# Sowing Seeds in Lab and Field

## Socioeconomic Impact of the Lao-IRRI Rice Research and Training Project

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Lao-IRRI Project

National Agriculture and Forestry Research Institute

IRRI International Rice Research Institute

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of the 15 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (CGIAR – www.cgiar.org).

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The responsibility for this publication rests with the International Rice Research Institute.



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# Contents

# Foreword

It is my great pleasure to take this opportunity to address the significance of the Lao-IRRI Rice Research and Training Project to rice production in the Lao People's Democratic Republic (Lao PDR). In the 15 years since the International Rice Research Institute (IRRI) arrived—with generous financial support from the Swiss Agency for Development and Cooperation (SDC)—rice production in Lao PDR has taken impressive steps forward. The increase in production—largely attributed to the adoption of Lao modern varieties—has been valued at US$8–19 million per year. Households adopting these varieties now have more than triple the cash income of households growing traditional varieties. These substantial improvements in food security have helped reduce poverty. Just as important, the project has helped develop a critical mass of well-trained research and extension personnel who staff a fully functional, independent rice research system spread across the country. .

Over 15 years, IRRI and Lao scientists, extension workers, and Lao farmers have worked tirelessly. Together, they have developed packages of technologies that help farmers produce more rice. This increased production means that not only do people have more rice to eat and better incomes, but also that Lao PDR's national revenue has improved. In 1990, total paddy rice production was 1.5 million tons. By 2005, this had increased more than 70% to 2.6 million tons.

On behalf of the Ministry of Agriculture and Forestry as well as Lao people across the country, I would like to acknowledge SDC, IRRI, the National Agriculture and Forestry Research Institute, and, most of all, the rice farmers of Lao PDR for their role in this rice revolution.

**Mr. Sitaheng Rasphonh**
*Lao Minister for Agriculture and Forestry*

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We particularly appreciate the valuable information provided to us by farmers and alumni of the Lao-IRRI Project who have devoted a generous amount of time to answering questions during the survey.

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# Acronyms

| | |
|---|---|
| ACIAR | Australian Centre for International Agricultural Research |
| ADB | Asian Development Bank |
| AGDP | agricultural gross domestic product |
| ARC | agricultural research center |
| BPH | brown planthopper |
| CIAT | Centro Internacional de Agricultura Tropical |
| CSIRO | Commonwealth Scientific and Industrial Research Organization |
| CURE | Consortium for Unfavorable Rice Environments |
| DAFO | District Agricultural and Forestry Offices |
| DOA | Department of Agriculture |
| FAO | Food and Agriculture Organization of the United Nations |
| GDP | gross domestic product |
| GIS | geographic information systems |
| GOL | Government of Lao PDR |
| HRD | human resource development |
| IBSRAM | International Board for Soil Research and Management |
| ICRAF | International Center for Research in Agroforestry |
| INSURF | International Network on Soil Fertility and Sustainable Rice Farming |
| IPM | integrated pest management |
| IRRI | International Rice Research Institute |
| Lao PDR | Lao People's Democratic Republic |
| LEAP | Lao Extension for Agriculture Projects |
| LECS | Lao Expenditure and Consumption Survey |
| LIRRTP | Lao-IRRI Rice Research and Training Project |
| LMVs | Lao modern varieties |
| MAF | Ministry of Agriculture and Forestry |
| MVs | modern varieties |
| NAFRI | National Agricultural and Forestry Research Institute |
| NAFES | National Agricultural and Forestry Extension Service |
| NPK | nitrogen, phosphorus, and potassium |
| NRRP | National Rice Research Program |
| NTN | Namtane |
| OMVs | other modern varieties |
| PAFO | Provincial Agricultural and Forestry Office |
| PNG | Phone Ngam |
| SDC | Swiss agency for Development and Cooperation |
| TDK | Thadokkham |
| USDA | United States Department of Agriculture |
| TSN | Thasano |
| TVs | traditional varieties |
| UNDP | United Nations Development Programme |
| UNWFP | United Nations World Food Program |

# Executive summary

The Lao-IRRI Rice Research and Training Project (LIRRTP), funded by the Swiss Agency for Development and Cooperation (SDC), was established in 1990 to help the government of Lao PDR to achieve rice self-sufficiency on a sustainable basis. The LIRRTP, also known as the "Lao-IRRI Project," has a broad-based mandate to help develop improved rice technologies by undertaking research, setting up a functional rice research system, and enhancing the scientific and managerial skills of national staff. In collaboration with the National Agricultural and Forestry Research Institute (NAFRI), the Lao-IRRI Project has developed technology packages consisting of improved varieties and complementary crop management practices. The project has also played a key role in the institutional development of the research systems and research capacity building.

This impact study reports on the impact of the Lao-IRRI Project at the farm and national levels. The major impact indicators considered are increases in rice production and income, and the rate of return on investment. These impacts are evaluated at the farm, regional, and national levels. Other dimensions of impact included are related to gender, ethnicity, biodiversity, and the environment. In addition, impact of the Lao-IRRI Project on the institutional development of research systems and capacity building is assessed. The assessment of these impacts is based on the analysis of national trends in rice production, farm survey data collected from all three regions of Lao PDR, and a survey of trainees. The rates of returns on investment are assessed using the multiperiod framework of investment analysis (i.e., benefit-cost analysis).

The impact assessment clearly shows that the Lao-IRRI Project has generated substantial impact during its operation. Some of these impacts are likely to increase further as improved technologies become widely disseminated. The major highlights of achievements are as follows:

- Total rice production increased from 1.5 million tons in 1990 to 2.5 million t in 2004, an increase of 70%. Most of the production growth was achieved after 1995, when improved technologies from the Lao-IRRI Project became increasingly available. Production grew at 7.3% per annum during 1996-2004.
- The estimated gain in production for 2004 that could be directly attributed to the Lao-IRRI Project is 226,000–282,000 tons. The value of this increased production is US$26–32.4 million at the farm-gate price of $115 per t. Over 70% of the increased production originated from the central region.
- Underpinning productivity growth has been the adoption of modern varieties (MVs) of rice. These MVs are adopted by 80% of the surveyed households and planted in 69% of the rice area. Almost all rice area in the dry season and 65% of the wet-season rice area are planted to MVs.
- The central region, accounting for more than 50% of the total rice area, has the highest adoption rate. Almost all households (over 95%) grow MVs, which account for over 86% of the total rice area.
- The Lao modern varieties (LMVs) developed by the Lao-IRRI Project account for 51% of the total area under MVs. LMVs dominate rice area in the dry season in all three regions (70%).
- TDK 1 and 5 and PNG 1 and 2 are the most commonly adopted LMVs. TDK 1 and TDK 5 are mostly cultivated in the central and southern regions. Phong Ngam 1 and 2 are almost exclusively grown in the southern region.
- The improved crop management practices recommended by the Lao-IRRI Project have also been widely adopted. These commonly adopted practices are improved nursery bed preparations, closer plant spacing (20 × 20 cm), fertilizer application, and the use of machinery for land preparation.
- The central region has the highest adoption rate of crop management practices. Over 50% of the farmers used inorganic fertilizer and 80% reported having used farmyard crop residue to replenish plant nutrient in this region.
- Overall, LMVs outyield the traditional varieties (TVs) and other modern varieties (OMVs) developed outside Lao PDR in neighboring countries. The yield advantage of LMVs is 29% and 19% over TVs and OMVs, respectively. This yield advantage of LMVs over OMVs indicates that the varieties developed by the Lao-IRRI Project are better adapted to Lao conditions. These percentage gains in yield translate into absolute increases in yield of over 600 kg per ha relative to TVs and 400 kg per ha relative to OMVs.
- LMVs are not only higher yielding but their yield stability is also higher than that of TVs and OMVs.

- The availability of irrigation and photo-period-insensitive short-duration varieties has contributed to the intensification of rice production through double cropping. Some 24% of the households are engaged in dry-season rice production, with most of the expansion in area occurring since 1995. The rice-cropping intensity due to the second rice crop is 113%. LMVs are the dominant rice varieties used in the dry season.
- Farmers who grow LMVs have approximately $42 per ha higher net returns than those who grow TVs and OMVs. This represents an increase in net returns of about 20% over other groups of varieties. The yield difference is the main factor driving this gain in net returns.
- Household self-sufficiency in rice has improved over time. Among the surveyed households, approximately 77% reported being self-sufficient in rice. Self-sufficiency is higher among MV adopters (82%) than among nonadopters (58%).
- Overall, the cash income from rice is 77% higher for adopters of MVs than for non-adopters.
- Proportionately more MV adopters reported improvements in general household welfare than nonadopters.
- Improved technologies developed by the Lao-IRRI Project are gender-neutral, with male- and female-headed households benefiting equally. Rates of adoption of MVs and yields are invariant between male- and female-headed households.
- The central region of Lao PDR has benefited the most from improved technologies, with the northern region benefiting the least. Thus, some regional bias favors lowland rice, which is the dominant ecosystem in the central and southern regions. Ethnic groups that inhabit mainly the northern region have benefited less because of this regional bias.
- The Lao-IRRI Project (along with related projects supported by SDC) has made a substantial contribution to the conservation of rice biodiversity. This includes a germplasm collection of over 3,000 landraces, establishment of a germplasm bank, documentation of indigenous knowledge regarding traditional varieties, and promotion of *in situ* conservation. Lao PDR is the second largest contributor to the International Rice Genebank maintained at IRRI.
- The investment in technology development shows a healthy rate of return, even under conservative assumptions about the extent of economic benefits. The net present value of investment in the Lao-IRRI Project is estimated to be $60 million at the 10% discount rate.

- Overall, the investment in the Lao-IRRI Project is estimated to pay off at the compound rate of 26% per annum over the period 1990-2020. The benefit-cost ratio is 7:1, indicating that, for every dollar invested in the project, the Lao economy is reaping a benefit of $7.
- The Lao-IRRI Project has made a substantial contribution to the establishment of a fully functional rice research system in Lao PDR. This includes the establishment of a network of 13 research stations and the development of a well-trained cadre of research scientists and managers. During 15 years of its operation, this project provided over 4,600 training slots, which include higher-degree training, short courses, on-the-job training, and participation in international conferences/seminars. This cadre of trained staff is now providing scientific and management leadership in the agricultural research system of Lao PDR. The composition of the training program has also shown a good gender balance. The research system of Lao PDR is now at the stage of development at which it can fully participate in regional research initiatives and consortia. In fact, this is already happening, with Lao PDR being identified as a key site for rice research in uplands under the Consortium for Unfavorable Rice Environments.

# 1. Introduction

The Lao-IRRI Rice Research and Training Project (Lao-IRRI Project) was established in 1990. It has been in operation for 15 years (1990-2005), with funding support of the Swiss Agency for Development and Cooperation (SDC). The Lao-IRRR Project was established to help the government of Lao PDR achieve the national goal of self-sufficiency in rice on a sustainable basis. The main objectives of this project are to increase rice production by undertaking rice research and enhancing the skills of Lao scientists. The research and training components are complementary and are considered essential for sustainable development of the sector and productivity growth.

The Lao-IRRI Project is in the fifth and final phase of implementation. The project is highly regarded by the national research system for its contribution to increases in rice production and the establishment of a functional research system in Lao PDR. Using quantitative analysis, an impact assessment commissioned in 2002 found the economic impacts to be substantial (Shrestha 2002). Farm-level impact estimated in that study was, however, based on a limited survey from the central and southern regions of Lao PDR and did not include the impact of the Lao-IRRI Project on other aspects such as gender, ethnicity, biodiversity, and the environment.

The current study was commissioned by the Lao-IRRI Project for a more complete assessment of the project impact considering all regions of the country and including economic and other dimensions of impact. The objectives of the study are as follows:

1. Assess the impact of the Lao-IRRI Project in increasing the production of lowland rice at the national level.
2. Assess the contribution of the project in establishing a functional rice research system.
3. Assess the impact of training activities undertaken by the project in building research capacity of Lao scientists and research managers.
4. Assess the farm-level impact of improved technologies, taking into account differential impact on gender, ethnicity, regional balance, biodiversity, and the environment.
5. Estimate the overall economic rate of returns to investments made in the Lao-IRRI Project.

The report is organized as follows. The first two sections provide an introduction and general overview of the Lao-IRRI Project. The analysis of rice production patterns in the country and the importance of rice are discussed in the subsequent part. This is followed by a description of the methodology employed for impact assessment and data collection procedures. The results of impact assessment are discussed subsequently. A summary of the findings is included in the concluding section.

Obviously, many factors have contributed to the increased rice productivity in Lao PDR. The government's commitment to increasing production, the changes implemented in the national agricultural research systems that are conducive to research, the introduction of supportive agricultural policies, and investments in irrigation are some examples. These factors have facilitated the diffusion of technologies developed by the Lao-IRRI Project in collaboration with NAFRI. It is neither possible nor desirable to separate out the impact of these individual factors and the many institutions involved in the development of agriculture in Lao PDR. The approach taken is to assess the overall impact of this collaboration in which the project has played a critical role.



# 2. Overview of the Lao-IRRI Project

During the 1970s and 1980s, rice production growth in Lao PDR was sluggish. The Green Revolution that led to rapid increases in rice productivity in other Asian countries seemed to have bypassed Lao PDR. The country was suffering from a food deficit, especially during flood and drought years. National capability to conduct rice research for developing improved technologies and adapting technologies from other countries was also weak. There was clearly a need to increase rice production rapidly and achieve the national goal of self-sufficiency in rice—the staple food of the population. The Lao-IRRI Project was established in 1990 with funding from the Swiss Agency for Development and Cooperation (SDC) to help the government of Lao PDR achieve the goal of rice self-sufficiency on a sustainable basis. In May 1987, the government of Lao PDR and IRRI signed a memorandum of understanding to undertake scientific and technical cooperation in research on rice and rice-based farming systems. In June 1989, SDC approved a grant. The project began in August 1990.

Figure 1 provides a picture of the organizational setup and broad coverage of research activities of the project. The Lao-IRRI Project is implemented through the National Rice Research Program (NRRP) of the National Agricultural and Forestry Research Institute (NAFRI). IRRI manages the project and has provided the scientific leadership for most of the project duration. An internationally recruited team leader based in Vientiane provided the overall research direction and leadership. Two agronomists, one each for lowland and upland, were also hired to work in the Lao-IRRI Project. In addition, an agronomist

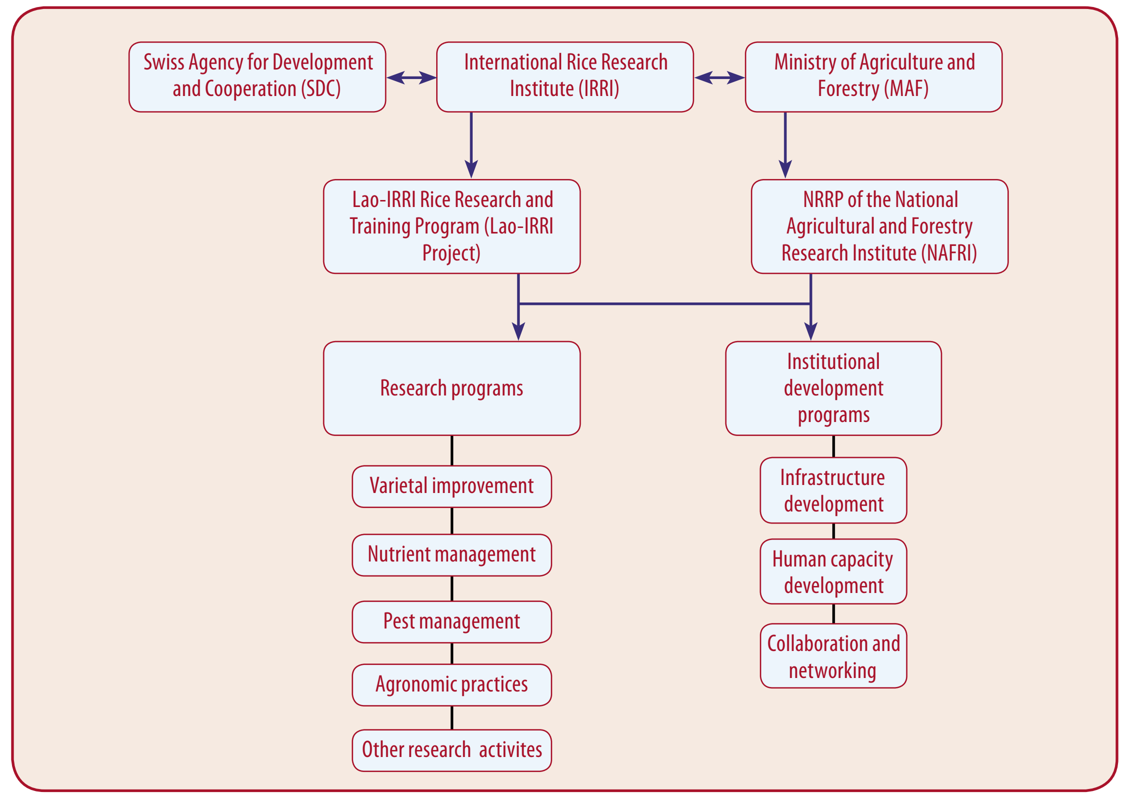



**Fig. 1. Organizational flow chart of the Lao-IRRI Project.**

supported directly by SDC was also placed in the project for two years (2001-03). Scientists based at IRRI headquarters in the Philippines also provided the required technical support.

During its 15 years of operation in five project phases, the total amount of financial support to the Lao-IRRI Project provided by SDC was approximately $16 million (Table 1).

**Table 1. Funding support from SDC for the Lao-IRRI Project, 1990-2005.**

| Phase | Date | Funding support (US$, millions) |
|---|---|---|
| I | Aug 1990-June 1993 | 2.91 |
| II | July 1993-June 1996 | 3.54 |
| III | June 1996-June 2000 | 4.57 |
| IV | July 2000-June 2003 | 2.80 |
| V | July 2003-Dec 2005 | 2.17 |
| Total funds | | 15.99 |

Source: Lao-IRRI Project (2005a).

## 2.1. Institutional Setup for Rice Research and Technology Development

The National Rice Research Program (NRRP) is a management body set up within NAFRI to oversee the overall development of the rice sector in the country. The Lao-IRRI Project is implemented through this program.

The specific objectives of NRRP are to ensure that

- rice research and technology development in the country are relevant and consistent with the overall development goals;
- new linkages with the extension agencies are developed, and new pathways for wider dissemination of research findings are established;
- national and international agencies working in the rice sector function in a coordinated manner; and
- the Ministry of Agriculture and Forestry (MAF) and NAFRI are kept updated on development in the rice sector.

Rice research in Lao PDR is conducted by various national, regional, and local organizations with NRRP being the overall umbrella organization that carries out the oversight and coordination functions. The Agricultural Research Center (ARC) and the National Agricultural and Forestry Resource Center (NAFReC) are the national-level organizations for conducting rice research. The Northern Agriculture Research Center, Thasano Rice Research and Seed Multiplication Center, and Phone Ngam Rice Research Center are the regional research centers located in the northern, central, and southern regions, respectively. The Provincial Agricultural and Forestry Offices (PAFO) and District Agricultural and Forestry Offices (DAFO) conduct adaptive research and help disseminate technologies. The research organizational setup is illustrated in Figure 2.

## 2.2. Overview of Rice Production Constraints

Various constraints have been identified as critical to rice productivity enhancement in Lao PDR. These can be grouped as abiotic, biotic, and socioeconomic. Abiotic factors include drought, flood, cold temperature, and poor soil fertility. Biotic factors are insects, diseases, and weeds. The socioeconomic factors include labor shortages and lack of access to credit and markets. For example, the top three production constraints identified by farmers in several districts (e.g., Nasaythong, Phonehong, Sayabouly, and Champassak) for the wet and dry seasons are listed in Table 2.

With most production based on rainfed ecosystems, it is vulnerable to climatic variability[1] (Pandey 2001). At the national level, annual droughts and floods are the most serious constraints to rice cultivation throughout the central and southern regions. Regular flooding of the Mekong River affects 10% to 30% of the rice area in the southern and central regions. Savannakhet Province in the central region suffers the most from early or late-season drought almost every year. Late-season drought alone can reduce grain yield by 30% (Fukai et al 1998). In the upland environment, drought at seeding is an important production constraint. In addition, a

[1]The rainfed ecosystem (lowland and upland) accounts for over 80% of the total rice area and production. Rainfed lowlands are the dominant ecosystem in the central and southern regions. The upland ecosystem dominates in the northern region (for details, see Section 4).



