Rice in Laos

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Contents

Foreword

Rice has been identified with the area now known as the Lao People's Democratic Republic (Laos) for much longer than the country has existed. Archaeological evidence has shown that rice has been grown in the region for at least 6,000 years. Laos is known to be within the region generally accepted as the area of origin and domestication of Asiatic rice (*Oryza sativa*). It is also believed to be near the center of the area of origin of "glutinous" or "waxy" rice.

Rice has long been the most important food crop cultivated in Laos, and at the beginning of the third millennium still accounted for more than 80% of the area under cultivation within the country. With an average annual consumption of more than 170 kg of milled rice, Laos is among the group of countries with the highest per capita consumption of rice in the world. In most rural areas of Laos, rice accounts for almost 80% of calorie intake. The strong cultural identity of the people of Laos with the consumption of "sticky" or glutinous rice is widely acknowledged. Laos has the highest per capita production and consumption of glutinous or waxy rice in the world. The Lao language expression "to eat" not only means "to eat rice" as in the language of neighboring Thailand, but "to eat glutinous rice."

This book, *Rice in Laos*, helps document the long association of Laos and its people with rice in historical, cultural, and agricultural contexts. It provides a record of the diversity of, and biodiversity within, the rice ecosystems within the country. It is not meant to provide a detailed record of all recent advances in rice research, reports on which are available from other sources. However, it does provide a summary of some of the more salient recent advances in rice-related research undertaken since about 1990. It is anticipated that the book will be an important reference both nationally and internationally. The planned Lao language version of the book will also provide an important reference book for the agricultural education sector within Laos.

The compilation of the book has been a genuine collaborative effort among international scientists and scholars, and researchers within Laos. The support of the Australian Center for International Agricultural Research (ACIAR), in collaboration with the International Rice Research Institute (IRRI), in the publication of English and Lao language versions of the book is gratefully acknowledged.

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CHAPTER 1

Population diversity and rice in Laos

Martin Stuart-Fox

Modern humans evolved in Africa beginning around 200,000 years ago, from where they spread first to the Middle East and thence to Asia and Australia. They were hunter-gatherers who developed a profound knowledge of the natural environment and evolved a sophisticated material culture in the course of their search for food and shelter. A large number of their temporary and semipermanent settlement sites have been discovered and excavated in different parts of mainland Southeast Asia reaching back some 40,000 years.

Southeast Asian stone-age sites fall roughly into two groups: (1) coastal, especially estuarine, sites whose inhabitants exploited the bountiful resources of the sea as well as the coastal lowlands; and (2) inland sites situated in caves and rock shelters above river valleys. Many early coastal sites must have been progressively submerged as sea levels rose after the last ice age, around 20,000 years ago, forcing people to move to higher ground. Inland sites reveal that, though population was more thinly spread than along the coast, most of the interior of mainland Southeast Asia, including the area covered by present-day Laos, was already widely inhabited by these early hunter-gatherers. Who they were we do not know, though they may have been akin to the Orang Asli of peninsular Malaya or the negritos of the Andaman Islands.

By 15,000 years ago, a material culture known as the Hoabinhian, named after sites excavated in the 1920s in the Vietnamese province of Hoa Binh, began to spread throughout much of mainland Southeast Asia. Hoabinhian sites in Laos have yielded core choppers, usually worked on one face only, stone axes and flake knives and scrapers, and points and spatulae made of bone. These were used to make traps, snares, and containers of wood, bamboo, and rattan that were easier and lighter to carry than the stone tools left at sites to which bands would repeatedly return. These material remains were associated with a modern fauna, including frogs, turtles, monkeys, squirrels, civets, and small deer. Some larger species—pigs, cattle, and large deer—also appear. By 10,000 years ago, hand-made pottery was being produced.

The hunter-gatherer lifestyle represented by the Hoabinhian "techno-complex" (Gorman 1971) has persisted as a successful way of life for forest hunter-gatherers such as the Mlabri (Yumbri) right up to the present. It was not, however, a static culture, but one that creatively evolved with changing environmental conditions to form regional variants. A number of cave sites in northern Thailand illustrate such developments. As sites became more permanent, the collection and grinding of wild seeds and grains appear to have provided an increasing proportion of the diet. Few excavations have been carried out in Laos, but there is little doubt that similar developments took place within the Mekong basin as were happening within that of the Chao Phraya. One significant development over this period was that we occasionally find deliberate inhumation of the dead, mostly in a flexed position. Another, judging by the human remains available, was that the population was becoming more characteristically Mongoloid in anatomy.

The transition to settled agriculture

It used to be thought that the domestication of rice might have taken place in mainland Southeast Asia. More accurate dating procedures now make this unlikely. Charles Higham argues that rice was probably first domesticated from wild strains in the Yangzi valley, which was, therefore, "one of the very few areas in Eurasia that witnessed a Neolithic Revolution, the transition from hunting and gathering to agriculture" (Higham 2002, p 84). This probably occurred between 8,000 and 6,000 BCE, after which the innovation diffused slowly into southern China and west into Yunnan. From there, settled agriculture based on rice production filtered southeast down the Red River valley and south down the Mekong valley by at least 4,000 BCE. Rice became widespread throughout mainland Southeast Asia by 2,000 BCE.

The key role of the upper and middle Mekong in the expansion of settled agriculture from Yunnan to the plains of northern and northeastern Thailand has been indicated by a site survey of the upper reaches of the river and its northern tributaries. This revealed numerous small settlement mounds, along with samples of the black incised pottery common to Yunnan and Vietnam (Higham 2002). None of these sites in Laos have yet been scientifically excavated, but what the pattern of settlement suggests is the intrusion of a new population, in all likelihood speakers of Austroasiatic (Mon-Khmer) languages, which by the last centuries BCE had spread south across the plains of the central Chao Phraya and down the Mekong into Cambodia. They were accompanied by the domestic dog, the first remains of which date from early agricultural sites. At the same time, Austronesian speakers (of the Chamic subgroup) had settled along the coast of Vietnam, perhaps around the lower Mekong Delta area later identified with the kingdom of Funan.

Four archaeological sites in northeast Thailand, of which the two best known are Ban Chian and Non Nok Tha, provide important evidence of new Neolithic settlements in the Mekong valley in the early second millennium BCE. The picture we have is of quite large agricultural communities practicing horticulture and rainfed wet-rice production, probably in natural wetlands and seasonal shallow ponds. Most remarkable is the extensive use of pottery and burial of the dead in defined cemeteries, in the graves of which much of the pottery was found. From the excavations it is evident that hunting and fishing still supplied a good percentage of the diet, including large animals such as wild buffalo, pigs, and large deer. Turtles, fish, and shellfish provided important additions to the diet. Shell ornaments and copper and bronze items have also been excavated, though claims of very early dates for metallurgy are now discounted.

By the mid-second millennium BCE, the large Neolithic settlements were in trading contact with each other. Marine shells, ornaments, and stone tools were extensively traded, and along these routes passed knowledge of techniques such as copper smelting, bronze alloying, and pottery production. Bronze metallurgy is known from western China in the third millennium BCE. From there, knowledge of early techniques probably diffused east to give rise to the wonderful Chinese Shang bronzes, and could well have also percolated south to the northern part of the Khorat Plateau. There, several important excavations have revealed a flourishing bronze-age civilization dating from between 1,500 and 500 BCE, when bronze began to give way to iron.

This bronze-age culture undoubtedly extended across the Mekong to Laos, where the tin essential to form bronze (which is stronger than copper) alloys was being mined in the Nam Pa Taen valley. In the foothills east of the Mekong, it seems that a parallel culture was developing, based on horticulture and cultivation of taro and other root crops and dry-field rice. By the mid-first millennium BCE, farmers on the Khorat Plateau in northeast Thailand were using iron-tipped ploughs pulled by domesticated water buffaloes.

The early iron age lasted roughly a millennium until the rise of the first large-scale kingdoms (*mandalas*) in mainland Southeast Asia. This coincided with a remarkable culture located in the region of Xieng Khouang in Laos. This was the megalithic culture associated in its early (Hua Phan) phase with standing menhirs (preiron age) and in its later (Xieng Khouang) phase with the remarkable stone jars that give the Plain of Jars its name. These jars measure on average around 1.5 m in height and diameter, with some much larger, weighing as much as 15 tons. That these were part of a funerary cult is indicated by what appears to be a central crematorium at Ban Ang. Higham (1989) dates the jars to between the third century BCE and the third century CE.

Archaeological investigations have thrown no light on the ethnic or linguistic affinities of the "people of the jars," but it seems more likely that they spoke an Austroasiatic rather than an Austronesian language. This would accord with a strong oral tradition among the Khmu, the largest Austroasiatic-speaking minority in northern Laos, that the jars were sculpted by their ancestors. Lao tradition concurs in ascribing the jars to the Khom, early Mon-Khmer speakers (Stuart-Fox 1998).

Ethnic diversity in mainland Southeast Asia

By the mid-first millennium CE, small, local principalities ruled by powerful families were beginning to coalesce into larger kingdoms. This process is often referred to as "state formation," but these expanding "circles of power" are better described by the Indian term *mandala* (Wolters 1982). At the time of Funan, in the first known mandala in mainland Southeast Asia, located in southeastern Cambodia and southern Vietnam, Austroasiatic-speaking peoples were spread thinly across all of what is now southern Vietnam, Cambodia, Laos, Thailand, and southern Myanmar. An Austronesian-speaking people, the Cham, were creating their own polity along the coast of central Vietnam, while, in the Red River Delta, Vietnamese and Muong speakers had been incorporated into the southernmost province of China.

Around the fifth century CE, a center of Khmer power developed in the region of Champassak, in what is now southern Laos. This kingdom extended its power south of the Falls of Khon marking the present-day boundary between Laos and Cambodia. It subsequently divided into two mandalas—"land Zhenla" on the middle Mekong and "water Zhenla" in Cambodia. Land Zhenla succeeded in defeating Funan to establish the basis for the growth of Cambodian power in the ninth century that came with the establishment of the mandala of Angkor. Meanwhile, a center of Mon power developed in southern Thailand, with smaller mandalas on the Khorat Plateau.

The economic basis for this process of mandala formation lay in the tribute extracted from villages (in the form of rice, other staples, resources, and products) by a powerful central ruler. Faced with demands for tribute, established villages could do little but pay. The only alternative was to move. Land was plentiful and people could reconstruct their villages relatively easily. This was more difficult if they grew wet rice, but was easy for villages growing dry-field rice, supplemented by vegetables and root crops. The dispersion of Austroasiatic (Mon-Khmer)-speaking peoples into the uplands of Laos, Cambodia, and Thailand and of Austronesian-speaking minorities into the highlands of southern Vietnam was probably partly a response to mandala formation by peoples determined to avoid being drawn into these early circles of power. This was a process that occurred frequently in the history of the region, right through to French colonial times.

By the beginning of the second millennium CE, centers of power, principally Khmer or Mon, were scattered across mainland Southeast Asia from southern Cambodia to northern Thailand, including in Laos—Champassak, the Thakhek region, the Vientiane plain, and probably also Luang Prabang (all four straddling the Mekong). Mon mandalas existed in northern as well as southern Thailand, and Mon influence probably extended throughout much of the middle Mekong. As the power of Angkor grew in the eleventh century, Khmer power extended up the Mekong and across the Khorat Plateau to reach its greatest extent in the twelfth century. Thereafter, it waned, leaving something of a vacuum that was quickly filled by new peoples who had been filtering for at least two or three centuries into northern and central Thailand and Laos.

These peoples spoke Tai (Daic) languages. They included peoples who came to be known as the Tai-Lao of the Mekong valley, the Tai-Phuan of Xieng Khouang, the Tai-Shan of the northeast Burma highlands, the Tai-Nyuan of northern Thailand, and the Tai-Sayam of central Thailand. All share certain cultural characteristics, including wet-field rice cultivation (of one variety or another), worship of nature spirits (*phi*), and political organization in the form of *meuang*. This was not a territorial unit, but a socio-political structure in which a hereditary aristocratic elite claimed the loyalty of a free peasantry based on reciprocal obligations. The peasantry helped cultivate the lands of the ruling family and could be conscripted to fight under its command. In return, the ruling elite was responsible for the protection and well-being of the *meuang* through propitiation of the *phi meuang* and organization of military defense.

Little is kown about the slow migration, probably from before the eighth century, of Tai peoples from southern China into northern Vietnam, Laos, and Burma (now Myanmar). It may have been, however, partly in response to Chinese attempts to tighten their administrative control over minority peoples in southern China (Wyatt 1984). Their movement would have been slow, from one river valley to the next as population expanded and land could be wrested from whoever was already there. Partly the process would have been peaceful: Tai farmers taking up vacant land along valley floors, laboriously constructing their rice fields and irrigation channels, intermingling with people already there, speaking Austroasiatic languages, and farming rain-dependent rice supplemented by hunting and gathering of forest products. At first, the Tai speakers were probably partly dependent on these neighbors (Khmu, Lamet) for food and assistance. But, as their numbers grew, conflict must have at times occurred. Eventually, their superior political organization would have enabled the Tai to take control of the valley and force the earlier inhabitants to move to higher ground.

