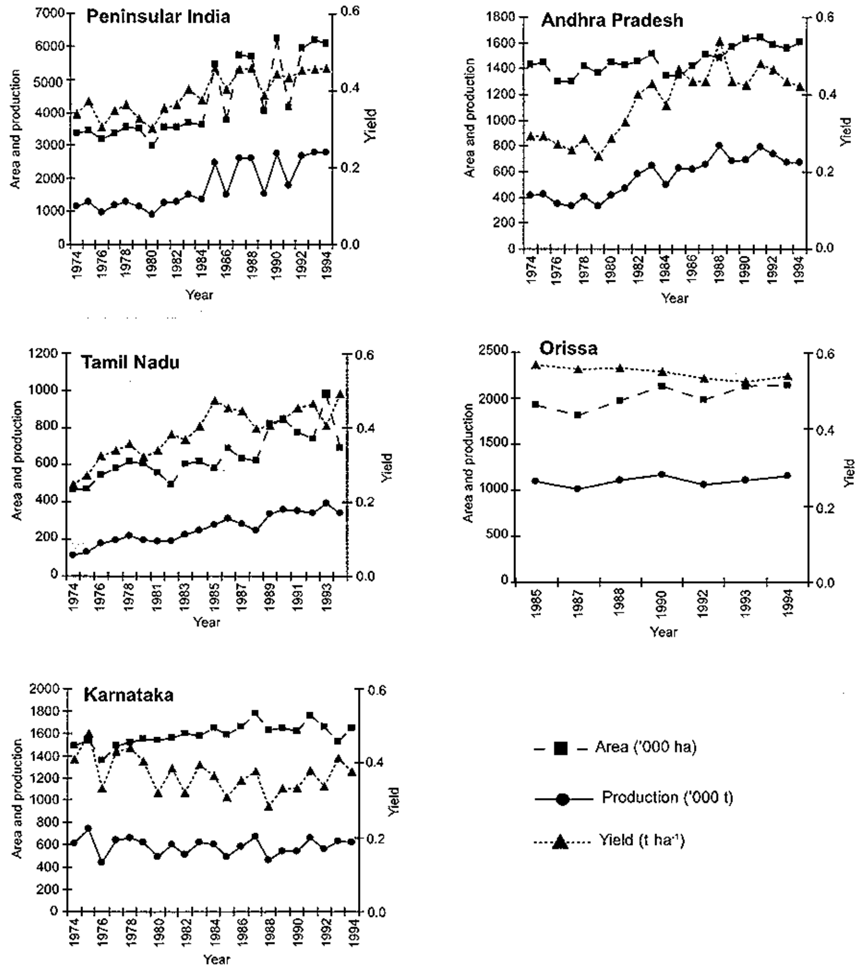


Figure 3.8. Area, production, and yield of total pulses in peninsular India.

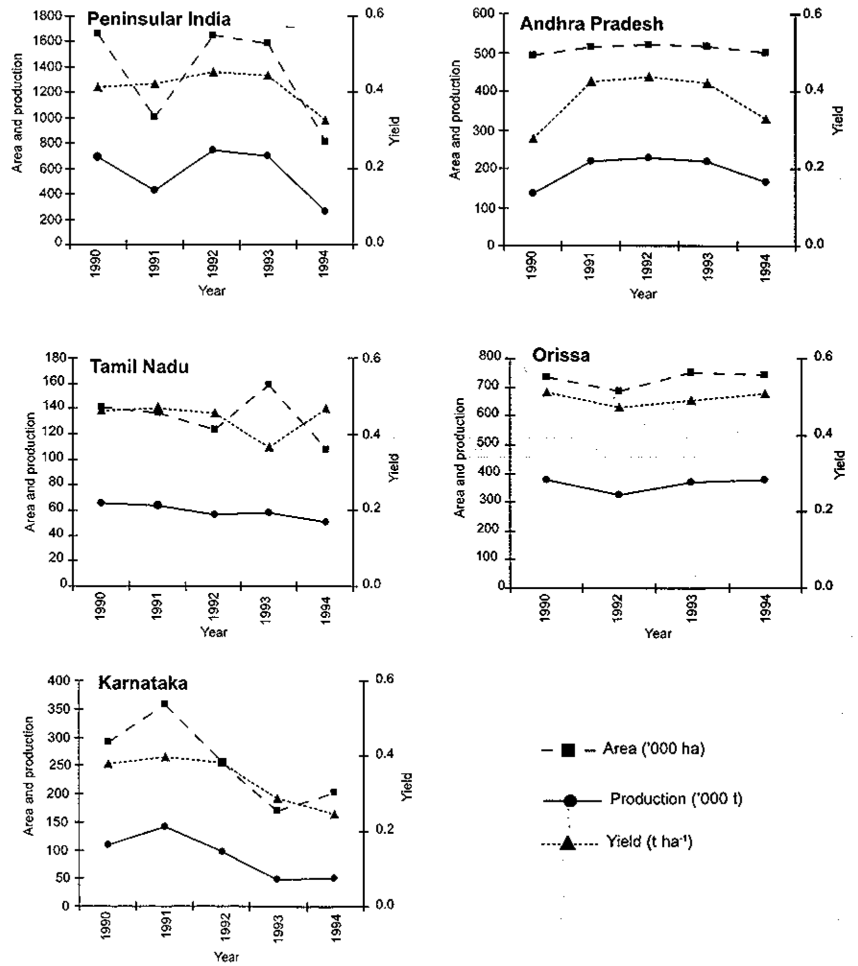


Figure 3.9. Area, production, and yield of mung bean in peninsular India.

increase in chickpea area, production, and yield is mostly due to introduction of short-duration, fusarium wilt resistant varieties.

Although, groundnut is widely grown in peninsular India (Fig. 3.13), the extent of its cultivation in rice-based system is minimal (around 5%). Horse gram is a minor crop, but grown across different states, mostly as a post-rice crop. It is also cultivated in other cropping systems.

Constraints to Legumes Production in Rice-based Cropping Systems

The problems of low productivity of legumes have been discussed at length in various forums and various measures to overcome problems were suggested, but pulses production has remained stagnant. Where did the planning go wrong? The problem of legumes production should not be viewed in isolation. These crops should be included in various cropping systems so that they share the advantage of fertile lands and better management. At the same time, the main cereal crops get the beneficial effect of legumes, which ultimately leads to sustainability (Prasad 1998). Legumes have been domesticated under rainfed ecosystems. Hence, growing these in RBCS offers more challenges than any other cropping system because optimal soil conditions for rice and grain legumes differ substantially.

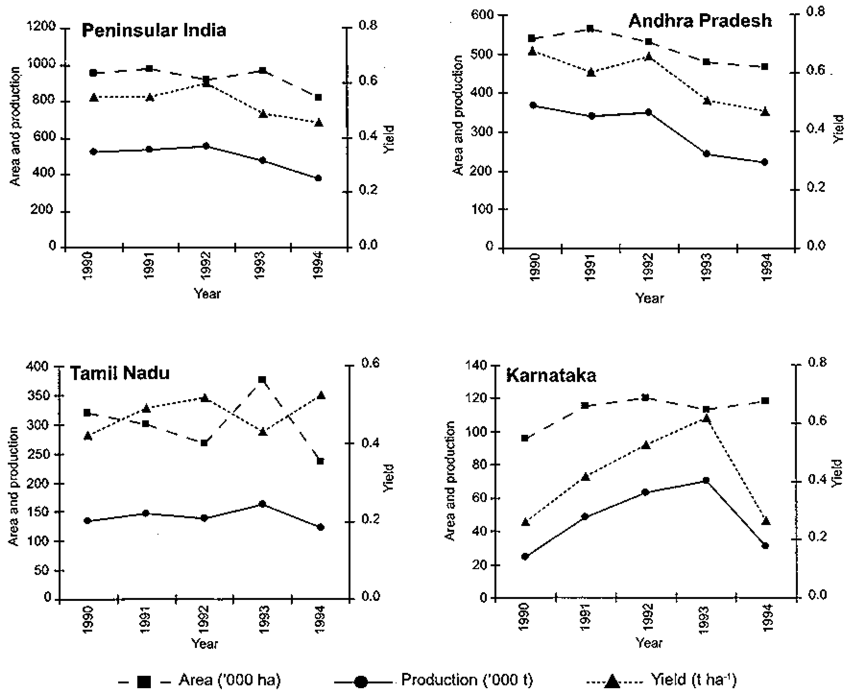


Figure 3.10. Area, production, and yield of black gram in peninsular India.

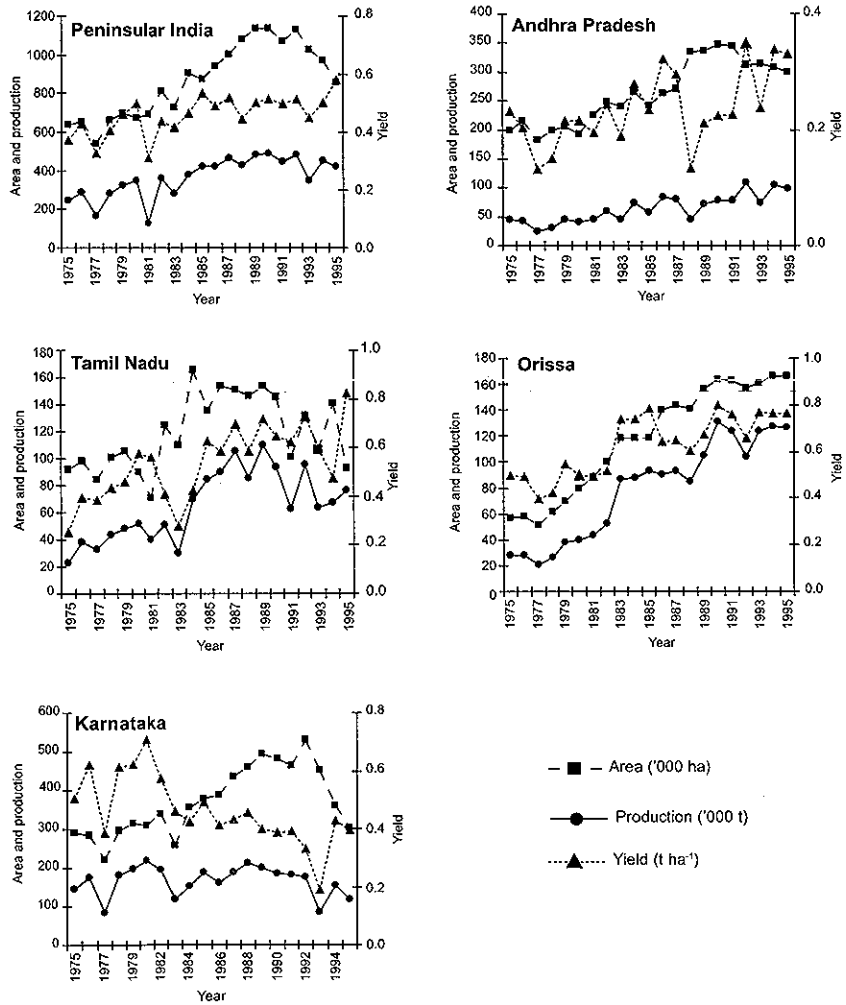


Figure 3.11. Area, production, and yield of pigeonpea in peninsular India.

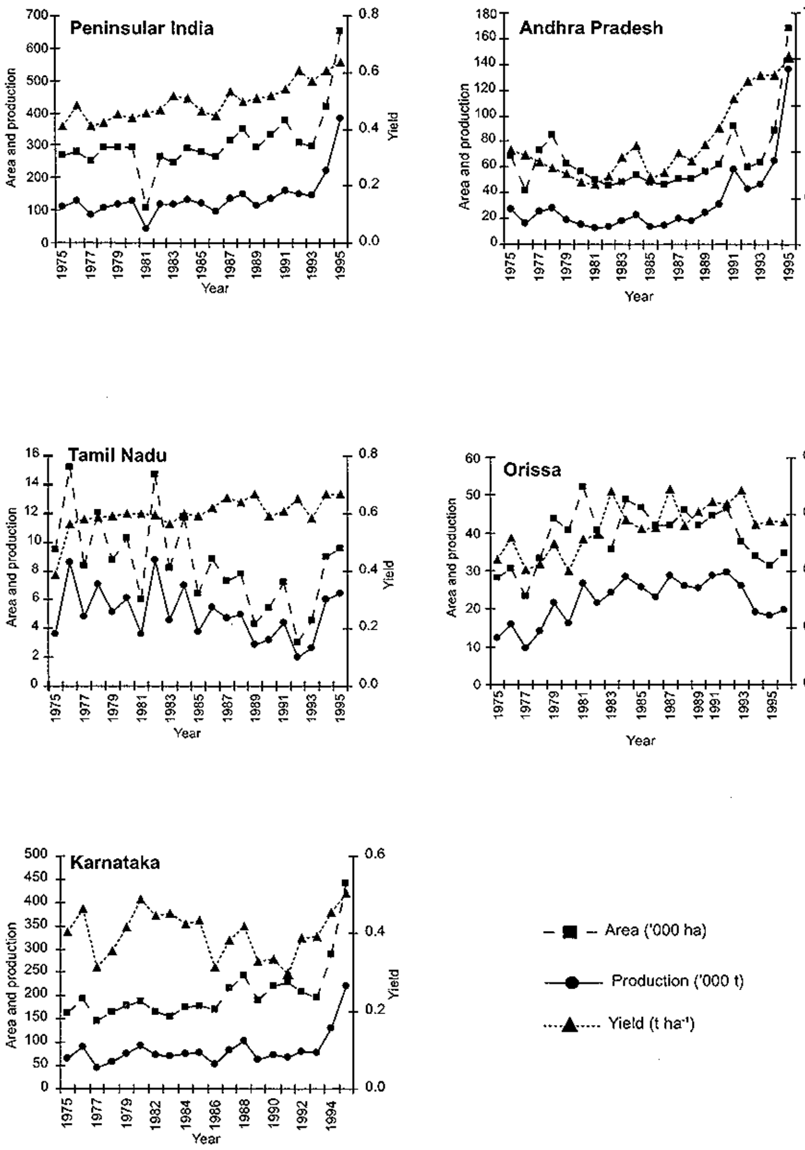


Figure 3.12. Area, production, and yield of chickpea in peninsular India.

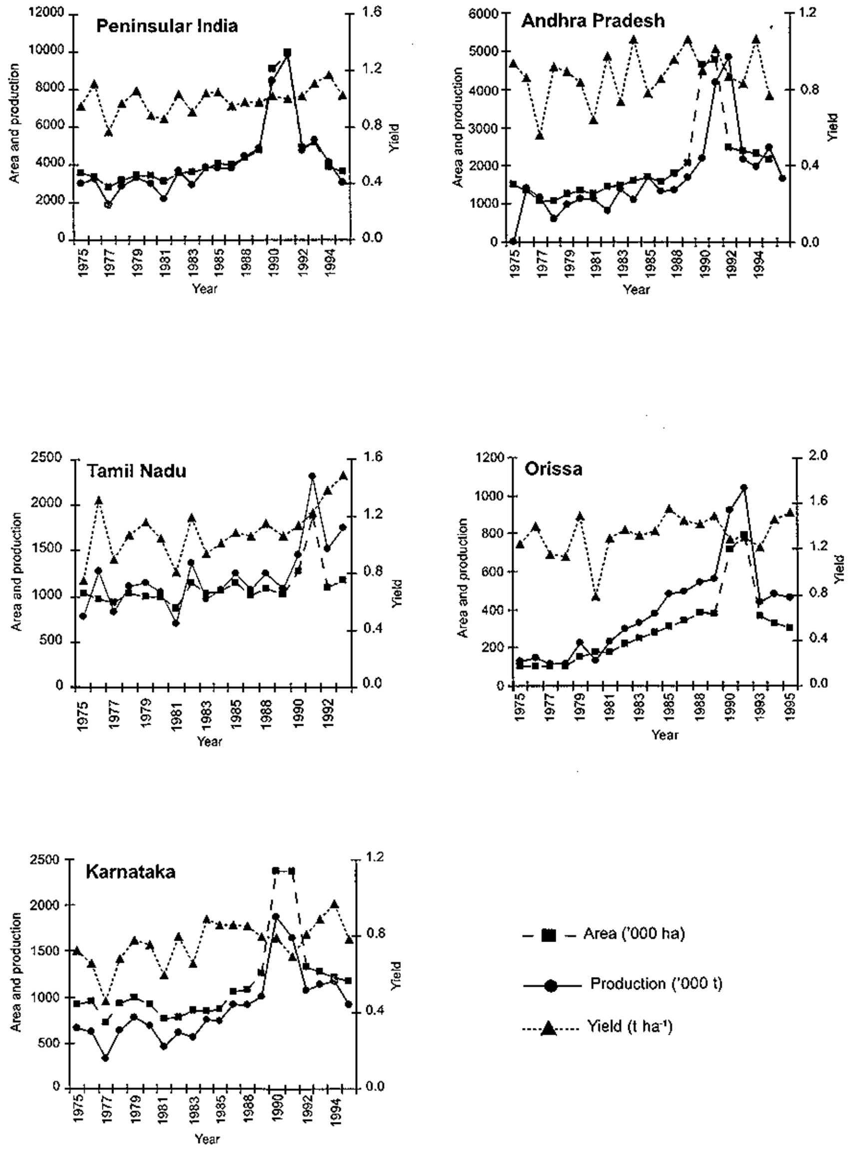


Figure 3.13. Area, production, and yield of groundnut in peninsular India.

Soil-related Constraints

- Hard and compact soil (due to puddling), resulting in restricted infiltration rate, aeration, seedling emergence, and root growth.
- Reduced porosity limiting the diffusion rate of nutrients such as phosphorus and micronutrients.
- Low organic matter resulting in poor water-holding capacity.
- Anaerobic conditions leading to production of phytotoxins and poor nodulation.
- High incidence of soilborne diseases caused by fungi (e.g., *Fusarium* spp and *Rhizoctonia* spp).

Agronomic Constraints

- Slow water loss from puddled soils limits early seedbed preparation for timely sowing of succeeding legume crops.
- Broadcasting of seed in standing rice crop (relay cropping) results in poor plant stand establishment.
- Excessive soil moisture and cooler temperatures at the time of sowing (post-rice) results in slow and early growth.
- Moisture and heat stress at terminal stages of crop growth leads to forced maturity and results in poor seed-filling and low yields.

Varietal Constraints

The low genetic yield potential of legumes in comparison to rice or wheat (*Triticum aestivum* L.), have been attributed to their domestication process aimed at survival in harsh environments. The existing yield potential of legumes is not being realized due to susceptibility to various diseases and pests. Improved, high-yielding varieties with resistance to major pests and diseases have been developed and released recently. However, adoption of these varieties is low because of lack of availability of good quality seed to farmers. Mung bean and black gram are extensively grown under rice fallows, while pigeonpea has scope as a bund crop. However, with concerted research efforts, both chickpea and pigeonpea can be cultivated in RBCS.

Biotic and Abiotic Constraints

The major biotic and abiotic constraints to production of grain legumes in peninsular India with special emphasis on RBCS are discussed below.

Mung bean

The production constraints and their intensity vary with growing season under RBCS in different states of peninsular India. Among diseases, angular black leaf spot is important only in the Telangana region of Andhra Pradesh, while yellow mosaic and leaf curl are important in all the states (Table 3.2 and Fig. 3.14). Powdery mildew is important on winter crop, i.e., under rice fallows. Among the abiotic stresses, pre-harvest sprouting is important when mung bean is grown as a preceding crop to rice (Table 3.2 and Fig. 3.15). This has been also recognized as the most important constraint at the national level.

Black gram

Black gram is the most widely cultivated legume under RBCS in peninsular India. The major constraints to black gram production are given in Table 3.2. Wilt is most important in Krishna delta region of Andhra Pradesh. Corynespora leaf spot and rust are problems in Andhra Pradesh and Tamil Nadu, while powdery mildew is a problem throughout the area (Fig. 3.16). With heavy dependence on chemical fertilizer in rice cultivation, salinity is on the increase in coastal rice-growing areas. In recent years, *Maruca* has emerged as the major pest of the crop. Among abiotic stresses, terminal drought and salinity are major problems in some areas (Fig. 3.17).

Pigeonpea

Fusarium wilt (*Fusarium udum*) and sterility mosaic are the major diseases of pigeonpea (Fig. 3.18). Other important diseases are web blight (*Rhizoctonia solani*) and stem canker (*Macrophomina phaseolina*). Pod borers are the major pests; *Helicoverpa armigera* is important, followed by *Maruca vitrata*.

Chickpea

Chickpea is not a major crop under RBCS in peninsular India but has potential for expansion, especially in Andhra Pradesh, Karnataka, and Orissa. Genotypes that establish under high initial soil moisture need to be developed. Major diseases are fusarium wilt (*Fusarium oxysporum* f. sp *ciceris*), collar rot (*Sclerotium rolfsii*), and dry root rot (*Rhizoctonia bataticola*) (Fig. 3.19). *Helicoverpa* pod borer is the major pest.

Groundnut

Among various biotic constraints, diseases (fungal and viral) play a vital role in groundnut production (Table 3.3). Crown rot, stem rot, and bud necrosis are of minor importance throughout peninsular India while bud necrosis is important in some pockets causing epidemic situation (Fig. 3.20). Early and late leaf spots and rust are widely distributed, and also cause substantial damage in many areas (Fig. 3.21). Among insect pests, leaf miner, *Spodoptera*, and *Helicoverpa* are widespread throughout the region and are of much

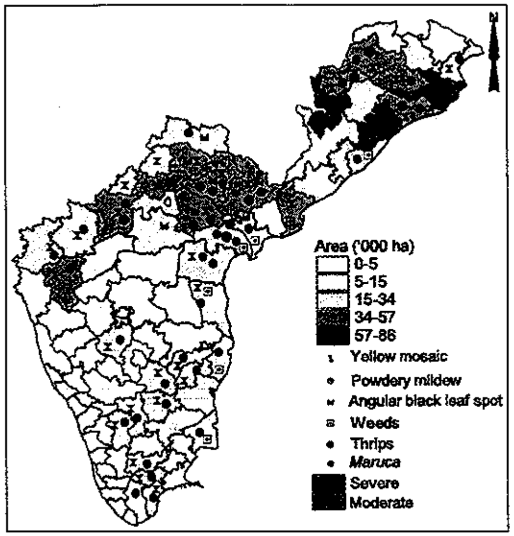


Figure 3.14. Biotic stresses of mung bean in peninsular India,1996 (Note: Data of Karnataka state is for 1994).

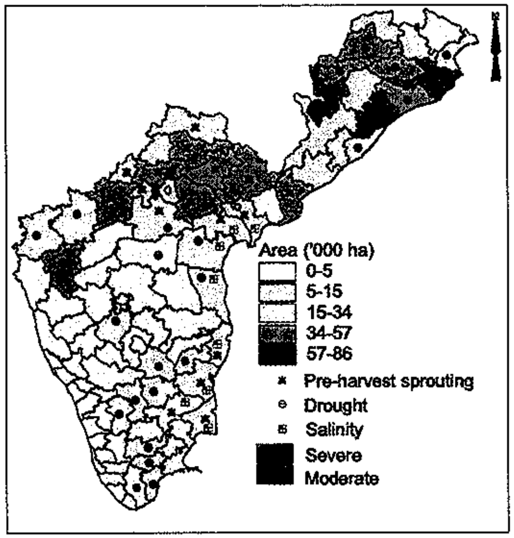


Figure 3.15. Abiotic stresses of mung bean in peninsular India,1996 (Note: Data of Karnataka state is for 1994).

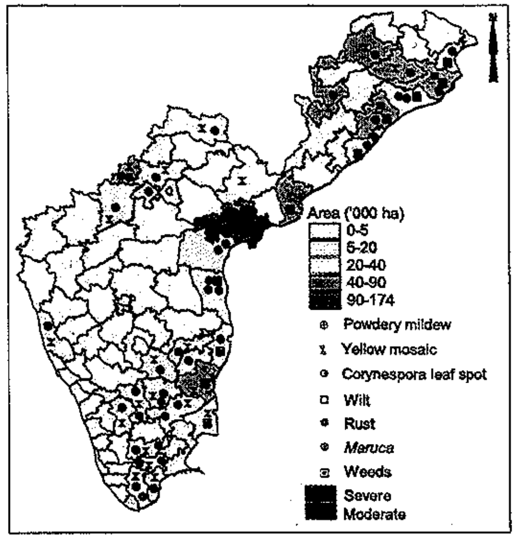


Figure 3.16. Biotic stresses of black gram in peninsular India,1996 (Note: Data of Karnataka state is for 1994).

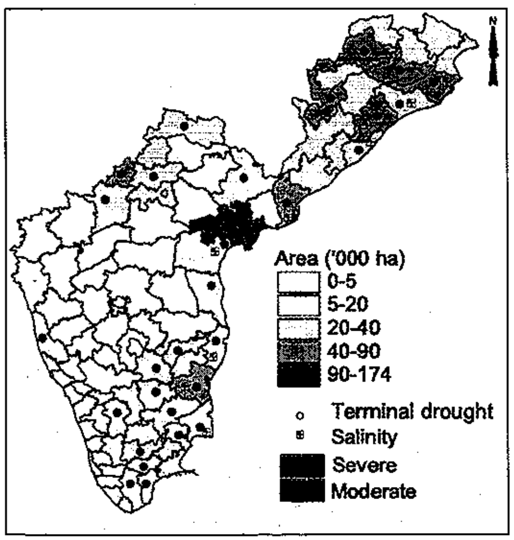


Figure 3.17. Abiotic stresses of black gram in peninsular India,1996 (Note: Data of Karnataka state is for 1994).

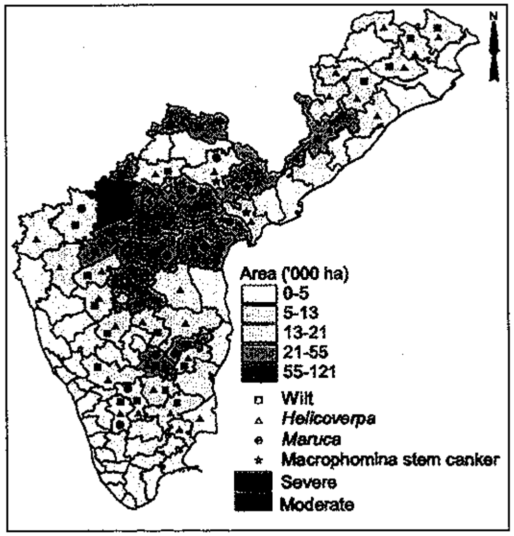


Figure 3.18. Biotic stresses of pigeonpea in peninsular India,1996 (Note: Data of Karnataka state is for 1994).

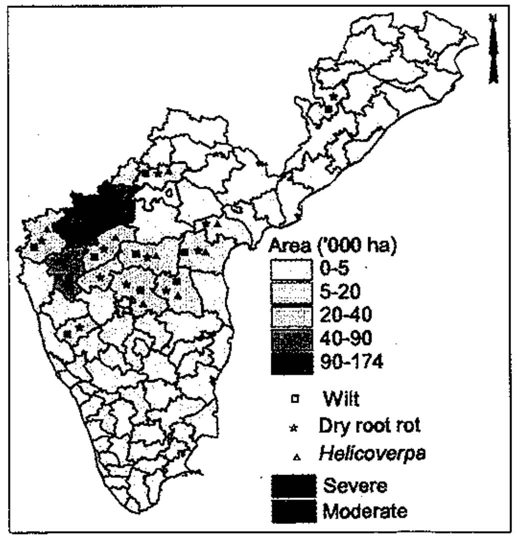


Figure 3.19. Biotic stresses of chickpea in peninsular India,1996 (Note: Data for Karnataka state is for 1994).

Table 3.2. Major biotic and abiotic constraints for production of mung bean and black gram in peninsular India.

Disease (Pathogen)	Insect pests	Abiotic constraints
Mung bean		
Yellow mosaic (mung bean yellow mosaic virus)	Thrips (*Scirtothrips dorsalis* Hood)	Pre-harvest sprouting
Leaf curl (tomato spotted wilt virus)	Maruca (*Maruca vitrata* Gey.)	Drought
Angular black leaf spot (*Protomycopsis phaseoli*)	Pod borer (*Helicoverpa armigera* Hübner)	Salinity
Powdery mildew (*Erysiphe polygoni* DC.)		
Cercospora leaf spot (*Cercospora cruenta* Sacc.)		
Black gram		
Powdery mildew (*Erysiphe polygoni* DC.)	Maruca (*Maruca vitrata* Gey.)	Terminal drought
Wilt (*Fusarium* sp)	Thrips (*Scirtothrips dorsalis* Hood)	Salinity
Rust (*Puccinia* sp)	Pod borer (*Spodoptera litura* F.)	
Yellow mosaic (mung bean yellow mosaic virus)		
Corynespora leaf spot (*Corynespora* sp).		

concern. Red hairy caterpillar is sporadic in nature and may reach alarming situation in some pockets of Andhra Pradesh, Karnataka, and Tamil Nadu (Fig. 3.22). Integrated disease and pest management options are now available, and are being evaluated in several farmers' fields.

Table 3.3. Major biotic constraints to groundnut production in peninsular India.

Disease (Pathogen)	Insect pests
Crown rot (*Aspergillus niger* Tiegh.)	Leaf miner (*Aproaerema modicella* Dev.)
Stem rot (*Sclerotium rolfsii* Sacc.)	Armyworm (*Spodoptera litura* F.)
Bud necrosis (bud necrosis virus)	Pod borer (*Helicoverpa armigera* Hübner)
Late leaf spot (*Phaeoisariopsis personata* (Berk. & Curtis) v. Arx)	Red hairy caterpillar (*Amsacta albistriga* Walk.)
Early leaf spot (*Cercospora arachidicola* Hori.)	
Rust (*Puccinia arachidis* Speg.)	

Drought is the only major constraint in most parts of the groundnut tract affecting the crop at different stages.

Horse gram

Horse gram is a cover crop under RBCS used both for grain and fodder. The major production constraints include dry root rot and yellow mosaic diseases (Fig. 3.23).

Sowing time

The sowing time of post-rice legume crops varies according to regions and cropping systems. Under rice-legumes cropping system, the normal sowing date of black gram or mung bean is during the second fortnight of November in Orissa, and in northern coastal and south coastal areas and Krishna delta in Andhra Pradesh; and in January in Cauveri delta in Tamil Nadu. Though the cropping system is the same, the production constraints vary with the sowing time. When sowings are delayed, as in January, the crops are vulnerable to cool temperatures at sowing and moisture stress at harvest. Under normal sowings in November, black gram suffers from powdery mildew, wilt, and corynespora leaf spot. The disease scenario shifts under late-sown conditions and yellow mosaic becomes a major problem in some legumes.

Weeds

Weeds are a menace in rice fallows because limited or no tillage is done. Herbicide application in standing rice crop is not feasible and manual weeding in rice fallows is rare. Therefore, weeds should be managed by smothering effect of the legumes grown. The parasitic weed *Cuscuta* sp has become a serious problem in recent years on legumes in RBCS.

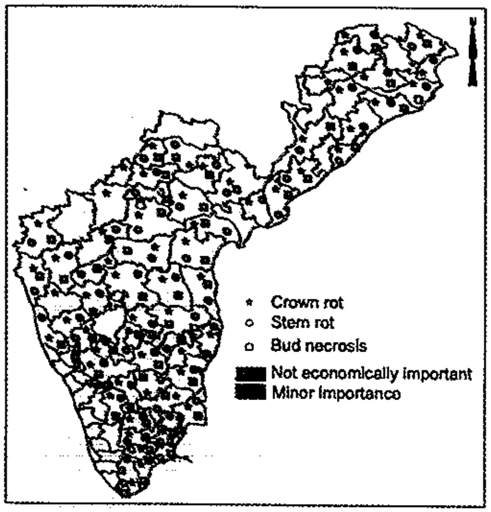


Figure 3.20. Prevalence and economic importance of three minor diseases of groundnut in peninsular India (Source: S. Pande et al., ICRISAT).

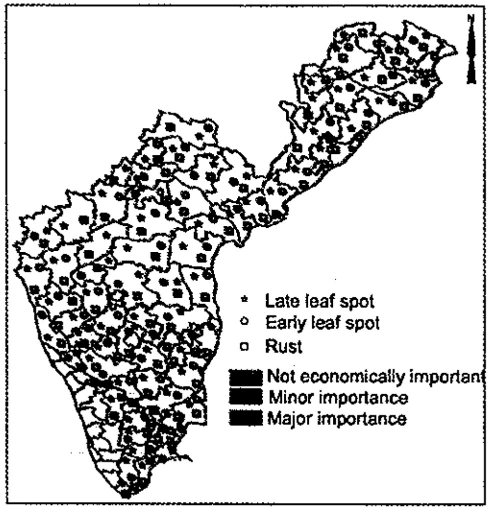


Figure 3.21. Prevalence and economic importance of foliar diseases in groundnut in peninsular India (Source: S. Pande et al., ICRISAT).

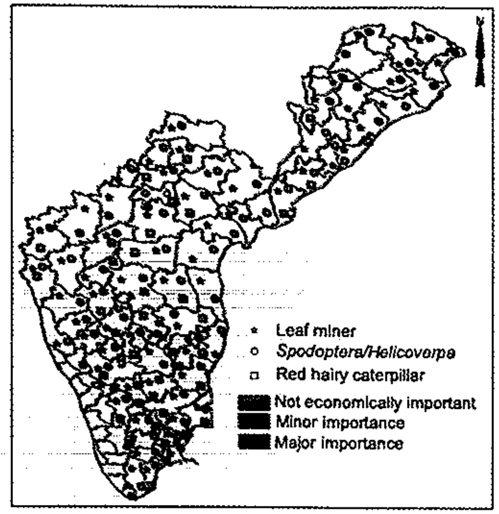


Figure 3.22. Prevalence and economic importance of major pests of groundnut in peninsular India (Source: S. Pande et al., ICRISAT).

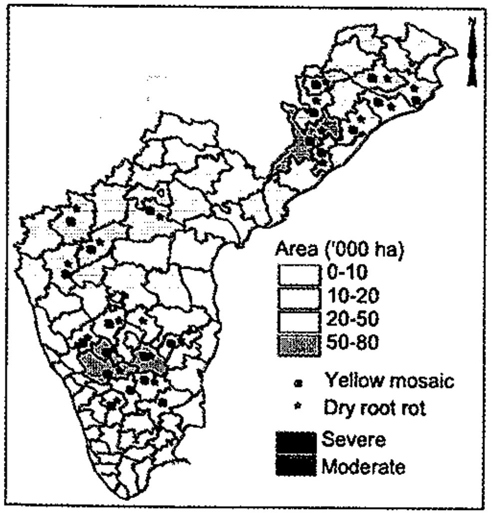


Figure 3.23. Biotic stresses of horse gram in peninsular India, 1996 (Note: Data of Karnataka is for 1994).

Role of Legumes in Rice-based Cropping Systems

Peninsular India is self-sufficient in rice production. With the development of irrigation potential, the area under rice has increased both under major and minor irrigation projects. However, only 10–12% of rice area is cropped with legumes at present (Fig. 3.2). Cultivation of rice as a monocrop and with heavy dependence on chemical fertilizers has resulted in the deterioration of soil health and stagnation of rice yields. Introduction of a grain legume aims at increased productivity of both rice and pulses with increased profitability to achieve food and nutrition security and sustainability (Paroda 1997, Swaminathan 1998).

The potential cropping systems for introducing a legume in RBCS are given below:

- One rice crop replaced in a three-crop rice system in southern Andhra Pradesh and Tamil Nadu (rice-legume-rice).
- Two rice crops followed by legumes in rice-rice system (rice-rice-pulse) of Godavari delta (Andhra Pradesh) and Cauveri delta (Tamil Nadu).
- Legumes in winter after single crop rice in Krishna delta (Andhra Pradesh) (rice-legumes-green manure).
- Legume crops preceding rice in Nagarjunasagar command area of Andhra Pradesh (legume-rice-green manure) and in all the new command areas in Karnataka.
- Legume green manure crop, whenever possible, between rice crops depending on the availability of water and duration of the rice crop.

Prospects for Increasing Production of Grain Legumes in Rice-based Cropping Systems

The yields of grain legumes are generally low when grown after rice due to poor physical conditions of the previously puddled soils. Hence, production of both rice and grain legume crops should not be viewed separately but as a system. Some factors influence grain legumes in RBCS:

- Duration of rice variety affects sowing time of legumes, but rice variety per se has no influence on legume productivity.
- Fertilizers (especially nitrogen and phosphorus) applied to rice influence productivity of the subsequent legume crop.
- Scope for fertilizer application to legume crops is less; hence foliar application of nutrition may be tried.
- Sowing of grain legume in the standing rice crop by broadcast requires higher seed rate to achieve optimum plant population and density.

Grain Legume Improvement for Rice-based Cropping Systems

Since agronomic management alone cannot overcome the constraint to productivity of grain legumes in rice fallows, developing a suitable genotype appears to be one of the alternatives (Satyanarayana 1988). Targeted breeding in mung bean (medium-duration, synchronous podding, resistance to major diseases) and black gram (short-duration, fruit-bearing habit, resistance to diseases, seedling vigor) have been successful (Satyanarayana et al. 1994). This resulted in large-scale adoption of varieties, as exemplified by the black gram success story in Andhra Pradesh.

Success Story of Black Gram in Rice-fallows in Andhra Pradesh

Muehlbauer et al. (1998) have quoted the success of black gram in Andhra Pradesh as an emerging trend in legumes. Although black gram had been traditionally cultivated after rice in coastal regions of Andhra Pradesh, it was considered only as subsistence crop with yields usually below 0.5 t ha^{-1}. Following a comprehensive constraint analysis for black gram in the 1980s, whereby powdery mildew was identified as the major yield reducer, a targeted cultivar improvement program was initiated (Satyanarayana et al. 1994), and a resultant cultivar, LBG 17, had yield potential of 1.5 t ha^{-1} in farmers' fields under minimal management conditions. Under ideal conditions, LBG 17 had a yield potential exceeding 2.5 t ha^{-1}. This cultivar catalyzed commercialization of the crop on a large scale as a rice-fallow crop and has stimulated further research on cultivar and agronomic improvement. Black gram production in rice fallows in Andhra Pradesh largely contributed to the large yield and area increase in the state during the 1980s from 410 kg ha^{-1} (on 219,000 ha in 1981/82) to 737 kg ha^{-1} (on 560,000 ha in 1991/92) (Satyanarayana et al. 1994).

Thus, understanding the local specific problems, and developing technologies for targeted areas (Lal 1997) will certainly help to achieve not only self-sufficiency of legumes but also sustainability of production systems. Awareness about the utility of grain legumes in human food, animal feed, and soil health is increasing, but with increased area under irrigation, the pulse crops are relegated to marginal and sub-marginal lands. At the same time, productivity of the irrigated crops such as rice and wheat has become stagnant with increased biotic and abiotic stresses and soil health problems due to continuous monocropping. Thus, there is a need for generating appropriate technology for introduction of pulses into RBCS to improve crop production on sustainable basis (Khush and Baenziger 1998).

The genetic improvement of legume crops at international and national research centers have long been hampered by the perceived need to develop genotypes for wide adaptation and not for specific areas. A more decentralized breeding to improve grain legumes for specific adaptation to RBCS is needed, if these have to play a significant role in future towards sustainability of RBCS, and global agriculture.

Strategies for Improving Legumes Production

As mentioned earlier, the strategies for improving production in RBCS have to be holistic, and hence complex. Management and production practices of the whole cropping system determine the success of improving legumes production. Some of the major issues are discussed here.

Management Options

- Effect of puddling on establishment and productivity of legumes after rice.
- Sowing methods to ensure optimum soil moisture for germination and crop establishment.
- Weed management to avoid competition with legumes in the early stages of growth.
- Optimum fertility and nutrient management, including green manuring and organic matter recycling.
- Water management for rice to avoid excess water during early stages (seedling) and moisture stress during maturity of legumes.

Genetic Options

- Improved plant type/architecture of legumes, including synchronous podding, tolerance to pre-harvest sprouting, early vigor, and canopy structure.
- Breeding for short-duration (of both rice and legumes) to fit into the cropping systems.
- Incorporating resistance to major pests and diseases to avoid yield losses.
- Breeding for adaptation to late sowing and tolerance to low temperatures.
- Introduction of new crops in non-traditional areas (e.g., pigeonpea on field bunds; and relay-sown chickpea).

Policy Issues

National policies concerning the thrust to be given on legumes vis-à-vis other crops in view of their role in nutritional security and sustainability of cropping systems would determine the extent to which production and productivity could further be improved. The national programs should increase funding support to research and technology development and transfer activities, as they need to meet the new and emerging challenges in the RBCS. Development of infrastructure for irrigation, roads and markets, and for supply of inputs will give the necessary impetus for legumes cultivation. National policies on price and price support to legumes is essential to keep them competitive and profitable to farmers in comparison to cereals.

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4. Legumes in Tropical Rice-based Cropping Systems in Indonesia: Constraints and Opportunities

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Abstract

Soybean, groundnut, and mung bean are major legume crops in Indonesian agriculture, and are being emphasized by the food diversification program of the government to achieve self-sufficiency and food security. Legumes are an important protein source and a large component of the staple diet of most Indonesians. Legumes are also used as stock feed. The importance of these crops is also indicated by their increasing demand over the last decade. Projected demand by 2000, both as food and feed, has been estimated at 3.1 million t of soybean, 1.9 million t of groundnut, and 0.6 million t of mung bean. Although, national production of legumes has increased steadily during the last two decades, the rate of increase is much less than demand resulting in import of soybean, groundnut, and mung bean. Legumes are grown under varied environmental conditions. Rice-based cropping systems cover about eight million ha, and food legumes occupy about 16% cropped area. Cultivation of legumes is not widespread, but is mainly concentrated in Jawa Island. The productivity of these crops is much lower compared to cereals due to various biotic, abiotic, and socioeconomic factors. Insect pests, diseases, and weeds are the main biotic stresses. Pod borers and sucking insects are major insect pests. Rust and soybean mosaic in soybean, late leaf spot and peanut stripe in groundnut, and cercospora leaf spot in mung bean are the major diseases. Weeds are common problems in all the legume-growing areas. Among the abiotic constraints, drought and waterlogging are major yield reducers. Nutrient deficiency (both macro- and micronutrients) limit legume cultivation in some areas. Among the socioeconomic constraints, high cost of inputs (fertilizer and pesticide), instability of yield, and lack of price support influence the farmer to follow traditional practices for legume cultivation which leads to poor yield. The government has launched a new pilot production program (Gema Palagung) for the period 1998–2001 on rice, maize, and soybean to increase production and reduce import. The constraints and opportunities to legumes in rice-based cropping systems in Indonesia are discussed in detail.

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Introduction

Soybean (*Glycine max* (L.) Merr.), groundnut (*Arachis hypogaea* L.), and mung bean (*Vigna radiata* (L.) Wilczek) are traditional food legume crops in Indonesia. These crops play an important role in the proper nutritional balance of the rural and urban populations, particularly in lowland agriculture. The projected demand by 2000, both as food and feed, has been estimated at 3.1 million t of soybean, 1.9 million t of groundnut, and 0.6 million t of mung bean (Affandi 1986). Legumes occupy the fourth largest cropped area after rice (*Oryza sativa* L.), cassava (*Manihot esculenta* L.), and maize (*Zea mays* L.). Among the legumes, soybean is the major crop and contributes more than 59% of total legumes production in the country. Soybean (65%) and mung bean (52%) are mostly grown after rice in wetland areas, while only 39% groundnut is grown after rice. Most of the groundnut is grown as rainfed crop in uplands. Cultivation of legumes is mainly concentrated in Java Island, and some provinces of South and North Sumatra, South Sulawesi, Bali, and Nusa Tenggara (Fig. 4.1).

Food legumes are traditionally cultivated with low inputs. Farmers generally pay little attention to legumes cultivation (in respect of good seed, adequate land preparation, fertilizer, weeding, and plant protection) which results in very poor yields. Hence, productivity of legume crops is low compared to rice and maize.

Rice production receives high priority at the expense of legumes. The area, production, and productivity of three major food legumes in Indonesia has increased over past twenty years with increase in area by 100% in soybean, about 20% in groundnut, and 30% in mung bean (Fig. 4.2).

Agroecological Features

Based on soil (Fig. 4.3), rainfall (Fig. 4.4), and length of growing period (Fig. 4.5), five pragmatic agroecological zones (Fig. 4.6) are recognized. In 1992, approximately 8.4 million ha was under lowland rice and 4.5 million ha under irrigated rice in Indonesia. Lowland rice cultivation is similar to those in other parts of South and Southeast Asia. During 1988–92, lowland rice area in Jawa Island increased due to conversion of rainfed lands into irrigated area. On the other hand, rainfed area decreased in other islands.

A common feature of most lowland areas in Indonesia is the fact that legumes can be grown after rice harvest in early or late dry season. This system is not extensively practiced, and productivity is still low (1.0 t ha^{-1}). Legumes are cultivated as pre- or post-rice crops in the lowlands, and in rotation with other crops in rainfed uplands (Table 4.1). The cropping pattern of major rice-producing regions in Indonesia is shown in Figure 4.7. Legume crops in rice-

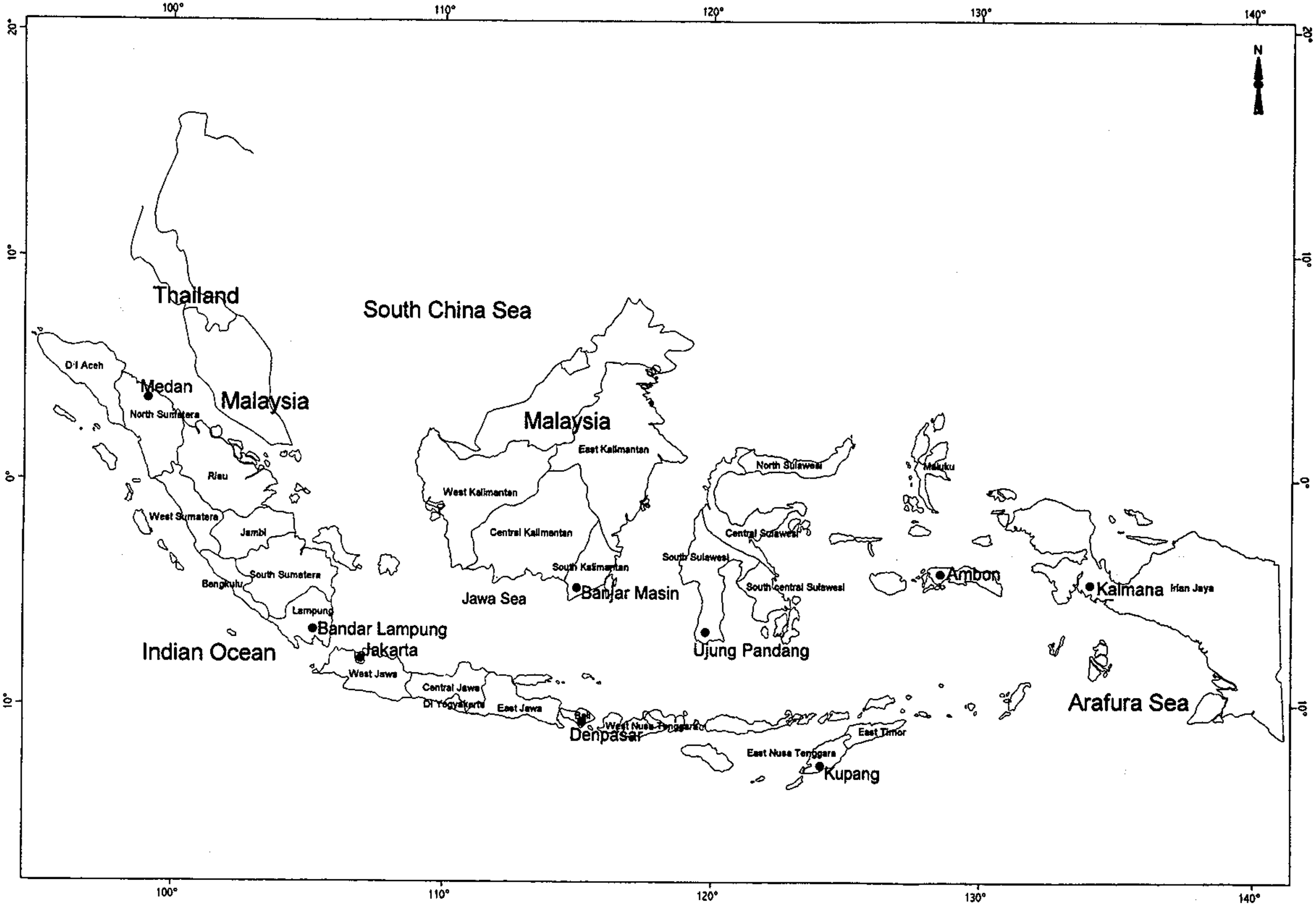

Figure 4.1. Administrative divisions of Indonesia.

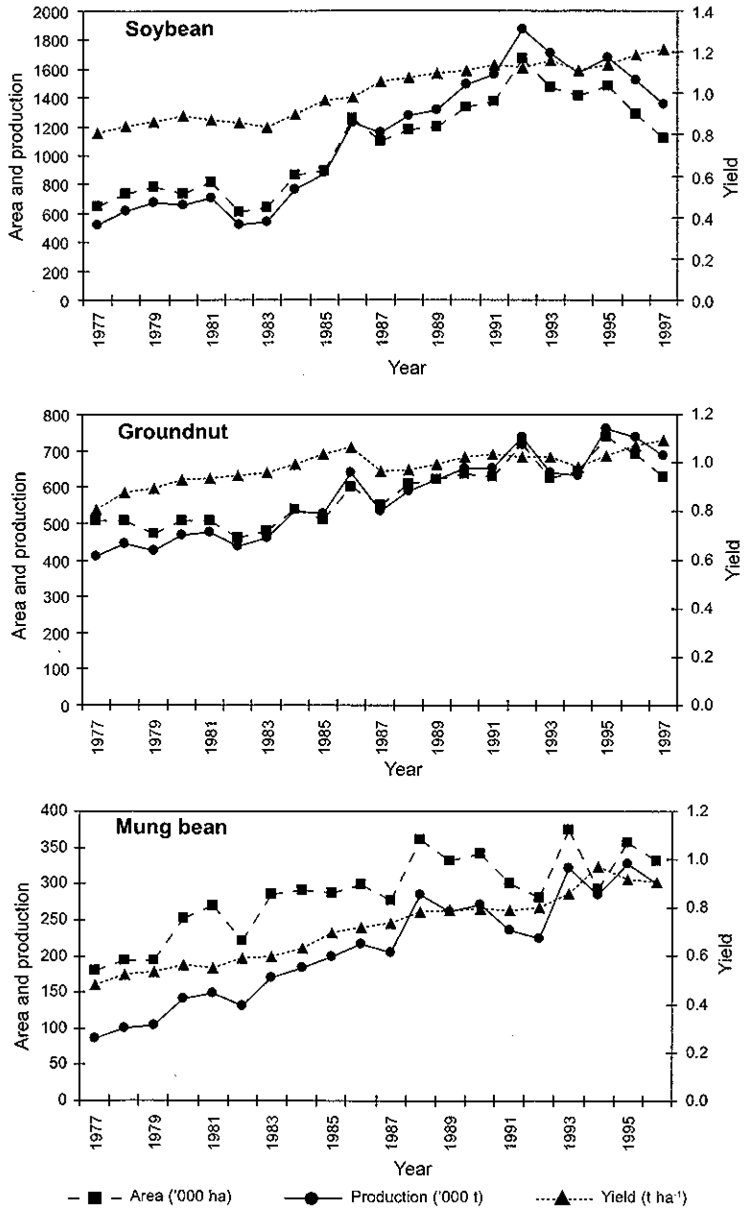

Figure 4.2. Area, production, and yield of legumes in Indonesia.

based cropping systems are mostly grown between 0 and 400 m above sea level on Entisols and Vertisols and the growing season for legumes is 65–110 days.

Major Legumes

Sumarno and Manwan (1990) have reviewed legumes cultivation in Indonesia. A brief note on the major legumes is given here.

Soybean

Nearly 70% of soybean cultivation is in Java and the rest in other islands (Fig. 4.8). Soybean is grown as both early (25%) and late dry season (35%) crop (after rice) in the irrigated wetlands, and as early rainy season (10%) crop (before rice) in rainfed wetlands (Fig. 4.7). About 30% is in rainfed uplands, both as monocrop and intercrop. The usual cropping pattern is rice-rice-soybean or rice-soybean-soybean in irrigated wetlands and soybean-rice-mung bean/soybean or sorghum (*Sorghum bicolor* (L.) Moench)-rice-soybean/maize/sorghum in rainfed wetlands. Average yield of soybean is 1.2 t ha^{-1}, while potential yield is 2 t ha^{-1}.

Table 4.1. Agricultural land classification in Indonesia.

Agricultural land	Crop season duration
Lowland rice areas	
Full irrigation	10 months
Partial irrigation	7–9 months
Rainfed	5 months
Upland rainfed areas	
Humid	9 months with >200 mm rainfall
	3 months with <100 mm rainfall
Dry	6 months with >200 mm rainfall
	3 months with <100 mm rainfall
Very dry	3–4 months with >200 mm rainfall
	3 months with <100 mm rainfall
Tidal swamp	
Systematically drained	Variable
Partially drained	Variable
Swamp areas	
Fresh water	Variable

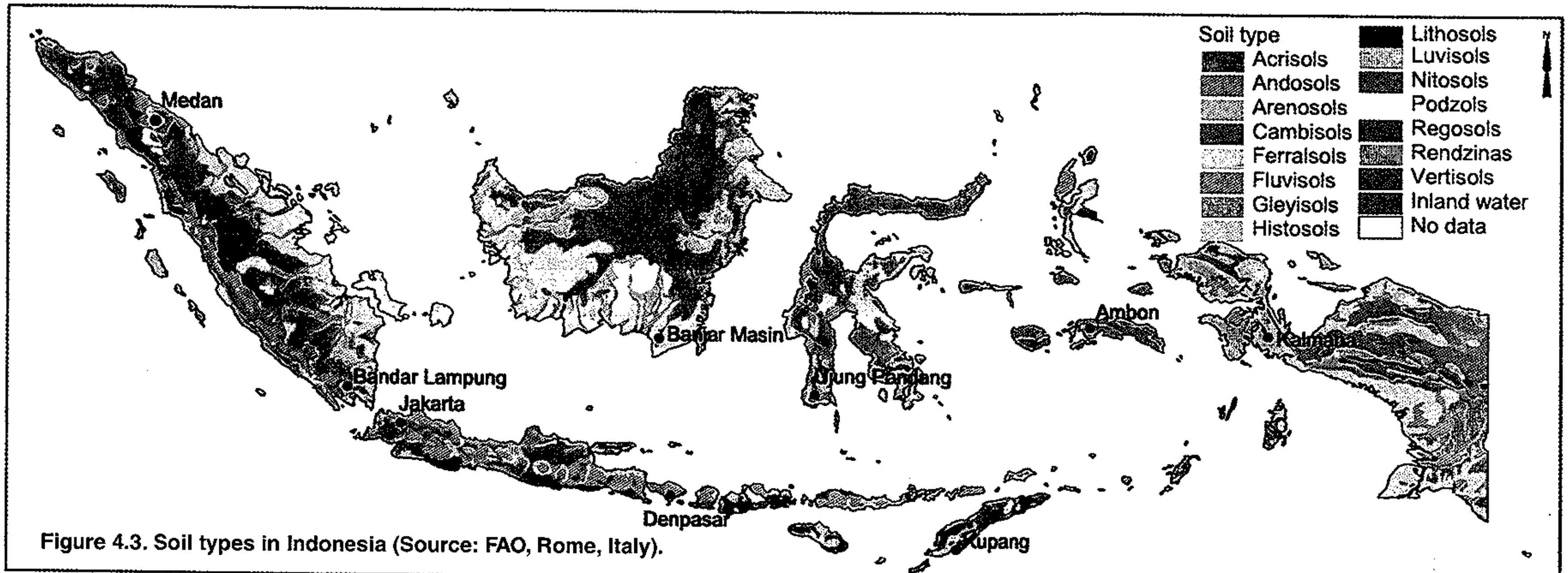

Figure 4.3. Soil types in Indonesia (Source: FAO, Rome, Italy).

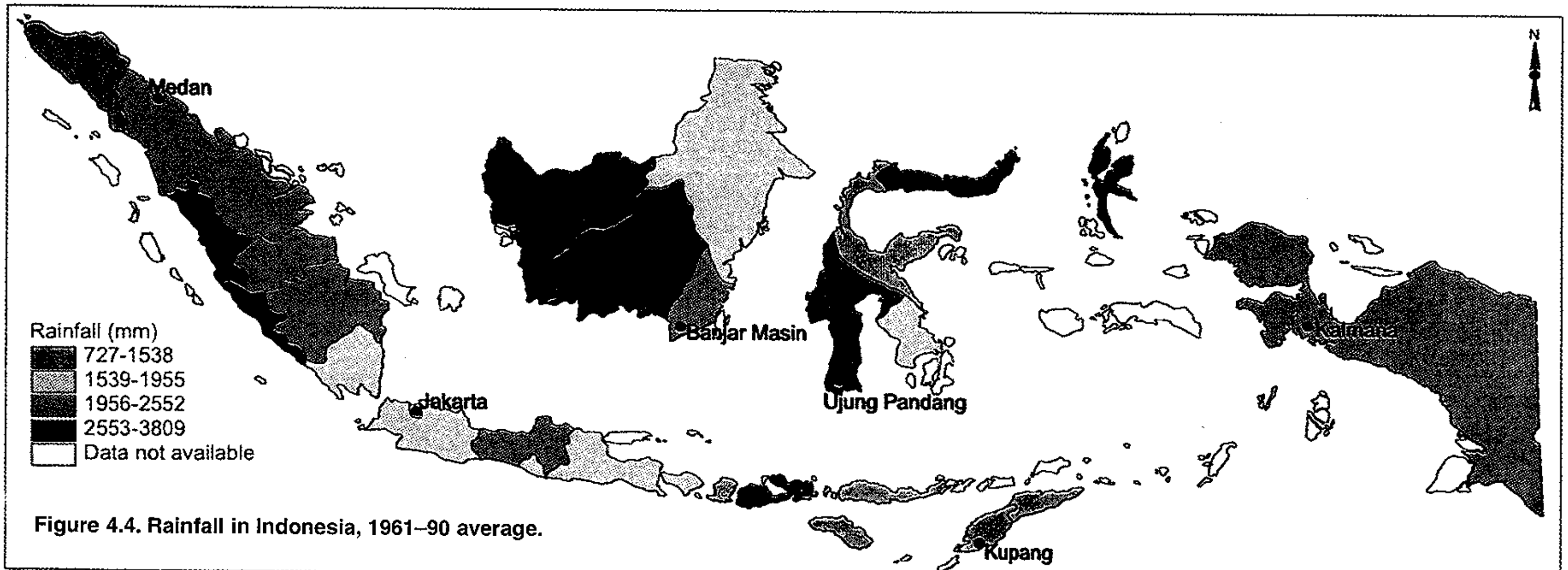

Figure 4.4. Rainfall in Indonesia, 1961–90 average.

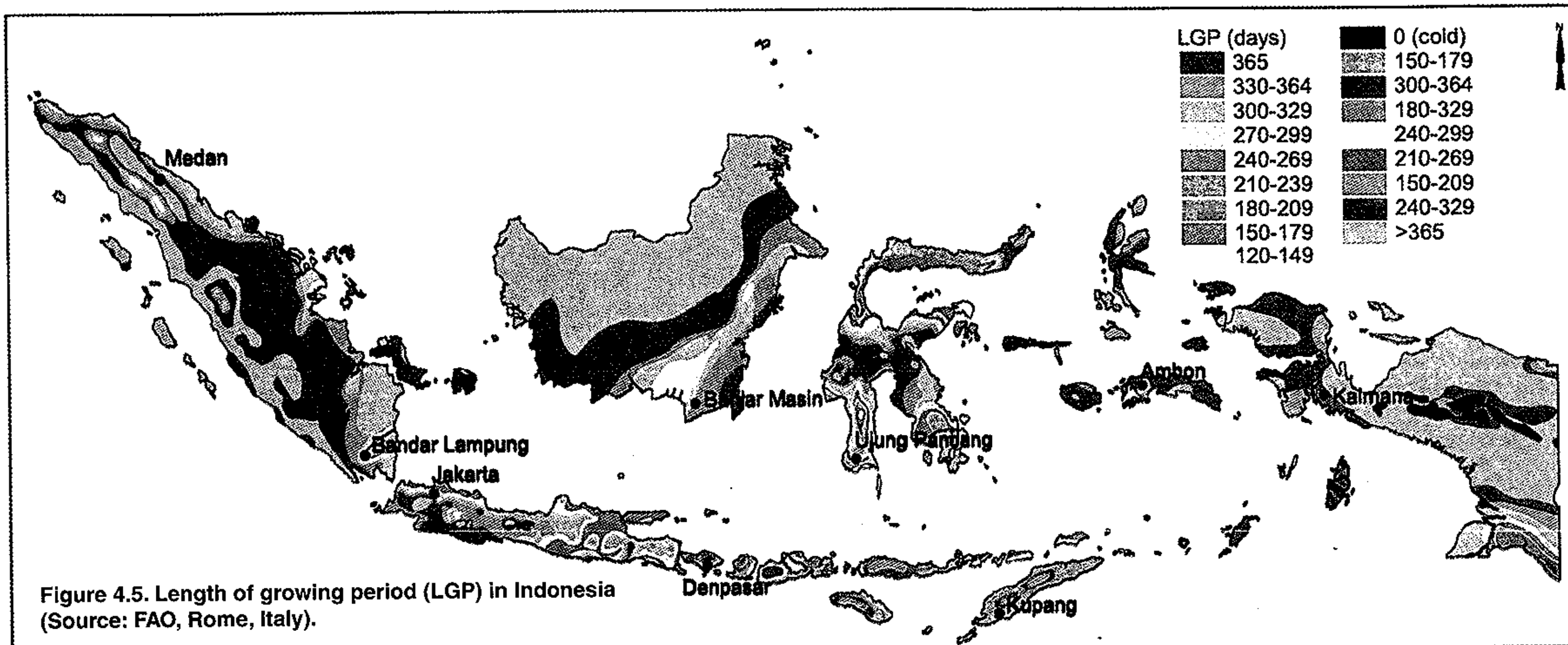

Figure 4.5. Length of growing period (LGP) in Indonesia (Source: FAO, Rome, Italy).

Groundnut

Majority of groundnut is cultivated in Java (Fig. 4.9). Nearly 39% of groundnut is grown in rice-based cropping systems in irrigated and rainfed wetlands, mostly as monocrop. The usual cropping pattern is rice-rice-groundnut or rice-groundnut-maize/fallow (Fig. 4.7). The average yield of groundnut is 1.2 t ha^{-1}, while potential yield is 3 t ha^{-1}.

Mung Bean

Around 50% of mung bean is in rice-based cropping systems, 40% in irrigated wetlands, and 10% in rainfed wetlands (Fig. 4.10). Mung bean is grown both during early dry season (April–June) and late dry season (July–October). The usual cropping pattern is rice-rice-mung bean or mung bean-rice-maize (Fig. 4.7).

Constraints to Legumes Production

Significant progress has been made in increasing the yield potential of legumes in Indonesia. Using improved technology, farmers have reported yields of 2 t ha^{-1}, while under experimental conditions yields of 3 t ha^{-1} in soybean, 4.5 t ha^{-1} in groundnut, and 2.5 t ha^{-1} in mung bean have been reported. These results indicate that higher yields can be achieved in legumes by improved technologies. A large yield gap exists and this needs immediate attention to develop and popularize improved varieties and technologies.

A number of varieties of soybean (30), groundnut (22), mung bean (11), cowpea (*Vigna unguiculata* (L.) Walp.) (7), and pigeonpea (*Cajanus cajan* (L.) Millsp.) (1) have been released for cultivation by farmers (Table 4.2). Despite this progress in developing improved varieties, the national average yield of legumes is around 1 t ha^{-1}, due to various production constraints (Table 4.3).

Seed germination and crop establishment is a major constraint in rice-based cropping systems. Legumes are grown in various agroecological zones, and seed quality deteriorates quickly in a tropical climate because of high humidity, high temperature, and seed moisture content. Legume seed cannot be kept longer than 3–4 months without good seed storage conditions. When legumes are sown after rice, germination is affected by several factors including soil physical conditions which result in a poor stand with uneven plant distribution (Baliadi et al. 1996). In most cases, poor crop performance is a result of poor seed germination and crop establishment (Adisarwanto et al. 1989). Legumes must be sown at the proper time to realize good yields. The important biotic, abiotic, and soicoeconomic constraints to legumes cultivation in Indonesia are summarized below.

Biotic Constraints

Several pests and diseases affect crop health, and weed competition reduces realizable yield.

Diseases

The important diseases of the major legumes are listed in Table 4.4.