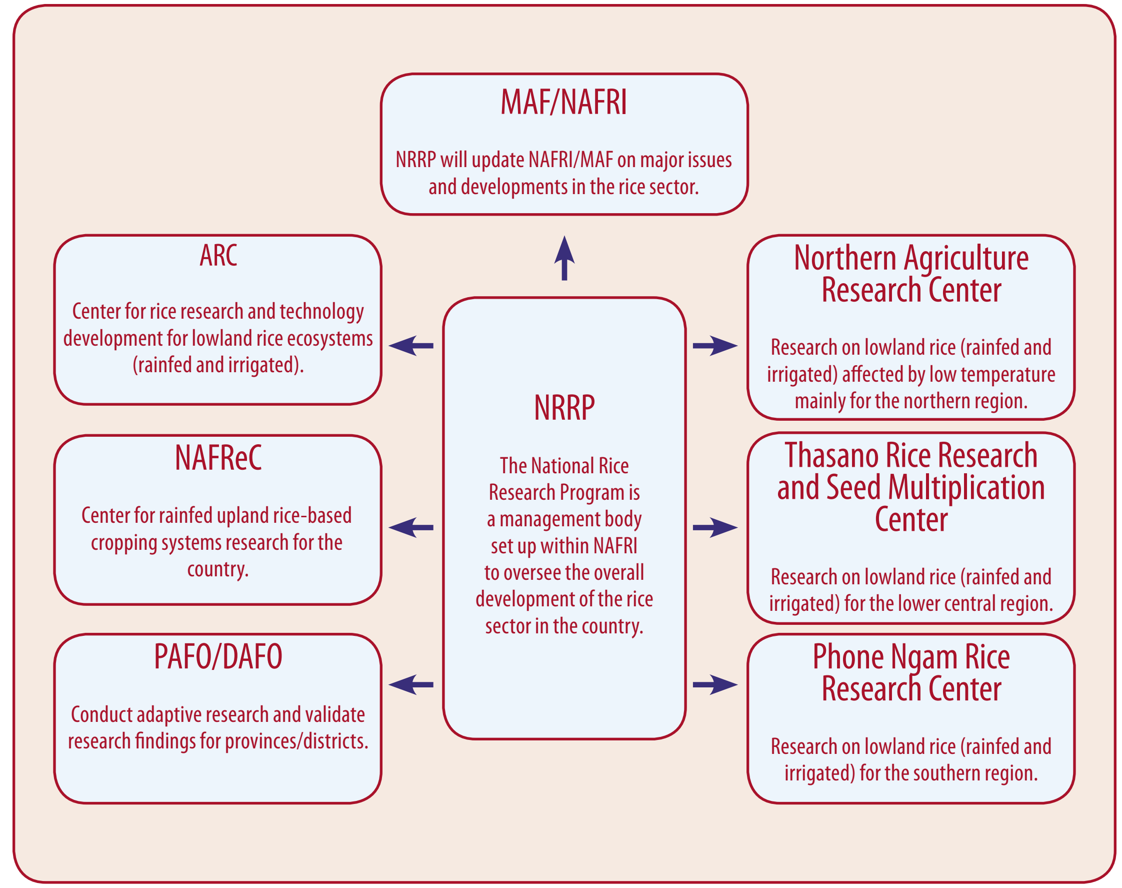



**Fig. 2. Research organizational setup in Lao PDR. Source: Shrestha (2004).**
Note: Research stations are spread across 17 provinces conducting location-specific adaptive research (see Section 7.2).

**Table 2. Farmers' ranking of the three most important constraints to rice production.**

| Province | Ranking of production problems | | | | | |
|---|---|---|---|---|---|---|
| | Wet season | | | Dry season | | |
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Vientiane Municipality | Drought | Weeds | Insects | Weeds | Insects | Labor shortage |
| Vientiane | Insects | Drought | Weeds | Water shortage | Insects | Weeds |
| Khammouane | Drought | Insects | Weeds | Weeds | Insects | Labor shortage |
| Savannakhet | Drought | Crabs and snails | Weeds | Insects | Weeds | Soil fertility |
| Saravane | Drought | Insects | Weeds | Weeds | Labor shortage | Soil fertility |
| Champassak | Drought | Insects | Weeds | Credit | Labor shortage | Weeds |
| Sayabouly | Drought | Insects | Weeds | n.a.[a] | n.a | n.a. |

[a]n.a. = not available.
Source: Schiller et al (2001a).

short fallow is one of the major causes of low yields.

Biotic constraints (insects and diseases, and weeds) are ranked as the most serious constraints affecting rice production in the uplands and the third most serious among lowland farmers (Schiller et al 2001a). Brown planthoppers, stem borers, rice bugs, golden apple snails, gall midge, and white grub (particularly in the drought period) are some of the insect pests reported to result in significant crop losses during both the wet and dry seasons. Blast, bacterial leaf blight, brown spot, bakanae in lowlands, and nematodes in uplands also reduce yields substantially. With increasing rice-cropping intensity in lowlands, and shortening fallow periods in uplands, these factors have become more constraining over time. In the upland ecosystem, weeds and rodents are the two major biotic constraints that result in significant economic losses (Fig. 3).

### 2.3. Research Program Under the Lao-IRRI Project and Its Evolution

The Lao-IRRI Project established a systematic rice research program to examine production constraints. The research program focused on varietal enhancement and development of complementary crop management practices for achieving higher and more stable yield of rice. The main research themes are summarized in Table 3 (for details, see Appendix 1).

At the start of the Lao-IRRI Project, a major investment was made to establish research infrastructure such as laboratories, research farms, and office buildings. The required scientific equipment and vehicles were purchased. A regional network of research stations was established. Thematic research began subsequently. Lao scientists received training on various aspects of rice science and research management. Research activities increasingly moved from research stations to farmers' fields. As the project approached its final phases, increasing emphasis was placed on rapid dissemination of technologies and on ensuring a smooth transition of research to the national system. Figure 4 summarizes the evolution of the project from the initial stage of infrastructure building, establishment of research programs, regionalization of research, and technology validation and dissemination to the handover to the national system.

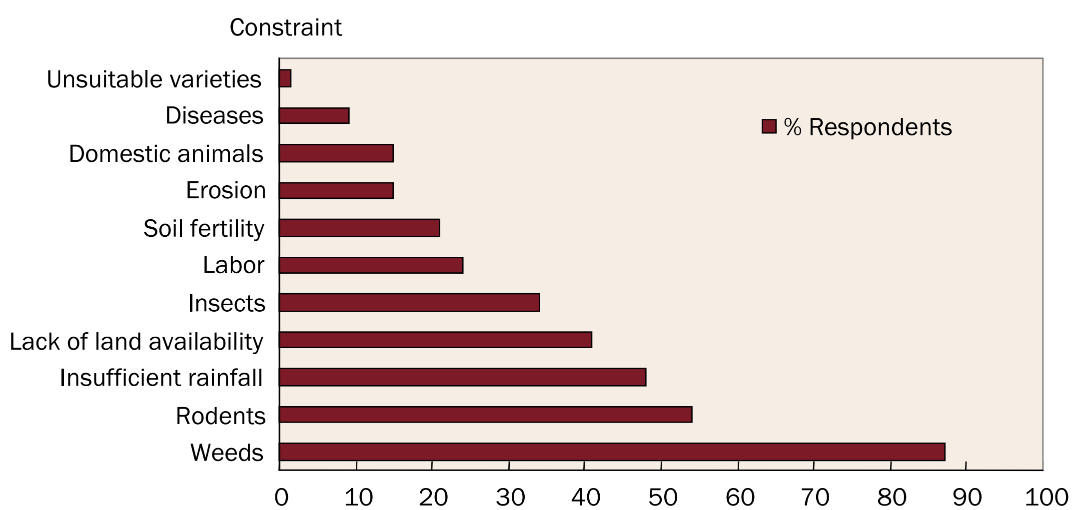



**Fig. 3. Farmers' perceptions of major constraints to upland rice production systems.** Source: Roder (2001).

[1]The rainfed ecosystem (lowland and upland) accounts for over 80% of the total rice area and production. Rainfed lowlands are the dominant ecosystem in the central and southern regions. The upland ecosystem dominates in the northern region (for details, see Section 4).

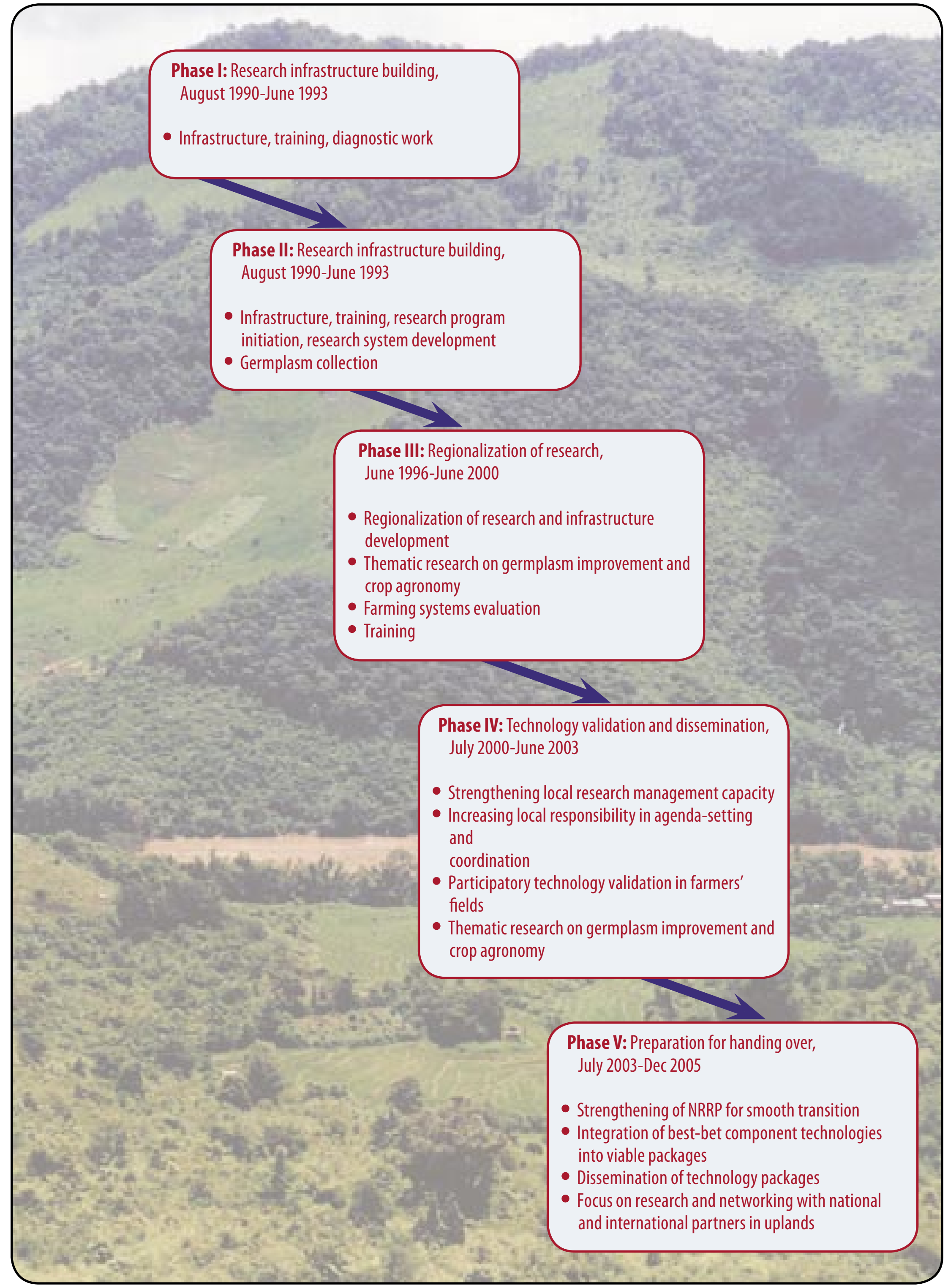



**Fig. 4. Evolution of the Lao-IRRI Project, 1990-2005.**

### 2.3.1. Varietal enhancement

Germplasm improvement is a major component of the overall research program. Glutinous rice accounts for 80–90% of the rice area (Lao Expenditure and Consumption Survey 2004).[2] Accordingly, germplasm improvement activities focused on increasing the yield potential of glutinous rice varieties. Collecting and characterizing the abundant biodiversity of traditional rice varieties were major activities undertaken initially. Along with these traditional varieties, introduced lines were also used for the selection of traits suitable to Lao conditions. During the past five years, some research to develop nonglutinous rice varieties mainly for urban and export markets also started.

Several improved short-duration varieties that avoid abiotic stresses such as drought and flood have been developed. Because of their early harvest, these varieties escape late-season damage from these stresses. Efforts are also under way to develop cold-tolerant varieties for the northern region. Breeding efforts to curb losses from biotic stresses include screening and developing new varieties with resistance to the common pests of Lao PDR.

### 2.3.2. Nutrient management

The soils in the central and northern regions are generally poor and lack an adequate level of basic nutrients—nitrogen, phosphorus, and potassium (NPK in order of severity of deficiency). Poor soil is less of a problem in the northern region although that region lacks adequate levels of nutrients (Linquist and Sengxua 2001).

[2] The Lao Expenditure and Consumption Surveys (LECS) are comprehensive national-level surveys sponsored by the World Bank. Three LECS have been conducted: the first, LECS1, covered 1992 to 1993, the second, LECS2, covered 1997 to 1998, and the third, LECS3, was recently completed for 2003 to 2004.



**Table 3. Major research themes of the Lao-IRRI Project, 1990-2005.**

| Production constraints | Research and technology development | | | | Ecosystem targeted |
|---|---|---|---|---|---|
| | Varietal improvement | Nutrient management | Plant protection | Agronomic practices | |
| Drought | Yes | _ | _ | Yes | RL, RU |
| Flood | _ | Yes | _ | Yes | RL |
| Low soil fertility | _ | Yes | _ | Yes | RL, RU, IL |
| Soil erosion | _ | Yes | _ | Yes | RU |
| Insect pests | Yes | _ | Yes | _ | RL, RU, IL |
| Diseases | Yes | _ | Yes | _ | RU, IL |
| Weeds | _ | Yes | Yes | Yes | RU |
| Rodents | _ | _ | Yes | Yes | RU |
| Labor shortage | _ | Yes | Yes | Yes | RL, RU, IL |

Source: Lao-IRRI Project (2002b). RL = rainfed lowland, RU = rainfed upland, and IL = irrigated lowland ecosystems.

The Lao-IRRI Project facilitated systematic research to determine the soil nutrient status throughout the country. Initially, nutrient management research focused on estimating yield responses to the application of NPK for major soil groups. This was followed by quantifying the minimum input level required to sustain yield improvements. With the progressive knowledge of fertilizer response under Lao conditions and increasing application over time, later studies were fine-tuned to improve nutrient-use efficiency (Schiller et al 2001b, Linquist et al 1998, Lao-IRRI Project 1997, 2000a,b).

Feasibility studies on the use of organic fertilizers for sustainable improvements in productivity were also conducted. Organic fertilizer research included residue management (rice straw, rice husk, and manure) and green manure (planting of a high-nitrogen crop before rice, i.e., *Sesbania rostrata*, a legume, etc.). Organic fertilizer use was found to be most effective in supplementing the third most deficient nutrient, K. The application of organic fertilizers with inorganic fertilizers was found to balance the K deficiency (Linquist and Sengxua 2001). As commercially available inorganic fertilizers such as urea (46-0-0) and compound (16-20-0) lack K nutrients, appropriate residue management could be an effective option. The need to supplement K is expected to increase with the expansion of double-rice cropping.

### 2.3.3. Plant protection

Studies have been conducted to determine the extent of economic loss from various insects and diseases. It was concluded that generally

the insect population and diseases have not reached a threshold level to cause any significant economic loss (Savongdy et al 1995). However, it is acknowledged that in some localized areas rice bugs, golden apple snails, and gall midge are becoming problematic. Studies were conducted to better understand the significance of the problem and develop control strategies.

Initial studies concentrated on screening and identifying varieties with resistance to common rice pests and diseases. Some of the released varieties already have these traits (see Section 6.1). Studies were undertaken to help farmers understand the benefits from pest control using natural predators. Public awareness campaigns on possible adverse effects of insecticide/pesticide use on general health were conducted through mass media and integrated pest management strategies were developed (Heong et al 2001).

### 2.3.4. Agronomic practices

Agronomic research was conducted for improving overall crop management. Major research activities included matching crop phenology with water availability, introducing early-maturing varieties to avoid late-season drought, and using direct seeding when soils are too dry for transplanting (Fukai et al 1998, Schiller et al 2001b). The feasibility of direct seeding to reduce the labor requirement was also assessed.

Agronomic research also targeted increasing the efficiency of resource use. Examples of such research are studies on the effects of plant spacing on efficiency of nutrient use, optimal sowing time, and optimal hill spacing for better weed management. Higher plant density was found to be essential in the cultivation of modern varieties to achieve yield potential and improve water- and nutrient-use efficiency for wet- and dry-season rice.

### 2.3.5. Other research activities

Other research work to complement these major research programs was also conducted. This includes socioeconomic characterization of rice farming systems (Pandey and Sanamongkhon 1998, Phouyyavong et al 2004), soil mapping using GIS, and validation of postharvesting technologies such as hermetically sealed bags for grain storage. Details of these and other related studies are available in the annual progress reports of the Lao-IRRI Project.



## 3. Significance of rice in Lao PDR

### 3.1. Rice and Ethnicity

The Lao people are made up of diverse ethnic groups, categorized into four ethno-linguistic families: Tai Kadai, Mon-Khmer, Hmong-Mien, and Tibeto-Burmese[3] (UNDP 2002). Rice is at the center of their lives as the staple food and it has cultural and religious significance. Many traditions and rituals are associated with rice production in different environments, and among ethnic groups. Many of these rituals are still practiced across the country. Centuries of farmers' selection and seed exchange among these different ethnic groups have resulted in the development of an amazing diversity of traditional rice varieties in Lao PDR. Rice varieties are both glutinous and nonglutinous, with colors such as black, purple, red, and white. Traditionally, farmers commonly plant three to four varieties, typically a combination of one early, one medium, and one or two late-maturing varieties, to provide continuity of food supply (IRRI 2005).

### 3.2. Rice Self-Sufficiency

Access to rice is the single most important factor determining the welfare status of Lao people. Rice consumption accounts for the bulk of the diet and supplies almost 70% of the calories (Lao-IRRI Project 2002a). This makes Lao PDR one of the top five countries where rice is the main source of calories (Fig. 5).

Because of the significance of rice, self-sufficiency in rice is equated to self-sufficiency in food in Lao PDR. Achieving rice self-sufficiency

[3] Generally, these groups are categorized into "lowlanders" and "highlanders" (UNDP 2002). The Tai Kadai inhabit the lowlands, mostly in central and southern regions, and cultivate paddy rice. This group is commonly referred to as Lao Leum. The three remaining groups traditionally reside in the mountains, mostly in the northern region, and practice swidden agriculture. These highlanders are further categorized into two groups, Lao Theung (high) and Lao Sung (very high). With recent changes in agricultural policies, and land allocation and distribution, these highlanders now also cultivate paddy rice in lowlands. The highlanders are the ethnic minority in the country. The incidence of poverty among the highlands is twice the national average (UNDP 2002).

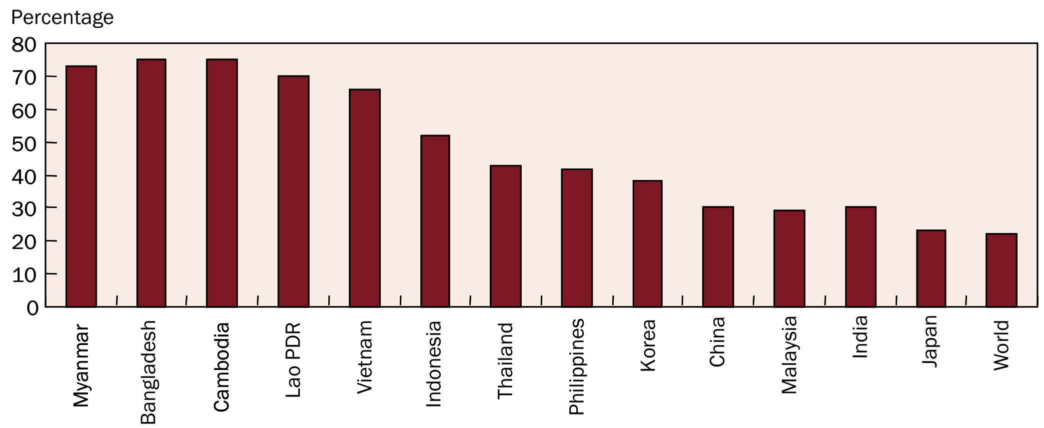



**Fig. 5. Calories derived from rice for select countries.**
Source: Lao-IRRI Project 2002a.

at the national level has been a top priority goal for the country. It was of great national pride when this was reported to have been achieved in 1999 with the production of over 2 million tons for the first time in the recent history of Lao PDR. There are some differences in opinion, however, on whether or not this goal has been fully achieved. Irrespective of the rice self-sufficiency status at the national level, various studies indicate that not all households are able to meet their rice consumption requirements (UNWFP 2005, ADB 2001).

### 3.3. Future Rice Demand and Supply Scenario

The demand for rice is expected to grow substantially as the current rate of population growth is 2.5% per annum, the highest in the region. At this rate of growth, the population is expected to increase from 5.3 million in 2000 to 8.8 million in 2020, an increase of 66%. Furthermore, in low-income countries, improvements in income generally lead to an increase in per capita consumption of rice. At the current rate of population growth and assuming the current rate of per capita consumption, the total demand for rice will increase to 3.6 million tons by 2020. This is equivalent to at least a million tons of additional production relative to the output achieved in 2004. Assuming that the total rice area will not increase, rice productivity would have to increase to 4.7 tons per ha nationally by 2020 to maintain self-sufficiency. Thus, it is important to keep up the momentum of rice productivity growth at least during the next 10 to 15 years.

### 3.4. Subsistence/Market Orientation of Rice Production

Rice production in Lao PDR is subsistence-oriented. Rice is produced mainly by smallholder households that have an average farm size of less



than 2 ha. Although rice production is the single most important economic activity, accounting for 39% of AGDP, with over 80% of the population being rural and consuming most of what they produce, very little rice is currently marketed. A Lao Expenditure and Consumption Survey conducted in the late 1990s estimated that, on average, only 8% of the rice produced is sold. Farmer communities closer to urban areas sell a higher percentage of rice (about 10%) compared to the national average.

The small domestic rice market and the poor marketing infrastructure have resulted in a lack of integration of the domestic rice market in the country. Accordingly, prices across provinces vary widely. These price differences across provinces in most cases cannot be explained solely on the basis of marketing costs, indicating that rice markets in Lao PDR are segmented spatially. Local demand and supply situations seem to determine price formations, with traders not being able to take advantage of the possibility of arbitrage. It has been found that, with few exceptions, the price of rice is positively correlated with per capita income in various provinces (Bourdet, Y., undated).