For the Tai-Lao, this slow migration eventually brought them down the southwest-flowing tributaries of the Mekong from the Tai highlands of Vietnam (and the region of Dien Bien Phu, known to the Tai as Meuang Thaeng). One of these tributaries was the Nam U and another was the Nam Khan, which brought them to Luang Prabang, then known as Meuang Sua, a river junction probably ruled over by a local Khmu prince. This became the first center of Lao power in northern Laos, and the first capital of the Lao kingdom of Lan Xang (founded in the mid-fourteenth century).

Migration of Tai peoples continued elsewhere—into the headwaters and central basin of the Chao Phraya River, onto the plateau of Xieng Khouang and the plateaus of central Laos, and south to the riverine plains along the Mekong. There they encountered what remained of earlier organized principalities of Austroasiatic-speaking peoples—Khmer, Mon, and others—with higher levels of material culture (based on Buddhism and Indian-derived writing systems and artistic canons). In the long process of mutual assimilation that followed, Tai princes adopted much of the superior Mon-Khmer culture of the Chao Phraya and Mekong basins, but imposed both their political control and their language on the existing population. Lao *meuang* thus came to incorporate a mixed population, in which intermarriage would have been increasingly common. As these expanded in power, they probably drew within their orbit upland villages of people determined to preserve their own ways of life. Other peoples moved deeper into the mountains to escape any form of political control.

Much later, in the late eighteenth and early nineteenth centuries, yet other ethnic groups began migrating into Laos mainly from southern China, once again to escape tightening administrative controls that threatened their cultural independence and freedom. These were the Hmong-Mien- and Tibeto-Burman-speaking peoples. Of these two broad groups, the Hmong spread most deeply into Laos, settling at high altitudes in the mountains of northern Laos, the mountainous areas surrounding the Plain of Jars in Xieng Kouang Province, to the provinces of Borikhamxay, and across to Sayabouly Province. The Mien and Tibeto-Burman tribes such as the Akha, Phunoi, and Lolo confined themselves to the far north. Thus was finally created the patchwork pattern of ethnic and linguistic diversity characteristic of Laos today.

Ethno-linguistic diversity in Laos

In its 1995 census, the government of the Lao People's Democratic Republic recognized 47 official ethno-linguistic groups (National Statistical Centre 1997). Other counts have identified as many as 130 different groups, based on self-definition (Chazée 1999). These can be divided into four major groups on the basis of language: Lao-Tai (66.2%), Austroasiatic (Mon-Khmer) (22.7%), Hmong-Yao (or Miao-Yao) (7.4%), and Tibeto-Burman (2.9%). To these may be added a fifth group comprising small numbers of Chinese from Yunnan, known as the Ho, who have been resident in northern Phongsaly Province for some two centuries. Some scholars include the Ho in the Tibeto-Burman family and distinguish them from immigrant Chinese from other parts of China, who together with resident Cambodians, Burmese (mainly Shan), Thai, and Vietnamese constitute the fifth population group. None in this fifth group are rice-growers, however.

Ethnic Lao (including the Phuan of Xieng Khouang) constitute 52.5% of the total Lao population and are concentrated in the Mekong lowlands, along river valleys and on plateaus. In the northern provinces of Phongsaly, Luang Namtha, and Bokeo, their place is taken by the Tai-Leu, accounting for 2.6%. A further 10.3% are upland Tai (Phutai), including Black, Red, and White Tai, named for the colors of their traditional dress, and the Phou Tai of Khammouane and Savannakhet in central Laos (Goudineau 2003, p 14). Several other small Tai groups speak different dialects and define themselves as different from the Lao. Chazée (1999, p 2) lists 27 different ethno-linguistic groups within the Lao-Tai family, though officially only six are recognized (Lao, Leu, Nyuan, Sek, Yang, and Phutai).

All groups in the Lao-Tai family cultivate wet-field rice, most commonly glutinous varieties. They live in sedentary villages, often quite large, of houses built off the ground on stilts or poles. Social distinctions persist, separating aristocrats from commoners. Most are Buddhists, and all propitiate local spirits (*phi*). The Lao-Tai family forms the general category of Lao Loum, or lowland Lao (UNDP 2002).

The 30 officially recognized ethno-linguistic groups of the Austroasiatic family can be divided into five subcategories, of which two—Palaungic and Khmuic—are located only in northern Laos, one (Vietic) is confined to a strip along the Lao-Vietnamese frontier, and the remaining two—Katuic and Bahnaric—are found only in the plateaus and mountains of southern Laos. Chazée (1999, p 51) reports having identified 59 distinct ethnic and "subethnic" minorities in this family. Many of the largest group are the Khamu, accounting for 11% of the Lao population. The two largest groups in the south are the Katang (2.1%) and the Makong (2%). No other group numbers more than 1%.

The minorities composing the Austroasiatic family all live at higher altitudes than the Lao, in smaller villages containing houses on shorter stilts or poles. Some produce rice in rainfed paddies; others grow dry-field rice using slash-and-burn methods. Communities are not hierarchically stratified, but kin groups may be identified with totemic animals. Most are animist, worshipping a variety of spirits identified with the locality, house, or family. Some have converted to Buddhism or Christianity through contact with Lao neighbors or foreign missionaries. Together these minorities in the Austroasiatic family constitute the general category of Lao Theung, Lao of the (mid-altitude) slopes.

The Hmong-Yao group contains the Hmong (6.9%) (divided by Chazée into two subgroups) and two smaller Yao minorities together amounting to 0.5%. Eight Tibeto-Burman minorities are officially recognized, of which only the Akha (1.9%) account for more than 1% of the total population. In contrast, Chazée recognizes 33 ethnic and subethnic groups. Both Hmong and Yao are further divided into exogamous patrilineal clans, 15 for the Hmong and 12 for the Yao, who are further divided into subclans. Most reside at higher altitudes than the Austroasiatic minorities, and differ from them by building their houses on the ground. They grow nonglutinous rice using slash-and-burn methods. Both have been influenced by centuries of contact with the Chinese before migrating to Laos, the Yao more than the Hmong. For example, the Yao use Chinese characters to write their religious and customary texts, and for both the worship of ancestral spirits is important.

The Tibeto-Burman minorities are mostly confined to the far north of Laos in the province of Phongsaly. They generally live at slightly lower altitudes than the Hmong and Yao, but like them build their houses on the ground. They are also swidden farmers who prefer nonglutinous rice to the glutinous varieties. Each group worships its own pantheon of animist spirits, except the Phounoi, who have converted to Buddhism. Minorities of the Hmong-Yao and Tibeto-Burman families are together referred to as Lao Soung, Lao of the mountain tops.

The persistence of the extraordinary ethno-linguistic diversity in Laos reflects, in part, past difficulties in communication throughout the country. The diversity and history of the individual ethnic groups are also reflected in the diversity of, and within, the rice-growing environments within the country that have also persisted until relatively recently, and which are reported elsewhere in this book. Changes, both government-initiated and as a direct result of improvements in communication, are resulting in increased interaction among the ethnic groups, with minority groups having increased contact with the ethnic Lao majority, particularly as a result of education initiatives and increased commercialization of agriculture. Traditional upland cultivation practices based on slash-and-burn systems will be replaced by more sustainable forms of agriculture. In the lowland environment, modern improved rice varieties have already largely replaced traditional varieties. Fortunately, extensive germplasm collections undertaken during 1995 to 2000 will enable the conservation and preservation of much of the traditional rice germplasm of Laos (see Chapter 9). However, much of the indigenous knowledge associated with past traditional agricultural practices has a high probability of being lost.

Government policies are not the only basis of the changes that are taking place in Laos. As in other parts of Southeast Asia, people of Laos are moving from villages into towns to seek employment and a better life. Although this is a movement that is now primarily affecting ethnic Lao, it is also likely to affect ethnic minority families in the future as differences in standards of living increase between the provincial cities along the Mekong and rural areas. Considerable internal migration is already taking place within provinces as families move to district and provincial capitals (Bounthavy and Taillard 2000, p 50-57).

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Notes

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CHAPTER 2

A history of rice in Laos

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Most historians trace the origins of the Lao nation-state back to 1353, the date of the coronation of Fa Ngum as the first ruler of the kingdom (mandala) of Lan Xang. The history of rice in what is now known as Laos predates the founding of Lan Xang, however, by thousands of years.

Although the history of the ethnic diversity of what is now known as Laos is generally well documented (Dommen 1995, Simms and Simms 1999, Stuart-Fox 1998), the history of some aspects of rice cultivation within the area is still open to conjecture. What is accepted, however, is that rice has been cultivated in the region for a long time. This is reflected in linguistic evidence where, in the Lao language, as in several other languages in the Asian region, the words for rice and food are synonymous. Anthropological studies in northeast Thailand have provided evidence of rice cultivation from pottery imprints of grain and husks of *Oryza sativa* dated to at least 2,000 BC and probably older (Khush 1997, White 1997). Palaeoenvironmental evidence suggests the presence of even older plant cultivation in the middle Mekong basin (White et al 2004), although the precise crops grown have yet to be determined. In a review of "the peopling and prehistory of Laos," Stuart-Fox (1998) suggests that rice was cultivated, using broadcasting techniques, along the margins of ponds and streams by small settlements in the area, from the late fourth and early third millennia BC. It is conjectured that, before the deliberate cultivation of rice in the region, harvesting of the grain of its wild rice progenitors probably took place (Harlan 1995, Oka 1988, Vaughan 1994, White 1995).

"Wet"-rice cultivation in the lowlands of Laos and neighboring countries has long been associated with ethnic groups connected with the main linguistic group of the region, the Tai. The Tai, in their area of origin in southern China, probably already had a staple diet of wet rice. They built their villages in river valleys where there was plenty of water and level ground that could be flooded in the growing season (Simms and Simms 1999). Golomb (1976) also supports the belief that the Tai were traditionally wet-rice cultivators in their ancestral homeland.

Stuart-Fox (1998) and Higham (2002) indicate that, as early as 500 BC, the local population in what is now known as the Khorat Plateau of northeast Thailand was using domesticated buffalo and iron-tipped ploughs for wet-rice cultivation. He suggests that, despite a lack of systematic evidence to date, similar agricultural developments likely occurred on the plains of the Lao provinces of Vientiane, Khammouane, and Savannakhet. When the Tai people moved into what now constitutes Laos, Thailand, and upper Myanmar, they brought with them their own wet-rice cultivation practices.

The Tai-Lao currently form the dominant linguistic group in several provinces of Laos, including Vientiane, Luang Prabang, Khammouane, Savannakhet, and Champassak (Batson 1991). Other Tai groups that live in Laos are the Tai-Leu of Luang Prabang and areas to the north, the Tai-Neua of Houaphanh, and the Tai-Dam (Black Tai) and Tai-Deng (Red Tai) of Phongsaly and Houaphanh. Of the Austroasiatic groups who live in the adjoining uplands, the Kasseng, Loven, Souay, and Bru are the larger groups inhabiting southern Laos, while the Lamet and Khmou are the major groups in the north. The largest single grouping of the Mon-Khmer comprises the Khmou, now concentrated in parts of Luang Prabang, Houaphanh, and Oudomxay provinces. The existence of canals and reservoirs in the southern Lao province of Champassak suggests that lowland irrigated rice cultivation was the principal sustenance crop in southern Laos during the period of Khmer dominance from the 5th to 11th centuries CE.

It is therefore reasonable to assume that, for the last two millennia, the main form of rice cultivation in what is now Laos was wet-rice cultivation in the lowlands. Just when dryland rice cultivation, which is found in the upland environment of Laos and neighboring countries, developed is a matter of conjecture. Khush (1997) suggests that early rice crops in the Asian arc were "probably grown by direct seeding and without standing water." Harlan (1995) also infers that, at least in the areas of original domestication of rice in Asia, wet-rice cultivation is a relatively more recent production method than dryland cultivation techniques. However, White (1995) argues on ecological grounds that dryland rice cultivation must have emerged from initial domestication in a wetland environment. The process of soil puddling and transplanting of seedlings seems to have originated in China and been brought to Southeast Asia (including Laos) through migration. It should be noted, however, that the last ethnic groups to arrive in Laos, the Hmong and Mien (Yao), who settled in the highlands of Laos in the 19th and early 20th centuries, brought with them dryland rice cultivation practices (Dommen 1995).