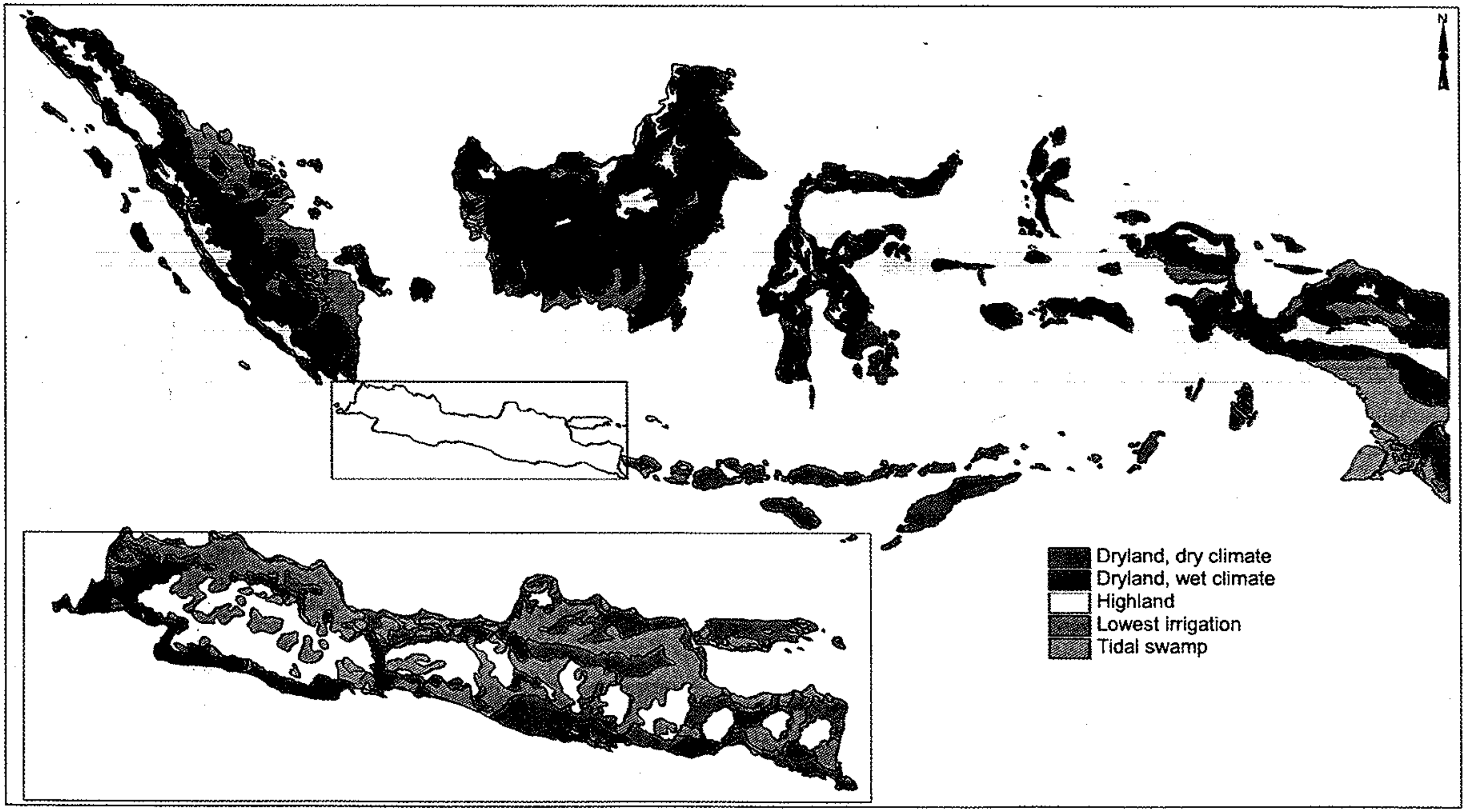

Figure 4.6. Agroecological zones in Indonesia.

Soybean. Soybean mosaic, soybean stunt, rust, bacterial blight, and bacterial pustule are the major diseases (Fig. 4.11). Rust may cause up to 55% yield loss (Hardaningsih et al. 1986).

Groundnut. Late leaf spot, rust, and peanut stripe are the most serious diseases (Fig. 4.12). Rust and late leaf spot may cause up to 50% yield loss without any protection. Their distribution is almost throughout the country with varying intensity.

Mung bean. Distribution of mung bean diseases is given in Figure 4.13. Cercospora leaf spot and rust are the major diseases and cause yield loss up to 35%.

Insect pests

The important insect pests are listed in Table 4.4. Pod borers (*Etiella zinckenella, Phaedonia inclusa, Riptortus linearis,* and *Nezara viridula*) are the major field pests of soybean and together cause an estimated crop loss of about 65–70% (Fig. 4.14). Aphids are common on mung bean and groundnut especially in late sowing (Marwoto and Suharsono 1996). Foliar feeders and jassids cause considerable damage to groundnut crop (Fig. 4.15). Distribution of major pests on mung bean is presented in Figure 4.16.

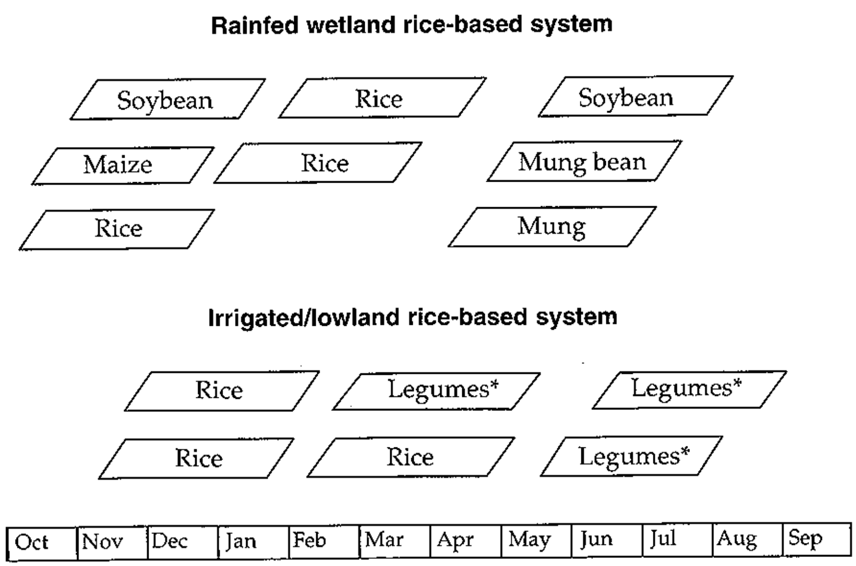

Figure 4.7. Croping pattern involving legumes in the rice-based croping systems in Indonesia (Note: * = soybean, groundnut, or mung bean).

Weeds

Farmers still consider legumes as minor crops and do not weed their crops. Hence, weeds compete with crops and cause substantial yield losses; for example, 18–68% in soybean. The most common weeds in the lowland rice-legume system are: *Digitaria ciliaris* (Retz.) Koel, *Boreenia latifolia* L., *Ageratum conyziodes* L., *Echinocloa colona* (L.) Link, *Paspalum distichum* L., *Cyperus* sp, *Heliotropium indicum* L., *Portulaca* sp, and *Imperata cylindrica* (L.) Beauv. Adisarwanto et al. (1996) reported that by using 5 $t\ ha^{-1}$ rice straw as mulch in soybean after rice, weed infestation can be reduced by 60–65%. Similar results were also reported in mung bean and groundnut (Suyamto et al. 1989).

Abiotic Constraints

Various climatic and soil factors limit the productivity of legumes grown in Indonesia. Among these, drought and excess moisture conditions are important. Distribution of abiotic constraints is given in Figure 4.17.

Drought

Legumes that are grown on conserved soil water suffer from drought. Germination and emergence are affected by lack of soil moisture, thus affecting optimum plant stand; hence yields are low.

Excess soil moisture

In some years, excessive rainfall occurs during early dry season causing substantial yield loss. If rainfall occurs in the reproductive stage, flowers are damaged resulting in poor pod development. High rainfall, coupled with high humidity, also encourages diseases such as root rot and leaf spots in groundnut; and foliar diseases in soybean and mung bean.

Socioeconomic Constraints

Lack of capital to purchase input for production, and non-availability of credit and price support are the major constraints.

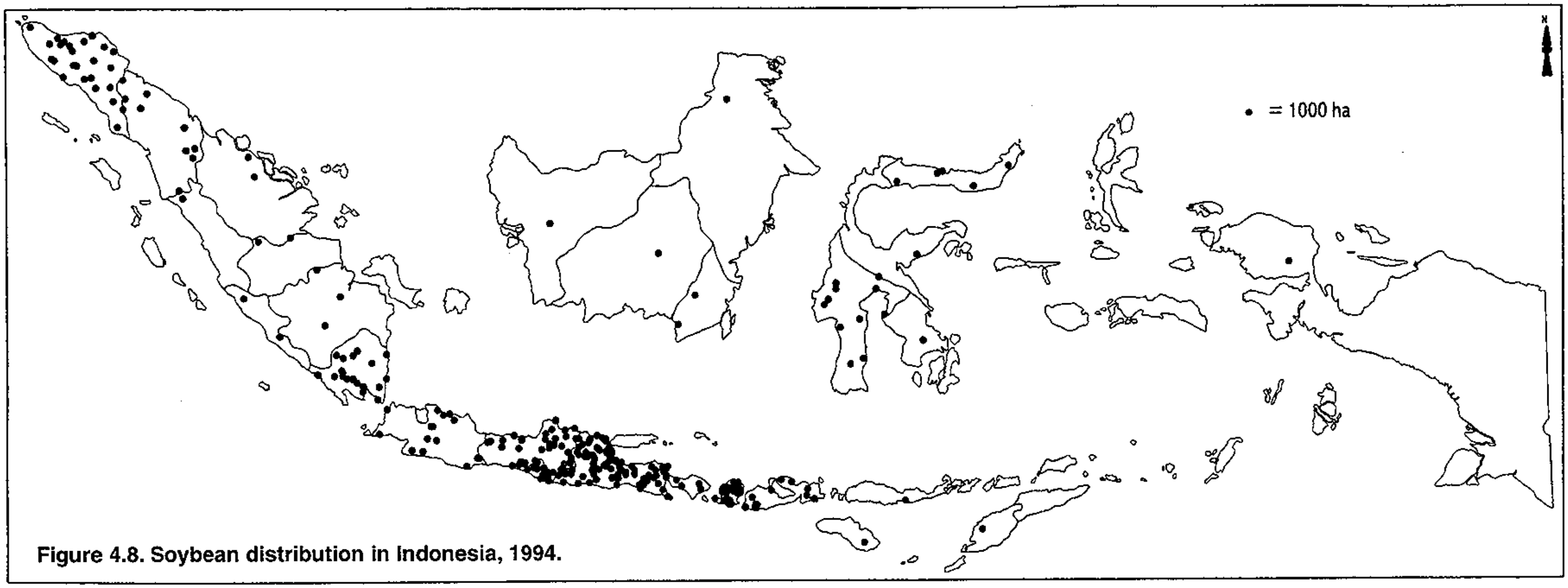

Figure 4.8. Soybean distribution in Indonesia, 1994.

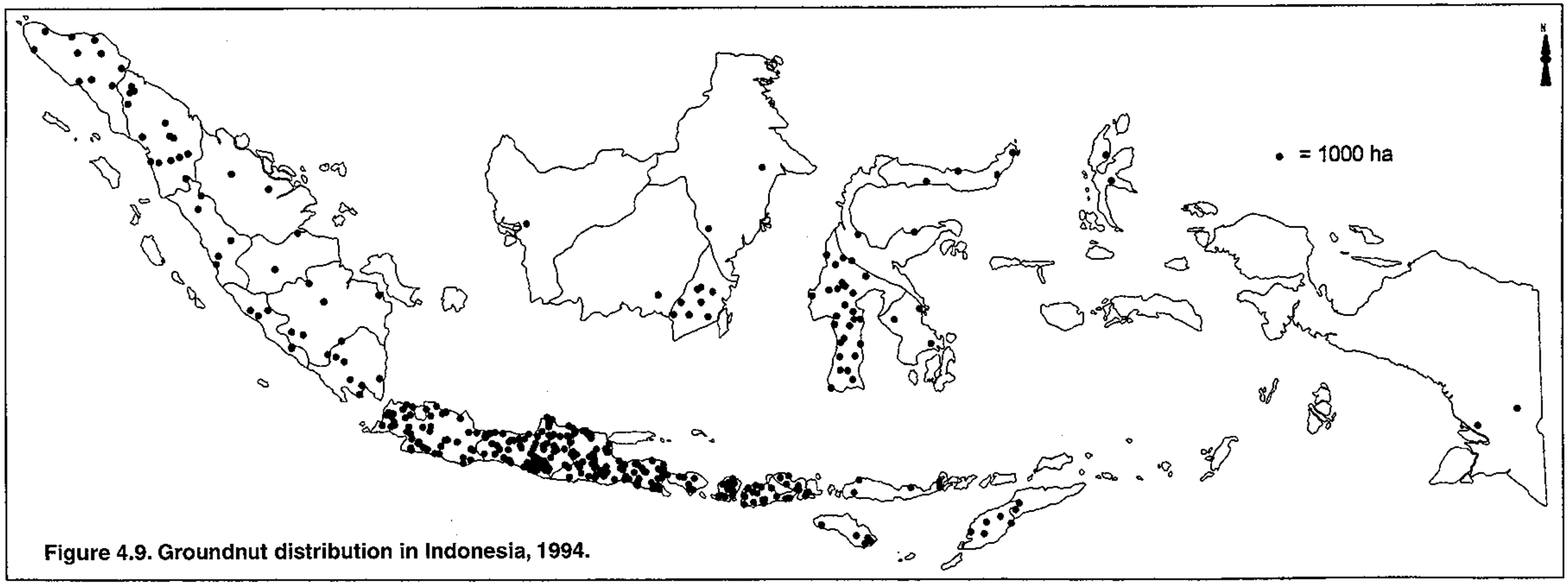

Figure 4.9. Groundnut distribution in Indonesia, 1994.

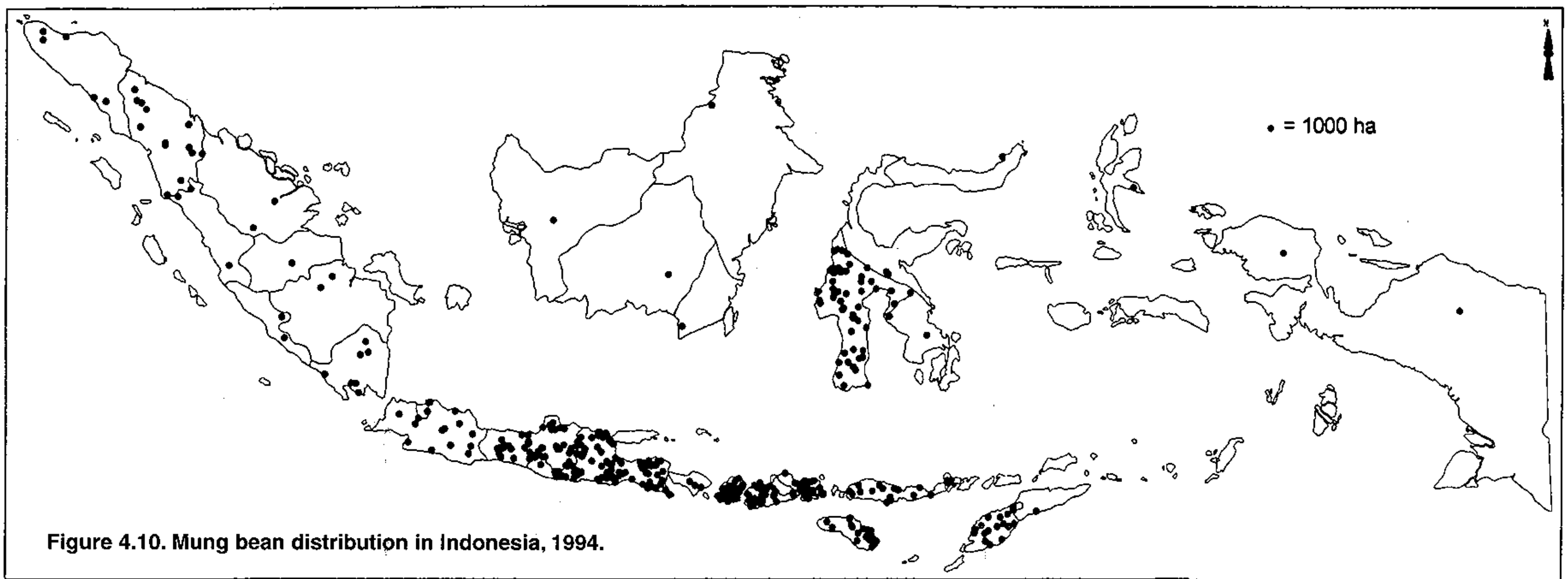

Figure 4.10. Mung bean distribution in Indonesia, 1994.

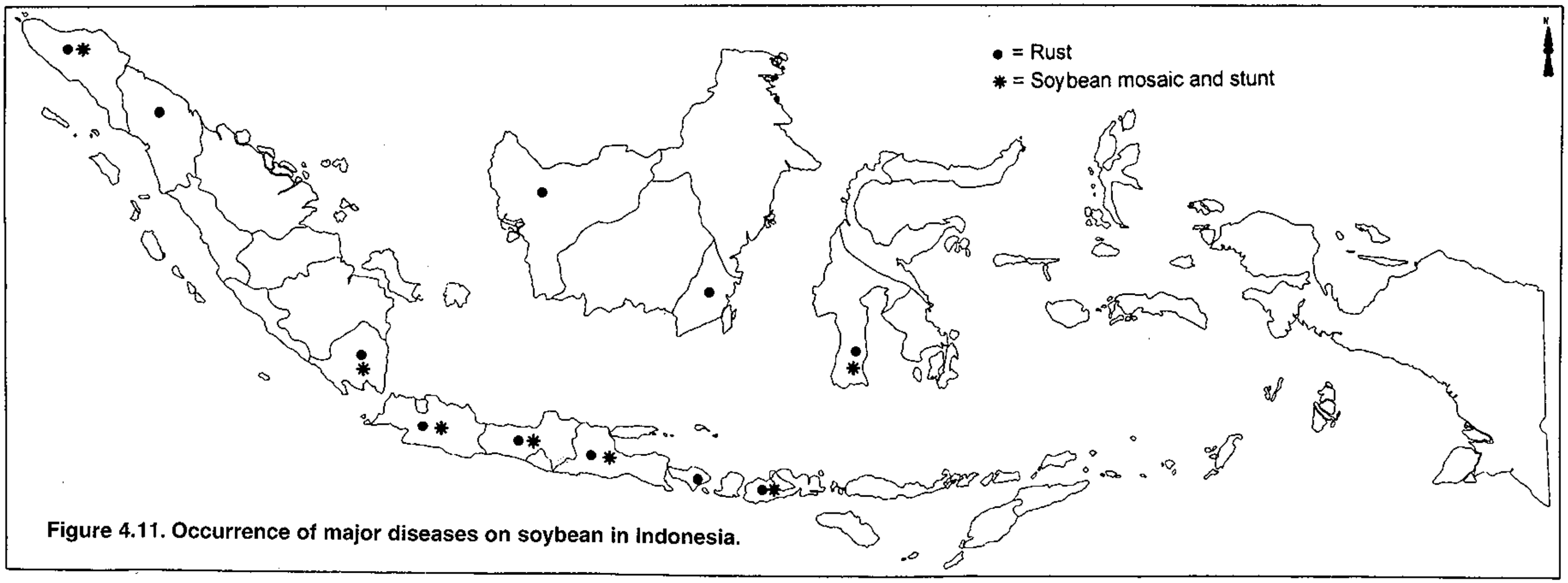

Figure 4.11. Occurrence of major diseases on soybean in Indonesia.

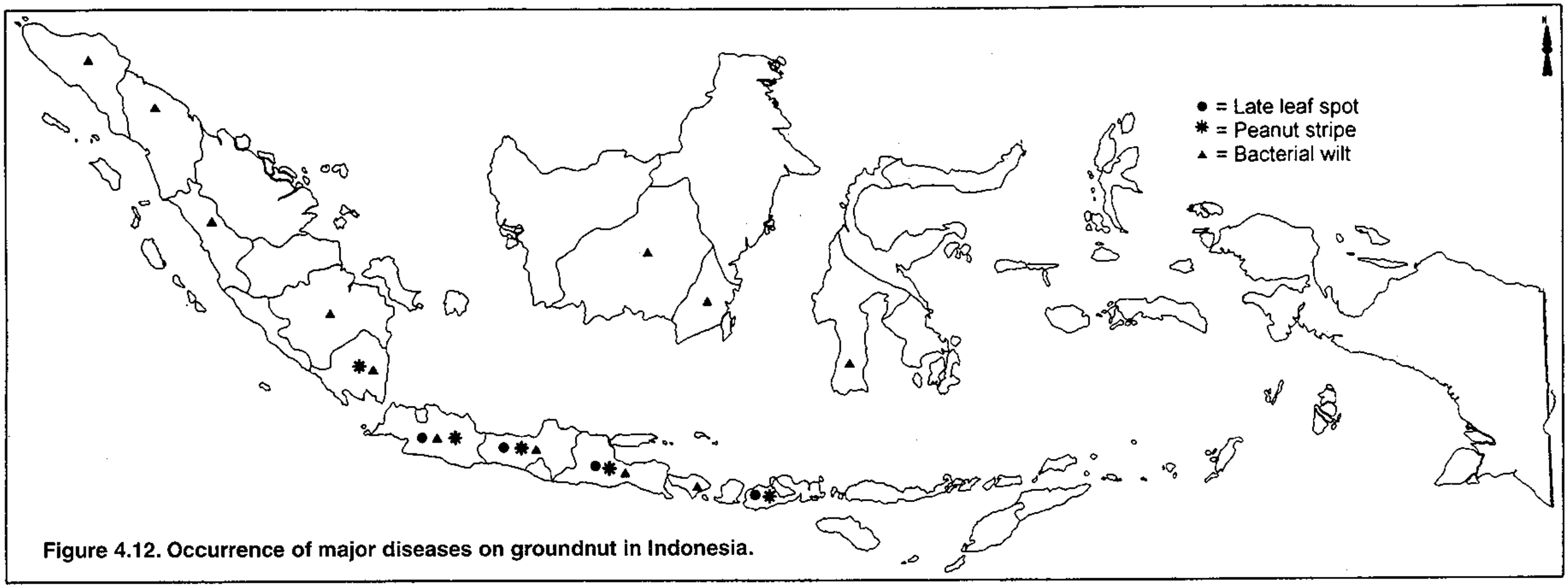

Figure 4.12. Occurrence of major diseases on groundnut in Indonesia.

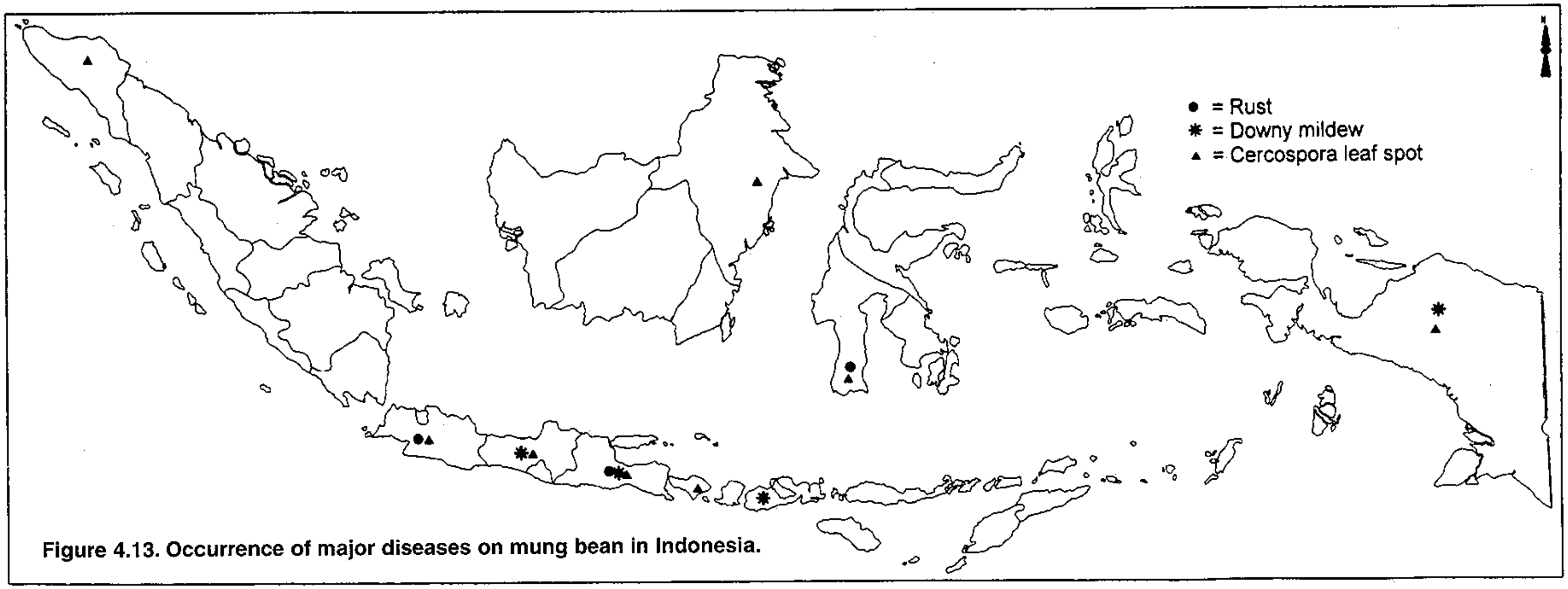

Figure 4.13. Occurrence of major diseases on mung bean in Indonesia.

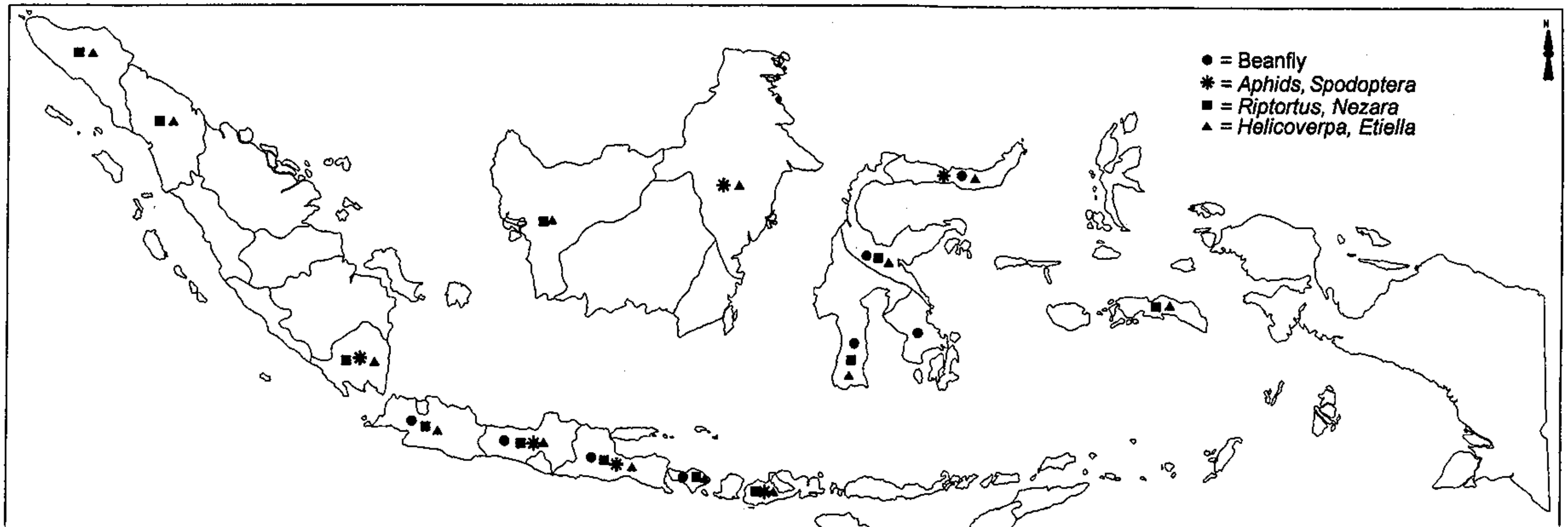

Figure 4.14. Occurrence of major insect pests on soybean in Indonesia.

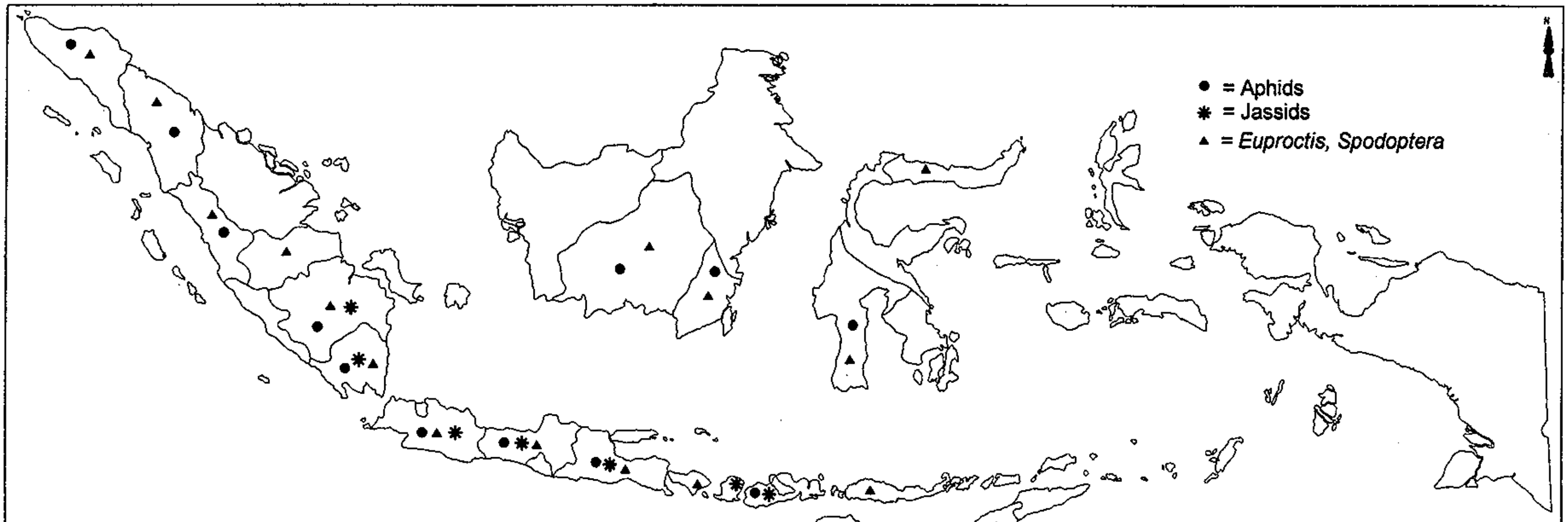

Figure 4.15. Occurrence of major insect pests on groundnut in Indonesia.

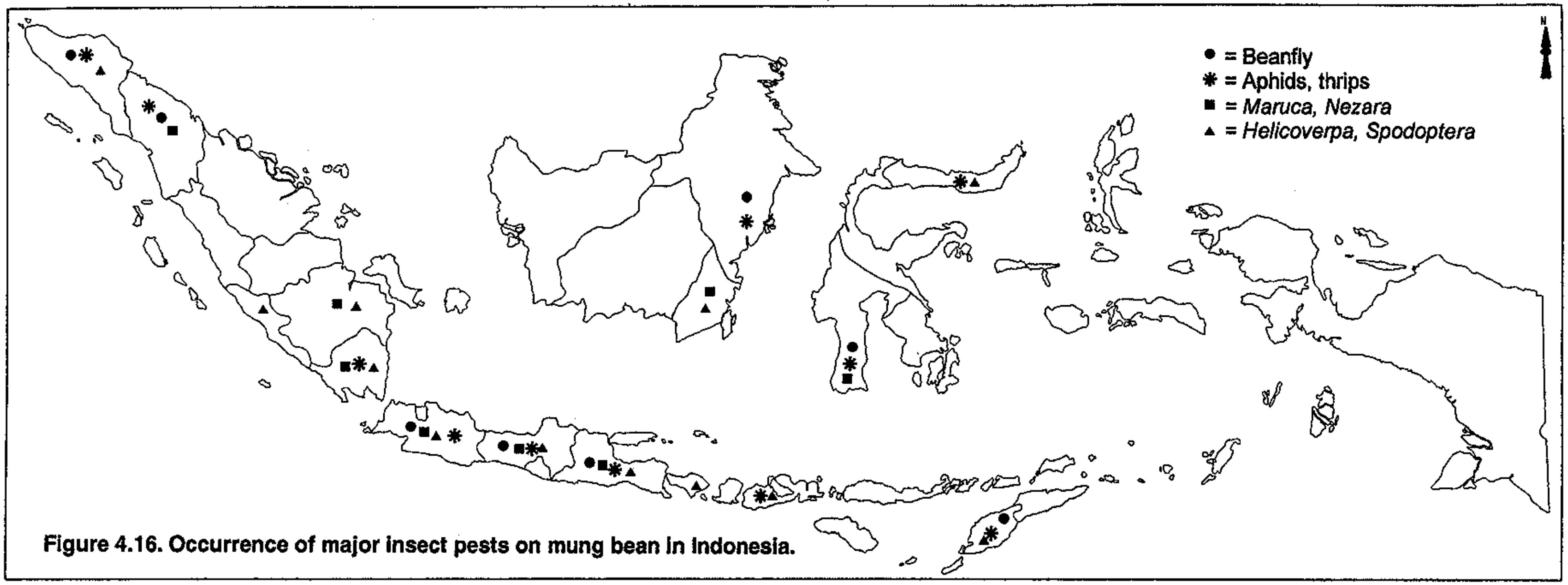

Figure 4.16. Occurrence of major insect pests on mung bean in Indonesia.

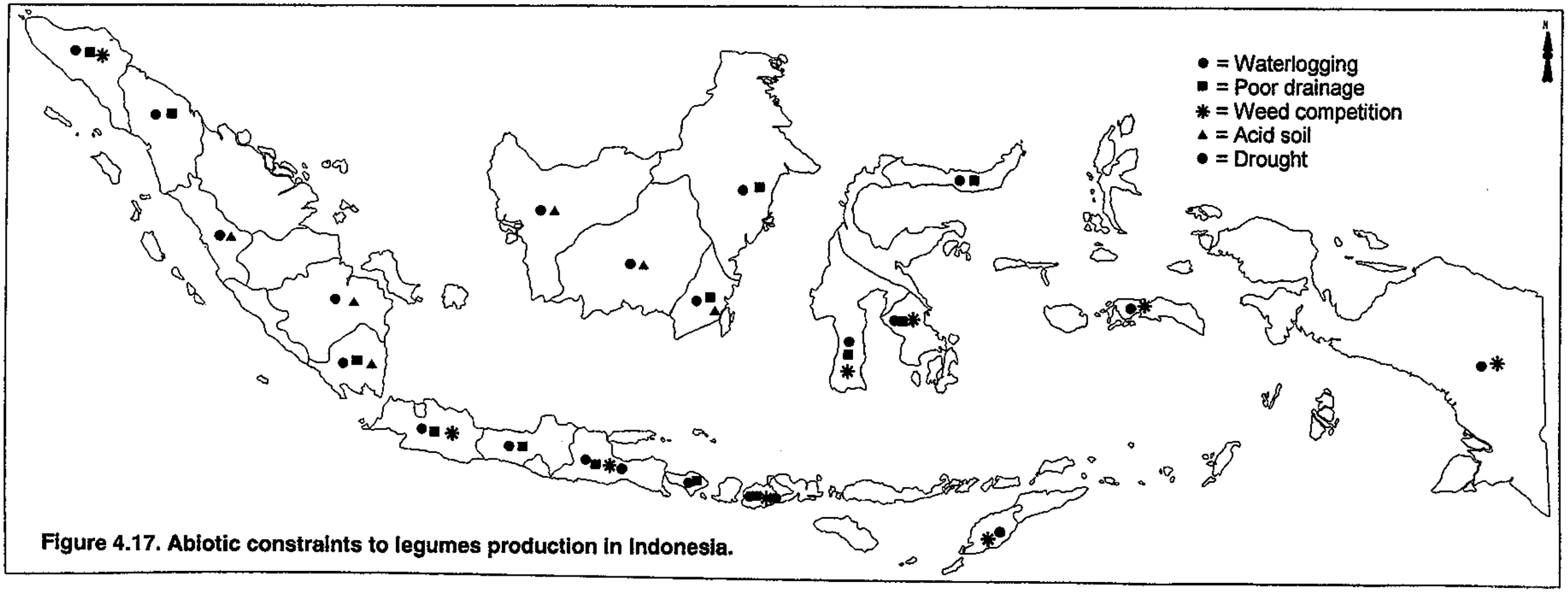

Figure 4.17. Abiotic constraints to legumes production in Indonesia.

Role of Legumes in Rice-based Cropping Systems

After achieving self-sufficiency in rice in 1984, the Indonesian government gave special attention to the *palawija* (upland, non-rice) crops, with emphasis on legumes, especially soybean, for increased production to improve farmers' income and nutritional status. Emphasis was laid on replacing the second or third rice crop with legumes in irrigated lowland areas and to grow legumes before or after rice in rainfed lowland areas. The usual cropping pattern of lowland rice areas is rice-legumes-legumes or rice-rice-legumes (Fig. 4.7). The amount of soil water remaining in the dry season after rice harvest is adequate for a dry season crop, including legumes. Where adequate irrigation water is available, improved technology for legumes has been recently launched through the agency, Agriculture Research and Development Program called SUTPA (Sistem Usahatani Padi ber wawasan Agribisnis – Special program for intensification of rice and other food crops) with the aim of raising legumes yield to more than 2 t ha^{-1}.

Table 4.2. Released varieties of major legumes (and year of release) in Indonesia.

Soybean	Groundnut	Mung bean
Shakti (1965)	Gajah (1950)	No. 129 (1979)
Orba (1974)	Macan (1950)	Manyar (1983)
Galunggung (1981)	Banteng (1950)	Merak (1981)
Wilis (1981)	Kidang (1950)	Nuri (1983)
Kerinci (1985)	Tupai (1983)	Betet (1983)
Merbabu (1986)	Pelanduk (1983)	Walet (1985)
Raung (1986)	Tapir (1983)	Gelatik (1985)
Tidar (1987)	Rusa (1983)	Parkit (1988)
Muria (1987)	Anoa (1983)	Merpati (1991)
Tambora (1989)	Kelinci (1987)	Camar (1991)
Lompobatang (1989)	Jepara (1989)	Sriti (1992)
Rinjani (1989)	Landak (1989)	
Lumajang Bewok (1989)	Mahesa (1991)	
Lawu (1991)	Badak (1991)	
Dieng (1991)	Komodo (1991)	
Tengger (1991)	Biawak (1991)	
Jayawijaya (1991)	Zebra (1992)	
Krakatau (1992)	Trenggiling (1992)	
Tampomas (1992)	Simpai (1992)	
Cikurai (1992)	Singa (1998)	
Singgalang (1992)	Jerapah (1998)	
Malabar (1992)	Panter (1998)	
Kipas Putih (1992)		
Sindoro (1996)		
Slamet (1996)		
Pangrango (1996)		
Bromo (1998)		
Agro Mulia (1998)		
Kawi (1998)		
Lauser (1998)		

Table 4.3. Important constraints to legumes production in rice-based cropping systems in Indonesia.

Legume crop	Early dry season (July to September)	Late dry season (April to June)
Soybean	Waterlogging	Drought stress
	Poor drainage	Weed infestation
	Low seed germination	Viral diseases
	Weed competition	Beanfly
	Leaf feeder pests	Leaf feeder pests
	Pod sucker	Pod borer
	Pod borer	
Groundnut	Waterlogging	Low seed germination
	Poor drainage	Soil compaction
	Soil compaction	Drought stress
	Seedbed preparation	Seedbed preparation
	Weed infestation	Weed infestation
	Leaf spot, rust, and viral diseases	
	Leaf feeder pests	
	Rats	
Mung bean	Waterlogging	Seedbed preparation
	Poor drainage	Weed competition
	Seedbed preparation	Powdery mildew
	Weed competition	Beanfly
	Leaf spot	
	Sucking insects	
	Pod borer	

Prospects for Increasing Production of Legumes

Yields of upland crops are low when grown after rice due to poor soil physical and chemical conditions of puddled soils (Pasaribu and McIntosh 1985). There are good prospects for increasing production of legumes in lowland rice-based cropping systems. The additional production can be achieved by (1) increased productivity through improved production technology including improved varieties; and (2) increased area of harvest by growing legumes as third crop after rice and introducing new cropping patterns. Improved production technologies are available for soybean (Adisarwanto et al. 1996), groundnut (Arsyad et al. 1995, Harsono 1996), and mung bean (Radjit 1996). The major components of improved technologies which influence the legumes are listed below:

- Appropriate cropping sequence to allow timely sowing of legumes.
- Availability of good quality seed of improved varieties released in the country (Table 4.2).
- Suitable and appropriate tillage practices for different crops and soils.
- Optimum sowing time to better utilize available soil moisture.
- Application of *Rhizobium* inoculum and recommended chemical fertilizers.
- Integrated management of pests and diseases to reduce yield losses.
- Irrigation, wherever feasible.

Table 4.4. Major diseases and insect pests of grain legumes in Indonesia.

Crop	Disease (Pathogen)	Insects
Soybean	Bacterial pustule (*Xanthomonas campestris* pv *glycines* (Nakano) Dye	Pod borers (*Helicoverpa armigera* Hübner, *Etiella zinckenella* Treitschke, *Riptortus linearis* F.)
	Soybean mosaic (soybean mosaic virus)	Bugs (*Nezara viridula* L.)
	Soybean stunt (soybean stunt virus)	Aphids (*Aphis glycines* Mats.)
	Rhizoctonia blight (*Rhizoctonia solani* Kühn)	Beanfly (*Ophiomyia phaseoli* Tryo.)
	Rust (*Phakopsora pachyrizi* Syd.)	Caterpillar (*Spodoptera litura* F.)
	Bacterial blight (*Ralstonia syringae* pv *glycinea*)	Leaf folder (*Lamprosema indicata* F.)
Groundnut	Late leaf spot (*Phaeoisariopsis personata* (Berk. & Curtis) v. Arx)	Hairy caterpillar (*Euproctis* sp)
	Rust (*Puccinia arachidis* Speg.)	Other caterpillars (*Helicoverpa armigera* Hübner, *Spodoptera litura* F.)
	Stem and root rot (*Sclerotium rolfsii* Sacc.)	Aphids (*Aphis craccivora* Koch)
	Peanut stripe (peanut stripe virus)	Leaf hopper/jassids (*Empoasca* sp)
	Leaf blight (*Rhizoctonia* sp)	Thrips (*Caliothrips indicus* Bag.)
	Bacterial pustule (*Xanthomonas campestris* pv *phaseoli*)	Leaf miner (*Aproaerema modicella* Dev.)
	Early leaf spot (*Cercospora arachidicola* Hori)	
	Bacterial wilt (*Ralstonia solanacearum* L.)	
Mung bean	Root rot (*Rhizoctonia solani* Kühn)	Beanfly (*Ophiomyia phaseoli* Tryo.)
	Yellow mosaic (mung bean yellow mosaic virus)	Thrips (*Caliothrips indicus* Bag.)
	Cercospora leaf spot (*Cercospora cruenta* Sacc.)	Whitefly (*Bemisia tabaci* Genn.)
	Rust (*Uromyces appendiculatus*)	Leaf folder (*Lamprosema indicata* F.)
	Powdery mildew (*Erysiphe polygoni* DC.)	Pod borers (*Helicoverpa armigera* Hübner, *Spodoptera litura* F., *Maruca vitrata* Gey.)
		Aphids (*Aphis craccivora* Koch)
		Bugs (*Nezara viridula* L.)

National Policies and Emphasis Towards Legumes Production

Several policies were initiated by the Government of Indonesia to increase legumes production to reduce import. The government has been campaigning for increasing the domestic legumes production through intensification and extension programs since 1983, especially for soybean. Intensification is aimed at increased productivity through introduction of improved technology, including improved varieties, *Rhizobium* inoculation, use of fertilizer, pest control, and liming of acid soils. Extensification is aimed at expanding the production to non-traditional areas. The program has been conducted mainly in newly opened areas in Sumatra, Sulawesi, and other islands. Diversification is also emphasized within the existing farming systems, to include food legumes as intercrops in rubber (*Hevea brasiliensis* Muell.), coconut (*Cocos nucifera* L.), oil palm (*Elaeis guineensis* Jacq.), sugarcane (*Saccharum officinarum* L.), and agroforestry systems. Improved technology options designed for the intensification and extensification are available. However, due to the large variation in environments, participatory on-farm adaptive research is needed for refining suitable technology and to generate technological alternatives.

Research on food legumes is conducted at the Research Institute for Legumes and Tuber Crops (RILET), Malang, as a national mandate under the Central Research Institute for Food Crops (CRIFC). RILET receives support from various sources for research facilities, human resource development, program formulation, enhancement of research communication, and improvement of research management. Several steps have been taken by RILET to improve productivity, efficiency, and the impact of research activities. At farmer level, the government provides credit to the farmers in intensification programs. In 1990/91, the government started a program on soybean called OpSus (special effort), whereby the soybean crop was introduced to new production areas. Similar efforts are essential for other legumes.

Research Priorities

Based on the constraints to legumes production in rice-based cropping systems, the following researchable issues were identified:

- Improvement of crop establishment: Sowing method, seedbed preparation, water management, and seed rate.
- Improvement in availability of quality seed: Seed production; pre-harvest and harvest management; seed drying, processing, and storage at farmer level; maintenance of seed quality; seed testing; and quality control.
- Improvement of crop management: Optimize plant spacing and population density; interculture and mulching; macro- and micronutrient application; and control of pests, diseases, and weeds.
- Germplasm evaluation and enhancement: Introduction, characterization, evaluation, documentation, and conservation of legume germplasm. Develop suitable varieties, with resistance to major pests and diseases and tolerance to acid soils and drought, using conventional breeding, biotechnology, and genetic engineering.
- Biological nitrogen fixation: *Rhizobium* effectiveness in different soils and compatibility between *Rhizobium* strains and legume variety.
- Production economics: Cost-benefit analysis of the recommended technology, constraints to technology adoption, pricing policy, and marketing problems.
- Resource allocation: Based on the importance of legumes and the constraint in production, the following resource allocation was made, in line with national priorities: soybean (55%), groundnut (30%), mung bean (10%), and cowpea and pigeonpea (5%).

Conclusions

In Indonesia, rice-legume cropping systems are predominant but productivity of legumes is low due to various biotic, abiotic, and socioeconomic constraints. Pod borers, sucking insects, drought, and weeds are the main yield reducers. A number of socioeconomic constraints also discourage farmers to produce legumes. Area and production of legumes are declining due to low profitability compared with other high-value crops such as watermelon (*Citrullus lanatus* (Thunb.) Mansf.), chili (*Capsicum annuum* L.), red onion (*Allium cepa* L.), and sugarcane. Low profitability of legumes is largely attributed to poor yield performance. However, there is good scope for increasing the area and production of legume crops if appropriate technologies are implemented by farmers. There is also a need to strengthen the extension effort to disseminate available legume technologies to the farmers through on-farm adaptive research.

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5. Legumes in Rice-based Cropping Systems in Myanmar: Constraints and Opportunities

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Abstract

Myanmar agriculture is predominantly cereal based and spread in about 10 million ha. Rice-based system is the most important cropping system covering 5 million ha. Legumes account for about 2.5 million ha. Myanmar has large spatial variation in rainfall distribution (600 mm in the central dry zone area to 5000 mm in extreme south). There is a wider variation in agroclimatic conditions, such as temperature, evapotranspiration, and length of growing period. Thirteen legume crops are grown extensively in different agroclimatic areas of Myanmar. Among food legumes, black gram, mung bean, pigeonpea, chickpea, cowpea, and soybean are regarded as major crops. Mung bean and black gram account for 45% of total food legumes area. About 34% of legumes area is cultivated in rainy season and the rest in winter. Although legumes are cultivated throughout the country, the area is mainly concentrated in lower and central Myanmar. In lower Myanmar (Bago, Yangon, and Ayeyarwady divisions) legumes are cultivated as sequential crops after lowland rice.

Legumes production in different parts of the country is severely constrained by a number of biotic, abiotic, and socioeconomic factors. Among biotic stresses, diseases, pests, and weeds are important. The major diseases are fusarium wilt and collar rot in chickpea, yellow mosaic in mung bean and black gram, leaf spots and root rot in groundnut, and sterility mosaic in pigeonpea. Among insect pests, Helicoverpa *is the major pest in chickpea, black gram, and pigeonpea. Aphids are common pests in many legume crops while bruchids are the most important storage pests. Among abiotic constraints, drought causes severe yield reduction. Excessive soil moisture also affects the growth and development of legume crops causing severe yield reduction. Micronutrient deficiencies and soil acidity are also becoming important constraints and limiting legumes cultivation.*

Market and price significantly influence legumes production. The newly introduced open market policy is very favorable for legumes production in Myanmar. Legumes area is increasing over the years. Myanmar has huge potential for legumes production through sequential cropping after rice if appropriate legumes production technologies are provided to farmers.

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Introduction

Myanmar is divided into 14 administrative divisions (seven states and seven divisions) (Fig. 5.1). These are further subdivided into 62 districts and 247 townships. The total area of Myanmar covers about 68 million ha. Rice (*Oryza sativa* L.), maize (*Zea mays* L.), soybean (*Glycine max* (L.) Merr.), pulses, oilseeds, cotton (*Gossypium* sp), sugarcane (*Saccharum officinarum* L.), and jute (*Corchorus* sp) are very important commodities. Sixty-four percent of Myanmar labor force is actively engaged in agriculture. The total cultivated area is about 10 million ha. Among the agricultural commodities, production of rice, food legumes, sugarcane, and cotton are being intensified as basic crops.

The agroclimatic conditions of Myanmar are favorable for growing a wide range of crops (Thu Kha 1993). The diversity of climate and parent rocks have together created a wide range of soil types. Different precipitation patterns and distinct seasons (monsoon, winter, and summer) have enabled cultivation of different crops. Sixty crops are extensively grown in Myanmar. Food legumes cover 25% of total cultivated land area and contribute 64% of the total agricultural product export income. More than 13 legume crops are grown in Myanmar annually. Among food legumes, black gram (*Vigna mungo* (L.) Hepper), mung bean (*Vigna radiata* (L.) Wilczek), pigeonpea (*Cajanus cajan* (L.) Millsp.), chickpea (*Cicer arietinum* L.), cowpea (*Vigna unguiculata* (L.) Walp.), and soybean are major crops and contribute more than 64% of total pulse production in the country (Table 5.1). During the rainy season (May–September) nine legume crops are grown covering about 34% of total legume area. Other legumes are grown during transition between rainy season and winter (September–November) and during winter (October–February).

Cultivation of food legumes in Myanmar is unevenly distributed, depending on the soil moisture and temperature. Most of the food legumes, except pigeonpea and mung bean, are grown under receding soil moisture conditions following the rainy season crops. Groundnut (*Arachis hypogaea* L.) is the second most important oilseed crop after sesame (*Sesamum indicum* L.). Forty-six percent of groundnut is produced during rainy season in upper and central Myanmar (Magwe and Mandalay divisions). About 54% of groundnut is grown during winter (October–December) in southern parts of the country. Groundnut production in winter is almost twice that of rainy season because of higher yields in winter.

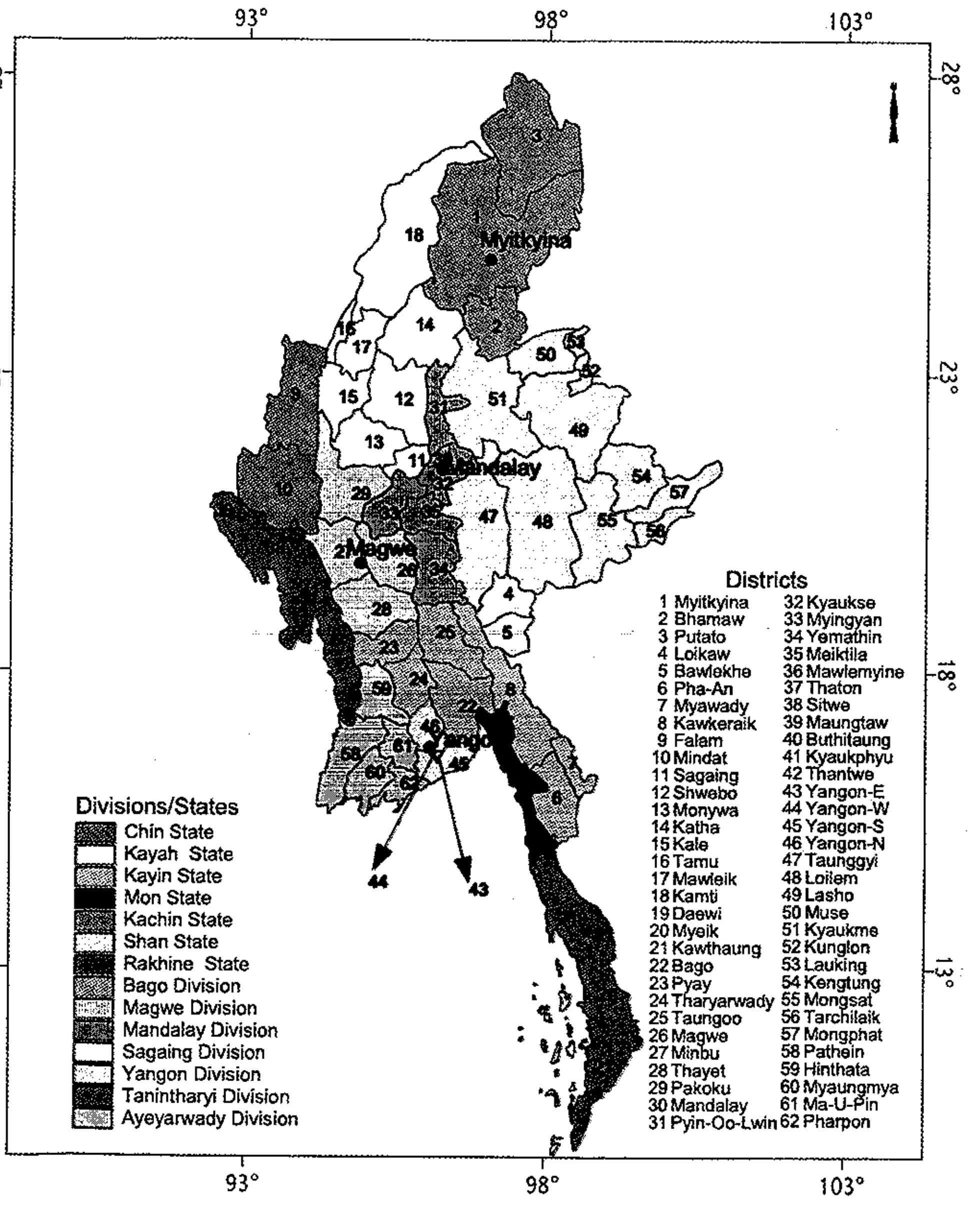

Figure 5.1. Administrative map of Myanmar.

Food legumes are cultivated traditionally under rainfed conditions with less monetary input since farmers believe food legume production is less productive compared to other crops. The low-yielding potential of legumes can be attributed to narrow genetic base. In addition, susceptibility to diseases and pests and sensitivity to microclimatic changes are the main causes for yield instability. Farmers are of the opinion that food legumes do not respond to high inputs (fertilizer and irrigation). Therefore, food legumes receive less attention with respect to good quality seed, timely sowing, proper land preparation, fertilization, weeding, and plant protection. As a result, the yield is lower than that of priority crops such as rice, sugarcane, cotton, and other high-yielding non-leguminous crops. Consequently, legumes are being relegated to marginal lands. However, the Government of Myanmar is currently encouraging expansion of legume crops. Open market policy allows export of surplus food legumes after meeting domestic requirements. As a result, the farmers are receiving relatively good income by growing legumes. Therefore, cultivated area under food legumes has been increasing steadily since 1993 (Fig. 5.2). Rice-rice, rice-legumes, sesame-legumes, rice-groundnut, and maize-legumes are the common cropping systems. Sesame-mung bean is an important cropping system in central Myanmar (Table 5.2). However, rice followed by a short-duration legume crop is the predominant cropping pattern covering about one million ha.

Agroclimatic Features

Diversity of climate and parent rock have resulted in a wide range of soil types, but only fluvisols, luvisols, and acrisols are agriculturally important (Aye Hla 1990). Agroecologically, Myanmar has been divided into fifteen agroclimatic regions. These are characterized by 20 soil types (Fig. 5.3), mean annual rainfall (Fig. 5.4), temperature (Fig. 5.5), and length of growing season (Fig. 5.6). The climate is relatively cooler in the north and high plateau and warmer in the south particularly in the delta area (Bago, Yangon, and Ayeyarwady divisions). Monthly mean maximum temperature in May varies from 38.2 °C in Monywa (Mandalay division) to 24.1 °C in Hakha (Chin state). Monthly mean minimum temperature in December varies from 2.3 °C in Hakha to 20.8 °C in Myik (Tanintharyi division). On the other hand, the highest monthly mean minimum temperature is observed in

Table 5.1. Total area and production of food legume crops grown in Myanmar, 1997/98.

Crop	Area ('000 ha)			Production ('000 t)			Yield (kg ha^{-1})		
	Rainy season	Winter	Total	Rainy season	Winter	Total	Rainy season	Winter	Mean
Black gram	0.3	482.5	482.8	0.1	410.4	410.5	457	850	850
Mung bean	308.9	234.3	543.2	184.7	253.5	438.2	598	1082	807
Pigeonpea	242.9	NR[1]	242.9	169.8	2.6	172.4	699	NR	710
Soybean	30.2	47.5	77.7	24.0	48.9	72.9	795	1029	938
Cowpea	14.4	63.1	77.5	6.9	51.2	58.1	482	811	750
Chickpea	NR	109.4	109.4	NR	88.4	88.4	NR	808	808
Pea	NR	36.0	36.0	NR	26.9	26.9	NR	747	747
Lima bean	37.5	77.8	115.3	21.3	69.2	90.5	568	889	785
Indian rice bean	8.3	9.5	17.8	5.0	7.1	12.1	603	747	680
Lablab bean	11.6	53.4	65.0	7.0	36.0	43.0	603	675	662
Lentil	NR	2.6	2.6	NR	1.1	1.1	NR	410	410
Groundnut	184.5	261.7	446.2	176.6	363.3	539.9	957	1388	1210
Other pulses	16.9	86.2	103.1	9.8	54.0	63.8	578	627	619
Total	855	1464	2319	605	1413	2018	634	839	767

1. NR = Not relevant.

May which is 26.6°C at Nyaung-oo. In many areas, minimum night temperature is <15°C and lasts for 20–100 days. The lowest minimum night temperature is observed in December and January. Annual precipitation varies considerably throughout the country. Rainfall varies from <600 mm in the dry zone area (Mandalay, Sagaiang, and Magwe divisions) to >5000 mm in the south (Tanintharyi and Rakhine). Annual precipitation varies from year to year and location to location. There are three clearly defined seasons, viz., rainy (June–October), winter (November–February), and summer (March–May).

Spatial Distribution

Twelve grain legumes occupied >2 million ha in 1997/98 (Ministry of Agriculture and Irrigation 1997), covering 16.4% of the gross total sown area. The major food legume crops are mung bean, black gram, pigeonpea, chickpea, cowpea, butter bean (*Phaseolus lunatus* L.; lima bean), soybean, and groundnut.

Mung Bean

Mung bean area increased from 48,268 ha in 1987/88 to 543,177 ha in 1997/98, and its share among grain legumes is the largest (about 25.8%) (Fig. 5.7). The exploitation of early-maturing varieties with synchronized flowering have made possible the sesame-mung bean cropping system in the central dry zone area in the rainy season. On the other hand, short-duration mung bean can also be successfully grown after rice in coastal and delta area (Fig. 5.8). The warmer night temperatures in coastal and delta area seem to be favorable for the growth and development of mung bean in winter, and the yield is significantly higher compared to that of the monsoon crop in central Myanmar dry zone area (Mandalay, Sagaing, and Magwe divisions).

Table 5.2. Major cropping systems of food legumes in Myanmar.

Crop	Cropping system	Land type
Pigeonpea	Pigeonpea-sesame (May–Jun)	Rainfed upland, sandy loam
Mung bean	Sesame-mung bean (May–Jun) (Sep–Oct)	Rainfed upland, sandy loam
	Rice-mung bean (Jun–Aug) (Nov–Dec)	Rainfed lowland, loamy to clay soils
Black gram	Rice-black gram (Jun–Aug) (Oct–Dec)	Rainfed lowland, clay loam/loam soil
Chickpea	Rice-chickpea (Jun–Aug) (Nov–Dec)	Lowland, silty clay to heavy clay soil
Cowpea	Rice-cowpea (Jun–Aug) (Oct–Dec)	Well-drained lowland sandy loam to clay loam
Soybean	Soybean-wheat (May–Jun) (Oct–Nov)	Highland, loam-clay loam
	Rice-soybean (Jun–Aug) (Oct–Nov)	Medium high-lowland, silty loam clay, loam soils
Groundnut	Sesame-groundnut (May–Jun) (Aug–Sep)	Medium highland, sandy loam
	Rice-groundnut (Jun–Aug) (Nov–Dec)	Rainfed lowland, sandy loam-light clay loam

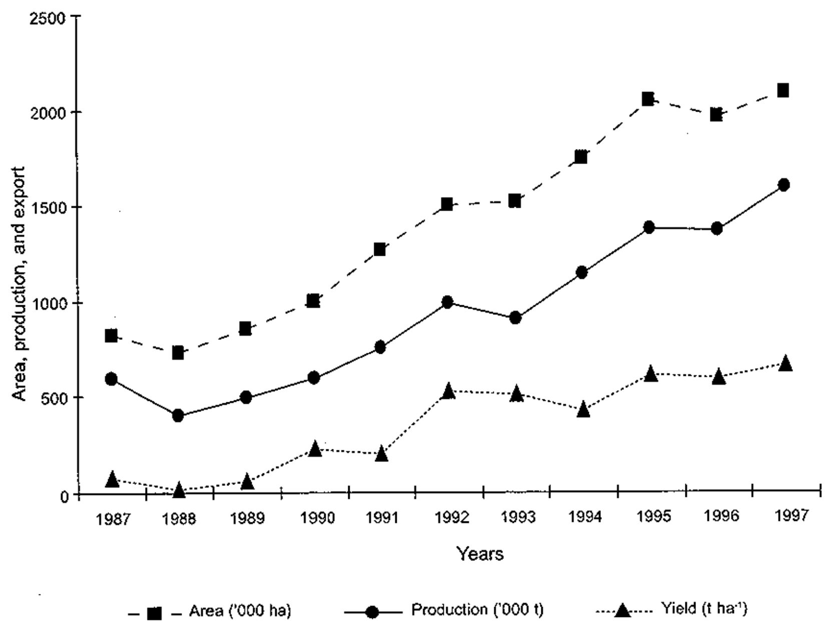

Figure 5.2. Area, production, and export of food legumes in Myanmar in 1987–97.

Black Gram

The crop covers about 0.5 million ha in Myanmar, representing 23.5% of the annual grain legume area. The area under black gram gradually increased from 76,502 ha in 1982/83 to 482,788 ha in 1997/98 (Fig. 5.7). Significant increase in area under black gram was observed in Bago, Yangon, and Ayeyarwady divisions. This region contributes about 90% of the total area under black gram in Myanmar (Fig. 5.9). The increase in area is attributed to the exploitation of short-duration and relatively high-yielding cultivars such as Yezin 2. Rice followed by black gram is a popular cropping pattern in lower Myanmar and delta areas.

Besides, there are areas where crops cannot be grown due to flooding in the rainy season. Farmers are exploring the possibility of growing black gram in these areas in October and November when flooding subsides. The area under black gram in such areas is about 10% of the total black gram area.

Pigeonpea

Pigeonpea is the third most important grain legume crop. The area under pigeonpea substantially increased over time from 53,653 ha in 1986/87 to 242,857 ha in 1997/98 (Fig. 5.7). Pigeonpea is mainly confined to the central dry zone area (Fig. 5.10) of Myanmar (Sagaing, Mandalay, and

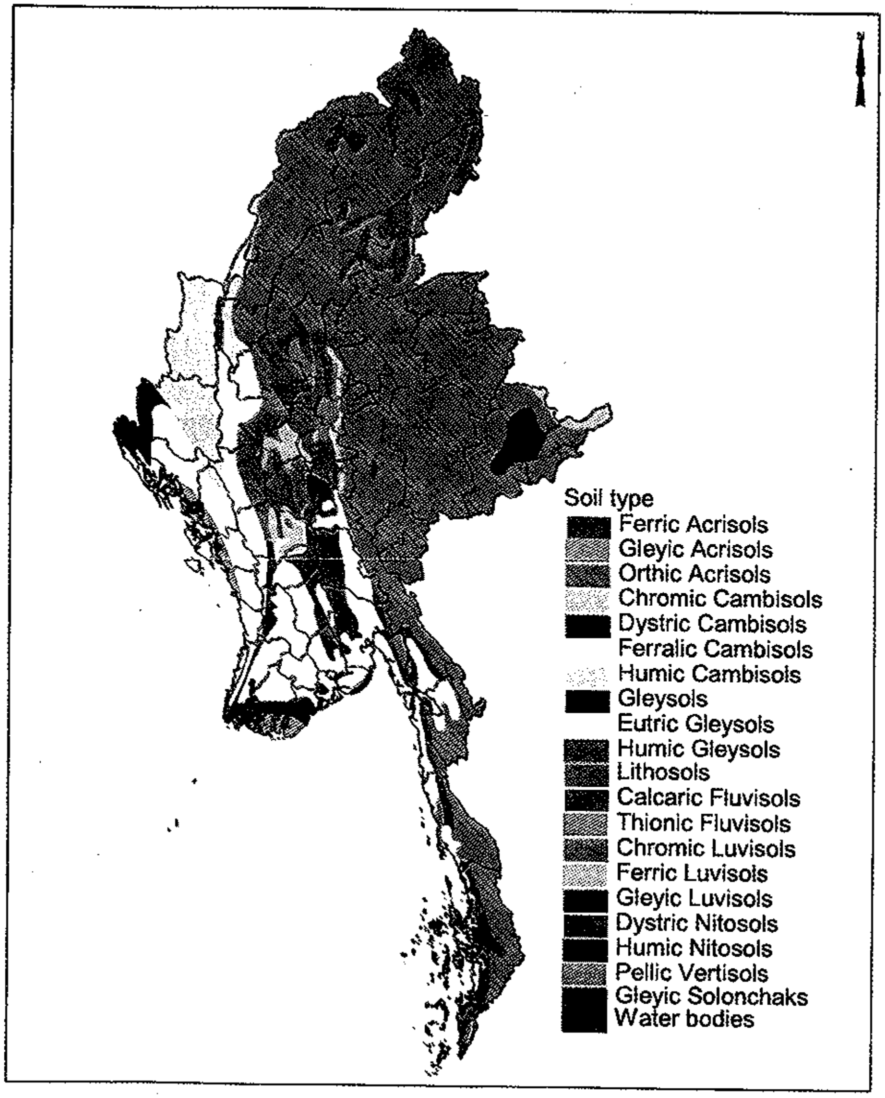

Figure 5.3. Soils of Myanmar (Source: FAO, Rome, Italy).