In recent years, a limited quantity of Lao rice has been exported across border towns into China, Vietnam, and Thailand. To get an edge for Lao rice in a competitive international rice market, the government is targeting niche markets such as organically grown rice or high-quality black rice.

### 3.5. Agricultural Strategy and Rice Policy

The strategic vision of Lao PDR for agricultural development is to improve rural livelihoods, reduce vulnerability of poor households, create opportunities for diversifying livelihoods, and maintain environmental quality in rural areas (Government of Lao PDR 2004). As rice production is the single most important economic activity accounting for over 20% of the national gross domestic product (GDP) and over 39% of the agricultural GDP, any progress made in this sector contributes directly to achieving these objectives (master plan). Accordingly, development of the rice sector commands a top priority in the national development policy.

Increasing rice production to maintain self-sufficiency and to generate an exportable surplus is one of the eight priority programs in Lao PDR (UNDP 2002). To achieve these objectives, specific strategies have been developed for lowland and upland rice production systems. For lowland rice, policies are geared toward increasing production through yield growth, increasing rice-cropping intensity, and modestly expanding rice area. For the uplands, the policy has been to reduce shifting cultivation practices, encourage crop diversification, and achieve long-term improvement in rice productivity. The comple-

mentary development policies necessary to achieve these objectives such as improvement of irrigation infrastructure, support to rice research and technology development and dissemination, improvement in transportation facilities and infrastructure, and access to agricultural credit and markets have also been given top priority.

## 4. National and regional rice production patterns

Rice accounts for more than 80% of the total cropped area in Lao PDR. In 2004, national rice production was 2.5 million tons. With a planted area of 770,300 ha, the average national yield was 3.28 tons per ha (Table 4). Relative to 1990, national rice production increased in 2004 by 70%.

Rice is grown in all regions throughout the country. The central region accounts for over half of the total rice area (51%) and production (55%). Savannakhet Province, located in this region, has the largest rice area of all provinces, and it accounts for over 21% of national production. Vientiane (including the municipality) and Khammouane also have large rice areas in the region.

The remaining half of the rice area is located in the northern (25%) and southern (24%) regions, which account for approximately 45% of the total rice production. Champassak and Saravane are the two major rice-producing provinces in the southern region. The northern region is characterized by mountainous terrain and accounts for approximately 22% of the total rice production. Of the three regions, the northern region has the lowest yield (2.89 tons per ha). Sayabouly, Luang Prabang, Houaphan, and Oudomxay are the provinces with most of the rice area in the northern region. Most of the rice production in these provinces (except for Sayabouly) is based on shifting cultivation.

**Table 4. Rice area, production, and yield in Lao PDR, 2004.**

| Region/province | Area % of total | Production % of total | Yield (tons per ha) |
|---|---|---|---|
| **Northern** | **24.6** | **21.6** | **2.89** |
| Pongsaly | 1.9 | 1.6 | 2.80 |
| Luang Namtha | 2.8 | 2.5 | 2.93 |
| Oudomxay | 3.9 | 3.0 | 2.54 |
| Bokeo | 2.3 | 2.3 | 3.43 |
| Luang Prabang | 4.3 | 3.3 | 2.53 |
| Houaphan | 3.6 | 3.3 | 2.99 |
| Sayabouly | 5.8 | 5.5 | 3.11 |
| **Central** | **51.4** | **55.2** | **3.53** |
| Vientiane Municipality | 9.4 | 11.7 | 4.06 |
| Xiengkhouang | 3.2 | 2.8 | 2.80 |
| Vientiane | 6.8 | 8.1 | 3.91 |
| Bolikhamxay | 4.5 | 5.0 | 3.66 |
| Khammouane | 6.7 | 6.1 | 2.98 |
| Savannakhet | 20.1 | 21.1 | 3.44 |
| Xaysomboun | 0.5 | 0.5 | 3.00 |
| **Southern** | **24.1** | **23.2** | **3.16** |
| Saravane | 9.1 | 9.0 | 3.27 |
| Xekong | 0.6 | 0.5 | 2.93 |
| Champassak | 12.3 | 12.0 | 3.21 |
| Attapue | 2.1 | 1.6 | 2.48 |
| National | 100 | 100 | 3.28 |

Data source: MAF (2005).
Note: Rice area 770 thousand ha and production 2.5 million t in 2004

**Table 5. Rice area and production by different regions and ecosystems (%), 2004.**

| Region | Rainfed lowland | | Rainfed upland | | Irrigated lowland | |
|---|---|---|---|---|---|---|
| | Area | Production | Area | Production | Area | Production |
| Northern | 46.8 | 64.0 | 48.9 | 30.1 | 4.3 | 5.9 |
| Central | 82.0 | 79.8 | 3.7 | 1.9 | 14.3 | 18.3 |
| Southern | 87.6 | 87.3 | 5.8 | 3.5 | 6.6 | 9.2 |
| Lao PDR | 74.7 | 78.1 | 15.3 | 8.4 | 10.0 | 13.5 |

Data source: MAF (2005).

The lowland ecosystem is the dominant rice ecosystem in Lao PDR. Rice cultivated in the lowlands accounts for almost 85% of the rice area and production. Lowland rice is grown under both rainfed and irrigated ecosystems. Rainfed lowland rice is planted in bunded fields that are flooded for at least part of the cropping season. Irrigated rice is grown in a similar manner but with irrigation facilities. Over 95% of the irrigated rice is grown as a second crop in the same field after the harvest of rainfed lowland rice (Schiller et al 2001b). Rainfed rice is commonly referred to as wet-season rice. During this season, rice is generally planted in May-July and harvested in November-December. The second rice crop, the irrigated rice in the dry season, is planted during December-January and harvested in April-June.

Rainfed lowland rice dominates rice cultivation in the country. In 2004, approximately 75% of the area cultivated (576,000 ha) and 78% of the production (approximately 2 million tons) originated from this ecosystem (Table 5). Only 10% (768,000 ha) of the total rice area and almost 14% (34 million tons) of the total production originated from the irrigated ecosystem. Rainfed upland rice accounts for over 15% of the total area and less than 10% of the total production.

## 5. Impact assessment: theory, methods, and data

Impact assessment is a process of estimating whether or not research, technology development, and capacity building efforts have produced their intended effects in meeting project objectives (Anderson and Herdt 1990). The assessment can be ex ante or ex post. The ex ante assessment is usually conducted before project implementation to estimate the potential impact on the target population. The ex post assessment is generally conducted after project completion and when uptake of the project results is evident. The estimated benefits usually constitute a realized (calculated from the start of the project to the time of the assessment) and a projected (from the time of the assessment until replacement of the technology) component.

Rice research and training projects generate new and improved rice varieties, better crop management practices, and enhanced human capacity for research and development. These outputs have direct, indirect, and intermediate impacts. Direct impact refers to impact on the welfare of people and the environment as a

result of adoption of a technology. It is measured mainly as an increase in productivity, reduction in per unit cost of production, and/or reduced pressure for expansion into fragile ecosystems. Indirect impact includes flow-on impacts to other crops and activities. An example of indirect impact would be diversification to high-value cash crops as rice requirements are fulfilled. Intermediate impact refers to increases in the knowledge base that could subsequently generate direct impact. For example, information on the evaluation of the gene pool, prototype technologies, and new skills and knowledge of researchers are intermediate benefits.

### 5.1. Economic Surplus Model

An economic surplus model is widely used in quantifying the returns to investment in agricultural research. The method is based on quantifying the increases in consumer and producer surpluses arising from the adoption of a new technology.

Figure 6 illustrates the basic framework. Initially, with the existing technique, $Q_0$ is produced at the $P_0$ price level on the supply curve $S_0$. The adoption of a new technology results in a shift in the supply curve from $S_0$ to $S_1$. As a result, rice production increases from $Q_0$ to $Q_1$ and the price is reduced from $P_0$ to $P_1$.

The benefits to consumers and producers of the improved technology are

- Consumers benefit because they can purchase more output at a lower price. This increase in consumer surplus can be estimated by the area $P_0abP_1$.
- Producers benefit from higher output and a decline in the unit production cost. This benefit can be estimated by the area $P_1bcd$.

The total benefit from the research program is the sum of the producers' and consumers' surplus. The rectangle area $P_0acd$ is often a close approximation because the triangle abc is relatively small. The distribution of the total benefit between producers and consumers depends on the size of the fall in price (change in P) relative to the fall in cost (R). In turn, this depends on the elasticities (slopes) of the supply and demand curves. When the absolute values of the elasticities are equal, the benefits from research are shared equally between producers and consumers.

To derive the net present value of research requires the projection of benefits and costs "with" and "without" the project. The project benefits and costs are obtained as the difference between with and without scenarios, illustrated in Figure 7. The conceptual aspects of this impact assessment methodology are discussed in detail in Shrestha et al (2002).

**Fig. 6. The supply and demand model of research benefits.**

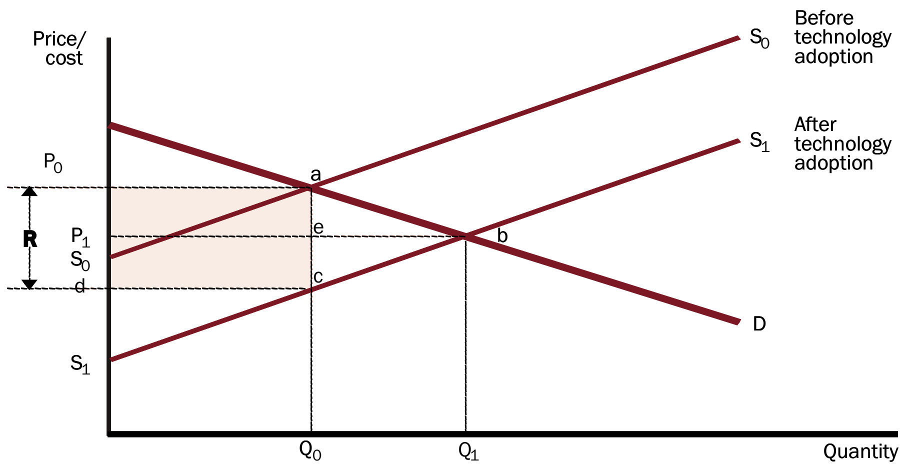
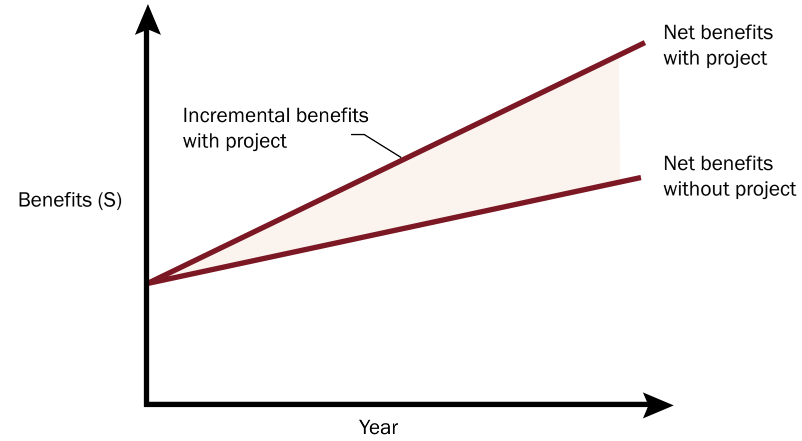





**Fig. 7. Benefits "with" and "without" the project.**




The Lao-IRRI Project was scheduled to finish at the end of 2005. However, the benefits generated by the project will be felt beyond this period. Hence, the analysis undertaken has ex ante and ex post components to account for the benefits realized so far and the potential benefits that are likely to be realized from wider adoption of improved technologies. Although economic surplus measures are not explicit in the analysis undertaken in this report, they are implicit in the benefit-cost analysis presented in Section 8.1.

### 5.2. Indicators of Impact for the Lao-IRRI Project

This study examines the impact of technology development in all three rice-producing regions in northern, central, and southern Lao PDR. In addition to the usual economic indicators of impact, other aspects such as the effects of on-farm biodiversity in varieties, environmental effects from the adoption of modern technologies, and the differential impact of technologies disaggregated by gender and ethnic groups are also considered.

The following major impact indicators are used in the study:

Farm household and national-level impact

- number of varieties and other improved technologies released
- adoption rate of improved technologies
- yield and its stability
- production effects by region
- household income from rice
- rice self-sufficiency
- impact on women and different ethnic groups
- impact on biodiversity and the environment
- return on investment in R&D

Institutional-level impact

- number of people trained
- relevance and quality of training
- effectiveness of research system in research planning and implementation
- effectiveness of research and extension system in disseminating research findings
- national and international networking capacity

### 5.3. Data Sources and Sampling Procedures

Both primary and secondary data sources are used in the study. Primary data were collected from farmers and Lao-IRRI Project alumni using structured questionnaires and focus-group discussions.

#### 5.3.1. Farm data collection

Farm surveys were conducted to collect basic farm-level information on lowland rice farming systems. Two provinces from each region, the northern region (Luang Namtha and Oudomxay), central region (Vientiane Municipality and Savannakhet), and southern region (Champassak and Saravane), were included. These provinces represent the major rice areas of the country. The provinces from the northern region were selected to represent the ethnic diversity of the country. Also, the rice production systems in the northern region differ significantly from those in the central and southern regions. Some of the reasons for these differences are the different ethnic groups, ecosystems and climatic factors, and geopolitical factors. These regional disparities may result in differences in technology adoption patterns.

The provinces and districts were selected in consultation with the NRRP director and other senior staff, PAFO/DAFO staff, and Lao-IRRI Project staff to represent different conditions. A multistage random sampling method was used to draw a representative sample. The criteria for selection used were the extent of rice production within the region, ethnic diversity, economic status of the district, proneness to flood/drought, access to markets, distance from roads, distance from research centers, and farm size. Villages and households were randomly selected from these districts. Women-headed households were identified and selected purposefully if they were not adequately picked up in the random selection process.[4] Similarly, farmers belonging to different ethnic groups were also included in the sample to represent ethnic diversity.

**Table 6. Provinces, districts, and villages included in the impact assessment survey.**

| Region/ province | Number of districts | Number of villages | Sample size |
|---|---|---|---|
| **Northern** | **6** | **16** | **255** |
| Luang Namtha | 3 | 8 | 133 |
| Oudomxay | 3 | 8 | 122 |
| **Central** | **5** | **12** | **240** |
| Vientiane Municipality | 2 | 6 | 120 |
| Savannakhet | 3 | 6 | 120 |
| **Southern** | **5** | **12** | **245** |
| Saravane | 2 | 6 | 125 |
| Champassak | 3 | 6 | 120 |
| **Total** | **16** | **40** | **740** |

Source: Impact assessment survey (2004).

[4] The households without the presence of a male breadwinner are defined here as women-headed households. Households managed by widows or divorcees, in which a male breadwinner is absent from the household for an extended period of time (i.e., migrant workers), are examples of women-headed households.



The household heads were interviewed with structured questionnaires to collect quantitative and qualitative data. The information was collected on lowland (rainfed and irrigated) rice farming systems on farm area, production, farming practices, cultivation of traditional and modern rice varieties, adoption (or lack of) of new technologies, changes in cropping patterns, access to new technology, and farmers' perceptions of changes in general living standards.

A total of 740 households from 40 villages were selected in the sample (Table 6). The sample included farmers from 16 districts, 6 each from the central and southern regions and 5 from the northern region. Depending on village size, the number of samples included from each selected village ranged from 10 to 21. The names of the districts by region and the corresponding names of the villages and household sample size are included in Appendix 2.

The survey was conducted from December 2004 to February 2005. The data were collected for rice production year 2004: dry-season (Jan-Apr in 2004) and wet-season (Jun-Nov in 2004) crop. This is a "normal" year for rice production for Lao PDR.

#### 5.3.2. Survey of trainees

One hundred and forty (30% of the total) trainees were included in a survey to obtain their perspective of the impact of the training program. The information was gathered through semi-open-structured questionnaires and focus-group discussions. The questionnaires were designed to get their assessment of the overall contribution of the training program implemented under the Lao-IRRI Project. In particular, information was collected on the trainees' capacity to undertake, plan, and implement rice research and technology development and dissemination, to develop networks and collaborations within the country and outside, and to do related development activities.

With some senior government officials, it was not culturally appropriate to send in a questionnaire or include them in group discussions. Hence, the consultant visited them personally

and elicited their perceptions of the impact of the Lao-IRRI Project.

The sample of trainees represented almost all organizations involved in the training program. These included staff of national and regional research organizations, PAFO/DAFO officials, and officials of MAF/NAFRI/DOA and agricultural colleges.

#### 5.3.3. Published secondary data

The main sources of secondary data were the statistics and other documents of the Lao government, the FAO rice database, and the annual and technical reports of the Lao-IRRI Project. The database on alumni was the sole information source used to document the number of Lao scientists who benefited from training, study tours, and attendance at workshops and international conferences (Lao-IRRI Project's Training Records 2005).

The consultant provided the required training to the staff involved in impact assessment methods, questionnaire design, farm data sampling, survey and collection methods, and the data management process. The government staff from NAFRI, PAFO/DAFO, and research centers and Lao-IRRI Project staff collected the farm data (see list in Appendix 3). The farm and trainee data were compiled by the Lao-IRRI Project under the supervision of Dr. Thiphavong Boupha (second author of this report).

# 6. Assessing the impact of research

## 6.1. Improved Varieties Released

Two major groups of modern rice varieties have been released in Lao PDR since the establishment of the Lao-IRRI Project. The first group consists of the Lao modern rice varieties (LMVs) developed from the Lao-IRRI research programs specifically for Lao conditions. In total, 16 such varieties have been officially released (Table 7). These are glutinous varieties selected for good quality, high yield potential, and suitability to saline and low-fertility soils. Some of these varieties are also resistant to common rice insects and diseases such as brown planthopper, gall midge, stem borer, leaf blast, bacterial leaf blight, and brown spot. Three new LMVs are in the pipeline for release during 2006-07 (Appendix 4). These varieties have been evaluated for several years at multiple locations.

The second group of improved rice varieties, referred to here as other modern varieties (OMVs), was developed in other countries (mainly Thailand and Vietnam) and at IRRI. Ten of these varieties, five glutinous and five nonglutinous ones, have been released in Lao PDR (see list in Appendix 5).

In addition to the improved varieties, 12 TVs (four black rice varieties) found suitable to areas other than from where they were collected have also been officially released for selected provinces (see list in Appendices 6 and 7).

**Table 7. Glutinous Lao modern rice varieties released in Lao PDR, 2005.**

| Name | Year released | Major positive traits[a] |
|---|---|---|
| TDK1 | 1993 | High N response, good tillering, and resistance to most biotypes of BPH and rice leaf diseases. |
| TDK2 | 1993 | Moderate resistance to leaf blast, bacterial leaf blight, BPH, GLH, gall midge, and stem borer. |
| PNG1 | 1994 | Good grain quality, moderate yield, broad adaptability, maturity at 125–130 days, and resistance to blast. |
| PNG2 | 1995 | Moderately resistant to brown spot, flowering in mid-October. |
| TDK3 | 1997 | Good grain quality, resistance to rice diseases, and suited to favorable rainfed lowlands. |
| TDK4 | 1998 | Good grain quality, high N response, suited to medium fertile and saline soils, etc. |
| TSN1 | 1998 | Good grain quality and high N response, best suited to fertile soils, etc. |
| NTN1 | 1998 | Good grain quality, 130 days' maturity, and resistance to blast. |
| TDK5 | 2000 | Good grain quality, maturity in 125–130 days, plant height 95–115 cm, resistance to blast and bacterial leaf blight. |
| TDK6 | 2003 | Good milling recovery of 62%, good response to N, good resistance to bacterial leaf blight, and suitable to dry land and acid soils. |
| TDK7 | 2003 | Good response to N, good resistance to bacterial leaf blight, suitable to wet and dry season in central and southern regions and some parts of northern region. |
| PNG3 | 2005 | Good eating quality with maturity time of 130–135 days, good resistance to brown spot disease, suits moderate and good soil. |
| PNG5 | 2005 | Suitable to good soil in wet and dry season. |
| PNG6 | 2005 | High N response (30–90 kg per ha), resistance to bacterial leaf blight, suitable to wet and dry seasons. |
| TSN2 | 2005 | Maturity of 135–140 days, high N response (30–90 kg per ha) with resistance to bacterial leaf blight, and suitable for wet and dry seasons. |
| TSN4 | 2005 | High N response (30–90 kg per ha), good resistance to bacterial leaf blight, suitable to wet and dry seasons. |

[a]BPH = brown planthopper, GLH = green leafhopper, N = nitrogen, NTN = Namtane, PNG = Phone Ngam, TDK = Thadokkham, and TSN = Thasano.
Source: The introduction of rice varieties in the Lao-PDR. Vientiane (Lao-PRD): NRRP and Lao-IRRI Project (2005b).

## 6.2. Improved Crop Management Practices Developed

The research outputs from crop management were packaged into technological options for wider dissemination to farmers. The recommended technology packages are well documented in the Lao-IRRI Project's technical and annual reports. The major components of the package are

- establishment of 25-day-old seedlings,
- plant spacing of 15 × 15 cm with 4 to 5 plants per hill,
- application of higher and balanced doses of inorganic fertilizers in three splits,
- use of organic fertilizers,
- direct seeding in furrows when transplanting is not possible,
- weed management strategies for uplands, and
- a recommendation of several legume crops to be planted in rice-based farming systems in uplands.

## 6.3. Farm-level Impact

Farm-level impact is assessed in terms of the extent of adoption of modern varieties, yield increases, gain in income, as well as other indicators of farmer welfare.