Laos and the origins of cultivated Asiatic rice

Though rice cultivation in Laos may date back only to the second millennium BCE, it should be acknowledged that Laos lies within the broader region of likely domestication of Asiatic rice (*Oryza sativa*) (Chang 1976, Oka 1988). Laos is also believed to be near the center of origin of glutinous rice (Golomb 1976, Watabe 1967). Laos is still rich in genetic diversity of wild and weedy rice, with 6 of the known 21 species of wild rice still to be found in the country: *O. rufipogon*, *O. nivara*, *O. minuta*, *O. officinalis*, *O. ridleyi*, and *O. granulata* (Kuroda et al, see Chapter 15). Two of these, *O. nivara* and *O. rufipogon*, are the generally accepted progenitors of Asian rice, *O.*

sativa (Chang 1976, Oka 1988, Yamanaka et al 2003). Weedy rice, believed to be the interspecific hybrids between the cultivated rice species (*O. sativa*) and wild rice species, has also been commonly observed in Laos.

Historical evidence for the quality of Lao rice

Reference to the quality of rice produced in Laos comes from historical records from the early 1660s, when the description of Laos by an Italian Jesuit priest who worked in the country between 1642 and 1648 was published. The account by Father Givvani Maria Leria was first published in Italian in 1663 (de Marini 1998). The description of rice (and other matters of interest) on both banks of the Mekong River runs as follows:

"However, one must understand that this part of the kingdom, west of the river, is not as prosperous or as fertile as that in the east which greatly surpasses in all respects. The elephants are bigger and stronger there, better trained and more suitable for warfare. The unicorns (rhinoceroses) are also better there than elsewhere. The staple rice is incomparable there and it has a characteristic odour and wildness that is specific to all that grows in this eastern part of the kingdom. There, forests and trees are high, straight and almost all durable, a quality which those growing on the eastern side of this river do not possess: there the virtue of the unicorns is not at all comparable to that of the eastern side. The rice is so hard that one could never boil it and the wood, badly shaped and twisted—it is more suitable for making smoke than fire. There is a kind of a small strait—it is like the center and middle of the kingdom—which produced such excellent rice that I do not believe that it has its equal anywhere else in the Orient" (de Marini 1998, p 4-5).

Ngaosyvanthn and Ngaosyvanthn (1998) also cite other sources from the 18th century saying that "this country produces abundantly the best kind of rice." Reference is also made to the royal paddy fields established by the last king of Vientiane, Chao Anouvong (1804-28), within an 18-km wall encircling the city. The occupying Thai armies of 1827 were reportedly surprised at how well endowed Vientiane was with rice. The royal rice fields were apparently still discernible more than 60 years later.

Rice-based power

Following the settlement of the Tai-Lao in the lowland areas in what now comprises Laos, and northeast Thailand, there evolved a number of small political centers known as *muang*, which were concentrations of social, economic, and military power. Stuart-Fox (1998) reports that the earliest of these Tai muang "of more than local extent" on the upper Mekong "probably dates from no earlier than the 11th century." These muang were generally centered in valley areas from where they controlled surrounding territory. Control over areas of reliable food production provided the basis of muang power for hundreds of years. The four oldest and strongest muang in what constitutes modern-day Laos were centered on what are currently the provinces of Luang Prabang, Xieng Khouang, Vientiane, and Champassak. All exercised domination over rice-growing areas that produced signficant surpluses (Whitmore 1970).

The decision, in 1560, of King Xetthathirât of Lan Xang to move the royal court from Luang Prabang (or Xieng Thong as it was called at that time) to Vientiane was partly based on the growing food needs (mainly rice) of the administrative center. As well as being at the crossroads for much overland commerce, compared with Luang Prabang, Vientiane lay in a much larger rich and fertile plain well suited to wet-rice cultivation (Simms and Simms 1999).

The significance of rice politically was demonstrated during the rule of Chao Anou, King of Vientiane (1805-28), who led the Lao war of independence against Siam (Thailand) in 1827-28. After Chao Anou's initial defeat, he returned to Vientiane, where he found a Siamese garrison in control of the only available rice supplies. Conflict again broke out between the Siamese and the Lao, leading to Chao Anou's capture and death, and the final destruction of Vientiane (Stuart-Fox 1998).

Rice and French colonialism

During the period of French colonialism in Laos (1893-1945), although coffee and potato growing were introduced to the Boloven Plateau in the south of the country, little effort was made to improve production of the staple crops of rice and maize (McCoy 1970). Almost 100% of the rice produced was grown under rainfed conditions and thereby subject to the vagaries of the weather, with periodic droughts affecting both upland and lowland crops, and periodic flooding occasionally devastating wet-season lowland rice and other crops grown in areas adjacent to the Mekong River and its tributaries. Production for most of this period did not exceed 350,000 t annually (equal to about 1 kg of rice per day per person for the population of that time) (Gunn 1990). An exception was in 1923 when production was reported to have reached a high of 500,000 t. Gunn (1990) reports that, for most of the period of French colonialism, Laos was a net rice-importing country, with only the Champassak area consistently producing a rice surplus. One of the few interventions by the French to address the chronic rice deficit during the time of their administration of Laos was to actually ban the export of rice in 1936 (Gunn 1990, Stuart-Fox 1997). This was in response to a drop in the estimated harvest from about 258,000 t in 1935 to about 204,000 t in 1936 (the cause of this reduction is not indicated but, as it was mainly from the traditional rice-exporting provinces adjacent to the Mekong River, it is likely to have been severe flooding). The rice deficit was of such a magnitude in Thakek Province (Khammouane) that there was a fear of starvation. At the time, emergency supplies of rice were requested by the *Résident Supérieur* from Tonkin and Annam (Gunn 1990).

USAID

The period 1955 to 1963 was a time when the per capita U.S. assistance to Laos exceeded, several fold, that given to other countries in the region. However, very little was spent on agriculture, although more than 90% of the population at that time was farmers (Stuart-Fox 1997). During the 1960s and early 1970s, agricultural development and efforts to achieve rice self-sufficiency were of minor importance in comparison to the escalating military conflict. In 1969 and 1970, USAID did undertake the evaluation of a number of introduced lines and varieties from IRRI, together with some well-known traditional varieties. The lines and varieties from IRRI would have been some of the earliest available, as the institution was established only in 1960. Early multilocation yield trials were undertaken in the provinces of Sayabouly, Khammouane, Luang Prabang, Vientiane, and Sedone (Sedone Province was later incorporated into the province of Champassak). Seed multiplication of several of these IRRI lines and varieties was undertaken for distribution at the Salakham Rice Research Station near the capital, Vientiane, in the 1973 wet season. In addition to the IRRI material (which included both glutinous and nonglutinous lines, the latter including IR22 and IR24), the Lao traditional glutinous variety *Do nang nouan* and the Thai glutinous variety *Sanpatong* were also multiplied and distributed to farmers (see Chapter 21). Some of these varieties were still being grown on a limited scale in the mid-1990s, being known as American rice, reflecting their origins as part of the USAID seed distribution program (Appa Rao et al 2000). Apart from the limited work on the introduction and distribution of rice varieties, little other agricultural development took place during this period because of the displacement of large parts of the population in many areas by the war, and the associated disruption of normal cropping cycles.

Socialist assistance 1977-90

Vietnam

In support of the agricultural cooperatives that were established in 1978 to 1984 in an attempt to improve agricultural productivity, Vietnamese agricultural advisers introduced and evaluated many improved lowland rice varieties from Vietnam. Most of these introductions were nonglutinous and many had IRRI parentage. However, few of the Vietnamese introductions were actually adopted by Lao farmers because of their poorer eating qualities relative to the traditional Lao varieties. One of the Vietnamese introductions, CR203, did become popular for the production of rice noodles and brewing of Lao beer. In 2002, it was still being grown on a limited scale.

USSR

Although large numbers of advisers from the socialist block countries (particularly Russia) were present in Laos during the late 1970s and 1980s, these advisers and related assistance programs had little influence on agricultural production. The advisers did undertake serious soil surveys and soil-mapping exercises during this time, the results of which were later used for the production of more standardized USDA-type soil maps that, in turn, were used for land-use planning purposes in the late 1990s. In 1982-84, in collaboration with USSR experts, a number of field trials were undertaken on rice, focusing on yield responses to fertilizer inputs. These studies were part of the soils classification mapping exercises.

The rise and fall of agricultural cooperatives: 1978-88

The most significant change relating to rice production in the period immediately after the Lao People's Revolutionary Party (LPRP) came to power in December 1975 was the adoption of a policy for the "collectivization of agricultural production" through the formation of "agricultural cooperatives." This was seen as the most appropriate strategy for "revolutionizing the country, both socially and technologically." The history of the "rise and fall" of these cooperatives has been reviewed in detail by Stuart-Fox (1980) and Evans (1988, 1995). As reported by Evans, the "experiment with collectivization was associated with attempts by the new government to revive the Lao economy following its collapse due to the flight of both capital and business entrepreneurs." It was hoped to use agricultural cooperatives as the basis for quickly increasing rice production to alleviate a serious and chronic rice deficit in the country. At the time, Laos was importing approximately 15% of its rice requirements. It was believed that cooperatives were the only way peasant agriculture could overcome natural calamities and achieve national food self-sufficiency (Evans 1995). To support these objectives, controls were placed on the price of a range of agricultural commodities, including rice.

Although the policy to create production-based collectives was announced soon after the change of government in 1975, it was not implemented until 1978, following a severe drought in 1977 that further aggravated the already serious rice deficit in the country. The focus of the move to cooperative-based production was in areas of lowland rice cultivation (mainly rainfed, as there was only a very small area of irrigated rice at the time the cooperatives were formed) in provinces with large lowland rice-growing areas in the Mekong River Valley, and in some northern provinces where the LPRP had a strong political base (particularly the provinces of Xieng Khouang, Houaphanh, and Phongsaly). A characteristic of the cooperatives was that they were generally small "village-level" initiatives involving an average of 30 to 40 families, rather than large area collectives. Although a few numbered over 200 families, generally such large cooperatives were not encouraged. The initial basis for the formation and operation of the early cooperatives was at a low level, involving the establishment of labor exchange units that could be used in a coordinated calendar of rice production. Members of the cooperative were expected to contribute their cultivated land for the cooperative's use (while property of other types remained under the control of individual households) (Evans 1988). From the outset, it was official government policy that the decision to join or leave a cooperative was to be left to the individual households. In practice, however, coercion was often used to encourage people to join a cooperative, and even more so to discourage a household from withdrawing. In late 1978, Stuart-Fox (1980) reported that 1,600 cooperatives had been set up throughout the country, involving 16% of all farming families. The majority were in the provinces of Khammouane and Champassak, in the central and southern parts of the Mekong River Valley. By early 1979, more than 2,500 cooperatives were reported to have been established. However, by mid-1979, it was recognized that the move to collectivization was seriously disrupting production rather than improving it. The disruptive effects

Table 1. Expansion of agricultural cooperatives in Laos, 1979-86.

Province	Year							
	1979	1980	1981	1982	1983	1984	1985	1986
Phongsaly	73	152	152	156	167	167	167	167
Luang Namtha	59	74	74	74	74	74	74	69
Oudomxay	72	93	93	98	98	111	115	182
Sayabouly	120	44	44	89	129	160	160	154
Luang Prabang	41	44	44	76	82	98	101	152
Xieng Khouang	200	212	212	252	251	251	247	247
Houaphanh	155	263	263	274	311	311	318	374
Vientiane[a] Municipality	–	–	–	63	104	119	167	192
Vientiane	486	101	101	47	71	93	176	242
Khammouane	433	12	12	24	67	99	104	372
Savannakhet	250	12	12	18	53	164	547	579
Saravane	235	18	18	168	107	216	254	314
Champassak	304	306	306	587	587	597	651	659
Attapeu	24	12	12	12	13	19	19	14
Bokeo[a]	–	–	–	–	–	40	40	67
Borikhamxay[a]	–	–	–	–	–	17	34	76
Sekong[a]	–	–	–	–	–	10	10	120
Total	2,452	1,343	1,352	1,943	2,114	2,546	3,184	3,976

[a]–indicates that the administrative area did not exist at the time statistics were recorded.
Source: Evans (1988, 1995).

on rice production of a severe drought in 1977, followed by a severe flood in 1978, which devastated rice crops in the main rice-growing areas of central and southern Laos, also affected the move to cooperative production. A lack of management skills on the part of officials responsible for the cooperatives was a further major obstacle to both their establishment and operation. In July 1979, a stop was put to the further expansion of the cooperative program, as there was little support for cooperative-based rice production in most rural areas (Stuart-Fox 1980).