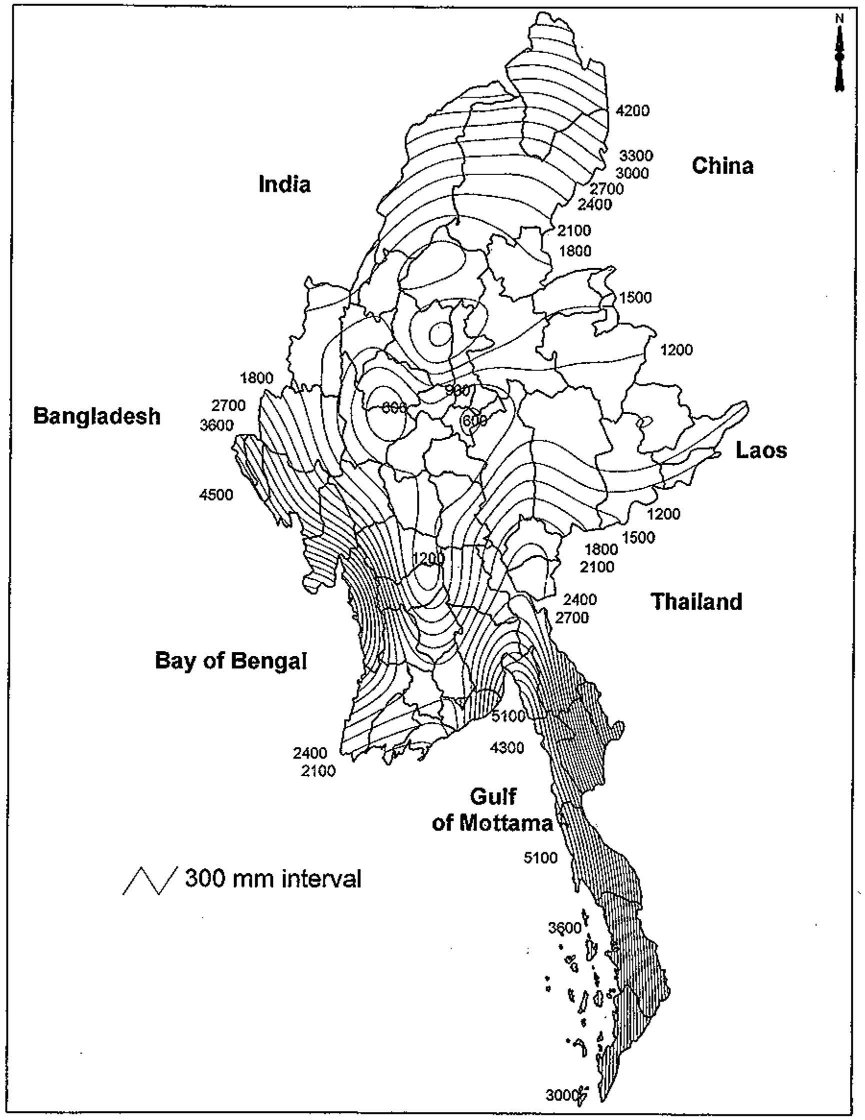

Figure 5.4. Rainfall isohyets in Myanmar (Source: University of Yangon, Myanmar).

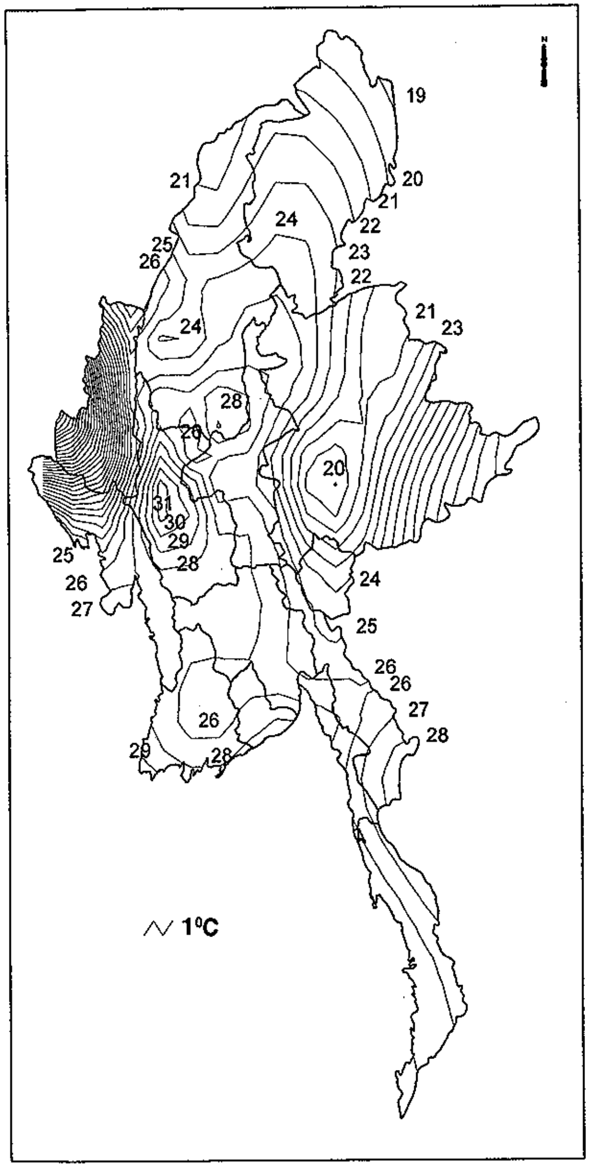

Figure 5.5. Isotherms in Myanmar (Source: University of Yangon, Myanmar).

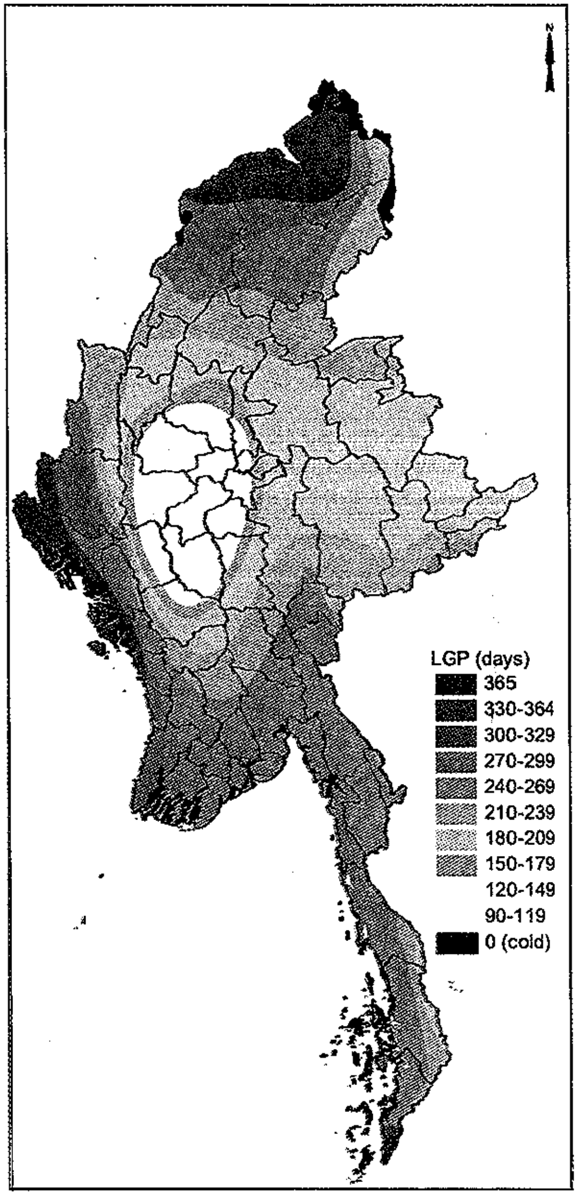

Figure 5.6. Length of growing period (LGP) in Myanmar (Source: FAO, Rome, Italy).

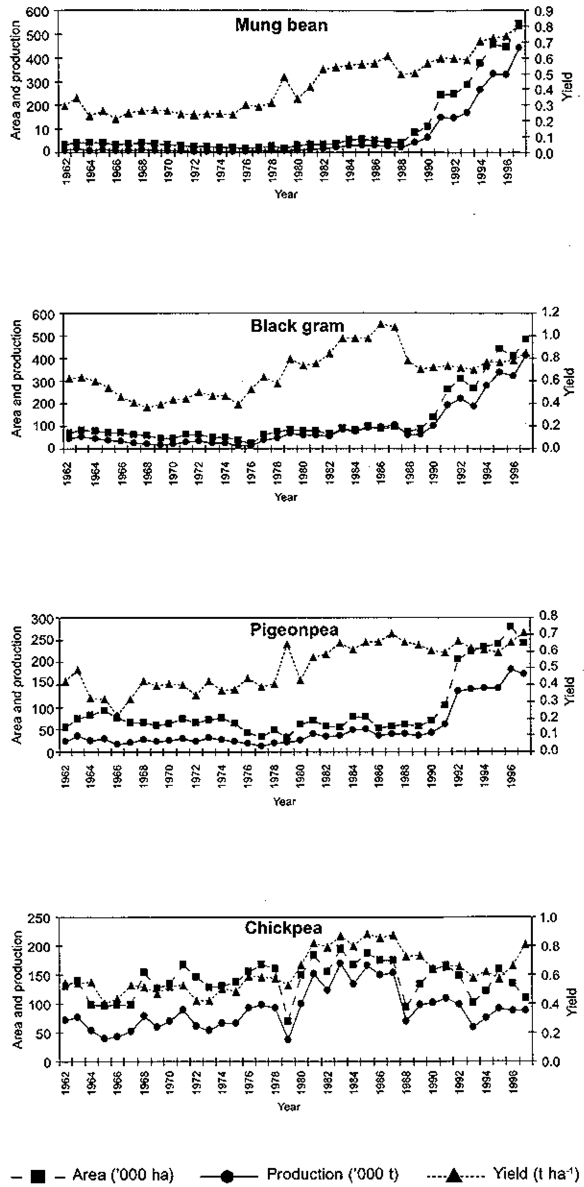

Figure 5.7. Area, production, and yield of major legumes in Myanmar, 1962–97.

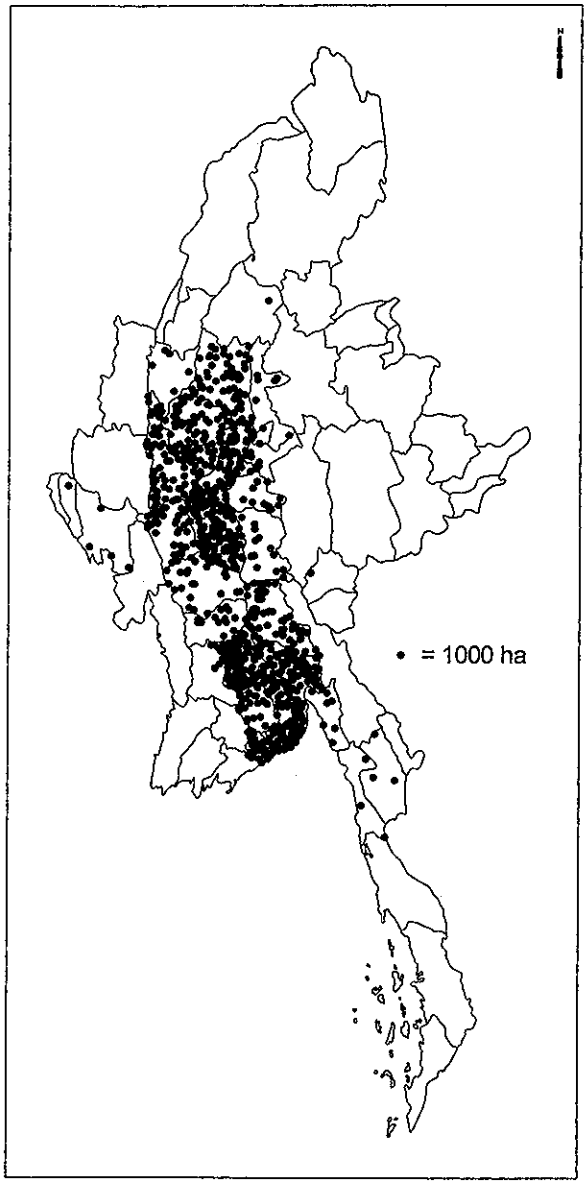

Figure 5.8. Mung bean distribution in Myanmar, 1998/99.

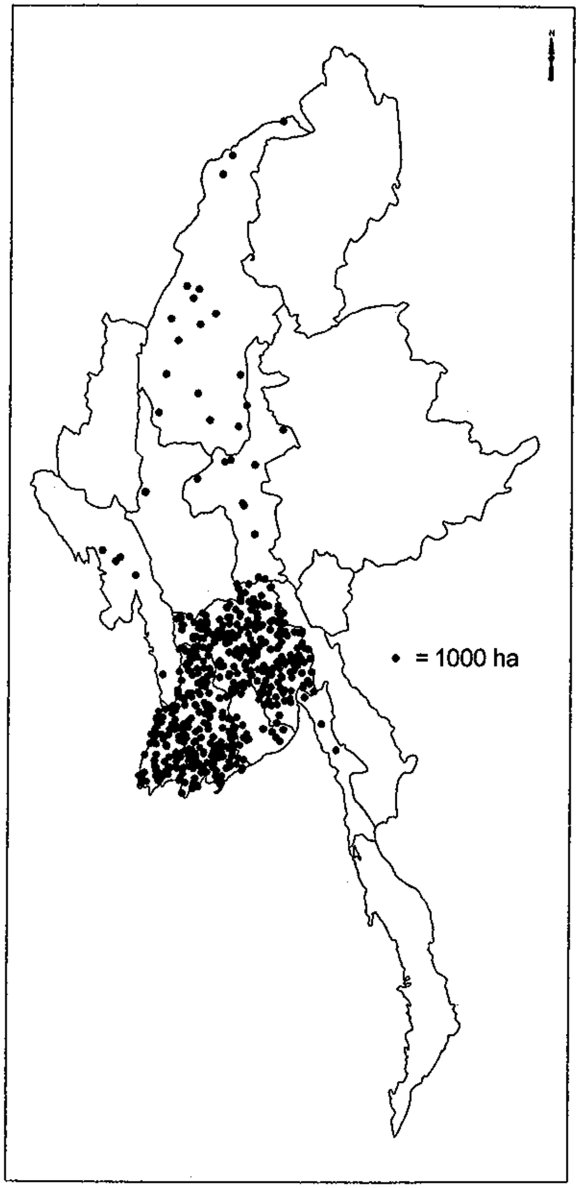

Figure 5.9. Black gram distribution in Myanmar, 1999.

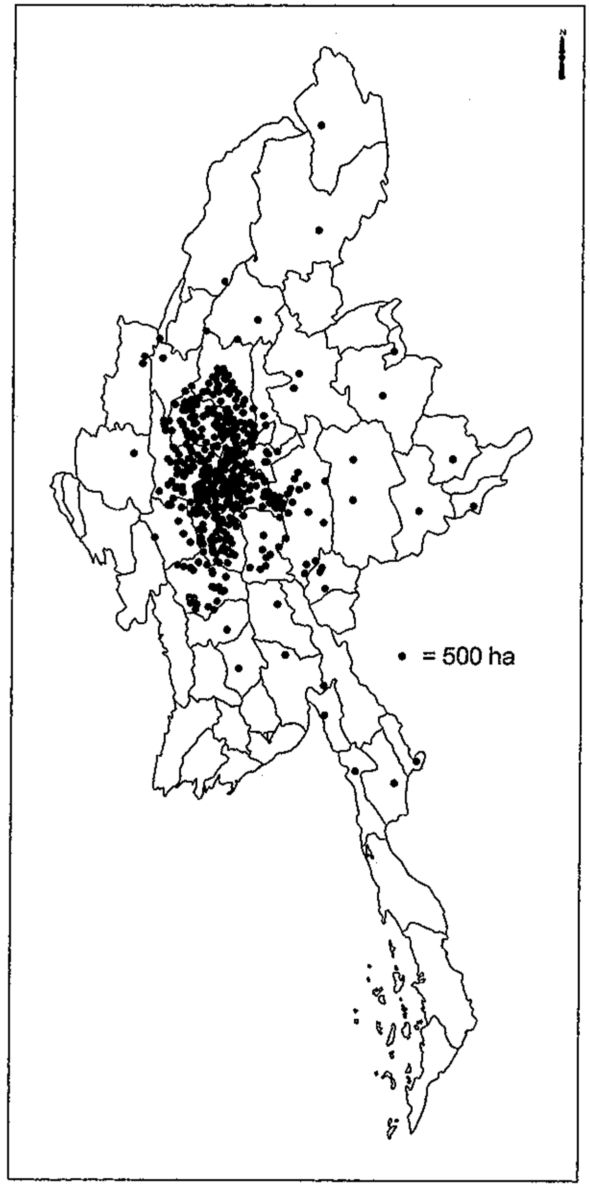

Figure 5.10. Pigeonpea distribution in Myanmar, 1998/99.

Magwe divisions). It is normally grown in the rainy season and accounts for about 11% of total area under pulses. Production was about 172,392 t with an average yield of 0.70 t ha^{-1} in 1997/98. The maturity duration of pigeonpea varieties ranges from 150 days to 270 days. Long-duration varieties are commonly sown as an intercrop with sesame, groundnut, and mung bean. Short- and medium-duration varieties can be grown in rice fallows (sown in late October/early November).

Chickpea

Chickpea is an important legume in Myanmar. The crop is usually grown in the Sagaing, Mandalay, Magwe, Bago, and Ayeyarwady divisions (Fig. 5.11). The area under chickpea declined during early 1980s but stabilized at 109,446 ha grown during 1997/98 (Fig. 5.7). It is mainly grown as relay or sequential crop after rice in the lowlands. It is also cultivated on soils with good water-holding capacity, after short-duration monsoon crop of maize or pulses, or after fallow (Virmani et al. 1991). Chickpea is sometimes intercropped with wheat (*Triticum aestivum* L.) and sunflower (*Helianthus annuus* L.) in Sagaing division. It is also planted after floodwater recedes, along the bank of Ayeyarwady river.

Cowpea

Cowpea is one of the major legumes in Myanmar. The area under cowpea is 81,000 ha, representing about 7% of the total grain legume area in 1998/99 (Fig. 5.12). Cowpea is usually grown after rice or as upland crop, mainly in the Magwe, Yangon, Bago, Mandalay, and Ayeyarwady divisions. The largest area is in Magwe division (central Myanmar). Cowpea area increased from 20,100 ha in 1977/78 to 77,500 ha in 1997/98 (Fig. 5.13) and the yield increased in the past five years from 515 kg ha^{-1} in 1990/91 to 732 kg ha^{-1} in 1997/98.

Soybean

The crop covers 78,812 ha (Fig. 5.13) which is about 4% of the total grain legume area in 1997/98. About 46% of total soybean area is in Shan state which is located about 1000 m above sea level. In Shan state, soybean is cultivated during rainy season. The rest of soybean is grown in winter (October–November) mainly after rice harvest. The majority of winter soybean area can be found in Sagaing, Mandalay, and Bago divisions and in Kachin state (Fig. 5.14). Most of the crop varieties currently grown are vegetable types. The crop area may be extended if the adapted high-yielding oil-type soybean cultivars are introduced.

Groundnut

Groundnut is an important oil crop and a good source of protein supplement for animals. The crop covered about 446,000 million ha in 1997/98 (Fig. 5.13). Forty-five percent of total groundnut area is sown during the rainy season (June–September) and 55% during winter (November–December). The rainy season groundnut is mostly grown in the Mandalay, Magwe, and Sagaing divisions, and Shan state which account for 70% of the production (Fig. 5.15). Winter groundnut is also grown along the river banks, and as post-rice crop in Ayeyarwady delta area, under receding soil moisture conditions.

Groundnut production in winter is almost double that of rainy season, due to higher average yield (about 1.2 t ha^{-1}) compared to rainy season. In the central dry zone area, long-duration (150 days) varieties are grown as they show tolerance to mid-season drought. However, the short- and medium-duration varieties of groundnut (90–120 days) are generally grown as a sequential crop after rice or on river banks.

Minor Legumes

Pea (*Pisum sativum* L.), kidneybean (*Phaseolus vulgaris* L.; common bean), and lentil (*Lens culinaris* Medic.) are relatively minor legumes in Myanmar. Their distribution is represented in Figures 5.16 and 5.17.

Butter bean

The crop is a minor legume group which consists of different land races, derived from *Phaseolus lunatus*, such as colored lima bean, butter bean, etc. There are five major crop groupings in butter bean, which are not botanically different. The area under butter bean is 43,500 ha which is 5.6% of the total legume area in 1997/98 (Fig. 5.13). The extensive area under butter bean can be observed in the Sagaing, Mandalay, Magwe, Bago, and Ayeyarwady divisions (Fig. 5.18).

Constraints

Biotic Constraints

The yield of grain legumes is low particularly when cultivated in the rice-based cropping systems due to several biotic and abiotic stresses. Diseases, pests, weeds, and seed dormancy reduce the yields. The information on biotic constraints is limited. The important diseases and insect pests affecting legumes production in Myanmar are listed in Table 5.3.

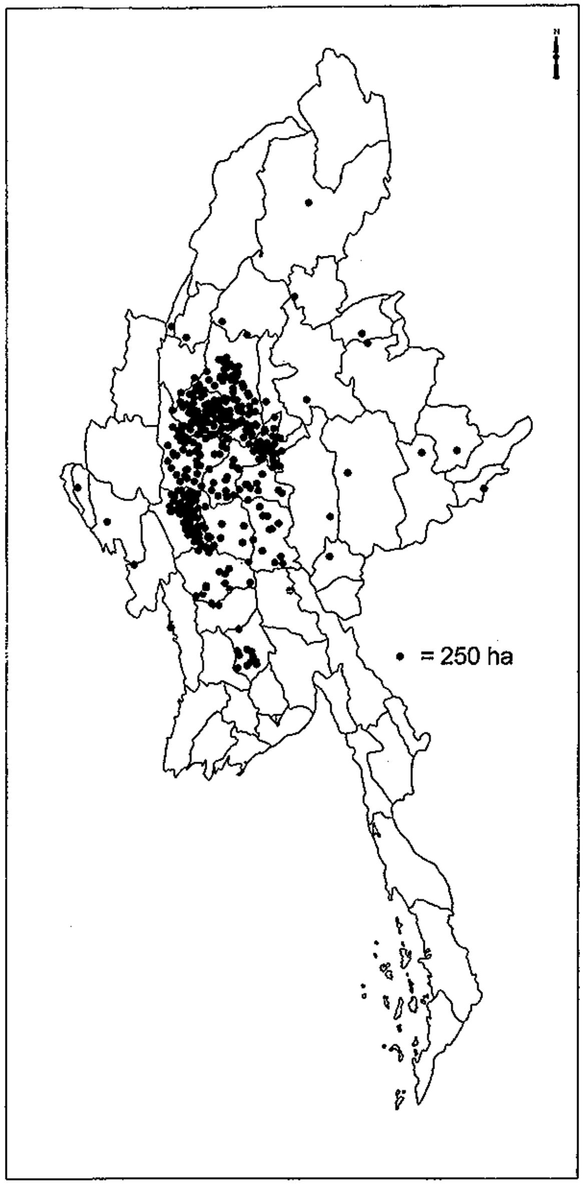

Figure 5.11. Chickpea distribution in Myanmar, 1998/99.

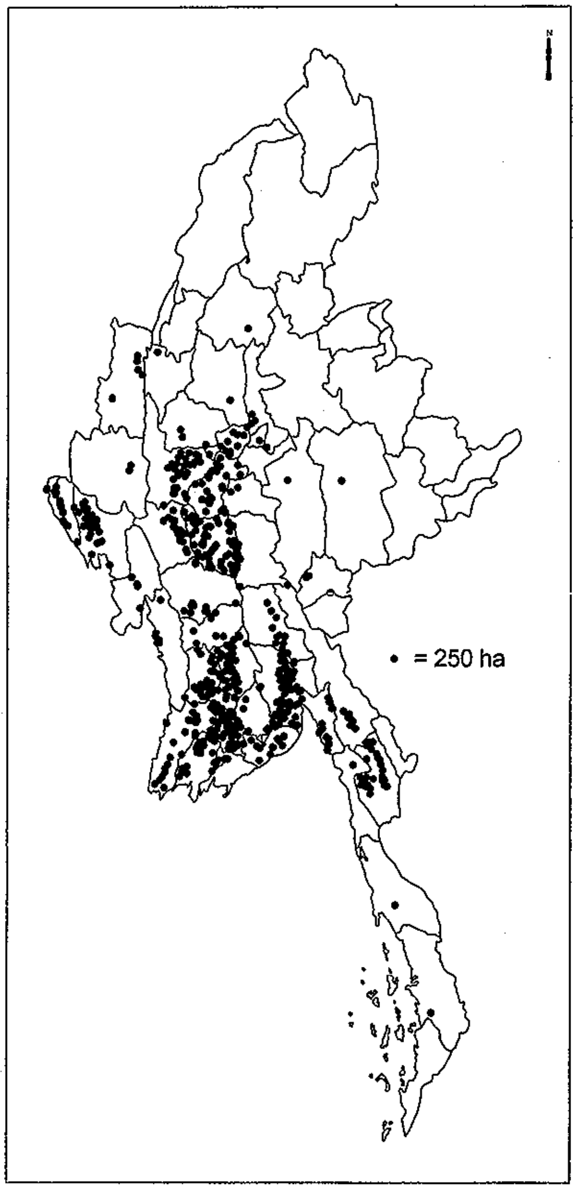

Figure 5.12. Cowpea distribution in Myanmar, 1998/99.

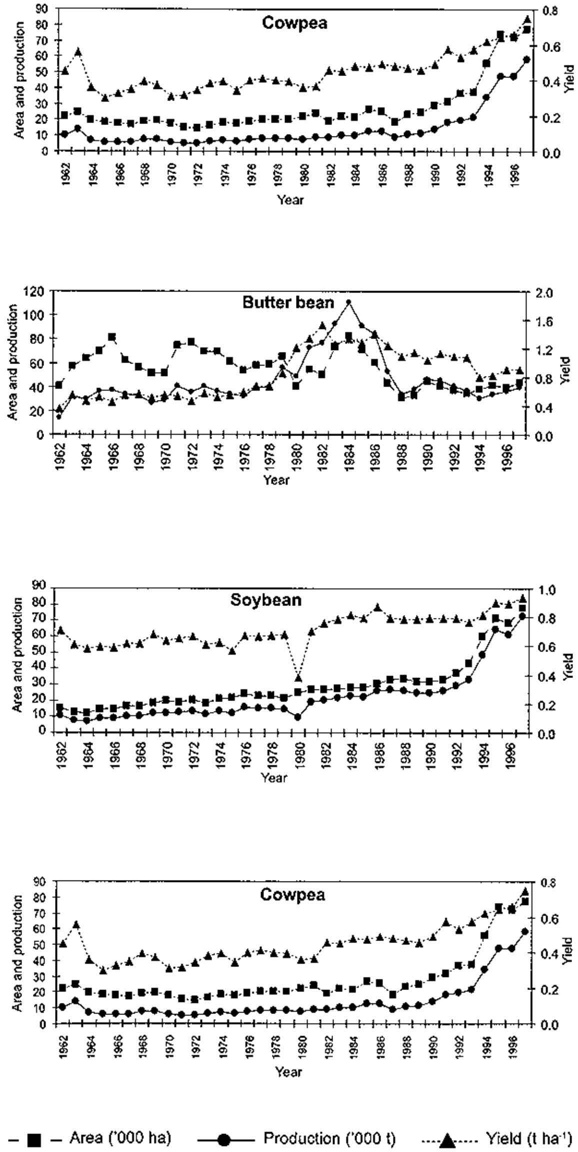

Figure 5.13. Area, production, and yield of other legumes in Myanmar.

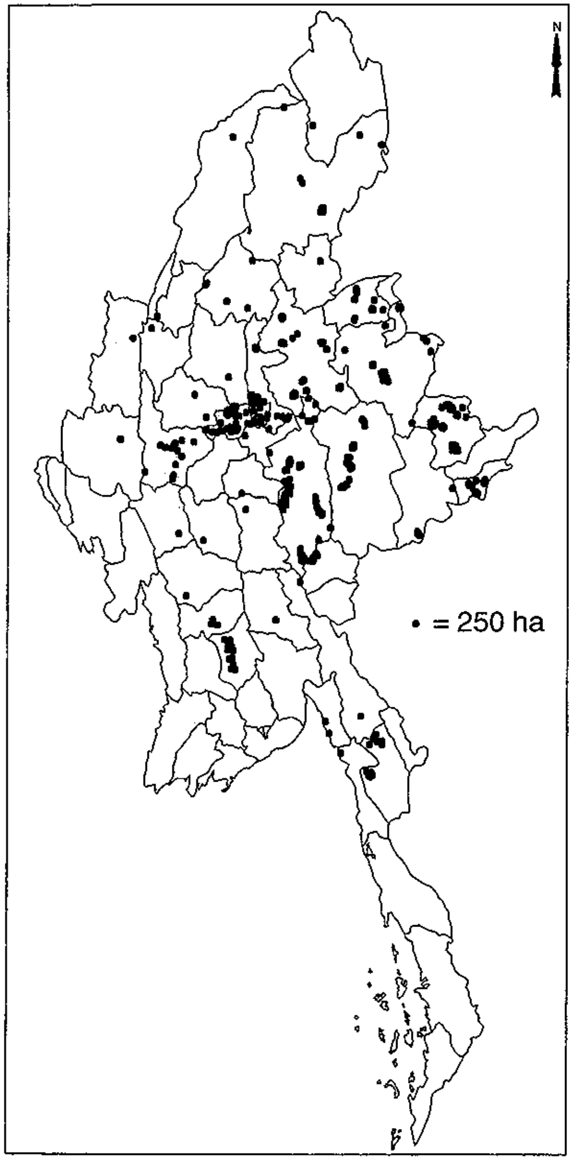

Figure 5.14. Soybean distribution in Myanmar, 1998/99.

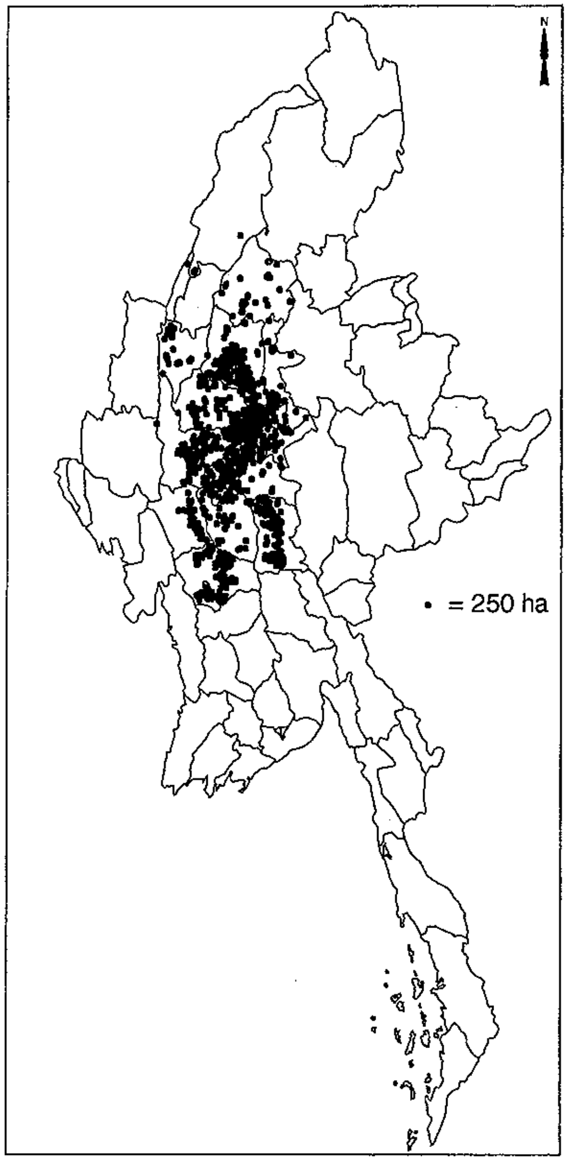

Figure 5.15. Groundnut distribution in Myanmar, 1998/99.

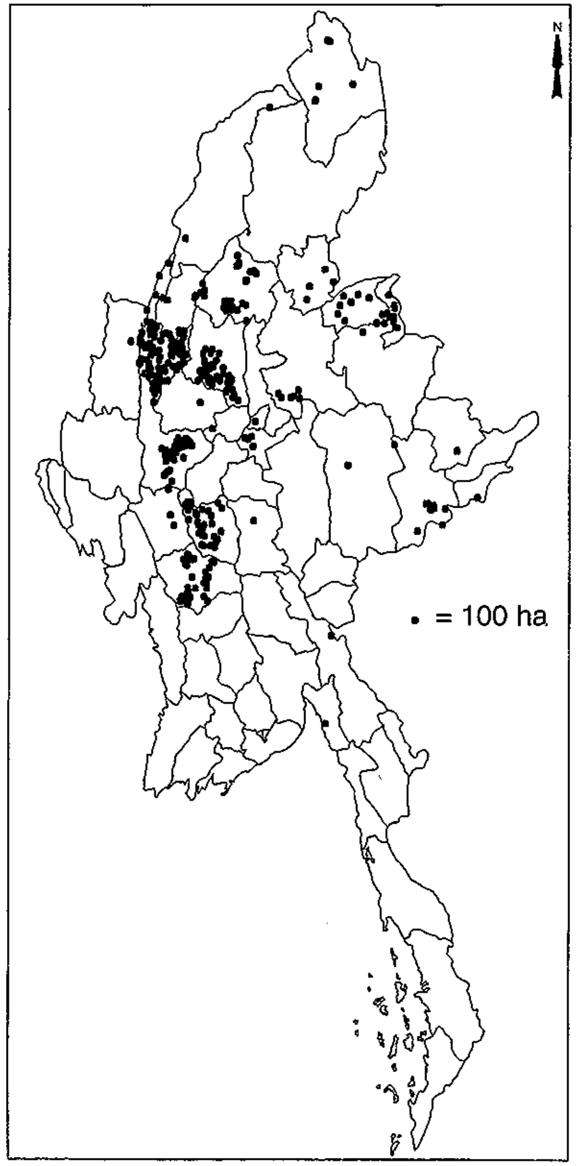

Figure 5.16. Pea distribution in Myanmar, 1998/99.

Chickpea

Among various diseases of chickpea, fusarium wilt (caused by *Fusarium oxysporum* f. sp *ciceris*) and wet root rot (*Rhizoctonia solani*) are well recognized by farmers as yield reducers (Fig. 5.19). The survey conducted in different divisions and states of Myanmar during 1998–99 indicated the occurrence of these diseases in four chickpea-growing states; however, the incidence in Sagaing and Mandalay was negligible. These diseases caused <1% plant mortality of chickpea in Bago and up to 2% plant mortality in Magwe.

During the survey in 1998–99, pod borer (*Helicoverpa armigera*) was noted as the most important pest. Occurrence of aphids (*Aphis craccivora*) in Ayeyarwady and of armyworms (*Spodoptera exigua*) and cutworms (*Agrotis ipsilon*) in Ayeyarwady and Magwe was observed (Fig. 5.19). But their infestation was low (1–2.9%) to cause any economic damage on crop yields. *Helicoverpa* inflicted 2–61% pod damage in different chickpea-growing areas. Though pod borer was present in all locations the infestation was high in Sagaing (12–36%) and Magwe divisions (36–61%).

The lack of native *Rhizobium* population affects the chickpea yield in the new soils. *Rhizobium* inoculation increases chickpea yield (Thein and Hein 1997) particularly during the first year. Weed problem is serious in chickpea, especially where the soil remains moist during early growth stages.

Pigeonpea

Plant mortality of pigeonpea due to fusarium wilt (*Fusarium udum*) was observed in Sagaing, Magwe, Mandalay, and Bago divisions, but wilt incidence was negligible.

Insect pests are a major constraint to pigeonpea production in Myanmar. Observations during a survey indicated that several species of insects feed on pigeonpea. But aphids (*Aphis craccivora*), armyworms (*Spodoptora exigua*), spotted pod borer (*Maruca vitrata*), and pod borer (*Helicoverpa armigera*) were most common (Fig. 5.20). *Helicoverpa armigera* was a serious pest in Kayin and Mandalay causing pod damage up to 16%. In Kachin, it caused 5% pod damage. In Shan, Magwe, Bago, and Sagaing divisions the infestation was negligible (<2%). Among defoliators, armyworm and *Maruca* were the most significant. These defoliators inflicted 8–9% damage in Kachin, Shan, and Kayah. Though these defoliators were present in Ayeyarwady division, they were not serious pests. Aphids were common in Ayeyarwady but the incidence was low (1–4%).

Pigeonpea is susceptible to weed competition in the early stages of crop growth, but it effectively suppressed weed growth during the later growth stages. Weed control during the first 5–7 weeks is important in attaining acceptable yields. Pigeonpea yield is also limited by poor nodulation in farmers' fields.

Mung bean and black gram

Among various diseases in mung bean, alternaria leaf spot was common in Yangon division but its severity was low with 0.3% foliar damage (Fig. 5.21). Mung bean insect pests were less serious than those of pigeonpea in Myanmar. Among insect pests, aphids (*Aphis craccivora*) was serious in Kachin and up to 15% plants were infested. The incidence of aphids in other states was 1–8% in Magwe, Bago, Yangon, Kayah, and Shan (Fig. 5.21). The defoliators, cutworm (*Agrotis ipsilon*) and armyworm (*Spodoptera exigua*) caused 1–9% damage in Kachin, Shan, Magwe, Bago, Yangon, and Ayeyarwady. Incidence of *Helicoverpa* pod borer was 7–15% in Shan and Kayin. The pod borer incidence in other states was low (1–7% damage). Though the incidence of stem borer was noticed in Mon state, the damage was negligible (<1%).

Fungal diseases [alternaria leaf spot and rust (*Uromyces appendiculatus*)] were common on black gram in only Yangon state in the southern region with low incidence of up to 2.5%. Armyworms and cutworms showed moderate infestation (13%) in black gram in Kachin state. These were less severe in south compared to north (Fig. 5.22). Aphid incidence was noticed in southern states (Ayeyarwady, Yangon, and Mon) but the incidence was <3.4%. Occurrence of *Helicoverpa* pod borer was noticed both in north and south with more damage in Kachin (43%) than Ayeyarwady and Yangon in south (<2%). Beanfly causing seedling mortality was observed only in Mon state, but was not severe (0.1%).

Weeds significantly suppress the growth and development of mung bean and black gram, in the seedling stage. Nut sedge (*Cyperus rotundus* L.) and broad leaf weeds are found in mung bean in rainy season. Hand weeding during the first 30 days of sowing provides effective weed control. When mung bean is grown in May–June, the pods mature in August–September, and the matured seeds tend to germinate when rain occurs for three to four consecutive days, resulting in substantial yield losses.

Cowpea

Fusarium wilt caused by *Fusarium oxysporum* is an important seedborne and soilborne disease. Cowpea yellow mosaic and ascochyta blight occur in some areas. Foliage feeders plumemoth (*Exelastis atomosa*), semilooper (*Autographa nigrisigna*), and armyworm (*Spodoptera exigua*) were most common in cowpea

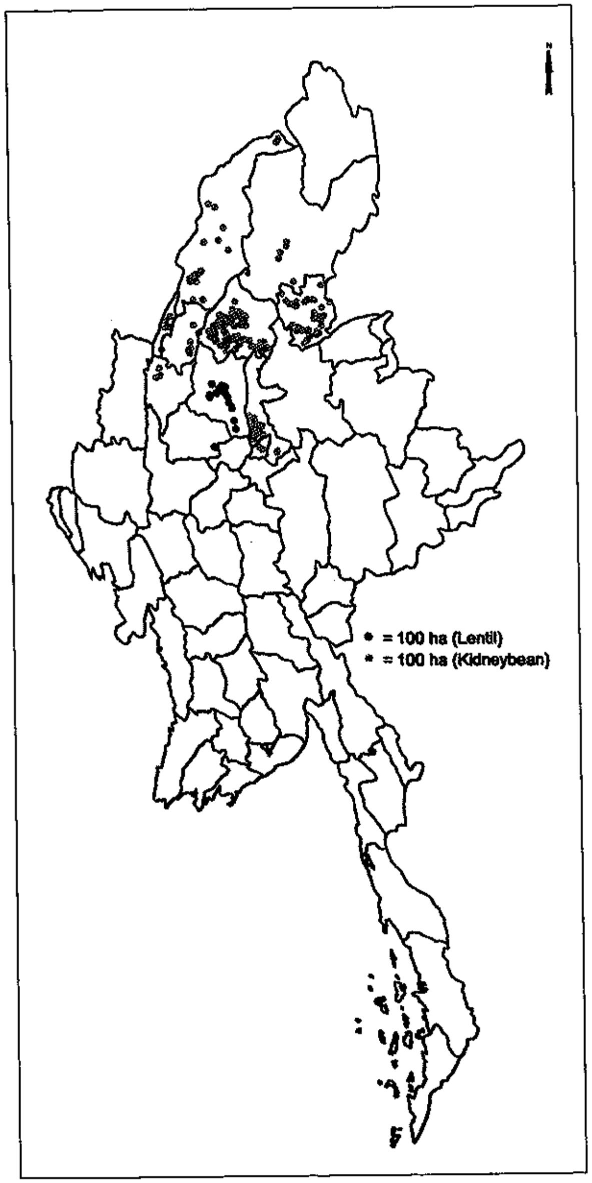

Figure 5.17. Kidneybean and lentil distribution in Myanmar, 1998/99.

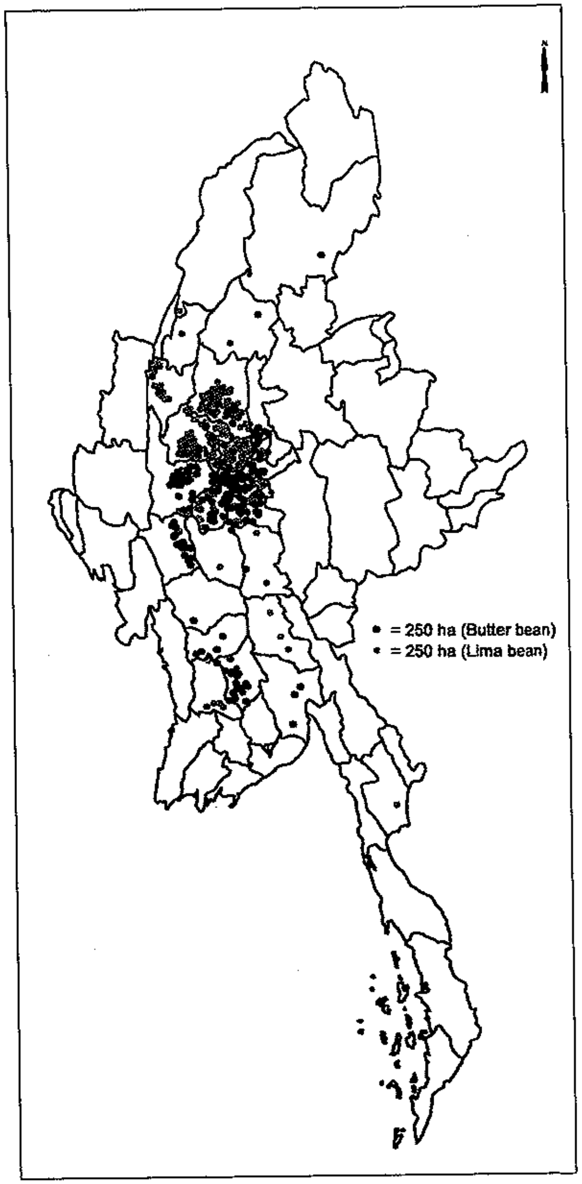

Figure 5.18. Butter bean and lima bean distribution in Myanmar, 1998/99.

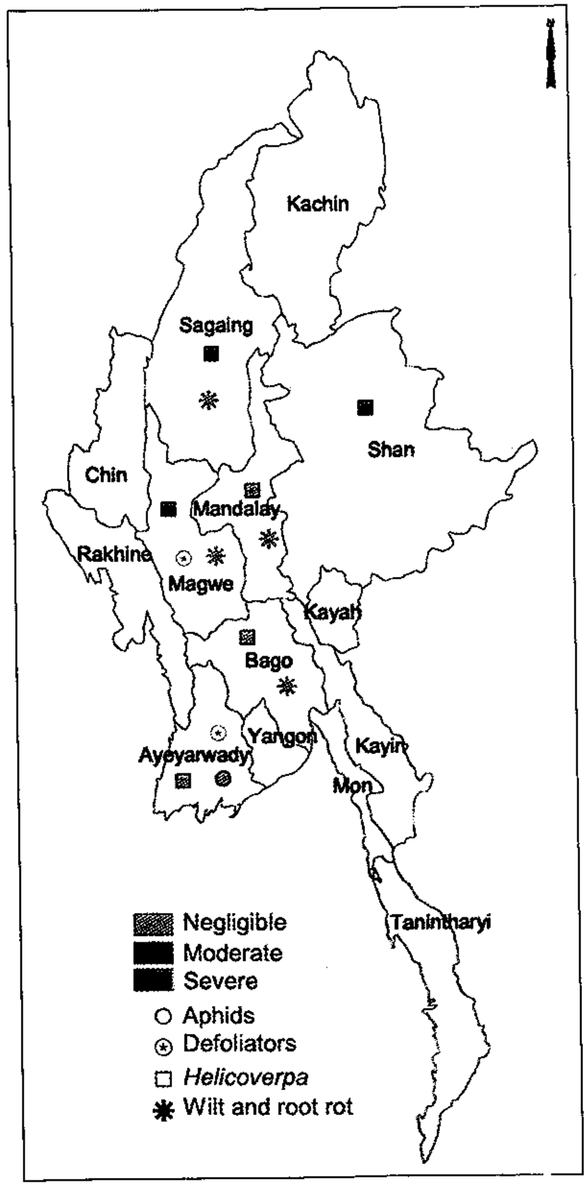

Figure 5.19. Severity of diseases and insect pests of chickpea in Myanmar in 1998/99.

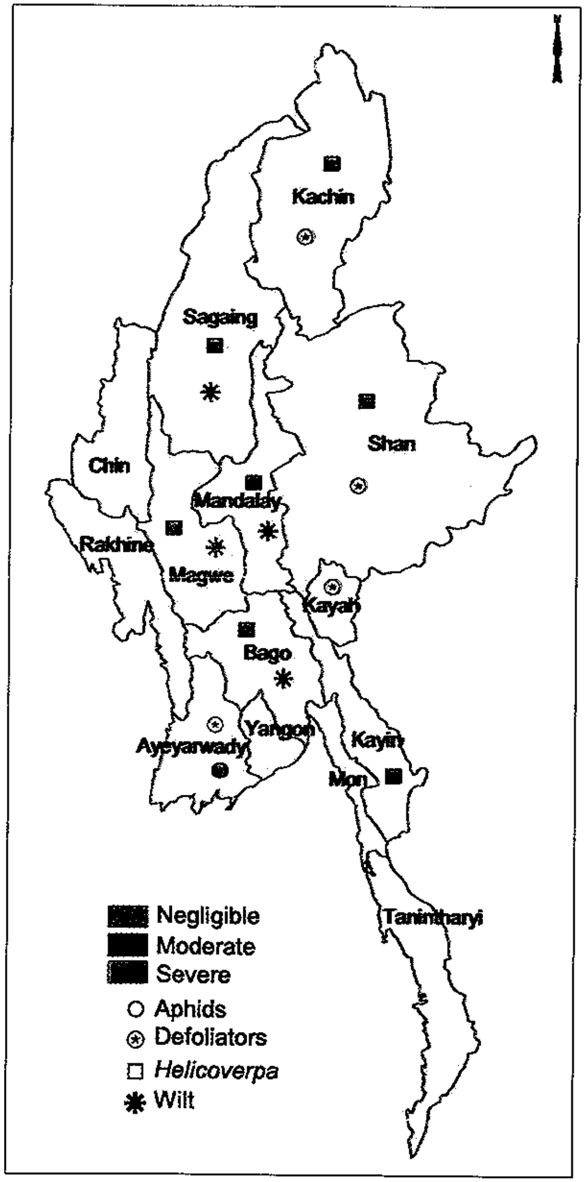

Figure 5.20. Severity of diseases and insect pests of pigeonpea in Myanmar in 1998/99.

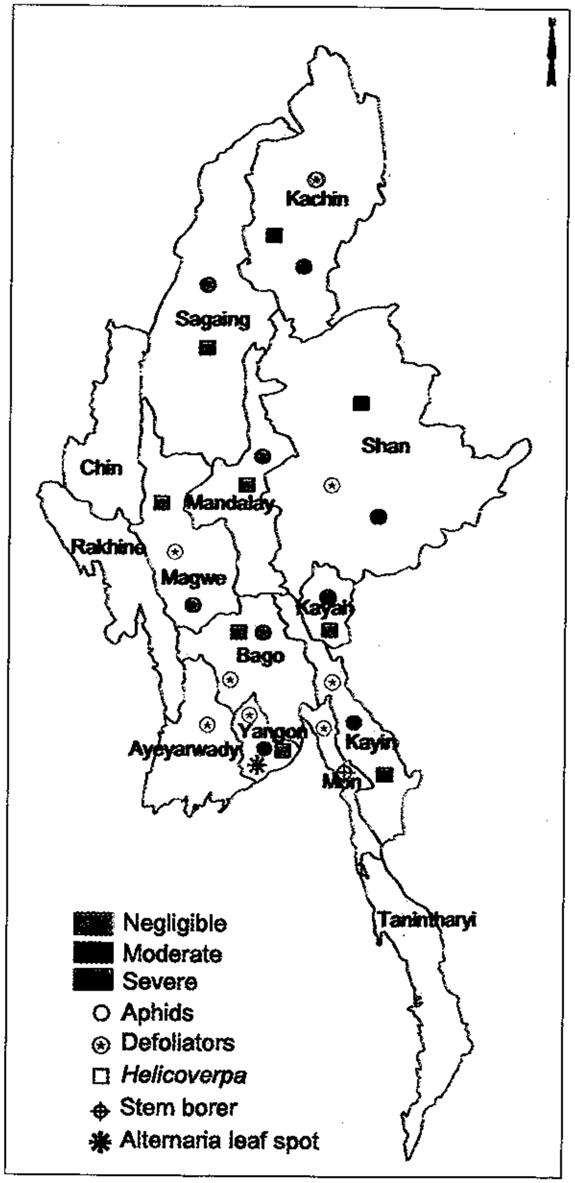

Figure 5.21. Severity of diseases and insect pests of mung bean in Myanmar in 1998/99.

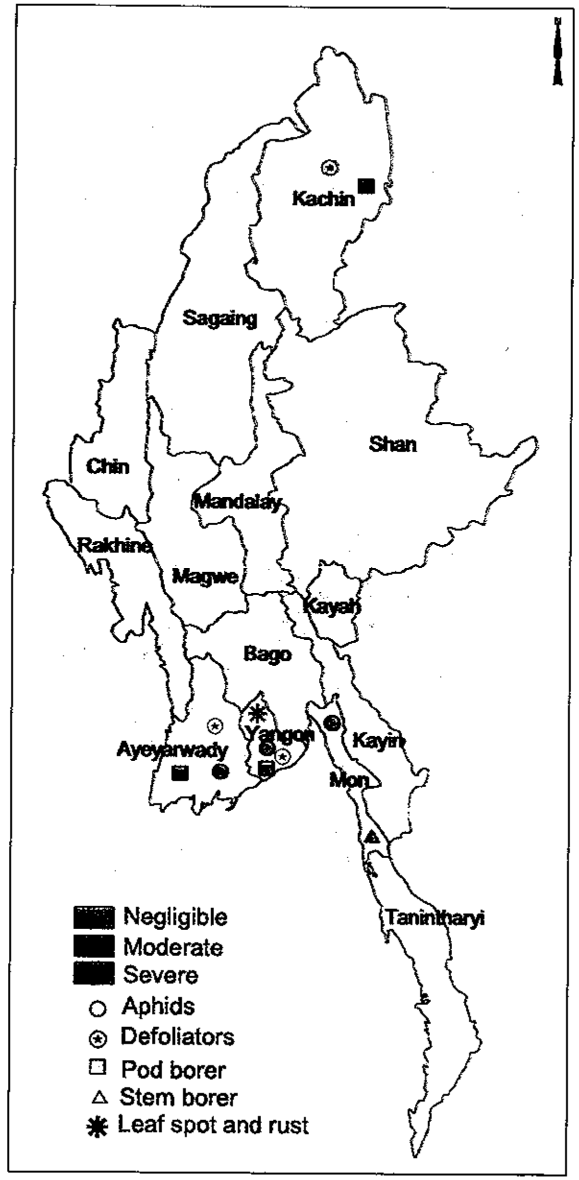

Figure 5.22. Severity of diseases and insect pests of black gram in Myanmar in 1998/99.

in Sagaing, Magwe, Ayeyarwady, Yangon, Kayin, and Mon states/divisions. Their severity was more in the east coastal Kayin with 10.7% infestation (Fig. 5.23). Aphid infestation was moderate in Shan with 6.8%.

Groundnut

Seedling diseases such as collar rot (*Aspergillus niger*) and root rot (*Sclerotium rolfsii*) were generally noticed in Magwe, Sagaing, and Bago divisions, but their severity was very low (0.1%). Early and late leaf spots were the most significant foliar diseases throughout the groundnut-growing areas (Fig. 5.24). Kayin in the east coast had high incidence (11.4%). Rust (*Puccinia arachidis*) was noticed in Magwe, Sagaing, and Yangon divisions with about 3.8% incidence. *Aspergillus*, *Penicillium*, and *Rhizopus* are common pathogens in storage. Groundnut infested by *Aspergillus flavus* produces aflatoxin, which is a serious storage problem.

Among various insects, defoliators, sap feeders, and root feeders were common throughout the groundnut-growing areas (Fig. 5.24). Armyworm (*Spodoptera exigua*), leaf miners (*Aproaerema modicella*), and hairy caterpillars (*Amsacta* sp) were common in all fields with less severity of 2–3% incidence. Aphids and jassids were moderate in Magwe division with 8–9% infestation while the root feeders were limited to Shan, Kayah, and Kayin states with 0.2–6.3% incidence.

Bruchids, *Callosobruchus maculatus* and *C. chinensis*, cause major losses during storage. These two species infest all pulses except black gram. Black gram is attacked only by *C. maculatus* (Rahman 1991).

Groundnut is very sensitive to weed competition and extent of damage by weeds depends on the weed species. Short-duration spanish and valencia groundnut lack seed dormancy. Farmers prefer the spanish and valencia types due to their short-duration compared to virginia types. However, the spanish types tend to germinate when rain occurs prior to harvest, resulting in considerable losses. On the other hand, groundnut seeds stored under ordinary conditions start losing viability after three months of storage and lose viability completely before the next season. Storage techniques have now been developed to retain 100% viability up to 9–10 months.

Soybean

Fungal diseases such as alternaria leaf spot and rust were observed on soybean crop only in Kayin and Shan states. Of these two diseases, rust was more severe with 39% plant infection in Shan state. Alternaria leaf spot was noticed only in 2–8% plants.

Armyworm (*Spodoptera exigua*), plumemoth (*Exelastis atomosa*), and semiloopers (*Autographa nigrisigna*) were most common on soybean (Fig. 5.25). These insects were severe in eastern states and the importance of insects pests was more distinct as one moved towards south (5.3–14%) from Kachin state. The pest problem was low (0.1%) in Bago and moderate (3.9%) in Sagaing division.

Lentil

Among diseases, fusarium wilt was the only disease observed in Shan state with 2.9% incidence. Aphids were the only insects noticed on lentil crop in Sagaing and Shan states and had 4.2% incidence.

Abiotic Constraints

Climatic and soil conditions influence the productivity of both monsoon and winter food legume crops. Drought, excess moisture, adverse temperature, and soil conditions are the common abiotic stresses that determine the productivity of food legumes in Myanmar.

Drought

Among abiotic stresses, drought is the most important factor limiting productivity of legumes. The occurrence of moderate to very severe drought mostly occurs in dry zone where legume cultivation is predominant. On the other hand, major legume crops are also grown in receding soil moisture environment. Very little rainfall occurs during the postrainy season and the crops are exposed to terminal drought stress.

Substantial improvement has been made in developing short-duration cultivars that escape the end-season soil moisture deficit. Chickpea cultivars, ICCV 2 and ICCV 88202, were reported to be drought tolerant due to their earliness. Similarly, mung bean variety V 3726 escapes terminal stress owing to the early and synchronized flowering and podding.

On the other hand, management techniques to improve soil moisture conservation and reduce evaporation provide scope to minimize drought effect on legumes. Appropriate crop duration to match soil moisture availability pattern offers the best scope for yield improvement under drought conditions. Matching of photoperiod in the target environment is also important.

Excessive soil moisture and humidity

Groundnut, pigeonpea, and mung bean are grown in early rainy season. High rainfall coupled with high humidity encourage insect pest infestation. Excessive vegetative growth leads to lodging. The foliar diseases such as early

Table 5.3. **Major diseases and insect pests of grain legumes in Myanmar.**

Crop	Disease (Pathogen)	Insect pests
Chickpea	Fusarium wilt (*Fusarium oxysporum* Schlect. f. sp *ciceris* (Padwick) Matuo & Sato) Wet root rot (*Rhizoctonia solani* Kühn)	Armyworm (*Spodoptera exigua* Hübner) Pod borer (*Helicoverpa armigera* Hübner) Semilooper (*Autographa nigrisigna* Walk.) Bruchids (*Callosobruchus maculatus* F., *C. chinensis* L.) Aphids (*Aphids craccivora* Koch) Cutworm (*Agrotis ipsilon* Hufnagel)
Pigeonpea	Fusarium wilt (*Fusarium udum* Butler) Sterility mosiac (sterility mosiac virus)	Pod borer (*Helicoverpa armigera* Hübner) Aphids (*Aphis craccivora* Koch) Spotted pod borer (*Maruca vitrata* Gey.) Armyworm (*Spodoptera exigua* Hübner) Podfly (*Melanagromyza obtusa* Mall.) Bruchids (*Callosobruchus maculatus* F., *C. chinensis* L.) Aphids (*Aphids craccivora* Koch)
Mung bean	Yellow mosaic (mung bean yellow mosaic virus) Cercospora leaf spot (*Cercospora* sp) Bacterial leaf spot (*Xanthomonas phaseoli*) Halo blight (*Pseudomonas phaseolicola* Burkh.)	Hairy caterpillar (*Diacrisia obliqua* Walk.) Pod borer (*Helicoverpa armigera* Hübner) Beanfly (*Ophiomyia phaseoli* Tryo.) Aphids (*Aphis craccivora* Koch) Bruchids (*Callosobruchus maculatus* F., *C. chinensis* L.)
Black gram	Yellow mosaic (mung bean yellow mosaic virus) Cercospora leaf spot (*Cercospora* sp)	Hairy caterpillar (*Diacrisia obliqua* Walk.) Armyworm (*Spodoptera exigua* Hübner) Pod borer (*Helicoverpa armigera* Hübner) Whitefly (*Bemisia tabaci* Genn.) Beanfly (*Ophiomyia phaseoli* Tryo.) Aphids (*Aphis craccivora* Koch) Bruchids (*Callosobruchus maculatus* F., *C. chinensis* L.)
Cowpea	Fusarium wilt (*Fusarium oxysporum* f. sp *tracheiphilum*) Yellow mosaic (yellow mosaic virus) Ascochyta blight (*Ascochyta rabiei* (Pass.) Labr.)	Pod borer (*Maruca vitrata* Gey., *Helicoverpa armigera* Hübner) Aphids (*Aphis craccivora* Koch) Plumemoth (*Exelastis atomosa* Walsingham) Semilooper (*Autographa nigrisigna* Walk.) Armyworm (*Spodoptera exigua* Hübner) Bruchids (*Callosobruchus maculatus* F., *C. chinensis* L.)

continued

Table 5.3. *continued*

Crop	Disease (Pathogen)	Insect pests
Soybean	Root rot (*Rhizoctonia solani* Kühn) Rust (*Phakopsora pachyrhizi* Syd.)	Armyworm (*Spodoptera exigua* Hübner) Pod borer (*Helicoverpa armigera* Hübner)
Groundnut	Late leaf spot (*Phaeoisariopsis personata* (Berk. & Curtis) v. Arx) Collar rot (*Aspergillus niger* van Tieghem) Early leaf spot (*Cercospora arachidicola* Hori) Root rot (*Sclerotium rolfsii* Sacc.)	Armyworm (*Spodoptera exigua* Hübner) Leaf miner (*Aproaerema modicella* Dev.) Jassids (*Empoasca kerri* Pruthi) White grub (*Lachnosterna* sp) Aphids (*Aphis craccivora* Koch) Termites (*Microtermes* sp) Bruchids (*Callosobruchus maculatus* F., *C. chinensis* L.) Hairy caterpillar (*Amsacta* sp)

leaf spot in groundnut become severe and crops may be damaged seriously due to waterlogging. When rainfall occurs at maturity, it affects crop yields due to pod shedding and seed germination, and hampers harvesting (Thein Han 1983).

Temperature

Terminal drought stress coupled with high temperature towards maturity, results in poor pod filling in chickpea.

Soil factors

Heavy rainfall areas in lower Myanmar are slightly acidic and available soil nitrogen content is <20 mg kg^{-1} soil. Similarly, available phosphorus and potassium in paddy soils are <100 and 200 mg kg^{-1} soil, respectively. In many areas of lower Myanmar and near coastal areas, aluminium, magnesium, iron, and manganese toxicities are present.

Many rice-growing areas have moderately to poorly drained, loamy to clayey pale brown soils, and affect legumes grown after rice. Plow pan formation in lowland rice areas in central and upper Myanmar restricts root penetration and moisture uptake by legumes.

Nitrogen fixation

In traditional chickpea-growing areas, the crop is adequately nodulated, when other factors are conducive. However, when chickpea is introduced to new areas, the host specific *Rhizobium* inoculation is necessary.

Socioeconomic Constraints

Low profit

Profitability is the most important determinant in deciding crops and cropping patterns. Legume crops have relatively low yield potentials, and therefore are grown in marginal areas. The net profit from legumes is low compared to maize, rice, and sugarcane.

Market and prices

Cultivation of legumes is associated with the market and price. Adequate market for output enhances legumes production. Since early 1990s, the export demand increased over time. The market for legumes is thin and fragmented compared to rice, which has assured market. Farmers often do not get good price. Price fluctuation for legumes is greater than that of rice, due to postharvest losses.

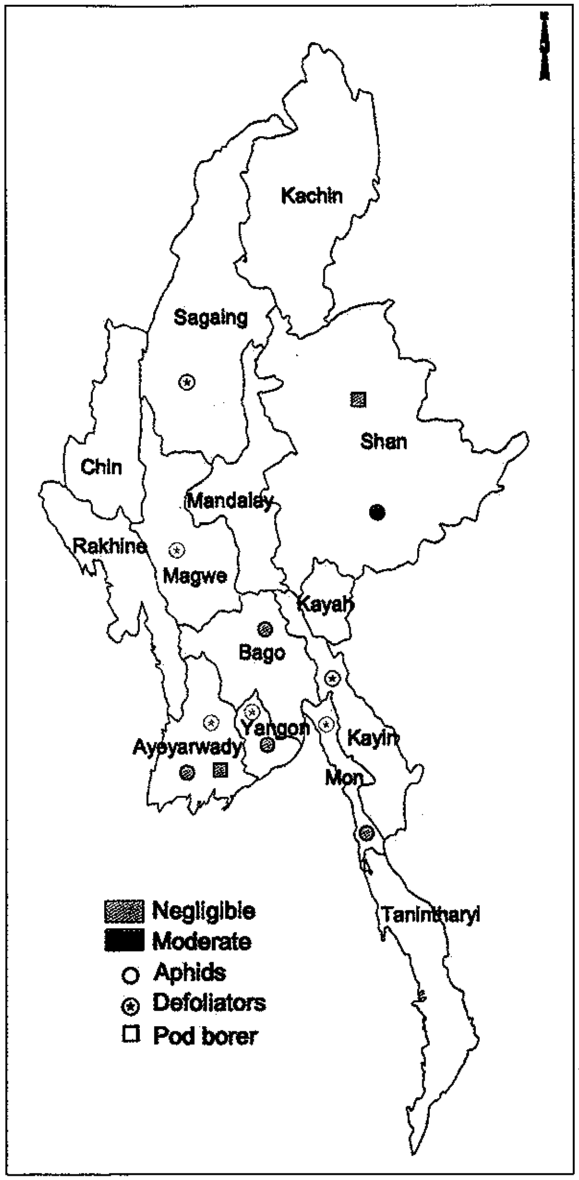

Figure 5.23. Severity of insect pests of cowpea in Myanmar in 1998/99.

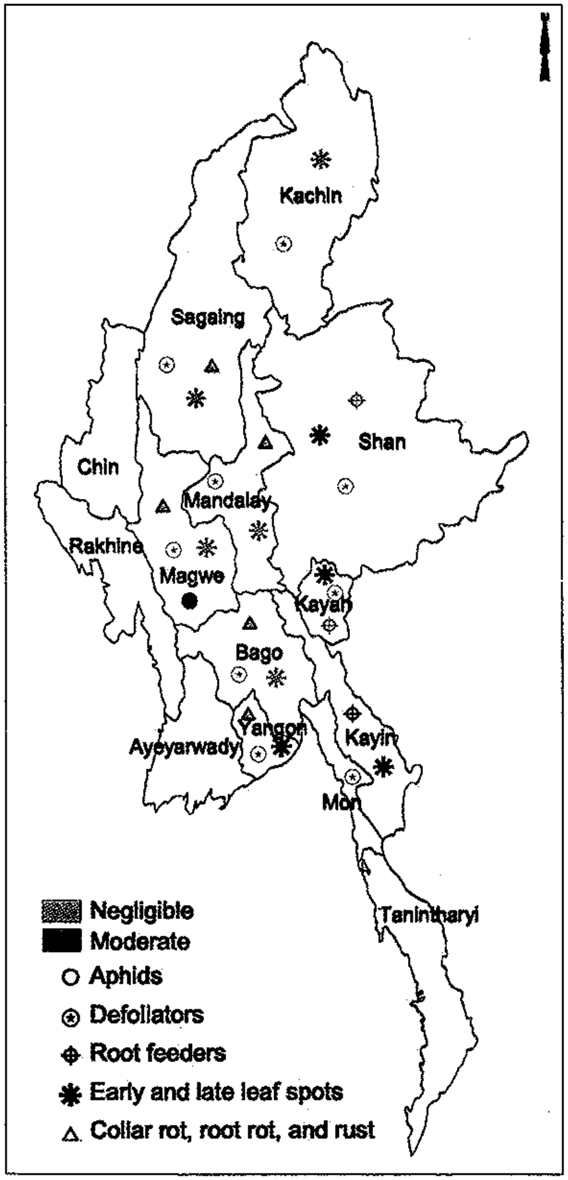

Figure 5.24. Severity of diseases and insect pests of groundnut in Myanmar in 1998/99.