### 6.3.1. Adoption of modern varieties

Two indicators of adoption are used here: the percentage of households adopting improved varieties and the percentage area under modern varieties. Households that grow MVs are considered as adopters in the first indicator irrespective of the size of the area planted to MVs. If households plant MVs on only a small portion of their farms, the percentage of households considered as adopters would be much higher than the percentage of area under MVs. These two indicators thus provide different information on the nature of the adoption pattern.

In total, some 80% of the sampled households have adopted MVs, with the proportionate area under MVs being 69% (Table 8). Thus, adoption rates are high in terms of both indicators. Regionally, the adoption rate is lower in the northern region than in the southern and central regions. The central region has the highest adoption rate of over 98% of households growing MVs in over 86% of the area. Thus, adoption of MVs is almost complete in this region.

The analysis of disaggregated data by season indicates that adoption is almost 100% in the dry season, when rice is grown under fully irrigated conditions. In the wet season, the percentage area under MVs is much lower at 65%. Thus, opportunities exist for further expansion of MVs in the wet season, especially in the northern region (Table 9).

Overall, LMVs account for 51% of the total area under MVs. LMVs dominate rice area in the dry season in all three regions. In the wet season, the proportionate area under LMVs is less than in the dry season. The northern region has the lowest rate of adoption of LMVs in the wet season (Table 10).

TDK 1 is by far the single most popular LMV (Fig. 8). This variety accounts for 41% of the area covered by LMVs. Other commonly planted LMVs are TDK 5, and Phong Ngam 1 and 2. Each of these varieties accounts for 10% to 13% of the total LMV area. TDK 1 and 5 are

**Table 8. Households and rice area with adoption of modern varieties (%), 2004.[a]**

| Region | Households | Rice area |
|---|---|---|
| Northern | 56.9 | 45.9 |
| Central | 98.3 | 85.7 |
| Southern | 86.5 | 65.6 |
| Overall | 80.1 | 68.9 |

[a]The total number of sampled households in the farm survey was 740 (northern = 255, central = 240, and southern = 245).
Source: Impact assessment survey, 2005.

**Table 9. Rice area under modern varieties by different seasons (%), 2004.**

| Region | Wet season | Dry season | Total |
|---|---|---|---|
| Northern | 39.8 | 100.0 | 45.9 |
| Central | 82.6 | 98.8 | 85.7 |
| Southern | 63.9 | 98.7 | 65.6 |
| Overall | 64.9 | 99.0 | 68.9 |

Source: Impact assessment survey, 2005.

**Table 10. MV area under LMVs and OMVs by different seasons (%), 2004.**

| Region | Wet season | | Dry season | | Total | |
|---|---|---|---|---|---|---|
| | LMVs | OMVs | LMVs | OMVs | LMVs | OMVs |
| Northern | 14.3 | 85.7 | 61.2 | 38.8 | 24.7 | 75.3 |
| Central | 42.3 | 57.7 | 66.0 | 34.0 | 47.5 | 52.5 |
| Southern | 65.1 | 34.9 | 97.2 | 2.8 | 67.4 | 32.6 |
| Overall | 47.2 | 52.8 | 69.9 | 30.1 | 51.0 | 49.0 |

Source: Impact assessment survey, 2005.

mostly cultivated in the central and southern regions. Phong Ngam 1 and 2 are almost exclusively planted in the southern region. Of the remaining LMVs, Namtan, Phong Ngam 5, and TDK 2 are the most popular. Namtan is in the pipeline to be released soon although farmers have already started to grow it (see Appendix 4).

Khaodak Mali and RD varieties from Thailand account for over 75% of the area under OMVs. These varieties are mostly planted in the central region and to a lesser extent in the southern region. The Chinese MVs, most of which are hybrids, are the second most widely grown OMVs, with almost all of the Chinese varieties being planted in the northern region (Figure 9).

The use of different groups of varieties (LMVs, OMVs, and TVs) in Lao PDR for the wet season and dry season is summarized in Figures 10 and 11, respectively. In the wet season, the overall estimate indicates that three groups occupy an almost equal proportion. However, TVs still dominate in the northern region. The central region has the most area allocated to MVs, with OMVs being more commonly used. In the southern region, over 64% of the rice area is planted to MVs and LMVs are widely cultivated. During the dry season, almost 99% of the rice area is planted to MVs and LMVs are the dominant group.

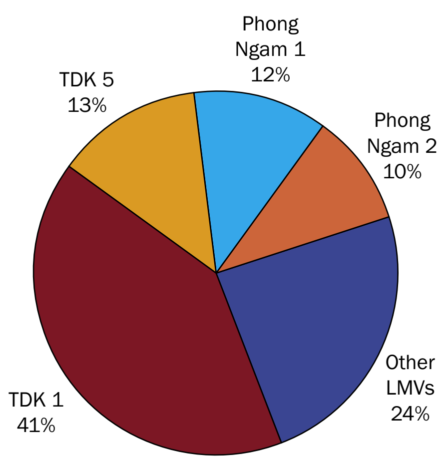



**Fig. 8. Area share of various LMVs (%), 2004.**
Source: Impact assessment survey, 2005.

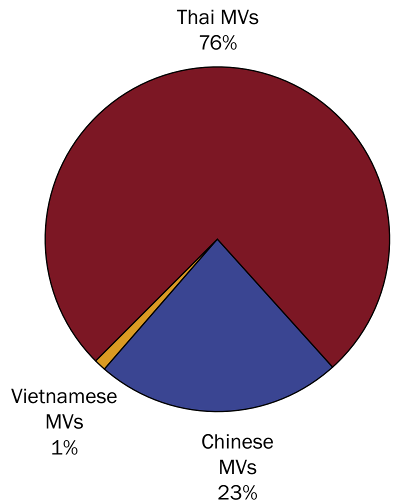



**Fig. 9. Area share of various OMVs (%), 2004.**
Source: Impact assessment survey, 2005.

### 6.3.2. Adoption of improved crop management practices

The most widely adopted improved crop management practices promoted by the Lao-IRRI Project are improved nursery bed preparation, the use of machinery for land preparation, the adoption of closer plant spacing (20 × 20 cm), and organic and inorganic fertilizer application (Table 11). Most of these technologies are adopted in the central region, with adoption being lowest in the northern region.

Over 50% of the farmers used inorganic fertilizer in the central region, 43% in the southern regions, and 17% in the northern region during rice cultivation. More than 80% of the surveyed households reported using farmyard crop residues to replenish plant nutrient. Animal manure, the other form of organic fertilizer, was used to a lesser extent. Only 20% of the farmers in the northern region used it. More farmers used fertilizer at the time of crop planting (basal application) than in any other stages of rice production.

Less than 31% of the surveyed households reported using insecticide/herbicide in rice production. The households from the central region had the highest percentage of use of insecticide (31%) and herbicide (13%) compared with other regions. Surveyed farmers from the southern region did not use herbicide.

Higher levels of inputs are used in MV cultivation than with TVs (Table 12). Except for organic fertilizers, higher levels of other inputs are used for MVs during the dry season. Most of the fertilizer is used during the rice planting stage (basal) for both groups of rice varieties. Only in the dry season are similar levels of inorganic

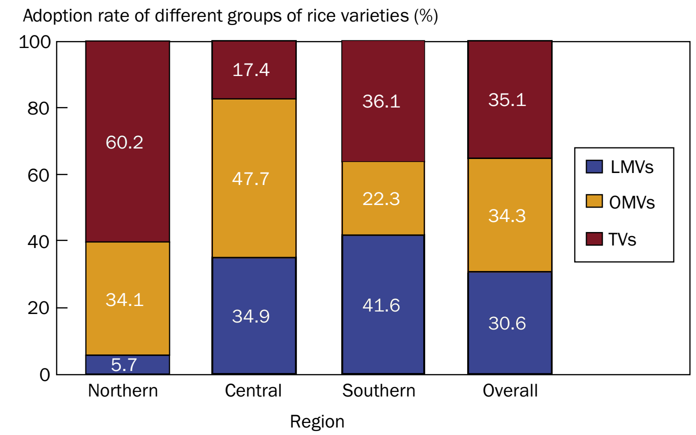



**Fig. 10. Adoption of different groups of rice varieties by regions, wet season 2004.**

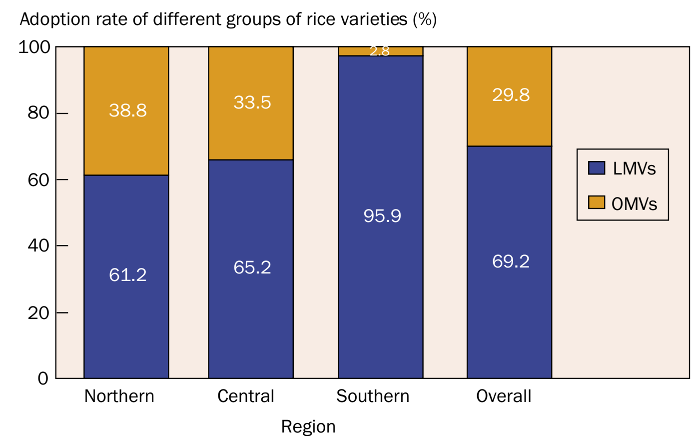



**Fig. 11. Adoption of different groups of rice varieties by regions, dry season 2004.**
Source: Impact assessment survey, 2005.

**Table 11. Household adoption of improved crop management practices (%), 2004.**

| Crop management practices promoted by the Lao-IRRI Project | Region | | |
|---|---|---|---|
| | Northern | Central | Southern |
| Seedling nursery | | | |
| Apply manure for seedbed | 29.0 | 64.2 | 66.9 |
| Apply other inorganic fertilizer during seedling stage | 38.0 | 86.7 | 56.3 |
| Seedlings grown in nursery for 25 to 30 days | 95.3 | 91.3 | 88.2 |
| Use machinery to plough land | 77.3 | 85.8 | 46.5 |
| Direct seeding for crop establishment | 1.2 | 12.5 | 0.4 |
| Plant spacing 20 × 20 cm per hill | 75.3 | 68.8 | 81.6 |
| Inorganic fertilizer | | | |
| Basal | 17.3 | 51.3 | 43.3 |
| Active tillering | 11.8 | 51.3 | 24.9 |
| Panicle initiation | 2.4 | 17.5 | 0.8 |
| Organic fertilizer | | | |
| Apply farmyard residue | 87.8 | 81.3 | 95.9 |
| Apply animal manure | 20.8 | 47.5 | 52.7 |
| Insecticide/pesticide use | 23.1 | 30.8 | 13.9 |
| Herbicide use | 12.5 | 13.3 | 0.0 |
| Practice a cropping system | 13.7 | 4.6 | 4.5 |

Source: Impact assessment survey, 2005.

**Table 12. Different levels of input use for different seasons, 2004.[a]**

| Input | Wet season | | Dry season | Total |
|---|---|---|---|---|
| | MVs | TVs | MVs | MVs |
| Inorganic fertilizer use at different stages of plant growth (kg per ha) | | | | |
| Basal | 33.0 | 11.1 | 50.0 | 41.1 |
| Tillering | 18.3 | 6.0 | 45.0 | 29.3 |
| Panicle | 4.0 | 0.7 | 17.8 | 6.4 |
| Organic fertilizer (kg per ha) | 176.7 | 69.2 | 85.9 | 161.4 |
| Insecticide (liters per ha) | 0.0 | 0.0 | 0.1 | 0.0 |
| Pesticide (liters per ha) | 0.3 | 0.3 | 0.2 | 0.3 |
| Herbicide (liters per ha) | 0.3 | 0.1 | 0.3 | 0.3 |

[a]Fertilizer use is expressed in terms of the actual quantity of fertilizer, not in terms of nutrients. The major fertilizers used are urea (60:0:0) and NPK (15:15:0). Pesticide use refers to all chemicals used (other than insecticide), including herbal treatments to curb rice insects and diseases.
Source: Impact assessment survey, 2005.

fertilizer used at planting (50 kg per ha) and at the tillering stage (45 kg per ha). Chemical use for pest control is not widespread.

### 6.3.3. Yield performance

LMVs outyield TVs in all regions (Fig. 12). The yield advantage of LMVs over TVs ranges from 0.3 t per ha to 1.3 t per ha depending on the region. LMVs also outyield OMVs except in the northern region. The yield advantage of LMVs over OMVs in the central and southern regions is 1.1 t per ha and 0.7 t per ha, respectively. In the northern region, over 90% of the OMVs are of Chinese origin. Hybrid rice, with its higher yield potential relative to that of inbred varieties, is the most popular of these Chinese MVs grown in the northern region.



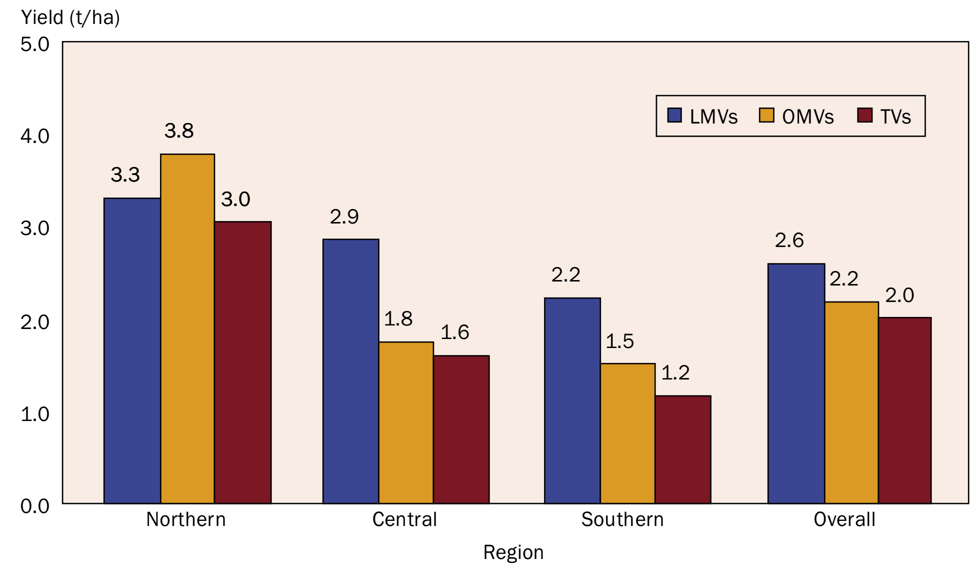



**Fig. 12. Average yield for different groups of rice varieties in Lao PDR.**
Note: OMVs planted in the northern region are mainly Chinese hybrid rice, which has higher yield potential than inbred MVs. Source: Impact assessment survey, 2005.

**Table 13. Yield among different groups of rice varieties by season (tons per ha), 2004.**

| Season | LMVs | OMVs | TVs | % yield difference | | Level of gain (t per ha) | |
|---|---|---|---|---|---|---|---|
| | | | | LMVs over OMVs | LMVs over TVs | LMVs over OMVs | LMVs over TVs |
| Wet | 2.4 | 2.1 | 2.0 | 11.8 | 18.9 | 0.3 | 0.4 |
| Dry | 3.3 | 2.6 | 2.1 | 24.7 | 57.5 | 0.6 | 1.2 |
| Total | 2.6 | 2.2 | 2.0 | 18.6 | 29.1 | 0.4 | 0.6 |

Source: Impact assessment survey, 2005.

LMVs outyielded OMVs in both seasons, with an overall increase in yield of 19%. This translates into an increase in production by over 400 kg per ha (Table 13). The magnitude of yield gain is higher in the dry season (25% yield advantage) than in the wet season.

### 6.3.4. Yield stability

Are LMVs, although higher yielding on average, also stable performers relative to OMVs and TVs? Yield stability is a desirable characteristic that helps improve household food security. Although temporal variability is a relevant indicator for this purpose, cross-sectional yield variability is used here as a proxy for the likely size of the temporal variability. The coefficient of variation (CV) of yield is a good measure of yield variability (or the inverse of stability). Based on this measure, LMVs are found to be the most stable in both the wet and dry seasons relative to other groups of varieties (Table 14).

### 6.3.5. Rice cropping intensity

Rice cultivation during the dry season started mainly in the mid-1990s with the availability of irrigation and photo-insensitive short-duration modern rice varieties. Some 24% (178 out of 740) of the surveyed households grew a second

**Table 14. Coefficient of variation of different groups of rice varieties by seasons, 2004.**

| Region | Wet season | | | Dry season | |
|---|---|---|---|---|---|
| | LMVs | OMVs | TVs | LMVs | OMVs |
| Northern | 0.5 | 0.3 | 0.4 | 0.4 | 0.5 |
| Central | 0.5 | 0.6 | 0.6 | 0.4 | 0.5 |
| Southern | 0.5 | 0.5 | 0.7 | 0.4 | 0.6 |
| Overall | 0.5 | 0.6 | 0.6 | 0.4 | 0.5 |

Source: Impact assessment survey, 2005.

**Table 15. Rice cropping intensity in Lao PDR (%), 2004.**

| Region | LMVs | OMVs | Total MV area | Total rice area |
|---|---|---|---|---|
| Northern | 121.8 | 112.9 | 128.5 | 111.4 |
| Central | 144.1 | 116.6 | 128.3 | 123.6 |
| Southern | 112.0 | 100.6 | 108.0 | 105.2 |
| Overall | 130.1 | 111.6 | 120.3 | 113.3 |

Source: Impact assessment survey, 2005.

**Table 16. Net returns from cultivation of different groups of rice varieties (US$ per ha), 2004.**

| Item | LMVs | OMVs | TVs | Difference (US$ per ha) | | % Difference | |
|---|---|---|---|---|---|---|---|
| | | | | LMVs over OMVs | LMVs over TVs | LMVs over OMVs | LMVs over TVs |
| Gross returns | 298.7 | 251.9 | 231.4 | 46.9 | 67.3 | 18.6 | 29.1 |
| Paid-out costs | 38.5 | 32.5 | 14.0 | 6.1 | 24.5 | 18.7 | 174.6 |
| Net returns | 260.2 | 219.4 | 217.4 | 40.8 | 42.8 | 18.6 | 19.7 |

Source: Impact assessment survey, 2005.

crop of rice in the dry season. The rice cropping intensity due to the second rice crop is 113%. The central region has the highest rice cropping intensity. LMVs are the dominant rice varieties used in the dry season. Thus, LMVs, along with irrigation, have contributed to an increase in rice cropping intensity (Table 15).

### 6.3.6. Increase in farmers' net income

Farmers' cost of production generally increases with the adoption of new rice technologies. The main expenses associated with the adoption of MVs are the cost of inorganic fertilizers and irrigation charges. These additional costs are accounted for while calculating the gain in net income.

LMVs generate an additional net return (gross returns minus cash costs) of $41–43 per ha depending on whether the increase is measured relative to OMVs or TVs. This represents an increase in net returns of about 20%. The yield difference is the main factor driving this gain in net returns (Table 16).

### 6.3.7. Improvement in household rice self-sufficiency

Approximately 77% of the sampled households reported being self-sufficient in rice (Table 17). The percentage of households that are self-sufficient in rice was higher among MV adopters (82%) relative to nonadopters of MVs (58%).

Households from the central region reported the highest frequency of being self-sufficient in rice among the adopters (90%) and nonadopters (75%) of MVs compared with those in other regions. The difference in the frequency of households reporting being self-sufficient in rice is large in the southern region (71% for MV adopters versus 21% for nonadopters).

For the households that are rice-deficient, the deficiency for 1–3 months was most frequent among MV adopter (55%) and nonadopter (66%) households. Some 10% of the MV adopters have a deficit for more than 7 months.



**Table 17. Household rice self-sufficiency (%), 2004.**

| Region | MV adopter | Nonadopter | Total |
|---|---|---|---|
| Northern | 82.1 | 67.3 | 75.7 |
| Central | 91.1 | 75.0 | 90.8 |
| Southern | 70.8 | 24.2 | 64.5 |
| Overall | 81.6 | 57.8 | 76.9 |

Source: Impact assessment survey, 2005.

### 6.3.8. Increase in household cash income from rice

The households that adopted LMVs have higher cash income from rice than nonadopter households. Overall, the additional cash income from rice for households adopting MVs relative to those growing only TVs is estimated to be $159 (Table 18).

**Table 18. Average household cash income from rice, 2004.**

| Region | MV adopters (US$) | Nonadopters (US$) | % Difference of adopters over nonadopters | Absolute difference of adopters over nonadopters (US$) |
|---|---|---|---|---|
| Northern | 559.5 | 213.8 | 161.7 | 345.7 |
| Central | 330.6 | 123.8 | 167.1 | 206.8 |
| Southern | 246.1 | 87.4 | 181.6 | 158.7 |
| Overall | 364.4 | 205.7 | 77.1 | 158.7 |

Source: Impact assessment survey, 2005.

### 6.3.9. Improvement in general welfare

To get a general impression on changes in rural livelihood, the households were asked whether they believed that their welfare had increased, decreased, or remained constant during the last 5 to 8 years. Different indicators of welfare were used for this analysis. Most households reported that their welfare had improved over time. The MV adopters have at least an equal or higher percentage increase for all indicators compared with nonadopters (Fig. 13).

The magnitude of difference is more prominent for indicators directly corresponding to the rice sector such as rice production, rice self-sufficiency, and access to farm machinery. For these indicators, the difference between adopters and nonadopters of improved rice technologies is more than 10 percentage points in most cases.

## 6.4. National-level Impact

National rice production increased from 1.5 million tons in 1990 to more than 2.5 million tons in 2004, an increase of almost 70%. This represents a growth rate of over 5% per annum. The increase in yield was the main factor driving this production growth. During this period, rice yield increased at 3% per annum (Table 19).