Even so, the government restated its commitment to collectivization of production, by emphasizing strengthening existing cooperatives rather than creating new ones. Because of a general lack of enthusiasm and support in many rural areas, from 1979 to 1980 the number of cooperatives dropped by 45% (from about 2,450 to about 1,340) (Table 1). However, official policy still favored the cooperative approach to production and in 1982 some attempt was made to extend cooperative-based rice production to areas of "swidden farming." Tax incentives and preferential terms for access to credit were offered as inducements to encourage rural households to join the cooperative movement. It was reported that, by mid-1984, 37.6% of the farm families and 35.3% of the farming land were involved in 2,402 cooperatives nationwide. The cooperative movement was recorded as having reached its peak in 1986, with almost 4,000 cooperatives being reported as having been established (Table 1). However, several authors (Zasloff 1991, Evans 1995, Stuart-Fox 1997) have indicated that most of these cooperatives existed "in name only," and that in reality there were very few genuine working cooperatives. In fact, the cooperative movement was steadily weakened as members became disillusioned and used their "right to withdraw." The provinces where the cooperative movement was most successful were Champassak, Savannakhet, Xieng Khouang, Saravane, and Sayabouly (Evans 1988). By mid-1988, the government officially recognized the lack of success of the "cooperative concept" under Lao conditions and a decision was made to formally abandon the movement as the basis for improving production. It was acknowledged that the family or individual household unit was a more appropriate basis for achieving both political stability and improved agricultural production, particularly of rice. At about the same time, a number of state farms, which were also established as part of the cooperative movement but that occupied no more than 0.2% of cultivated land, were also privatized, as they were absorbing a disproportionate component of public and other resources (World Bank 1995).

Independent of the cooperative movement (but also influencing it), a significant change in government policy that influenced rice production in the early 1980s was the increased flexibility of pricing and market exchange in the agricultural sector (Evans 1991). In 1980, the prices of most crops and export products were raised by 300% to 500%; retail prices of commodities marketed by the state went up by 200% to 300% and approached parallel market prices. One immediate consequence of these increased incentives was a 16.5% increase in rice production. However, it has also been surmised that some of the production increase reported about this time resulted from changes in tax policy. In 1979, the government replaced the rice output tax with a land tax. One result of this was to remove the incentive to underreport yields and production (though this was replaced by an incentive to underreport the area under cultivation, the basis of the land tax). Although in the early years of the cooperative movement the land of those wishing to withdraw was expropriated, this policy was halted in 1979 and land was returned to those households that had opted to leave the cooperatives. As no general program of land reform had been associated with the cooperative movement, the reversion back to the family unit as the basis of production was not difficult.

Development of irrigated rice production

Farmers throughout Laos have been building traditional weirs and canals for centuries to provide supplementary irrigation to their wet-season rice crops. A typical traditional scheme would include a weir made of logs, stones, and sometimes bamboo and earth, with small hand-dug canals. The command area of these traditional irrigation schemes has varied from a few hectares to about 100 ha, governed mostly by the limited areas of flat land within the mountainous watersheds. These small diversion schemes irrigate terraced or valley-floor paddy fields. As of 2002, thousands of these small weir and canal systems were still in operation in Laos.

Although traditional schemes mainly focus on wet-season rice production, some also produce limited dry-season crops in areas where the streams have a significant dry-season flow, and where farmers have seen the potential for producing additional crops. However, on account of low efficiency levels and high labor demand for frequent repairs of the traditional weirs, over the past 20 years, hundreds of traditional systems have been replaced by more permanent structures.

Irrigation schemes

As recently as 1976, shortly after the LPRP came to power within the country, less than 1% (2,700 ha) of the planted rice area, and less than 1% of rice production (about 3,000 t), was associated with dry-season irrigated cultivation (Table 2). The relatively small irrigated area that existed prior to 1975 was mainly in the form of small weir schemes developed by USAID in the north of the country, particularly in the 1960s. The first relatively large scheme, about 900 ha in area, also initiated by USAID, was the Faay Namtane scheme in Phiang District of Xayabouly Province.

In 1977-78, the expansion of irrigated rice cultivation became one of the agricultural development objectives of the socialist government in its bid to achieve food self-sufficiency (basically rice self-sufficiency), and to reduce the year-to-year vagaries in food production caused by the effects of the weather. This development initiative was closely linked to the policy to develop a national network of agricultural cooperatives as the basis for achieving improvements in agricultural production (Evans 1991).

The first large irrigation schemes to be developed in Laos began in the late 1970s and were located on the floodplains of the Mekong River, not far from the capital, Vientiane. The first of these schemes, the Nam Houm scheme, was implemented through the Ministry of Agriculture and Forestry in Nasaythong District of Vientiane Municipality. This reservoir-based scheme, whose development commenced in 1977, had a projected capacity of about 3,000 ha of dry-season irrigated crop production. In its development phase, the Mekong Committee provided some financial assistance for the purchase and installation of pumping equipment for the scheme. The second scheme, also initiated in Nasaythong District of Vientiane Municipality, was the Nam Soang scheme. With a projected dry-season irrigation capacity of 4,000 ha, the development of this scheme began in 1978 through the Ministry of Defense. Despite the construction of reservoirs, a lack of funds to complete the network of delivery canals resulted in failure to meet the planned irrigation potential of both these schemes, and they did little to improve productivity at the time of their development (World Bank 1995). A lack of appropriate management and technical skills also contributed to the inability to properly develop and use these two schemes.

In the early 1990s, a decision was made to expand the area of rice under irrigated production in order to accelerate improvements in rice production to achieve the joint goals of national rice self-sufficiency and greater production stability. The expanded irrigated production was to focus on developing irrigation schemes that could be used for dry-season cropping activities rather than for wet-season production. However, it was also recognized that the proposed schemes had the potential for wet-season supplementary irrigation use as well. From 1990 to 2001, the dry-season irrigated

Table 2. Development of irrigated rice cultivation, 1976-2002.

Year	Area (000 ha)(% total)				Production (000 t)(% total)			
	Rainfed lowland	Rainfed upland	Irrigated lowland[a]	Total	Rainfed lowland	Rainfed upland	Irrigated lowland[a]	Total
1976	317.7	204.1	2.7	524.5	455	202	3	660
(%)	(60.6)	(38.9)	(0.5)	(100.0)	(68.9)	(30.6)	(0.5)	(100.0)
1978	398.6	216.6	7.5	622.7	508	217	9	734
(%)	(64.0)	(34.8)	(1.2)	(100.0)	(69.2)	(29.6)	(1.2)	(100.0)
1980	426.9	297.4	7.7	732.0	705	337	11	1,053
(%)	(58.3)	(40.6)	(1.1)	(100.0)	(67.0)	(32.0)	(1.1)	(100.0)
1982	435.2	296.2	5.7	737.1	731	349	12	1,092
(%)	(59.0)	(40.2)	(0.8)	(100.0)	(66.9)	(32.0)	(1.1)	(100.0)
1984	360.3	256.2	8.6	625.1	919	380	21	1,320
(%)	(57.6)	(41.0)	(1.4)	(100.0)	(69.6)	(28.8)	(1.6)	(100.0)
1986	385.0	256.6	10.1	651.7	1,082	341	27	1,450
(%)	(59.1)	(39.4)	(1.6)	(100.0)	(74.7)	(23.5)	(1.9)	(100.0)
1988	331.3	213.5	11.4	556.2	686	283	35	1,004
(%)	(59.6)	(38.4)	(2.1)	(100.0)	(68.3)	(28.2)	(3.5)	(100.0)
1990	392.4	245.9	12.0	650.3	1,081	369	41	1,491
(%)	(60.3)	(37.8)	(1.9)	(100.0)	(72.5)	(24.8)	(2.8)	(100.0)
1991	322.8	234.1	13.3	570.2	842	337	44	1,223
(%)	(56.6)	(41.1)	(2.3)	(100.0)	(68.9)	(27.6)	(3.6)	(100.0)
1992	392.5	200.1	15.5	608.1	1,153	292	55	1,500
(%)	(64.6)	(32.9)	(2.5)	(100.0)	(76.9)	(19.5)	(3.7)	(100.0)
1993	350.4	188.3	13.0	551.7	921	284	46	1,251
(%)	(63.5)	(34.1)	(2.7)	(100.0)	(73.6)	(22.7)	(3.7)	(100.0)
1994	380.9	219.1	11.0	611.0	1,198	342	38	1,578
(%)	(62.3)	(35.9)	(1.8)	(100.0)	(75.9)	(21.7)	(2.4)	(100.0)
1995	367.3	179.0	13.6	559.9	1,071	296	50	1,417
(%)	(65.6)	(32.0)	(2.4)	(100.0)	(75.6)	(20.9)	(3.5)	(100.0)
1996	363.1	172.6	18.0	553.7	1,076	266	72	1,414
(%)	(65.6)	(31.2)	(3.3)	(100.0)	(76.1)	(18.8)	(5.1)	(100.0)
1997	421.1	153.6	26.6	601.3	1,300	247	114	1,661
(%)	(70.0)	(25.5)	(4.4)	(100.0)	(78.3)	(14.9)	(6.9)	(100.0)
1998	430.2	134.2	53.1	617.5	1,249	214	212	1,675
(%)	(69.7)	(21.7)	(8.6)	(100.0)	(74.6)	(12.8)	(12.7)	(100.0)
1999	477.2	153.4	87.0	717.6	1,502	247	354	2,103
(%)	(66.5)	(21.4)	(12.1)	(100.0)	(71.4)	(11.8)	(16.8)	(100.0)
2000	475.5	152.1	91.8	719.4	1,553	259	390	2,202
(%)	(66.1)	(21.1)	(12.8)	(100.0)	(70.5)	(11.8)	(17.7)	(100.0)
2001	486.8	158.1	102.0	746.9	1,620	279	436	2,335
(%)	(65.2)	(21.2)	(13.7)	(100.0)	(69.4)	(12.0)	(18.7)	(100.0)
2002	519.5	134.6	84.0	738.1	1,801	240	375	2,416
(%)	(70.4)	(18.2)	(11.4)	(100.0)	(74.6)	(10.0)	(15.5)	(100.0)

[a]Statistics represent dry-season (Nov.-April) irrigated area only and do not take into account areas receiving supplementary irrigation during the wet season (May-October).
Sources: World Bank (1995), Ministry of Agriculture and Forestry, Vientiane, Lao PDR.

capacity increased by 750% (from 12,000 to 102,000 ha). Production from the dry-season irrigated environment during this time also increased more than tenfold, from 41,000 to 436,000 t (Table 2).

Most (94.5%) of the expansion in irrigated area took place in the central (70,816 ha) and southern (25,578 ha) agricultural regions. In 2001, still only about 5,600 ha were developed for irrigation in the northern agricultural region. Most of this expansion in irrigated capacity during the 1990s depended on pumping water directly from the Mekong River and, to a lesser extent, from tributaries of the Mekong. There was less investment in the development of appropriate water reticulation systems. However, by 2001, the capacity of these recently developed schemes was being underused because of a combination of factors. Farmer groups were increasingly unable and unwilling to meet the increasing fuel costs of diesel pumps (both diesel and electric pump programs had been installed). This was aggravated by the fact that crop yields were well below the expected potential because of low levels of inputs, particularly fertilizer. In some areas, farmers also encountered difficulties in marketing the second rice crop (the dry-season irrigated crop). Water-use efficiency in many scheme areas was also well below the potential because of a lack of concurrent investment in networks of water distribution canals. Further, farmer organizations, to which responsibility for the pumping schemes was being transferred, did not possess the required skills and resources to maintain the systems. By 2002, it also started to be recognized that the dry-season irrigation potential might be better used for crops with higher returns than rice. The 2002-03 dry season therefore saw a significant reduction in the use of the potential of many of the schemes developed during the 1990s.

In 2000, it was estimated that Laos had 22,240 irrigation systems, with a capacity to serve about 280,000 ha in the wet season, or about 36% of the country's 800,000 ha of annually cultivated land. Irrigated land accounted for about 65% of total agricultural production. The majority of the schemes were traditional weirs, some 18,150 in total, located mostly in mountainous areas, and accounting for about 35% of the total irrigated area.

Since 1975, various agencies have been involved in programs of assistance to improve irrigation capacity within Laos. These agencies are the European Community, United Nations Development Programme (UNDP), United Nations Capital Development Project (UNCDP), Mekong River Commission, Organization of Petroleum Exporting Countries (OPEC), the World Bank, the national assistance agencies of Australia and Sweden, and many NGOs.

The impact of natural disasters on rice production

Lao agriculture generally and rice production in particular have always been at the mercy of the weather, bad years being fatalistically accepted along with the good ones. With rice production accounting for more than 80% of the cultivated land area and rice consumption accounting for more than 80% of the calorie intake in many rural areas, the impact of adverse climatic conditions on the livelihood of the Lao people has always been potentially threatening. The occurrence and level of poverty in many areas are recognized as being largely determined by the level and frequency of natural disasters, particularly droughts and floods (ADB 2001).