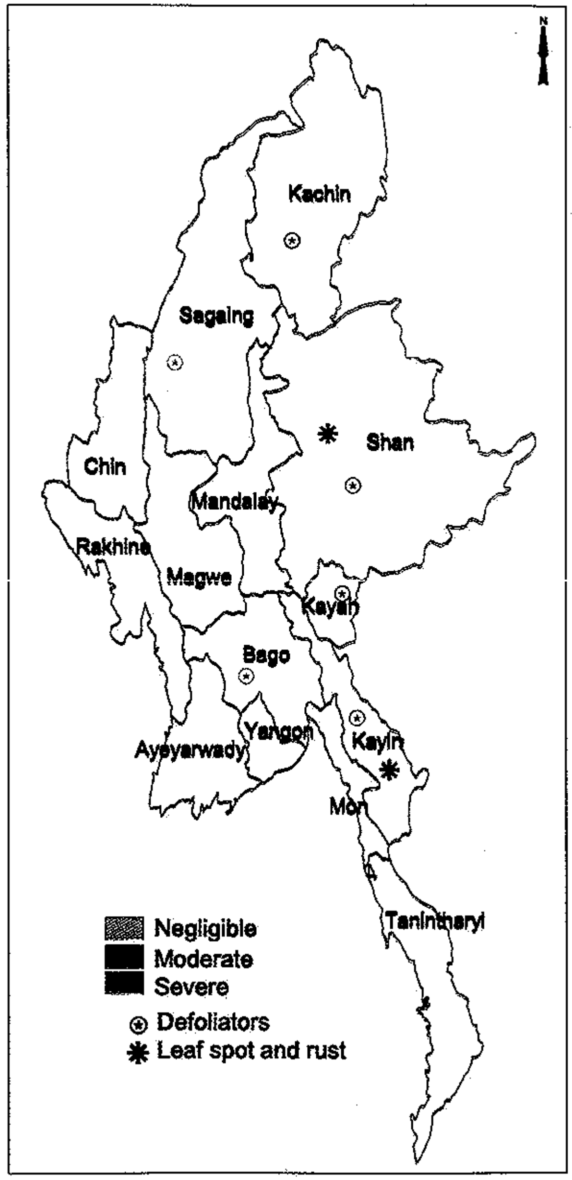

Figure 5.25. Severity of insect pests of soybean in Myanmar in 1998/99.

Fixed resources

About 76% of legumes in Myanmar are grown as sequential crops. Insufficient labor force and farm machinery limitations are the major constraints for rice-based cropping systems. Fixed resources should be fully utilized in favor of legume development in rice-based systems.

Risk

Farmers consider legume yields unpredictable. The price fluctuation can significantly affect the profit margin. Since there is no crop security measures, farmers prefer to avoid risk. The price and yield risks of legumes are higher compared to rice and other cereals. If the export demand is low, the price decreases significantly.

Lack of cash and credit

Majority of the farmers do not have sufficient money to buy quality seeds and inputs. Credit systems do not cover monetary support for legumes production. The prices of fertilizers, pesticides, fungicides, and herbicides are rather expensive and discourage farmers from using these inputs.

Production technology

Farmers use conventional technology for legume crops. They have very limited knowledge about improved varieties and technology.

Role of Legumes in Rice-based Cropping Systems

The role of legumes for soil fertility enrichment has been well recognized. About 5 million ha is under rice during rainy season in Myanmar. The existing irrigation facilities are sufficient for about 1 million ha for growing the second rice crop. There is a growing concern about the rice monocropping system and legumes are regarded as ameliorative crops to break continuous rice monocropping. Therefore, rice-legume cropping patterns play an important role in the agroecosystem.

Due to the availability of short-duration legume varieties, legumes can now be grown as a preceding or succeeding crop to rice in rice-based cropping systems. Nitrogen contribution through legumes increases rice yield. A legume crop may contribute 20–60 kg nitrogen equivalent to the succeeding crop (Ahlawat and Srivastava 1997). Legumes are grown in different cropping systems in Myanmar. Pigeonpea is usually intercropped mainly with sesame. It is the only legume that is sown in early rainy season (May–June) and harvested in winter (January–February). The other legume crops are generally grown in late rainy season or early winter (September–December).

Introduction of short-duration legume crop varieties has made it possible to grow three crops in one year, where moisture is not a limiting factor. For example, short-duration mung bean variety is grown in May with pre-planting irrigation followed by rice in August. Then short-duration chickpea cultivars can be sown in November conveniently.

National Policies Towards Legumes Production

Per capita consumption of food legumes in Myanmar is estimated at about 12 kg $year^{-1}$. Sixty-four percent of the total agricultural product export is from food legumes. Demand for export of legumes is increasing. The government has given high priority for food legumes production in recent years, along with rice, cotton, and sugarcane. Oilseed crop production is also encouraged to attain self-sufficiency. The Government of Myanmar has launched short-term and medium-term programs to boost crop production potential.

The Food Legume Working Group is responsible for improvement and development of all legume crops, and draws support from specialists. Technology generation and dissemination are coordinated by the Working Group. It envisages application of improved technology for different agroclimatic regions. Six legume crops, chickpea, pigeonpea, black gram, mung bean, cowpea, and soybean, are given high priority.

For improved production technology awareness among farmers, on-farm demonstrations are carried out in different agroclimatic conditions. Special production programs are launched in major pulses-growing areas. Farmers and extension personnel are given training to disseminate the improved varieties and appropriate technology, including seed multiplication programs (involving farmers) in different regions.

The government encourages export of surplus legume produce, and farmers receive relatively good price. Introduction of open-market policy has led to increase in price of legumes substantially. Food legumes export increased greatly in recent years, and about 818,173 t was exported in 1997–98 (5% of legumes production). Black gram, pigeonpea, mung bean, and butter bean account for about 75% of the total legume export.

Prospects for Increased Production of Legumes

Myanmar offers a vast scope for enhancing legumes production under both rainfed upland and post-rice conditions. The area extension can cover both in time and space. Prevailing agroclimatic conditions favor production of legume crops year-round in different regions with appropriate improved varieties and technologies.

Pigeonpea

The existing long-duration pigeonpea varieties are intercropped with sesame or other crops in rainy season. However, there is potential to grow short- and medium-duration pigeonpea after rice, especially in the delta regions.

Chickpea

Most of the chickpea is grown after rice. Yield is low due to diseases and late sowing in relay cropping practice which results in poor plant stands. Large areas are left fallow after rice due to lack of sufficient moisture to grow a sequential crop. This problem can be tackled by replacing long-duration rice cultivars with short-duration varieties. Identification/development of warm temperature tolerant and short-duration chickpea cultivars will promote further expansion of chickpea area after rice harvest in delta regions. Short-duration cultivars such as ICCV 2, ICCC 37, and ICCV 88202 have potential to expand the area.

Black Gram

Black gram area after rice is increasing at a faster rate due to the relatively hardy characteristics. The government is also encouraging farmers by providing loans for cutivation and assured export market through export agencies. The area of black gram after rice will further increase with the availability of short-duration cultivars such as Yezin 2 and IBG 17.

Mung Bean

In upland areas, mung bean follows early sesame. Of late, rice-mung bean cropping pattern is becoming popular in near coastal areas. It can be grown as pre-monsoon crop in February and during May–September as monsoon crop in the central dry zone area. On the other hand, photo-insensitive short-duration mung bean varieties (Yezin 1, Yezin 2, V 3726, and KPS 2) produce very good yield after rice.

Soybean

Majority of soybean is found in highlands of Shan state. It is also grown in lower Myanmar delta area (Bago, Yangon, and Ayeyarwady divisions) after rice. The existing cultivars are mostly vegetable types with low oil content. The short-duration oil type varieties will fit in the rice-based cropping systems.

Groundnut

The yield of rainy season groundnut is relatively low. Groundnut cultivation in postrainy season is most desirable, particularly in river banks and basin areas as the yield is relatively high. Groundnut grown after rice produces fairly good yield. The major constraint for groundnut area expansion is the availability of quality seed. Currently, seed comes from upper and central Myanmar. Since winter groundnut yields are relatively high, farmers are willing to expand the area in central and lower Myanmar after rice.

Conclusions

Rice-based cropping systems are predominant in Myanmar. Due to continuous rice cropping, farmers are encountering a number of production constraints and resource degradation. Legumes can play a very important role in minimizing soil fertility degradation and increasing the production potential of the system. Important legumes in Myanmar are black gram, mung bean, pigeonpea, chickpea, cowpea, lima bean, lablab bean (*Lablab purpureus* (L.) Sweet), soybean, and groundnut. Despite various biotic and abiotic constraints, legumes area and production are increasing. Yield of legume crops vary greatly depending on moisture availability, pests and diseases infestation, and improved agronomic practices. Diseases and insect pests reduce the productivity of legumes considerably. There is an urgent need to develop integrated pest management strategies.

Alleviation of abiotic stresses is essential for legumes production. Vast area of legumes are under sequential cropping. Terminal drought stress is a common problem. Nutrient deficiency, particularly micronutrients, is a threat to legumes production. Major abiotic constraints should be addressed for sustainable legumes production.

Low profitability of legumes is attributed to poor yields. There is an urgent need to increase yields of legumes through appropriate technological innovations. Strengthening of the extension services is also essential to disseminate improved technology through on-farm demonstration and farmers' participatory research. There is considerable scope for enhancing legumes production both under irrigated and rainfed ecosystems. Availability of short-duration mung bean, chickpea, cowpea, and black gram cultivars has resulted in area expansion of these crops after rice. There is enough scope for further expansion of legumes in rice-fallow areas of Myanmar.

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6. Legumes in Tropical Rice-based Cropping Systems: Constraints and Opportunities – A Philippine Case Study

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Abstract

Legumes area, production, yield, agroclimatic zones, land use, and land suitability in the Philippines were identified using geographic information system (GIS) tools and techniques. Using different thematic maps and secondary data, different biotic, abiotic, and socioeconomic constraints to legumes production were also identified. Recommended courses of action are discussed. Production of legumes is expected to increase due to favorable government policies, among other factors. Priority areas for research, development, and extension are outlined including strategic activities to be undertaken.

Introduction

The Philippines is an archipelago in the western Pacific Ocean comprising a total land area of around 30 million ha. About 13 million ha are devoted to agricultural production of which only 0.12 million ha are planted to legumes (NSO 1997, BAS 1998c). Consequently, production of legumes was less than 77,000 t annually during the past 17 years (Table 6.1). In contrast, demand has grown to more than 100%. To satisfy this demand, importation was resorted. In the last 6 years, local supply of legumes [groundnut (*Arachis hypogaea* L.) and mung bean (*Vigna radiata* (L.) Wilczek)] meet only about half of the demand. This chapter outlines the major constraints and opportunities for legumes production and utilization in the Philippines. It also attempts to chart the future direction of legumes research and development and extension to further enhance the legume-based industry.

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Table 6.1. Area, production, and import of legumes in the Philippines during 1980–97.

Crop	Period	Area ('000 ha)	Production ('000 t)	Import ('000 t)
Groundnut	1980–85	49.13	42.31	1.78
	1986–91	48.35	38.16	25.72
	1992–97	40.08	34.93	42.26
Mung bean	1980–85	34.24	25.24	0.02
	1986–91	35.70	25.79	8.62
	1992–97	34.39	25.30	20.18
Soybean	1980–85	9.28	9.19	18.00
	1986–91	4.58	4.74	28.68
	1992–97	2.06	2.43	97.45

Spatial Distribution

Administrative Boundaries

Philippines consists of 7,107 islands, located between 4° and 21° N latitude and 116° and 127° E longitude, of which only 2,000 are inhabited. About 1,000 islands are larger than 1 km² and 2,500 are not even named. The country has three principal geographic divisions: Luzon, Visayas, and Mindanao. Luzon is the largest island representing 47% of the country's total land area (14,139,492 ha) followed by Mindanao (34%; 10,199,890 ha) and Visayas (19%; 5,678,535 ha). Luzon is divided into 7 regions: CAR, NCR, and Regions 1, 2, 3, 4, and 5. Visayas is comprised of Regions 6, 7, and 8; while Mindanao includes Regions 9, 10, 11, and 12, CARAGA, and ARMM (Fig. 6.1).

Land Use

In terms of land use, the country is divided into five major categories: agricultural areas or cultivated land, grassland/shrub land areas (cogon and open land), forest or woodland areas (commercial and non-commercial forest and bush land), wetland areas (marsh and swamp), and miscellaneous areas (villages and cities, major rivers, mine pit, quarry, volcanic ashes, and infrastructure). Agricultural areas account for about 31% of total land area in Luzon (BSWM 1993a), 34% in Mindanao (BSWM 1993c), and 45% in Visayas (BSWM 1993b).

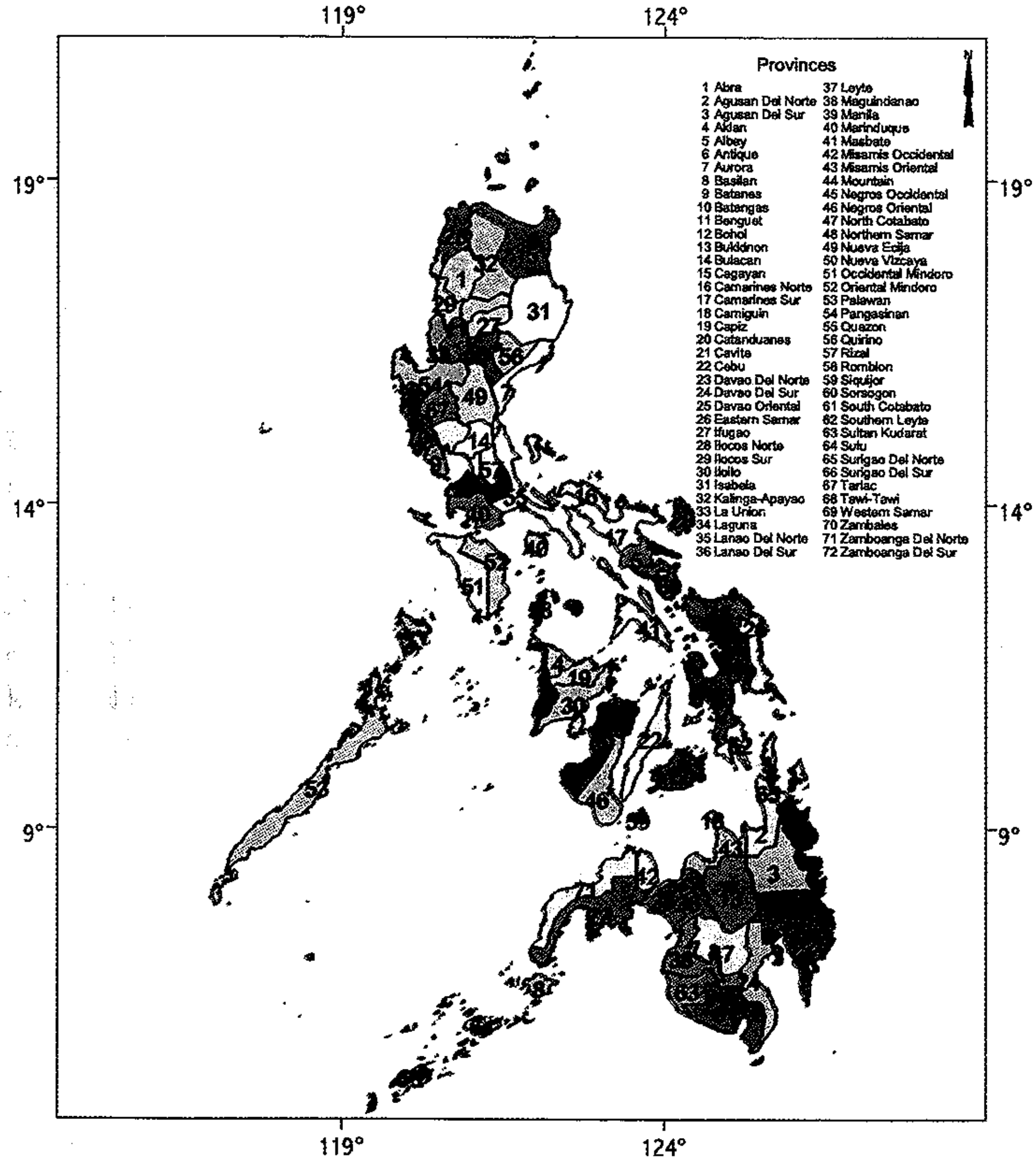

Figure 6.1. Administrative map of the Philippines.

Legumes are found in areas where diversified dry farming is practiced [i.e., maize (*Zea mays* L.), upland rice (*Oryza sativa* L.), tobacco (*Nicotiana tabacum* L.), and vegetables] and where rice is grown (Fig. 6.2). In 1997, Luzon had the largest share in legumes area (59.7%), followed by Mindanao with 20.2% and Visayas with 20.1% of legumes area (Table 6.2).

Groundnut

Groundnut is mostly grown in Luzon particularly in Regions 1, 2, and 4 and occupies 14,211 ha (53.4%) of total national area (Fig. 6.3). These regions also account for the bulk (66.4%) of groundnut production in the country (17,155 t). Region 1 in Northern Luzon has highest yield of 1.44 t ha^{-1} while Central Mindanao (Region 12) has yield of 1.16 t ha^{-1}. All other regions have yields less than the national average of 0.97 t ha^{-1}.

Mung bean

Mung bean predominates Regions 1 and 3 of Luzon, and 6 of Visayas, accounting for 55.7% or 20,388 ha of total area (Fig. 6.4). Region 1 ranks first in mung bean production with 10,244 t or 39.6% of total production. Northeastern Mindanao recorded the highest yield at 0.94 t ha^{-1}, followed by Region 1 at 0.92 t ha^{-1}. Only Regions 1, 2, 3, 4, 11, and CARAGA produce yields greater than the national average of 0.75 t ha^{-1}.

Soybean

Most of the soybean (*Glycine max* (L.) Merr.) areas are in Southern Mindanao (Region 11). Recently soybean was successfully introduced in Luzon (Region 2) and Visayas (Region 7). Region 11 produces 632 t of soybean, more than half of the country's total soybean production (Fig. 6.5). Mindanao (Regions 10, 11, and 12) and Region 2 of Luzon produce higher yields than the national average (1.09 t ha^{-1}).

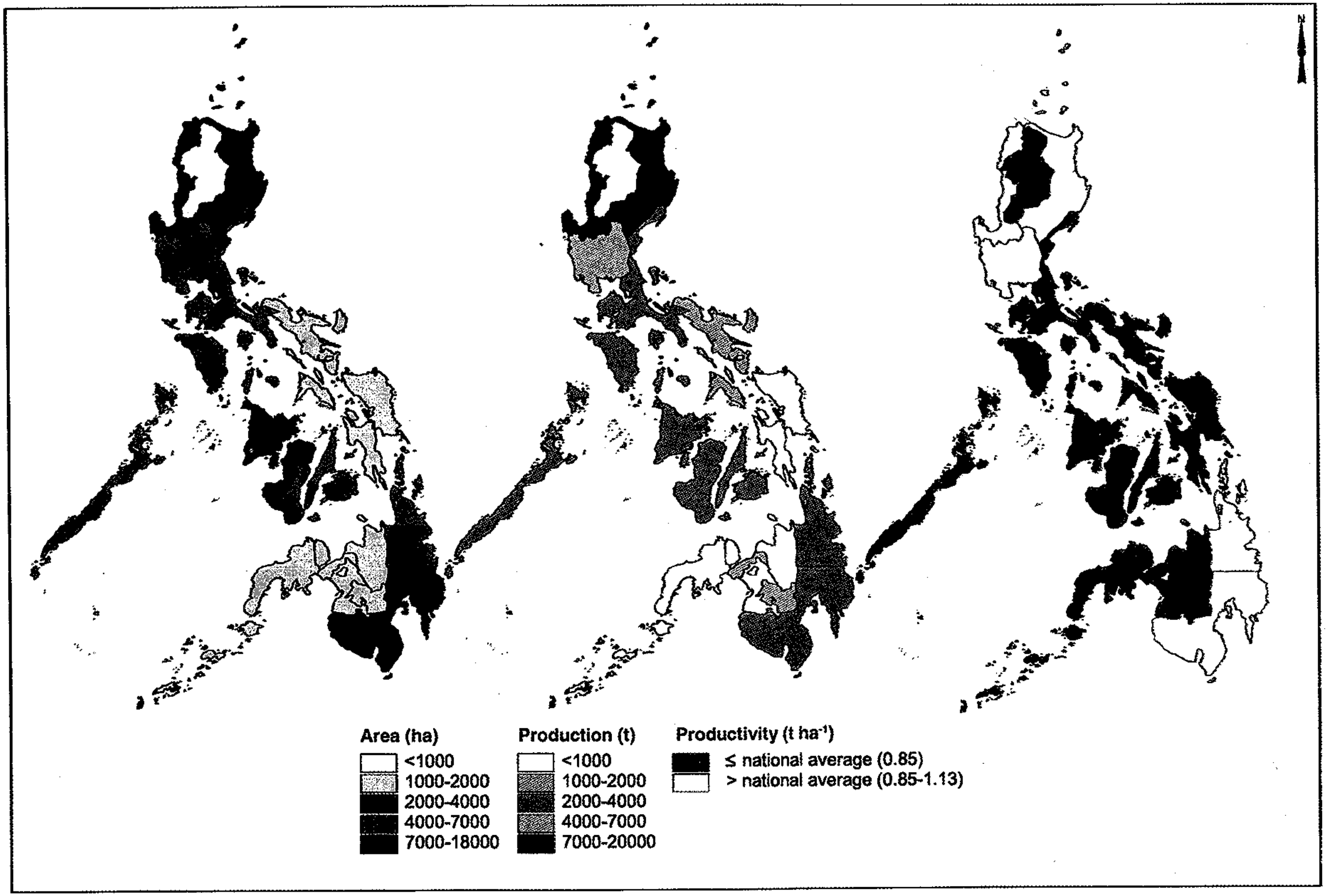

Figure 6.2. Legumes area, production, and productivity in the Philippines, 1997.

Table 6.2. Area (ha), production (t), and yield (t ha^{-1}) of major legumes in the Philippines, 1997.

Island/Region	Groundnut			Mung bean			Soybean			Total		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Luzon	18,830	19,621	1.04	21,282	17,788	0.84	133	178	1.34	38,205	37,587	0.98
CAR[1]	279	133	0.48	146	103	0.71	-[2]	-	-	425	236	0.56
1	7,096	10,244	1.44	10,546	9,663	0.92	-	-	-	17,642	19,907	1.13
2	3,992	4,632	1.16	3,346	2,655	0.79	133	178	1.34	7,471	7,465	1.00
3	922	1,249	1.35	4,972	3,845	0.77	-	-	-	5,894	5,094	0.86
4	3,123	2,279	0.73	1,754	1,325	0.76	-	-	-	4,877	3,604	0.74
5	1,478	1,084	0.73	418	197	0.47	-	-	-	1,896	1,281	0.68
Visayas	5,249	3,085	0.59	7,404	3,440	0.46	284	157	0.55	12,937	6,682	0.52
6	2,559	1,241	0.48	4,770	2,125	0.45	9	6	0.69	7,338	3,372	0.46
7	1,814	1,451	0.80	2,206	1,078	0.49	252	126	0.50	4,272	2,655	0.62
8	876	393	0.45	428	237	0.55	23	25	1.09	1,327	655	0.49
Mindanao	4,465	3,130	0.70	7,834	6,241	0.80	611	784	1.28	12,910	10,155	0.79
9	1,202	478	0.40	580	295	0.51	3	2	0.60	1,785	775	0.43
10	703	566	0.81	319	204	0.64	29	36	1.24	1,051	806	0.77
11	775	517	0.67	1,684	1,366	0.81	457	632	1.38	2,916	2,515	0.86
12	629	729	1.16	1,033	567	0.55	57	68	1.20	1,719	1,364	0.79
CARAGA[3]	332	202	0.61	3,864	3,649	0.94	-	-	-	4,196	3,851	0.92
ARMM[4]	824	638	0.77	354	160	0.45	65	46	0.71	1,243	844	0.68
Total	28,554	25,836	0.90[5]	36,520	27,469	0.75[5]	1,028	1,119	1.09[5]	64,052	54,424	0.85[5]

1. Cordillera Agricultural Region.
2. Data not available.
3. Region XIII, consists of four provinces (Agusan del Sur, Agusan del Norte, Surigao del Sur, and Surigao del Norte).
4. Autonomous Region for Muslim Mindanao.
5. Average.
Source: BAS, Philippines.

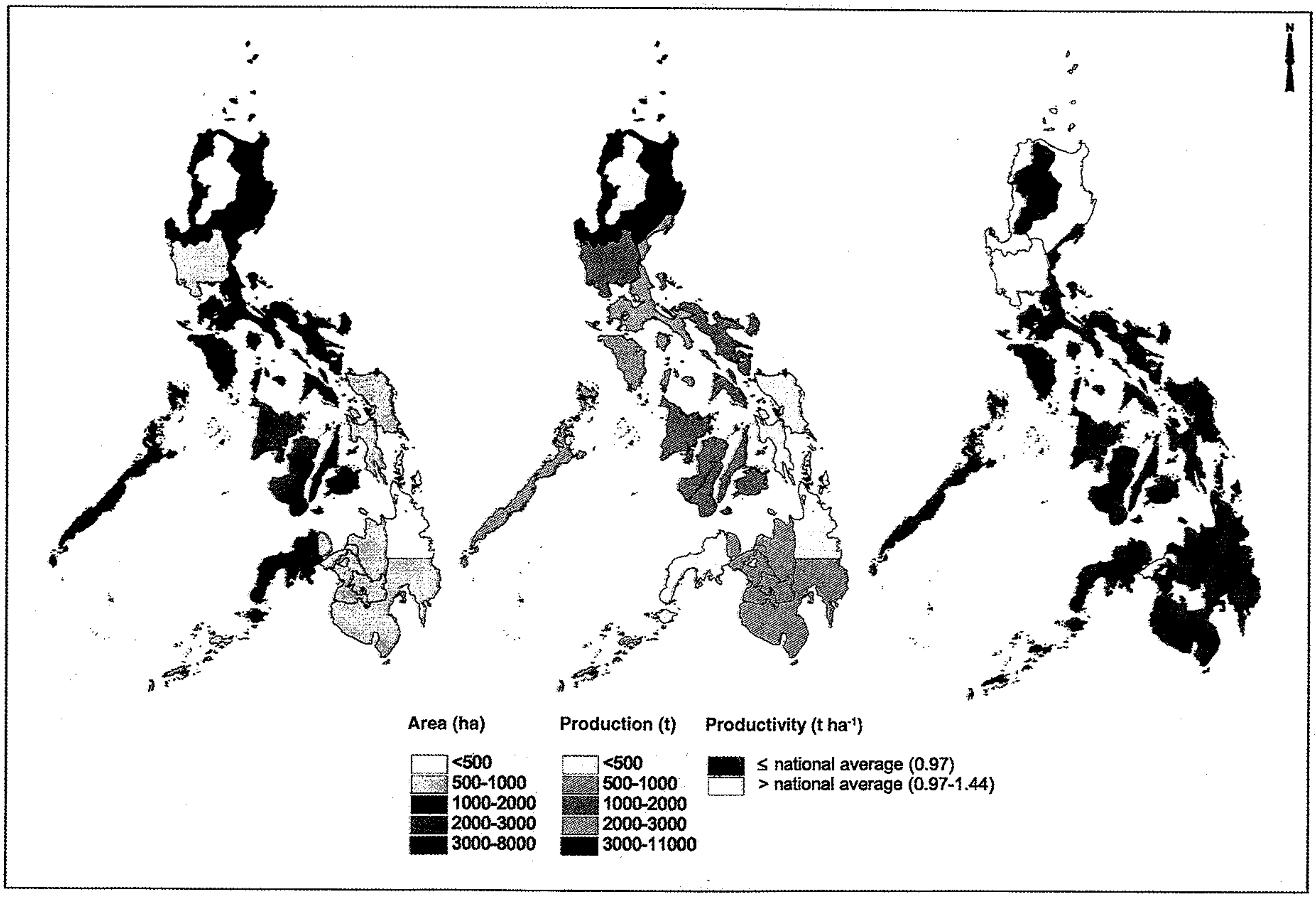

Figure 6.3. Groundnut area, production, and productivity in the Philippines, 1997.

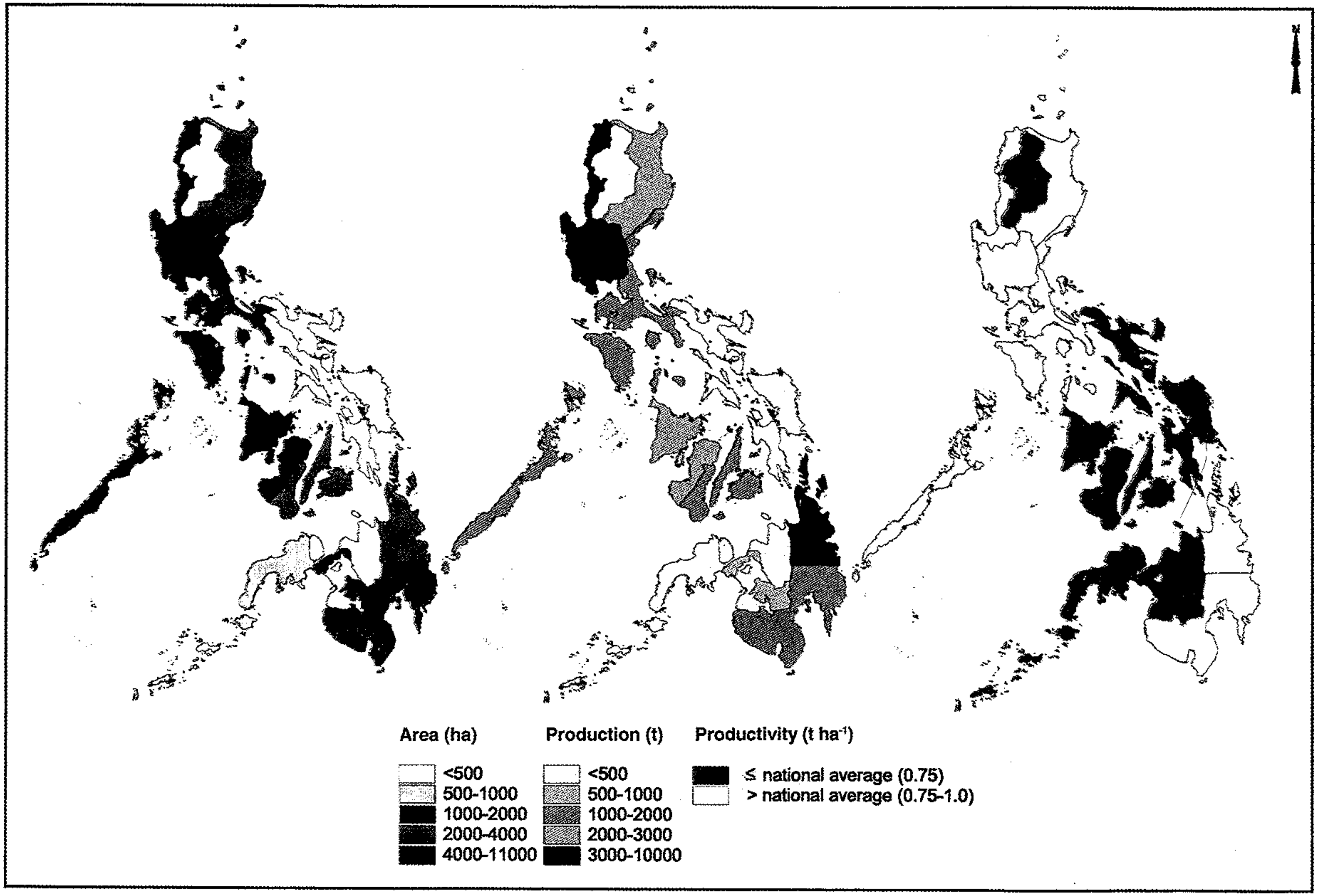

Figure 6.4. Mung bean area, production, and productivity in the Philippines, 1997.

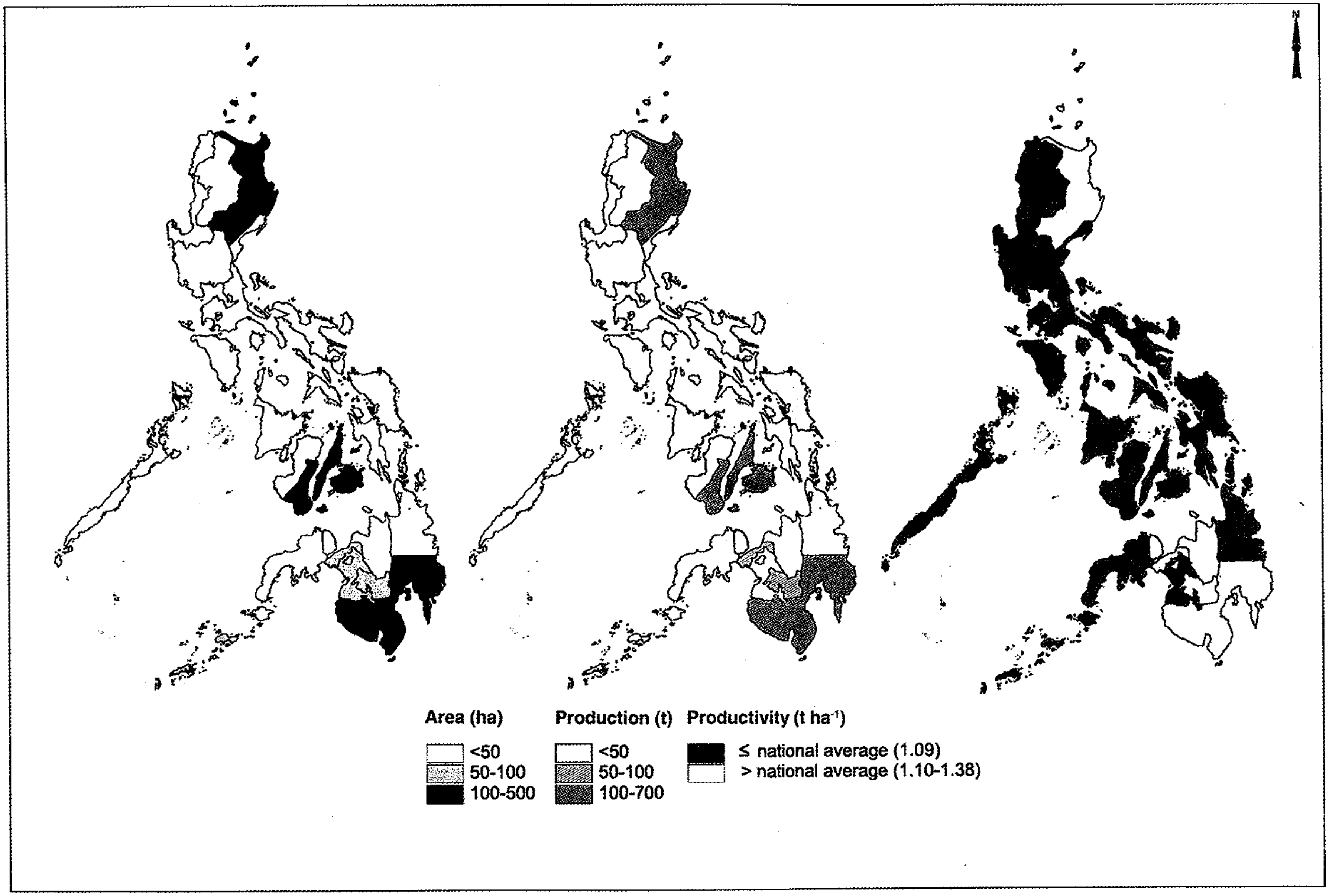

Figure 6.5. Soybean area, production, and productivity in the Philippines, 1997.

Agroclimatic Zones

Based on rainfall, landforms, and vegetation, three agroclimatic zones are identified in the country: wet zone (>2500 mm rainfall), moist zone (1500–2500 mm rainfall), and dry zone (<1500 mm rainfall) (Fig. 6.6). Dominant features of each zone are shown in Table 6.3 and Figure 6.7 and serve as basis for determining the ecological suitability for legumes.

Wet Zone

The wet zone is characterized by an annual rainfall of 2,500 mm and a growing period of 270–320 days (Fig. 6.6). It generally contains hilly and highland areas with cooler temperatures (19–27°C), favoring production of crops that require mild temperature conditions. Mountain soils are generally found in hilly lands, and highlands with slopes >18% predominate these areas.

Moist Zone

The moist zone has an annual rainfall ranging from 1,500–2,500 mm and a growing period of 210–270 days (Fig. 6.6). It covers most of the present agricultural and expansion areas in the lowland, upland, and hilly lands. Generally, soils in uplands with slopes of 8–18% are ultisols which are acidic and heavy, with low fertility.

Dry Zone

The dry zone is characterized by an annual rainfall of <1,500 mm and a growing period of 90–210 days (Fig. 6.6). Soils in lowlands with elevation of 100 m and slopes that do not exceed 8% are predominantly inceptisols, entisols, and vertisols. Due to the strategic location of lowlands, these soils are less prone to soil erosion and are more fertile than other areas.

Suitability of Legumes under Philippine Conditions

Areas where Legumes Predominate

Agroclimate

Legumes are generally sown during the dry season after rainfed rice, maize, or other major crops, and predominate in areas with moist to

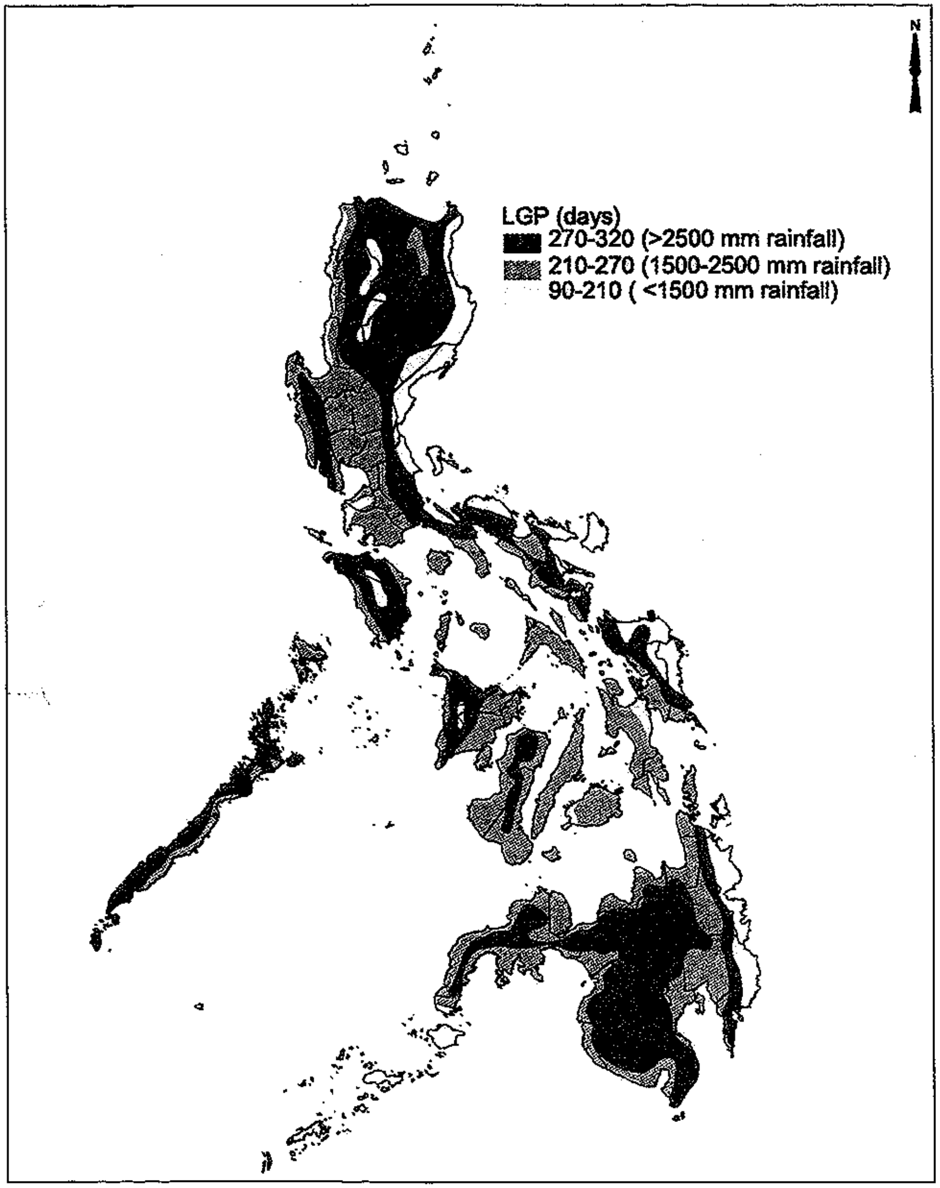

Figure 6.6. Length of growing period (LGP) in the Philippines.

Table 6.3. Dominant features of agroclimatic zones in the Philippines.

Factors	Agroclimatic zones[1] Wet	Moist	Dry
Annual rainfall	Very high (surplus); 2500 mm.	Moderately adequate/variable; 1500–2000 mm.	Highly variable; <1500 mm.
Slope	>18%	0–18%	0–8%
Elevation	>500 m	<500 m	<100 m
Temperature	Temperate; 15–20°C	Temperature varies widely; soil crusting occurs due to warm temperature.	Less variability in temperature (25–35°C).
Pedo-ecological zones	Hilly lands and highlands.	Lowlands, uplands, and hilly lands.	Lowlands and uplands.
Growing season	270–320 days. 8–9 months (April–December). Severe drainage problem.	210–270 days. 7–8 months (May–December). Moderate drainage problem.	90–210 days. 5–6 months (June–October). Negligible drainage problem.
Dry season	40–90 days. 3–4 months (January–April). Negligible irrigation problem.	90–150 days. 4–5 months (January–May). Moderate irrigation problem.	15–270 days. 6–7 months (November–May). Severe irrigation problem.
Cropping intensity of major crops	3 cropping seasons.	2 cropping seasons.	1 cropping season.
Soil[2]	Mountain soils. Medium-fine texture. Moderate-high erodibility. Low fertility. Very acidic. Deep soil (>100 cm).	Ultisols and oxisols. Medium-fine texture. Moderate-high erodibility. Low-moderate fertility. Very acidic (pH <5.5). Deep soil (>100 cm).	Vertisols, inceptisols, and entisols Coarse-fine texture. Low-high erodibility. Moderate-high fertility. Acidic-neutral (pH 5.2–7.6). Shallow to deep (soil depth >100 cm except for inceptisols averaging 25–60 cm and 50–100 cm).
Suitability for different crops	Moderately suitable for soybean particularly in Mindanao. Not suitable for groundnut and mung bean.	Suitable for soybean. Moderately suitable for mung bean and groundnut.	Suitable for mung bean and groundnut. Moderately suitable for soybean.

1. Zone factors are described based only on their dominant features.
2. Textural classes:
   (i) Coarse-sands, loamy sands, and sandy loams with <18% clay and >65% sand.
   (ii) Medium-sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams, and clay loams with <35% clay and <65% san d.
   (iii) Fine clay, silty clays, sandy clays, clay loams, with >35% clay.

Source: BSWM (1993a).

dry rainfall zones (4–9 dry months a year). Soybean dominates in areas that are characteristically wet and humid while groundnut and mung bean predominate in areas under dry and moist zones.

Elevation and temperature

Legumes are generally grown in low elevation areas where temperatures are usually warmer and the difference in night and day temperatures are not very pronounced (Fig. 6.8). A wide range of crops is also grown in these areas either in monocroping or multiple cropping systems. These areas have less erosion.

Slope

Legumes predominate in areas below 18% slope. Legumes are mostly found in areas with 0–3% slope, since they are usually planted after rice or maize which dominate the lowlands and undulating slopes (3–8%).

Soil

Soils whose parent materials are alluvial soils, shale and sandstone soils, and soils from igneous rock predominate areas where legumes are presently grown. Moreover, legumes are grown in areas where soils are dominantly inceptisols (tropeptseutropepts with detropepts), entisols (psamments—tropopsamments with troporthents), and vertisols (chromusterts, pellusterts) (Fig. 6.9).

Suitable Areas for Legumes Production

Based on requirements for legumes production (Table 6.4), suitable areas for growing legumes are predominantly inceptisols and entisols and with conditions of dry to moist agroclimatic zone type (Ali et al. 2000). By overlaying the agroclimatic zone map and soil map a land suitability map for legumes can be developed (Virmani et al. 1991). Three zones were identified as suitable for the production of legumes: suitable, moderately suitable, and not suitable (Fig. 6.10).

Temporal Changes

Area

Legumes are usually grown in combination with rice or maize either as an intercrop (maize with groundnut) or in rotation (maize-legume, maize-maize-legume; rice-legume; rice-rice-legume). Groundnut and

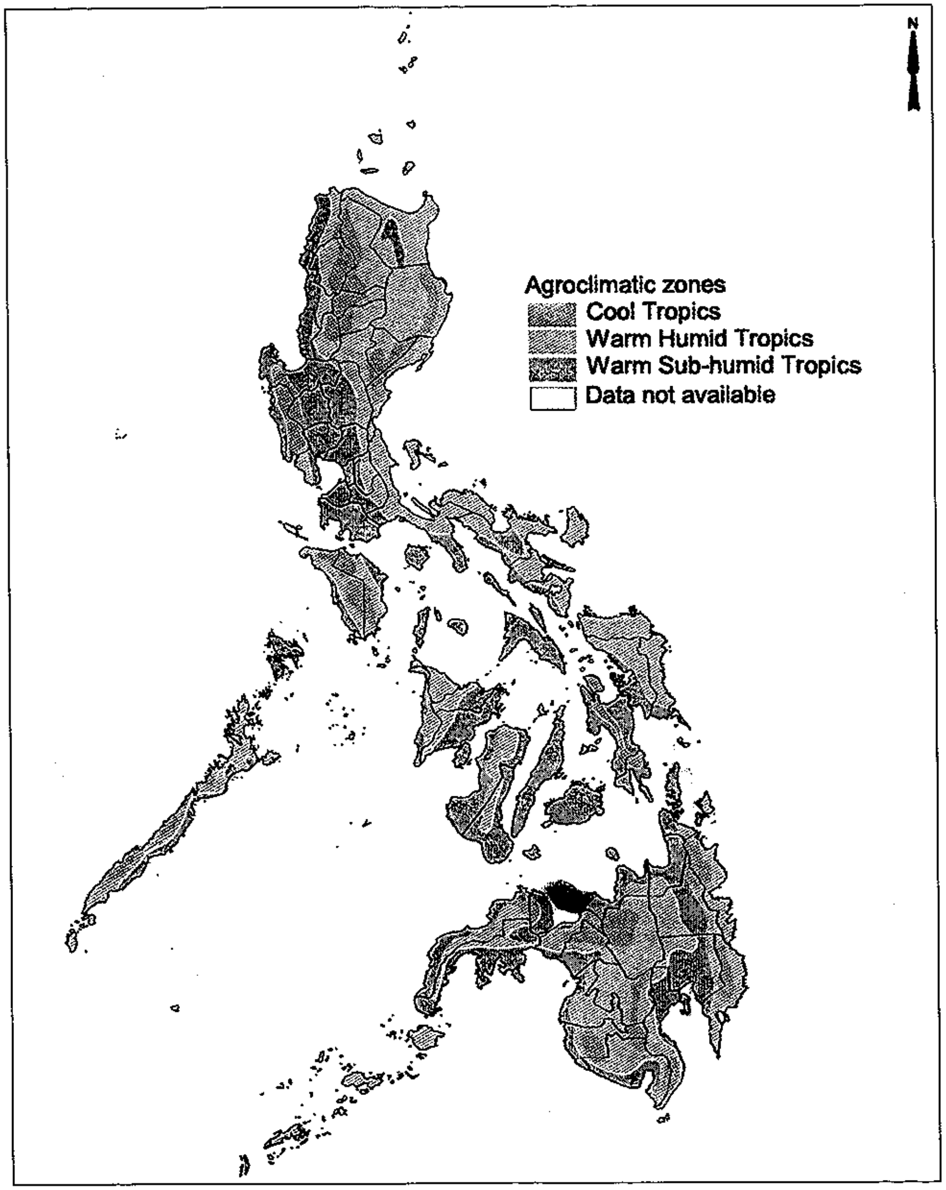

Figure 6.7. Agroclimatic zones of the Philippines.

soybean showed a declining trend in area nationwide. Around 367,000 ha were substituted by rice and other crops during 1980–97. Mung bean, however, had more or less constant area of about 35,000 ha during the same period. Mung bean can be grown year-round in different areas of the country; thus, seed is not a problem, unlike other legumes.

A gradual increase in cultivated area of legumes was observed during 1992–95 (Fig. 6.11). This can be attributed to favorable weather, renewed focus of the government on legumes production as well as farmers' awareness of legume benefits. However, the area of legumes again decreased during 1995 and 1996 due to prolonged drought in the early part of 1995 and three consecutive typhoons toward the end of the year. The unavailability of legume seeds prompted farmers to shift to rice cultivation. Unless the government intervenes through programs of crop intensification and diversification, the risk of continuous displacement of legumes by rice remains.

Production and yield

Changes in area affect the total production. Thus, similar trends were observed in production of legumes as described under temporal changes in area (Fig. 6.11).

Among the regions, Regions 1, 2, CARAGA, 3, and 11 have yields greater than the national average of 0.85 t ha^{-1}. Region 2, in particular, which had an average yield of 0.5 t ha^{-1} during 1980–85 increased its yield significantly even above the national average in the last seven years (Fig. 6.11). This suggests that among others, the government's efforts to increase productivity of legumes are successful in Region 2. In spite of this encouraging prospect, the national average yields of groundnut, mung bean, and soybean are below the potential yield.

Groundnut. Trends in production and area were similar. Production reduced by 17% and area declined by 18%. This implies that the volume of production is more affected by area rather than productivity. Nationwide, groundnut yield has been fluctuating at around 0.72 t ha^{-1} for the past 17 years. Although package of technologies (POTs) for groundnut (i.e., high-yielding and pest resistant varieties, cultural management, etc.) are already available, the low yield suggests that much has to be done for increasing the adoption of these technologies. Common problems of adoption are unavailability of quality seed during

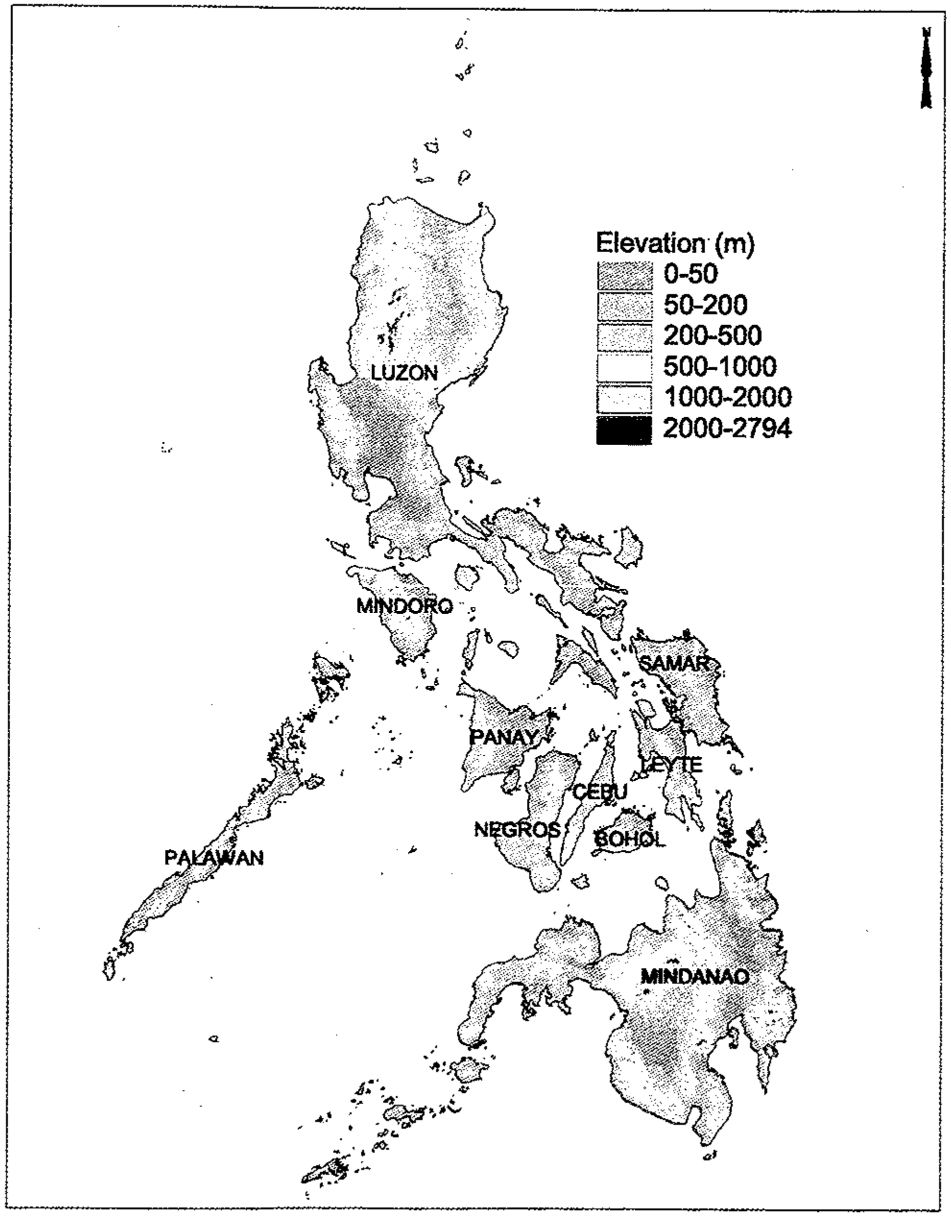

Figure 6.8. Elevation map of the Philippines.

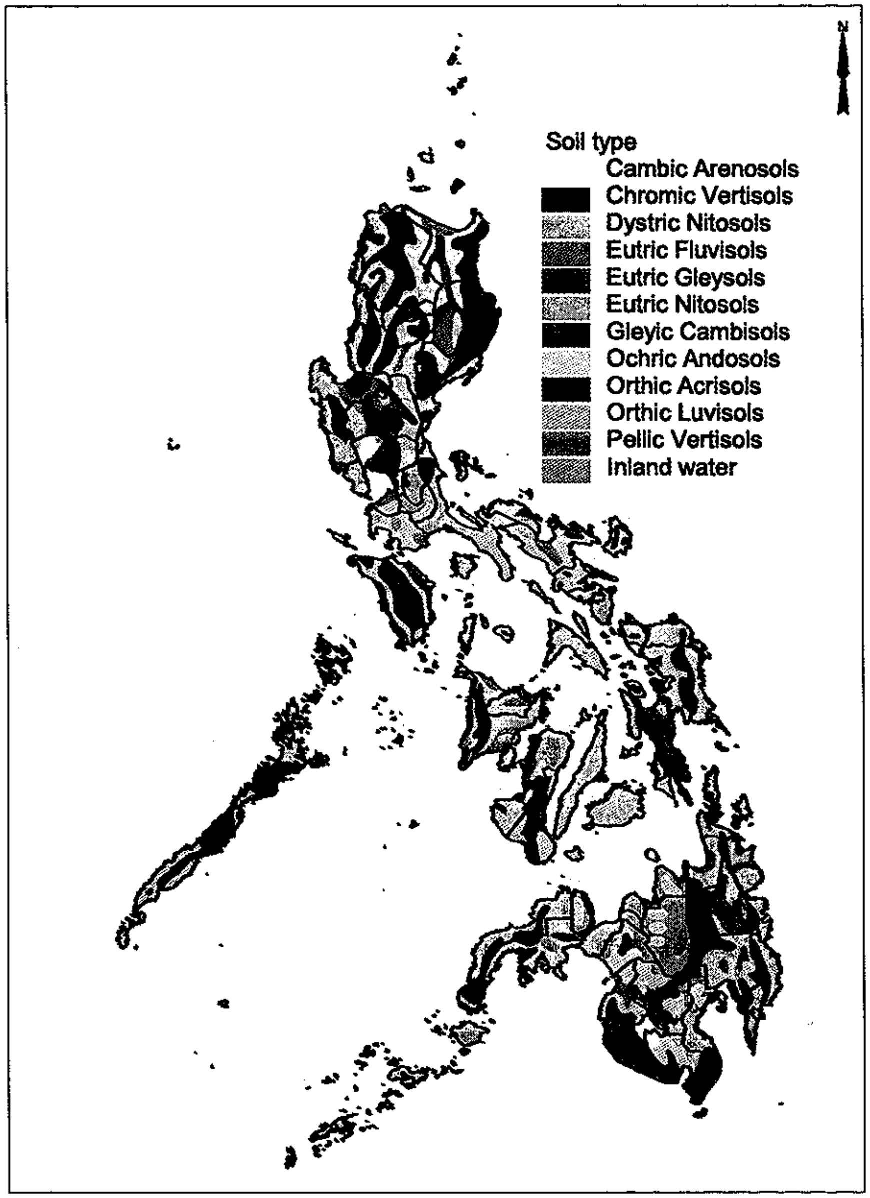

Figure 6.9. Soil map of the Philippines.

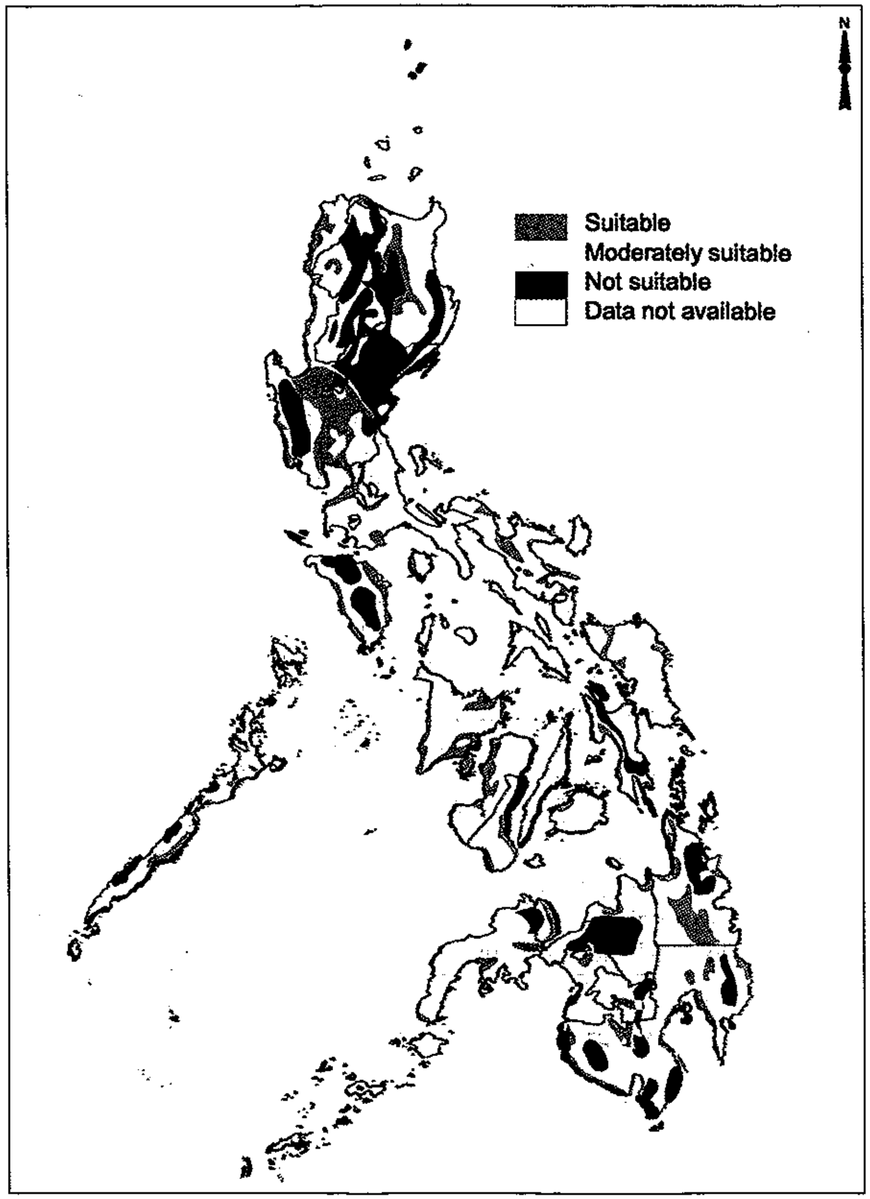

Figure 6.10. Land suitability for legumes production in the Philippines.

Table 6.4 Requirements for legumes production in the Philippines.

Factors	Groundnut	Mung bean	Soybean	Remarks
Annual rainfall	Moderate rainfall, about 5–7 mm day^{-1} during peak growth. Maximum water requirement on dry lands is 500–600 mm during the cropping season.	3.2 mm day^{-1}; 410 mm during the cropping season. Growing season should not coincide with periods of heavy rainfall.	3.2–3.3 mm day^{-1}; 530 mm during the cropping season. Grows best in humid climate with plenty of rain during the growing season and more or less dry weather during ripening (Type 3 climate).	Soybean can be grown in any part of the Philippines except in areas with heavy rainfall because diseases and harvesting problems prevail in these areas. Groundnut and mung bean are more suited in dry-moist zone.
Length of growing period	90–110 days	60–68 days	80–90 days	
Planting time	Wet season (May–June) (planting should be timed so that the crop matures when there is less rainfall). Early dry season (early October–December) (planting should be timed so that soil moisture is available during the crop's reproductive stage). Late dry season (February–March).	Wet season (May–June). Early dry season (September–October). Late dry season (February–March). Generally recommended for post-rice production; planting time should be scheduled so that harvesting mung bean crop would be completed at the onset of rainy season in late May or early June.	Wet season (late May–June). Early dry season (October–early November). Late dry season (February–March).	If plants are prone to diseases and pests attack, planting time should be adjusted 1–4 weeks before regular planting season.
Dry season planting (irrigation problem)	Highly resistant to drought; critical stage is during germination, flowering, pod development, and pod-filling stages. When planting during the early dry season, supplemental irrigation is not needed. On the other hand, supplemental irrigation is necessary for the late dry season planting in February.	Fairly drought tolerant; critical stage is before and during flowering. High yields of good quality grains are generally obtained during the dry season. Grows best during the late dry season if supplemental irrigation is available.	Less drought resistant than cowpea; critical stage is during flower bud differentiation until the end of fruiting, particularly during flowering and fruit formation.	Groundnut is most tolerant to dry zone condition followed by mung bean and soybean.
Wet season planting (drainage problem)	Does not tolerate waterlogging. Waterlogging leads to poor germination, stunted growth, and pre-harvest seed germination.	Grows best on well-drained soils. Excessive moisture tends to increase disease incidence.	Can endure more wet weather than maize, sugarcane, groundnut, and cowpea.	Groundnut and mung bean are not suited in wet zone. Soybean is more tolerant to moist-wet condition.

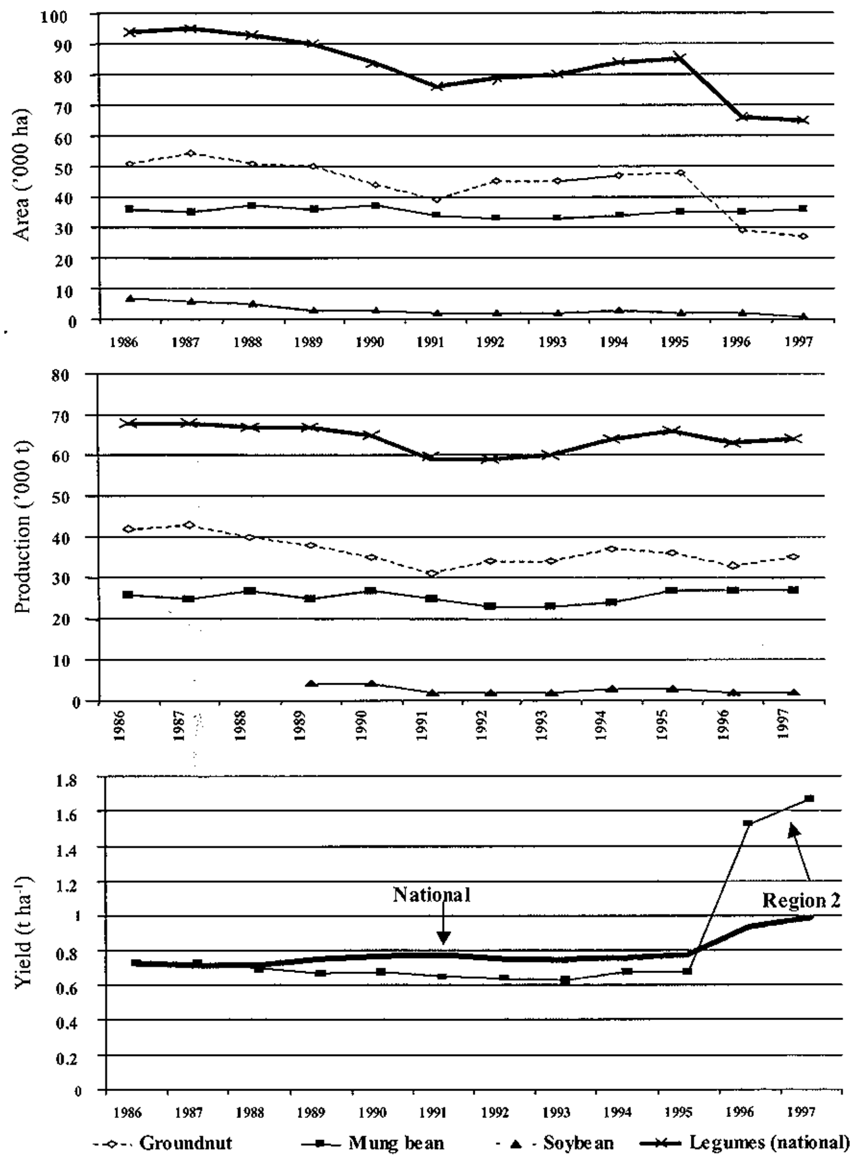

Figure 6.11. Area, production, and average yield of legumes in the Philippines, 1986–97 (Source: BAS, Philippines).

the sowing season, particularly of high-yielding varieties; pests and diseases; and inefficient or ineffective extension services (DA-BAR 1990).