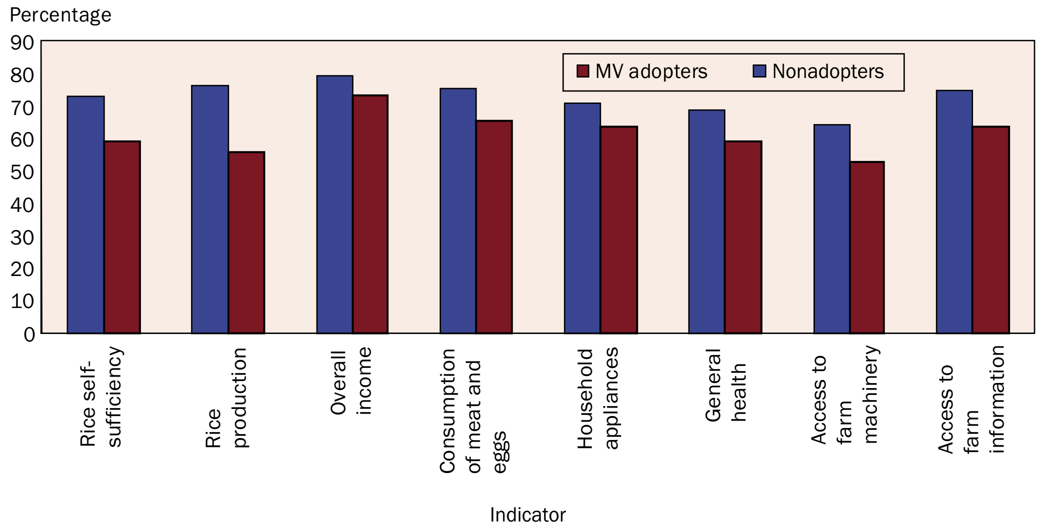



**Fig. 13. Increase in welfare among MV adopters and nonadopters in last 5 to 8 years.**
Source: Impact assessment survey, 2005.

**Table 19. Sources of growth in rice production for Lao PDR, 1990-2004.[a]**

| Item | Year | | Average for 1990-2004 | % Change, 1990-2004 | Compound annual growth rate, 1990-2004 |
|---|---|---|---|---|---|
| | 1990 | 2004 | | | |
| Area (000 ha) | 650.3 | 770.3 | 651.5 | 18.5 | 2.2 |
| Yield (tons per ha) | 2.29 | 3.28 | 2.75 | 43.14 | 3.09 |
| Production (000 t) | 1,491.5 | 2,529.0 | 1,819.4 | 69.6 | 5.3 |

[a]Growth rates estimated by fitting semi-logarithmic trend lines to time-series data.
Source: MAF (2005).

Rice production averaged around 1.3 million tons until the early 1990s, with no clear trend. A significant break occurred during the mid-1990s, with yield and production rising steeply (Fig. 14). Most of the production growth was achieved after 1995, when improved technologies from the Lao-IRRI Project became increasingly available (Table 20). As a result, production grew at 7.3% per annum during 1996-2004. Both rice area and yield increased rapidly, with the expansion of dry-season rice being the main source of area growth. The availability of photoperiod-insensitive MVs of rice was an important factor for the expansion of area under dry-season rice.

The contribution of improved varieties (and associated crop management technologies) to this production increase at the national level can be estimated using information from the farm survey. The magnitude of increase in production is dependent on rice area, MV adoption rate, and yield difference between the two groups of rice varieties. Using the estimates of adoption rate and yield advantage of LMVs, the total production gain at the national level in 2004 is estimated to be 226,000 to 282,000 tons (Table 21).

Using a farm-gate price of $115 per t, the value of increased production at the national level is estimated to be approximately $26–32.4 million (Table 22). Over 70% of the increased production originated from the central region and the balance mainly from the southern region. The



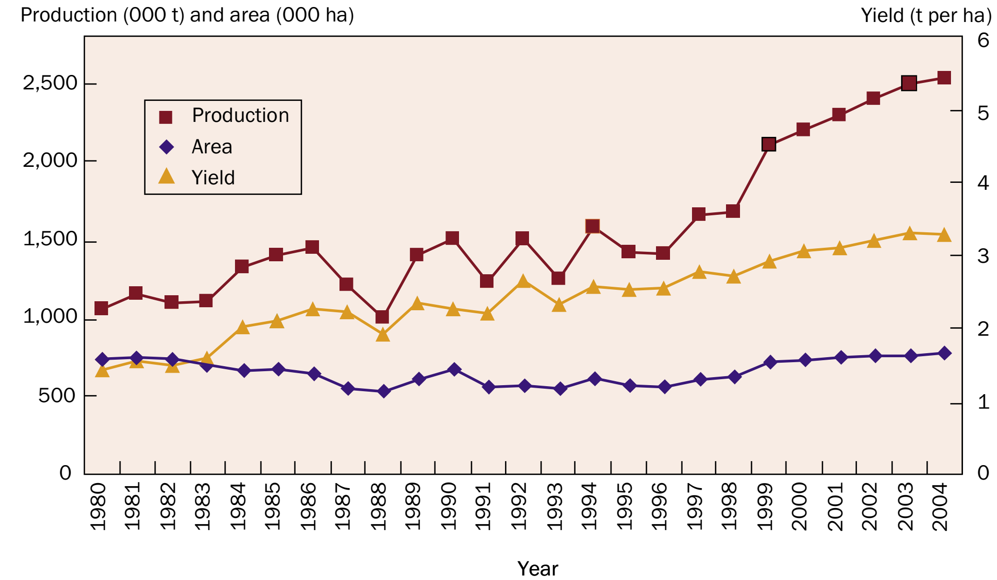



**Fig. 14. Rice area, production, and yield in Lao PDR, 1980 to 2004.**
Source: MAF (2005).

**Table 20. Sources of growth in rice production for 1990-95 and 1996-2004.[a]**

| Items | Technology development period | | Technology dissemination period | |
|---|---|---|---|---|
| | % Change, 1990-95 | Compound annual growth rate, 1990-95[a] | % Change, 1996-2004 | Compound annual growth rate, 1996-2004 |
| Area (000 ha) | –13.9 | –1.80 | 39.1 | 4.01 |
| Yield (tons per ha) | 10.4 | 2.75 | 28.6 | 3.31 |
| Production (000 t) | –4.9 | 0.93 | 78.9 | 7.32 |

[a]Growth rates estimated by fitting semi-logarithmic trend lines to time-series data.
Source: MAF (2005).

**Table 21. Estimate of increase in rice production at the national level, 2004.**

| Region | Estimated area under LMVs (000 ha)[a] | % Yield difference | | Production gain from LMVs (000 t) | |
|---|---|---|---|---|---|
| | | LMVs over OMVs[b] | LMVs over TVs | LMVs over OMVs[b] | LMVs over TVs |
| Northern | 11.0 | 0 | 0.3 | 0 | 2.9 |
| Central | 155.1 | 1.1 | 1.3 | 170.6 | 196.9 |
| Southern | 77.4 | 0.7 | 1.1 | 54.9 | 82.0 |

[a]Obtained using the estimated LMV adoption rate by region, northern = 11.4%, central = 40.7%, and southern = 44.3%.
[b]For the northern region, the average yield data from the survey indicate a lower yield of LMVs relative to OMVs, which are mostly Chinese hybrids. These Chinese hybrid varieties are grown mainly in the border region and in fields with good water control. LMVs have started to spread in the northern region in other areas where hybrid rice is not grown. Thus, the domain for LMVs and hybrid rice seems somewhat separate. The yield difference between LMVs and OMVs is assumed to be zero for this calculation to avoid any upward bias for the contribution of LMVs.
Source: Impact assessment survey (2005).

**Table 22. Estimated value of the increase in production by regions, 2004.**

| Region | Value of production gain (US$ million) | | % contribution by region | |
|---|---|---|---|---|
| | LMVs over OMVs | LMVs over TVs | LMVs over OMVs | LMVs over TVs |
| Northern | 0 | 0.3 | 0.0 | 1.0 |
| Central | 19.6 | 22.6 | 75.6 | 69.9 |
| Southern | 6.3 | 9.4 | 24.4 | 29.1 |
| Overall | 25.9 | 32.4 | 100.0 | 100.0 |

Source: Impact assessment survey, 2005.

contribution of the northern region is less than 5%, mainly because of the smaller rice area and lower rate of adoption of LMVs in this region.

## 6.5. Other Impact Considerations

The main and overriding objective of the Lao-IRRI Project has been to been to help Lao PDR to increase rice production for achieving food self-sufficiency. Other development considerations (goals) such as equity across gender and different ethnic groups, equitable regional development, biodiversity conservation, and environmental protection were secondary objectives not explicitly built into the project, except in Phase V of the Lao-IRRI Project. In this final phase, these considerations were included as desired goals of the project (Chamberlain et al 2002, Lao-IRRI Project 2005).

Rice production is an important source of livelihood in rural areas of Lao PDR. It is well established that technology-induced growth in rice supply helps reduce poverty in two ways (Timmer 2005). First, it increases rice production and availability for household consumption. Increased availability of food will contribute to poverty reduction directly by raising consumption. Second, an increased supply of rice in the market will also help keep the price of rice low. The urban poor, landless farm laborers, and food-deficit households rely on rice purchases to meet their food needs. For these households, a reduction in the price of rice is equivalent to an increase in income. This price effect will help reduce overall poverty indirectly. These direct and indirect effects on poverty are dependent on the size of the production gain resulting from improved technologies.

In Lao PDR, it has been well established that the incidence of poverty is negatively correlated with household rice availability (ADB 2001).



Households that have a rice deficit are almost always poor. Given this, an increase in rice production resulting from improved technologies would have definitely helped reduce poverty throughout the country. In the previous section, the increase in rice output directly attributed to the Lao-IRRI Project was estimated to be on the order of 225,000–282,000 tons in 2004 alone. As indicated in the previous section, households that adopted improved technologies increased rice consumption, generated more cash income from rice, and their overall welfare improved. At a broader level, it can be stated that improved technologies have contributed to an overall reduction in poverty.

Despite this overall effect, the technology-generated impact will be initially limited mainly to those households that have adopted the technology, although the flow-on effects will most likely benefit others also in the longer run. Hence, the differential impact of improved technologies across regions and among households can be related to technology adoption. The impact differentiated by gender, ethnic groups, and regions is discussed below.

### 6.5.1. Gender

One of the concerns in development literature is that technology interventions may have intrinsic biases that favor male-headed households relative to female-headed households. The study illustrated that the adoption of MVs by male- and female-headed households is similar, indicating that the technology has a broadly gender-neutral effect. The percentage of households and area with adoption of MVs disaggregated by gender is presented in Tables 23 and 24, respectively. Similarly, the rice self-sufficiency level and yield of improved varieties are marginally different between male- and female-headed households (Table 25). There is no apparent built-in bias in the nature of technologies that disadvantages the female-headed households.

Despite the apparently neutral gender effect of rice technologies, male-headed households are able to generate more cash income (Table 26). Proportionately more of the male-headed households reported an improvement in their general

**Table 23. Adoption of MVs among female- and male-headed households (%), 2004.**

| Region | Females | Males | Total |
|---|---|---|---|
| Northern | 54.2 | 57.5 | 56.9 |
| Central | 100.0 | 98.1 | 98.3 |
| Southern | 89.5 | 85.6 | 86.5 |
| Overall | 79.9 | 80.2 | 80.1 |

Source: Impact assessment survey, 2005.
Note: Total sampled households were 740 (females = 139 and males = 601).

**Table 24. Rice area under MVs among female- and male-headed households (%), 2004.**

| Region | Females | Males | Total |
|---|---|---|---|
| Northern | 42.8 | 46.4 | 45.9 |
| Central | 82.2 | 86.2 | 85.7 |
| Southern | 76.8 | 62.9 | 65.6 |
| Overall | 71.7 | 68.3 | 68.9 |

Source: Impact assessment survey, 2005.

**Table 25. Rice self-sufficiency in female- and male-headed households (%), 2004.**

| Region | MV adopters | | |
|---|---|---|---|
| | Females | Males | Total |
| Northern | 84.6 | 81.5 | 82.1 |
| Central | 91.2 | 91.1 | 91.1 |
| Southern | 68.6 | 71.4 | 70.8 |
| Overall | 79.3 | 82.2 | 81.6 |

Source: Impact assessment survey, 2005.

**Table 26. Cash income from rice among MV adopters in female- and male-headed households, 2004.**

| Region | Females (US$) | Males (US$) | % Difference | Absolute difference ($) |
|---|---|---|---|---|
| | | | Males over females | Males over females |
| Northern | 331.8 | 603.4 | 81.9 | 271.6 |
| Central | 333.8 | 330.2 | –1.1 | 3.7 |
| Southern | 219.1 | 255.1 | 16.5 | 36.1 |
| Overall | 284.9 | 381.0 | 33.7 | 96.1 |

Data source: Impact assessment survey, 2005.

**Table 27. Welfare among MV adopters in female- and male-headed households (%), 2004.**

| Welfare indicators | Females | Males | Total |
|---|---|---|---|
| Overall income | 70.3 | 81.5 | 79.4 |
| Rice production | 69.4 | 77.8 | 76.2 |
| Rice self-sufficiency | 61.3 | 75.7 | 73.0 |
| General health | 65.8 | 69.3 | 68.6 |
| Consumption of meat/eggs | 70.3 | 76.6 | 75.4 |
| Access to household electrical appliance | 65.8 | 72.0 | 70.8 |
| Access to farm information | 63.1 | 77.8 | 75.0 |
| Farm machinery | 48.6 | 67.6 | 64.1 |

Data source: Impact assessment survey, 2005.

welfare (Table 27). This differential impact from an apparently gender-neutral technology is indicative of different socioeconomic conditions that enable male-headed households to benefit more from emerging economic opportunities.

### 6.5.2. Ethnicity

The Lao population is made up of diverse ethnic groups, categorized into four ethno-linguistic families: Tai Kadai, Mon-Khmer, Hmong-Mien, and Tibeto-Burmese. Generally, these groups are categorized into lowlanders and highlanders (UNDP 2002). The Tai Kadai inhabit the lowlands, mostly in the central and southern regions, and cultivate paddy rice. This group is commonly referred to as Lao Leum. The three remaining groups traditionally reside in the mountains, mostly in the northern region, and practice swidden agriculture. These highlanders are further categorized into two groups, Lao Theung (high) and Lao Sung (very high). With recent changes in agricultural policies, and land allocation and distribution, these highlanders now also cultivate paddy rice. The highlanders are the ethnic minority in the country. The incidence of poverty among the highlanders is twice the national average. The impact of technology intervention on these three groups is examined to explore the benefits across different ethnic groups.

The Lao Leum ethnic group has the highest MV adoption rate as indicated by households and rice area with adoption of MVs (Table 28). This lowland-based ethnic group has obviously benefited from improved technologies for lowland rice production. Approximately 84% of the households from this ethnic group have adopted MVs. Other ethnic groups (Lao Theung and Lao Sung) have also adopted improved technologies but to a slightly lower extent. This differential effect, however, seems to be related to the regional location of these ethnic groups rather than to ethnicity per se. For all ethnic groups, adoption is lowest in the northern region (Table 29).

There is some difference in the adoption pattern of OMVs and LMVs among ethnic groups, however. The adoption of LMVs is higher among the Lao Leum and Lao Theung, while the adoption of OMVs is higher among the Lao Sueng. The Lao Seung, who are mostly located in the northern region, have easy access to Chinese hybrid rice varieties (or OMVs as defined here). Again, this differential effect seems to be related to the regional factor rather than to ethnicity per se.

**Table 28. MV adoption at the household level and rice area among different ethnic groups (%), 2004.**

| Ethnic group | Households | Area |
|---|---|---|
| Lao Leum | 83.9 | 74.5 |
| Lao Theung | 63.6 | 35.5 |
| Lao Sung | 74.3 | 60.0 |
| Overall | 80.1 | 68.9 |

Source: Impact assessment survey, 2005.



**Table 29. Households adopting MVs by region and ethnic group (%), 2004.[a]**

| Region | Lao Leum | Lao Sung | Lao Theung |
|---|---|---|---|
| Northern | 59.3 | 74.3 | 28.9 |
| Central | 98.3 | n.a. | 100 |
| Southern | 90.2 | n.a. | 79 |
| Overall | 83.9 | 74.3 | 63.6 |

[a]Total sample number is 740 (Lao Leum = 584, Lao Sung = 35, and Lao Theung = 121). The Lao Sung group is represented only from the northern region. n.a. = not applicable. Source: Impact assessment survey, 2005.

### 6.5.3. Region

There is clearly a differential regional impact of improved technologies developed through the Lao-IRRI Project. The technologies were targeted mainly to the lowland rice ecosystem of the central and southern regions. Naturally, the adoption of LMVs and associated rice technologies is higher in these regions relative to the northern region, where farmers are mainly growing OMVs. In recent years, there has been some spread of LMVs in the northern region also, but the overall impact is much larger in the southern and central regions than in the northern region. Almost all of the gain in production attributed to LMVs originated in the central and southern regions.

### 6.5.4. Biodiversity

Maintenance or improvement in biodiversity is considered desirable to facilitate the natural process of evolution and to provide gene pools for future use. Farmers have traditionally exploited natural biodiversity to develop a resilient production system that is able to meet their livelihood needs. However, such traditional systems are under threat as agricultural production systems are intensified to meet the increasing demand for food and other products for the growing population.

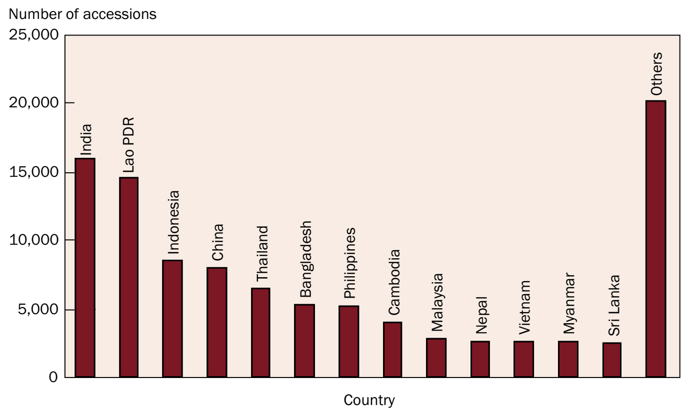



**Fig. 15. Origin of the germplasm in the International Rice Genebank at IRRI.**
Source: IRRI (2005). Genetic resources. Available at http://irriwww1/irrihome/GRC/GRCHome/Home.htm.

It is widely accepted that Lao PDR has one of the highest amounts of biodiversity of rice in the world. It appears to be the center of biodiversity for glutinous rice. To preserve this, the Lao-IRRI Project started a program to collect traditional varieties throughout the country. Later, this effort was enhanced by the Lao PDR Rice Biodiversity Project started in 1995 (also supported by SDC, currently in Phase II). More than 13,500 rice samples have been collected, of which the majority (85%) are glutinous types. These samples represent more than 3,000 rice varieties. In addition, more than 200 samples of wild rice of different species were also collected. Dr. Rod Lefroy, the representative of the International Center for Tropical Agriculture (CIAT) in Vientiane, said,
" ...the presence and documentation of rice genetic diversity is of enormous pride to Lao people and this is one aspect of the Lao-IRRI Project that is going to be remembered long after the project has been completed" (personal communication, 2005).

These resources are conserved in the national gene bank in the country, and in the International Rice Genebank at IRRI, which holds the world's most comprehensive collection of rice genetic resources. Lao PDR's contribution to the International Rice Genebank ranks the second highest (Fig. 15). In addition to seeds, indigenous knowledge about traditional rice varieties has been documented. These varieties are also being used in the current varietal enhancement program. Some varieties from this collection are in the pipeline to be released for upland farming systems. Some of the achievements to date include

- Collection of 659 germplasm accessions together with indigenous knowledge in 18 districts across the country.
- Four short training courses on indigenous knowledge, with two students conducting higher studies on this topic (M.Sc. and Ph.D.).
- Over 1,000 traditional varieties evaluated through participatory varietal selection for promoting *in situ* conservation of biodiversity.

It is widely believed that biodiversity of rice in Lao PDR has eroded over the past 15 years with the increased adoption of a limited number of modern varieties. The farm survey data indicated that the area under traditional varieties is now only about 30% at the national level as improved varieties are increasingly taking the place of traditional varieties. There is also an accompanying loss in indigenous knowledge on varietal characteristics and uses. Such a reduction in biodiversity is a general phenomenon observed in other countries also as the process of intensification and commercialization of agricultural production takes place. There can be little doubt that such a loss in biodiversity would have taken place in Lao PDR also irrespective of the improved varieties developed by the Lao-IRRI Project.



**Table 30. The top five most popular TVs in the surveyed area, 2004.**

| Ranking | TV name | Region | Preferred characteristics |
|---|---|---|---|
| 1 | Khao san patong | Northern and southern | Soft, white, and aromatic rice; tolerance of flood and drought; short and early maturity; good milling quality; suitable to different soil types; resistance to some diseases; good demand and high market price. Over 90% of the farmers reported that they will continue to plant these varieties. Khao san patong was mentioned as a "heritage variety." |
| 2 | Khao meuang nga | Northern | |
| 3 | Khao ta khiat | Northern | |
| 4 | Khao dam khai | Northern | |
| 5 | Khao purt nam | Southern | |

Source: Impact assessment survey, 2005.

Despite this loss, the extent of rice biodiversity in Lao PDR remains relatively high. The study indicated that 92 TVs were planted in the surveyed area in 2004. The most commonly planted TVs in the region where they are grown is illustrated in Table 30. These five popular varieties are planted on 31% of the total TV area (reported above), and the remaining 87 other varieties account for approximately 70% of TV area.