Droughts and floods

Although detailed historical records on the frequency and severity of droughts and floods do not exist, some severe droughts and their effects were recorded in court chronicles (Stuart-Fox 1998). Recent records clearly indicate the high level of both incidence and significance of floods and droughts. In the 37-year period from 1966 to 2002, for every year, at least part of the country was affected by either drought or flood, or a combination of both (Table 3). The potential impact on rice production was dramatically demonstrated shortly after the LPRP came to power in 1975. As previously noted, in 1977, severe drought conditions throughout the country reduced the national rice harvest by 40% relative to that of 1976 (which was already a year of deficit), with some southern provinces experiencing a decline of up to 95% (Evans 1988). It was estimated that more than 350,000 t of rice aid were required to prevent famine conditions in 1977. In 1978, a disaster of the reverse order—serious flooding—occurred. In some areas of central and southern Laos, crop losses on the order of 90% were reported. At the time, it was estimated that half the population was potentially affected by famine conditions. In both years, without reserve stocks of rice, the government depended on rice donations from the international community to avert potentially serious catastrophes. It was partly in response to the impact of the 1977 and 1978 disasters that the socialist government initiated the agricultural cooperatives movement in an effort to improve rice production and achieve a higher level of rice self-sufficiency. In 1988 and 1989, severe droughts cut annual yield by about one-third, again forcing the government to rely on food aid for its domestic requirements. In 1988 and 1989, approximately 140,000 t of rice were donated or sold to Laos (Hopkins 1995).

More recently, in 8 of the 12 years from 1991 to 2002, significant areas of lowland rice in the Mekong River Valley were destroyed by floods (Table 4). In 1991, more than 21% (about 70,000 ha) of the rice area was destroyed; in 1995, almost 30% of the planted area in the central agricultural region was destroyed; whereas, in 1996, 17.5% and 18.7% of the rice area in the central and southern agricultural regions, respectively, were destroyed. As periods of submersion associated with the flooding of the Mekong River can often extend beyond 2 weeks, total crop loss usually results in areas affected by flooding. Some areas particularly prone to flooding have recently been withdrawn from wet-season cropping activities following the development and expansion of the potential for dry-season irrigated cropping. Flooding in the northern mountainous agricultural region is usually of short duration and crops can sometimes recover from the impact of such floods; however, the nature of floods is such that they are potentially capable of causing significant levels of soil erosion, particularly in areas with a history of intensive slash-and-burn agriculture.

Drought, although less spectacular than devastating floods, is a regular occurrence throughout the rice-growing areas of Laos (Table 3). Farmers in the rainfed lowland environment of the Mekong River Valley consider drought as their most

Table 3. Occurrence of damage to rice crops by floods and drought, 1966-2002.

Year	Type of damage	Region affected
1966	Severe flood	Central
1967	Drought	Central, southern
1968	Flood	Central
1969	Flood	Central
1970	Flood	Central
1971	Severe flood	Central
1972	Flood and drought	Central
1973	Flood	Central
1974	Flood	Southern
1975	Drought	All regions
1976	Flash flood	Central
1977	Severe drought	All regions
1978	Severe flood	Central, southern
1979	Drought and flood	Northern (drought), southern (flood)
1980	Flood	Central
1981	Flood	Central
1982	Drought	All regions
1983	Drought	All regions
1984	Flood	Central, southern
1985	Flash flood	Northern
1986	Flood and drought	Central, southern
1987	Drought	Central, northern
1988	Drought	Southern
1989	Drought	Southern
1990	Flood	Central
1991	Flood and drought	Central
1992	Flood and drought	Central (flood and drought), northern (drought), southern (flood)
1993	Flood and drought	Central, southern
1994	Flood and drought	Central (flood and drought), southern (drought)
1995	Flood	Central, southern
1996	Flash flood, drought	Central
1997	Flood	Central, southern
1998	Drought	All regions
1999	Flood	Central, southern
2000	Flood	Central, southern
2001	Flood	Central, southern
2002	Flood	Central, southern

Source: Unpublished reports of Department of Meteorology, Ministry of Agriculture and Forestry.

Table 4. Wet-season lowland crop losses (ha destroyed) due to flood damage, 1991-2002.

Region	Year							
	1991[a]	1994	1995	1996	1997	2000	2001	2002
Central								
(ha)		28,783	55,061	41,863	26,300	28,350	30,193	24,151
(%)		(13.7)	(29.0)	(17.5)	(10.2)	(10.6)	(11.4)	(8.5)
Southern								
(ha		3,135	5,759	23,720	6,750	14,530	11,790	8,103
(%)		(2.6)	(4.9)	(18.7)	(5.2)	(11.0)	(8.2)	(5.3)
Northern								
(ha)		4,464	1,500	354	225	20	240	1,810
(%)		(8.3)	(2.5)	(0.5)	(0.3)	(<0.1))	(0.3)	(2.2)
Total								
(ha)	70,000	36,382	62,820	65,937	33,275	42,900	42,223	34,064
(%)	(21.3)	(9.5)	(16.9)	(15.3)	(7.9)	(9.0)	(8.7)	(6.6)

[a]Regional flood damage data are unavailable.
Source: Ministry of Agriculture and Forestry and the Ministry of Labor and Social Welfare.

consistent production constraint (Khotsimuang et al 1995). The soils in this region are predominantly loams, sandy loams, and sands, and are particularly drought-prone (Lathvilayvong et al 1996). Although the effects of drought can often be less severe than those of floods, drought usually affects a much larger area than floods. Both early and late wet-season droughts occur and affect rice production (Fukai et al 1998). Early-season drought usually occurs from mid-June to mid-July as the monsoons change from southeast to southwest. The effects of this type of drought can be reduced by appropriate crop management practices, particularly by matching crop phenology with water availability (Fukai et al 1998). Late-season drought occurs if the regular monsoon rains end early. Fukai et al (1995) have demonstrated that late-season drought alone can reduce grain yields by an average of 30%. The use of earlier-maturing improved varieties to replace later-maturing, and often lower-yielding, traditional varieties can significantly reduce the potential impact of late-season drought. Fukai et al (1998) also demonstrated that the effect of drought on grain yield also depends on soil fertility, and that improved soil fertility increases grain yield, even in drought-affected seasons.

The occurrence of drought in uplands is equally as frequent and can be equally as severe as in lowlands. Lebar and Suddard (1960) reported on the occurrence of a serious drought throughout much of northern Laos in 1955, the severity of which was so great that rice was flown in on U.S. planes and dropped by parachute to villagers in order to avert potential starvation. Although ranked third among production constraints by upland farmers (Roder et al 1997), the impact of drought in the upland environment is of increasing significance and concern. Dry conditions in this environment have the greatest impact when occurring at or about the time of dry-seeding, affecting both germination and establishment. Late-season drought (i.e., when the wet-season rains end early) is not normally a concern, as most upland crops are harvested 30 to 50 days earlier than lowland crops in the same region.

Even with the recent increase in the area of cultivation under irrigated conditions (Table 2), the majority of both the planted area and production in Laos will remain at the mercy of the vagaries of the weather for the foreseeable future. However, it is possible to achieve greater yield stability under such conditions through varietal improvement.

Biotic disasters

Pests and diseases are also chronic production constraints for both upland and lowland environments (Schiller et al 2001). Normally, their impact is relatively localized and often the implementation of appropriate management practices can minimize their potential damage to rice crops. However, one category of pest in upland environments that has traditionally had an impact on production often of the same magnitude as natural disasters is rodents (Roder et al 1997, Singleton et al 1999). Although actual grain losses due to rodents have yet to be quantified, it is estimated that they probably account for at least 15% of the annual rice harvest (Singleton and Petch 1994). At irregular intervals, conditions favor massive rodent population explosions, resulting in local losses of more than 50% of the rice crop. Occasionally, entire rice crops are lost, as happened in parts of Luang Prabang Province in 1991 (details of the ecology of rodent and related problems in relation to rice production in Laos are reviewed by Aplin et al in Chapter 19).

National rice sufficiency

Rice production in Laos has generally been on the basis of meeting immediate household needs. In the absence of an established market for rice, until recently, there has been little incentive to produce a rice surplus, particularly under upland conditions. As a result, small fluctuations in yield caused by climate, pest problems, or labor shortages have usually been immediately reflected in rice shortages (Roder et al 1996). These authors also report that occasional shortages of rice are not a recent phenomenon. Observations in the uplands as long ago as the early 1940s report rice stores often being empty in July, forcing farming families to rely on hunting and gathering for provisions for periods of 3–4 months before the harvest of the next rice crop.

Independent of the impact of the vagaries of the weather and pest problems, changes in the level of rice self-sufficiency have, until relatively recently, often reflected the level of political stability throughout the country. During the period of French administration from 1893 to 1945, there was considerable resistance of many ethnic groups to a number of government policies. In particular, resistance was strong to some of the taxation measures, as well as the system of annual unpaid labor that was imposed (Batson 1991, Simms and Simms 1999). The often physical resistance of some ethnic groups to the implementation of these laws and measures was associated with a lack of stability in many upland areas, which interrupted normal upland rice-cropping cycles. As a result, during the period of French administration, significant areas of Laos often had periodic and chronic rice shortages because of factors other than the impact of natural disasters and pest damage. Total annual rice production during this period fluctuated from a maximum of just over 500,000 t in 1923 to an average of less than 300,000 t during the 1930s. In upland areas, shortages were made up by maize (from upland swiddens) and various tuber crops. However, in lowland areas, the deficits were not so readily replaced by alternative foods. A 20% decline in the national rice harvest in 1936 was associated with subsequent near-starvation conditions in parts of Khammouane Province.

After Lao independence in 1953, under the Royal Lao government there was a 20-year period during which the disruptive effects of the ongoing civil conflict in much of the country also disrupted the normal rice-cropping cycles, in both upland and lowland environments. For much of this time, there was a chronic national rice deficit, with shortages at both regional and local levels often being critical. In the upland environment, the frequent displacement of villages in some areas generally meant that the rice shortages were more acute than in lowland areas. At the height of the conflict in the 1960s and early 1970s, tens of thousands of members of mainly upland ethnic groups fled their villages to avoid the fighting in the north of the country, while the Plain of Jars in the northeastern region was almost depopulated (Stuart-Fox 1997). Stuart-Fox (1997) reports that during this time "as many as three-quarters of a million people, a quarter of the entire population, had been driven from their homes to become refugees in their own country." In some remote areas, displaced villages became totally dependent on food supplies dropped by American planes. At the peak of the shortages in the early 1970s, more than 170,000 refugees were understood to be dependent on receiving rice in this way in the north of the country alone. The rice used for these "sky drops" was all imported. It was even reported that some young children of this era came to believe that "rice came from the sky." Appa Rao et al (Chapter 10) report that some of this "rice from the sky" was used as seed for planting, and was still being planted at the time varieties were collected for conservation and preservation in the latter part of the 1990s, having been given the varietal name "American rice." Batson (1991) reports that it was not until 1984 that some degree of national rice self-sufficiency was first achieved. However, even for that year, the same author noted that "a combination of uneven production, poor land, poor transportation, and climatic vagaries left people in the rugged, highland areas without enough rice or with very marginal surpluses."

In the main areas of lowland rice cultivation, rice self-sufficiency from year to year has primarily reflected the occurrence of natural disasters—droughts and floods, and occasionally pest and disease problems. At a national level, the decision in the early 1990s to expand the area of irrigated rice production has, in association with the adoption of improved production practices in lowland environments, brought about a rapid change in the reported level of national rice self-sufficiency. Production from the 2001 dry-season irrigated environment accounted for about 19% of total production for that year, compared with less than 3% coming from the irrigated environment in 1990.

Table 5. Levels of rice sufficiency (months per year) according to region and ethnicity.

Region	Ethnicity			
	Mon-Khmer	Tibeto-Burman	Hmong-Mien	Lao-Tai
North	6.2	7.0	8.2	11.5
East	6.3	–	7.8	6.5
Central	7.9	–	8.0	10.8
South	5.5	–	–	9.3
Average	5.9	7.0	8.1	9.0

Source: UNDP (2002).

Although the official statistics of the Ministry of Agriculture and Forestry indicated that national rice self-sufficiency was achieved in 1999 with the production of 2.1 million tons of paddy rice (Table 2), with further increases in subsequent years to in excess of 2.4 million tons in 2002, unofficially it is acknowledged that these figures are overestimates. It has also been long acknowledged that national rice self-sufficiency does not necessarily translate into regional, provincial, or household self-sufficiency. Rice surpluses of recent years in areas with double-cropping potential as a result of the expansion of irrigated rice cultivation have not necessarily alleviated the increasing chronic rice shortages of many upland areas. Recent studies on poverty and human development in Laos (ADB 2001, UNDP 2000) reveal that 90% of villages classified as poor throughout the country depend on swidden agriculture as their primary means of livelihood. Levels of poverty are closely linked to levels of food (primarily rice) sufficiency. Generally speaking, the level of rice deficiency is currently greatest within Mon-Khmer groups in upland areas and least in the Tai-Lao, who predominately inhabit the lowlands (Table 5). Rice shortages in the uplands generally average 3–4 months but can be as much as 8 months and are chronic; in the lowlands, they average 1–3 months and vary from year to year, depending on natural disasters, particularly drought and floods, and place to place, reflecting irrigation potential and the availability of land.