Mung bean. The area of mung bean during 1986–97 has remained almost stagnant (Fig. 6.11). The status of mung bean as a subsistence crop prevented the decline in area. The slight increase in mung bean yield (10%) between 1980 and 1997 may have been the result of adoption of improved variety BPI Mg9 or EG 2768B. This cultivar, popularly known as "Taiwan Green", is a drought resistant variety [bred by the Asian Vegetable Research and Development Center (AVRDC), Taiwan] with a mean yield of 1.0 t ha^{-1}.

Soybean. Yield of soybean increased by as much as 19% over the past 17 years. National average yield of soybean (1.18 t ha^{-1}) from 1992 to 1997 was higher than that of groundnut (0.72 t ha^{-1}) and mung bean (0.56 t ha^{-1}). Soybean area has been declining since 1985 with a corresponding decrease in production. During 1992–97 soybean area was 2,059 ha as compared to 9,275 ha in 1980–85. The decrease is mainly attributed to the decline in soybean's international market price resulting in preference for imported soybean. Despite the good demand for the crop, soybean production has not increased. Processors do not opt local produce because of lack of assured and quality supply while producers do not want to grow soybean due to lack of ready market.

The bulk of soybean in the country is produced in Mindanao where three crops can be grown due to even distribution of rainfall throughout the year. Soybean production is done mostly through contract growing scheme between farmers and big processors and multinational companies. Besides favorable climate, ample contractor's support, higher adoption of POTs, adequate supply of seeds, higher seed viability, and better soil condition in Mindanao areas contributed in increasing the productivity of soybean.

Constraints in Legumes Production and Utilization

Biotic Constraints

Biotic stresses are the main constraints for legumes production. Weeds are a major deterrent to legumes production, while diseases, insect pests, and nematodes are also important (Quebral et al. 1986). However, losses have not always been quantitatively assessed. A national pest survey was conducted by the National Crop Protection Center of the Philippines (NCPC) in 1996 to rapidly assess the state of crop protection in the country. Results of this assessment, however, include only groundnut and mung bean pests in the country. The major pests and diseases of legumes are listed in Table 6.5. A total of 46 weeds, 51 diseases, and 48 insect pests of the three major legumes in the country have so far been recorded (Quebral et al. 1999).

Diseases

Groundnut. Of the 17 important diseases of groundnut, 10 are fungal diseases. The remaining are bacterial (1), viral (3), and nematode (3) diseases. In 1996, these diseases were estimated to cause 10–68% yield loss (NCPC 1998). Pod rot and powdery mildew have become recently major problems in groundnut (Table 6.5).

Mung bean. Three nematode, five viral, and nine fungal diseases on mung bean have been recorded. About 20% mung bean yield is lost from disease infestation (NCPC 1998). Integrated pest management (IPM) has been initiated. Cost of pesticides represents 44% of the inputs. The major diseases of mung bean, cercospora leaf spot, and powdery mildew are controlled with minimum cost by using resistant varieties (Table 6.6). In addition, intercropping and crop rotation with cereals can suppress pest population build up (PCARRD 1991).

Soybean. Twelve important diseases of soybean are recorded. Rust, damping-off, stem rot, aerial blight, wilt, and purple seed stain are important fungal diseases (Table 6.5). Soybean mosaic and bacterial pustule are other important diseases (PCARRD 1986, 1997). Varieties resistant to rust and bacterial pustule have been approved for commercial release by the National Seed Industry Council (NSIC). Development of varieties resistant to other diseases still needs to be pursued.

Insect pests

Groundnut. About 14% of groundnut yield loss is attributed to insect pests (NCPC 1998). Vigorous research has been carried out to address the problem of pod borer (*Helicoverpa armigera*), stink bug (*Nezara viridula*), and tussock moth (*Euproctis* sp) infestation. Varieties resistant to leafhopper and defoliators are available (Table 6.6). Results of surveys conducted by NCPC showed that only 2% of farmers use IPM, 1% use biological control, and 23% follow physical control.

Mung bean. Yield loss of mung bean due to insect pests was as high as 50% (NCPC 1998). Insecticides are still limited to the major pests cutworm, leaffolder, semilooper, aphids, beanfly, pod borer, and armyworm (Table 6.5). Presently, mung bean varieties resistant to insect pests are very few.

Soybean. The important insect pests of soybean are listed in Table 6.5. Farmers do not use chemicals to control pests on soybean.

Weeds

Groundnut. Weeds contribute more than 50% crop loss in groundnut production (NCPC 1998). Of the 19 major weeds recorded on groundnut, only *Amaranthus viridis* L., *Echinochloa* sp, *Ipomoea triloba* L., and *Rottboellia exaltata* L. are important. Weeds are widespread in Cagayan due to dominant monocropping scheme employed by farmers. Weeds are controlled through a combination of pre-emergence herbicides and physical management. In Region 2, hand weeding, harrowing at 5–25 days after sowing, and hilling up are commonly employed (NCPC 1998). Groundnut is intercropped with maize to smother weeds and minimize weed problems.

Mung bean. Fifteen major weeds have been recorded of which three are considered important: *Cyperus rotundus* L., *Brachiaria mutica* Stapf., and *Mimosa pudica* L. About 50% yield reduction could result due to severe weed competition (NCPC 1998). The combination of manual weeding and herbicide application is the best alternative.

Soybean. Thirteen weeds are recorded on soybean, *R. exaltata* being the most important weed. Weed control comprises a big input (34%) of soybean production.

Abiotic Constraints

Bad weather and natural calamities

The Philippines is a typhoon-prone area. Typhoon ranks first as a constraint to groundnut cultivation and third for mung bean production (BAS 1998a, 1998b). There is a pressing need to develop climatic models for site-specific weather forecasting and timely sowing. The data for modeling has yet to be institutionalized. Information is comprehensive for some areas while it is lacking in others. Due to inadequate government funding support and technical expertise, some data are collected every 10 years (farm census) or every three years (income). This calls for the widespread use of advanced scientific tools such as global positioning system (GPS), geographic information system (GIS), and remote sensing to ensure accurate, timely, cost-effective, and efficient data collection for modeling to forecast weather.

Table 6.5. Major diseases and pests of grain legumes in the Philippines.

Crop	Disease (Pathogen)	Pest
Mung bean	Cercospora leaf spot (*Cercospora* sp) Rust (*Uromyces appendiculatus* Link) Powdery mildew (*Erysiphe polygoni* DC. /*Oidium* sp)	Beanfly (*Ophiomyia phaseoli* Tryo.) Flea beetle (*Etiella zinckenella* Treitschke) Pod borer (*Maruca vitrata* Gey.) Bruchids (*Callosobruchus chinensis* L., *C. maculatus* F.) Armyworm (*Spodoptera litura* F.) Leaffolder (*Homona coffearia* Nietn., *Lamprosema indicata* F.) Semilooper (*Chrysodeixis chalcites* Esp.) Aphids (*Aphis craccivora* Koch)
Soybean	Purple seed stain (*Cercospora kikuchii* Matsu.) Bacterial pustule (*Xanthomonas campestris* pv *glycines* (Nakano) Dye) Aerial blight (*Rhizoctonia solani* Kühn) Damping-off (*Scleortium rolfsii* Sacc.) Root rot (*Rhizoctonia solani* Kühn) Wilt (*Fusarium* sp) Rust (*Phakopsora pachyrhizi* Syd., *Uromyces sojae*) Stem rot (*Fusarium* sp)	Beanfly (*Ophiomyia phaseoli* Tryo.) Pod borer (*Maruca vitrata* Gey.) Leaf miner (*Stomopteryx subsecivella* Zell.) Coffee leaffolder (*Homona coffearia* Nietn.) Corn ear worm (*Helicoverpa armigera* Hübner) Cutworm (*Spodoptera litura* F.) Bean leaf roller (*Lamprosema indicata* F.) Semilooper (*Chrysodeixis chalcites* Esp.) Bean lycaenid (*Catochrysops strabo* F.) Leafhoppers (*Empoasca biguttula* Mats.) Aphids (*Aphis glycines* Mats.)
Groundnut	Late leaf spot (*Phaeoisariopsis personata* (Berk. & Curtis) v. Arx Rust (*Puccinia arachidis* Speg.) Early leaf spot (*Cercospora arachidicola* Hori) Powdery mildew (*Oidium arachidis* Chorin) Bacterial wilt (*Ralstonia solanacearum* L.) Black leaf spot (*Cercospora personata* Ell. & Ev.) Damping-off (*Rhizoctonia solani* Kühn, *Fusarium* sp) Pod rot (*Fusarium solani* (Mart.) Sacc., *F. oxysporum* Schlect.) Bud necrosis (bud necrosis virus)	Corn ear worm (*Helicoverpa armigera* Hübner) Slug caterpillar (*Thosea sinensis* Walk.) Grasshopper (*Atractomorpha crenulata* F.) Leaf miner (*Aproaerema modicella* Dev.) Whitefly (*Bemisia tabaci* Genn.) White grub or June beetle (*Holotrichia consanguinea* Blanch) Cutworm (*Spodoptera litura* F.) Leaffolder (*Homona coffearia* Nietn., *Lamprosema indicata* F.) Semilooper (*Chrysodeixis chalcites* Esp.) Aphids (*Aphis craccivora* Koch)

Inadequate irrigation facilities

Irrigation facilities are usually lacking in legume-growing areas since legumes are treated as minor crops. Lack of water/irrigation ranked fourth (23%) among the major problems of mung bean farmers and sixth (5%) among groundnut growers (BAS 1998a, 1998b).

Poor soils

Poor soil conditions ranked as the seventh major constraint for both mung bean (8%) and groundnut (10%) (BAS 1998a, 1998b). The acidic nature (pH <7.0) of most soils is a problem. This is further aggravated when legumes are relegated to marginal areas, since productive agricultural lands are usually

Table 6.6. Grain legume varieties resistant to selected diseases and pests in the Philippines, 1982–97.

	Diseases									Insects	
Crop	Aflatoxin	Bacterial pustule	Blight (*Rhizoctonia* sp)	Cercospora leaf spot	Mottle virus/ viruses	Powdery mildew	Rust	Sclerotium leaf spot	Sclerotium wilt	Defoliators (leaf miner, cutworm)	Leafhopper
Groundnut	PSB Pn-2[1]	-	UPL Pn-8[1]	UPL Pn-4 PSB Pn-2 PSB Pn-3	-	-	UPL Pn-4 PSB Pn-2 PSB Pn-3	UPL Pn-2	UPL Pn-8[1]	UPL Pn-10	UPL Pn-10
Mung bean	-	-	-	UPL Mg-2 UPL Mg-1 BPI Mg-7 Pagasa 2[1] BPI Mg-2[1]	UPL Mg-3 PSB Mg-1[1] PSB Mg-2[1] PSB Mg-3[1]	UPL Mg-1 UPL Mg-2	BPI Mg-7	-	-	-	-
Soybean	-	PSB Sy-8 EGSy 93-1807 EGSy 93-62 AGS-186 AGS-190 AGS-191	-	-	-	-	PSB Sy-8 PSB Sy-2 UPL Sy-2 BPI Sy-2 SJ-4 BPI Sy4[1]	-	-	-	-

1. Moderately resistant.
Source: BPI (1988, 1993, 1997).

reserved for cereals and other high income generating cash crops. Use of fertilizers (organic and inorganic) is also limited for legumes; hence, yields are low.

Socioeconomic Constraints

Production

Among the socioeconomic constraints, high cost of inputs ranks second among mung bean producers (49%) and fifth among groundnut growers (15%). Although net profit-cost ratio for mung bean (0.42) is much higher than groundnut (0.17), economies of scale makes groundnut farmers less susceptible to high/fluctuating input cost (Palis et al. 1984). Seed was one of the major input costs, along with pesticides and fertilizers. Seed production at farmer level, and promotion of low-cost inputs such as organic fertilizers and botanical pesticides should be intensified.

Lack of capital was ranked fourth by groundnut growers (10%) and fifth by mung bean farmers (14.2%) (BAS 1998a, 1998b). To address these gaps, legume farmers should have greater access to loans/credit assistance, with adequate support services, and be assisted in the formation and strengthening of cooperatives. Inadequate supply of seeds should be addressed by strengthening the seed supply system. Although improved production technologies have been developed, adoption is slow due to inadequate technology dissemination and extension. Appropriate implementation of effective technology transfer activities should be put in place.

Marketing

Unstable price (60%) and price monopoly (45%) were given top importance by both groundnut and mung bean farmers (BAS 1998d). Variability in prices are due to fluctuating supply and imports. Continuous supply should be assured by planning production sites, planting seasons, and cropping systems. There is a need for improved farm-to-market roads to lessen transport costs of locally produced legume products. There should also be policies that provide fiscal support for rural infrastructure.

Although there is high demand for local produce, market information is lacking. This is contributing to lack of buyer or market as a major marketing constraint. There is a need for market information network.

Processing and utilization

The high price of legumes (especially groundnut), lack of quality supply, and inadequate processing facilities were cited as major constraints in the manufacturing sector. Lack of acceptability of legume products is a major constraint to increase legume utilization. Shelf-life is not a problem in the production Region 2 because the products of small-scale manufacturers are marketed locally, but is a problem in cities. Increased utilization of legumes can be achieved by increasing the awareness of consumers of its nutritive and health qualities, continuous promotion of legume products, and sustained product development. Formulation of standards that would ensure quality and safety of legume products are essential so that legitimate producers and processors can have market advantage. Likewise, formulation of policies that will address problems that contribute to non-competitiveness of legume food exports should be in place.

Role of Legumes in Cropping Systems

The cropping systems in Region 2 are based on rice, maize, coconut (*Cocos nucifera* L.), sugarcane (*Saccharum officinarum* L.), banana (*Musa paradisiaca* L.), vegetables, root crops, and other cash crops. Legumes are usually grown as rotation or relay crops, or intercropped with the main crops. Multiple cropping of cereals with legumes are commonly practiced.

Groundnut

Groundnut can be planted after a major crop for two cropping seasons under the dry zone, and one cropping season each under the moist zone and wet zone. Monocropping, however, is not advisable due to pest build-up.

Mung Bean

Generally, mung bean is produced year round with harvesting periods from February to June. High yields of good quality grain are generally obtained during the dry season because of the low precipitation and good light intensity at flowering and maturity and irrigation. Mung bean can be planted in three cropping seasons in the dry zone, 2–3 cropping seasons in the moist zone, and 1–2 cropping seasons in the wet zone after the main crop. Multiple cropping is best as it breaks the pest and disease cycle.

Soybean

During the wet season, soybean can be planted in the later part of May and in June. During the dry season, sowing can be done in October/November if enough moisture is available after rice or maize. Soybean can be planted after the main crop in two cropping seasons under the dry zone, and one cropping season each in the moist and wet zones. Where soybean monocropping is practiced, three crops are possible.

Research, Development, and Extension Programs/Priorities

Government Interventions

Legumes play an important role in attaining food security for national economic development. The Department of Agriculture (DA) and the Department of Science and Technology (DOST) through the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) are in the forefront of spearheading research and development (R&D) programs for the development of the legume industry in the country. These programs are coordinated or implemented by DA and DOST in collaboration with the concerned state colleges and universities, non-government organizations (NGOs), and the private sector.

The following are the programs of DA to increase legumes production in the country:

- Gintong Ani High Value Commercial Crops Program (GAHVCCP) includes market studies, improvement of postharvest technologies, establishment of irrigation facilities, seed storage, and mechanical drying and processing plants.
- Seed production program is the mandate of the Bureau of Plant Industry (BPI)-DA and is responsible for legumes seed supply and exchange.

- Product development program is a regular activity of BPI-DA and evaluates different varieties of legumes, develops products, and conducts regular seminars.
- The Bureau of Postharvest Research and Extension (BPRE) of DA sets up production and postharvest systems for legume farmers' cooperatives, identifies cultivars resistant to storage pests, conducts insect pests survey, performs evaluation and acceptability testing of post-production facilities, and studies drought and irrigation management.

PCARRD coordinates the following interventions to boost legumes production in the Philippines.

Groundnut (peanut)

- Peanut Collaborative Research Support Program (CRSP) aims to facilitate economic growth through market expansion of high quality groundnut products.
- Peanut Technology Commercialization Project (PTCP) focuses on the use of quality seeds, *Rhizobium* inoculant, monoculture of groundnut, and promotion and adoption of improved management practices.
- Peanut Integrated Research and Development Program (P-IRDP) aims to establish an adequate seed support system; increase production through varietal improvement and on-farm trials of promising technologies in Cagayan Valley; and develop and fabricate production and post-production facilities/equipment.

Mung bean

- Mungbean Technology Commercialization Program (MTCP) promotes the cultivation of variety Taiwan Green and use of *Rhizobium* inoculant and drill method of sowing covering about 16,000 ha.
- Mungbean Development Action Project (MDAP) aims to increase the yield of mung bean from 0.68 t ha^{-1} (national average) to 1.25 t ha^{-1}.

Soybean

- Soybean Pilot Production Project (SPPP) developed the soybean POT which can give a yield of 2.44 t ha^{-1}.
- Soybean Technology Commercialization Program (STCP) aims to commercialize the growing of soybean in some selected, non-traditional soybean-growing areas through seed supply, inoculant production, training, applied communication and extension, and credit and market assistance.
- Accelerated Soybean Production and Utilization Program (ASPUP) showed the economic viability and profitability of using an integrated soybean production, processing, and utilization scheme.

International Collaboration

International collaboration for R&D work on legumes has been a strong component of the national R&D system. Linkages have been forged with AVRDC for vegetable soybean, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (India) for groundnut and chickpea, the International Development Research Center (IDRC) (Canada) for mung bean, groundnut, and soybean, the United Nations Development Programme (UNDP) and the Food and Agriculture Organization of the United Nations (FAO) for soybean, and the United States Agency for International Development (USAID) and World Bank for several legume crops.

Prospects for Increasing Legumes Production

There are bright prospects for increasing the production of legumes. This can be achieved partly through yield improvement and expansion of areas planted to legumes. Another strategy would be through strengthening major legumes production zones in terms of institutional and technical support, marketing, and infrastructure.

Yield

Improved varieties

Productivity of legumes can be increased through use of improved and suitable varieties which are high yielding, resistant to pests and diseases, well-adapted to different ecological conditions, and with long seed viability.

Adoption of package of technologies (POTs)

Adopting developed POTs with special emphasis on soil and pest management, and postharvest handling can also increase the yield of legumes. There is a need, however, to fine-tune these technologies to suit location-specific needs in order to sustain adoption by farmers. The available crop simulation models and spatial analysis methods can be used to optimize management for precision farming. Likewise, continuous search, verification, and promotion of suitable cropping systems technologies especially in the uplands and hilly lands should be continued.

Adequate support services

The available POTs can be optimally used when adequate support is provided, particularly credit, inputs (seed production and exchange, fertilizer, pesticides, irrigation), production and post-production equipment and facilities, marketing, technology dissemination, and favorable government policies. Efforts are underway to strengthen research-extension linkage among the various stakeholders such as the farmers, business sector, local government units, and research agencies.

Area

Suitable sites

Legumes are suitable in the warm lowlands of the dry zone with inceptisols and entisols (about 3 million ha). Presently, legumes occupy only 0.12 million ha. This implies that 2.88 million ha of potential areas is available for legume expansion. Most of these lands, however, are traditionally planted to rice and maize, and legumes are considered best candidates to break this continuous cereal monocropping system.

Acid soils

Most of the soils in the country are acidic. Only one mung bean variety, PSB Mg4, has tolerance to acidic soils. The variety is also a good nitrogen-fixer and is high yielding. Research activities are geared towards the development of groundnut and soybean varieties well-adapted to acid soils.

Drought areas

Northern Luzon is considered a drought-prone area. The 1997–98 El-Nino phenomenon prompted the government to identify drought-resistant varieties. Mung bean varieties Pagasa 7 and Pagasa 9 have good tolerance to drought.

Uplands and hilly lands

The topography of the country is mostly uplands, hilly lands, mountains, and highlands that are prone to erosion which results in declining productivity and soil degradation. Cultivation of legumes in these areas helps sustain soil productivity by improving soil fertility. They also serve as excellent forage crops in pasture areas. A soybean variety, PSB Sy2, was released with good adaptation for the uplands.

Raising permanent crops such as coconut and fruit trees such as *Musa* spp and *Citrus mitis* Blanco. in the highlands are common. Legumes can be grown as an intercrop between these fruit trees and can be excellent cash crops. They are less perishable which make them a suitable commodity for the highlands where roads and transportation facilities are inadequate.

Conclusions and Recommendations

- In general, the production of groundnut and soybean show declining trends, mainly due to unavailability of good quality seeds and inconsistent government policies.
- Mung bean has a more stable production across time which fits very well in many existing cropping systems.
- The national soybean production area sigificantly decreased, but has expanded in Region 2 due to intensified government interventions on soybean production and promotion of village-level processing technologies.
- Productivity of legumes, except groundnut, show increasing trends. Yields of legumes, however, are still relatively lower than their potential. Major production constraints are pests and diseases, calamities, and low seed viability. The prevailing attitude of farmers who consider legumes as a minor crop also hinders better productivity.
- The major constraints in utilization are the slow growth and substandard quality of supply of legumes necessitating imports.
- Through the crop intensification and crop diversification programs of the government coupled with good marketing schemes and favorable policies, prospects for increasing legume area and production is bright.

The following strategies shall be pursued for increasing legume production:

- Tapping uplands and other marginal areas for planting legumes.
- Intercropping, crop rotation, relay cropping of legumes with crops other than rice and maize [i.e., coconut, banana, vegetables] for flexible cash returns.
- Precision farming for optimum land management through the use of crop models interfaced with GIS.

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7. Legumes in Rice-based Cropping Systems in Sri Lanka: Constraints and Opportunities

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Abstract

Length of growing period (at least 180 days) and temperature (average of 21–28°C) allow growing of rice and legumes round the year. The island receives rainfall round the year in most parts of Sri Lanka. High rainfall (>2000 mm in central, southwest, and southern parts of the country) prevents cultivation of legumes. As a result, most of the legumes can be grown only in northern and southeastern part of the island. In total, it accounted for 51,000 ha area in 1997 under five legumes (mung bean, cowpea, soybean, black gram, and pigeonpea). Winter legumes are essentially absent and can potentially be grown on a limited area (in the up-country). Red brown earth (RBE) (Chromic Luvisols) and low humic gley (LHG) (Ferric Acrisols) are the two major soil groups on which legumes are largely grown. RBE is the most widespread Great Soil Group and is mainly confined to the dry zone in northern and southeastern Sri Lanka.

Although the island receives rain round the year, legumes face mid-season drought leading to crop failures in some years. Waterlogging during crop establishment and rains at pod maturity are the other threats to high yield of legumes, particularly in cowpea. Pod borers (Maruca *and* Helicoverpa)*, collar rot* (Sclerotium rolfsii)*, powdery mildew* (Erysiphe polygoni/Oidium *sp), fungal leaf spots, and viral diseases are among the major biotic constraints of different legumes. Lack of sufficient water for rice cultivation provides an opportunity for growing legumes, particularly in* Yala *(minor rains) season.*

Potentially 0.15 million ha can be put to legumes in both Maha *(major rains) and* Yala *seasons. Examples of successful adoption of at least one of the five legumes exist. Diversification of rice-based cropping systems and increasing per capita consumption of legumes are parts of national policies to enhance legume production.*

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Introduction

Sri Lanka is an island situated between 6° to 10° N and 80° to 82° E. The maximum length is 432 km and maximum breadth is 224 km. Total land area is 6.55 million ha including an inland water area of 0.32 million ha. Population as reported in 1994 is 17 million and average population density is 277 km^{-2}. The country is divided into 24 administrative districts (Fig. 7.1). Kurunegala, Moneragala, and Anuradhapura districts report largest area of legume cultivation.

Legumes in Sri Lanka are grown mainly under rainfed conditions, but there is a great scope for cultivating legumes in the rice (*Oryza sativa* L.) fallows. Important legumes currently grown are mung bean (*Vigna radiata* (L.) Wilczek), cowpea (*Vigna unguiculata* (L.) Walp.), soybean (*Glycine max* L.), black gram (*Vigna mungo* (L.) Hepper), groundnut (*Arachis hypogaea* L.), and pigeonpea (*Cajanus cajan* (L.) Millsp.). It had been estimated that by 1997, 146,000 ha legumes were to be grown to meet the national requirement (Rathnayake et al. 1995). However, it was reported that legume cultivation in 1997 was only on 51,000 ha. Significant achievements were made in cowpea and groundnut cultivation, but utter failures were reported in soybean and pigeonpea cultivation. For successes in legume production biotic, abiotic, and socioeconomic factors need to be identified, and the potential resource base for the different legumes under various agroecological situations determined. The available information is synthesized in this chapter so as to form the base for identifying constraints and opportunities of legume cultivation in rice-based cropping systems in Sri Lanka.

About 90% self-sufficiency in rice was reached in 1985 as a result of heavy investment in irrigation, rice research, and institutional support (Aluwihare and Kikuchi 1990). In 1990, rice was cultivated on 735,000 ha, i.e., 41% of the total agricultural land use. Later, however, the rice area increased marginally (Wijayaratna 1994). It is not possible to develop new land for rice in near future as irrigated areas cannot be expanded. Therefore, exploring the possibility of promoting legume cultivation in new rainfed lands, diversifying low productive lands, and rice fallows for legume cultivation should be the main emphasis of agricultural development in Sri Lanka.

Agroecological Features

Climate

Solar radiation

In Sri Lanka the radiation energy available for plant growth is very favorable in terms of total annual amount, seasonal distribution, and direction of

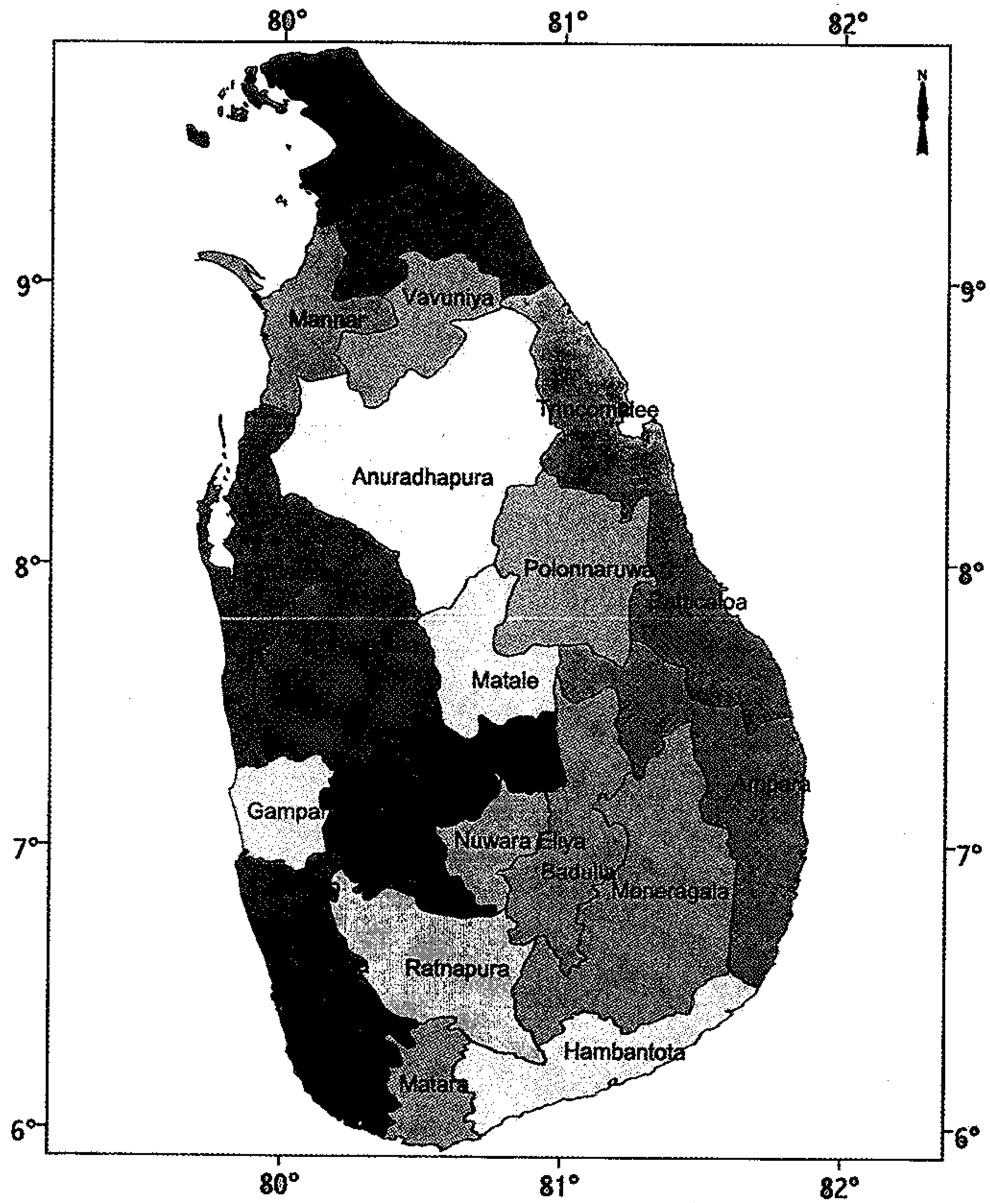

Figure 7.1. Aministrative divisions of Sri Lanka.

incidence. The duration of day length does not vary much regionally but there is a small seasonal variation. This is of importance in Sri Lanka in photoperiod-sensitive physiological processes of certain crops.

Temperature

Since Sri Lanka is an island near the equator, there is little or no regional variation of temperature due to latitude, but variation occurs due to altitude. Regional and seasonal variations of temperature are shown in Figure 7.2. It is evident from the maps (Fig. 7.2) that during the coolest month (January), isotherm (with <25°C) encloses an area which is about $\frac{1}{3}$ the area of the island, whereas in the warm month of July, this area contracts to <20%. These isotherms are nearly parallel to the elevation contours. Therefore, three temperature zones can be identified: (1) <330 m above sea level (asl) as hot lowland; (2) 330–1000 m asl as warm midland; and (3) >1000 m asl as mild upland. Temperature is seldom a limiting factor, but favorable for plant growth in Sri Lanka.

Rainfall

According to occurrence and origin of rainfall, four broad climatic seasons have been identified as follows:

First inter-monsoonal season	:	March–April
Southwest monsoonal season	:	May–September
Second inter-monsoonal season	:	October–November
Northeast monsoonal season	:	December–February

Regional and seasonal distribution of rainfall is quite complex due to interaction between above mentioned seasonal variation and the topographical configuration of the island (Fig. 7.3). Mean annual rainfall in any part of the country is not below 750 mm. During rainless periods evaporation is >100 mm per month, and can be as high as 300 mm per month. Rainfall in the dry zone is <100 mm during the dry period of southwest monsoonal season. These factors greatly affect agriculture in the country. Shallow rooted plants cannot grow and their aerial shoots dry up due to lack of soil moisture. Soil becomes hard when dry and difficult to till and clayey soils show typical cracks. Within each of the main rainfall zones it is possible to recognize several sub-zones due to variation of seasonal rainfall regimes.

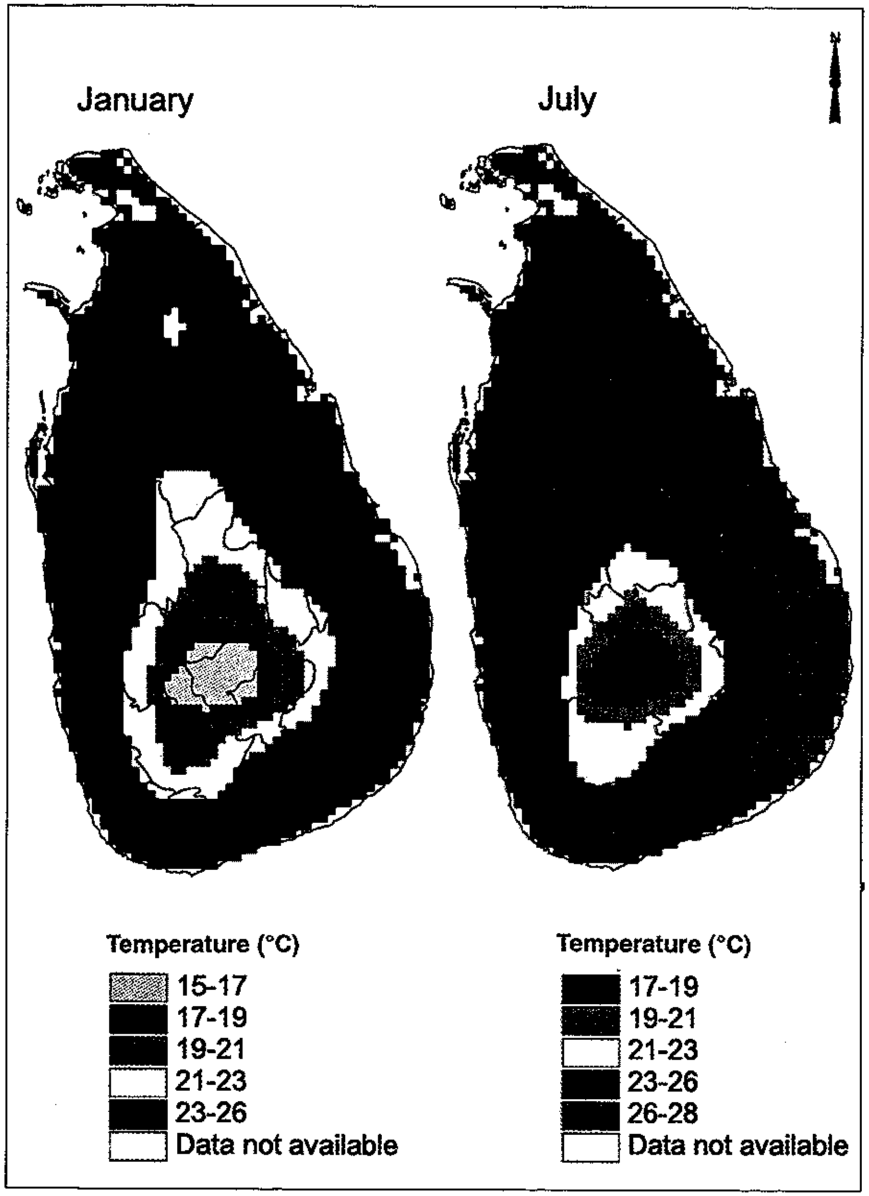

Figure 7.2. Isothermol map of Sri Lanka.

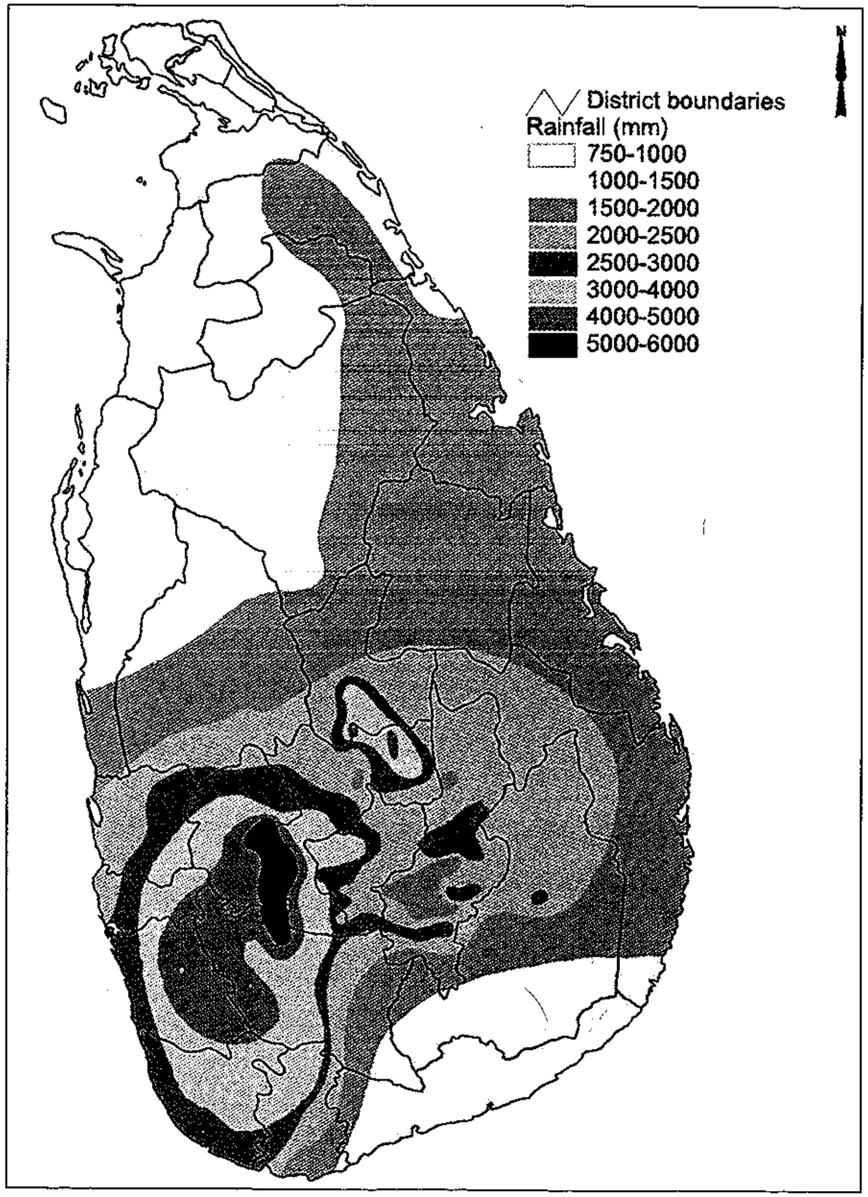

Figure 7.3. Mean annual rainfal in Sri Lanka.

Soils

There are 13 Great Soil Groups in the country, and 9 soil phases are recognized across the country (Fig. 7.4). Reddish Brown Earth (RBE) soil (Chromic Luvisols) is the most widespread Great Soil Group in Sri Lanka and occupies the largest area (1.6 million ha) compared to all other soils (Panabokke 1988). This soil is mainly confined to the dry zone and it occurs in a catenary sequence with the other drainage members, and on crests and well-drained upper and mid slopes of the undulating landscape. Most of the legumes, both under rainfed and irrigated conditions, are grown on this soil (Panabokke 1996).

After RBE, Low Humic Gley (LHG) soil (Ferric Acrisols) is the most extensive Great Soil Group (0.95 million ha) in Sri Lanka. The LHG soil is essentially hydromorphic and developed on the local colluvium that has been built up at the bottom lands of the undulating landscape. It is found throughout the lowlands of Sri Lanka (Panabokke 1996). It is the most dominant soil for rice-based cropping systems where possibilities for legumes are discussed in this chapter. Two broad categories of LHG are found in the dry zone. The first and more widespread category consists of deep sandy clay loams underlain by sandy clays, and associated with RBE. The second is of light texture and associated with Non-Calcic Brown Soils (Orthic Luvisols). The surface soil structure is sub-angular blocky to massive. These soils are extremely hard when dry and sticky when wet. The water-holding capacity of the subsoil is fairly good because of the presence of smectite clay minerals.

Agroecological Situations

Based on soil, rainfall, and water availability, the length of growing period (LGP) in Sri Lanka varies from 90 to 365 days. Based on the LGP, Sri Lanka can be divided into 10 LGP regions (Fig. 7.5). Further micro-level variations in climate along with physiography and soil have led to further divisions of the agroecology in Sri Lanka. Altogether 24 agroecological regions have been demarcated, and some of them have been divided into sub-regions. Most of the legume-growing areas are located in the Dry Zone and Intermediate Zone lowland situations (DL and IL subdivisions) (Fig. 7.6).

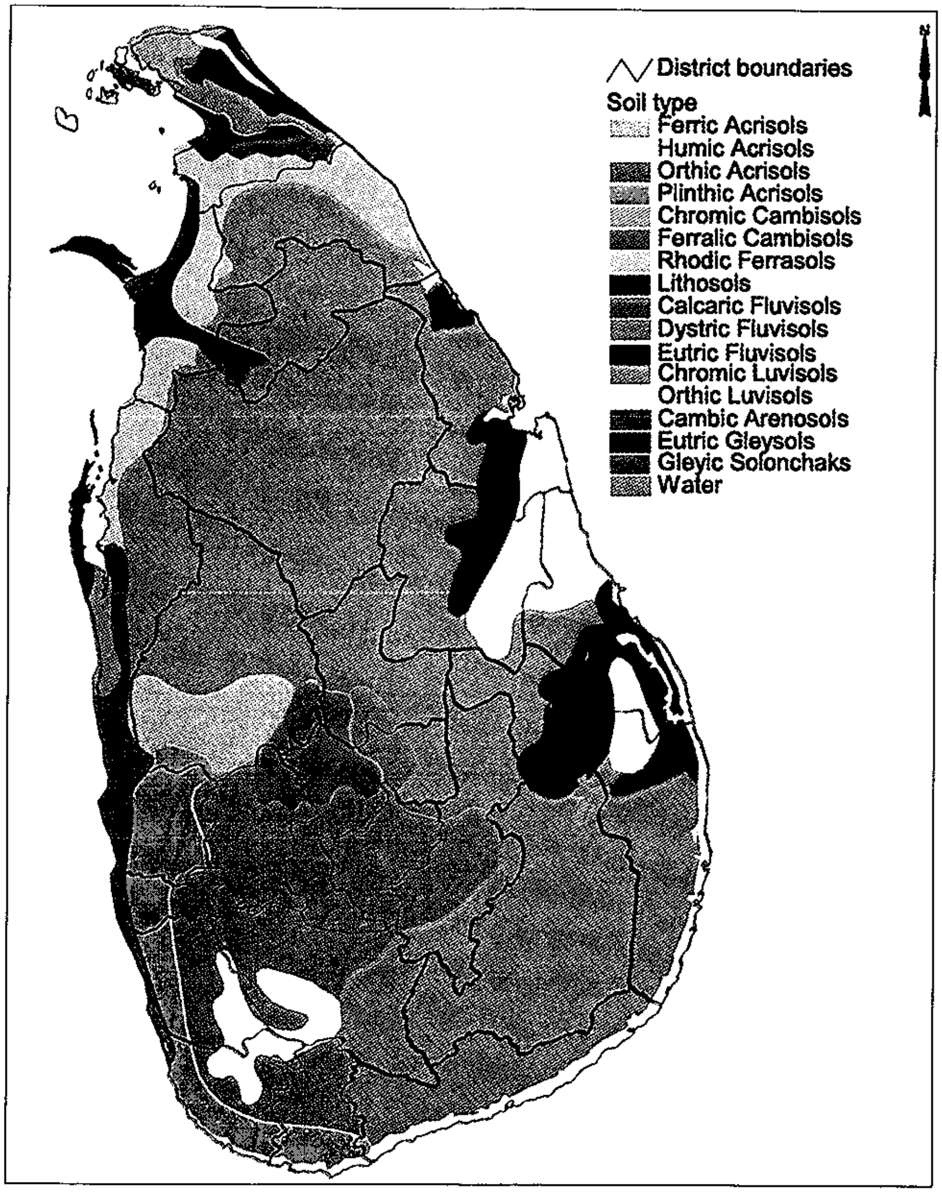

Figure 7.4. Distribution of soil types in Sri Lanka (Source: FAO, Rome, Italy).

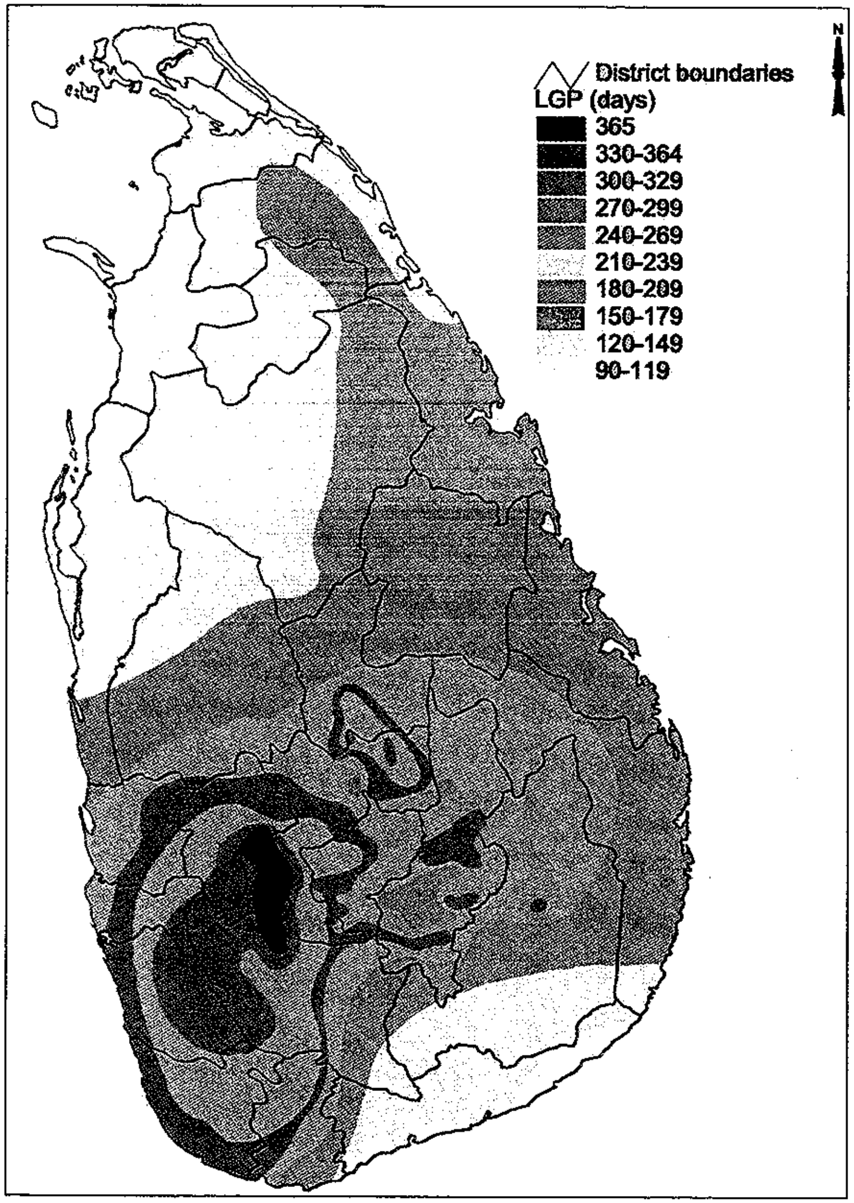

Figure 7.5. Length of growing period (LGP) in Sri Lanka.

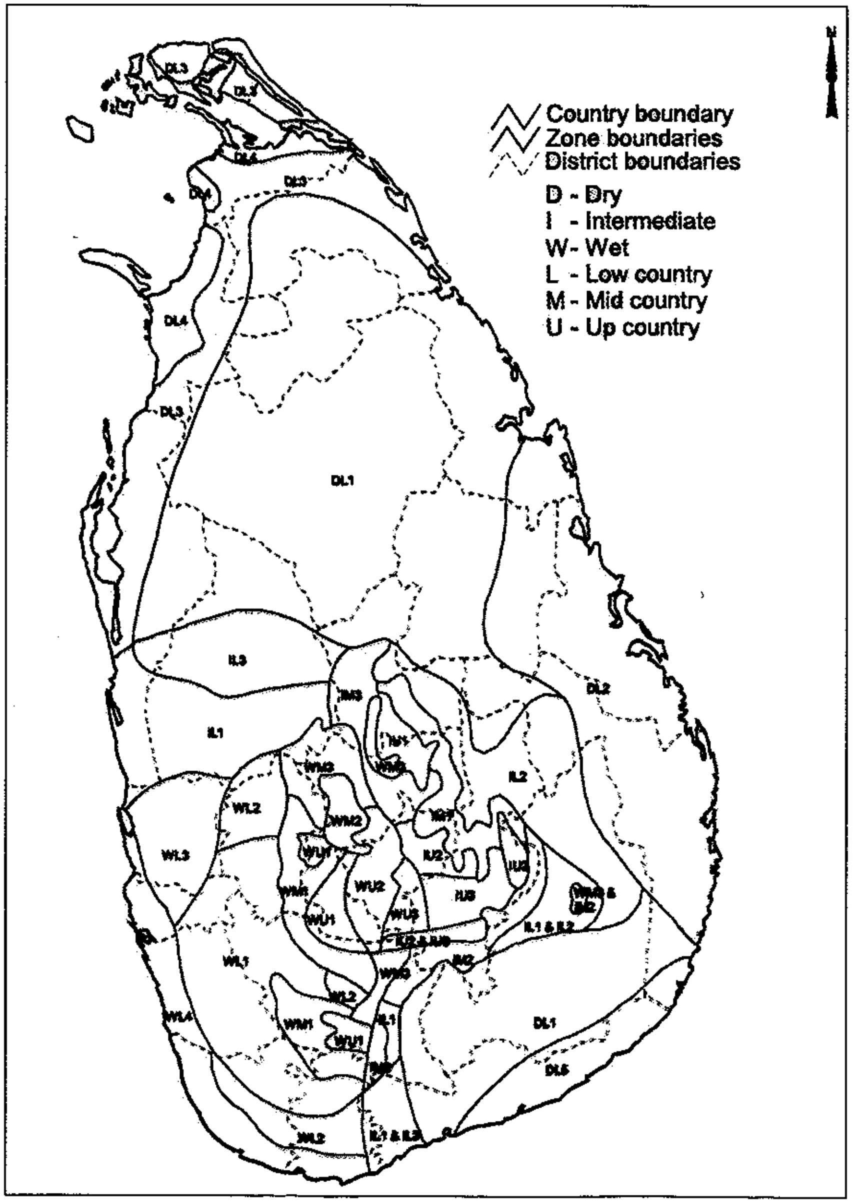

Figure 7.6. Agroecological zones of Sri Lanka.

Area, Production, and Yield of Major Legumes

Mung Bean

Mung bean is mainly grown in Kurunegala, Moneragala, and Hambantota districts (Fig. 7.7), in well-drained sandy loam to clay loam soils. Average cultivated area during 1993–97 was 20,000 ha and the national production was 17,000 t. However, average yield (0.87 t ha^{-1}) is low compared to potential yield (1.2 t ha^{-1}). Relatively high yields were reported from Mullaittivu and Hambantota districts. Mung bean yield showed an increasing trend due to adoption of improved varieties. However, area and production have declined since 1991 (Fig. 7.8).

Cowpea

Cowpea is mainly grown in Kurunegala and Puttalam districts (Fig. 7.9), in well-drained sandy loam to clay loam soils. Average cultivated area during 1993–1997 was 19,000 ha and production was 17,000 t. However, the average yield was low (0.88 t ha^{-1}) compared to the potential yield (1.6 t ha^{-1}). Relatively high yields were reported from Mullaittivu, Mannar, Polonnaruwa, Kegalle, Ratnapura, Moneragala, and Hambantota districts. Cowpea yield has been maintained at 0.9 t ha^{-1}, but production has declined drastically during 1993–97 due to reduction of cultivated area (Fig. 7.8).

Soybean

Soybean is not grown extensively in Sri Lanka, except in Anuradhapura district where 900 ha was reported during 1990–97 (Fig. 7.10). Soybean is one of the crops which can be promoted by increasing the demand for processed foods. Average cultivated area during 1993–97 was only 1,000 ha and production was 1,000 t. Average yield was low (0.96 t ha^{-1}). Relatively, high yield was reported from Polonnaruwa district. Average yield of soybean has been stable but area and production have declined in recent years especially due to poor marketing arrangements and low price that farmers obtained for their produce (Fig. 7.11).

Black Gram

Black gram is mainly grown in Anuradhapura and Vavuniya districts (Fig. 7.12), in well-drained sandy loam to clay loam soils, and also on LHG soils during *Yala* (March to July; minor rainy) season. It is also grown as a catch crop after harvesting the *Maha* (October to January; major rainy) season rice crop. Average

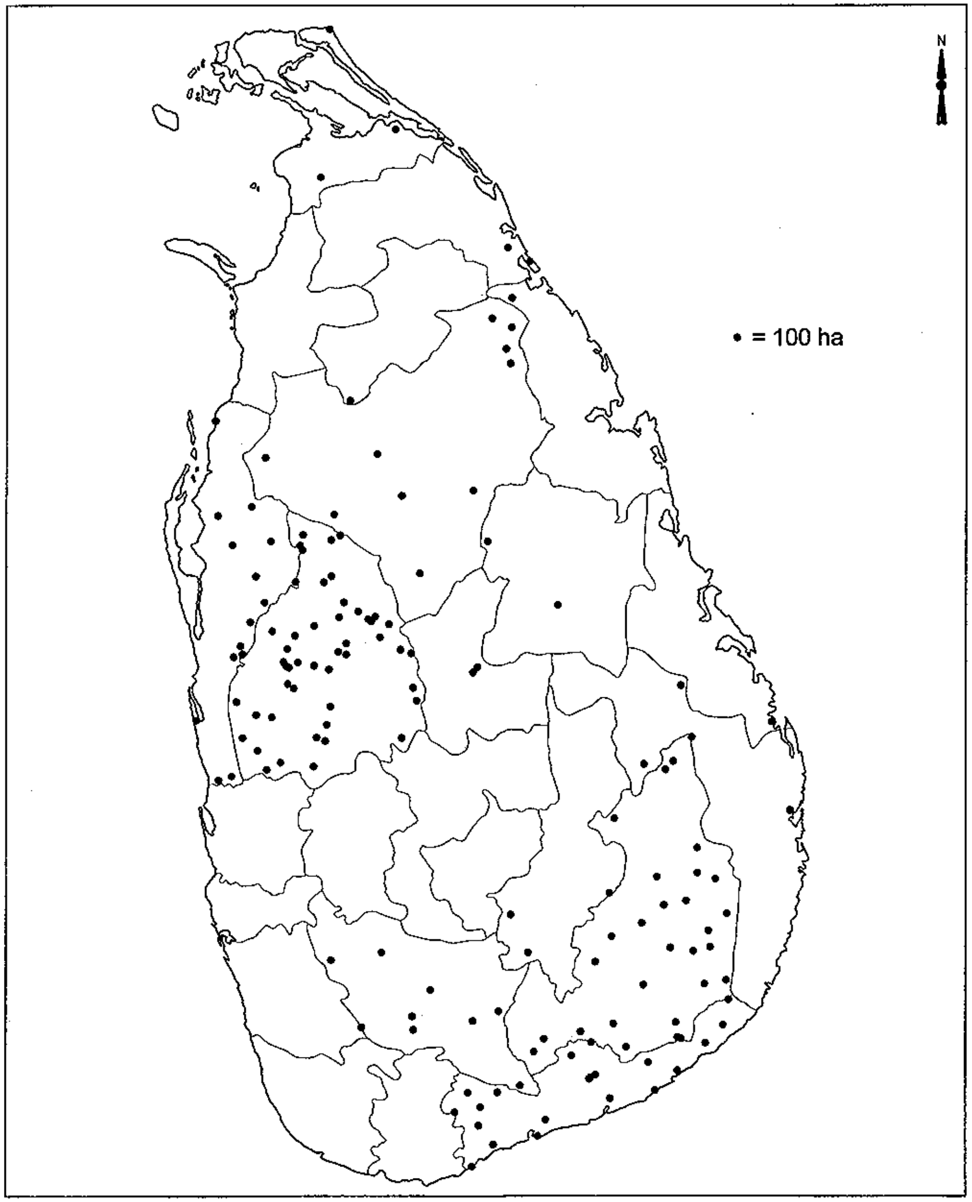

Figure 7.7. Distribution of mung bean in Sri Lanka, 1984–97.

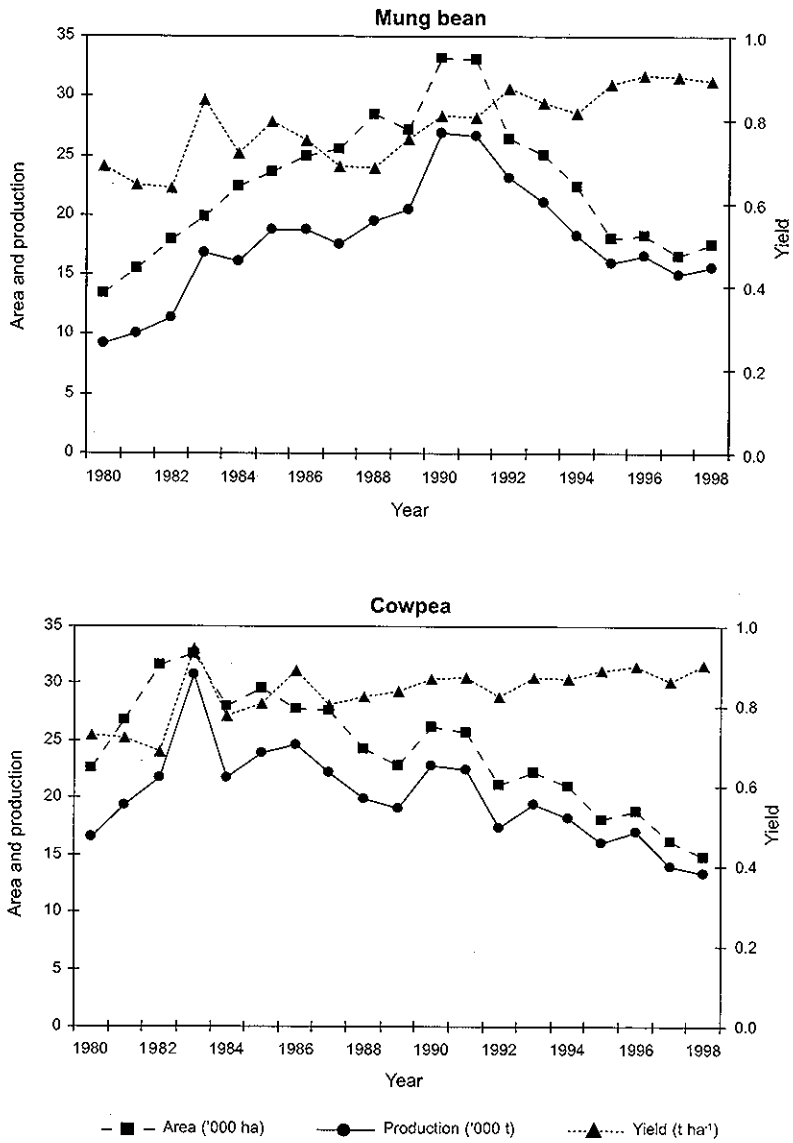

Figure 7.8. Area, production, and yield of mung bean and cowpea in Sri Lanka, 1980–98.

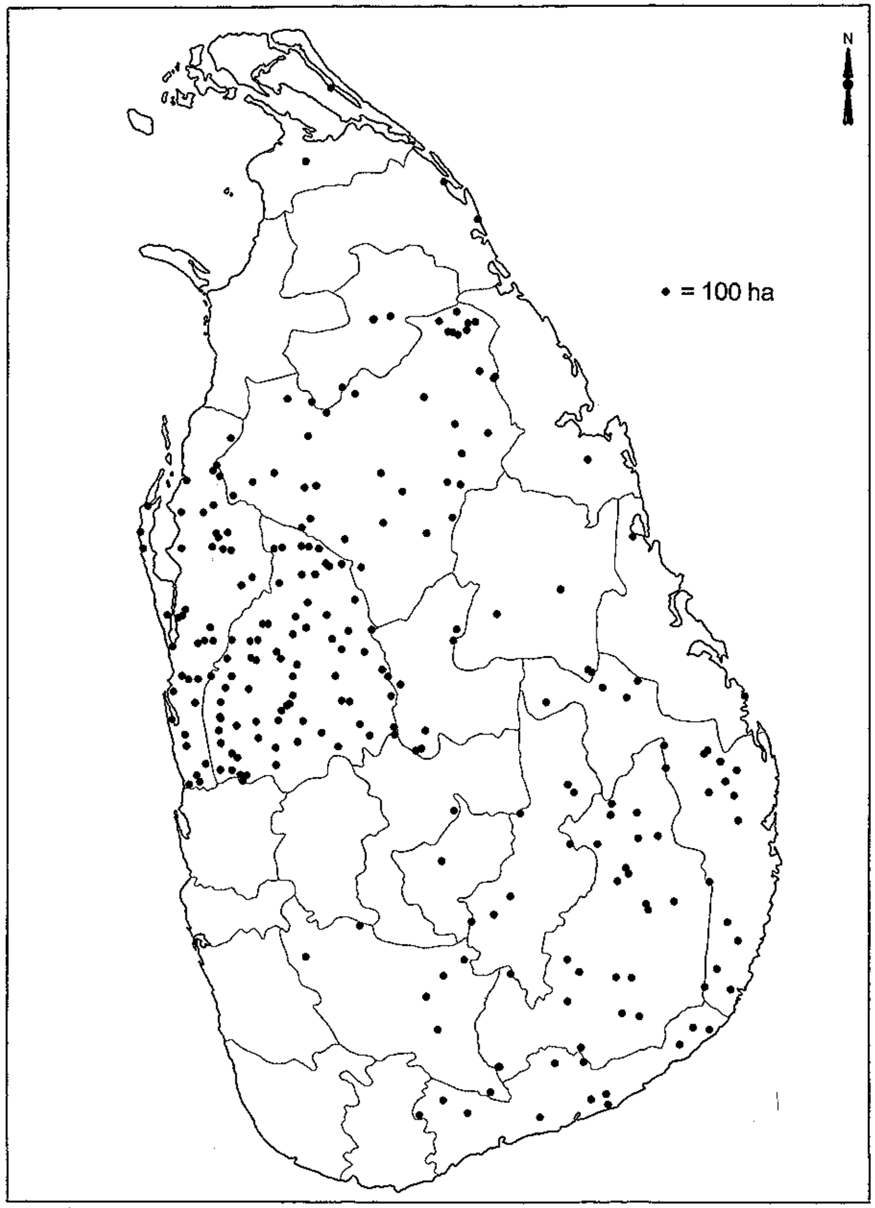

Figure 7.9. Distribution of cowpea in Sri Lanka, 1984–97.

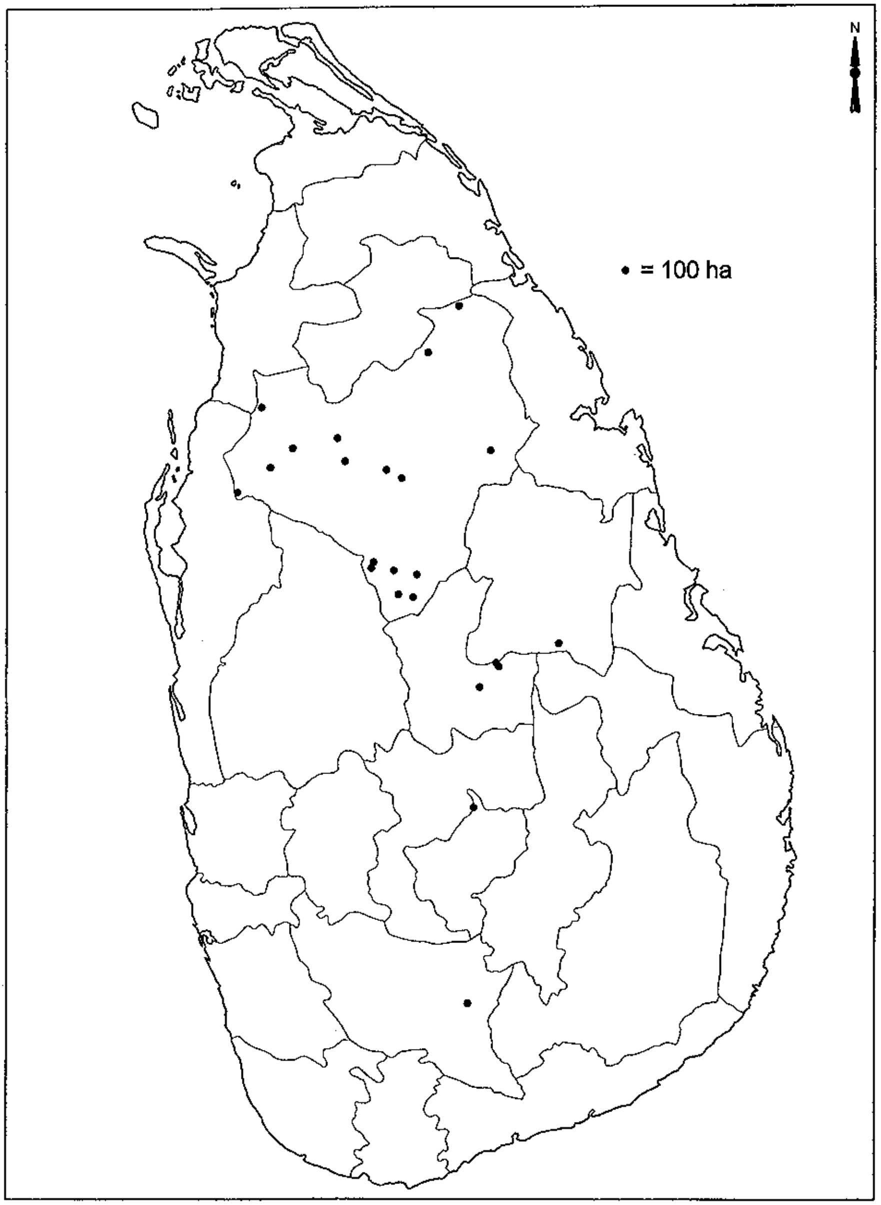

Figure 7.10. Distribution of soybean in Sri Lanka, 1984–97.