Despite some loss of rice biodiversity in Lao PDR, the *ex situ* collection of rice germplasm supported by the Lao-IRRI Project is an important achievement. This will help conserve the germplasm for the benefit of current and future generations. Detailed analysis and documentation of the extent of biodiversity are currently being conducted through the Lao PDR Biodiversity Project Phase II. That project supports the documentation and dissemination of indigenous knowledge of local TVs and *in situ* conservation that links up with *ex situ* collection for protecting and promoting future biodiversity of rice germplasm in Lao PDR (IRRI 2005).

### 6.5.5. Environment

Major environmental concerns related to agricultural intensification are the excessive use of hazardous chemicals (fertilizers, pesticides), overexploitation of groundwater, and degradation of marginal lands. The impact of the Lao-IRRI Project on these issues is considered here.

The farm-level data indicate that the average quantity of fertilizer use in Lao PDR is still quite low. A substantial proportion of farmers still do not use fertilizers. The recommendation developed by the Lao-IRRI Project is 60 kg per ha of N in the rainfed lowland ecosystem (Linquist and Sengxua 2001). At this rate of usage, chemical contamination of groundwater is unlikely. A main concern in Lao PDR is the insufficient use of fertilizer, not an excessive use.

A similar argument applies to the use of toxic pesticides. Farmers barely use various forms of pesticides (insecticides, herbicides, and fungicides) in rice. The recommendation from the Lao-IRRI Project is to practice integrated pest management and apply pesticides only when they are absolutely necessary (Savongdy et al 1995). To minimize any potential adverse effect on human health from inappropriate application, the Lao-IRRI Project has specified clear guidelines on application procedures and has provided the required training to local staff (Lao-IRRI Project Training Records 2005).

Irrigated rice accounted for less than 10% of the total rice area in the country in 2004. Most of the irrigation involves pump-lifting of

water from the Mekong River. Groundwater is scarcely used to irrigate rice. Thus, the question of overexploitation of groundwater for irrigating rice is unlikely to be an important concern in the future.

Land degradation arising from the practice of slash-and-burn shifting cultivation in the mountainous areas of Lao PDR is an important concern. This practice contributes to soil erosion and deforestation as farmers expand production in steeply sloping areas and encroach upon forests. The root cause of such a practice is low (and often decreasing) food productivity. Rising population pressure in the face of low agricultural productivity often forces farmers to expand food production into marginal land. Given this, an increase in food productivity through improved technology can reduce the intensification pressure in these marginal uplands. The improved rice technologies generated by the Lao-IRRI Project have the potential to help reduce the environmental degradation in sloping uplands. Improved rice technologies are being increasingly adopted in the northern mountainous region. With the further spread of these technologies, positive environmental benefits can be expected as intensification pressure in these marginal uplands decreases. In recent years, the rice area in uplands of the northern mountainous region has in fact started to decrease (see Appendix 8).

# 7. Establishing the Institutional Impact

The rice research system in Lao PDR was in its infancy at the start of the Lao-IRRI Project. The Department of Agriculture had approximately five staff members conducting adaptive research on rice at the Solakham Agricultural Institute, which was the only research center in the country at that time. Contact and exchange of information on rice technologies with the international community was naturally limited. A fully functional national agricultural system consisting of several research stations located in different regions of the country and managed by well-trained staff has evolved during the past 15 years. The Lao-IRRI Project played a key role in this institutional evolution.

## 7.1. Infrastructure Development

Infrastructure development was undertaken mostly during the first two phases of the Lao-IRRI Project implementation. Physical infrastructure such as access roads, buildings, laboratories, and screening facilities was constructed and research farms were established. Facilities were constructed to support research and training in Vientiane and various regions of the country. The major research stations and facilities constructed using support from the Lao-IRRI Project are listed in Table 31.

## 7.2. Establishment of the Research System

In addition to the physical infrastructure, the Lao-IRRI Project contributed substantially to the development of a functional national rice research system and the establishment of a network of research stations across the country in all 17 provinces (Fig. 16). A network of regional research centers under the umbrella of a national coordinating agency (NRRP) was established for developing and validating locally adapted agricultural technologies (see Fig. 2). (See Appendix 9 for the mandates and functions of the various research organizations.)

**Table 31. Major infrastructure development supported by the Lao-IRRI Project, 1990-2005.**

| | |
|---|---|
| **The Agriculture Research Center, 1995-98** | **Phone Ngam Rice Research Center, 1994-98** |
| Administrative building | Seed drying/processing building |
| Library | Renovation of dormitory |
| Renovation of the IPM office, 1998 | Administrative building |
| Rice breeding screenhouse, 1998 | |
| Plant breeding building, 1996 | **Northern Agriculture Research Center, mid-1990s to 2001** |
| Training building and facilities, 1995 | Office and laboratory |
| Dormitory, 1995 | Seed drying facility |
| Water tower, 1995 | Water tower |
| | Parking area |
| **Houay Khot Agricultural Research Center, Luang Prabang Province, mid-1990s** | Electrical control house |
| | Dormitory kitchen |
| Road access improvement | Drying area |
| Conference hall | |
| Seed storage and drying facility | **Ha Research Station, Sayabouly Province, 1999 to 2001** |
| Drying facility | Dormitory and kitchen |
| Adminstrative building | Seed storage facility |
| Dormitory | Bridge and arch |
| | |
| **Thasano Rice Research and Seed Multiplication Center, Savannakhet Province, mostly in 1997** | **Pakchaeng Station, Vientiane Province, 1996-99** |
| | Seed drying facility |
| Seed storage facility | Office building |
| Dormitory and fence | Training building |
| Drying facility | |
| Administrative building | **Houaphan Provincial Research Station, 1999** |
| Screenhouse | Administrative building |
| Water tower | Renovation of dormitory |

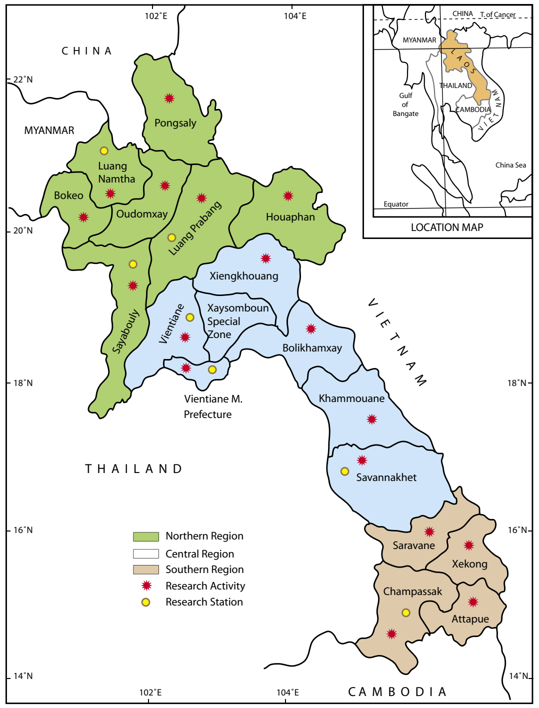



**Fig. 16. National rice research program network and research centers, 2000.**
Source: Lao-IRRI Project (2000c).

## 7.3. Human Resource Development

Human resource development (HRD) is one of the top priorities of the Lao-IRRI Project. Training provided to Lao staff included participation in workshops and conferences, degree and nondegree training, and other skill-building activities. Given the initial limited capacity, it was important to build the foundation for research through the development and upgrading of skills in almost all aspects of rice science and research planning, management, and implementation. Hence, the HRD program was designed to quickly build a critical mass of staff with various skills needed to set up a functional research system. A broad spectrum of agricultural organizations consisting of research, education, development planning, and extension was targeted for HRD in rice science and related disciplines.

### 7.3.1. Accomplishments of human resource development

The Lao-IRRI Project provided a total of over 4,600 individual training opportunities,[5] or about 335 per annum from 1990 to 2004 (Fig. 17).

A summary of short-term training conducted at IRRI headquarters, in other countries, and in-country is provided in Table 32. A majority (over 75%) of the training was provided through in-country programs.[6]

These training courses were broad-based and covered various disciplines and a range of skills. Over half of the total training was geared toward the development of basic technical skills. The English for agriculture training was supported throughout the Lao-IRRI Project implementation and accounted for 22% of the total training. The varietal improvement and crop management programs (nutrient, pest, and farming systems research) each accounted for 17% of the total training opportunities.

Most of the training conducted at IRRI headquarters consisted of farming systems research (32%), development of technical skills (25%), and germplasm improvement (16%). The main focus of the training in Thailand was on agricultural research management (52%) and varietal improvement (28%).

***Nondegree training***

Nondegree training activities were generally of short duration and covered a wide range of topics. Initially, this training was aimed at developing basic skills on various aspects of agricultural R&D. Such training was mainly conducted in-country as this is a cost-effective approach to train more people rapidly. Furthermore, the limited English language skills of the Lao people also necessitated this approach. The Lao-IRRI Project also supported training on research management and other general aspects of operations such as computer and library skills, and information management. These generic programs evolved subsequently to cover specific technical areas such as germplasm improvement, crop management, and postproduction practices.

These short-term programs also included on-the-job training. Senior and middle-level scientists and managers were invited to IRRI headquarters to work under the guidance of IRRI scientists on specific topics as a part of the training program.

***Formal degree training***

The Lao-IRRI Project sponsored staff for formal degree training (B.Sc., M.Sc., and Ph.D.) in reputed universities in and outside the region. These training programs were aimed at building the basic scientific knowledge of staff.

The Lao-IRRI Project supported undergraduate and postgraduate degrees for qualified Lao nationals working with NRRP. These programs were designed to provide formal credentials, recognition, and analytical skills to the Lao scientists. Some 22 individuals were sponsored for an advanced degree outside Lao PDR (Table 33). As a part of the study program, they conducted research on problems relevant to Lao PDR. These trained staff are now assuming a leadership role in scientific research and research management.

Another professional development component of the HRD was to enable scientific staff from Lao PDR to attend international conferences, seminars and workshops, and study tours related to rice science and technology

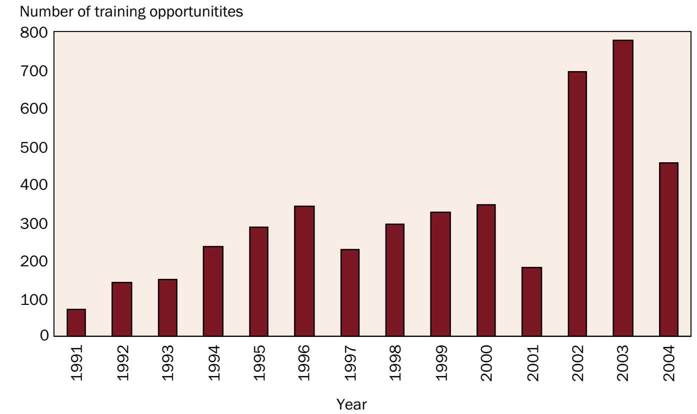



**Fig. 17. Number of training opportunities supported by the Lao-IRRI Project, 1990-2004.**
Data source: Lao-IRRI Project Training Records (2005).

[5] Training opportunities are defined broadly as participation in degree and nondegree training, workshops/conferences/study tours, and other skill-building activities made available to Lao staff.
[6] The total number of short-term training opportunities was 4,666 (nondegree training at IRRI = 146, nondegree training mainly in Thailand = 137, and in-country training = 4,383).

**Table 32. The short-term training supported by the Lao-IRRI Project (%), 1992- 2004.**

| Training courses | Nondegree training at IRRI | Nondegree training mainly in Thailand | In-country training | Total |
|---|---|---|---|---|
| **Variety improvement** | **16.4** | **28.5** | **16.6** | **17.0** |
| Genetic resources collection, evaluation, and utilization | 10.3 | 2.9 | 0.7 | 1.1 |
| Varietal selection and breeding | 2.1 | 18.2 | 5.5 | 5.8 |
| Seed health production and multiplication | 1.4 | 7.3 | 0.0 | 0.3 |
| Participatory research methods for breeding | 2.7 | 0.0 | 10.3 | 9.8 |
| **Nutrient management** | **8.2** | **1.5** | **4.9** | **4.9** |
| Integrated nutrient management | 7.5 | 0.0 | 0.0 | 0.2 |
| G × E analysis and interpretation of results | 0.7 | 0.7 | 0.0 | 0.0 |
| Soil fertility management | 0.0 | 0.7 | 4.9 | 4.6 |
| **Pest management** | **3.4** | **10.9** | **5.7** | **5.8** |
| Integrated pest management | 2.1 | 1.5 | 4.3 | 4.2 |
| Weed management | 0.7 | 6.6 | 0.0 | 0.2 |
| Postproduction pest management | 0.7 | 2.9 | 1.4 | 1.4 |
| **Farming systems research** | **31.5** | **0.0** | **5.2** | **5.9** |
| Rice production course | 19.9 | 0.0 | 3.6 | 4.0 |
| Rice intensification and rice-based farming systems | 11.6 | 0.0 | 1.6 | 1.9 |
| **Social science research** | **6.8** | **0.0** | **1.6** | **1.7** |
| Gender analysis in agriculture | 3.4 | 0.0 | 0.2 | 0.3 |
| Research methods for technology assessment | 1.4 | 0.0 | 0.8 | 0.8 |
| Socioeconomic survey design and analysis | 2.1 | 0.0 | 0.5 | 0.5 |
| Needs, opportunities, and diagnostic analysis | 0.0 | 0.0 | 0.1 | 0.1 |
| **Farm and agricultural research management** | **8.2** | **51.8** | **7.0** | **8.3** |
| Research planning and management | 4.1 | 4.4 | 6.7 | 6.5 |
| Farm management, experimental design, and data analysis | 4.1 | 29.9 | 0.3 | 1.3 |
| Information systems management and development | 0.0 | 17.5 | 0.0 | 0.5 |
| **Technical training** | **25.3** | **7.3** | **59.0** | **56.4** |
| Agricultural machinery use and development | 5.5 | 0.7 | 0.2 | 0.4 |
| Computer skills | 2.1 | 0.0 | 4.9 | 4.7 |
| Instructional video production | 0.7 | 0.0 | 0.0 | 0.0 |
| Geographic information systems (GIS) | 5.5 | 0.0 | 0.0 | 0.2 |
| Training of trainers | 4.1 | 0.0 | 0.0 | 0.1 |
| English for agriculture | 0.0 | 0.0 | 23.6 | 22.2 |
| Scientific writing and presentation skills | 0.7 | 2.9 | 3.8 | 3.6 |
| Intellectual property rights | 0.0 | 0.0 | 3.3 | 3.1 |
| Work experience in agricultural science | 0.0 | 0.0 | 8.1 | 7.6 |
| Others | 6.8 | 3.6 | 15.0 | 14.4 |
| **Total** | **100.0** | **100.0** | **100.0** | **100.0** |

Data source: Lao-IRRI Project Training Records (2005).

development. These opportunities were valuable in establishing scientific collaboration internationally. Senior scientists and research managers obtained 380 such opportunities.

### 7.3.2. The impact of human resource development

***Capacity building and setting up of research systems***

The Lao-IRRI Project clearly played a key role in building the capacity of research and related agricultural organizations to develop and implement various programs effectively. The hands-on involvement of IRRI scientists based at headquarters and in Lao PDR combined with the generous external funding from SDC allowed the Lao-IRRI Project to serve as an effective model for the design and implementation of commodity-focused research. The government of Lao PDR has well recognized these contributions to capacity development and establishment of research systems. The MAF's national strategy

**Table 33. The Lao-IRRI Project's support for university degrees.**

| University degree courses | Number |
|---|---|
| **Ph.D. degree** | |
| Varietal enhancement | 2 |
| **Master's degree** | |
| Varietal enhancement | 5 |
| Nutrient management | 1 |
| Pest management | 4 |
| Farming systems research | 1 |
| **Undergraduate degree** | |
| Bachelor of science | 5 |
| University bridging degree studies | 4 |
| **Total** | **22** |

Source: Lao-IRRI Project Training Records (2005).

for agricultural development in the country states, *"The project (Lao-IRRI Project) has been the principal source of capacity building and technological development in the rice sector in Lao PDR"* (MAF and JICA 2001). Dr. Monthathip Chanpengsay, deputy director of the NAFRI, is of the opinion that during 15 years of operation, "…strong foundations for rice research capacity have been developed by the Lao-IRRI Project and the National Rice Program can sustain itself, even without further direct assistance from IRRI."[7]

***Broad-based support to agricultural organizations***

Training opportunities were broad-based. The research centers/stations, provincial and district agricultural organizations, and other related organizations benefited directly and indirectly from the training program. "*You can't go anywhere in Laos and not bump into somebody who benefited from the training provided by the Lao-IRRI Project*," mentions Dr. Linquist, ex-Lao-IRRI Project representative and long-term staff (1997-2005) of the Lao-IRRI Project (IPMO 2005).

Research centers/stations and provincial and district organizations (PAFO/DAFO) that are mainly responsible for conducting adaptive research accounted for 80% of the training opportunities (Table 34). The Ministry of

**Table 34. Human resource development by the Lao-IRRI Project, 1992 to 2004.**

| Organizations | Support to different organizations (% of total) | Total personnel (number) | Males (% trained) | Females (% trained) |
|---|---|---|---|---|
| **Research organizations** | **25.2** | **117** | **81.2** | **18.8** |
| Agricultural Research Center | 15.5 | 72 | 80.6 | 19.4 |
| Luang Namtha Station | 1.9 | 9 | 55.6 | 44.4 |
| Hoykhot Station | 2.4 | 11 | 81.8 | 18.2 |
| Thaseno Station | 2.8 | 13 | 92.3 | 7.7 |
| Phone Ngam Station | 2.6 | 12 | 91.7 | 8.3 |
| **Provincial (and district) agricultural and forestry offices (PAFO/DAFO)** | **57.5** | **267** | **94.8** | **5.2** |
| Northern region | 21.8 | 101 | 94.1 | 5.9 |
| Central region | 22.8 | 106 | 95.3 | 4.7 |
| Southern region | 12.9 | 60 | 95.0 | 5.0 |
| **Agricultural ministry and planning organizations** | **6.5** | **30** | **88.7** | **11.2** |
| Ministry of Agriculture and Forestry | 1.3 | 6 | 83.3 | 16.7 |
| National Agricultural and Forestry Research Institute | 3.0 | 14 | 92.9 | 7.1 |
| Department of Agriculture | 2.2 | 10 | 90.0 | 10.0 |
| **Other agricultural organizations** | **10.8** | **50** | **94.0** | **6.0** |
| Nabong Agricultural College | 3.0 | 14 | 92.9 | 7.1 |
| National Agricultural Extension Agency | 3.7 | 17 | 94.1 | 5.9 |
| Soil Survey and Land Classification Center | 4.1 | 19 | 94.7 | 5.3 |
| **Total** | **100.0** | **464** | **90.9** | **9.1** |

Data source: Lao-IRRI Project Training Records (2005).

[7] Personal interview, February 2005.

Agriculture, the National Agricultural Extension Agency, and Nabong Agricultural College also benefited from the training program. Around 7% of the training opportunities went to national agencies that are generally responsible for planning and policy design such as MAF, DOA, and NAFRI. The remaining 11% of the support was allocated to strengthening the nation's only agricultural college, the newly established Soil Survey and Land Classification Center, and extension agencies. These trained people are now planning, implementing, and supervising research in their respective institutions.

Support for HRD to a broad spectrum of organizations played a critical role in establishing linkages across different agricultural and related organizations. Almost every agricultural organization in the country now has staff trained by the Lao-IRRI Project. Over 75% of these organizations are headed by or have senior research and management staff trained by the Lao-IRRI Project. Almost all current staffers working with the NRRP have received training supported by the Lao-IRRI Project. All these indicators clearly demonstrate the extent of the training program within the overall research system of Lao PDR.

In the final phase of the Lao-IRRI Project, the national staff undertook an increasing role in research planning and management. The Lao-IRRI Project further supported training for senior and middle managers to improve their planning and management skills to enable a smooth transition of research management to national staff when the Lao-IRRI Project comes to an end. These trained personnel are now ready to take on leadership roles in the overall management of research systems and in scientific areas of their specialization.

***Professional growth of scientific staff***

The Lao scientists were supported and encouraged to publish and present their findings in domestic and international conferences/seminars and meetings of professional associations. These activities have proven to be instrumental in fostering the exchange of scientific information about developments in rice science among peers. More than 150 papers on rice and related science

have been presented in professional meetings and many of them have been published (see list in Appendix 10). Most of these publications are coauthored by Lao scientists and include topics such as research and training prioritization, identification of production constraints, breeding, and nutrient and crop management practices. The diversity of topics covered indicates that the training has been broad-based. To encourage the publication of scientific research nationally, the Lao-IRRI Project also supported the development of the Lao Journal of Agriculture and Forestry.

***Development of training modules, tools, and fact sheets***

IRRI's publications in general and training manuals in particular have been a main source of information on rice science. This information was translated into Lao and adapted to Lao specifications. Almost all in-country training conducted by Lao nationals who were trained at IRRI relied exclusively on these training manuals.

In addition, fact sheets and other forms of information related to the management and operation of research/extension systems developed at IRRI have been adapted and used for research planning and management in Lao PDR. Such information is being used by extension agents, government officials, and international agencies working in Lao PDR.



***Trainees' perceptions of benefits from training***

During the survey, trainees were asked to provide a self-assessment of the impact of training on various aspects of their professional development and the operation of the organizations where they are based. A total of 140 trainees were interviewed.

The major benefits perceived by the trainees and the percentage of interviewees reporting the benefits (within parentheses) are listed below:

- ability to better plan, execute, and report experimental work (72%)
- increased recognition from peers (84%) and from various institutions (58%)
- ability to motivate peers to improve their work performance (64%)
- ability to better prioritize, plan, and implement research programs (39%)
- ability to view research activities in a broader perspective (59%)
- improved linkages with national and international organizations (34%)

(Source: Trainees survey for impact assessment 2004.)