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Notes

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CHAPTER 3

Rice production systems of Laos

B.A. Linquist, B. Keoboualapha, Sipaseuth, and P. Inthapanya

The rice production systems in Laos can be classified into three broad ecosystems (Table 1 and Photos 3.1–3.3): irrigated lowland, rainfed lowland, and upland. Lowland rice (sometimes referred to as paddy rice) grows in bunded fields and the soil is flooded for at least part of the crop season. Water for rice production comes from either rainfall or irrigation. Upland rice grows as a rainfed dryland crop and is usually only grown during the wet season and is often associated with being grown in a slash-and-burn system on steep slopes.

The terms "upland" and "lowland," as used in describing rice production ecosystems, have no relation to the elevation or topography where the rice is grown. Indeed, lowland rice production systems can be found at over 2,500 m elevation in countries such as Bhutan. In Laos, lowland rice fields are found at over 1,000 m elevation in Xieng Khouang Province. Similarly, upland rice fields can be on flat fields at low elevations, such as those in Vientiane Municipality.

Lowland rice (both rainfed and irrigated) is common in the mountainous northern region and along the eastern border with Vietnam. This system will be referred to as montane lowland rice in this chapter (see also Chapter 25). It is distinguished as lowland rice grown in the mountains in small valley bottoms or on terraced hillsides. Although it is lowland rice by definition, the management practices in this system are sufficiently different to warrant separate discussion.

Table 1. Terminology for rice-growing environments found in Laos.

Ecosystem	Description
Irrigated lowland (paddy)	Rice grown in bunded fields and fields are flooded for at least part of the season. Irrigation water is used.
Rainfed lowland (paddy)	Rice grown in bunded fields and fields are flooded for at least part of the season. Water comes from rainfall.
Upland	Rice is grown in unbunded fields and water comes from rainfall. Rice is typically grown on sloping fields and associated with slash-and-burn systems.

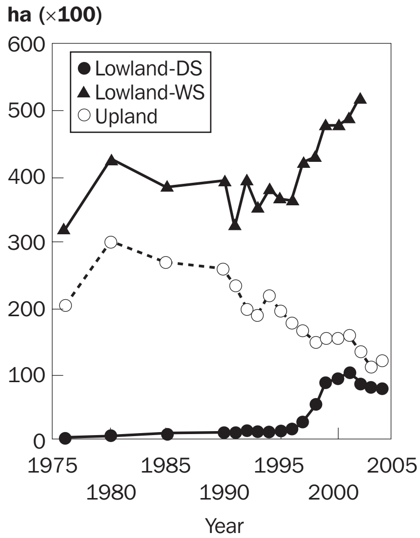

Fig. 1. Total area devoted to rice production in the lowland (wet season and dry season) and upland environments from 1976 to 2004.

Although three rice production ecosystems are recognized in Laos, production statistics collected and published relate to the following: (1) wet-season lowland rice (rainfed and irrigated), (2) dry-season irrigated lowland rice, and (3) rainfed upland rice. The statistics for wet-season lowland rice do not indicate the relative areas of rainfed lowland production and wet-season irrigated production.

Relative importance of production systems

Government statistics indicate that the total rice area in 2004 was 770,320 ha (Fig. 1). The most important system is wet-season lowland rice production, with over 550,000 ha in production. This area has been expanding annually since 1996. Dry-season irrigated rice production area increased rapidly between 1995 and 2001 from 13,600 to 102,000 ha. Since 2001, however, dry-season area has declined and, in 2004, 77,000 ha were in production. Upland rice area declined from about 300,000 ha in 1980 to less than 120,000 ha in 2004; however, some satellite imagery data suggest that the area under slash-and-burn production is actually increasing. Regardless, these statistics represent only the area planted to upland rice in a given season. Since most upland rice is grown in slash-and-burn systems, the total area devoted to upland rice depends on the fallow length. If the average fallow period is 3 years, then the total area under slash-and-burn would be close to 500,000 ha.

In the northern region, the upland rice production system is most important, although there is a large area of wet-season lowland rice (Fig. 2). In the north, the

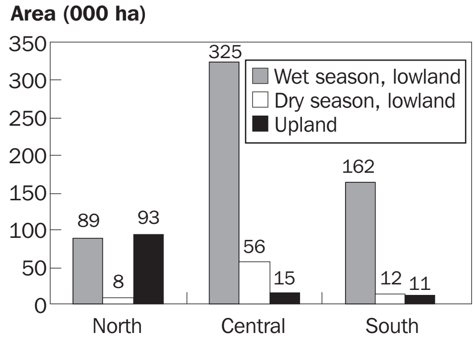

Fig. 2. Area of production systems by region (2004 data).

Table 2. Rice production statistics by environment for 2004.

System	Area (ha)	Yield (t ha^{-1})	Production (t)	Production (% of total)
Lowland (wet season)	575,520	3.43	1,976,000	78
Lowland (dry season)	76,840	4.45	341,703	14
Upland	117,960	1.79	211,200	8

Source: Ministry of Agriculture and Forestry, Vientiane, Laos.

province of Sayabouly has the largest wet-season lowland rice area (over 24,000 ha) but all the other northern provinces, with the exception of Phongsaly (which has 6,000 ha), have in excess of 11,000 ha. In the central and southern agricultural regions, the upland area is relatively small (a total of about 25,000 ha) and largely confined to the Lao-Vietnam border area. Wet-season lowland rice is the dominant rice system in these regions. Savannakhet Province, in central Laos, has the largest area of wet-season lowland rice (135,000 ha) for any single province. Dry-season irrigated rice is most important in the Central Agricultural Region, with Vientiane Municipality (21,000 ha) and Savannakhet (19,000 ha) having the largest areas.

According to government statistics, total rice production in 2004 was 2.53 million tons (Table 2). Of this, 2 million tons (78% of the total) was produced in the wet-season lowland environment, 0.34 million tons (14%) in the dry-season lowland environment, and 0.21 million tons (8%) in the upland environment.

The rainfed lowland rice production system

Annual cropping cycle

The annual cropping cycle begins in May or June, depending on the onset of rains, with the preparation of the nursery seedbed and the sowing of seeds for the nursery (Table 3). Seedlings are transplanted about 1 month after sowing; however, transplant-

Table 3. Seasonal cropping calendar for the different rice production systems in Laos.

System	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Season	Dry season				Wet season						Dry season	
Rainfed lowland						Sow	TP			Harvest		
Irrigated lowland	TP[a]			Harvest		Sow	TP			Harvest		Sow
Montane lowland	TP			Harvest		Sow	TP	TP2[b]		Harvest	Sow[c]	
Upland	Slash		Burn; make fence and hut		Plant				Harvest			

[a]TP = transplant. [b]TP2 = transplant second time (double transplanting is practiced by some farmers). [c]A dry-season crop is planted only if irrigation water is available.

ing may be delayed if the onset of wet-season rains is delayed. Harvesting is during October and November, depending on the varieties and planting time. During the dry season, fields are often grazed by livestock.

Varieties

Before the release and distribution of improved Lao glutinous varieties in the mid-1990s, about 95% of the varieties grown in the lowlands were traditional varieties. These varieties were predominantly glutinous and photoperiod-sensitive. This situation changed rapidly in the latter half of the 1990s as farmers adopted the newly released varieties, and, by 2002, more than 80% of the lowland area in the Mekong River Valley was being sown to improved varieties. Laos has the highest per capita production and consumption of glutinous rice in the world, and although accurate data are not available, it is estimated that, in the 2002 production year, about 85% of the rice produced in Laos was glutinous (see Chapter 14). Further evidence on the preference for glutinous rice is that over 85% of the lowland varieties collected between 1995 and 2000 were glutinous (Appa Rao et al 2002).

Farmers sometimes grow up to nine different varieties in any given year, with the norm being four or five (Pandey and Sanamongkhoun 1998), although, with the increased adoption of improved varieties, there is a trend to growing fewer varieties overall. Choice of variety is based on available water, maturity time, yield potential, and grain quality. Early-maturing varieties (flowering in mid- to late September) are traditionally grown in upper terraces where water supply is less certain. Late-maturing varieties (flowering in mid- to late October) are typically grown in the lower terraces where water supply is more reliable, but where occasional submergence can sometimes be a problem (Schiller et al 2001). Further details on both the traditional and improved varieties grown in Laos can be found in Chapters 9 to 13 and Chapter 21.

Nursery management

Most lowland rice in Laos is transplanted as opposed to direct-seeded. Wet-season rice production typically begins in May or early June at the start of the monsoon rains with the planting of the rice nursery. Following sufficient rain, the seedling nursery is prepared by plowing and puddling using a harrow. This is often done by buffalo but increasingly small handheld tractors are being used (enough water is required to make the soil soft enough to plow, especially for buffalo). If farmers apply manure to the nursery, they do so prior to plowing; however, many farmers do not use manure or other forms of fertilizer in the nursery. Some farmers presoak seeds for a day or two before sowing. Rice is sown by broadcasting the seeds immediately after puddling. Nurseries occupy a small area (5–10% of the total area to be planted) and are usually fenced to protect them from livestock. Seedlings grow for about 30 days in the nursery, although farmers may transplant at any time from 25 to 40 days or longer depending on rainfall. Sufficient rainfall is required to plow the main field and prepare for transplanting.

Most lowland rice landscapes feature small huts in and around the rice paddies. These huts (*thieng na*), which provide a place to rest and eat while working in the field and to guard the crop, are usually erected around the time the nursery is established.

Field management

The main fields are first plowed 2 to 4 weeks before transplanting. Just before transplanting, when the soil is flooded, the field is plowed again and puddled using a harrow. In sandy soils, this is done immediately before transplanting, as the soil settles fast and becomes harder and more difficult to transplant the longer the time lapse between harrowing and transplanting. Transplanting is a labor-intensive operation and, in many cases, especially near urban areas, labor is hired for transplanting. Farmers typically transplant at a hill density of 16 m^{-2} using about 3 seedlings per hill.

Fertilizers are not used extensively in the rainfed lowlands. Until the mid-1990s, very little chemical fertilizer was available and use was very little in the wet-season lowland production system. The more recent adoption of fertilizer is largely confined to areas of lowland rice production along the Mekong River corridor in southern and central Laos. Fertilizer use is increasing, as is evident from survey information from southern Laos (Pandey and Sanamongkhoun 1998), which indicated that, in 1995, 60% of the farmers using fertilizer had only started using it in the two years immediately prior to the survey. The amount of fertilizer used and time of application often depend on individual farmers' financial resources. The most common fertilizers imported and available are 16-20-0 and 46-0-0 (urea), which represented 73% of the total fertilizers imported in 1999. Some farmers apply rice husks and manure to their fields but this is not a common practice. If they are applied, this is done before the first plowing.

Pesticide use is limited and has followed a similar pattern of adoption as for fertilizer (for more specific information on pests and their management, refer to Chapter

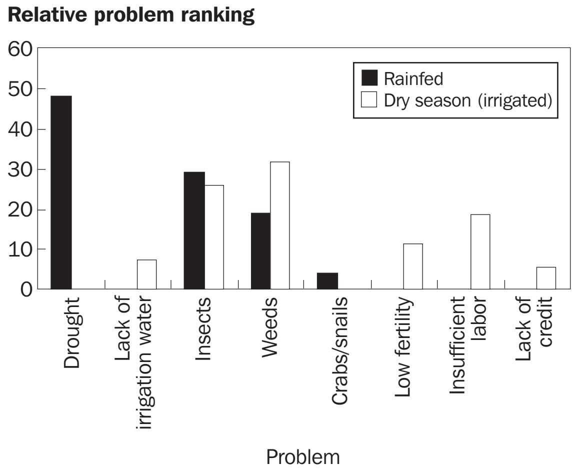

Fig. 3. Relative ranking of the top three problems identified by farmers in the wet-season rainfed lowland and dry-season irrigated environments. Source: Schiller et al (2001a).

17). Weeding is done manually once or twice during a season and, in the main lowland rice-growing area in the Mekong River Valley, is not normally perceived as a major production constraint (Fig. 3). Rice usually starts to mature in October, and continues through November depending on location, variety, and time of planting.