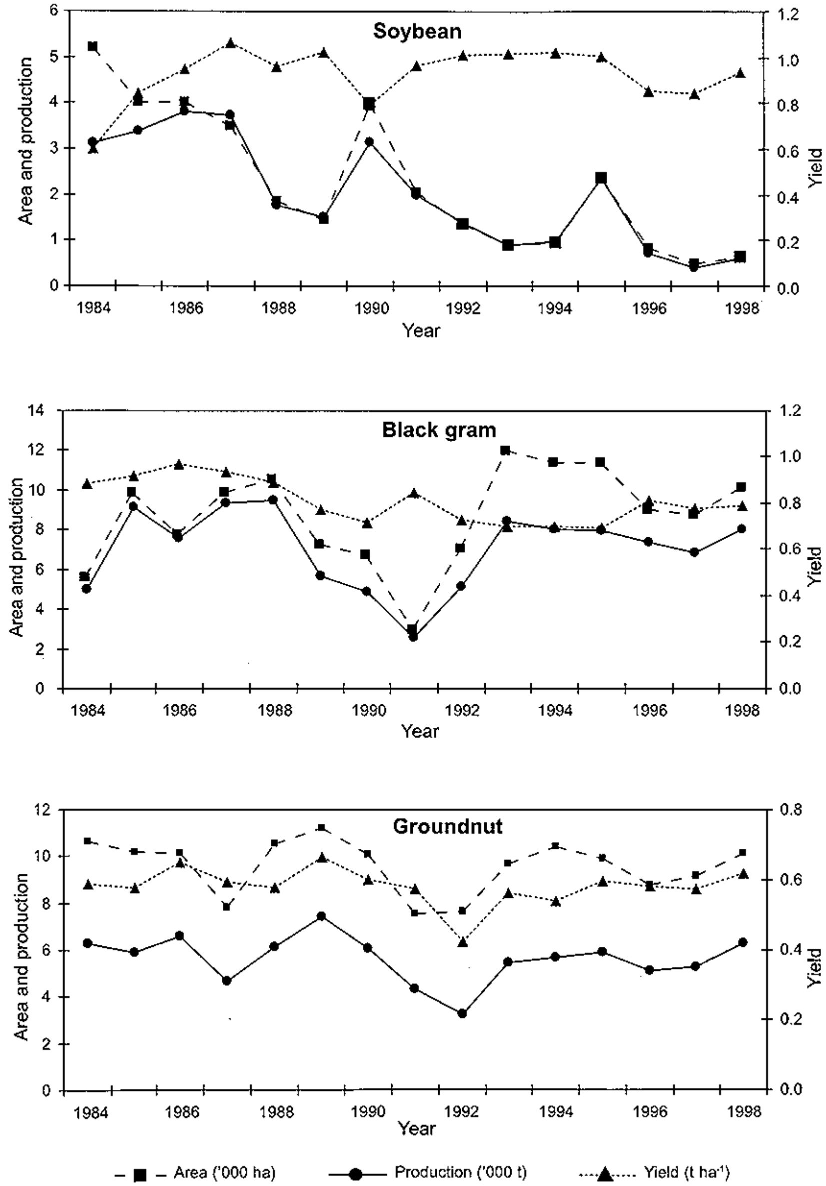

Figure 7.11. Area, production, and yield of soybean, black gram, and groundnut in Sri Lanka, 1984–98.

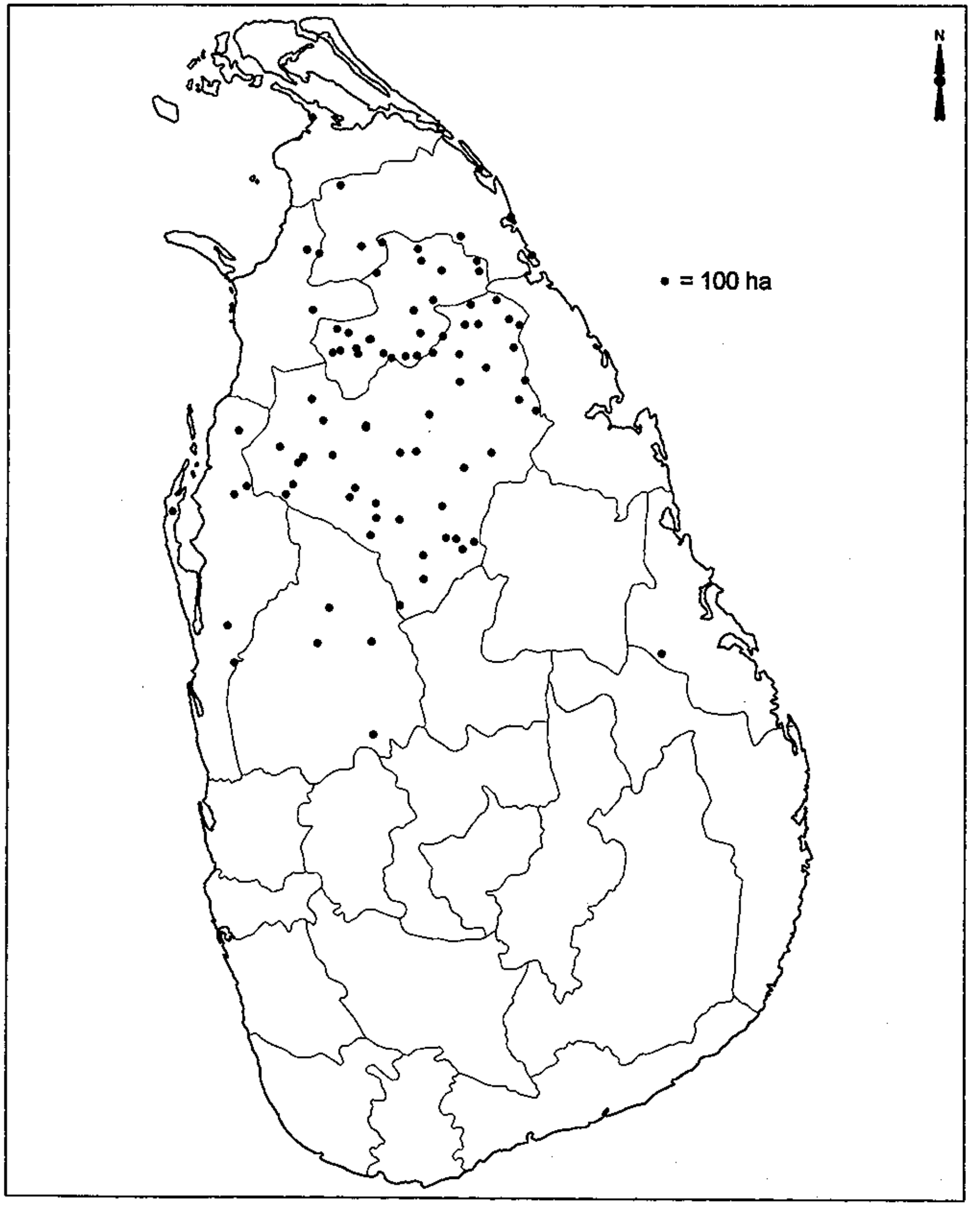

Figure 7.12. Distribution of black gram in Sri Lanka, 1984–97.

cultivated area during 1993–97 was 10,500 ha and production was 8,000 t. Average yield was low (0.73 t ha^{-1}) and relatively high yields were reported from Trincomalee district (<100 ha area). A declining trend in yield has been observed in recent years. Also, fluctuation in area and production of black gram has occurred during 1984–97 (Fig. 7.11).

Groundnut

Groundnut is mainly grown in Moneragala, Puttalam, and Kurunegala districts (Fig. 7.13). The crop is planted during mid- to end October in *Maha* season and in April with first rains in *Yala* season. Well-drained sandy soils are the most suitable soils for groundnut cultivation. *Yala* season cultivation is practiced in rice-based cropping system in minor tank irrigation areas. Average cultivated area during 1993–97 was 10,000 ha and production was 5,500 t. Yield of presently available groundnut varieties was quite low (0.57 t ha^{-1}) compared to potential yield (3.5 t ha^{-1}). Relatively high yields were reported from Polonnaruwa, Trincomalee, and Mannar districts. A slightly decreasing trend in the production of groundnut was observed during the last 15 years. This was mainly due to reduction in the area cultivated. Yield, although low, has been stable in recent years (Fig. 7.11).

Constraints to Legume Cultivation

Constraints to legume cultivation can be broadly categorized as abiotic, biotic, and socioeconomic factors.

Mung Bean

Mung bean is sown in 1st to 2nd week of November in *Maha* season and early April with first rains in *Yala* season. Risk of crop loss due to inadequate rains during the end of the season has made farmers to adopt dry seeding as well as sowing soon after the first rains. Low yields are reported from lands with poor soil fertility. Yellow mosaic, cercospora leaf spot, rust, and powdery mildew are the major diseases and pod borer and bruchids are the major pests that constrain mung bean production (Table 7.1). Other constraints are moisture shortage during the end of the season and inadequate use of fertilizers.

Generally, the crop is cultivated by resource-poor farmers; hence, input use is very low. The most significant socioeconomic

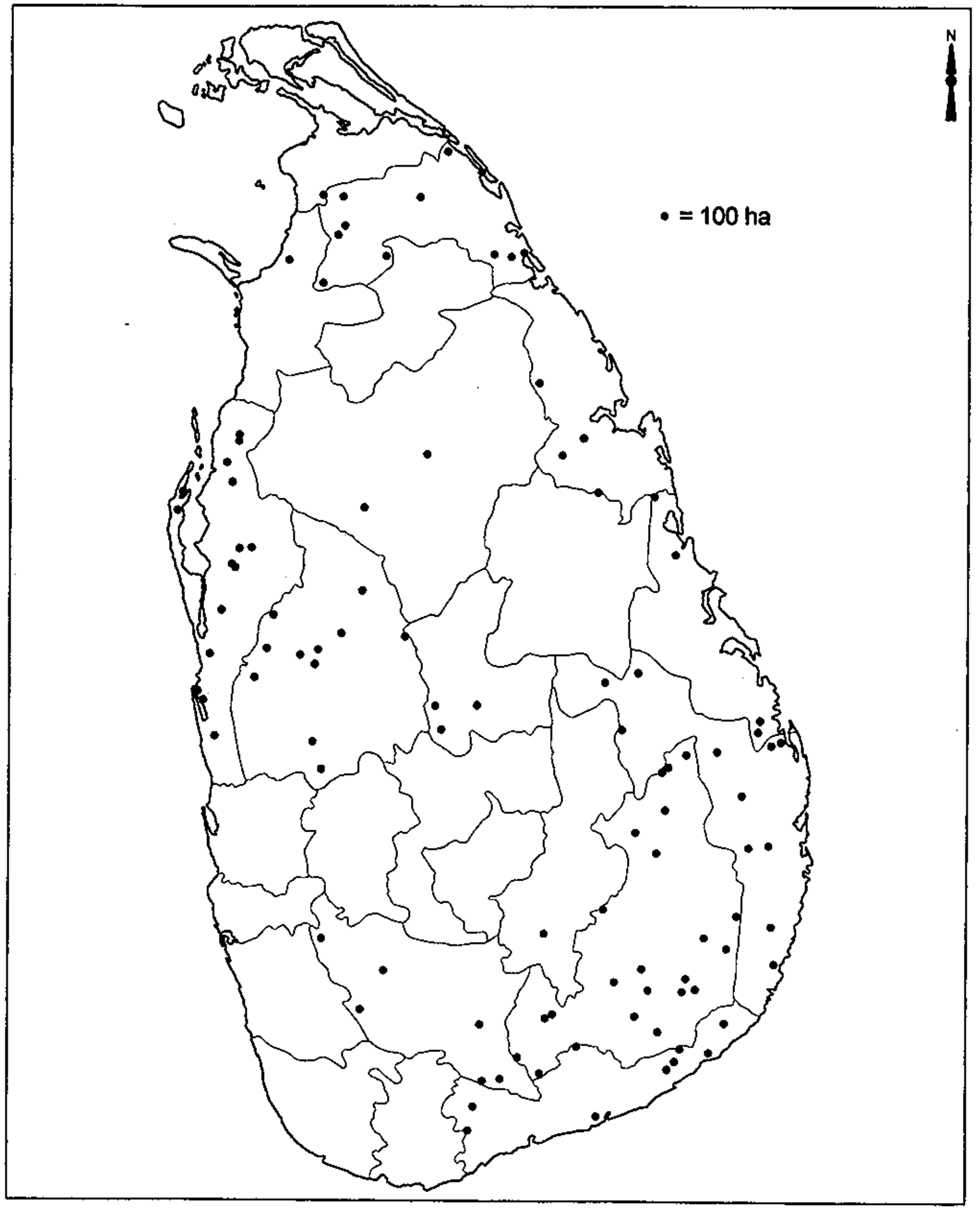

Figure 7.13. Distribution of groundnut in Sri Lanka, 1984–97.

constraints are: (1) use of poor quality seeds; (2) poor crop management; (3) lack of value-added products; (4) poor marketing facilities; and (5) high labor wages.

Cowpea

Cowpea is sown during 1st to 2nd week of November in *Maha* season and early April in *Yala* season. Frequent crop losses are reported in cowpea cultivation due to waterlogging during crop establishment and excessive crop growth due to heavy rains during flowering and podding stages. Collar rot is severe during *Maha* season when excess moisture prevails. Powdery mildew and rust also occur on cowpea (Table 7.1). During the pod setting stage, pod borer poses serious threat to cowpea. Another production constraint is inadequate soil moisture during *Yala* season. Poverty, low and fluctuating price for produce, and low profits from the crop are the most pronounced socioeconomic constraints in cowpea cultivation.

Soybean

Soybean is sown in mid-October to mid-November in *Maha* season and in mid-April to mid-May in *Yala* season. Sowing has to be done early enough to provide adequate moisture for crop growth but heavy rains that are likely to affect germination should be avoided. Excess soil moisture at establishment stage and moisture stress at flowering and pod filling stage cause yield reduction of the crop. Waterlogging during germination and pod formation is not favorable for soybean. Acid soils are not suitable. High temperatures cause seed deterioration, loss of viability, and seed coat cracking. Upland rainfed lands are not plowed generally for soybean cultivation, but when cultivated in rice fallows during *Yala* season the land is tine-tilled. Purple seed stain, bacterial pustule, bud blight, and yellow mosaic are major diseases (Table 7.1). Beanfly, leaf eating caterpillars, and pod sucking insects are major pests (Table 7.1). Inadequate weed controlling practices lead to reduction in yield. Other production constraints are: (1) loss of seed viability during storage under ambient conditions; (2) moisture stress during flowering and pod filling stage; and (3) non-application of fertilizer. However, excess nitrogen reduces nodule development and seed viability. Important socioeconomic constraints are: (1) lack of capital; (2) low price; (3) marketing, storage, and processing problems; and (4) non- availability of good quality seeds.

Table 7.1. Major diseases and pests of grain legumes in Sri Lanka.

Crop	Disease (Pathogen)	Pest
Mung bean	Yellow mosaic (mung bean yellow mosaic virus)	Pod borer (*Helicoverpa armigera* Hübner)
	Cercospora leaf spot (*Cercospora cruenta* Sacc.)	Bruchids (*Callosobruchus chinensis* L.)
	Rust (*Uromyces appendiculatus* Link)	
	Powdery mildew (*Erysiphe polygoni* DC., *Oidium* sp)	
Cowpea	Collar rot (*Sclerotium rolfsii* Sacc.)	Pod borer (*Helicoverpa armigera* Hübner)
	Powdery mildew (*Erysiphe polygoni* DC., *Oidium* sp)	
	Rust (*Uromyces appendiculatus* Link)	
Soybean	Purple seed stain (*Cercospora kikuchii* Matsu. & Tomoyasu)	Beanfly (*Ophiomyia phaseoli* Tryo.)
	Bacterial pustule (*Xanthomonas campestris* pv *glycines* (Nakano) Dye)	Hairy caterpillars (*Amsacta albistriga* Walk., *Spilosoma* sp)
	Yellow mosaic (mung bean yellow mosaic virus)	Other caterpillars (*Spodoptera litura* F.), *Helicoverpa armigera* Hübner)
	Bud blight (tobocco ring spot virus)	Aphids (*Aphis craccivora* Koch)
		Jassids (*Empoasca* sp)
		Pod-sucking bug (*Nezara viridula* L.)
Black gram	Cercospora leaf spot (*Cercospora cruenta* Sacc.)	Pod borers (*Spodoptera litura* F., *Helicoverpa armigera* Hübner)
	Yellow mosaic (mung bean yellow mosaic virus)	Bruchids (*Callosobruchus chinensis* L.)
	Rust (*Uromyces* sp)	Beanfly (*Ophiomyia phaseoli* Tryo.)
	Powdery mildew (*Erysiphe polygoni* DC., *Oidium* sp)	
Groundnut	Bud necrosis (bud necrosis virus)	Hairy caterpillars (*Amsacta albistriga* Walk., *Spilosoma* sp)
	Late leaf spot (*Phaeoisariopsis personata* (Berk. & Curtis) v. Arx)	Other caterpillars (*Helicoverpa armigera* Hübner, *Spodoptera litura* F.)
	Rust (*Puccinia arachidis* Speg.)	Jassids (*Empoasca* sp)
		Aphids (*Aphis craccivora* Koch)
Pigeonpea		Pod borers (*Maruca vitrata* Gey., *Helicoverpa armigera* Hübner)
		Pod fly (*Melanagromyza obtusa* Mall.)
		Bruchids (*Callosobruchus chinensis* L.)
		Pod-sucking bugs (*Nezara viridula* L., *Clavigralla* sp)

Black Gram

Black gram is sown in latter part of October or early November in *Maha* season and early April with first rains in *Yala* season. Moisture stress and low soil fertility cause poor growth and low yield. The crop is capable of competing effectively with weeds. Yellow mosaic, cercospora leaf spot, rust, and powdery mildew are the major diseases (Table 7.1). Pod borers and beanfly damage the crop while bruchids cause losses in storage (Table 7.1). The most critical socioeconomic issues are: (1) use of poor quality seeds; (2) poor crop management; and (3) poor marketing facilities.

Groundnut

Groundnut yield is reduced mainly due to moisture stress and low soil fertility. Bud necrosis, late leaf spot, and rust are important diseases of groundnut (Table 7.1). Hairy caterpillar, pod borer, and jassids (leafhoppers) are the major pests (Table 7.1). Proper postharvest practices are not adopted; therefore, seed quality is affected. Another production constraint is non-availability of quality seeds. The most important socioeconomic constraints are: (1) use of poor quality seeds; (2) poor crop management; and (3) high labor wages.

Pigeonpea

There have been several attempts to promote pigeonpea production in Sri Lanka. These attempts were unsuccessful due to insect menace and practical difficulties in managing them at field level and non-availability of suitable processing techniques. However, during 1990–95, a concerted effort was made to overcome these constraints and it was demonstrated that pigeonpea can be grown successfully in Sri Lanka. A new processing machine was developed to prepare dhal (Joseph and Saxena 1996).

Competition from weeds at an early stage is a constraint. The major pests are *Maruca* and *Helicoverpa* pod borers, and pod fly. Bruchids cause considerable damage in storage (Table 7.1). Non-availability of quality seed for sowing, inadequate extension, low prices, and lack of market-processing and consumer channel are socioeconomic constraints.

Role of Legumes in Rice-based Cropping Systems and Prospects for Increased Production

Rice being the staple food, its cultivation continues to play a vital role in Sri Lankan economy. Despite all efforts to intensify rice cultivation, farmers are compelled to keep rice lands fallow due to two main reasons: (1) inadequacy of water; and (2) less profit from rice cultivation. At present, about 50% of the rice fields are not cultivated during *Yala* season. The situation is worse in minor tank-irrigated rice-based cropping systems where more than 60% of the rice fields are left fallow during *Yala* season.

The potential extent of rice land which can be utilized for legume cultivation is given in Table 7.2. This shows ample opportunities to promote legumes in rice-based minor tank-irrigated cropping systems especially in Uva, North Central, North Western, Northern, and Eastern provinces of Sri Lanka. It is clear that annually about 150,000 ha can be utilized for legume cultivation. However, this land has a competing demand for use in production of other crops such as chili (*Capsicum annuum* L.), onion (*Allium cepa* L.), and maize (*Zea mays* L.). At present, about 63,000 ha are cropped with legumes and largest extent is reported from Kurunegala, Moneragala, and Anuradhapura districts (Table 7.3).

Evidence can be traced from past records to confirm that the above anticipated opportunities are realistic. Favorable cultivation conditions, ready markets, and farmer preferences may have been the reasons for this particular trend.

Table 7.2. Potential areas for legumes in minor tank-irrigated rice-based cropping systems in Sri Lanka.

		Potential area (ha)	
Province	Irrigated area (ha)	*Maha* season	*Yala* season
Western	6,692	340	1,680
Southern	11,980	2,990	4,490
Uva	14,678	4,405	10,275
Sabaragamuwa	12,095	3,055	7,320
Central	21,770	3,340	9,630
North Western	45,826	13,750	31,070
North Central	45,401	15,775	20,430
Northern & Eastern	29,193	10,080	13,200
Total	187,935	53,735	98,095

Source: Jayawardena et al. (1991).

Table 7.3. Successful adoption of legumes in rice-based cropping systems in districts of Sri Lanka.

Legume	Districts
Mung bean	Kurunegala, Moneragala, Hambantota, Puttalam, Ratnapura
Cowpea	Kurunegala, Puttalam, Anuradhapura, Moneragala, Hambantota
Soybean	Anuradhapura, Matale (Kalawewa)
Black gram	Vavuniya, Anuradhapura, Mullaittivu, Kurunegala, Puttalam
Groundnut	Moneragala, Puttalam, Mullaittivu, Ampara, Kurunegala

In general, legumes are grown where length of the growing season is below 300 days, and even where a shorter growing season of 120 days prevails (Fig. 7.5). DL1 and DL2 regions (Fig. 7.6) provide length of growing season of 180–210 days and appear to be most appropriate for legumes cultivation. Some climatic data for this region are shown in Figure 7.14 extracted from a representative meteorological station (Maha Illuppallama). In DL3 region (e.g., Puttalam) rainfall is relatively low in latter part of *Maha* season although the evaporation is somewhat similar (Fig. 7.14). Fluctuation of air temperature is lower in Puttalam compared to that in Maha Illuppallama. DL5 region (e.g., Hambantota), where length of the growing season is below 180 days, is not favorable for legume cultivation as rainfall is relatively low, and evaporation is high (Fig. 7.14). Exception to above interpretation can be observed in Kurunegala district which extends to IL1 and IL3 regions where length of the growing season is 210–300 days.

Pigeonpea, unlike other legumes, has an exceptional role in rice fields. It has an extensive root system. Taproots penetrate through hard plow pan or gravel layers, and facilitate moisture and nutrient uptake. Therefore, pigeonpea has the ability to adapt to a range of soil types and agroclimatic zones. On-farm trials have demonstrated that pigeonpea cultivation is profitable in rice fallow areas without irrigation. Although statistics show less importance of pigeonpea as a legume in Sri Lanka, its potential cannot be underestimated. Recent research has adequately addressed the problem of *Maruca* pod borer through identification of *Maruca* tolerant lines which exhibit a considerable level of compensation and produce reasonable yield levels. The technology adopted from India for processing grain into dhal has been improved in Sri Lanka and transferred to private sector. Adequate arrangements have been made to catalyze marketing and local consumption of pigeonpea dhal within different ethnic groups. As pigeonpea has the ability to survive and produce reasonable yields under limited moisture conditions it has good potential in rice-based cropping systems as an alternative crop.

Four broad categories of rice-based cropping situations have been identified (Wijayaratna 1994). These provide opportunities for legume cultivation.

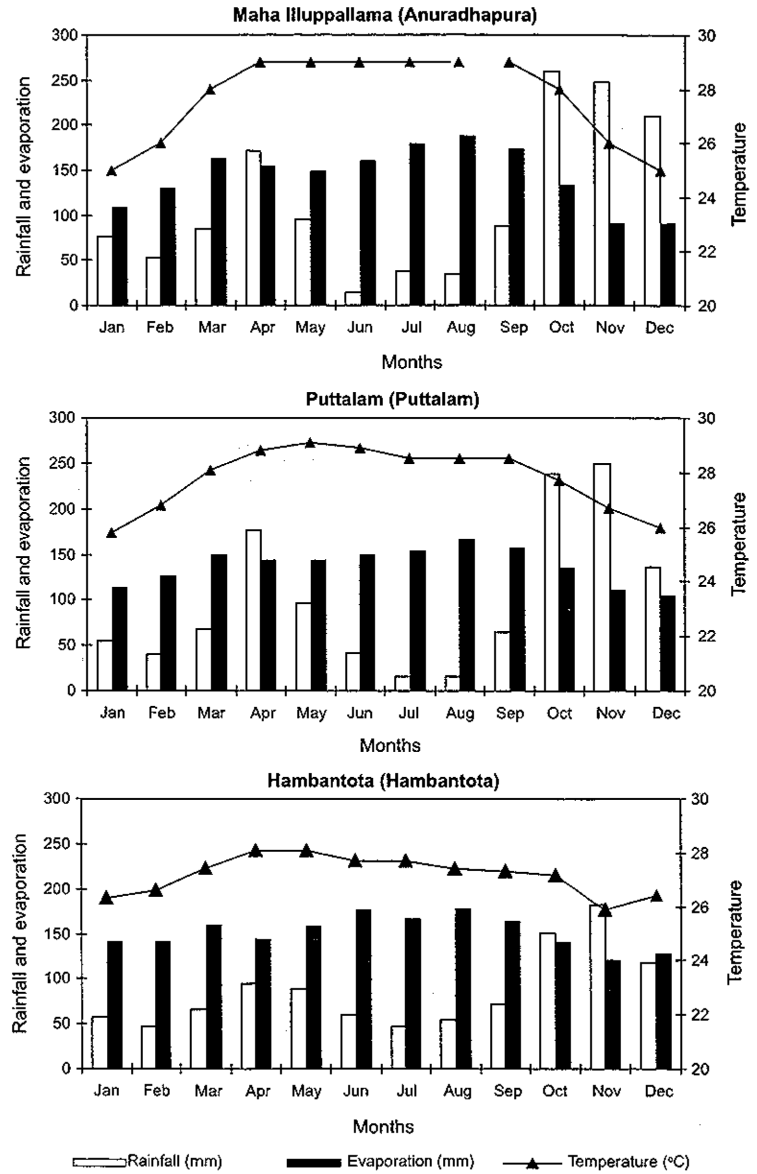

Figure 7.14. Average climate data at representative locations in Sri Lanka, 1961–90.

1. Major irrigation schemes with adequate supply of water for both *Yala* and *Maha* seasons.
2. Major irrigation schemes with adequate supply of water for *Maha* season but inadequate for *Yala* season.
3. Medium irrigation schemes with moderately stable water supply for *Maha* season only.
4. Minor irrigation schemes with an unstable water supply.

Legumes may be cultivated in these areas, depending on availability of water for rice cultivation.

National Policies and EmphasisTowards Legume Production

Diversification should be considered as an important national policy in order to increase the productivity in low productive areas. The potential for diversification of rice-based cropping systems in Sri Lanka has been previously discussed. While increasing the extent of legume cultivation through crop diversification, the following policies need to be pursued:

- Promote processing industries to increase per capita consumption.
- Impose import restriction on all legumes, including lentils (*Lens culinaris* Medic.), to encourage local production.
- Improve marketing facilities in major producing areas.
- Encourage contract growing programs to satisfy requirements of processing industry.
- Increase access to credit facilities and initiate crop insurance schemes to avoid farming risk.
- Develop appropriate farming, processing, and storage technologies and storage facilities to suit small-scale producers.
- Disseminate technology through an effective extension mechanism and train farmers to produce high quality seeds.

However, there is risk involved in legume cultivation compared to rice and cash crops. High cost of production, low price levels, and poor marketing arrangements are the major factors causing the economic risk. Land fragmentation, competition among rainfed upland crops and lowland rice cultivation, and farmers' traditions and customs related to rice cultivation are dominant socioeconomic factors affecting legume cultivation in rice lands. There are no institutional arrangements to provide inputs such as seed, fertilizer, chemicals, and machinery in time for legume cultivation. This can be considered as the major issue in promoting legume cultivation in rice-based cropping systems in Sri Lanka.

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8. Legumes in Rice-based Cropping Systems in Thailand: Constraints and Opportunities

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Abstract

Rice is one of the major foreign exchange earners of Thailand and is grown on about 11 million ha. Much of this rice area (70% area) is rainfed dryland with an average yield of 1.8 t ha^{-1}. About 7.5% of the rice area is irrigated and has average yield of 4 t ha^{-1}. Rainfed lowland in river deltas is an important rice area with an average yield of 2.5 t ha^{-1}. The average yield of rice in different environments is perceived to be declining and requires greater inputs than before, due to environmental stresses. The threat is supported by the declining yield trends in the long-term trials despite use of best available cultivars and management practices.

Lowland rainfed rice offers more opportunities for diversification than that in other areas. Growing rice after or before a non-cereal crop has been a common practice. Pre-rice mung bean performed better than post-rice crop, perhaps due to factors that adversely affect native rhizobia during rice cultivation. Post-rice crops (soybean, mung bean, groundnut, and sesame) grown on residual moisture benefit significantly if duration of the rice crop is short. The need for diversification is also felt due to increased incidence of diseases, insect pests, and weeds because of continuous rice monoculture. Legumes do not compete well with rice and other crops due to low yield but other observed benefits of legumes to subsequent crops and improved soil quality should draw the attention of all concerned, particularly of policy makers to evolve strategies to encourage use of legumes for crop diversification.

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Introduction

Total land area of Thailand is 51.3 million ha. Forest occupies 13.4 million ha, and agricultural land covers 21 million ha; unclassified lands covering 17 million ha swamp lands are used for industrial uses, rail, roads, and other infrastructure. Distribution and utilization of the farmland can be classified as: 2.65% housing, 52.06% rice (*Oryza sativa* L.), 24.55% upland crops (field crops), 15.99% horticulture, 1% floriculture, and 1% range lands. Administrative divisions of Thailand are presented in Figure 8.1.

Agriculture in the past was dominated by excessive use of natural resources for various production processes beyond the carrying capacity of natural resources. Lack of concern for sustenance of the natural resource base has resulted in its degradation, affecting the agricultural production and welfare of the farming community in the long run. It is therefore, important to conserve, rehabilitate, and put the natural resources for sustainable use.

Rice Production Environments in Thailand

Rice production environments in Thailand can be grouped into: irrigated, rainfed dryland, rainfed lowland, and deepwater rice areas. Prior to 1970s most of the irrigated areas were in the valleys in northern Thailand. Construction of dams and canals during 1970s and 1980s created irrigation facilities.

Irrigated area in Thailand during 1992 was 719,000 ha accounting for about 7.5% of the total rice area. However, irrigated area contributes 14% of the total rice output with average yield of about 4 t ha^{-1} (Flinn and De Datta 1984), which is the highest among all the production environments.

Rainfed dryland rice covers about 6.7 million ha and accounts for 70% of the rice area and 60% of production with an average yield of 1.8 t ha^{-1} below the national average. The rainfed dryland areas are characterized by long dry periods and short and intense rain. Farmers grow mostly traditional photoperiod-sensitive varieties. Cultivation methods and varieties vary depending on onset of rainy season. This leads to variations in yield across the regions.

Rainfed lowland rice areas are found in the Chao Phya River delta. This environment covers about 1.9 million ha (20% of rice area) with an average yield of 2.5 t ha^{-1}. Deepwater rice or floating rice is grown in flood-prone areas in central and eastern plains in 195,000 ha (about 2% rice area). The average yield is declining over the years due to increased environmental stresses and high labor requirement.

Rice plays three major roles in Thai economy: (1) it covers over 50% of the total cultivable area and engages half the labor force; (2) it is the main

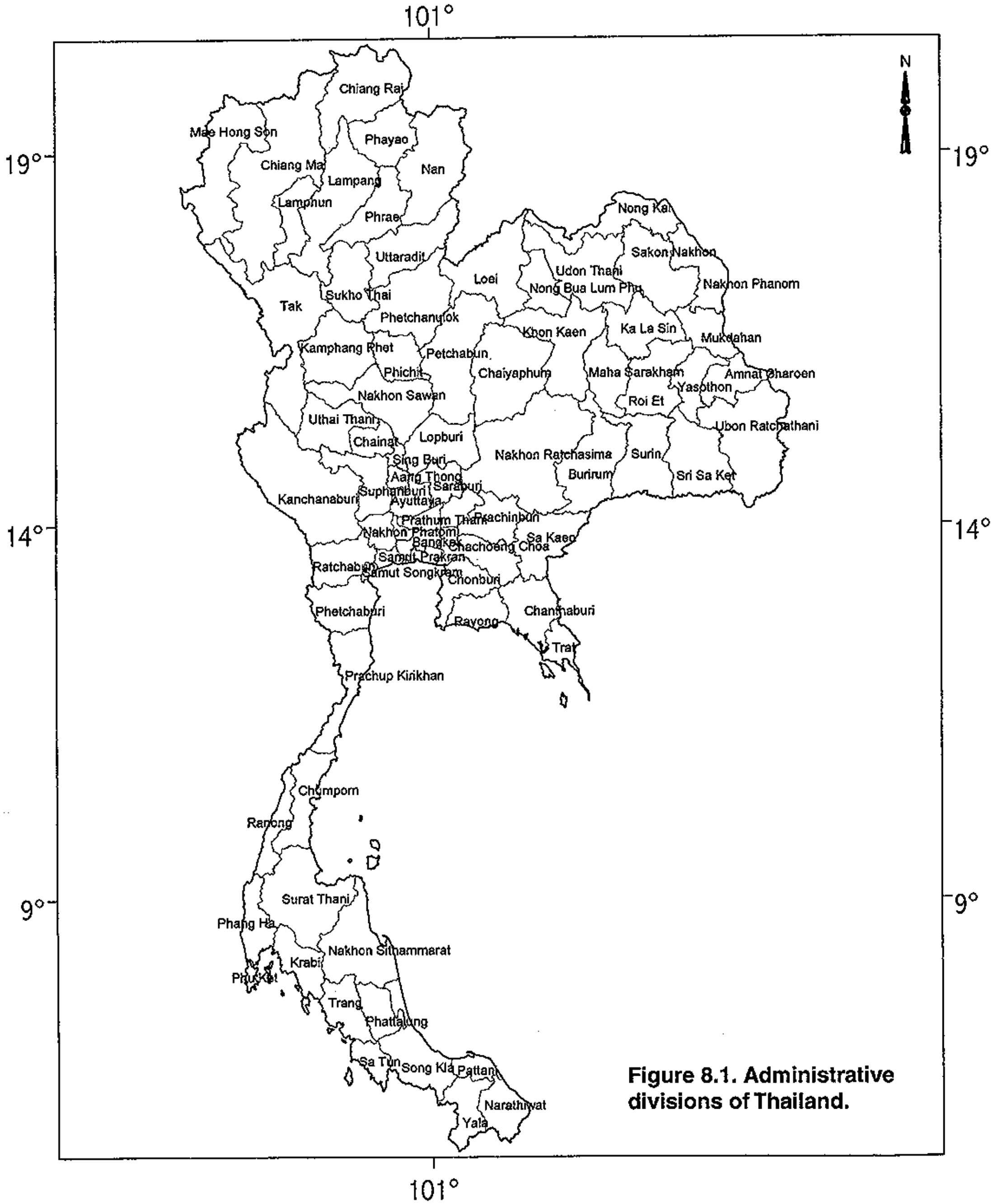

Figure 8.1. Administrative divisions of Thailand.

staple food crop; and (3) it is one of the major foreign exchange earners. However, rice economy is facing some challenges: increased competition in the international market; competition from other sectors resulting in higher labor wages and scarcity; and degradation of ecological conditions resulting in higher production costs.

Intensification Induced Degradation of the Rice Production Systems

The green revolution strategy for increasing food production was based on the intensification of lowlands through massive investments in irrigation infrastructure. It was presumed that the lowlands are resilient to intensification pressures and would sustain long term. This strategy was meant to relieve pressure on the fragile uplands and worked exceptionally well for rice production up to mid-1980s (Herdt and Capule 1983, Dalrymple 1986). Since then rice productivity has slowed down in Asia particularly in the intensively cultivated areas (Rosegrant and Pingali 1994). There is increasing evidence that the growth in rice yields has leveled off and there is a danger of future declines in yield growth, especially in the irrigated lowlands of Asia. Intensive rice monoculture itself is the major contributor to the degradation of the natural resource base and declining productivity. The trends from the long-term trials in Thailand also indicated that, even with the best available cultivars and management, yields are declining over long term (Gypmantasiri et al. 1980).

The essential message from the long-term experiments is that under intensive rice monoculture systems, productivity over the long term is difficult to sustain, even with the best scientific management because of stagnant yields and declining trends in total factor productivity as well as in partial factor productivity, especially for fertilizers (Pingali 1994, Cassman and Pingali 1995). The primary leverage point appears to be in the cropping system, a break in the continuous flooded rice cycle with a dry season non-rice crop. In the southern coastal plains of China, a cropping system consisting of two crops of rice followed by a crop of soybean (*Glycine max* (L.) Merr.) or barley (*Hordeum vulgare* L.) practiced over 18 years has maintained a high and stable crop yield (Kundu and Ladha 1995). The choice of crop grown in the dry season determines the level of contribution of the crop rotation.

Intensive rice monoculture system over the long term is not sustainable without adequate changes in the current technologies and management practices (Cassman et al. 1995). Therefore, the focus of research resources ought to shift from a fixation on yield improvements to a holistic approach to the long-term management of the agricultural resource base.

Diversification of Rice-cropping Systems: Constraints and Opportunities

Switching between rice and other crops is possible in uplands because the fields are not bunded and do not require special land preparation for crop establishment. Crop choice is constrained by water availability and drainage during the dry season. The irrigated lowlands have the highest flexibility in choice of upland crop. The period of irrigation water availability is also an important determinant for upland crop diversification. The large partially irrigated areas that support dry season rice crop have a natural advantage in diversifying into upland crops during the dry season.

A major part of Thailand's rice area is grown under lowland rainfed conditions. It is possible to develop rice-based cropping systems program for rainfed lowlands by utilizing existing natural resources and available production inputs. To maximize use of the rainfall, direct seeding of rice or timely sowing of upland crops in early monsoon season shows great promise (Takahashi and Sasiprapa 1976). Legumes or other crops can be grown before or after rice. Mung bean (*Vigna radiata* (L.) Wilczek) sown before rice showed promise over that sown after rice. Factors such as lack of native *Rhizobium* in the soils have to be considered. Nevertheless, early-maturing crops before rice have considerable potential in northeastern Thailand. Grain yields of legumes and oilseed crops [e.g., sesame (*Sesamum indicum* L.)] after rice would be low if moisture is insufficient. Germination will be poor if sowing is delayed. Proper selection of the second crop and its sowing date needs further research. Sequential rice-based cropping systems have good prospects of success in northeastern Thailand. Relay cropping should be aimed for effective use of residual moisture.

Opportunities for diversification in rainfed lowlands and deepwater areas are limited by water availability for post-rice crop production. However, rainfall and distribution are such that a post-rice or pre-rice crop in the rainfed lowlands is possible. Post-rice cropping of legumes (e.g., mung bean) and oilseeds [e.g., groundnut (*Arachis hypogaea* L.)] can take advantage of late season rains or residual moisture, in areas that grow early-maturing rice cultivars. In the rainfed lowlands of northeastern Thailand, upland crops would not be possible even if traditional rice varieties were replaced by appropriate short-duration modern varieties, due to lack of soil moisture. However, there is potential for a short-duration pre-rice crop followed by a short-duration rice crop. Suitable crops are mung bean and green manure crops such as *Sesbania* and forage legumes.

Role of Legumes and Oilseeds in Rice-based Cropping Systems

Rice is the staple food in Thailand. Therefore, maintaining rice production is the key to improving food security. At the same time, increased production of high-protein non-rice food crops such as legumes and oilseeds are also important for reducing malnutrition.

Legumes (classified as field crops in Thailand) significantly contribute to the dietary needs of the people and possess considerable potential for export besides restoring the soil fertility. Legumes are mainly grown during dry period (both pre-monsoon and post-monsoon seasons) in Thailand. The main legumes are soybean, black gram (*Vigna mungo* (L.) Hepper), mung bean, and groundnut. Legumes are second most important crops grown in rotation with rice after vegetables.

Although, rice-legumes is a traditional cropping system in Thailand, introduction of short-duration rice cultivars and commercial crops [maize (*Zea mays* L.), vegetables, fruits, and flowers] has relegated legumes to more marginal fields. However, rise in cost and unavailability of fertilizers, coupled with high labor costs have limited the potential of rice monocropping systems in Thailand. Besides, the increasing concerns of deterioration of soil health and increased incidence of diseases and insects [brown planthopper (*Nilaparvata lugens*) in rice] and weeds resulting in decline in rice yields has opened up new opportunities for legumes in rice-based cropping systems. However, yield levels of legumes are low and cannot compete with other crops unless market prices are favorable and their indirect benefits on soil fertility and environment are considered.

Legumes in rotation with rice not only improve their productivity but also economize nitrogen use. Research conducted in rice-growing areas showed that rice-rice cropping resulted in low rice yields over the years. Farmers need to invest more on fertilizer to maintain rice yields. Mung bean-rice cropping system can increase rice yield by 13.5%. Legume crop residue is used as green manure for rice; about 300 kg ha^{-1} mung bean residue can be plowed in. Legume green manure increases absorption of soil moisture, soil porosity, activity of soil microorganism, and soil organic matter (Thavornmat and Phanpruk 1994). All these factors have direct effect on rice yield. Research on growing short-duration legume crop (soybean, mung bean) before rice in rainfed areas of Suphanburi and Phetchaburi provinces indicated that the mung bean-rice cropping system is highly accepted by farmers. The soybean-rice cropping system also gave high yields and economic returns.

Agroclimatic Features

The agroecological characters of Thailand, viz., rainfall, temperature, evapotranspiration, and sunshine hours are provided in Figures 8.2 to 8.5. The agroecological zones are classified based on rainfall, soil type, and length of growing period (Fig. 8.6). Thailand is located in the tropical monsoon area and the average temperature is not extreme.

Rainfall

Based on intensity and pattern of rainfall, six rainfall zones have been recognized:

R1 - Areas that have sufficient rainfall throughout the year, without a clear drought period. These areas are mostly in the east coast of southern Thailand.

R2 - Areas that have enough moisture in all months, with two peak rainfall periods, mostly located in the west coast of southern Thailand.

R3 - Areas having enough precipitation for crop growth, with two months of dry period. This covers the western part of mountain range in northern Thailand.

R4 - Rainfall in this area is uncertain but is enough for crops, with at least three months of dry period and two rainfall peaks (none in Thailand, currently).

R5 - Rainfall in this area is highly uncertain, with a dry season of at least three months and one rainfall peak. This pattern occurs in upper and lower northeastern Thailand and some parts of lower northern and central Thailand.

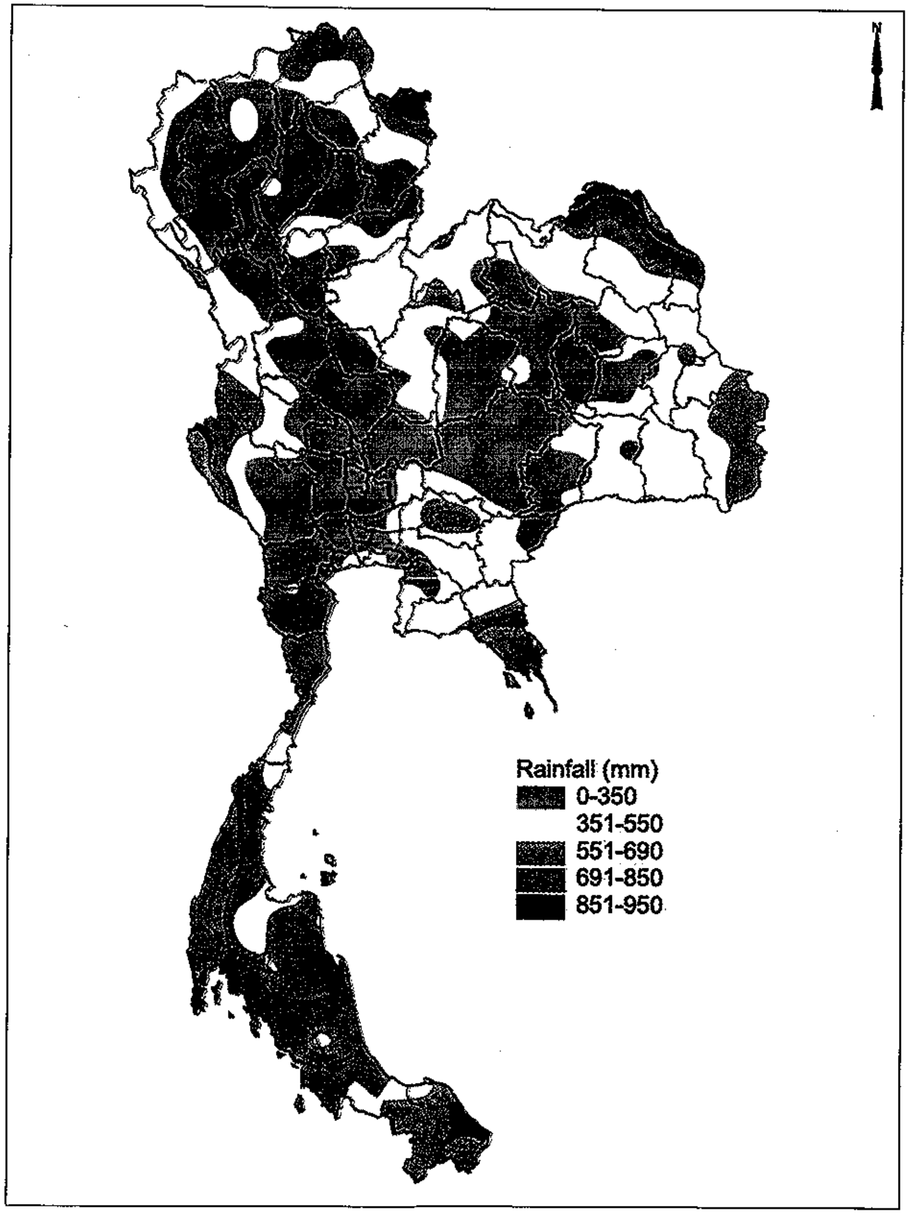

Figure 8.2. Average annual rainfall in Thailand (Source: FAO, Rome, Italy).

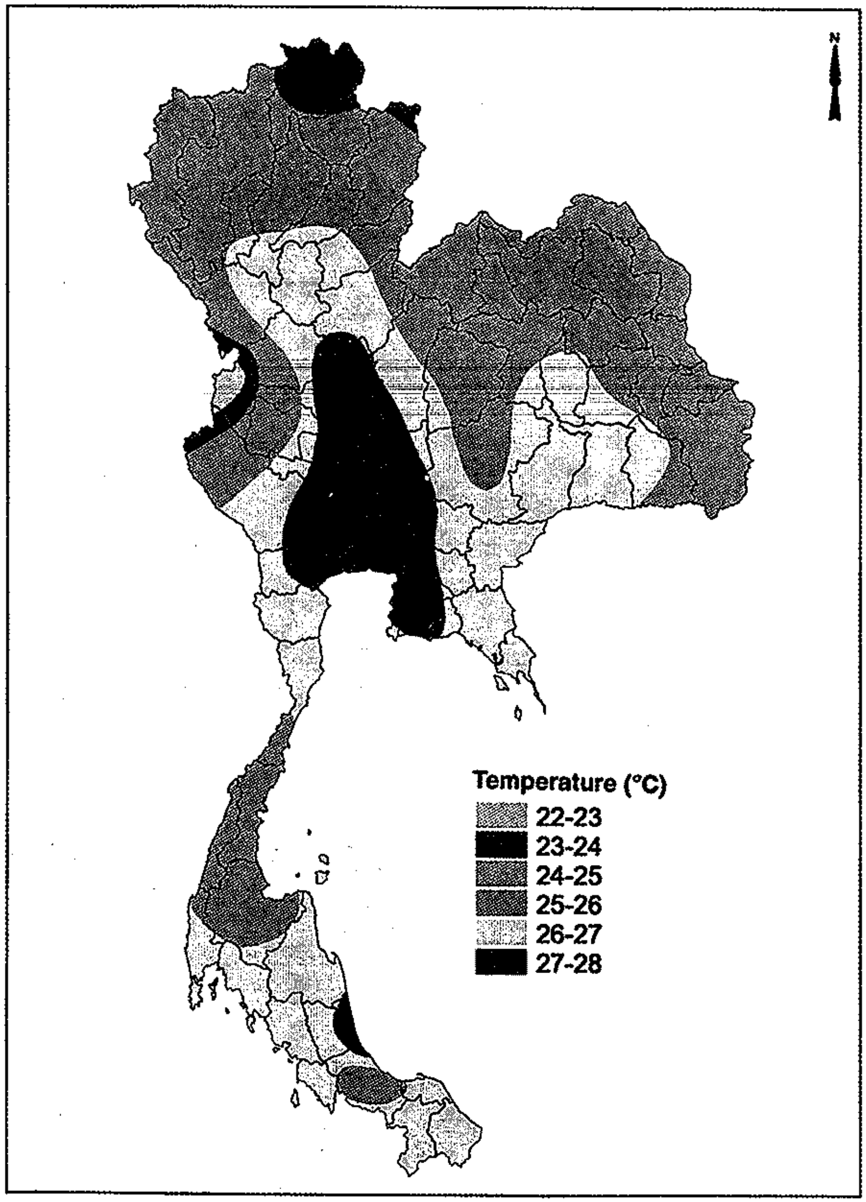

Figure 8.3. Average annual temperature in Thailand (Source: FAO, Rome, Italy).

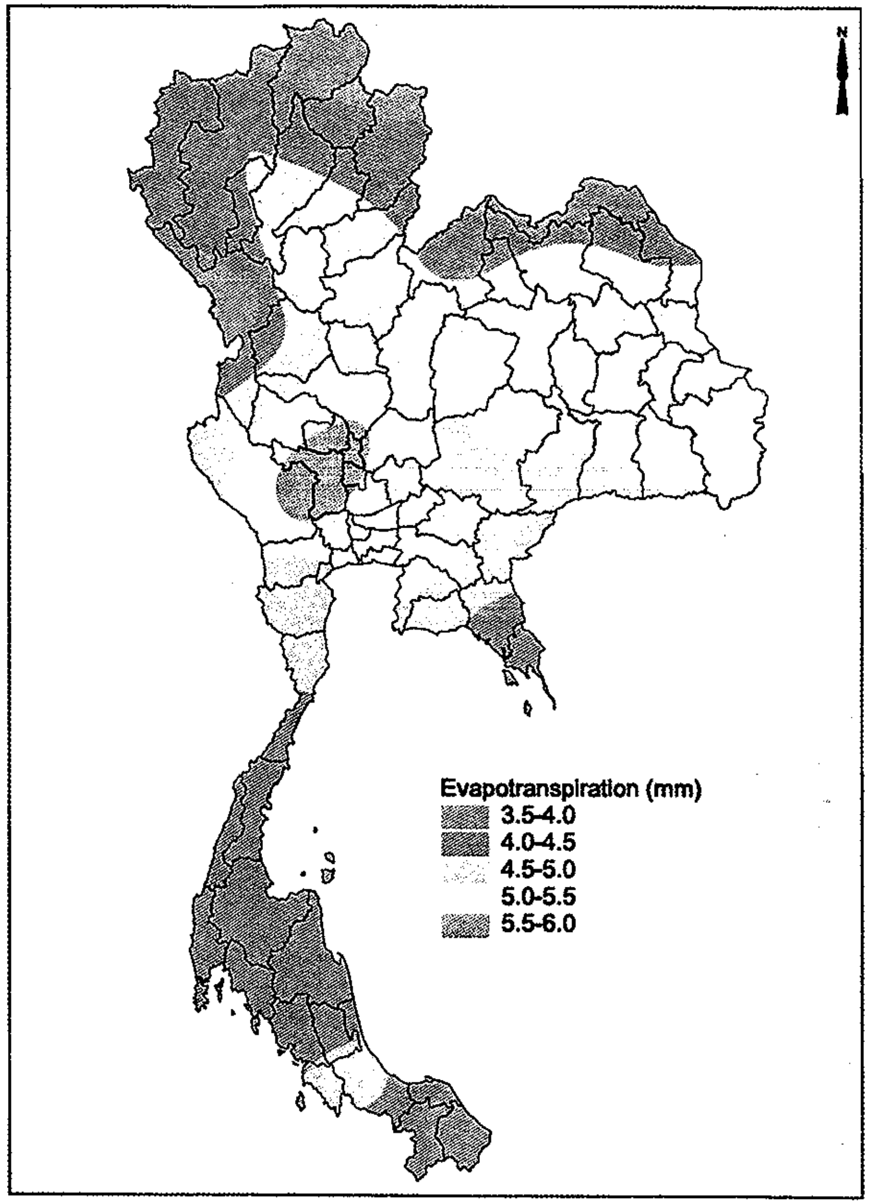

Figure 8.4. Evapotranspiration in Thailand (Source: FAO, Rome, Italy).

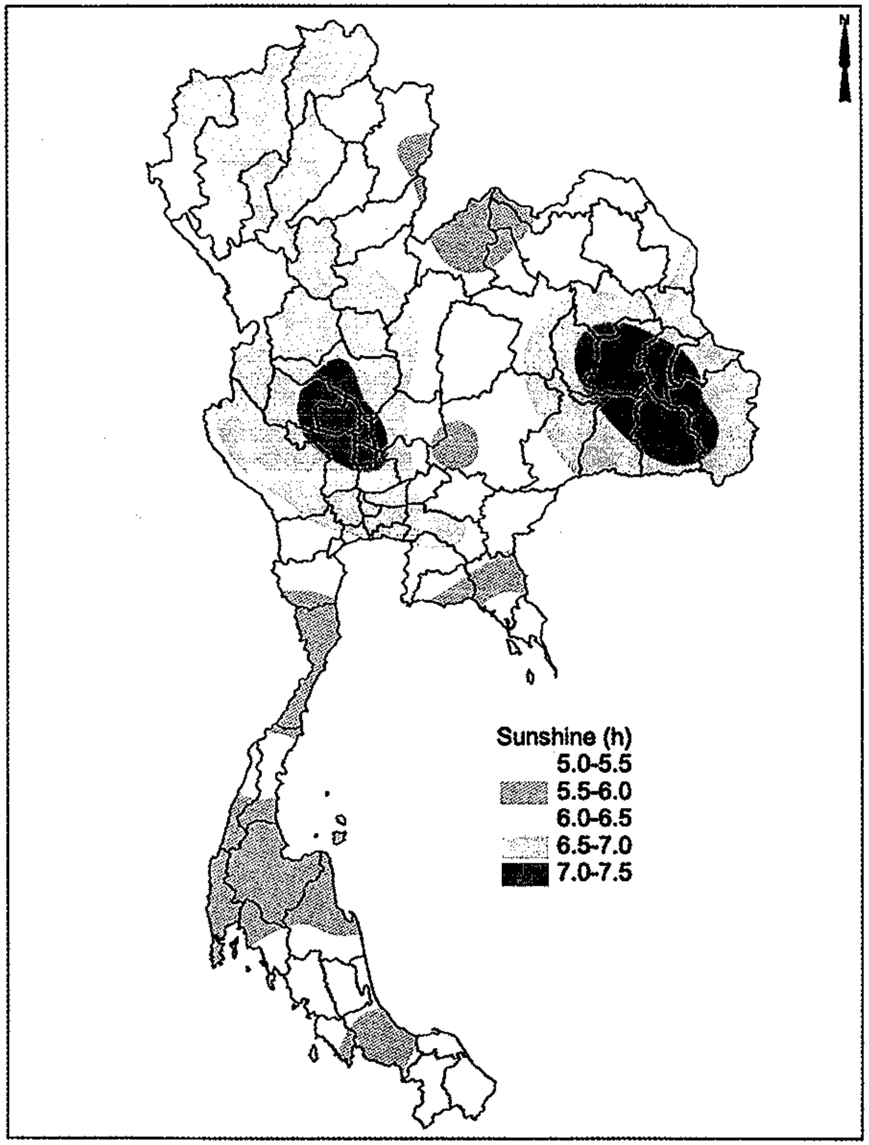

Figure 8.5. Sunshine in Thailand (Source: FAO, Rome, Italy).

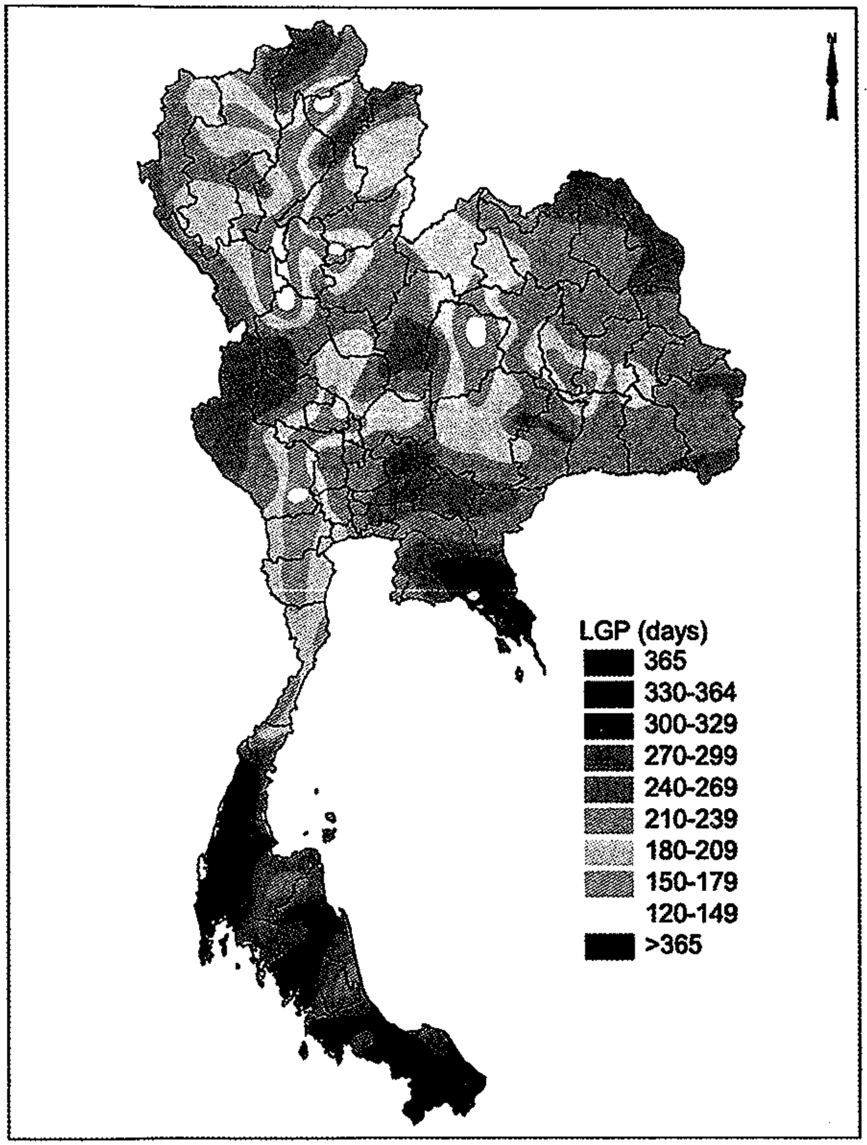

Figure 8.6. Length of growing period (LGP) in Thailand (Source: FAO, Rome, Italy).

R6 - Rainfall in this area is uncertain, with at least three months of dry season. The area covers the rain-shadow areas in western part of northeastern Thailand and the eastern part of Thanounsari range.

Soils

Main soils in Thailand can be divided into three groups (Fig. 8.7):

S1 - Fluvisols, Gleysols, Entisols, sandy loam or clay loam. The topsoil is shallow, lower profile sometimes reported to have hard pan with no clear soil profile. The topography is spread in foothills with moderate and high slope.

S5 - Luvisols + Nitosols = Alfisols. The soils are loamy to sandy loam, color ranging from gray to brown. The lower profile is clay with moderate to strongly alkaline. This type of soil is classified as fertile and covers western to eastern Thailand.

S6 - Acrisols, Ferrasols = Utisols, Oxisols. This type of soil can be further classified into two groups as: (1) the soil is red, yellow, or brown, highly moist, and highly acidic, and the lower profile is clay with high organic matter; and (2) the soil has low organic matter with a combination of aluminium, iron oxide, and clay (1:1) (Kaolin).

Based on rainfall distribution and soil type, 13 agroecological zones have been identified (Fig. 8.8).

Area, Production, and Yield Trends

Mung Bean

Mung bean distribution in Thailand is presented in Figure 8.9. The area and production of mung bean during 1993/94 to 1997/98 have increased slightly due to high local demand (Fig. 8.10). During the past five years, 85% of the produce was consumed locally and its export dropped. Government is making all efforts to reverse the trend.

Black Gram

Black gram is grown mostly in northern and northeastern Thailand (Fig. 8.11). The area and production have decreased by 10% and 5% respectively during the last five years, as farmers have started growing other crops that give higher returns (Fig. 8.10). Local demand for black gram is low and is around 10% of total production. Hence, most of the produce has to be exported.

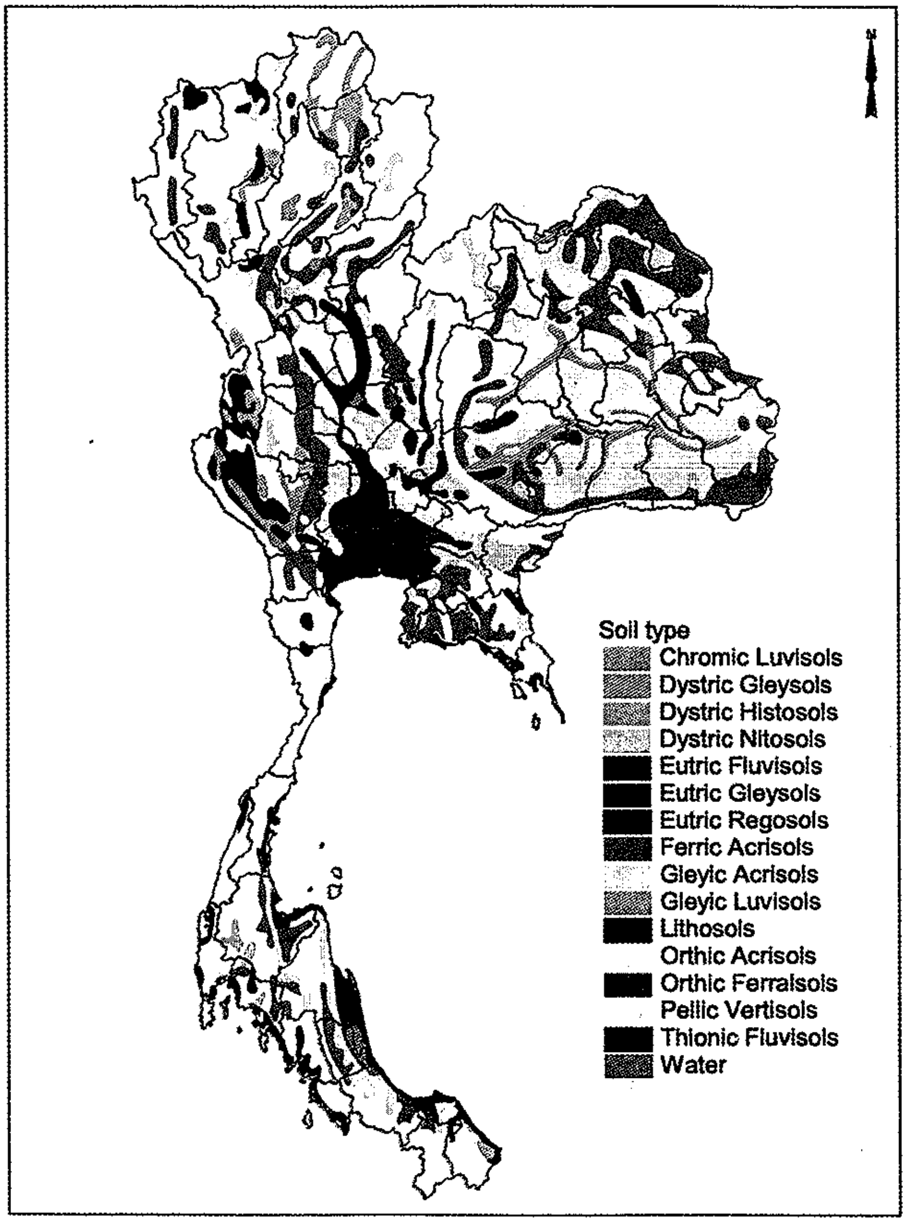

Figure 8.7. Soil distribution in Thailand (Source: FAO, Rome, Italy).