The list highlights the important impact of the training program. The benefits cover all major aspects of the conduct of scientific research and research management.

There were also clearly some spillover effects of the training program on others. The key staffers who were trained initially also became role models for others. Those who did not participate in training initially were motivated to avail of training opportunities subsequently as they clearly perceived the potential value of training. Many sought future training opportunities by themselves (54%) and were successful in receiving such support (51%).

***Emphasis on training female staff***

The Lao-IRRI Project emphasized the need to include as many women staffers as possible in its training programs. However, a major constraint has been that the proportion of women who work in Lao agricultural and related organizations is low (10–15%). As a result, only 10% of the trainees were women (Table 34). Thus, the proportion of women trained is almost equal to their proportion in the total number of staffers.

The share of women trainees varies among various organizations. In research organizations, women account for almost 20% of the total number of trainees. The PAFO/DAFO and other agricultural organizations had a lower share of female trainees (around 5% to 6%). In research organizations, the training provided to women was mostly aimed at developing their research and management skills. Several of them now occupy senior management positions. At least two female staffers have received Ph.D.-level training.

Given the gender composition of the current staffing in the Lao PDR, the Lao-IRRI Project's HRD program can be viewed as having a good gender balance. Dr. Monthathip Chanpengsay, deputy director of research at NAFRI, a beneficiary of many of the training programs herself, mentioned that "*…qualified women have had an equal chance of being selected in any of the Lao-IRRI Project's training programs. There is no evidence at any level of discrimination in a training program based on gender*."

***Research collaboration and network development***

The Lao-IRRI Project played critical roles not only in the initial establishment of the rice research system, but it has also been instrumental in providing the necessary support for its evolution to a fully functional system. The investment in training helped build the necessary cadre of scientific staff. In addition, the Lao-IRRI Project functioned as a valuable platform for developing collaboration of the national research system with various national and international organizations. The Lao-IRRI Project provided guidance and support in establishing initial contacts and, subsequently, assistance in developing project proposals. For many international organizations, the Lao-IRRI Project served as the first point of contact and an important source of information and advice for developing new projects.

The facilitation, advisory, and support role of the Lao-IRRI Project contributed to the success of NAFRI in establishing linkages and receiving financial and other forms of support from various international agencies. Mr. K. Douangsila, director of the NRRP, states, "*The Lao-IRRI Project has been instrumental in bringing into the country complementary collaborative research, extension programs and training, and potential donors and developing linkages, thereby facilitating NRRP collaboration with other international agencies*." The Lao-IRRI Project alumni are now generally the main personnel collaborating with various development agencies, as they are the most qualified in their area of work.

Some highlights of the Lao-IRRI Project support in the development of research networks and collaboration follow.



Collaboration with IRRI

- Contributed toward conceptualization and establishment of the SDC-funded Rice Biodiversity Project. This project is coordinated by the Genetic Resources Center of IRRI, and is implemented in partnership with NAFRI.
- Developed a strong linkage with the Consortium for Unfavorable Rice Environments (CURE) and its predecessor, the Upland Rice Research Consortium. As a result of this linkage, CURE has identified Luang Prabang as the "key site" for upland rice research in mountainous areas of South and Southeast Asia.
- Supported Novartis Foundation's program for training on socioeconomic capacity development and a benchmark study on rainfed lowland rice production systems. This study was conducted by the Social Sciences Division of IRRI.
- Contributed to the development of the GIS Unit within the Soil Survey and Land Classification Center in collaboration with IRRI's Social Sciences Division (GIS Unit). This collaboration was crucial in developing soil and land-use maps in the country for the first time.
- Supported the IRRI-coordinated international network of the integrated pest management (IPM) program.
- Supported IRRI-coordinated international rice research networks, such as the International Network on Soil Fertility and Sustainable Rice Farming (INSURF).
- Supported an IRRI-coordinated shuttle breeding program. Improved genetic materials are being made available through this program to Lao PDR.

Collaboration with Australian organizations

- The Lao-IRRI Project was an important partner in a rice research project funded by the Australian Center for International Agricultural Research (ACIAR). This is the second major rice research project for the country. The project's main focus is on developing breeding strategies for rainfed lowland rice in the drought-prone environment. This project is implemented through the University of Queensland, Australia.
- Supported collaboration with the Commonwealth Scientific and Industrial Research Organization (CSIRO) on a project on "Rodent management in Southeast Asia." The program was coordinated by the Division of Wildlife and Ecology (Australia).
- Supported collaboration with the AusAID-funded "Smallholder Forages Project" and the Sloping Lands Network implemented through CIAT-CSIRO and the International Board for Soil Research and Management (IBSRAM), respectively.

Collaboration with other international agencies

- Supported the establishment of Helvestas/SDC-funded project, the Lao PDR Extension for Agriculture Project (LEAP).
- Facilitated the establishment and operation of the Integrated Upland Agricultural Research Project (IUARP), a major research project to develop rice-based farming systems technologies for uplands. This collaborative project involves several partners, including two other CG centers, ICRAF and CIAT. The project is implemented by NAFReC.
- Supported collaboration with Kyoto University in a program supporting research on production constraints related to soil and

water in the upland environment. This study was later incorporated into the IUARP.

- Supported the participation of the International Potash and Phosphate Institute and the World Phosphate Institute for integration into the IUARP. These organizations worked toward identifying more sustainable technology for upland farming and management practices.
- Supported a collaborative project on "Evaluation and improvement of glutinous rice germplasm," funded by the United States Department of Agriculture (USDA) and implemented through the University of California, USA.
- Supported collaboration with the Yunnan Agricultural Research Academy (China) and The University of New South Wales (Australia) for the development of aromatic rice. This collaboration includes Lao PDR, Thailand, China, and Australia. Through this collaboration, the Lao government is looking into opportunities for export of "specialty" aromatic rice.
- Supported collaboration with Shizuoka University and the Institute of Genetic Ecology of Tohoku University (Japan). This project focused on *in situ* conservation of wild rice.
- Supported collaboration with Khon Kaen University, Thailand. Eight senior research and research management staffers have completed or are in the process of completing Ph.D. and M.Sc. studies through this collaboration.
- Supported linkages with the Lao National Radio Station, Vietnam National Radio Station, and NAFES to disseminate approaches to integrated pest management. An education entertainment program funded by the Rockefeller Foundation is currently being implemented.
- Supported collaboration to develop a soil kit with the University of Hawaii, USA.
- Supported programs of various international organizations, including the Food and Agriculture Organization (FAO) of the UN, GTZ, World Vision, and GAA, to enhance staff capacity development in agriculture and the rice sector.




Support to Lao organizations

- Supported information exchange programs between NAFRI and NAFES in rice technology dissemination.
- Supported establishing linkages in four main agricultural colleges and extension agencies in Lao PDR to disseminate rice technologies to agricultural staff and students.

(Source: Lao-IRRI Project's annual and progress reports, 1990-2005.)

## 8. Return on investment

### 8.1. Benefit-cost analysis

For benefit-cost analysis, the direct production benefits from the Lao-IRRI Project are assumed to continue until 2020. Three stages of technology development and diffusion are assumed.

***Stage I: Technology development (1990-95)***
At the start of the Lao-IRRI Project, efforts concentrated on building the infrastructure and human capacity of the national research system. Although the technology package was developed during this stage, only a few farmers had access to new technologies. So, the impact at the national level was probably minimal. Hence, it is assumed here that any change in rice production during that period is not attributable to the Lao-IRRI Project. The production level, based on official statistics, is assumed to be the same with and without the project.

***Stage II: Increased adoption of new technologies (1996-2004)***
The benefits from rice technology development are assumed to increase during this period with the diffusion of technology. Benefits are also expected from ongoing specific targeted research and further refinements of technologies. The establishment of the National Agricultural and Forestry Extension Service (NAFES) in 2001 and the startup of extension projects such as the Lao Extension for Agricultural Projects (LEAP) are expected to help reduce the yield gap that exists between experimental farm and farmers' yield.

***Stage III: Full maturation of benefits (2005-20)***
Even after the completion of the Lao-IRRI Project, the benefits from its research, training, and technology development are expected to continue until 2020. Benefits continue as breeding materials and scientific knowledge developed earlier are fully used. In reality, these long-term benefits may also continue beyond 2020, but benefits up to 2020 only are included in the calculation.

### 8.2. Estimation of benefits during stages I, II, and III

The size of benefits depends on incremental yield, the area under improved technology, and the incremental cost of inputs. As the Lao-IRRI

Project impact is likely to differ by rice ecosystem, benefits for each ecosystem need to be calculated separately. Several assumptions are needed to estimate these components of benefits.

***Yield with and without the Lao-IRRI Project***

Up until 2004, yield with the Lao-IRRI Project is the current national yield by ecosystem. Yield without the Lao-IRRI Project from 1995 to 2004 is estimated by assuming that farmers would have grown TVs and OMVs had the project not been implemented. Based on the current yield data for OMVs and TVs, the yield growth rate that would have occurred in the absence of the project is estimated to be 0.5% per annum.

For the period 2005-20, yield data for both the with and without Lao-IRRI Project scenarios need to be projected. Yields for 2010 and 2020 were projected using the "likely" growth rates in yield that are consistent with the past pattern of growth in Lao PDR and yield levels currently achieved in irrigated, rainfed lowland, and upland environments in other rice-producing countries. The yield trajectory used is summarized in Table 35.

**Table 35. Rice yields in tons per ha with and without the Lao-IRRI Project.**

| Year | Rainfed lowland | | Irrigated lowland | | Rainfed upland | |
|---|---|---|---|---|---|---|
| | With | Without | With | Without | With | Without |
| 1990 | 2.8 | 2.8 | 3.4 | 3.4 | 1.5 | 1.5 |
| 1995 | 2.9 | 2.9 | 3.7 | 3.7 | 1.7 | 1.7 |
| 2004 | 3.4 | 3.0 | 4.5 | 4.0 | 1.8 | 1.8 |
| 2010 | 3.7 | 3.1 | 4.9 | 4.3 | 1.9 | 1.8 |
| 2020 | 4.3 | 3.3 | 5.7 | 4.7 | 2.1 | 1.9 |

***Area under improved technology***

The area under improved technology (LMVs and associated crop management practices) is assumed to increase in a sigmoid pattern for each subecosystem. A sigmoid growth pattern indicates a slow initial adoption rate, followed by rapid diffusion in the second stage and a final slowdown and tapering off. The sigmoid curve is widely used to represent the adoption pattern of innovations (Alston et al 1995). The shape of the sigmoid adoption curve is determined by three parameters: the initial rate of adoption, the ceiling adoption rate, and the time to reach the ceiling rate. The assumed values of these three parameters for the rice ecosystems are presented in Table 36. Because of the favorable environmental conditions, the initial rate of adoption and the ceiling adoption rate are assumed to be highest for the irrigated dry-season crop. The time required for the ceiling adoption for irrigated conditions is assumed to be lowest for the same reason. The lowest ceiling and the lowest rate of adoption are assumed for the upland ecosystem. The adoption curve for the rainfed lowland ecosystem represents an intermediate pattern.

**Table 36. Adoption parameters for a sigmoidal adoption curve.**

| Parameter | Irrigated lowland | Rainfed lowland | Rainfed upland |
|---|---|---|---|
| Adoption ceiling (%) | 90 | 70 | 40 |
| Initial rate of adoption (%) | 10 | 3 | 1 |
| Years until ceiling adoption | 10 | 15 | 15 |

***Cost of improved technologies***

Improved technologies increase farmers' costs as additional labor and/or material inputs are normally required. The increases in farmers' costs are estimated from the farm survey data (Table 16). The increase in cost per ha is expressed as a proportion of the increase in gross revenue per ha (i.e., the value of additional output per hectare). This ratio is estimated to be equal to 26%. This implies that 26% of the increase in the value of output per ha is accounted for by the increase in farmers' costs. This ratio is used to estimate the total increase in cost at the national level.

***Local cost of research and extension***

Additional costs are incurred by the national government to support research and extension staff. These costs need to be included in the benefit-cost analysis. The additional costs are assumed to be 1% of the additional value of production.

***Cost of irrigation infrastructure***

The government of Lao PDR invested considerably to expand irrigation during the 1990s. This investment targeted rice and several other crops. It is safe to assume that the public-sector investment in irrigation would have occurred irrespective of the Lao-IRRI Project. From the Lao-IRRI Project perspective, the investment in irrigation is a sunk cost and should not be included in the benefit-cost analysis. Rice production, especially in the dry season, has benefited from the expansion of irrigation. To avoid an upward bias on the estimate of the Lao-IRRI Project benefit, a sensitivity analysis is conducted later by excluding the irrigated dry-season rice completely from the benefit estimation.

***Farmers' costs of irrigation development***

To make use of the irrigation facility provided by the government irrigation program, farmers also need to invest in land improvement such as land leveling, channel building, and the purchase of small lifting devices. These costs are assumed to be $100 per ha for irrigated rice land.

***Discount rate***

A discount rate of 10% is assumed for discounting benefits and costs of the Lao-IRRI Project to obtain present values.

***Sensitivity analysis***

The effect of several assumptions made earlier on the estimated benefit-cost analysis of the Lao-IRRI Project is assessed by conducting a series of sensitivity analyses. The purpose of these analyses is to obtain lower-bound estimates of the returns on Lao-IRRI Project investment. The major scenarios considered are

- Lao-IRRI Project benefits are limited to rainfed lowlands only.
- Lao-IRRI Project benefits terminate in 2010 rather than in 2020.
- The price of rice decreases to $100 per t.

## 8.3. Results of benefit-cost analysis

Under the base set of assumptions described in Table 37, the net present value of the investment at a 10% discount rate is estimated to be $60 million. This is equivalent to a benefit-cost ratio of 7:1 (Table 38). Hence, each dollar invested in the Lao-IRRI Project is estimated to generate

**Table 37. Baseline assumptions for the net present value calculations.**

Baseline assumptions

1. Price of rice is $115 per t (farm-gate price).
2. Farmers' cost of irrigation development is $100 per ha.
3. Local research and extension cost is 1% of the incremental value of production.
4. The farmers' extra cost for adoption of LMVs is 26% of the incremental value of production.
5. Yield with and without the project as per Table 35.

**Table 38. Estimation of return on investment at 10% discount rate, 2004.**

| | |
|---|---|
| Year | 2020 |
| Price of rice per t | $115 |
| Net present value | $60 million |
| Internal rate of return | 26% |
| Benefit-cost ratio | 7:1 |

a net benefit (net of all costs, including the cost of the Lao-IRRI Project itself) of $7 for the Lao economy. This is a handsome rate of return indeed. The estimated internal rate of return of the Lao-IRRI Project is 26%. In other words, each dollar invested in the Lao-IRRI Project is estimated to earn an average net annual rate of return of 26% up until 2020.

### 8.4. Results of sensitivity analysis

If the Lao-IRRI Project is assumed to benefit rice production in the rainfed lowland only, the estimated net present value is still $48 million (Table 39). This accounts for 80% of the NPV obtained in the base scenario. Thus, the impact of the Lao-IRRI Project is driven mainly by the technological changes in the rainfed lowland. Although production growth in the irrigated dry season has been substantial in recent years, its smaller share in production (7%) means that future research benefits will depend mainly on production growth in the rainfed lowland. The effect of alternative assumptions about production growth in the uplands on NPV is also quite small as the productivity impact in uplands is currently limited.

If the Lao-IRRI Project benefit is assumed to terminate in 2010 rather than in 2020, the NPV drops to $28 million, with the internal rate of return being 24%. This is still a good return on investment.

If the price of rice decreases to $100 per t, the internal rate of return in all situations remains at least 20%. Thus, the economic returns from the Lao-IRRI Project are quite robust even under the unfavorable scenarios.

**Table 39. Sensitivity analysis of return on investment at 10% discount rate, 2004.**

| Price rice/year | Rainfed ecosystem only | | | All ecosystems | | |
|---|---|---|---|---|---|---|
| | Net present value (US$ million) | Internal rate of return (%) | Benefit-cost ratio | Net present value (US$ million) | Internal rate of return (%) | Benefit-cost ratio |
| Rice price $115 per t | | | | | | |
| 2010 | 20 | 21 | 2 | 28 | 24 | 3 |
| 2020 | 48 | 25 | 5 | 60 | 26 | 7 |
| Rice price $100 per t | | | | | | |
| 2010 | 16 | 20 | 2 | 23 | 22 | 3 |
| 2020 | 40 | 22 | 5 | 51 | 24 | 6 |

## 9. Conclusions

The results presented in this report clearly demonstrate the substantial contribution of the Lao-IRRI Project to achieving the twin objectives of national self-sufficiency in rice and the establishment of a fully functional rice research system. Rice production in Lao PDR increased at the compound rate of 7.3% per annum during 1996-2004 as the improved technologies developed by the project spread throughout the country. In 2004 alone, the gain in production as a result of the spread of improved varieties (and associated crop management technologies) developed by the project is estimated to be 226,000 to 282,000 tons. Modern rice varieties have spread rapidly and cover 69% of the rice area. Of this, the varieties developed by the Lao-IRRI Project (LMVs) account for half the area. These LMVs are well adapted to Lao conditions and have a yield advantage of 29% and 19% over other modern varieties (OMVs) and traditional varieties (TVs), respectively.

The estimated production gain is expected to increase with a further expansion of area under improved varieties already released and those in the pipeline. As rice production is a major economic activity, future increases in its production will most likely generate additional employment and income in other sectors through multiplier effects.

Lao PDR attained rice self-sufficiency at the national level for the first time during the past 20 years in 1999. There is little doubt that the project played a critical role in this achievement although there were other contributing factors.

The impact of technologies developed by the Lao-IRRI Project has been gender-neutral with both male- and female-headed households achieving similar adoption rates and yields of rice. The regional impact has been more in the central region, which is the main lowland rice-growing region of Lao PDR. Impact in the northern region has been the least as the technologies targeted mainly the central and southern regions. Nevertheless, improved varieties developed by the Lao-IRRI Project are now spreading in the northern region also.

The environmental impact of the Lao-IRRI Project has been benign or positive. The usual environmental problems associated with excessive use of farm chemicals such as fertilizers and pesticides are nonexistent in Lao PDR as the use of such inputs is not widespread. The recommendations for the use of chemical fertilizers are for moderate quantities that are unlikely to result in environmental problems. Similarly, the Lao-IRRI Project has promoted the use of integrated pest management techniques to avoid using toxic pesticides. On the positive side, increased rice production in the lowlands has contributed to environmental protection by reducing the pressure to intensify rice production in the fragile marginal uplands. Although this impact is not explicitly documented in this report, the observed long-term decrease in upland rice area is indicative of this positive environmental benefit.

The Lao-IRRI Project has also contributed to the conservation of rice biodiversity in Lao PDR. The establishment of the rice genebank in Lao PDR, the

collection of over 3,000 samples of landraces, and documentation of indigenous knowledge regarding the use of this germplasm are some of the evidences of the contribution of the Lao-IRRI Project.

An analysis of the economic rate of return on investment in the Lao-IRRI Project shows a healthy rate of return that is fairly robust under alternative assumptions about various parameters built into the benefit-cost analysis. The net present value of investment is estimated to be $60 million. Each dollar spent in the project is generating a net economic benefit of $7 to the Lao economy.

In addition to these various economic impacts, the Lao-IRRI Project has made a substantial contribution to the establishment of a fully functional rice research system in Lao PDR. This includes the establishment of a network of 13 research stations and the development of a well-trained cadre of research scientists and managers. During 15 years of its operation, the project provided over 4,600 training slots, which include higher degree training, short courses, on-the-job training, and participation in international conferences/seminars. This cadre of trained staff is now providing scientific and management leadership in the agricultural research system of Lao PDR. The Lao-IRRI Project also served as a valuable platform for developing collaboration of the national system with other national and international agencies. The research system of Lao PDR is now at the stage of development at which it can fully participate in regional research initiatives and consortia. In fact, this is already happening with Lao PDR being identified as a key site for rice research in uplands under the Consortium for Unfavorable Rice Environments.

The Lao-IRRI Project effectively "nurtured" the research system through its infancy to make it a fully functional "mature" institution that is able to operate effectively on its own. This is indeed a tremendous and lasting contribution to institutional development that will continue to pay handsome dividends well into the future.