Harvesting and threshing

Harvesting is done manually and the harvest is usually bundled and left in the field for a few days to dry (Photo 3.4). Panicles may be left on top of the stubble straw to dry or be placed on an elevated pole or rack. Once dried, rice is often stored for a short period in the field before threshing by piling the cut rice neatly into a large round stack with the rice panicles in the middle of the stack to protect them from rain and rodents (Photo 3.5). Traditionally, threshing has been done manually, and manual threshing continues in the more isolated areas of Laos. However, in many of the larger lowland rice-growing areas, threshing is becoming increasingly mechanized.

Storage

How grain is stored depends on whether it is to be used for food or seed. Grain is usually stored when the grain moisture content is between 12% and 14%, and is always stored unmilled. Most farmers store grain in a wooden rectangular structure supported on stilts, which often carry physical measures for protection against rodent damage. The size of the grain stores varies, and depends on the quantity of grain to be stored. Some farmers put the grain directly in the store while others first bag the rice before storage. Another storage method is the occasional use of large bamboo baskets that are woven from split bamboo; the outer walls of these baskets are often plastered with mud or manure. The basket is usually placed on a platform and protected from rainfall by a temporary roof. These stores are situated close to the house. If the fields are far away from the village, a grain store may be built in the fields and grain carried to the home at regular intervals.

Seed rice is commonly stored in nylon bags and kept inside the grain store. Less common but occasionally used is the tying of panicles into bundles, which are then stored hanging from the roof. Only varieties that are difficult to thresh (nonshattering) can be stored in this manner.

Milling

Food rice is stored unmilled, as rice quality is better maintained when the rice is left inside the husk until required for consumption. When rice is needed for consumption, farmers will usually mill enough to meet family consumption requirements for 1 or 2 weeks. Traditionally, farmers milled rice in a mortar. This is still done in some of the more remote areas but increasingly farmers take their rice to a village-level rice mill for milling. Usually, the cost of milling at a rice mill is the bran from the rice, which the miller subsequently sells as a livestock feed.

Crop residue management

At harvest, farmers remove the panicle, leaving about half (depending on variety and farmer) of the rice straw in the field. This stubble straw is most commonly grazed by livestock during the dry season, but it may also be burned. The panicle straw, which is removed with the grain, is moved to a central location for threshing. In the case of the use of large mechanical threshers, the panicles are often moved to a location near a road, which provides access for the thresher; after threshing, the straw is often burned. Hand threshing is usually done either in the field or near the home, after which the straw is often stored for livestock feed. During the dry season, livestock graze freely on the straw residue left standing in fields. Little effort is made to collect and use any of the straw as a potential manure or mulch. Survey data from southern Laos in the mid-1990s revealed that only 11% of the farmers used manure, with application rates (mostly to nurseries) varying from 35 to 1,050 kg ha^{-1} (Lao-IRRI 1995). Rice husks following milling are often left at the mill, although in recent times there has been increasing use of them in areas of the Mekong River Valley, following recognition of their potential as organic fertilizer.

Labor inputs

Based on benchmark survey information collected in 1996 in a nonmechanized production system, a total of about 120 person-days per ha were required for rainfed lowland rice production (Pandey and Sanamongkhoun 1998) (Fig. 4). The main labor-intensive activities were winnowing and hauling (48 person-days), crop establishment (35 person-days), and land preparation (30 person-days). Land preparation was primarily done by men while the other two activities were done by both men and women. Manual weeding required less than 3 person-days per ha. With increased mechanization of both

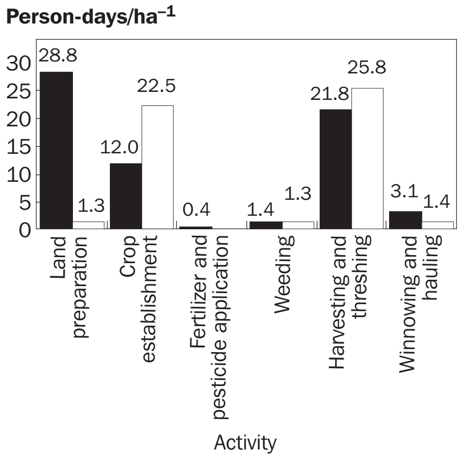

Fig. 4. Labor input in the rainfed lowland rice system. Source: Pandey and Sanamongkhoun (1998).

land preparation and threshing in the main lowland rice-growing area of the Mekong River Valley, the labor input has probably dropped considerably.

Constraints

The main production constraints identified by lowland farmers in the Mekong River Valley are shown in Figure 3. Drought is identified as the main constraint, followed by insect pests. Interestingly, soil fertility is not listed high even though this has been identified by Linquist et al (1998) as a main constraint. This probably reflects the fact that, at the time the survey was undertaken in the mid-1990s, farmers were less aware of soil fertility problems and potential yield responses to fertilizer inputs.

The irrigated lowland rice production system

Irrigation allows for double cropping. During the wet season, the cropping cycle is similar for the rainfed and irrigated lowland systems (Table 3). For the dry-season crop, the nursery is sown in December. The time of sowing is often determined by the availability of irrigation water. Transplanting is normally done in January, about 1 month after sowing. During crop growth, farmers are busier during the dry season than in the wet season as they tend to apply more fertilizer and weeds are a greater problem. Harvest usually takes place between March and May depending on location, varieties, and planting dates.

Although management practices in the irrigated rice system are generally similar to those in wet-season rice production, dry-season production differs in the following areas:

- Stubble straw (straw remaining after the wet-season harvest) is often burned following harvest to allow for easier and quicker land preparation. In the rainfed system, with only one crop grown per year, livestock typically graze the remaining stubble straw.
- Improved varieties are almost exclusively used. As in the wet season, glutinous rice is primarily grown. Most of the improved varieties planted are those that have been developed primarily for wet-season cropping. Although these varieties are generally suited to dry-season irrigated areas in southern and central Laos, often they have not performed well in the northern region, which experiences low winter temperatures, particularly during the period of seeding and transplanting in December and January.
- Generally, more inorganic fertilizer inputs are used for dry-season irrigated cropping than during the wet season; this largely reflects the lack of cropping risk associated with the known availability of irrigation water.
- Plants are usually transplanted using a closer spacing (25 to 44 hills m^{-2}).
- Weeds tend to be a more significant problem than with the wet-season crop.
- Some pests are also perceived as causing bigger problems in the dry season than in the wet season; these include a perceived higher incidence and damage from rice bug and brown planthopper.

The Montane lowland rice production system

Lowland (rainfed and irrigated) rice production is commonly practiced in the highland areas of Laos (in northern Laos, particularly in provinces adjacent to the Lao-Vietnam border). There are some large lowland rice areas (mainly in the northern provinces of Sayabouly and Luang Namtha) where lowland rice production practices are similar to those found in southern and central Laos. There are also considerable amounts of lowland rice production in narrow valley bottoms and along terraced hillsides (Photo 3.2). These areas are not extensive; many highland villages have only 1 to 10 ha of such lowland rice. Most farmers owning montane lowlands also have upland fields where they grow upland rice and cash crops. Although management in many ways is similar to that in other lowland areas, there are some significant differences.

1. Since farmers also own upland fields, the timing of the various lowland activities needs to fit in with their upland activities (Table 3).
2. Local varieties are more common in the montane lowlands.
3. Nurseries are in upland fields, adjacent to lowland fields (Photos 3.6 and 3.7). Having upland instead of lowland nurseries is primarily due to the high labor demand for upland fields and limited water availability.
4. Double transplanting is often practiced (see box, page 38).
5. Small irrigation schemes are common. Farmers typically form groups to make a weir from logs and stones. Canals are dug to carry water to paddy fields by cutting a canal out of the slope. Bamboo is often used to carry water over low areas to fields.

> **Double transplanting**
> Double transplanting is where farmers transplant twice: first from the upland nursery to a lowland nursery and then from the lowland nursery to the main field. In each nursery, rice is grown for about 1 month. Some reasons given by farmers for double transplanting are
>
> 1. To spread labor demand. Even though total labor may be higher, the labor is spread out. As mentioned earlier, many farmers also own upland fields and they need to balance their labor betwen these areas.
> 2. To reduce excessive vegetative growth, especially in good soils where traditional varieties (susceptible to lodging) are grown.
> 3. To reduce damage caused by crabs. Crabs are a problem in many lowland nurseries (crabs cut the stems of young seedlings); planting larger seedlings helps reduce this damage.
> 4. To cope with water shortages. Many lowland areas are irrigated from mountain streams that may dry up in the dry season. There may not be enough water early in the wet season to transplant into the main field.

6. Pest problems are often different, as montane lowland fields are often surrounded by forest or fallow vegetation that provide a good habitat for rodents and other pests.
7. Gall midge (*Orseolia oryzae*) appears to be a particularly common pest problem, especially in wet years.
8. Farmers rarely use fertilizer. Local varieties are not responsive to fertilizer and fertilizer increases problems with gall midge.
9. Dry-season production is limited because of inadequate irrigation water, low dry-season temperatures, and high susceptibility to pest damage (small cropped areas are often targeted by pests such as rodents and birds).
10. When dry-season rice is grown, farmers typically sow their nurseries very early (mid-November) before the onset of the lowest winter temperatures. They then transplant in early to mid-January when temperatures start to moderate.

Upland rice production practices

Upland rice production is practiced widely in northern Laos as well as in the eastern parts of central and southern Laos, which are also very mountainous. Upland rice production is practiced on slopes ranging from 0 to 120%. Upland rice is usually grown in slash-and-burn production systems where rice is grown for 1 or 2 years (but usually only 1 year), with the field then being allowed to return to a natural fallow. In some areas (5–10% of the area), a rice crop is followed by rice or other crops (Roder 2001); however, this is in response to population pressure and farmers are simply testing new strategies. Historically, this practice has been sustainable, but in recent times it has become increasingly unsustainable because of shortening fallowing periods as a result of increasing population pressure. The shorter fallows have led to increases in soil erosion and increased weed ingress (which has, in turn, resulted in significant increases in labor inputs required for weed control, thereby reducing the area capable of being cropped by individual households), with a resulting decline in fertility and rice yields. Another system observed in the north is what farmers call "garden rice," in which rice is grown in permanent fields, either successively or in rotation with other crops; however, this is practiced in a very small percentage of the area. A detailed discussion of upland issues and research can be found in Chapter 24.

Rituals and religion are intertwined with most aspects of slash-and-burn cultivation. Some of these traditions and beliefs associated with the different ethnic groups are described in Chapters 5 to 8.

Land use and ethnicity

One characteristic of the northern Laos uplands is their high ethnic diversity. Certain ethnic minorities are often blamed for causing environmental damage and forest destruction because of unsustainable land-use practices associated with slash-and-burn upland rice cultivation. Between 1991 and 1994, Roder (2001) conducted a survey to quantify differences in land-use patterns among various ethnic groups. The results of this survey did not indicate that the upland cultivation practices of any particular ethnic group were more unsustainable than for other ethnic groups. Variations in land use within the same ethnic group were generally larger than between ethnic groups. Some specific findings from this survey can be summarized as follows.

1. All ethnic categories are engaged in slash-and-burn cultivation to varying degrees, including some Lao-Tai, who are generally associated only with lowland rice cultivation. Conversely, members of the Mon-Khmer group (particularly the Khmu) and the Hmong-Mien group, more usually associated with upland cultivation systems, were found to have lowland rice fields when conditions allowed.
2. There are no consistent differences between ethnic categories with regard to rice yields, slope gradient of fields, labor input, weeding requirements, and fallow periods.
3. Some ethnic groups tended to have their villages at higher elevations and their villages were more remote. This is particularly the case for the Hmong-Mein and is believed to probably reflect the fact that (1) these groups moved to Laos more recently and had to use land that was not yet occupied and thus more remote, and (2) partly the preference of cultural isolation, cooler climate, and environments relatively free of malaria.
4. The Hmong-Mein ethnic group generally follows longer cropping cycles and their soils had higher organic matter levels, which may reflect the fact that (1) they are recent immigrants and are still working on land with relatively high fertility status, having gone through fewer cropping cycles; (2) the overall cooler climate (higher elevation) results in slower organic matter breakdown; and (3) wider crop diversity allows for longer cultivation by reducing the impact of weeds and pests.
5. The Hmong-Mein generally had higher crop diversity and maize was a more important component of their cropping systems.

Although there may not be marked differences in relation to land-use practices, diversity does exist in relation to upland rice production practices, some of which are discussed below.

Annual cropping cycle

The annual upland rice production cycle (Table 3) starts in January, when farmers slash the vegetation that has grown in their fields. In March and April, when dry, the vegetation is burned. Sowing takes place between mid-April and the end of May, depending on the rains and location. During the growing season, farmers weed their fields from three to five times (areas with shorter fallows requiring more frequent weeding). Harvesting begins in early September with the early-maturing varieties, whereas late-maturing ones are usually harvested by the end of October.