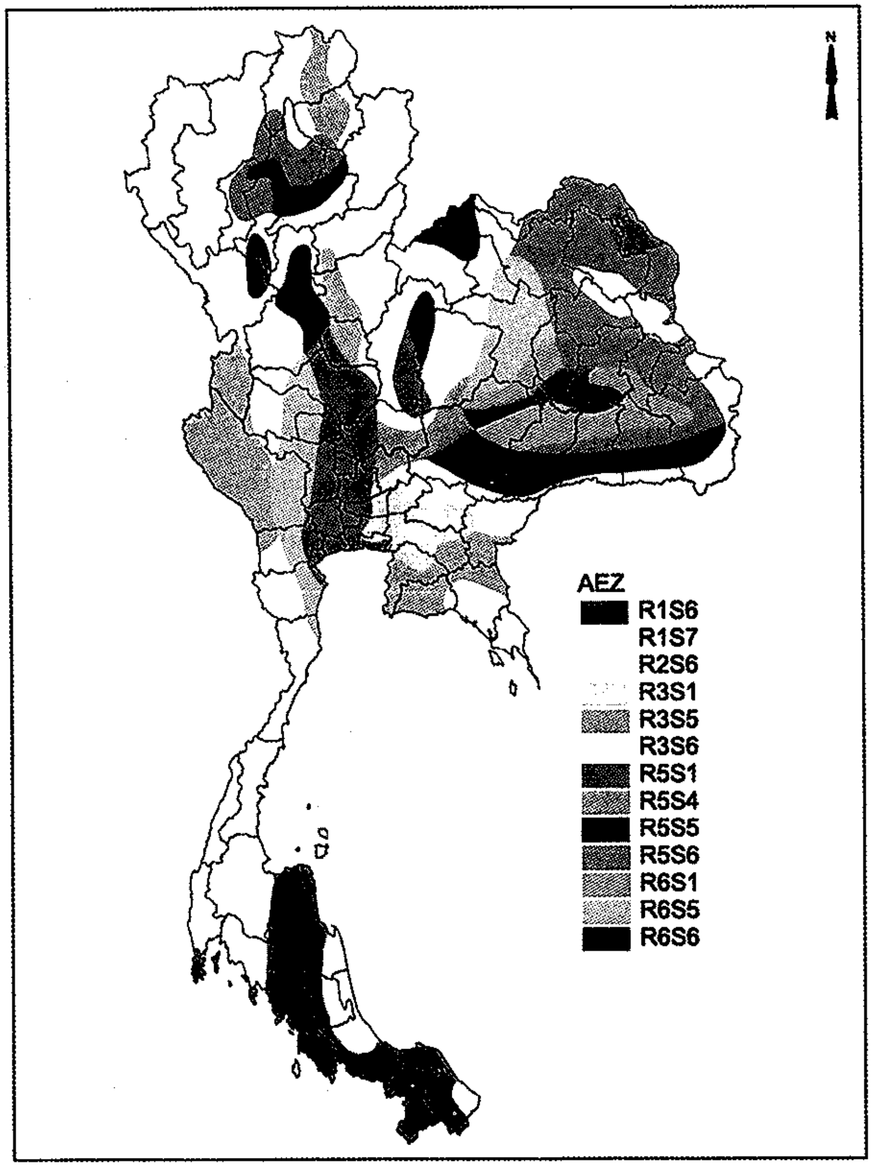

Figure 8.8. Agroecological zones (AEZ) in Thailand (Source: FAO, Rome, Italy).

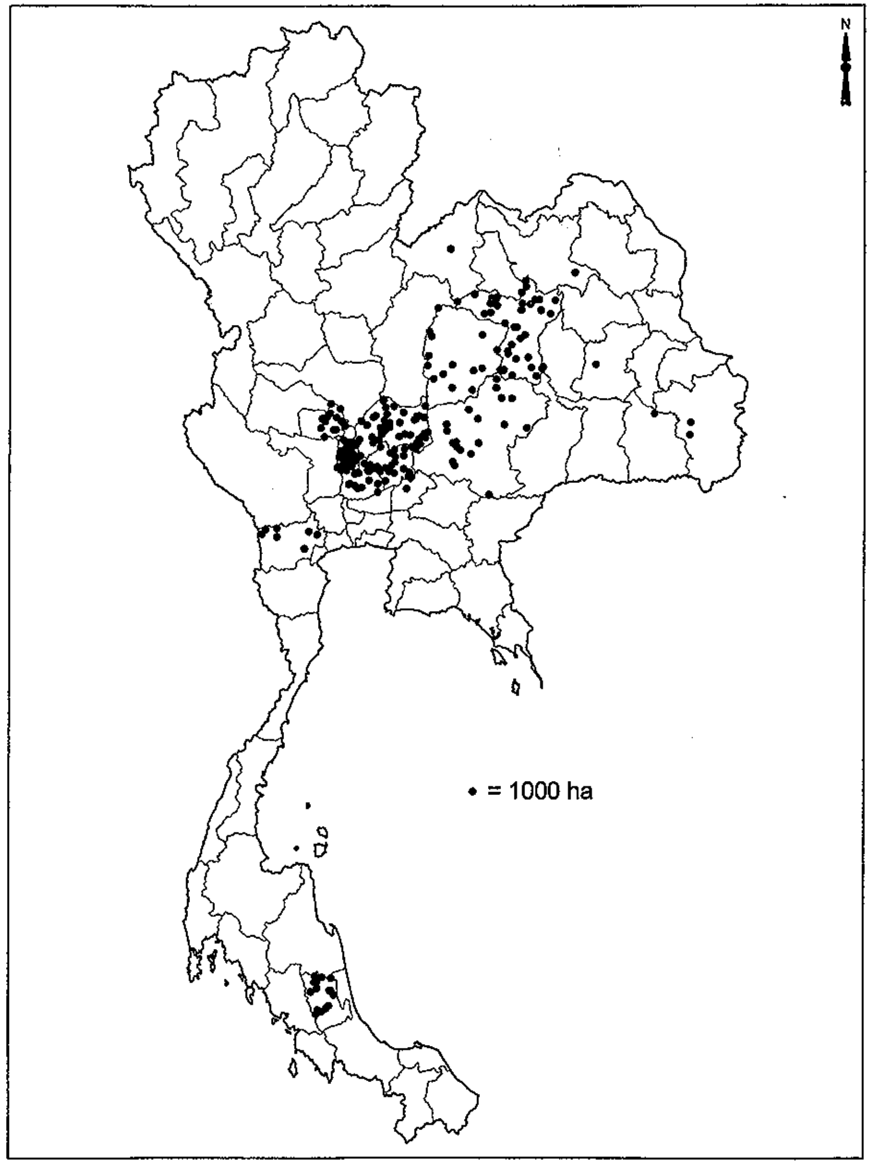

Figure 8.9. Mung bean distribution in Thailand, 1997/98.

Groundnut

Distribution of groundnut in Thailand is presented in Figure 8.12. Ninety percent of groundnut production is used for local consumption as processed food, vegetable oil, and animal feed. Import of groundnut and groundnut products (groundnut oil and animal feed) have shown increasing trend since the production has remained stagnant since 1995 (Fig. 8.10). Stagnation in groundnut production could be attributed to decrease in area, as a result of drought and less profits to farmers.

Soybean

Distribution of soybean area in Thailand is given in Figure 8.13. During 1992/93 to 1997/98, the production declined (Fig. 8.10) while local demand increased.

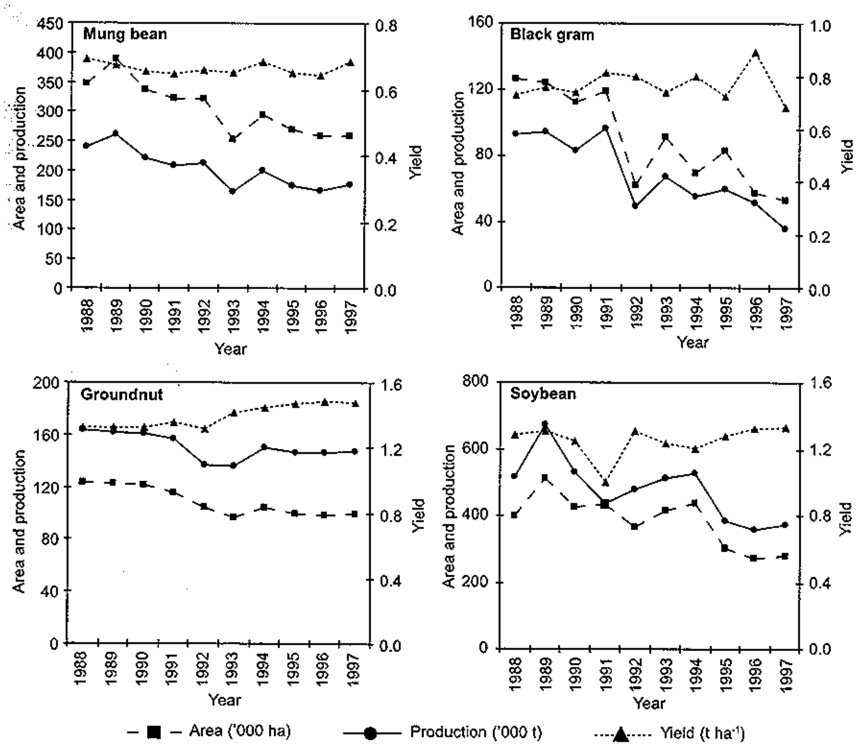

Figure 8.10. Area, production, and yield of legumes in Thailand.

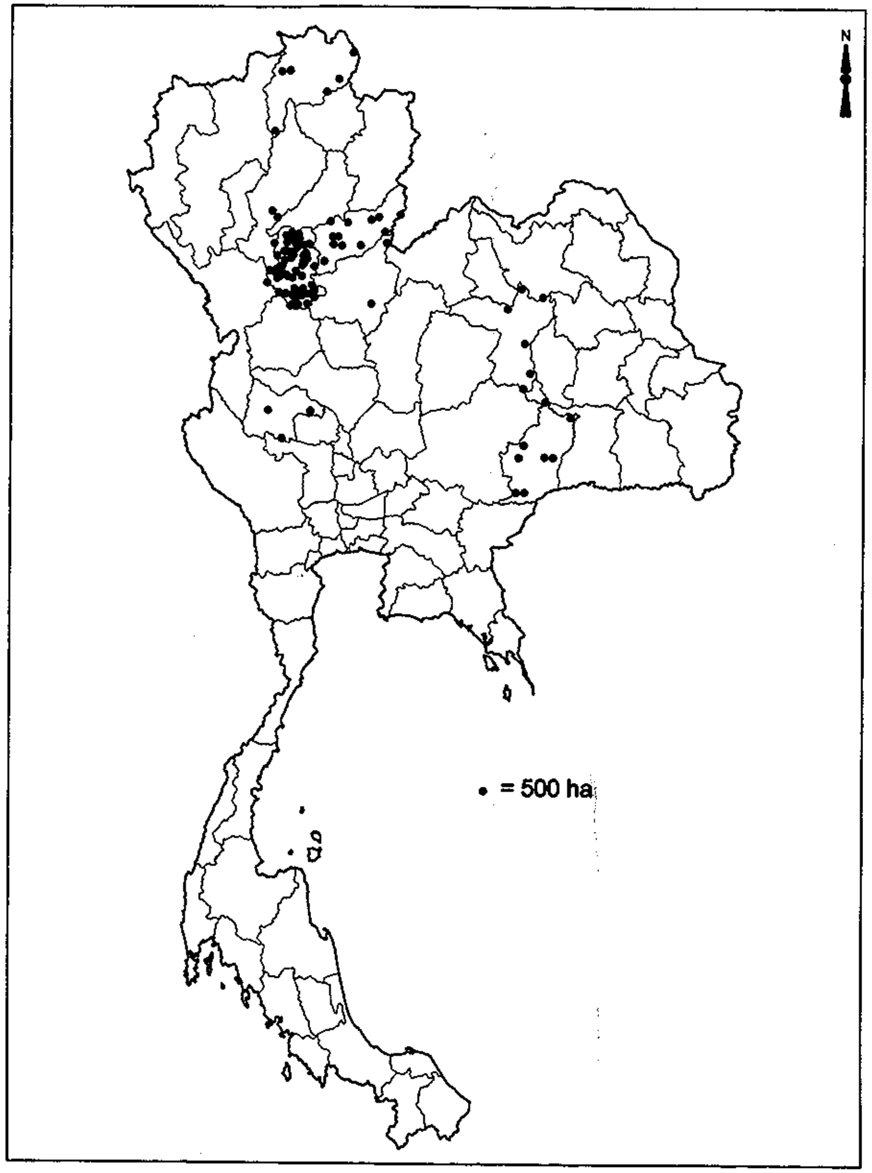

Figure 8.11. Black gram distribution in Thailand, 1997/98.

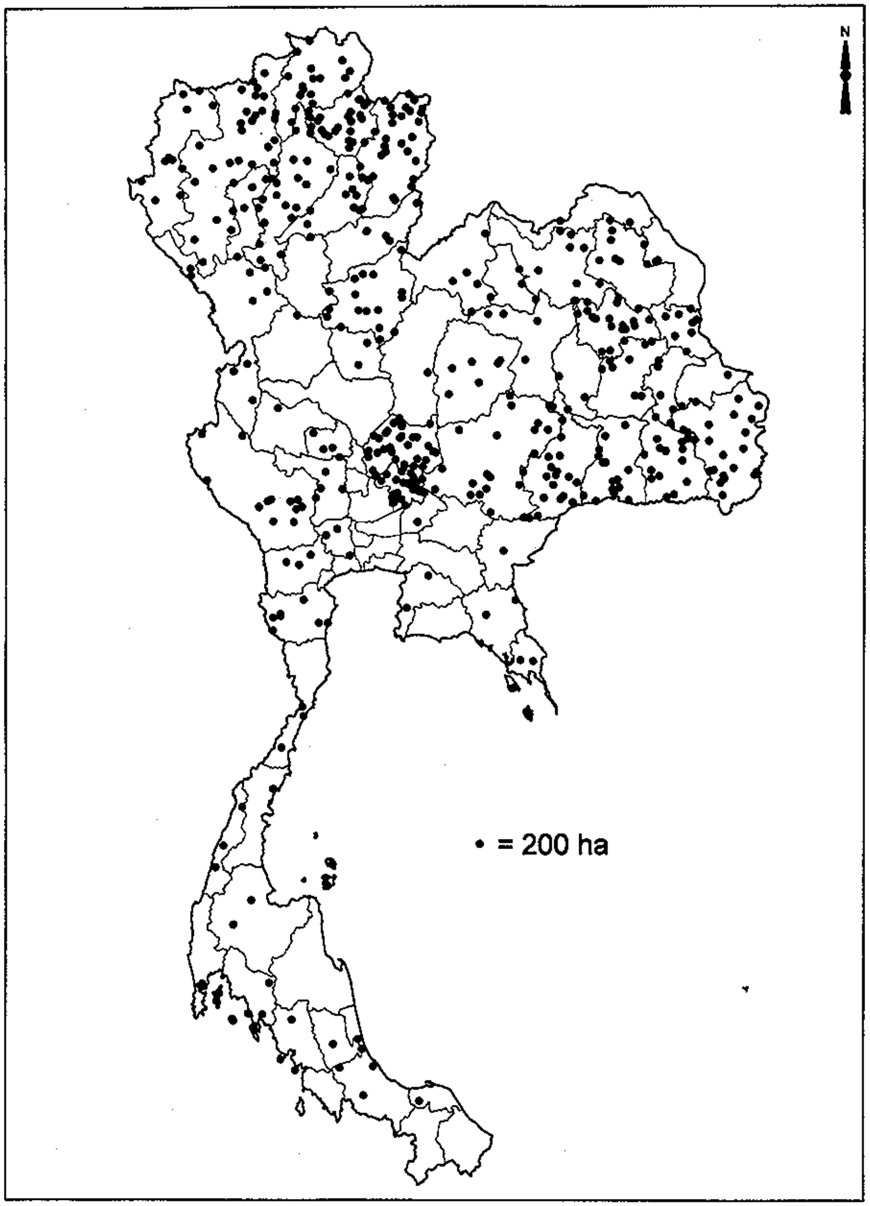

Figure 8.12. Groundnut distribution in Thailand, 1997/98.

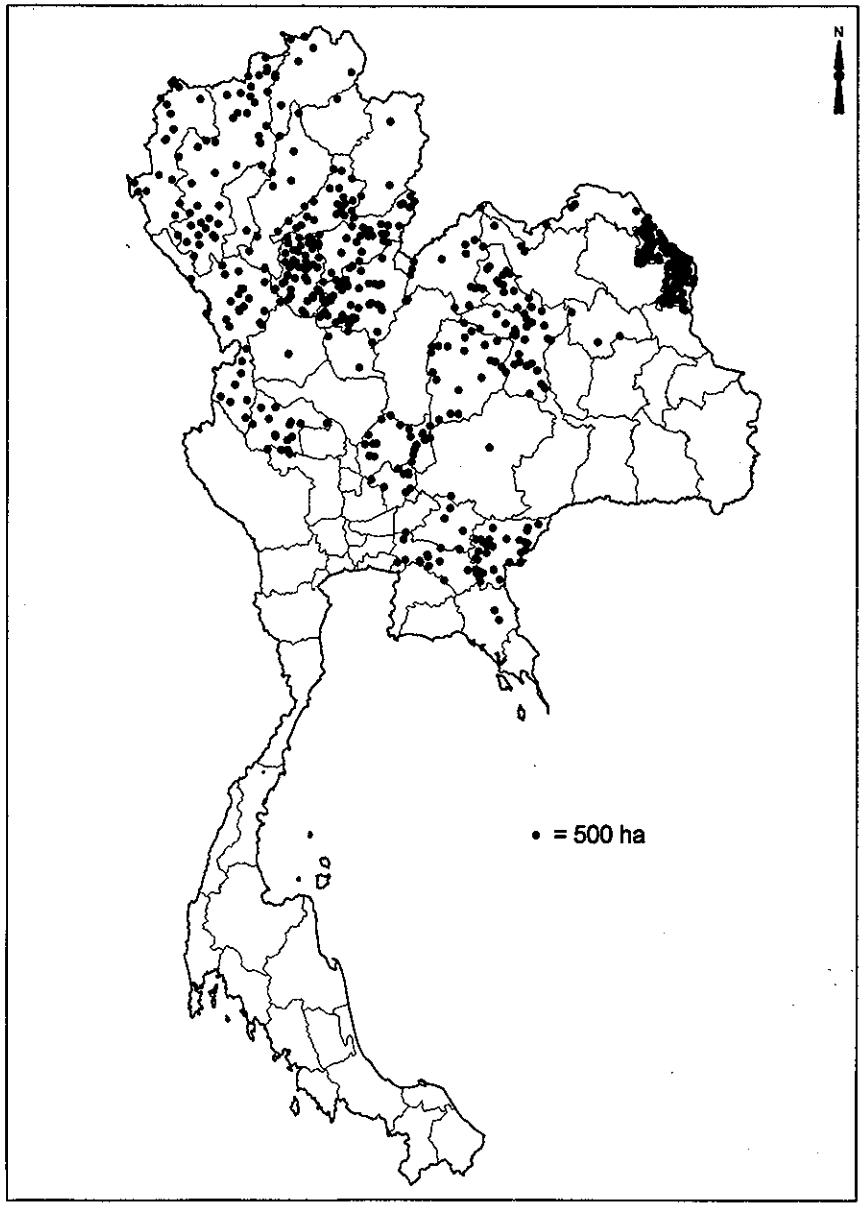

Figure 8.13. Soybean distribution in Thailand, 1997/98.

This resulted in increased soybean imports. Most of the imported soybean is used for animal feeds. There is an urgent need to curtail the imports to save foreign exchange.

Constraints to Legumes Production

Biotic Constraints

Diseases and insect pests (including storage pests) are the major biotic constraints to legumes production in Thailand. Weeds and lack of fresh-seed dormancy also limit the productivity of groundnut and soybean.

Diseases and insect pests

The major diseases and insect pests of legumes in order of importance in Thailand are listed in Table 8.1. Several insects are common pests of legumes. Aphids are common in mung bean, black gram, soybean, and groundnut, although they are considered a major pest of mung bean and black gram. *Helicoverpa armigera* (pod borer) and *Ophiomyia phaseoli* (beanfly) are major pests of soybean, mung bean, and black gram.

Weeds

Weeds are considered a major constraint to legumes and cause substantial production losses. However, extent of yield losses range from 30% to 70% due to weed competition. Farmers usually practice 1–2 hand weedings, but high labor wages are discouraging farmers to practice adequate weed management. Some farmers use pre-emergence herbicides to manage weeds.

Storage problems

Soybean seeds deteriorate rapidly particularly under tropical conditions. After seeds are threshed and cleaned, seed moisture has to be reduced to approximately 8%. Then the seeds have to be stored in moisture-proof container at room temperature. Groundnut pods dried for 5–7 days under the sun, to pod moisture content of about 7%, can be kept for eight months under normal conditions without any reduction in seed germination. Bruchids are major insect pests of mung bean in storage; proper drying and storage are recommended.

Abiotic Constraints

Drought

Drought directly affects the economic yields of legumes. Upper Thailand experienced severe drought during 1977 and 1993.

Floods

Excess rainfall due to tropical storms cause flooding in lowland areas in the Central plain and northeastern part of the country.

Socioeconomic Constraints

A number of socioeconomic constraints such as low profitability of legumes in comparison to rice, lack of credit facilities, infrastructure and financial institutions, and apathy towards legumes cultivation are important. Subsequent to the economic crisis (1997–98) in the country, government has cut the budget on research, which has directly affected crops such as legumes. Many research and development (R&D) projects have to be postponed. The uncertainty of market prices of legumes also put the farmers at higher risk, associated with dumping of imported legumes. As legume cultivation is labor intensive, lack of farm labor in many parts of Thailand is also becoming a major constraint.

National Policies and Emphasis Towards Legumes Production

The Ministry of Agriculture and Cooperatives has set up a national strategy to increase production of legumes in Thailand.

Mung Bean and Black Gram

- Establish zoning for mung bean and black gram to increase production area and yield in areas that have climatic conditions suitable for these crops. This area needs infrastructure for input supply and secure marketing system.
- Improve seed production and marketing of improved varieties (Khampheangsean 1, Khampheangsean 2, Chainat 36, Chainat 60, and U-Thong 1).
- Encourage farmers to use good agricultural practices.
- Improve R&D in postharvest technologies, seed storage, and packaging to keep good quality seeds for a long period.

Table 8.1. Important diseases and insect pests of legumes in Thailand.

Crop	Disease (Pathogen)	Insects
Mung bean and black gram	Root and basal stem rot (*Pythium* sp) Charcoal rot (*Macrophomina phaseolina* (Tassi) Goid.) Cercospora leaf spot (*Cercospora* sp)	Beanfly (*Ophiomyia phaseoli* Tryo.) Common cutworm (*Spodoptera litura* F.) Pod borers (*Helicoverpa armigera* Hübner, *Etiella zinckenella* Treitschke, *Maruca vitrata* Gey.) Bruchids (*Callosobruchus maculatus* F., *C. chinensis* L.)
Soybean	Rust (*Phakopsora pachyrhizi* Syd.) Anthracnose (*Colletotrichum dematium* (Pers.) Grove) Bacterial pustule (*Xanthomonas campestris* pv *glycines* (Nakano) Dye) Downy mildew (*Peronospora manshurica* (Naum.) Syd. Soybean mosaic (soybean mosaic virus)	Beanfly (*Ophiomyia phaseoli* Tryo.) Pod borer (*Etiella zinckenella* Treitschke.) Leaf roller (*Archips micaceana* Walk.) Bugs (*Nezara viridula* L.) Common cutworm (*Spodoptera litura* F.) Aphids (*Aphis glycines* Mats.) Thrips (*Caliothrips indicus* Bag.) Tobacco whitefly (*Bemisia tabaci* Genn.)
Groundnut	Rust (*Puccinia arachidis* Speg.) Late leaf spot (*Phaeoisariopsis personata* (Berk. & Curtis) v. Arx Root rot (*Sclerotium rolfsii* Sacc.) Crown rot (*Aspergillus niger* van Tieghem) Bacterial wilt (*Ralstonia solanacearum* Smith)	Subterranean ants (*Dorylus orientalis* Westew.) Leaf miner (*Aproaerema modicella* Dev.) Thrips (*Caliothrips indicus* Bag.) Aphids (*Aphis craccivora* Koch) Leaf roller (*Archips micaceana* Walk.) Common cutworm (*Spodoptera litura* F.) Pod borer (*Helicoverpa armigera* Hübner)

- Continue research in developing new lines that have biotic and abiotic tolerance.
- Encourage farmers to establish farmers' associations for credit, inputs, and marketing.
- Set up price policy.

Groundnut

- Increase production efficiency and reduce production costs by:
  - Indicating groundnut zoning with recommended variety, soil suitability and climatic conditions.
  - Using good agricultural practices and promoting transfer of technologies.
  - Developing improved high-yielding varieties with disease and insect resistance.
  - Improving seed production and distribution of new varieties (Kampang, SK 38, Tainan 9, Khon Kaen 60-1, Khon Kaen 60-2, Khon Kaen 60-3, and Khon Kaen 5, Songkhla 1, and Khon Kaen 4).
- Improve postharvest technologies to reduce aflatoxin contamination.
- Establish groundnut farmers' association to organize managing and marketing of groundnut.
- Develop farm machinery for groundnut harvesting to reduce labor costs and production losses.
- Develop integrated production methods.

Soybean

- Improve seed production and distribution of new varieties (SJ 1, SJ 2, SJ 4, SJ 5, Sukhothai 1, Nakhorn Sawan 1, Chiang Mai 60, KKU35, Sukhothai 2, Chiang Mai 2, SSR 8407Y-2-1, SSRSN 36-25-7, CPAC 131-76, GC 81031-6-2-1, and GC 81031-6-3-1).

- Establish soybean database based on geographic information system (GIS) and remote sensing techniques in order to understand the actual land use, production sites, and the impact of environmental and yield prediction.
- Transfer good agricultural practices for soybean to farmers, and encourage them to use farm machinery.
- Research on developing new promising lines with high yield potential.
- Set up soybean standards to comply with international standards.
- Encourage farmers to establish soybean farmers' associations for loan and marketing, and to adopt government policies.
- Set up price policy.

Prospects for Increased Production and Use of Legumes

The principal objectives of the Department of Agriculture for R&D are to enhance the production efficiency of farmers by increasing crop yields, reduce production cost, and improve seed quality. The Field Crops Research Institute, Bangkok and its research centers are responsible for R&D of legumes.

The prospects for increased production and use of legumes in Thailand are:

- Identification of agroecological zones through analysis of potential and geographical characteristics of the agricultural lands in Thailand, and the suitability of agricultural practices to ensure appropriate utilization of natural resources to sustain and increase production efficiency. Zoning for major legumes, viz., soybean, groundnut, and mung bean, have been done based on the data as mentioned above.
- Prioritization of crops for R&D as per government policies on agricultural development. Soybean and groundnut are among the group of import subsidies. The policy for both legumes aims to raise the production to cope with the local demand.
- Varietal improvement to develop varieties that can produce high yield with good adaptability to various climatic and environmental stresses such as drought, insect pests, and diseases, and good seed quality.
- Development of package of production technologies for soybean, groundnut, mung bean and black gram.
- Emphasis on research on water requirement of legumes in rainfed and partially irrigated areas.
- Development of agricultural machinery aimed to reduce input costs.
- Research on the management of an integrated farming system to attain self-sufficiency and obtain maximum benefit.

Conclusions

The Department of Agriculture has undertaken many activities to attain the targets specified in the Eighth National Economic and Social Development Plan. Agriculture policies were reviewed and modified to suit the needs of the country. The national policy visualized that future direction of agricultural development will place an emphasis on restructuring of the agricultural system geared towards production of commercial crops (including legumes) and for self-sufficiency, efficient management of natural and human resources, economic rehabilitation, enhancing farmers' capabilities and strengthening farmers' organizations, encouraging investment and saving, and improving technology transfer and management information system.

Legumes are likely to become more important crops in terms of economic returns. The clear vision of government for self-sufficiency in soybean, mung bean, and groundnut guarantee secure future of these legumes. Legumes may be grown as monocrop in Thailand in the near future when some of the existing problems are resolved. More efforts have to be put into R&D of legumes production and marketing, and its positive effects on stability of farmers' income and socioeconomic conditions.

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9. Legumes in Vietnam: Constraints and Opportunities

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Abstract

Vietnam is a humid tropical country with an average annual rainfall of 1500–2000 mm. The country has been classified into 9 agro-ecological regions based on rainfall, temperature, length of growing period, evapotranspiration, and land suitability. Rice is the major crop and occupies 50% of the cultivated area. Rice-based cropping systems therefore, play an important role in Vietnam's agriculture and economy. Groundnut, mung bean, and soybean are the main legume crops. Investments in legumes research and development and strengthening extension network resulted in increase of groundnut yield from 1.0 t ha^{-1} to 1.4 t ha^{-1} during 1991–98.

Major production constraints to legumes are lack of credit facilities, low and unstable market price, and non-availability of high-yielding varieties with suitable maturity period and resistance to major diseases and pests. Availability of short-duration, drought-tolerant cultivars can lead to expansion of grain legume cultivation in niches such as Red River Delta and Mekong River Delta (after two rice crops) and highlands (as sole and intercrop). Good prospects for increasing grain legume area also exist in upland rice areas with unstable rice production with appropriate cropping systems and crop diversification. This, however, requires replacement of existing long-duration rice cultivars with short-duration, photo- and thermo-insensitive rice cultivars.

The action plan for grain legume improvement developed by the Government of Vietnam envisages that area and production of legumes will increase to 1.37 million ha and 2.48 million t respectively by 2010. It is predicted that increase in cultivated area will be mainly due to expansion of legumes into new areas and increased cropping intensity while production increase will be due to adoption of improved production technology. The Government of Vietnam has recently initiated several steps to boost legumes production.

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Introduction

Vietnam lies between 8° 33′ N and 102° 10′ to 109° 26′ E. Administratively, the country is divided into 62 provinces (Fig. 9.1). Although a humid-tropical country, it has tropical, subtropical, and temperate climates in pockets. This diverse climate provides for harnessing ecological productivity through various crops and cropping systems. Rice (*Oryza sativa* L.) and maize (*Zea mays* L.) among cereals, and groundnut (*Arachis hypogaea* L.), soybean (*Glycine max* (L.) Merr.), and mung bean (*Vigna radiata* (L.) Wilczek) among legumes are important crops in Vietnam. Although land area of Vietnam is more than 330,000 km^2, about 75% is covered by mountains and midlands. Cultivated area is about 8.3 million ha, of which 4.2 million ha is occupied by rice. Arable area can be expanded up to 10 million ha or more, in plateau and slopes (<15° slope) with the probability of drought and unfavorable growth conditions for crops. Average area for cultivation per head is approximately 0.1 ha. It is therefore necessary to enhance use of improved land management methods to ensure sustainability of land resources.

Vietnamese diet is simple, mainly starch (rice); hence it is necessary to improve the nutrition with protein, essential vitamins, and minerals from crops and animals. Therefore, crop and system diversification is being explored in various ecological regions. Rice being the major crop occupying >50% of the cultivated area, rice-based cropping systems will naturally be the focal point for crop diversification and system intensification.

Agroecological Features

Vietnam has been divided into 9 agroecological zones (Fig. 9.2) based on soil type (Fig. 9.3), rainfall (Fig. 9.4), temperature (Fig. 9.5), and length of growing period (LGP) (Fig. 9.6). The agroecological zones are briefly described in Table 9.1.

Legumes Production in Vietnam

Although legumes have been grown in Vietnam for a long time, they received scant attention of the policy makers. However, the area under legumes increased steadily from 0.46 million ha in 1985 to 0.57 million ha in 1997 (Fig. 9.7).

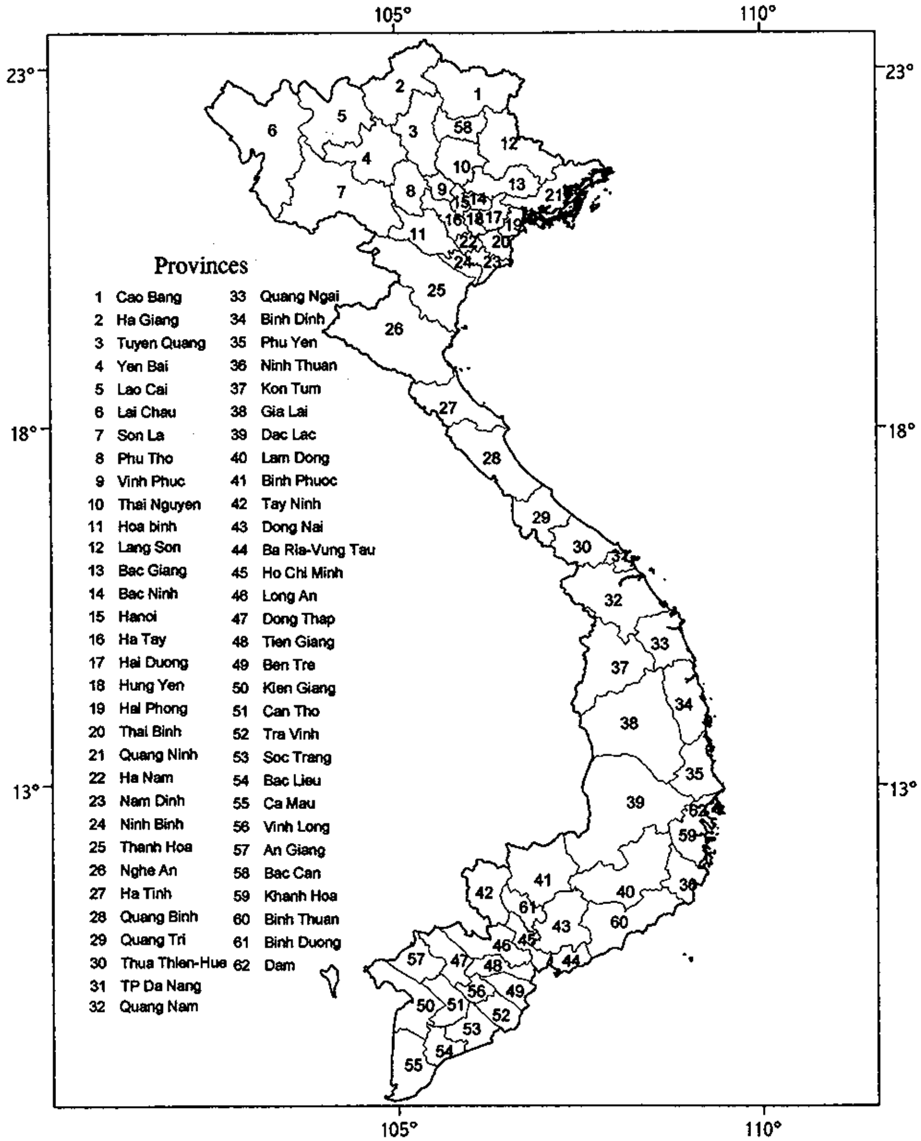

Figure 9.1. Administrative divisions of Vietnam (Source: National Institute for Agricultural Planning and Projection 1998).

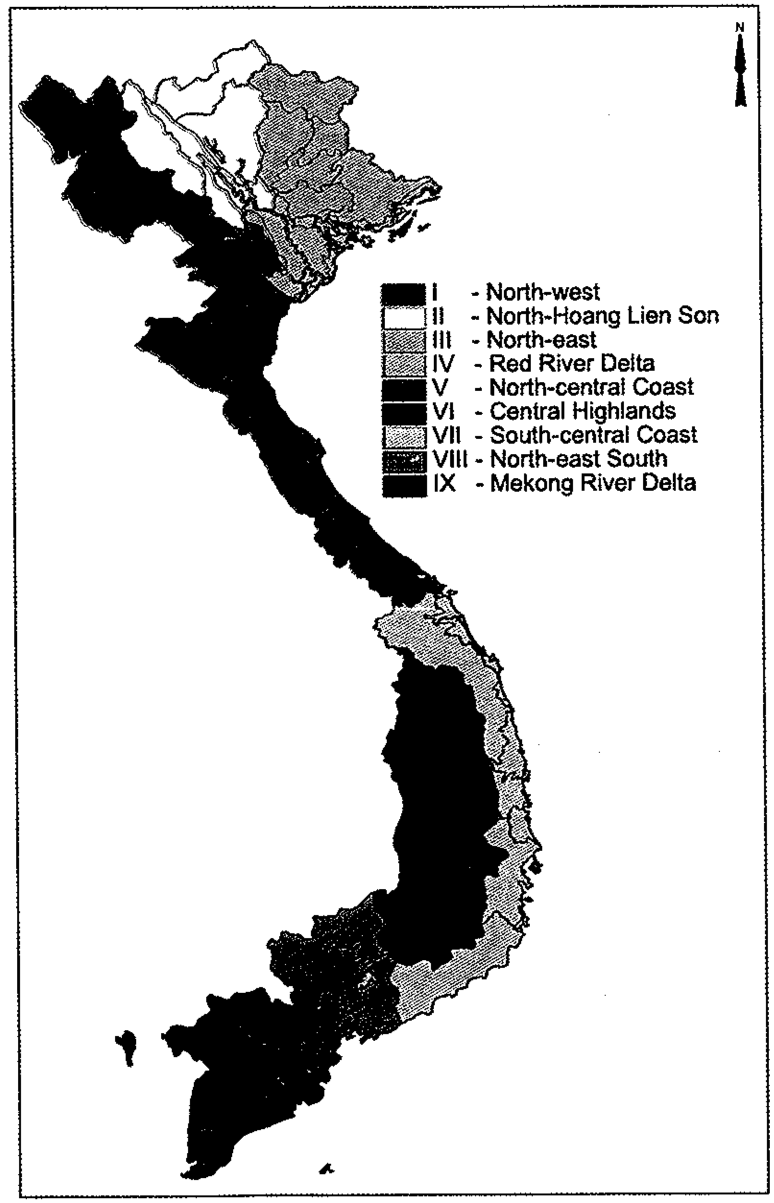

Figure 9.2. Agroecological zones of Vietnam (Source: National Institute for Agricultural Planning and Projection, Hanoi, Vietnam).

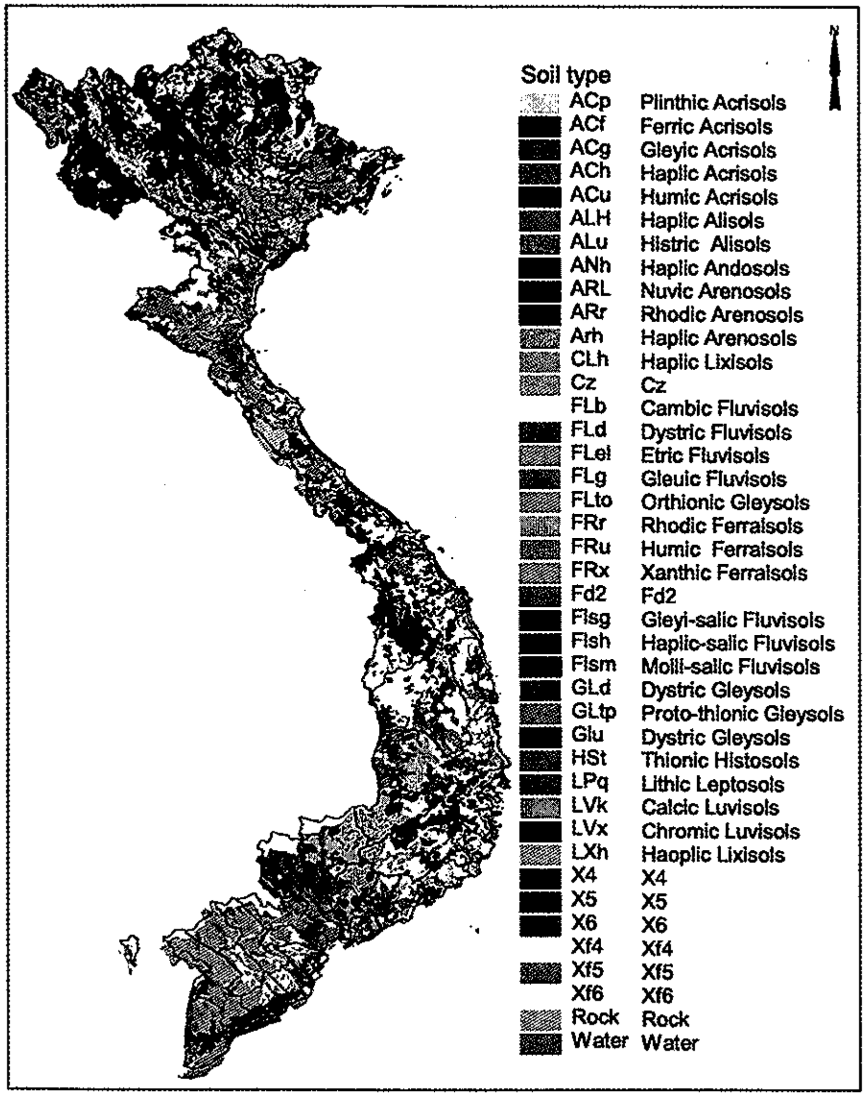

Figure 9.3. Soil map of Vietnam (Source: National Institute for Agricultural Planning and Projection, Hanoi, Vietnam).

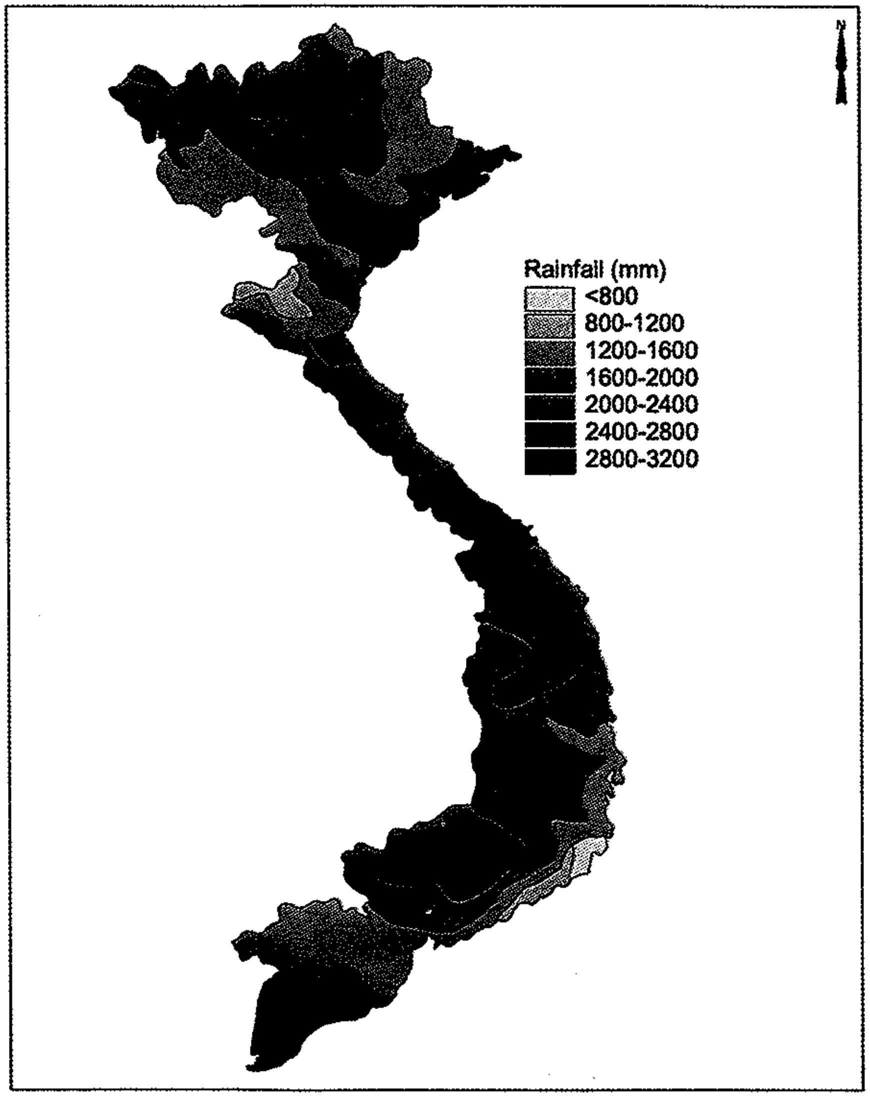

Figure 9.4. Annual rainfall in Vietnam (Source: National Institute for Agricultural Planning and Projection, Hanoi, Vietnam).

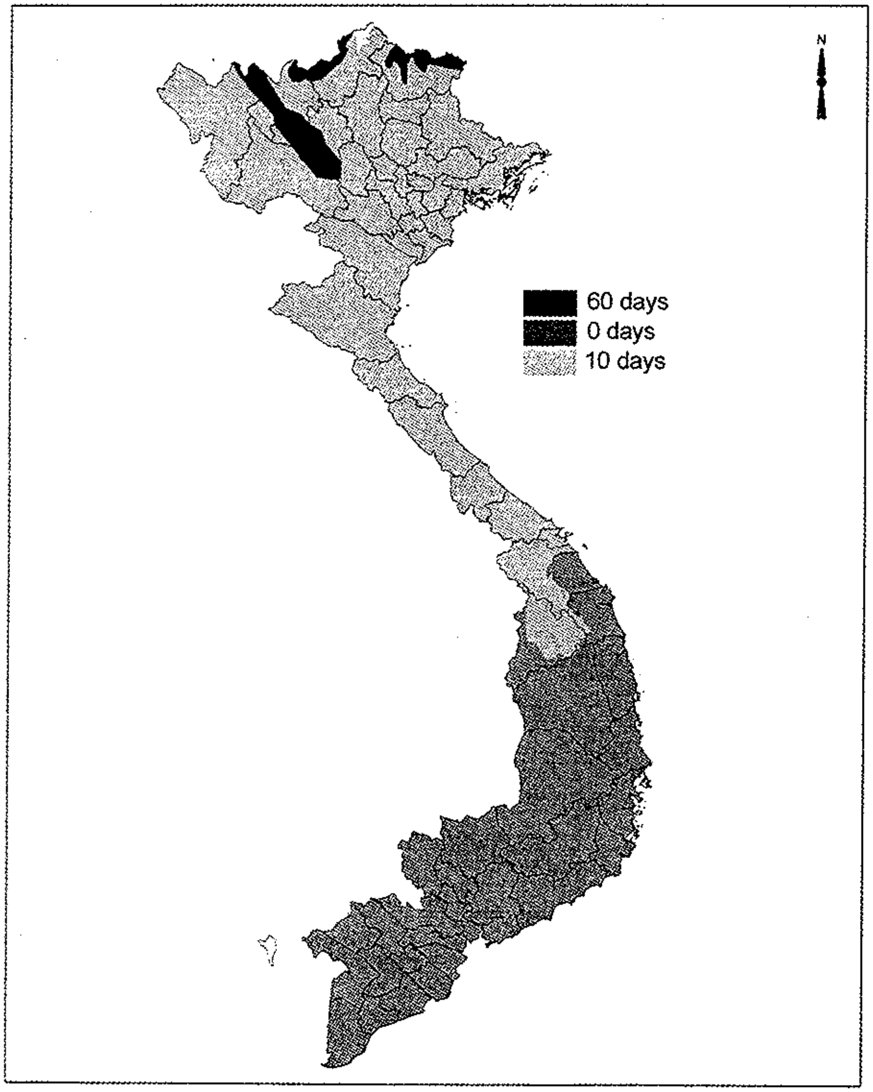

Figure 9.5. Number of days with <10°C during cold period (Source: National Institute for Agricultural Planning and Projection, Hanoi, Vietnam).

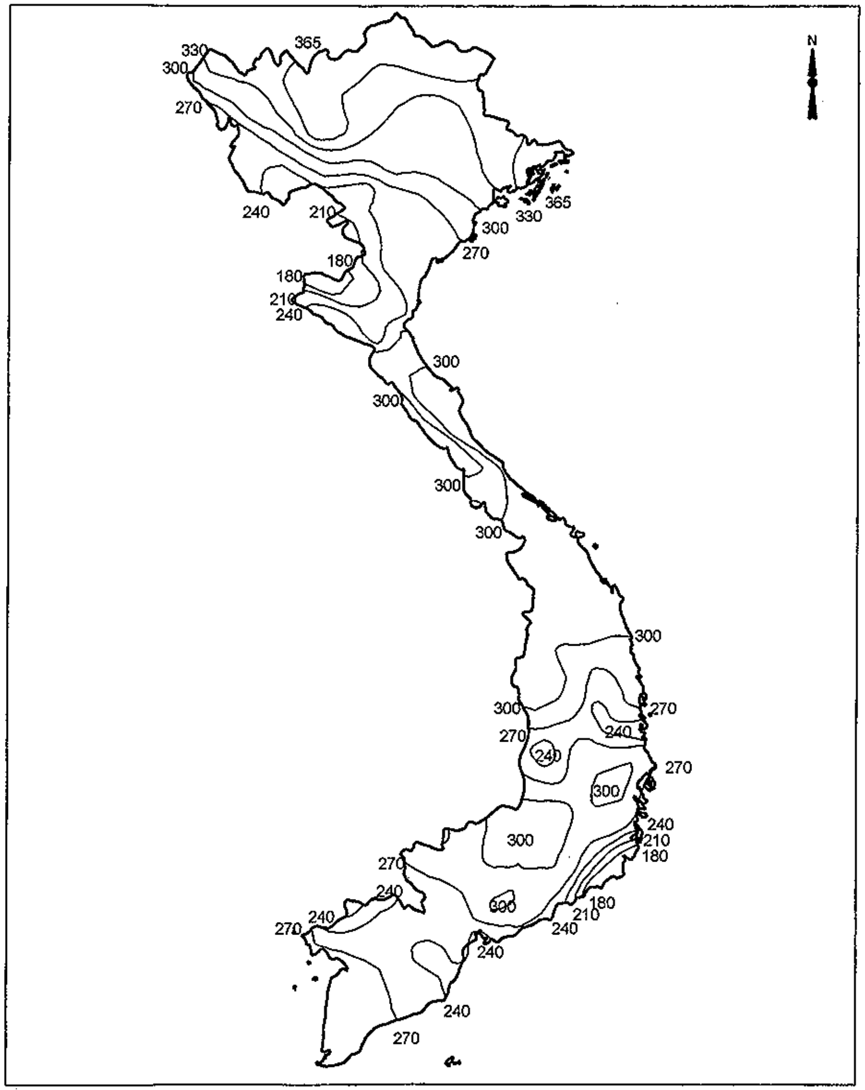

Figure 9.6. Length of growing period (LGP) (days) in Vietnam (Source: FAO, Rome, Italy).

Groundnut

Groundnut is one of the main foreign exchange earning crops apart from being the source of oil, protein, and food for people and fodder for cattle. Spring (February–June) is most important for production of the crop. The autumn crop is mainly for obtaining high quality seed for the spring crop. Spring groundnut is grown under rainfed production systems in northern Vietnam, while in southern Vietnam it is grown mostly under irrigation. It is predominantly grown as a sole crop, but in some areas it is intercropped with sugarcane (*Saccharum officinarum* L.), maize, cassava (*Manihot esculenta* Crantz), and upland rice during rainy season. Groundnut is also grown to some extent as an intercrop in rubber (*Hevea bresiliensis* Muell.) or coffee (*Coffea arabica* L.) plantations. Area and production was almost stagnant during 1975–90, but has shown steady increase since 1994 (Fig. 9.7).

Groundnut is grown in >250,000 ha (Fig. 9.8) mainly in the following five ecoregions of Vietnam:

- North-east and North-west (mountain and midlands) region: Groundnut is grown in about 41,000 ha in Vinh Phuc, Bac Giang, and Thai Nguyen provinces.
- North-central coast ecoregion: This is the most important groundnut production zone with an area of about 71,100 ha in Thanh Hoa, Nghe An, and Ha Tinh provinces.
- South-central coast ecoregion: Groundnut cultivation is mostly concentrated in Quang Nam and Da Nang provinces in about 29,000 ha.
- Central highlands: Groundnut is grown in about 18,600 ha mainly in Dac Lac, Gia Lai, and Kon Tum provinces.
- Southern north-central highlands: Groundnut is mostly concentrated in Binh Dinh, Binh Phuoc, and Tay Ninh provinces in 68,800 ha.

Distribution of groundnut during 1997 indicated that it is grown all over the country except in southwestern areas.

Soybean

Soybean is the second most important legume in Vietnam. However, area and production have remained stagnant (Fig. 9.7). Although soybean is grown in more than 30 provinces of Vietnam, about 60% of it is grown in Son La, Cao Bang, and Bac Giang provinces of northern Vietnam, and the remaining in Dong Nai, Dong Thap, and Dac Lac provinces of southern Vietnam (Fig. 9.9).

Sixty-five per cent of soybean is grown in highlands on soils with low fertility. Red River (northern Vietnam) and Mekong River (southern Vietnam) Deltas are next important areas of soybean production since soybean can be grown all round the year in various cropping systems. Spring crop (February–July) is grown under favorable weather conditions, while summer or summer-autumn crop (May–September) experience high temperature and rainfall during growth and development stages. In winter (mid-September–December), low temperature and terminal drought are the main

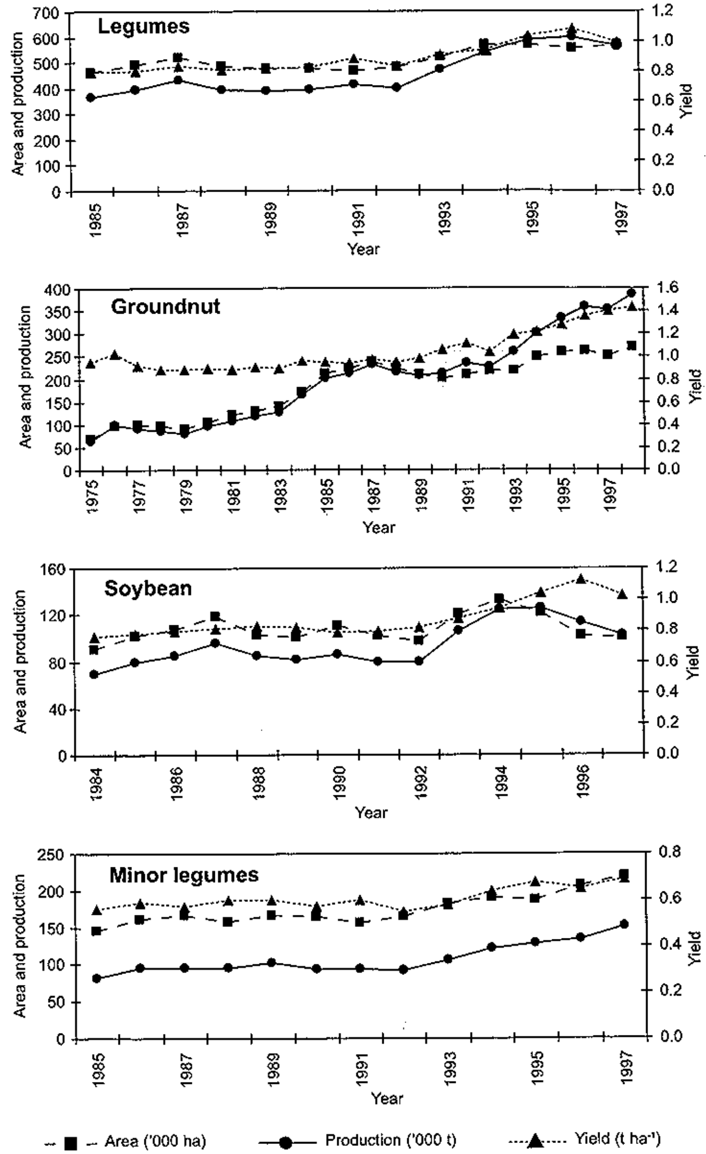

Figure 9.7. Area, production, and yield of legumes in Vietnam (Source: General Statistical Office 1995, 1997).

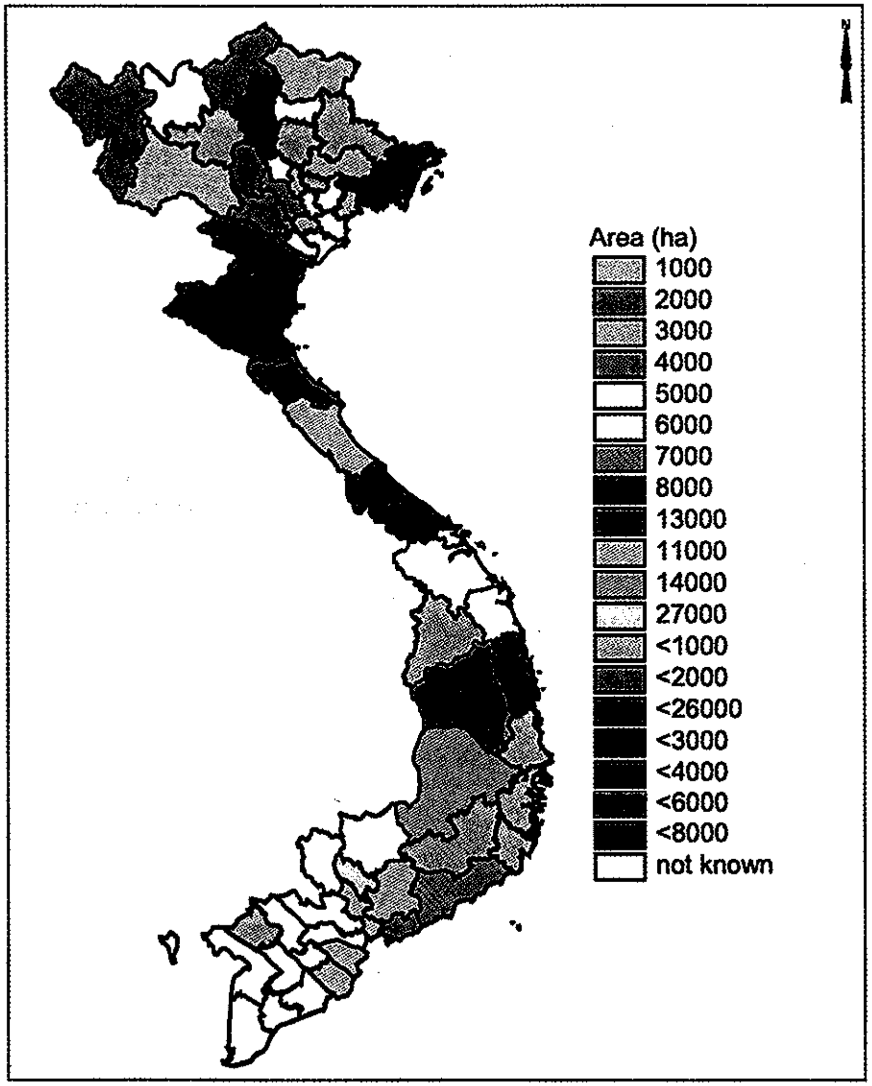

Figure 9.8. Sown area of groundnut by province in Vietnam (Source: General Statistical Office 1997).

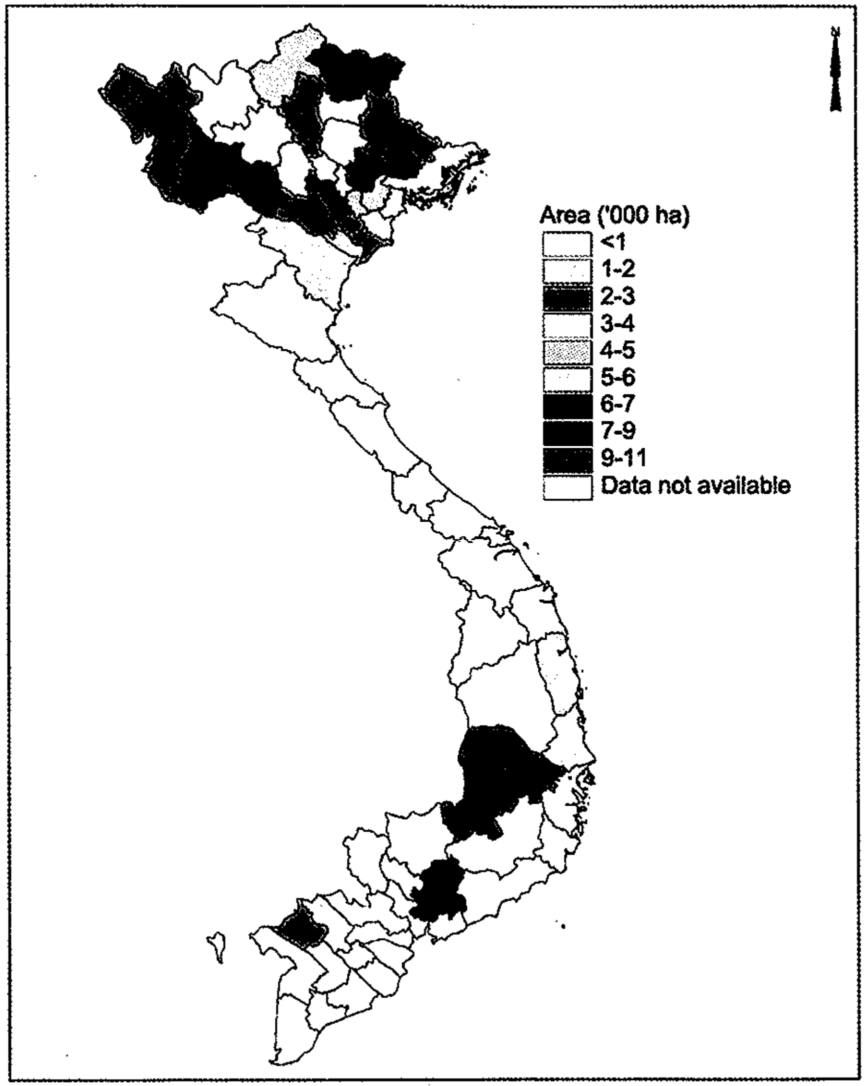

Figure 9.9. Sown area of soybean in Vietnam (Source: General Statistical Office 1997).

Table 9.1. Features of the agro-ecological zones of Vietnam.

Agro-ecological zone (AEZ)	Provinces	Rainfall (mm)	Temperature	Soils	Length of growing period	Remarks
North-west (AEZ I)	Lai Chau, Son La, Hoa Binh	1108–3000	8–42°C	Plinthic Acrisols, Humic Ferralsols	NA[1]	Potential evaporation varies from 800 mm to 1818 mm. Important crops are maize, sweet potato, cassava, medicinal plants, and seed vegetables.
North-Hoang Lien Son (AEZ II)	Lao Cai, Yen Bai, Ha Giang, Tuyen Quang, Vinh Phuc	1500–3000	10–15°C (in winter) >20°C (other months)	Ferric Acrisols	8–12 months	Severe soil erosion due to storms, intensive rains, and deforestation. Good potential for soybean, wheat, maize, cassava, medicinal plants, and timber and fruit trees.
North-east (AEZ III)	Cao Bang, Quang Ninh, Lang Son, Bac Can, Thai Nguyen	1276	>20°C (November – March) <20°C (remaining months)	Plinthic Acrisols (Yellow-red group)	7 months	Suitable for fruit trees, tea, tobacco, winter crops, medicinal plants, and seed vegetables.
Red River Delta (AEZ IV)	Hanoi, Ha Tay, Hai Phong, Hung Yen, Hai Duong, Ha Nam, Nam Dinh, Thai Binh, Ninh Binh	1600–2200	NA	Fluvisols	10–11 months	Important crops are rice, maize, sweet potato, and food legumes.
North-central Coast (AEZ V)	Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien-Hue	1263–1300	12–41°C	Plinthic Acrisols, Haplic Arenosols	10–11 months	Major crops are rice, maize, groundnut, citrus, pineapple, black pepper, and coconut.
Central Highlands (AEZ VI)	Kon Tum, Gia Lai, Dac Lac	1600–1800	21–23°C	Ferralsols	4 months	Soybean, groundnut, sesame, maize, sweet potato, cassava, black pepper, coffee, and tea are grown.

continued

Table 9.1. *continued*

Agro-ecological zone (AEZ)	Provinces	Rainfall (mm)	Temperature	Soils	Length of growing period	Remarks
South-central Coast (AEZ VII)	Da Nang, Quang Nam, Quang Ngai, Binh Dinh, Phu Yen, Khanh Hoa	700–3000	20–42.5°C	Sandy, alluvial soils, Humic Ferralsols	NA	Rice is grown in lowlands, coffee, tea, groundnut, sesame, soybean, and tobacco in plateau region, and coconut and rubber in coastal region.
North-east South (AEZ VIII)	Ho Chi Minh, Lam Dong, Ninh Thuan, Binh Phuoc, Tay Ninh, Binh Duong, Dong Nai, Binh Thuan, Ba Ria-Vung Tau	1500–2500	21–25°C	Acrisols, Rhodic Ferralsols	Round the year	Potential for two rice crops and one dryland crop (soybean, groundnut, maize, and sweet potato).
Mekong River Delta (AEZ IX)	Long An, Dong Thap, An Giang, Tien Giang, Vinh Long, Ben Tre, Kien Giang, Can Tho, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau	2000	26–27°C	Fluvisols, Haplic–salic Fluvisols	NA	Rice, maize, sweet potato, soybean, sugarcane, groundnut, tobacco, orange, banana, coconut, and vegetables are grown.

1. NA = Information not available.

production constraints. Soybean is mainly grown after spring and autumn rice in the Red River Delta. In southern Vietnam the main cropping season is November–April (dry season), but it is also grown in the rainy season (April–August).

Mung Bean

Mung bean is the third most important legume after soybean and groundnut. However, statistics on area and production for mung bean are not readily available since mung bean is clubbed with other minor legumes such as cowpea (*Vigna unguiculata* (L.) Walp.), lablab bean (*Lablab purpureus* (L.) Sweet), and common bean (*Phaseolus vulgaris* L.). In 1997, these minor legumes (including mung bean) were cultivated on 218,000 ha (Fig. 9.7) of which mung bean occupied about 60,000 to 70,000 ha with a production potential of 0.6 to 0.8 t ha^{-1}.

Mung bean is mostly grown in Bac Can, Thai Nguyen, Cao Bang, and Quang Ninh in North-east region and Ha Giang, Tuyen Quang, and Phu Tho in North-Hoang Lien Son region during April–July. Yields are usually low (about 0.6 t ha^{-1}). In Red River Delta, mung bean is grown round the year under irrigation and high input conditions for vegetable purpose with good yields (about 1 t ha^{-1}). It is cultivated extensively in North-east ecoregion covering about 26% of the total cultivated area. However, yields are low (0.5 t ha^{-1}) due to lack of suitable genotypes with resistance to diseases [Cercospora leaf spot (*Cercospora cruenta*) and powdery mildew (*Erysiphe polygoni, Oidium* sp)] and insect pests (*Helicoverpa armigera*).