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# APPENDICES

**Appendix 1. Research highlights of the Lao-IRRI Project, 1990-2005.**

| Research program | Rainfed lowland | Rainfed upland | Irrigated lowland |
|---|---|---|---|
| Gene bank | • Collection, characterization, and preservation of traditional glutinous and nonglutinous cultivars.<br>• Variety improvement of indigenous and introduced lines.<br>• Documentation and dissemination of indigenous knowledge on local rice.<br>• Enhancement of the sustainability of *ex situ* and *in situ* conservation through PVS. | • Collection, characterization, and preservation of traditional upland glutinous and nonglutinous cultivars.<br>• Selection of cultivars for improved drought-tolerance traits. | • Evaluation and characterization of existing varieties and cultivars. |
| Varietal development | • Selection of MVs and TVs particularly for medium- and short-maturing varieties.<br>• Selection of MVs for different stresses, i.e., drought, flood, and low temperature.<br>• Development of nonglutinous cultivars for cash cropping.<br>• Varietal improvement for improved yield potential, early-to-medium maturity, with and without photoperiod sensitivity, tolerance of drought, resistance to gall midge, green leafhopper, blast, and bacterial blight, and suited to moderate to low inputs.<br>• Demonstration of new released varieties through PVS.<br>• Research on grain quality improvement. | • Characterization of different rice production systems.<br>• Evaluation and identification of MVs and TVs for tolerance of drought and cold temperature, and resistance to pests and diseases.<br>• Screening and evaluation of legumes for rice-based farming systems.<br>• Identification of promising lines and varieties through PVS.<br>• Identification of an early- and medium-duration variety suited to short fallows or continuous cropping.<br>• Improvement of short-fallow management practices. | • Selection and identification of glutinous and nonglutinous MVs for medium maturity, photoperiod insensitivity, tolerant of low temperature.<br>• Evaluation and characterization of existing varieties and cultivars.<br>• Identification of promising glutinous, nonglutinous, and aromatic lines.<br>• Identification and demonstration of introduced lines. |
| Nutrient management | • Evaluation of N and P deficiency and development of management practices.<br>• Demonstration of acute P deficiency in most areas of central and southern Lao PDR.<br>• Assessment of organic fertilizers and green manure crops to help improve rice yield and soil fertility.<br>• Development of appropriate cultural practices for low-input cultivation.<br>• Assessment of organic fertilizers and green manure crops to reduce dependence on inorganic fertilizers.<br>• Plant nutrition and fertilizer responsiveness focusing on organic and inorganic fertilizer management.<br>• N application through LCC evaluation and the System of Rice Intensification (SRI). | • Soil fertility management studies.<br>• Assessment of upland soil fertility, land use, and management practices.<br>• Assessment of the significance and development of control measures for soil erosion. | • Characterization of soil fertility and development of management practices based on organic and inorganic fertilizer use.<br>• Nutrient response studies for crop intensification.<br>• Soil management studies to demonstrate acute P deficiencies.<br>• N timing and residual P studies. |
| Plant protection | • Identification of biotic constraints, assessment of yield loss, and development of appropriate IPM technologies.<br>• Screening and identification of varieties with resistance to common rice insects (gall midge, rice bug, brown planthopper, golden apple snail) | • Yield loss assessment from pests and diseases, and development of appropriate IPM technologies.<br>• Development of weed biology management technologies.<br>• Identification of biotic constraints to rice | • Identification of insects and other pests, assessment of yield loss and development of appropriate IPM technologies.<br>• Formulation of control strategies for BPH.<br>• IPM studies on the economic effects of stem borers on irrigated rice yield. |

*continued on next page...*

**Appendix 1 continued.**

| Research program | Rainfed lowland | Rainfed upland | Irrigated lowland |
|---|---|---|---|
| | and diseases (leaf blast, bacterial leaf blight, and brown spot).<br>• Classification of glutinous TVs for resistance to gall midge. | production systems.<br>• Assessment of yield loss and development of appropriate IPM technologies.<br>• Weed management on the effects of mulching, variation in planting density of rice, intercropping, and crop rotation.<br>• Development of rodent management technologies. | • Variety screening for brown planthopper, golden apple snail, rice bug, bakanae, etc.<br>• Weed management strategies. |
| Agronomy | • Development of low-input use management practices for resource-poor farmers.<br>• Development of strategies for minimizing loss from drought and flood.<br>• Studies on crop growth patterns and yield improvement strategies.<br>• Development of strategies for yield loss minimization from dry conditions. | • Assessment of soil erosion and development of control measures.<br>• Evaluation of agronomic practices, soil fertility, and weed problems.<br>• Introduction of improved lowland rice practices in uplands.<br>• Analysis of nutrient cycling in upland agricultural systems.<br>• Evaluation of various management practices to enhance soil fertility such as burning versus nonburning of crop, fallowing, rotation with a legume crop, use of N fertilizer. | • Evaluation of the effect of planting time on growth and grain yield. |
| Farming systems research | • Development of rice-based farming systems technologies.<br>• Demonstration of combined application of improved varieties and crop-growing practices through on-farm trials.<br>• Integration of participatory research methods.<br>• Demonstration of technology package including improved varieties, improved fertilizer management, and higher plant populations.<br>• Evaluation of potential fallow improvement species. | • Development of sustainable rice-based technologies.<br>• Characterization of different upland rice-based farming systems.<br>• Development of various integrated farming options including combining of teak with rice and/or other food crops and livestock production.<br>• Identification of suitable fallow improvement species such as pigeon pea and paper mulberry.<br>• Development of rice-based production systems for optimizing production and income. | • Identification of legumes for crop rotation to improve soil fertility. |
| Other research | • Verification of rice drying systems at farm and commercial level.<br>• Verification of hermetic sealed storage systems.<br>• Dissemination of rice production technologies.<br>• Socioeconomic studies.<br>• Collection of market data. | | • Evaluation of selected pre- and postharvest technologies.<br>• Collection of market data.<br>• Verification of drying systems at farm and commercial level.<br>• Verification of hermetic sealed storage systems. |



**Appendix 2. Farm survey locations with corresponding sample size.**

| Region/province | District name | Village name | Sample size |
|---|---|---|---|
| **Northern region** | **6** | **16** | **255** |
| Luang Namtha | Sing | Yang Piang | 18 |
| | | Siliheuang | 17 |
| | | Xiang Moun | 21 |
| | Long | Paka | 17 |
| | | Hua Kua 2 | 17 |
| | | Done Yea | 13 |
| | Namtha | Nam Ngean | 19 |
| | | Hua Kua | 11 |
| Oudomxay | Na Mou | Na MouNear | 16 |
| | | Pang Sa | 19 |
| | | Na Thong | 18 |
| | Xay | Done Keo | 16 |
| | | Thin | 12 |
| | Ra | Phon Xay | 14 |
| | | Done Sa ad | 16 |
| | | Buam Suam | 10 |
| **Central region** | **5** | **12** | **240** |
| Vientiane Municipality | Sangthong | Na Thiam | 20 |
| | | Tha Nakam | 20 |
| | | Ang Noy | 20 |
| | Nasaythong | Phathana | 20 |
| | | Na Nad | 20 |
| | | Num Kiangtai | 20 |
| Savannakhet | Saybouri | Phon Than | 20 |
| | | Som Saad | 20 |
| | Outhoumphone | Aa Hong | 20 |
| | | Na Huakua | 20 |
| | Champhone | Nong Viak | 19 |
| | | Na Kou | 22 |
| **Southern region** | **5** | **12** | **245** |
| Saravan | Saravan | Ko | 21 |
| | | Phao | 22 |
| | | Na Khoysao | 19 |
| | Toumlarn | Na Vienghong | 19 |
| | | Na Hongkam | 22 |
| | | Dindak | 20 |
| Champassak | Phonthong | Oupalad | 21 |
| | | Non Saad | 20 |
| | Pathoumphone | Nong Bouanoy | 17 |
| | | Lak 30 | 20 |
| | Soukouma | Boug Keo | 20 |
| | | Hiang | 21 |
| **Total** | **16** | **40** | **740** |

**Appendix 3. Names of enumerators and their organizational affiliation.**

Agricultural research organizational staff
- Mr. Khamouane Khamphoukeo, NAFRI
- Mr. Bounthieng Manivong, Phone Ngam Center
- Ms. Viengmany Many, Northern Agriculture Research Center
- Mr. Sengmany, Nongdeng Station
- Ms. Phouthone Onkeo, Northern Agriculture Research Center
- Ms. Vielkham Phiasakha, National Agricultural and Forestry Research Institute
- Mr. Sonekham Phamixay, Northern Agriculture Research Center
- Mr. Manith Sengthonghak, Northern Agriculture Research Center
- Mr. Keosuvanh Sihathep, Phone Ngam Center
- Ms. Southamaly Sisavath, Northern Agriculture Research Center
- Ms. Pany Vanmanivong, Agricultural Research Center

PAFO/DAFO staff
- Mr. Kensi Keomanichanh, Oudomxay Province
- Mr. Chanthy Manichit, Oudomxay Province
- Mr. Khampee, Saravane Province
- Mr. Sinthalay, Savannakhet Province
- Mr. Phouthone Sumphonpakdi, Savannakhet Province
- Mr. Somphong Vongsuthi, Savannakhet Province
- Mr. Bounthong Xayavong, Luang Namtha Province

The Lao-IRRI project staff
- Dr. Thiphavong Boupha
- Mr. Khamsouk Mosky
- Mr. Bounmy Sengthong

**Appendix 4. Lao modern rice varieties in the pipeline to be released for the lowland ecosystem.**

| Introduced lines | Expected year of release | Traits |
|---|---|---|
| TDK 9 | 2006-07 | Photoperiod-sensitive with yield potential of 3.5–4 t per ha. |
| TDK 10 | 2006-07 | Yield potential of 3–5 t per ha, plant height of 130 cm, with 7 panicles per hill. |
| NTH 1 | 2006-07 | Non-photoperiod-sensitive, maturity time of 135–140 days with plant height of 90–110 cm, yield potential of 4–6 t per ha, good milling recovery, and good resistance to bacterial leaf blight. |



**Appendix 5. Other modern rice varieties recommended.**

| Introduced line | Country source | Year | Traits |
|---|---|---|---|
| RD6 | Thailand | 1985 | Aromatic glutinous rice with excellent eating quality, photoperiod-sensitive, resistant to blast and brown leaf spot, can be direct-seeded, suitable for middle terraces in central and southern regions.<br>**Weaknesses:** Susceptible to bacterial leaf blight, BPH, and GLH, tendency to lodge. |
| RD8 | Thailand | 1985 | Glutinous variety with good eating quality, photoperiod-sensitive, plant height 140–160 cm, tolerant of dry conditions, moderate resistance to blast and brown spot, can be direct-seeded, suitable for middle terraces in central and southern regions.<br>**Weaknesses:** Susceptible to bacterial leaf spot, BPH, and gall midge, tendency to lodge. |
| RD10 | Thailand | 1978 | Glutinous with good eating and milling qualities, photoperiod-insensitive, plant height 90–110 cm, moderate yield potential, responsive to moderate rather than high input levels, broad adaptability, and can be grown in lowlands during wet and dry seasons.<br>**Weaknesses:** Low resistance to insect pests and diseases, susceptible to gall midge, stem borer, BPH, GLH, blast, and bacterial leaf blight. |
| KDML105 | Thailand | 1975 | Aromatic nonglutinous rice with good eating and milling qualities, photoperiod-sensitive, plant height 135–140 cm, good tolerance of dry conditions, resistant to root-knot nematode, can be direct-seeded, suitable for acid and saline soils and for lower terraces in central and southern regions.<br>**Weaknesses:** Susceptible to bacterial leaf blight, orange leaf virus, grassy stunt virus, BPH, GLH, and stem borer. |
| RD23 | Thailand | 1994 | Nonglutinous rice with good eating quality, photoperiod-insensitive, plant height 100–120 cm, resistant to some BPH biotypes and suitable for lowlands for wet and dry seasons.<br>**Weaknesses:** Susceptible to leaf and neck blast. |
| NSG19 | Thailand | 1996 | Nonglutinous variety with good eating quality, photoperiod-sensitive, plant height 125–130 cm, good tolerance of dry conditions, suitable for upper and middle terraces for rainfed lowlands in central and southern regions.<br>**Weaknesses:** Susceptible to blast, bacterial leaf blight, orange leaf virus, BPH, GLH, and gall midge. |
| IR66 | IRRI | 1994 | Nonglutinous variety, photoperiod-insensitive, short maturity of 115–125 days, plant height 80–85 cm, resistant to BPH and GLH, suitable for direct seeding, suitable for wet and dry seasons in central and southern regions.<br>**Weaknesses:** Susceptible to blast. |
| CR203 | Vietnam | 1983 | Nonglutinous variety, photoperiod-insensitive, plant height 80–90 cm, high yield potential and performs best on soils of high fertility or with high fertilizer inputs, can be direct-seeded, good resistance to most biotypes of BPH, leaf blast, and bacterial leaf blight, good for noodle and beer production, suitable for wet and dry seasons. |
| Hang-yi 71 | Thailand | 1995 | Glutinous variety with excellent eating quality, photoperiod-sensitive, plant height 140–145 cm, tolerant of dry conditions, resistant to blast and brown spot diseases, suitable for high and middle terraces in rainfed lowland environment in central and southern regions.<br>**Weaknesses:** Susceptible to bacterial leaf blight, BPH, GLH, and gall midge. |
| IR253-100 | IRRI | 1975 | Glutinous variety with high yield potential and nitrogen-responsive, photoperiod-insensitive, strong stemmed, can be direct-seeded, suited to rainfed lowlands and dry-season irrigated conditions, broad adaptability in central region, also suitable for northern region. Moderate resistance to GLH, gall midge, and bacterial leaf blight. |

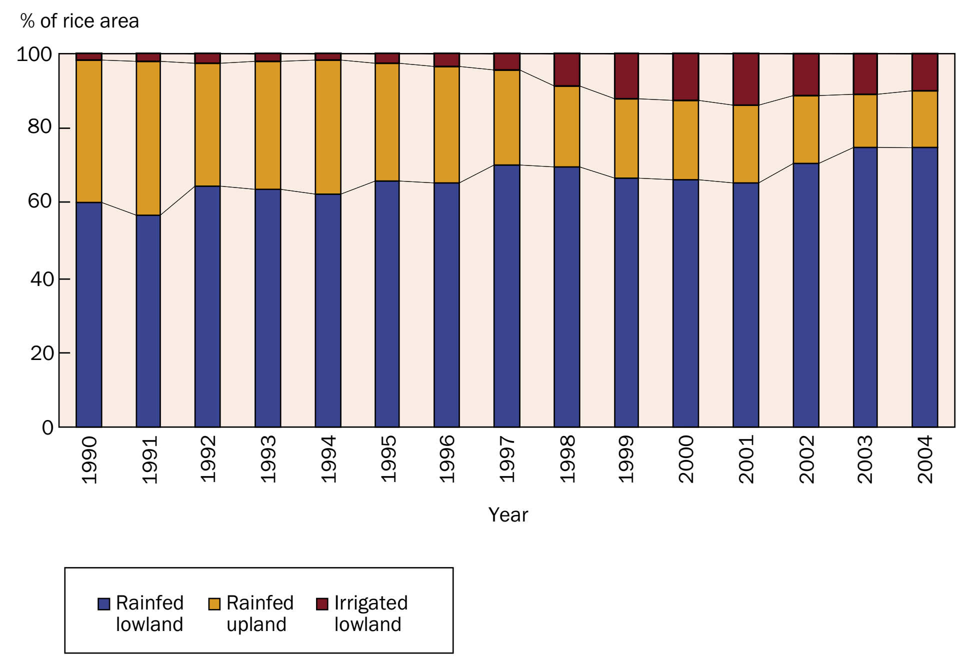
**Appendix 6. Traditional varieties recommended for the rainfed lowland ecosystem.**

| Traditional variety | Year | Region | Traits |
|---|---|---|---|
| Dokmai | 1995 | Upper and middle terraces in central and southern regions. | Glutinous variety with good eating quality, photoperiod-sensitive, plant height 145–150 cm, good adaptability to areas of low fertility. **Weaknesses:** Susceptible to bacterial leaf blight, BPH, and GLH. |
| Makhing | 1991 | Upper and middle terraces in central and southern regions. | Glutinous, photoperiod-sensitive, plant height 135–145 cm, tolerant of dry conditions at the end of the growing season. **Weaknesses:** Susceptible to lodging, bacterial leaf blight, blast, gall midge, BPH, and GLH. |
| Makyom | 1992 | Central and some northern provinces. | Glutinous, photoperiod-sensitive, height 140–150 cm. **Weaknesses:** Susceptible to lodging, gall midge, BPH, GLH, blast, and bacterial leaf blight. |
| Takhiat | 1991 | Northern provinces and main plains of central and southern regions. | Glutinous, photoperiod-sensitive, plant height 130–140 cm, good tolerance of blast. **Weaknesses:** Susceptible to lodging, bacterial leaf blight, BPH, and GLH. |
| Nangnuan | 1991 | Upper and middle terraces of central and southern regions and some northern provinces. | Glutinous, photoperiod-sensitive, and tall (130–140 cm). **Weaknesses:** Susceptible to lodging, gall midge, blast, bacterial leaf blight, BPH, and GLH. |
| Hom Nangnuan | 1992 | Main rice-growing plains in central and southern regions. | Aromatic glutinous rice with good eating quality, photoperiod-sensitive, plant height of 145–150 cm. **Weaknesses:** Susceptible to lodging, gall midge, BPH, GLH, blast, and bacterial leaf blight. |
| Meang Nga | 1991 | Northern provinces, also suitable in main plains of central and southern regions. | Glutinous, photoperiod-sensitive, plant height of 140–150 cm, blast-resistant. **Weaknesses:** Susceptible to lodging, bacterial leaf blight, gall midge, BPH, and GLH. |
| Lay keaw | 1991 | Main rice-growing regions in central and southern regions and some provinces in northern region. | Good eating quality, photoperiod-sensitive, plant height of 140–150 cm. **Weaknesses:** Susceptible to bacterial leaf blight, BPH, and GLH. |

**Appendix 7. Traditional black rice varieties recommended for the rainfed lowland ecosystem.**

| Traditional variety | Traits |
|---|---|
| Kham 6 | Glutinous rice, photoperiod-sensitive with maturity of 148 days, plant height of 137 cm, yield potential of 2.3 tons per ha. **Weakness:** Susceptible to lodging and low yield. |
| Kham 7 | Glutinous rice, photoperiod-sensitive with maturity of 144 days, height of 141 cm, yield potential of 2.7 tons per ha. **Weakness:** Susceptible to lodging and low yield. |
| Kham 14 | Glutinous rice, photoperiod-sensitive, maturity of 142 days, height of 134 cm, yield potential of 2.7 tons per ha. **Weakness:** Susceptible to lodging and low yield. |
| Kham 17 | Glutinous rice, photoperiod-sensitive with maturity of 140 days, height of 138 cm, yield potential of 2.6 tons per ha. **Weakness:** Susceptible to lodging and low yield. |

**Appendix 8. Changes in rice area in Lao PDR by ecosystem, 1990 to 2004.**
Source: MAF (2005).




## Appendix 9. Functions and responsibilities of the research organizations in Lao PDR.

| Research organization | Mandate | Designated provincial/regional responsibilities | Functions |
|---|---|---|---|
| Agricultural Research Center (ARC) | Rice research and technology development for the lowland rice ecosystem in the rainfed and irrigated ecosystems.<br><br>The center also has direct responsibilities in research for the five provinces in the central region. | Sayabouly, Vientiane, Borikhamxay, and Vientiane Municipality | Research planning and technology development for the lowland rice eco system.<br><br>Germplasm conservation, evaluation, and use.<br><br>Coordinates and provides technical support to RRCs on the national rice research program.<br><br>Conducts on-station and on-farm experimentation and develops general recommendations for lowlands (in particular for the lower central region).<br><br>Network with national and international agencies working in the region. |
| Northern Agriculture and Forestry Research Center (NAFReC) | Upland (rainfed) rice-based cropping systems research for the country. | Provinces with upland rice farming systems. | Research planning and coordination for upland farming systems.<br><br>Provides support in research and institutional development for the northern research stations.<br><br>Conducts on-station and on-farm research throughout the country and develops recommendations for the upland rice ecosystem.<br><br>Network with national and international agencies working in the region. |
| Northern Agriculture Research Center | Lowland rice research for rainfed and irrigated rice ecosystems affected by low temperature mainly in the northern region. | Luang Namtha, Oudomxay, Phongsaly, Borkeo, Luang Prabang, Houaphan, Xiengkhouang, Sekong (southern provinces affected by low temperature) | Research and technology development in their region of responsibility.<br><br>Conducts on-station and on-farm experimentation in the designated provinces and develops recommendations. |
| Thasano Rice Research and Seed Multiplication Center | Lowland rice research for rainfed and irrigated rice ecosystems for the lower central region. | Khammouane and Savannakhet | Conducts on-station and on-farm experimentation in the designated provinces and develops recommendations.<br><br>Network with national and international agencies working in the region. |
| Phone Ngam Rice Research Center | Lowland rice research for rainfed and irrigated rice ecosystems for the southern region. | Saravane, Champassak, Sekong, and Attapeu | |
| Provincial Agriculture and Forestry Offices (PAFO) | Adaptive research and validation of research findings for the provinces. | Designated province(s) for PAFO | Conducts adaptive research and provides technical support and training for district extension staff.<br><br>Network with national and international agencies working in the province. |
| District Agriculture and Forestry Offices (DAFO) | Research validation and upscaling for districts. | Designated district(s) for DAFO | Provides research-based extension services and training to farmers. |



## Appendix 10. Publications of the Lao-IRRI Project, 1990 to 2005.


### 1991

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Roder B, Manivong W, Leacock VW, Soukhaponh H. 1992. Farming systems research in the uplands of Laos. Proceedings of the Upland Rice-Based Farming Systems Research Planning Meeting, Chiang Mai (Thailand). p 39-54.

Soukhaphonh H, Roder W, Phengchanh S, Vannalath K. 1992. Research at a key upland farming systems site: Luang Prabang. In: Proceedings of the Upland Rice-Based Farming Systems Research Planning Meeting, Chiang Mai (Thailand).

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### 1994

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Roder W. 1994. On-farm management of biodiversity and genetic resources. In: Proceedings of the Regional Conference on Sustainable Development of Fragile Mountain Areas of Asia, Kathmandu (Nepal), 13-16 Dec. 1994.

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Lathvilayvong P, Schiller JM, Phommasack T, Kupkanchanakul T. 1995. Nutrient management in the rainfed lowland rice environment of Laos. In: Proceedings of the 1995 International Rice Research Conference, 13-17 Feb. 1995, Manila (Philippines).
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Chanphengsay M, Whitbread AM, Schiller JM, Blair GJ, Linquist B, Lathvilayvong P, Sengxua P. 1999. Soil fertility decline in Lao PDR and the potential of pre-rice green manures to improve the sustainability of rice production systems. In: Whitbread AM, Blair GJ, editors. Integrated nutrient management in farming systems in Southeast Asia and Australia. Australian Centre for International Agricultural Research, ACIAR Proceedings No. 93. p 21-27.

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