Constraints to Legumes Production

Diagnostic surveys in the major groundnut-growing provinces of northern (Ha Tinh and Nghe An) and southern (Tay Ninh and Long An) Vietnam were conducted by multi-disciplinary teams of scientists during 1991 to identify production constraints. The farmer-perceived constraints were prioritized according to the spatial and temporal occurrence of each problem and the extent of yield loss caused (Table 9.2). The national soybean development program of the Legumes Research and Development Center at the Vietnam Agricultural Science Institute conducted a survey to identify constraints to soybean production in 1993 (Table 9.3). These were grouped into biotic, abiotic, and socioeconomic constraints.

Biotic Constraints

Groundnut and soybean can be grown in several cropping systems. However, area expansion and production have remained low because of low yield and susceptibility of the existing varieties to disease and insect pests (Khoi 1991). Lack of high-yielding varieties with suitable maturity period and resistance to major diseases and pests were the major production constraints (Ramakrishna et al. 1999). Leaf-eating insects, soilborne and foliar diseases, and weeds were other important production constraints. The window for soybean cultivation is only 80–90 days in rice-based cropping systems. Therefore, development of extra-short-duration varieties with high yield potential and resistance to major diseases and pests is urgently needed.

Table 9.2. Production constraints in major groundnut-producing provinces of Vietnam.

	Priority ranking[1]			
Constraints	Nghe An	Ha Tinh	Tay Ninh	Long An
Socioeconomic				
Lack of cash for input	1	1	1	1
Low and unstable price	2	1	-	3
Lack of drainage system	2	2	-	-
Lack of improved production Technology	2	1	-	-
Abiotic				
Drought	3	2	-	-
Poor soil fertility	-	2	-	-
Lack of manure	2	2	-	-
High rainfall at maturing period	3	3	-	-
Biotic				
Foliar diseases	3	2	2	2
Bacterial wilt	2	3	-	-
Seeding on the field	3	3	-	-
Weeds	1	-	2	2
Others				
Lack of high-yielding varieties	1	1	1	1
Germination in the field	1	-	2	2

1. 1 = High; 2 = Moderate; 3 = Low priority; - = Not identified.
Source: Lai (1991).

Table 9.3. Importance of soybean production constraints in Vietnam[1].

Constraints	1970s	1980s	Current
Socioeconomic	1	1	1
Lack of cash for inputs	1	1	1
Low price	1	1	1
Lack of market			
Abiotic			
Drought/lack of irrigation	2	2	2
Poor soil fertility	2	2	2
Biotic			
Lack of high-yielding varieties	1	1	1
Rust (*Phakopsora pachyrhizi* Syd.)	1	1	1
Bacterial wilt (*Pseudomonas* sp)	2	2	2
Damping-off (*Rhizoctonia solani* Kühn)	2	2	2
Leaf miner (*Stomopteryx subsecivella* Zell.)	1	1	1
Stink bug (*Euschistus* sp)	1	1	1

1. 1 = Most important; 2 = Less important.
Source: Lai (1993).

Another area which needs attention is seed storage as soybean seed deteriorates quickly.

Soybean varieties suitable for different regions and seasons have been developed in the recent past. However, farmers like to grow a single cultivar all round the year, and are not willing to change varieties in every season. Current emphasis is therefore to develop varieties with wider adaptability.

Diseases

Groundnut. Rust (*Puccinia arachidis*) and late leaf spot (*Phaeoisariopsis personata*) were the most severe foliar diseases causing 30–70% pod yield loss (Hong and Yen 1991). Bacterial wilt was important (Table 9.4) in many groundnut producing provinces (Hong and Mehan 1995). Aflatoxin production (*Aspergillus flavus*) is becoming a serious problem particularly during storage. Intensity and distribution of groundnut diseases during 1997 are presented in Figure 9.10.

Soybean. Rust (*Phakopsora pachyrhizi*) was the most serious disease (Table 9.4) in spring causing yield losses up to 40–60%. Total crop failure was not uncommon, if proper care was not taken. Incidence of soybean diseases during 1997 is presented in Figure 9.11.

Insect pests

Groundnut. Among the 21 insect pests recorded so far, seven are important (Table 9.4). *Spodoptera litura* is the most serious pest and causes 18% pod yield loss (Vuong 1998). Black cutworm (*Agrotis* sp) damages young plants and reduces plant density resulting in 10–15% yield losses, while *Helicoverpa armigera* causes yield losses of 15–20% (Khoi 1991).

Soybean. Among various insect pests that attack soybean, black cutworm (*Agrotis ipsilon*) in spring and beanfly (*Ophiomyia phaseoli*) in winter are the most serious pests, while pod borer (*Maruca vitrata*) is serious year round (Table 9.4). Though hairy caterpillars (particularly *Amsacta* sp) are common on soybean, it is not considered as severe as the above pests.

Lack of seed dormancy

Currently, the groundnut varieties grown in Vietnam are spanish types. Farmers prefer these because of their short-duration compared to virginia types. However, heavy rains during harvesting of the main season crop in May/June generally result in seed germination in situ leading to yield loss. Varieties with fresh seed dormancy are needed for this production system.

Abiotic Constraints

Groundnut in northern Vietnam is mainly grown in spring (February–June). Rainfall is limited at the time of sowing (20–40 mm) and heavy at the time of harvest resulting in poor pod yields and seed quality. Summer soybean faces drought stress at grain formation and maturity stages. Potential for soybean expansion exists in mountainous and other upland areas, but terminal drought is the major production constraint for expansion of area.

Socioeconomic Constraints

Unstable and low price was identified as an important socioeconomic constraint for both soybean and groundnut. Another constraint was the lack of cash with farmers to buy quality seeds and fertilizers, as credit facilities are not available for legume crops. High cost of production is making the domestic soybean cultivation unviable as imported produce is cheap.

Table 9.4. **Major diseases and insect pests of grain legumes in Vietnam.**

Crop	Disease (Pathogen)	Pest
Groundnut	Rust (*Puccinia arachidis* Speg.)	Black cutworm (*Agrotis ipsilon* Huf.)
	Late leaf spot (*Phaeoisariopsis personata* (Berk. & Curtis) v. Arx	Caterpillar/armyworm (*Spodoptera litura* F.)
	Early leaf spot (*Cercospora arachidicola* Hori)	Leaf miner (*Aproaerema modicella* Dev.)
	Collar rot (*Sclerotium rolfsii* Sacc.)	Thrips (*Scirtothrips dorsalis* Hood.)
	Bacterial wilt (*Ralstonia solanacearum* L.)	Jassids (*Empoasca kerri* Pruthi)
	Pod rot (*Fusarium solani* (Mart.) Sacc., *F. oxysporum* Schlect.)	Podborer (*Helicoverpa armigera* Hübner)
	Leaf blight (*Rhizoctonia* sp, *Alternaria* sp)	Aphids (*Aphis craccivora* Koch)
Soybean	Rust (*Phakopsora pachyrhizi* Syd.)	Pod borer (*Maruca vitrata* Gey.)
	Damping-off (*Rhizoctonia solani* Kühn)	Hairy caterpillar (*Amsacta albistriga* Walk.)
	Downy mildew (*Peronospora manshurica* (Naumov) Syd.	Beanfly (*Ophiomyia phaseoli* Tryo.)
	Leaf spot (*Cercospora* sp)	Black cutworm (*Agrotis ipsilon* Huf.)

Role of Legumes in Cropping Systems

Rice covers more than 50% of the total agricultural land. In irrigated areas rice (spring)-rice (summer)-maize/sweet potato (*Ipomoea batatas* (L.) Lam.) (winter) cropping system is generally followed. Spring rice is grown without irrigation on 2 million ha (out of total cultivated area of 6.5 million ha) and yields are very low (1.5–2.0 t ha^{-1}). Continuous monocropping of rice is causing deterioration of soil fertility and quality. Policy makers and researchers are now looking at the opportunities for crop diversification to break cereal monocropping. Good scope exists for legumes in multiple cropping systems particularly in winter (as autumn-winter crop). Legumes area can also be increased by intercropping short-duration legumes with maize after spring and summer rice and introducing crop rotations with legumes.

In coming years, the strategic goal is sustainable eco-agricultural development through introduction of new cropping systems to make cultivation intensive and profitable. Food legume improvement (as winter crop) through appropriate research and development is the only alternative for increasing cropping intensity since the winter cropped area has stagnated in potential areas such as Red River Delta. However, area of legumes will be governed by the market price and favorable government policies. Farmers are willing to effect changes in cropping systems if higher income can be generated.

Legumes in Multicropping Systems

Rice-rice-fallow or maize-rice-fallow is the predominant cropping system in the Red River Delta. Introduction of soybean or groundnut as autumn-winter crops can successfully break the cereal monocropping in the region (Thang et al. 1997). Among various crops tested, soybean gave highest income. Besides increasing system productivity, soybean biomass (7–12 t ha^{-1}) when incorporated in the soil contributed 14–21.5 kg nitrogen (N) ha^{-1}, 3–3.5 kg P_2O_5 ha^{-1}, and 11–22.4 kg K_2O ha^{-1}.

Legumes in Intercropping Systems

Intercropping of short-duration soybean with maize in spring and winter, and groundnut with maize in spring have good potential for legume expansion in northern Vietnam. Groundnut and soybean can be successfully intercropped with cotton (*Gossypium* sp) and fruit trees in southern Vietnam. Intercropping these legumes with cotton increased net returns by US$ 43–50 ha^{-1}. Rotation of groundnut with rice and sweet potato in spring resulted in increase in productivity of rice by 0.36 t ha^{-1} and sweet potato by 0.9 t ha^{-1}.

National Policies and Emphasis Towards Legumes Production

Investment in legumes research and development has been very meager in the past and received scant attention of the policy makers primarily due to national priority towards attaining self-sufficiency in staple food. After attaining food self-sufficiency during 1990s, priority was diverted towards research and development of industrial and horticultural crops. The Legumes Research and Development Center was founded in 1988 at the Vietnam Agricultural Science Institute to conduct research on legumes and develop improved cultivars and production practices suitable for all ecoregions of Vietnam and to meet increasing export and local consumption demands. The Oil Plant Institute (groundnut) and Institute of Agricultural Sciences (all legumes) are also responsible for research and development in legumes in Vietnam. The Ministry of Agriculture and Rural Development (MARD), Vietnam has prepared an action plan for legumes crop improvement and rapid expansion of improved production technologies for 1999–2003 with an estimated budget of 3.3 billion VND (US$ 2.2 million). This opens up new prospects for legumes research and development program in Vietnam.

Prospects for Increasing Production of Legumes

Legumes production can be increased substantially through introduction of improved varieties and management practices. Extending legumes cultivation to rice fallows and introduction of legumes in new cropping patterns would also help increase area and production of legumes in Vietnam. Potential areas for legumes introduction are discussed below (Table 9.5 and Fig. 9.12):

- Currently in Red River Delta, rice (spring)-soybean (summer)-rice (autumn), maize-soybean-rice, and soybean-soybean-rice cropping systems are mostly practiced. Groundnut, instead of soybean or maize, is more profitable in these cropping systems since the soils are light textured.
- Farmers are currently following rice-maize-sweet potato or rice-maize cropping systems on Haplic Arenosols of North Central Coast. Groundnut has good potential instead of rice in these systems, as rice suffers moisture stress and produces low yields.
- Soybean-rice-maize system is widely practiced on midlands of Red River Delta. Introduction of newly developed medium-duration (95–100 days), high-yielding, rust resistant varieties of soybean such as DT 93, DT 84, AK 06, AK 05, and AK 04 can produce high yields. However, success of this system depends on sowing soybean by March and harvesting by early June.
- In rice-rice-fallow areas (Red River Delta), newly developed early maturing (80–85 days) and high-yielding varieties of soybean, with tolerance to cold (DT 93, AK 03, AK 02), can be introduced successfully. However, success of this system will depend on selection of short-duration (90–95 days) rice varieties and timely sowing of soybean (25 September to 10 October).
- In Bac Giang and Bac Ninh provinces farmers are following groundnut-rice cropping system. In this system, short-duration soybean (70–75 days) can be introduced successfully between spring groundnut and summer rice. However, success of this system will depend on introduction of photo-insensitive rice and short-duration, heat tolerant soybean varieties such as Cuc Luc Ngan and DT 93.
- Soil evauation in the nine agroecological zones of Vietnam clearly suggested that about 4.6 million ha is suitable for expanding legumes cultivation (Table 9.5). Groundnut can be grown successfully in 1.8 million ha and soybean and other legumes in about 2.8 million ha.
- Legumes production in these areas can be increased by: (1) introduction of legumes in rice fields with no irrigation facilities; (2) adopting legumes cultivation in rice fallows in winter after two rice crops (specially in Red River Delta); and (3) intercropping legumes with maize, cassava, sweet potato, sugarcane, tobacco (*Nicotiana tabacum* L.), cotton, coffee, tea (*Camellia sinensis* (L.) Kuntze), and pineapple (*Ananas comosus* (L.) Merr.).

Table 9.5. Land suitability for expansion of legume cultivation in Vietnam[1].

	Area ('000 ha)			
Region	S1	S2	S3	Total
North-west	48	153	49	250
North-Hoang Lien Son	27	97	80	204
North-east	33	221	260	514
Red River Delta	107	126	110	343
North-central Coast	80	110	272	463
Central Highlands	123	201	344	668
South-central Coast	139	126	202	467
North-east South	348	321	219	788
Mekong River Delta	550	238	603	896
Total	860	1593	2139	4592

1. S1 = Highly suitable; S2 = Suitable; S3 = Moderately suitable.
Source: Son (1994).

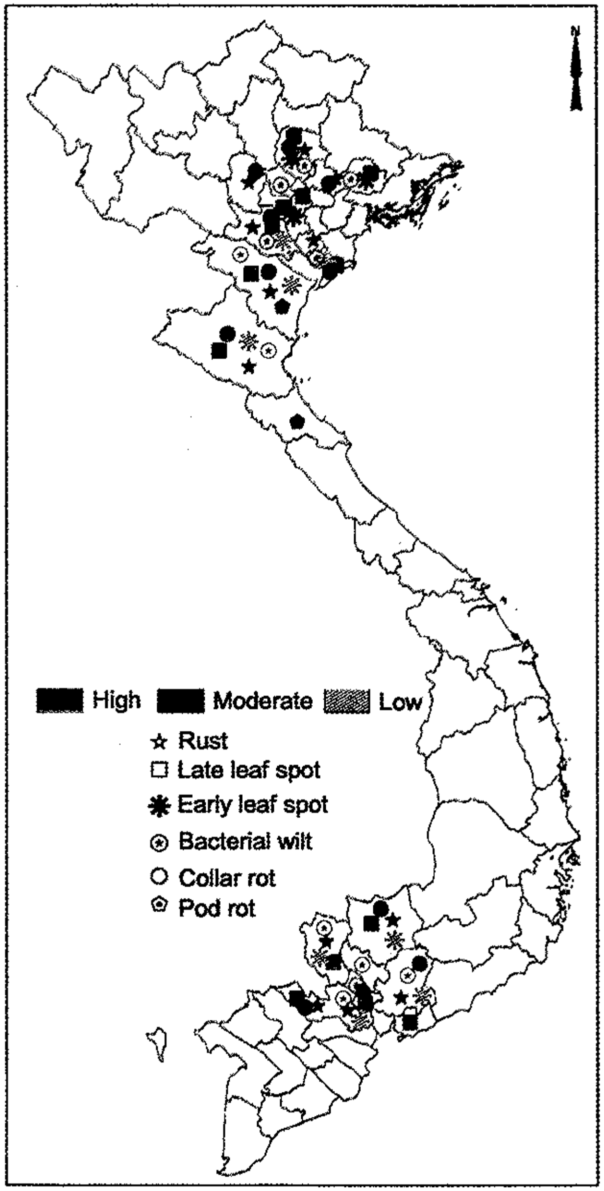

Figure 9.10. Incidence of groundnut diseases in Vietnam (Source: Hong and Mehan 1995).

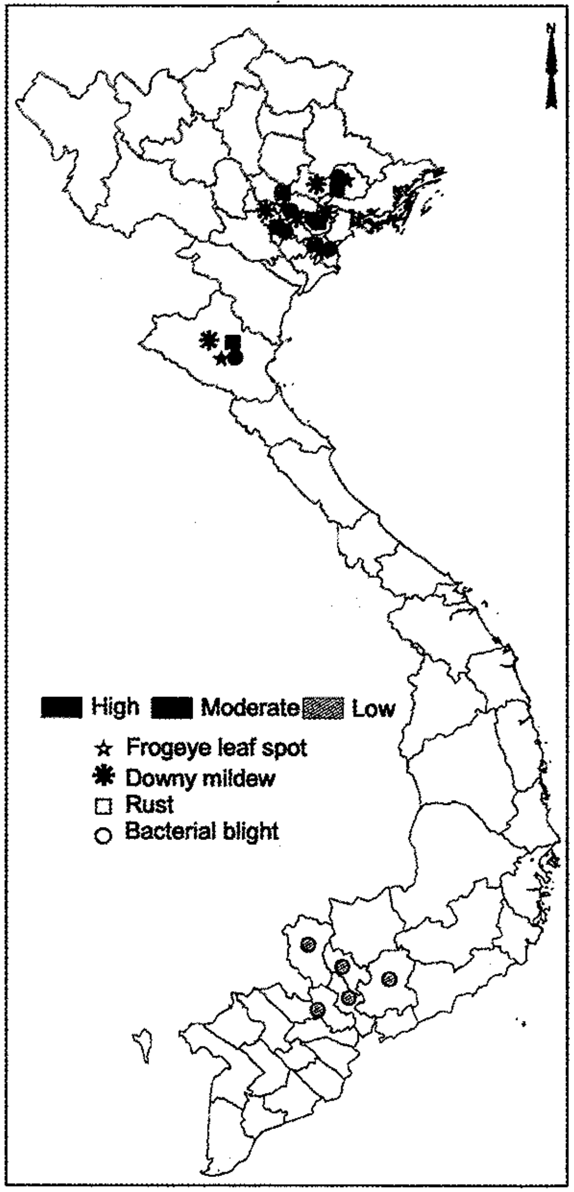

Figure 9.11. Incidence of soybean diseases in Vietnam.

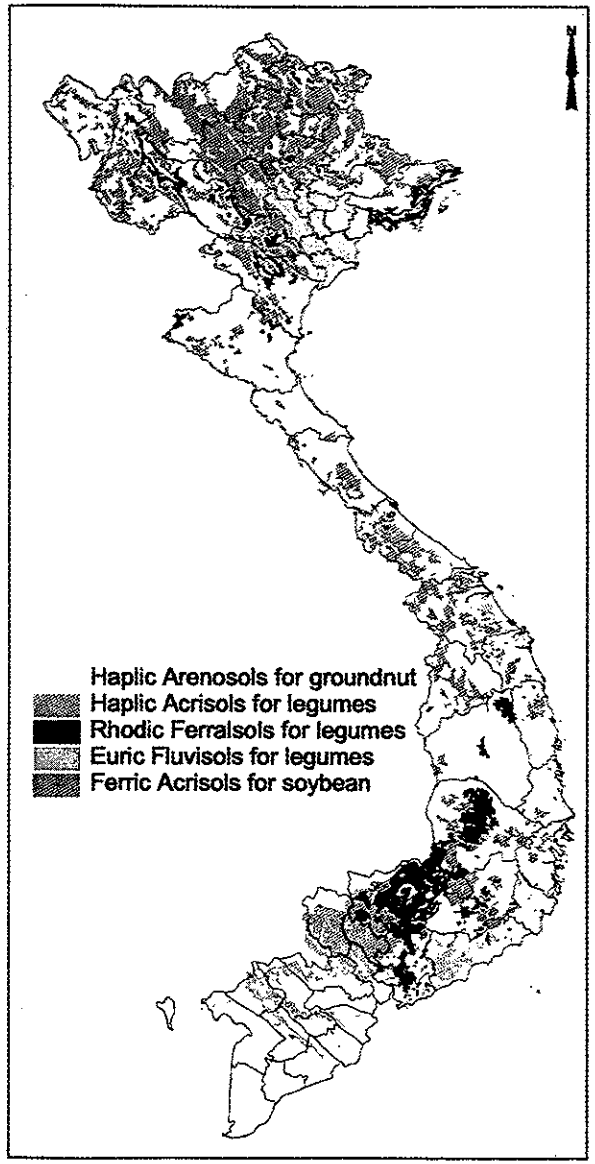

Figure 9.12. Soils suitable for legumes cultivation in Vietnam (Source: National Institute for Agricultural Planning and Projection, Hanoi, Vietnam).

Looking Ahead

Legumes area was about 1.7 million ha in 2000 and is expected to be around 2.75 million ha in 2010 (Table 9.6). Increase in area and production of legumes will occur mainly by extending legumes cultivation into new areas. But in 2010, increased production has to come mainly by yield improvement through adoption of improved production technologies.

The national legumes program is focusing on the following areas to reach the target:

- Strengthening crop improvement and production technology research extension services.
- Improved seed production and distribution system.
- On-farm research and demonstration of improved production technologies in farmers' fields.
- Enhanced infrastructure for processing and marketing.

MARD has entrusted coordination of legumes research and development in Vietnam to the Legumes Research and Development Center. This center will work in close collaboration with national (Agricultural Genetics Institute, Institute for Foodgrains and Foodstuffs, Plant Protection Institute, Oil Plants Institute, and Institute of Agricultural Sciences in South Vietnam) and international [International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Asian Vegetable Research and Development Center (AVRDC), and International Institute of Tropical Agriculture (IITA)] institutions to achieve these goals.

Conclusions

Rice, maize, and sweet potato are the main crops in Vietnam. Rice covers more than 50% of the total agricultural area. Rice-rice or rice-maize systems are predominant. Out of 6.5 million ha of rice grown in spring, irrigation facilities are not available in 2 million ha. Rice yields in these areas are very low and unsustainable (1.5–2.0 t ha^{-1}) as compared to 6–7 t ha^{-1} yields in irrigated areas. Continuous cereal monocropping is resulting in land degradation and soil quality problems. Policy makers and research administrators are now looking at the opportunities for crop diversification through legume introduction particularly in multiple cropping systems (e.g., autumn-winter crop), and intensification through intercropping (short-duration legumes with maize or with industrial crops) and crop rotations with legumes.

In coming years, the strategic goal is to develop sustainable production systems through introduction of new crops and cropping systems to make cultivation more profitable and sustainable. Development of food legumes is of high priority since the winter crop area has stagnated in potential niches (like Red River Delta) and good scope exists for increasing cropping intensity. However, legume area increase will be governed by the market price since farmers are interested in new avenues that can provide higher income.

Constraints such as lack of credit facilities, low and unstable market price, lack of high-yielding varieties with drought tolerance, disease and insect resistance and improved production practices are the main bottlenecks for legumes production in Vietnam. Legumes production can be increased substantially by addressing these production constraints, extending legumes cultivation in rice fallows and through crop diversification. There is a strong need to strengthen extension efforts to disseminate available improved legumes production technologies through on-farm demonstrations and farmer participatory on-farm research.

Table 9.6. Estimated area and production of legumes in Vietnam in 2000 and 2010.

Crop	2000 Area ('000 ha)	2000 Production ('000 t)	Annual growth rate (%)	2010 Area ('000 ha)	2010 Production ('000 t)
Groundnut	345.6	501.6	7.3	555.6	938.4
Soybean	224.7	306.3	10.6	404.5	770.4
Mung bean	280.3	282.0	9.8	413.1	561.0
Minor legumes (cowpea and beans)	850.6	1079.9	8.2	1373.0	2262.8
Total	1701.2	2169.8	9.0	2746.2	4532.6

Source: Son (1994).

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10. Regional Overview on Green Manure in Rice-based Cropping Systems

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Abstract

A large number of green manure and grain legume crops are used to improve soil fertility and increase rice production. Green manuring techniques differ in various rice-growing regions. Leguminous green manures used in rice-based cropping systems are broadly grouped as pre-rice or post-rice crops. Green manures such as Sesbania aculeata *and* S. rostrata *can also be grown as intercrops with post-rice mung bean and pigeonpea and the flood tolerant* S. rostrata *as intercrop in transplanted rice. Suitable green manures should be identified for each rice growing ecosystem for better results and benefits. Green manures widely vary in their biomass production and nitrogen (N) accumulation ability. Different green manures increase the rice grain yield to 20–114% over control. Several factors influence the extent to which green manures contribute to increased yield of rice. About 38 to 136 kg of fertilizer N ha^{-1} can be saved by green manuring with different species. The residual effect of green manuring on the succeeding crops depends upon soil type, fertility status, environmental condition, and quantity (and quality) of green manure and frequency of application. Repeated green manuring improves the soil fertility status compared to fertilizer application alone. Research on the above aspects is reviewed in this paper and the constraints to green manuring in rice-based cropping systems are discussed.*

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Introduction

Rice (*Oryza sativa* L.) is the major staple food crop globally cultivated on 150 million ha with a production of 563 million t (FAO 1998). Asia accounts for the largest growing region (134.6 million ha), with India, China, Bangladesh, Indonesia, Thailand, Vietnam, Myanmar, Philippines, Cambodia (Kampuchea), Sri Lanka, and Laos being the major producers. Rice is grown under different intensive cropping systems and in varied soil types, both as irrigated and rainfed crop. High productivity of rice and rice-based cropping systems cannot be sustained unless the declining trend in the soil fertility resulting from nutrient mining by crops is replenished adequately. In traditional rice systems, soil fertility was generally maintained by keeping the field fallow, applying organic manures and incorporating green manure grown in situ. During the last few decades, with the introduction of high-yielding, short-duration, and fertilizer-responsive rice varieties and with the supply of subsidized fertilizers to farmers, application of organic manure was overlooked. Organic manures are now regaining popularity due to increase in fertilizer costs and greater concern for sustainability of productivity. Since availability of farmyard manure is limited in rice-growing areas, green manures provide a more feasible supplement to organic matter and form a viable component of integrated nutrient management in rice-based cropping systems.

Green Manuring Practices

Green manuring involves incorporating easily decomposable green or fresh plant material into the soil to supply nutrients, particularly nitrogen (N), to the next crop or subsequent crop. It has been a traditional practice in the rice-based cropping systems in Asia. A large number of plant species have been used as green manures in rice systems. In a broad sense green manures include non-grain legumes (e.g., *Crotalaria, Sesbania,* and *Tephrosia*), grain legumes [e.g., cowpea (*Vigna unguiculata* (L.) Walp.), mung bean (*Vigna radiata* (L.) Wilczek), soybean (*Glycine max* (L.) Merr.), and groundnut (*Arachis hypogaea* L.)], woody legumes (e.g., *Leucaena, Gliricidia, Pongamia,* and *Delonix*) and weeds (e.g., *Calotropis, Ipomoea, Eichhornia,* and *Parthenium*) (Palaniappan et al. 1990, 1991).

Green manuring techniques differ in different rice-growing regions. In semi-dry, tank-irrigated rice areas of Tamil Nadu, India, rice seed is drilled under semi-dry condition during July–August. At the onset of the northeast monsoon, rice crop is brought under permanent flood, incorporating green leaf manure (Subramanian and Dorairaj 1952). However, decomposition of incorporated green matter is not uniform and often incomplete. An alternative method involves drilling sunn hemp (*Crotalaria juncea* L.) with rice and trampling the green manure crop in about two months after sowing, when the rice crop is irrigated.

Leaves of bushes such as wild indigo (*Tephrosia purpurea* (L.) Pers.), *Calotropis* sp and *Cassia* sp, collected from fallow lands were incorporated into rice fields and allowed to decompose before planting rice seedlings (Ratnam 1966). Palaniappan et al. (1990) identified the special features and suitability of different green manure crops for varied rice ecosystems (Table 10.1). Growing green manure species such as sunn hemp or dhaincha (*Sesbania aculeata* Pers.) during pre-rice summer season and in situ incorporation into soils is the normal practice in the lowland irrigated rice systems (Abrol and Palaniappan 1988).

Table 10.1. Green manure crops suitable for varied rice ecosystems.

Green manure crop	Season	Green matter ($t\ ha^{-1}$)	Special features
Crotalaria juncea (sunn hemp)	Dry/Wet	14.5	Quick growing, high biomass, easily decomposable, easy seed production.
Sesbania aculeata (dhaincha)	Dry/Wet	24.4	High biomass and nitrogen accumulation; suitable for salt-affected and problem soils.
Sesbania rostrata	Wet	22.8	Stem nodulating, well suited to waterlogged soils, suitable to grow in between two rice crops and as intercrop in transplanted rice.
Vigna trilobata (pillipesara)	Dry/Wet	15.2	Fodder and green manure; suitable for heavy clay soils.
Tephrosia purpurea (wild indigo)	Dry	8.8	Drought hardy, self seeding, keeps more foliage for long period, not browsed by cattle, suitable for light-textured soil.
Canavalia gladiata (sword bean)	Dry	13.6	Vegetable, fodder, and green manure; acts as cover crop in soil erosion proned areas.

In the Godavari and Cauvery delta areas in India, cowpea and mung bean pods are harvested at 50–60 days after sowing and the residues are used for green manuring. *Vigna trilobata* (L.) Verdc. (pillipesara) is used as forage and green manure crop. During the fallow season, it is allowed to grow for 45–50 days before it is incorporated in the soil. In some fields, the green manure is grazed, then allowed to regrow for about one month before it is incorporated. In northern India, a green manure crop, mostly *S. aculeata,* is sown after wheat (*Triticum aestivum* L.) harvest in mid-April. The green manure crop is incorporated before transplanting rice at the end of June or early July.

Inclusion of Green Manures and Grain Legumes in Rice-based Cropping Systems

Leguminous green manures used in rice-based cropping systems can be broadly grouped as pre-rice or post-rice crops (Garrity and Flinn 1988). Species such as sunn hemp, *Sesbania rostrata* Brem., *S. speciosa* Taub., *S. aculeata,* cowpea, and cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) have been used as 45- to 60-day catch crop in the pre-rice season between April and June (Lauren et al. 1998). Biomass from these legumes is incorporated into the soil, just before rice is transplanted. Wherever limited irrigation facilities are available grain legumes such as mung bean, black gram (*Vigna mungo* (L.) Hepper), cowpea, and soybean can be grown during pre-rice summer season (April–June). After harvesting pods for grain, their haulms are often used as fodder or green manure for rice (Prasad and Palaniappan 1987, Siddeswaran 1992). Post-rice green manure species include forage legumes such as *Trifolium alexandrinum* L. (Egyptian clover), *T. repens* L. (white clover), *Clitoria ternatia* L., *Desmanthus virgatus* Willd., sword bean (*Canavalia gladiata* (Jacq.) DC.), and cowpea (Meelu and Rekhi 1981, De et al. 1983, Palaniappan et al. 1991, Ladha et al. 1996). Mung bean, *T. purpurea,* and *V. trilobata* are often relay-sown in the standing rice crop 7–10 days before harvest. The residues of mung bean, after harvesting pods for grain, are incorporated before planting rice during June–July (Srinivasulu Reddy 1988). *Sesbania aculeata* and *S. rostrata* can also be grown as intercrops with post-rice mung bean and pigeonpea (*Cajanus cajan* (L.) Millsp.). While mung bean and pigeonpea are harvested for grains, the biomass obtained from the green manures is used as fodder and the regrowth can be incorporated in the soil. It will decompose in 30–40 days and serves as manure to rice (Kalpana 1992). As *S. rostrata* is flood tolerant, it can be grown as intercrop in transplanted rice and the biomass incorporated in between the rice rows, 30–35 days after planting (Padmavathy 1992).

Biomass Production and Nitrogen Accumulation of Green Manure Crops

A wide array of green manure crops was evaluated by various researchers for their biomass and N accumulation ability (Table 10.2). Individual green manures vary widely in the quantity of biomass and N accumulation. Among the conventional intercrops, *S. aculeata* has wide adaptability including problem soil conditions, whereas better performance of *S. rostrata* is restricted to long day periods (March–July), both for biomass as well as seed production, under tropical conditions (Palaniappan and Reddy 1990). Legumes such as cowpea, mung bean, black gram, and sunn hemp are very sensitive to excess moisture and flooded environments and produce more biomass under dry soil conditions (Vachhani and Murty 1964, Singh et al. 1981). Age of the green manure crop has a definite impact on its N content, with optimal level at around 45 days and declining level as the age advances (Yadvinder Singh et al. 1991).

Grain Legumes in Rice Systems

A number of grain legumes are grown in rice-based cropping systems for protein, fodder, and green manure. The practice of incorporating the stalks of

Table 10.2. Biomass production and nitrogen accumulation of major green manure crops grown in India.

Green manure	Biomass/ dry matter (t ha^{-1})	Nitrogen accumulation (kg ha^{-1})	Crop age (days)	Reference
Sesbania aculeata	23.2 (F)[1]	133	60	Sanyasi Raju (1952)
S. aculeata	5.0	108	60	Beri et al. (1989a)
S. aculeata	24.4 (F)	165	50	Palaniappan et al. (1990)
S. aculeata	2.8–9.9	81–225	50–60	Meelu et al. (1992)
S. rostrata	22.8 (F)	182	50	Palaniappan et al. (1990)
S. rostrata	22.6 (F)	152	50	Siddeswaran (1992)
S. rostrata	10.2 (F)	90	50	Siddeswaran (1992)
S. rostrata	11–18 (F)	46–73	45	Palaniappan et al. (1991)
S. rostrata	17–24 (F)	81–108	60	Palaniappan et al. (1991)
S. rostrata	-	161–227	60	Buresh et al. (1993)
S. rostrata	-	67	60	Patel et al. (1996)
Sesbania sp	-	97–149	50	Sharma and Mittra (1990)
Sesbania sp	22 (F)	113–161	50	Palaniappan et al. (1990)
Sunn hemp	2.4	63	28	Khan and Mathur (1957)
Sunn hemp	4.4	99	42	Khan and Mathur (1957)
Sunn hemp	6.6	140	56	Khan and Mathur (1957)
Sunn hemp	3.9	117	45	Palaniappan et al. (1990)
Cowpea	2.1	49	49	Singh (1962)
Cowpea	2.3–2.5	62–70	45	John et al. (1989)
Cowpea	0.6–3.6	18–69	30–60	Meelu et al. (1992)
Mungbean	1.9	42	49	Singh (1962)
Mung bean	1.1–4.7	32–136	30–60	Meelu et al. (1992)
Clusterbean	3.8	87	60	Beri et al. (1989a)

1. F = Fresh biomass.

grain legumes to rice, after harvesting their pods for grain, is a common practice in many Southeast Asian countries. Byth et al. (1987) reported that about 18 legume species are important in various rice farming situations of Asia. In the irrigated environment of tropics and subtropics, grain legumes can be grown in rotation with one or more rice crops per year (Buresh and De Datta 1991). Inclusion of grain legumes such as cowpea, black gram, and mung bean during pre-rice summer season in the rice-rice-legumes system yielded 0.5–0.7 t ha^{-1} of grain while the haulms contributed appreciable amount of N, phosphorus (P), and potassium (K) to the soil when incorporated. Mung bean, in a rice-wheat system, provided 0.9 t ha^{-1} grain and the residues supplied about 100 kg N ha^{-1} to rice soils (Rekhi and Meelu 1983).

Non-conventional Green Manures

Farmers often use the leaves and twigs of leguminous or other trees grown on the farm, avenues, and wastelands as a source of organic manures to rice. Palaniappan et al. (1993) assessed the manurial value of various tree leaves and weed species (Table 10.3). Carbon (C)-N ratio is one of the factors associated with decomposition and N mineralization rate of green manures (Palm and Sanchez 1990). Most of the green leaf collected from tree species have wide C-N ratio and high lignin content. This results in slow decomposition and release of N over a longer period of time (Buresh and De Datta 1991).

Table 10.3. Nutrient content of some non-conventional green manure sources[1].

Species	C-N ratio	Total N(%)	Total P(%)	Total K(%)
Trees (leaves and twigs)				
Azadirachta indica Juss.	70:1	2.83	0.28	0.35
Delonix elata (L.) Gamble	27:1	3.51	0.31	0.31
Delonix regia Rab.	32:1	2.76	0.46	0.50
Peltophorum ferrugineum Benth.	34:1	2.63	0.37	0.50
Weeds				
Adhatoda vasica Nees.	60:1	1.32	0.38	0.15
Parthenium hysterophorus L.	30:1	2.68	0.68	1.45
Eichhornia crassipes Solurs	29:1	3.01	0.95	0.15
Trianthema portulacastrum L.	32:1	2.64	0.43	1.30
Ipomoea carnea Jacq.	43:1	2.01	0.33	0.40
Calotropis gigantea Ait.	64:1	2.06	0.54	0.31
Cassia fistula L.	120:1	1.60	0.24	1.20

1. C = Carbon; N = Nitrogen; P = Phosphorus; K = Potassium.
Source: Palaniappan et al. (1993).

Effect of Green Manures on Yield of Crops

The efficiency of green manure crop is assessed by its capacity to raise the yield of the succeeding crop. Yadvinder Singh et al. (1991) and Becker et al. (1995) have reviewed the effect of green manures on the succeeding rice crop (Table 10.4). Soil fertility level, quantity of biomass added and its quality, time of incorporation, decomposition, and N release pattern, and fertilizer applied to the crop are some of the factors that influence the magnitude of yield increase due to green manuring.

Green manuring increased rice yield by 78% in low fertile soils compared to 22% in high fertile soils (Gu and Wen 1981). Greater response to green manures was realized in coarse-textured soil with low organic matter content (Yadvinder Singh et al. 1991). Though magnitude of yield increase is greater for lesser quantity of green manure addition, more biomass incorporation produced higher total grain yield. However, the effect was not pronounced when the biomass added was >13 t ha^{-1} (Siddeswaran 1992, Kolar et al. 1993). Time of incorporation of green manure has great influence on its efficacy as synchronization between rate of N mineralization of green manure and plant uptake is required. A decomposition period of 7–10 days is needed, under tropical and subtropical conditions before rice is planted. A transplanting delay of 15–20 days after incorporation of green manure significantly reduced rice yields (Beri and Meelu 1981, Ghai et al. 1988). Factors such as N content, C-N ratio, lignin-fiber ratio, and polyphenolic content have been found to be associated with the decomposition and N mineralization.

Inorganic fertilizer application to the green manure and to the succeeding rice crop determines the ultimate productivity level of crop or crops in the system. Conjunctive use of green manure and fertilizer N at optimum levels improved the productivity levels compared to applying either of them alone. In a rice-rice-mung bean system, inclusion of *S. rostrata*, black gram, or cowpea in the pre-rice summer season increased the productivity level of the system over the conventional rice-rice-mung bean system (Siddeswaran 1992). Total productivity of rice-wheat cropping system with green manuring (*Sesbania*, sunn hemp, and cowpea) and N at 60 kg ha^{-1} to rice and 90 kg ha^{-1} to wheat was 13.1 t ha^{-1} compared to 10.1 t ha^{-1} without green manuring.

Table 10.4. Direct effect of green manure (GM) and grain legumes (GL) on rice grain yield.

GM/GL	Crop age (days)	Rice grain yield (t ha^{-1}) Without GM/GL	With GM/GL	Yield increase over control (%)	Reference
Sunn hemp	-[1]	3.0	3.6	20	Roy et al. (1988)
Sunn hemp	-	1.8	3.5	98	Sanyasi Raju (1952)
Sesbania aculeata	66	2.6	5.6	114	Dargan et al. (1975)
S. aculeata	60	2.9	4.0	38	Ramaswami et al. (1988)
S. aculeata	60	2.7	5.8	115	Beri et al. (1989b)
S. aculeata	50	1.6	2.7	74	Tiwari et al. (1980)
S. aculeata	-	2.8	4.5	61	Srinivasulu Reddy (1988)
S. aculeata	45	1.6	3.2	104	Mann (1988)
S. rostrata	48	1.8	3.5	94	Morris et al. (1989)
S. rostrata	60	3.3	4.5	36	Bhattarai and Maskey (1996)
S. rostrata	50	3.2	4.4	38	Siddeswaran (1992)
S. rostrata	50	2.9	3.7	29	Malathi (1989)
S. rostrata	-	3.0	4.3	43	Pandey (1983)
S. cannabina	-	3.3	3.9	17	Morris et al. (1989)
S. cannabina	48	1.8	3.5	92	Bhattarai and Maskey (1996)
S. cannabina	60	3.3	4.7	42	John et al. (1989)
Cowpea	45	3.3	4.4	33	Morris et al. (1989)
Cowpea	42	2.1	4.1	95	Siddeswaran (1992)
Cowpea[2]	75	3.2	3.7	14	Siddeswaran (1992)
Black gram[2]	70	3.2	3.5	10	Siddeswaran (1992)
Soybean[2]	87	3.2	3.4	6	Siddeswaran (1992)

1. Data not available.
2. Pods harvested for grain and haulms incorporated as green manure.

Residual Effects of Green Manuring

In general, contribution of nutrients to the first crop for which green manures are applied, is comparatively higher, particularly for N, than in the succeeding crop(s) in a cropping system. However, residual effects have been observed on the second succeeding crop depending upon soil types, environmental conditions, and quality and quantity of green manure application (Meelu and Morris 1984). Hence, continued green manuring over a long period would result in significant residual effect in intensive cropping systems (Palaniappan 1992).

Lauren et al. (1998) examined more than 30 documented experiments to generalize trends on residual benefits from green manures. In rice-rice rotations, more than 50% studies surveyed recorded residual effects, while other studies reported small but significant yield increase (13–43% over control) in the second crop of rice. The reasons for lack of response are attributed to various N loss mechanisms. More definitive residual effects were evident from rice-wheat system studies. While a few researches found low responses (11–14% over control), most studies reported 15–38% increase. This variability in responses to green manuring was attributed to addition of fertilizer N, quality of green manure applied, or experimental variations.

Nitrogen Economy through Green Manuring

The benefits of green manuring are generally interpreted in terms of their capacity to substitute for inorganic N. The most common method for expressing N benefits from green manures is the nitrogen fertilizer equivalence (NFE). After considering various losses, the economy of fertilizer N through green manure ranged from 38 kg ha^{-1} to 136 kg ha^{-1} (Table 10.5). In most instances, it was around 50–80 kg N ha^{-1}. The variation in NFE reflects differences in N additions, agronomic efficiency, and N recovery.

Table 10.5. Nitrogen fertilizer equivalence (NFE) of green manure crops on rice yield.

Green manure	Crop age (days)	Nitrogen added (kg ha^{-1})	NFE (kg ha^{-1})	Reference
Sesbania aculeata	67	-	80	Dargan et al. (1975)
S. aculeata	50	80	60	Kolar et al. (1993)
S. aculeata	60	104	120	Beri and Meelu (1981)
S. aculeata	50	57	50	Bhardwaj et al. (1981)
S. aculeata	-	97–150	136	Yadvinder Singh et al. (1990)
S. rostrata	45	45–83	97	Buresh et al. (1993)
S. rostrata	50	152	47	Siddeswaran (1992)
S. rostrata	50	90	38	Siddeswaran (1992)
Sunn hemp	50	78	75	Bhardwaj et al. (1981)
Sunn hemp	-	41–70	72	Yadvinder Singh et al. (1990)
Cowpea	60	68	60	John et al. (1992)

Soil Fertility and Green Manuring

The favorable effects of different sources of plant nutrients, when integrated in a judicious manner, have been confirmed by many researchers. It has been hypothesized that legumes grown in rotation with lowland rice can intercept soil mineral N, which might, otherwise, be lost by denitrification or leaching due to flooding of soil. This helps recycling of soil N for uptake by rice (Buresh and De Datta 1991). Nutrient balance sheet of different rice-based cropping systems applied with organic sources showed a positive apparent balance of N and P and negative balance of K in almost all the cropping systems studied at Faizabad in Uttar Pradesh, India (Yadav and Kumar 1993). Addition of green manure sustained the N availability in rice soils as compared to soils without addition of organic matter. A study conducted at the Tamil Nadu Agricultural University farm in Coimbatore, India, in a heavy soil revealed that the incorporation of green manure a week before rice planting sustained the release of the inorganic N fraction (NH_4^+ and NO_3-N) up to a period of 60 days (Sivabal 1989).

In a rice-rice-mung bean cropping system, inclusion of green manure or grain legume increased the available soil N (Palaniappan and Siddeswaran 1993). It was highest (up to 254 kg N ha^{-1}) in the systems incorporating green manure, followed by grain legume; and was lowest (45 kg N ha^{-1}) when both these components were absent. Within each of these groups, available N was inversely related to the level of additional urea input (Table 10.6).

Green manure application also maintained the availability of P to rice under submerged conditions from insoluble P sources such as rock phosphate (Lekha Sreekantan 1987). Similarly, enhanced iron availability due to green manuring has also been reported under submergence (Swarup 1987).

Economics of Green Manuring

In spite of the positive influence of green manures on increased yield of crops and improved soil fertility, farmers are reluctant to devote land and resources for growing legumes solely for green manure, because it provides no immediate income or food (Buresh and De Datta 1991). The economic viability of including green manure in rice systems has been brought out by many researchers. Green manuring to either of the rice crops in a rice-rice-mung bean system increased the net returns considerably. Incorporation of grain legume haulms as organic sources gave net returns comparable to that with green manuring. Combined application of green manure and recommended fertilizer N to rice produced high net returns (Srinivasulu Reddy 1988, Sivabal 1989, Padmavathy 1992, Siddeswaran 1992).

Constraints in Green Manuring Practice in Rice-based Cropping Systems

The symposium on the "Role of green manure crops in rice farming systems" held at the International Rice Research Institute, Los Baños, Philippines outlined the beneficial effects of green manures and also identified the constraints in their use (IRRI 1988). The constraints are:

- In a high density cropping system, the situation may not induce the farmers to set apart 6 or 7 weeks exclusively for green manure cultivation without any revenue. The fallow season (summer) alone will be left

Table 10.6. Components of the nitrogen (N) balance (kg N ha^{-1}) of rice-based cropping systems (GM/GL-rice-rice-mung bean)[1].

Treatment	N added (kg ha^{-1})			N removed by crops[2]	Computed balance[3]	Final soil N	Soil net gain	I_{net}[4] (kg ha^{-1})
	Applied	Residue	Total					
Control	-	17	17	255	55	214	−79	176
50 kg N ha^{-1}	200	26	226	360	251	268	−25	135
100 kg N ha^{-1}	400	36	436	443	286	295	+ 2	45
GM alone	-	344	344	310	327	237	−56	254
GM + 50 kg N ha^{-1}	200	353	353	425	420	296	+ 3	228
GM + 100 kg N ha^{-1}	400	380	380	502	370	326	+33	135
GL alone	-	119	119	309	109	226	−67	242
GL + 50 kg N ha^{-1}	200	133	133	420	206	275	−18	202
GL + 100 kg N ha^{-1}	400	138	138	491	341	301	+ 8	99

1. N applied to rice crops (4) only; GM = Green manure; GL = Grain legume (cowpea).
2. Two manual cropping cycles of eight crops.
3. Initial soil = 293 kg ha^{-1}.
4. I_{net} = final soil N − initial soil N − added fertilizer N + amount removed by crops.

without any crop and during this period the farmers cannot think of growing any green manures for want of sufficient irrigation facilities.

- Inadequate availability of quality seeds of preferred green manure types at reduced cost is one of the major problems in the adoption of green manure cultivation.
- Incorporation of green manure is considered difficult and costly. Rarely implements and machines are used to incorporate the residues into the soil.
- Benefits of green manure addition could not be seen visually as that of the mineral fertilizer N. From the farmers' point of view, organic and inorganic sources are complementary or synergistic.
- The benefits expected from green manuring may not always be uniform in all the crops, because of the variation in the soils, green manure species, environmental conditions, etc.
- The possibility of using green manures as intercrops has its own limitations since it is believed that these intercrops may compete for nutrients with the main crops.

Conclusions

Green manures, both non-grain legumes and grain legumes, are identified as viable components for sustaining rice productivity. Their value in inorganic N substitution and soil fertility maintenance are adequately established by many research workers all over the world. Nevertheless, there is a lot of scope to improve the utilization of green manures by overcoming some of the constraints in the use of green manures in different rice-based cropping systems.

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11. Regional Opportunities for Pulses in Rice-based Cropping Systems: An Overview

A Satyanarayana[1]

Abstract

Rice is a predominant cereal crop in tropical Asia. The productivity of rice is stagnating due to continuous monocropping. Mung bean is grown in all the South and Southeast Asian countries, while black gram is predominant in rice-based cropping systems (RBCS) in India, Myanmar, and Sri Lanka. Cowpea is also grown in a limited scale in Southeast Asia under RBCS. Large areas of rice fallows are available for introducing grain legumes between two rice crops, which might bring in sustainability to production system by enriching the soil. Country presentations were aimed at quantifying scope for inclusion of pulses (grain legumes) in RBCS. It was felt necessary to identify proper genotype of pulses for RBCS. Location specific research for specific constraints by national programs and back up research for general constraints at an international institute is required to properly address the production bottlenecks in the region.

Rice (*Oryza sativa* L.) is a predominant crop in the Asia-Pacific region where 53% world population live on 30% arable land. About 90% of the world rice area is in Asia (73.7 million ha). The productivity of rice is stagnating due to continuous monocropping. Grain legumes contribute to sustainability of global food production systems by enriching the soil. Grain legumes (pulses) are the major source of dietary protein in the Asia-Pacific region. Hence, the food and nutrition security, and economic and employment security depend on the ecological sustainability of the rice-based cropping systems (RBCS) in the developing countries of Asia.

Increased irrigation potential in recent years in most of these countries has led to the increase in area under monocropping of rice replacing the traditional sustainable coarse cereals + pulses cropping systems. Growing upland crops such as pulses in RBCS offers more challenges than any other system because optimal soil conditions for rice and grain legumes differ substantially.

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From the presentations made during the workshop, mung bean (*Vigna radiata* (L.) Wilczek) is grown in all the South and Southeast Asian countries, while black gram (*Vigna mungo* (L.) Hepper) is predominant in India, Myanmar, and Sri Lanka in RBCS. Pigeonpea (*Cajanus cajan* (L.) Millsp.) is grown as a bund crop. Cowpea (*Vigna unguiculata* (L.) Walp.) is grown in RBCS on a limited scale in Southeast Asia (Table 11.1).

Table 11.1. Pulse crops grown in rice-based cropping systems in South and Southeast Asia.

Region/Country	Major pulse crops	Potential pulse crops
South Asia (India, Sri Lanka, Myanmar, Thailand)	Black gram, mung bean, lentil, lathyrus (khesari), chickpea	Cowpea, chickpea, horse gram, pigeonpea (bund crop)
Southeast Asia [Philippines, Indonesia Cambodia (Kampuchea), Vietnam]	Mung bean	Black gram, cowpea

Large areas of rice fallows can be used better by introducing short-duration pulse crops in between two rice crops. This may enhance rice yields and at the same time pulses will find a more favorable environment in the RBCS. This will increase pulses productivity, and thus the production system will be sustainable.

The country presentations aimed at quantifying the scope for inclusion of legumes in different cropping systems. The three cropping systems in different countries were: (1) rice-pulses; (2) rice-rice-pulses (both post-rice); and (3) pulses-rice (pre-rice). In all countries, the sowing time of the pulse crops was influenced by the transplanting time and duration of rice.

The constraints in pulses production under rice fallows are:

- Hard and compact soil (due to puddling) leading to poor plant stand establishment.
- Excessive moisture at the time of sowing resulting in slow initial growth.
- Moisture stress at terminal stages leading to forced maturity.
- High incidence of soilborne diseases.
- Severity of diseases and insect pests.
- Weeds and *Cuscuta* menace.
- Pre-harvest sprouting in high rainfall zones.
- Lack of proper genotypes suitable for RBCS.

The production constraints, especially the biotic constraints, are similar across the countries while the abiotic constraints are location specific. It is necessary to identify appropriate genotypes (plant type) with fast initial growth, high biomass, medium-duration, and resistance to soilborne diseases. At present the pulse crops for RBCS have a very poor research base. Location specific research for specific constraints and back up research for general constraints at an international institute is required.

The need for better understanding of adaptation of pulse crops in RBCS, biotechnological options for ideotype development, and integrated pest and disease management to overcome biotic stresses have been thoroughly discussed by different speakers.

Most of the country reports have emphasized the need to introduce mechanization for sowing to have good plant stand establishment by developing either manual or mechanical seed dibblers. Presently the sowings are done either by broadcasting or hand dibbling seed close to paddy stubbles. There is also a need to study the impact of combine harvesters for rice on the establishment and management of the pulse crop grown as relay crop.

The experience of Indonesian farmers in improving yields by mulching pulse crops with paddy straw @ 5 t ha^{-1} in RBCS should be studied and extended to other countries as this practice not only helps in moisture retention but also checks weed growth.

Lack of capital input was pointed out by all the speakers. This indicates the need for profitable technologies, and also rural credit schemes to farmers. Prices of pulses are increasing in Southeast Asia. This should make them attractive for introduction in RBCS.

Agricultural policies of the different countries should give thrust to pulse crops in view of their role in human nutritional security and sustainability of the RBCS. The national programs should increase financial support, which will be needed for research and development and technology transfer to meet the new and emerging challenges in the RBCS.

12. Opportunities for Oilseed Crops in Rice-based Cropping Systems in Southeast Asia: An Overview

S N Nigam[1]

Abstract

Groundnut, soybean, and sesame are the important oilseed crops in Southeast Asia. Opportunities for intra-regional trade exist as some countries are net exporters and the others are net importers of these commodities. Besides, there are opportunities available for global trade as well. Legumes (groundnut and soybean) have a much greater role to play in rice-based cropping systems in Southeast Asia than had been realized in the past. There is scope for increasing the area under these crops but equal or more emphasis should be given to improve their productivity in the region. Ultimately, economic benefits of the crop will be the overriding consideration for choice of the crop by the farmers. There is a strong need to prioritize the production and productivity constraints of these crops in each country of the region. Only those constraints, which have major influence on productivity and production, should receive immediate research attention.

Southeast Asia is predominantly a rice-growing region. The daily dietary requirement of fat/oil of the population has to be met either by importing these or growing oilseed crops locally. From the presentations made during the workshop, groundnut (*Arachis hypogaea* L.) and soybean (*Glycine max* (L.) Merr.) emerge as leading oilseed crops in the region. Sesame (*Sesamum indicum* L.) is also important in Cambodia (Kampuchea), Myanmar, and Vietnam. Groundnut area and production has shown an increasing trend over the years in Indonesia, Myanmar, and Vietnam and a decreasing trend in Cambodia and the Philippines. On the other hand, soybean area and production showed an increasing trend in all the countries except the Philippines. Sesame area and production also increased in Myanmar.

The trade in these crops in the region gives an indication of their potential future prospects and economic viability. Vietnam is the largest exporter of groundnut in the region. It is followed by Myanmar. Most other countries such as Indonesia, Malaysia, the Philippines, and Thailand import groundnut. Vietnam, Myanmar, and Cambodia export soybean whereas Indonesia, Malaysia, the Philippines, and Thailand import soybean. Sesame is exported by Myanmar, Thailand, Vietnam, Cambodia, and Laos, and is imported by Indonesia, the Philippines, and Malaysia. All the three commodities are imported by Indonesia, Malaysia, and the Philippines. Thailand imports only soybean and groundnut. During 1994–96, the region had surplus of sesame (247,135 t export and 29,546 t import) and deficit of soybean (17,594 t export and 46,325 t import) and groundnut (351,186 t export and 723,765 t import) (FAO 1996). Thus, clear opportunities exist for expansion of groundnut and soybean cultivation in the region.

Rapid industrialization and other economic activities have had an impact on agricultural growth and development in the region. The main focus of agricultural policy, justifiably, continues to be self-sufficiency in the staple food, rice (*Oryza sativa* L.). This has led to the marginalization of other crops due to the limited support from governments and policy makers. Recently, however, there has been an increasing awareness of the importance of legumes in rice-based cropping systems. This has opened up opportunities to expand and improve groundnut and soybean cultivation in the region. Economic returns is the major determinant of the crop choice for the farmers. In a free-trade environment, if these oilseed crops are able to maintain and improve their economic competitiveness vis-à-vis other crops, within the country and the region, their expansion in the region is inevitable.

Abiotic and biotic constraints to increased production of groundnut and soybean in different countries have been presented during the workshop. There is a need to prioritize these constraints for each country. Often in a given production system or agro-ecology, only one or two constraints predominate. For example, defoliating insects (*Spodoptera litura*) and late leaf spot (*Phaeoisariopsis personata*) were found to be the major constraints to groundnut production in Vietnam (Ranga Rao 1996). Also, leaf spot resistance was found to be the major determinant of groundnut productivity in various management systems, including low-yielding environments in USA (Kvien et al. 1993).

These major constraints should get priority research attention. In a multiple cropping situation, which generally exists in Southeast Asia, short crop duration becomes an overriding requirement for component crops of the rice-based cropping system. For both, groundnut and soybean, early-maturing, high-yielding cultivars adapted to local conditions are required for the region.

Expansion of area and increase in productivity have been suggested for increasing production of soybean and groundnut by different country representatives. While expansion in area provides a short-term solution, the long-term solution lies in increasing productivity, as this would make these crops competitive in the market and would also result in more economic benefits to the farmers.

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National average yields of groundnut and soybean in the region are low by world standard. There is a wide yield gap in realized yield at the farm level and potential yield of currently available cultivars. Immediate attention should be given to narrow this yield gap by appropriate cultural and management research. Simultaneously, efforts should continue to improve yield potential further to ensure consistent gains in the long run.

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13. Priorities for Research and Development of Legumes in Tropical Rice-based Cropping Systems of Asia

C L L Gowda, A Ramakrishna, O P Rupela, and S P Wani[1]

The country papers presented in the earlier chapters of this book have discussed the importance and role of legumes in the tropical rice (*Oryza sativa* L.)-based cropping systems in each country. These, together with the regional outlook papers on oilseeds, pulses, and green manures, provide ample insights into the current situation, trends, and future prospects for increased inclusion of legumes in the Asian tropical rice-based cropping systems. Overall, there are many similarities between the study on the role of legumes in the rice and wheat (*Triticum aestivum* L.) cropping systems in the Indo-Gangetic Plains (Johansen et al. 2000) and this study, in tropical rice-based systems of Asia. The commonalities are in terms of rice ecosystem (especially lowland, and irrigated rice) and legumes [pigeonpea (*Cajanus cajan* (L.) Millsp.), chickpea (*Cicer arietinum* L.), groundnut (*Arachis hypogaea* L.), mung bean (*Vigna radiata* (L.) Wilczek), and black gram (*Vigna mungo* (L.) Hepper)] in different cropping systems. Hence, some of the statements and conclusions in this book are likely to be common and may overlap.

Characterization of the Ecosystem

Intensive monocropping of rice is reported to be leading to productivity declines or plateauing of yields in many countries. Although not substantiated, many authors have indicated degradation of rice lands due to intensification following introduction of high-yielding varieties of rice in the mid-1960s and early 1970s, and suggested a break in the rice monocropping with an upland crop.

The characterization exercise of tropical rice ecosystem was much more difficult than envisaged in the beginning. This was due to: (i) non-availability of statistics on crop area and production and constraints (biotic and abiotic) to production of legumes, and (ii) non-uniformity in geographic information system (GIS) maps in different countries due to different sets of maps using varied softwares. The GIS workshop held in 1997 (Pande et al. 1999) helped in training the scientists of the national agricultural research systems (NARS) in the use of GIS. However, we were not fully successful in getting standard sets of maps for all countries. Legumes being secondary crops, accurate and up-to-date data were not published or readily available in many countries. However, the authors of country papers were able to assemble and report the most recent and reliable data. Due to lack of complete information, we were not able to delineate the areas/zones suitable for legumes in all the countries. Similarly, information on location and extent of soil acidity, salinity, and nutrient deficiency and toxicity was not available to delineate areas unsuited to legume cultivation. Since the maps are on GIS, we will be able to update these as and when additional information becomes available.

Policy Issues

The regional and country papers presented in this volume, and the earlier volume on scope for legumes in the Indo-Gangetic Plain (Johansen et al. 2000) clearly indicate the excellent opportunities for increased inclusion of legumes in the rice-based cropping system. It is evident that water for rice cultivation is becoming scarce, and we need to incorporate crops that have high water-use efficiency (WUE), such as the legumes and other upland crops. However, policy support for non-staple crops (such as legumes) is not very encouraging. Some national governments have emphasized crop diversification to increase WUE and also as a means of widening the food basket (with many diverse crops) and for sustainability of the production system. But, the efforts are dispersed and disjointed to show the needed impacts in crop diversification. There are many success stories of introducing and/or increasing the area and production of legumes in many countries (Muehlbauer et al. 1998, Johansen et al. 2000). The success was due to suitable crop varieties, management practices and policy support by governments to reduce or partially alleviate the production constraints. We should learn from these and implement the elements that provided impetus for success in legume adoption in those countries.

As clearly enunciated by Palaniappan et al. (this volume), the potential of green manure crops in improving soil fertility and reducing the need for chemical fertilizers is immense and needs consideration by policy makers. However, adoption of green manuring by farmers is low. There is need to consider production of nitrogen-rich organic material in situ by growing fast growing nitrogen-fixing green manure crops on the farm bunds. This is becoming much more relevant as the cost of chemical fertilizers is increasing. Both grain legume and green manure species have a major role in sustainable agriculture, and need support (such as for seed multiplication and supply) by governments in all countries.

Global trade under trade liberalization will have a bearing on prices for legumes. Countries that produce legumes at lower costs will have the competitiveness to survive. Hence, it is essential for governments to provide policy

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support, and infrastructure to achieve cost effectiveness in production. Policies that promote rural credit facilities, better road and transport to bring the produce to markets at low cost, storage infrastructure, small scale and cottage industries for postharvest handling and processing are essential. Emphasis and policy support is also needed for providing appropriate machinery for sowing (to ensure optimum plant stand) and harvest (to reduce postharvest losses). Consumers' eating habits are changing, driven by urbanization. Hence value addition by processed foods will not only increase the demand for legumes, but also improve the health of people, especially children and women.

Research Needs

Despite the spectacular progress in crop improvement during the last two decades, legumes are still not as high-yielding as the cereals. Possibility of hybrid cultivars in pigeonpea has provided a limited yield advantage, but hybrid production in other legumes is only a distant possibility. Hence, efforts should be to improve the yield potential through ideotype breeding. Concerted efforts are needed to design crop improvement strategies to improve the yield levels of legumes to become competitive with cereal crops. On the other hand, efforts should continue to breed short-duration varieties to fit into cropping system niches in rice-based systems, without unduly affecting the yield levels. Considering the various stresses faced by legumes, the following traits need to be incorporated in different agroclimatic areas: (i) resistance to prevailing diseases and pests, (ii) increased ability to fix nitrogen under stress conditions, (iii) tolerance to waterlogging (early in the season) and drought tolerance (late in the season), (iv) resistance to shattering and pre-harvest sprouting, (v) fresh seed dormancy, and (vi) tolerance to acidity, salinity, and other soil toxicities. It is difficult to incorporate all the traits mentioned above, but the aim should be to incorporate essential tolerance/resistance in varieties for the given agroclimatic conditions. Using sophisticated techniques in molecular biology, it should now be possible to transfer desirable characters using marker-assisted selection for accelerated breeding. With emphasis on processed and value-added products in the future, quality traits of individual legumes will be important in high-yielding varieties.

A few national programs are still weak and are in early stages of development, especially for research on legume improvement and management. Therefore, stronger NARS and international agricultural research centers and programs should help the weaker NARS to develop and strengthen their base for legumes research and development. Research to refine technologies to suit local conditions and meet farmers' needs is a continuous need in all countries to meet the emerging challenges to legumes production. Similarly, research to provide resource conservation technologies (zero or minimum tillage) and machinery and management practices to reduce demand for labor are essential to mechanize and commercialize legume cultivation. Other research needs are listed by Johansen et al. (2000).

Development Needs and Activities

Although the current potential yields of legumes is around 3–5 t ha^{-1}, the average yields across Asia is only around 1 t ha^{-1}. Hence, the yield gap is 2–4 t ha^{-1} among different legumes (Johansen and Nageswara Rao 1996). With proper planning and policy support the productivity of legumes can be improved by good crop husbandry. Farmer participatory on-farm research is appropriate to generate and refine technologies to meet the needs of farmers in different agroecosystems (Gowda et al. 1993). Researcher-extension-farmer linkages should also be strengthened to popularize necessary technologies and information and to get feedback for supportive and backup research. Similarly farmer-trader-processor linkage is essential, with necessary government support to ensure proper pricing, transport, processing, and distribution of legumes and legume products. This will provide the necessary conduit for legumes' demand that in turn will keep the prices at a profitable level for farmers.

One of the major constraints to adoption of improved varieties reported by farmers is the non-availability of quality seed of improved varieties. Efforts of government seed corporations and distribution agencies are geared towards the major staple cereals and commercial crops. It is therefore necessary to develop institutional mechanisms and strategies for seed production and distribution of improved legume varieties. Involvement of non-governmental organizations (NGOs), and farmers' organizations and cooperatives is necessary to ensure supply of quality seeds at a reasonable cost and at proper time. This also needs involvement of farmers (especially women farmers) in seed production and storage at community or village level. Similarly, supply of other inputs such as fertilizers, pesticides (biological and chemical), machinery, and irrigation should be improved.

Public sector extension system is either weak or not efficient in many countries. On the other hand, many NGOs and the private sector are becoming involved in rural development activities, including technology transfer. Hence, both NGOs and private sector should be partners in development activities. Efforts should be towards intensification of legume production in traditional areas (to enhance sustainability) and extending legumes to non-traditional areas (to improve land use, e.g., by using legumes as intercrops in new plantations).

Conclusions

Demand for legumes is increasing in most countries. However, production is not keeping pace with the demand although there are regional production increases in some countries (such as black gram in Andhra Pradesh, India). Many South and Southeast Asian countries are importing legumes to meet the local demand. There are ample opportunities and good scope for increasing the area and production of legumes in the rice-based cropping system in all tropical Asian countries. Emphasis should be on both varietal improvement and agronomic management, including development of new crop ideotypes and bridging the yield gap. "Food Legume Councils" that involve farmers, traders, and processors should be created in each country, by levying tax on legumes and legume products, to support research and development (Gowda et al. 2000). This strategy of enhancing research and development of legumes has succeeded in countries such as Australia and Turkey. Overall, a concerted effort involving public sector, private sector, NGOs, and farmers' organizations is essential to enhance legume production to improve human health and sustainability of rice-based cropping systems in Asia.

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About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.