Field preparation

In January, farmers meet together to discuss and identify the areas to be cleared and cropped. Usually, farmers like to have their fields adjacent to those of other farmers, as this creates a system where they work together to protect the area from livestock and other pests. In January and February, the vegetation is slashed and allowed to dry. The time and effort spent doing this depend on the length of the preceding fallow. Large trees and other perennials dominate fields that have been in fallow for a long time, whereas fields that have been in fallow for only a short time are dominated by shrubs and annual weeds. In March and April, the dried vegetation is burned (Photo 3.8). This usually takes place in two steps: an initial burning and then a reburning when all the unburned vegetation is stacked and burned again. During this time, fences are also built around the field to provide protection from grazing animals (both wild and domesticated). Fences are usually made from wooden poles collected from the burned field area, although some ethnic groups, such as the Hmong, are known to make quite elaborate fences. A field hut (*thieng hai*) is also built during this time. As many upland rice fields are a long way from the village (often a 2- to 3-hour walk), the field hut is important as the farmers rest in it during the day, cook and eat meals there, and occasionally use it for overnight stays, especially close to harvest time when they need to guard the field from pests and wandering animals.

Planting

Sowing takes place in mid-April to May. Under upland rainfed conditions, there is no soil preparation but rather rice is dibble planted into the ash from the preceding burning of the vegetation in the area being cropped. Dibble planting requires making a hole in the soil about 5 cm deep with a dibble stick and then putting the rice seed into the hole. Different ethnic groups have different preferences and types of dibble sticks. The most common is a 2-m-long stick made of hard wood with either a point carved onto the end or a metal point attached to the end. A modification of this is a sounding dibble stick, which the Khamu sometimes use. As the holes are made with a sounding dibble stick, a sound is made to give a pleasant rhythm to the planters so they can work faster and the job will be less tiring (Simana and Preisig 1997). Finally

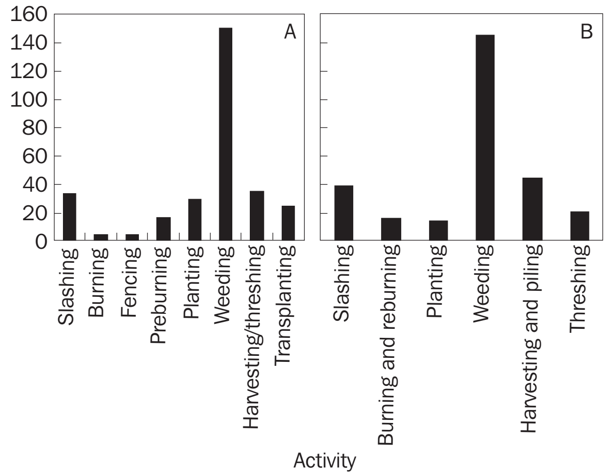

Fig. 5. Labor requirement (person-days ha^{-1}) for upland rice cultivation: (A) from household survey conducted in 1992 in the provinces of Luang Prabang and Oudomxay (Roder et al 1997); (B) from Pak Ou District, Luang Prabang Province, collected in 2001 (Lao-IRRI 2003).

is a short planting stick with a small, narrow, spade-like metallic blade attached to the wooden handle. Dibble planting usually requires two people, one making the holes and the other putting seeds into the holes, although one person can do the operation. Holes are usually spaced at a density of 10 to 16 hills m^{-2}, with 10–15 seeds being planted in each hole (Photo 3.9). The rice seed may sometimes be mixed with a pesticide to provide some protection against pests before germination. As upland rice is often intercropped with other crops, the seed of other crops is in some instances mixed with the rice seed before dibble sowing.

Weeding and crop management

Weeding requires more labor than any other activity—about half the annual labor requirement (Photo 3.10) (Fig. 5). Depending on the length of the previous fallow, a farmer may weed the field two to five times. All members of the family weed. Weeding may be done using only household labor or in a group whereby farmers exchange labor for weeding. In the first case, where only family members weed their fields, weeding needs to be done almost every day to provide adequate weed control, particularly in areas where the fallow period is short. Where group weeding is undertaken, a single field can be weeded in a few days. When weeding sloping fields, farmers weed by walking up the slope and in this sense they prefer steep fields, as they bend over less while weeding. Chapter 20 provides a more detailed outline of the ecology of weeds in the different rice production systems in Laos.

Rice is harvested in three ways:

1. Stripping the grain from the panicle by hand from the standing rice crop.
2. Cutting only the rice panicle using a small knife held between the fingers.
3. Using a sickle to cut the top portion of the rice crop.

Rice harvest and threshing

Rice is harvested during September and October depending on the maturity time of a variety. Some early varieties may be harvested before they are fully mature. This is especially the case if the farmers' rice supplies have been depleted. When harvested before maturity (during the dough stage), the grain is lightly roasted, fried, and then the hulls removed. This rice can be steamed and eaten as normal rice (*khao mao*) or used to make deserts such as "*khao hang*" (a desert with coconut milk and sugar). If a family has run out of rice from the previous season, this rice provides sustenance until the main crop is harvested.

Harvesting is done in different ways depending on ethnic group and rice variety. Three types of harvesting methods (see box) are recognized and each involves different methods of drying and threshing. First, rice can be stripped by hand from the panicles directly into a basket and hence there is no need for threshing. This type of harvesting is associated with rice varieties that have grains that are easily stripped from the panicle. The rice grain is dried on mats in the sun before storing. Second, a practice that is associated particularly with the Hmong ethnic group, is harvesting only the rice panicle using a small knife held between the fingers. These panicles are often taken directly to the village where they are separated from the grain using a mortar, trampling with feet, or beating with a stick. Third, and perhaps most common, is using a sickle to cut off the top half of the plant (similar to what is done in the lowlands). When harvesting the rice with a sickle, the panicles are tied together in bundles and left to dry for several days, most commonly on top of the remaining rice stubble, but also sometimes on an improvised platform or, as practiced in parts of Luang Namtha Province, hung on a large scaffold. As in the lowlands, once the rice has dried, it is often stored for a short period in the field before threshing by piling the cut rice neatly into a large round stack with the rice panicles in the middle of the stack to protect them from rain and rodents (Photo 3.5).

In the upland environment, almost all threshing is still undertaken manually; mechanical threshers are rarely used. Threshing is usually done by holding a bundle of rice together with two sticks that are tied together; the panicles are then beaten against a log slab or stone to dislodge the grain (Photo 3.11). After threshing, the chaff is removed from the grain. This is done in several ways, the most common being placing the rice in a large, flat woven basket and tossing it into the air to let the wind carry away the chaff. A practice associated with the Hmong is to build a platform 3 to 5 meters high and carry the threshed rice to the top and slowly drop it, letting the wind carry the chaff away (this is also seen in the montane lowland rice system—Photo 3.12). Following threshing, the grain is bagged and carried back to the village. Some farmers store the grain as "panicles" without threshing; this is only possible for varieties that do not shatter easily.

Storage

Rice is stored in many ways depending on whether it is to be used for eating or for the following year's seed, and the methods used in the upland environment do not differ much from those used in the lowlands. Rice that is eaten can be stored in nylon bags and stored in the house, in a separate store on stilts or in large woven baskets covered with mud or manure. Often, rice stores are built on stilts with aluminum or smooth bamboo around the stilt poles to deter the entry of rodents. In some villages, these stores are outside of the village to minimize the loss of food reserves in the event of a fire within the village.

Seed rice is often stored in nylon bags. These bags may be put in the farmer's house and stored above the cooking fire, the smoke from which helps minimize infestation by insects and other pests. Sometimes the bags of seed rice are buried in the rice that is being stored for consumption.

Milling

Methods of milling do not differ significantly from practices in the lowlands. However, as many of the upland villages are more remote, the use of manually operated mortars is much more common than rice mills. However, once villages have road access, one or two farmers will set up small rice mills to meet the needs of the village.

Varieties

Most traditional upland rice varieties belong to the tropical japonica variety group (Roder et al 1996). Upland farmers clearly differentiate between early, medium, and later maturing varieties and most households will plant varieties from each group. This allows them to harvest rice for consumption as early as possible, distribute labor requirements for harvest, and spread risk (Roder et al 1996). In addition, special varieties are sometimes grown for religious ceremonies, nonglutinous varieties are used for noodle making, and some varieties are suited to making alcoholic beverages. Most upland farmers grow two to five varieties, with each variety showing differences in maturity. Any given village may have up to 18 different varieties (see Chapter 10).

Most Lao farmers prefer glutinous rice varieties. However, a small number of ethnic groups grow and consume mainly nonglutinous rice, the most notable being the Hmong and Mien (Yao); originating from southern China, these two ethnic groups migrated to Laos during the 19th and 20th centuries. There are no known improved upland rice varieties being used in Laos. While variety preference varies, most farmers prefer upland rice varieties that are tall with thick stems and have long, large panicles and big grain.

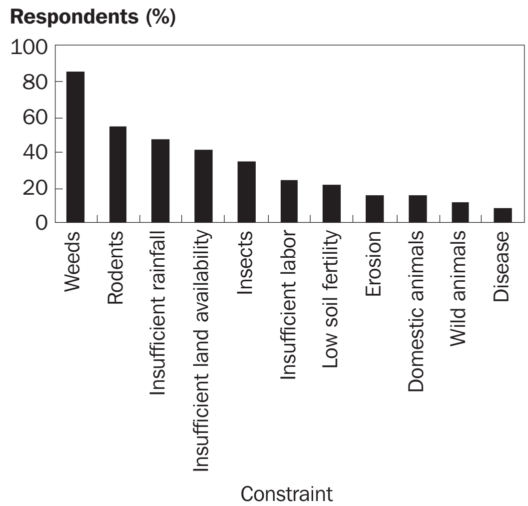

Fig. 6. Constraints to rice production in slash-and-burn systems (household survey conducted in 1992 with 129 correspondents from four districts in Luang Prabang and Oudomxay provinces). Land availability includes the constraint of short fallow and insect pests are mostly white grub. Source: Roder (2001).

Multiple cropping

Upland rice is rarely monocropped; maize, cucumber, pumpkin, taro, cassava, chilies, sesame, Job's tears, loofah, smooth loofah, sweet potato, long bean, peanut, eggplant, ginger, sweet-stalk sorghum (for chewing stalks), Italian millet, finger millet, yam-bean, pigeonpea, and sun hemp are often grown with the rice or along paths in rice fields (Photo 3.13). In some cases, seeds of these crops are mixed with the rice seed and planted at the same time as when the rice is dibble planted. Most of these crops are for home consumption (crops that are grown as cash crops are usually grown in a separate area, often as a monocrop).

Labor and tools

All labor in upland fields is manual and the only tools used are machetes, weeding blades, dibble sticks, harvesting tools (a sickle or small knife), and threshing tools. On average, upland rice slash-and-burn cultivation requires almost 300 person-days per ha (Fig. 5), with about 50% of the labor being devoted exclusively to weeding, whereas slashing, planting, and harvesting are the next largest consumers of labor (Roder et al 1997, Lao-IRRI 2003).

Problems and constraints

Farmers consider the main upland rice problem to be weeds, followed by rodents, insufficient rainfall and land availability, and insect pests (Fig. 6). Data were collected in the early 1990s and it was probable that by early 2000 the problems relating to land availability would have become more significant as a result of land allocation policies that started going into effect in the late 1990s, which restrict the land area that can be used for upland cropping.

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Notes

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CHAPTER 4

Climatic diversity within the rice environments in Laos

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Laos is a country with a natural beauty created by many rivers and mountains. More than 85% of the land area has an elevation of at least 180 m above sea level. Most of the rice-growing lowlands are located in the Mekong River Valley, in the central and southern parts of the country. Most of the northern region is mountainous, the mountains being a continuation of the Himalayan range, rising steeply from valleys, from where the majority of streams flow toward the Mekong River. The highest mountain, Phu Bia, at 2,772 m, is located in the north.

As most Laotians are farmers, their livelihoods are greatly affected by climatic variability, in particular by the occurrence of floods and droughts. Rice cultivation, the core of the life of most rural Lao, is dependent on the monsoons. Most rice is grown under rainfed conditions in the wet season, between May and November. The southwest monsoon rains during this period are heaviest during July and August, and usually last until late October. Up to 30 cm of rainfall can be received per month during this period, depending on the region. The northeast monsoons bring cool and dry conditions in November to February. During this period, the mountainous areas in the northeast of the country, with altitudes above 1,500 m, can experience nighttime temperatures as low as 0 °C. Water levels in the Mekong River can vary from 0.5 m (Pakse) to 12.5 m (Luang Prabang) between their April low and August peak (Van Zalinge et al 2003). Flooding of areas adjoining the Mekong River and its tributaries is common during the wet season, particularly in the central and southern parts of the country.

Data on climate, topography, and soils in Laos have been routinely collected by various agencies, during and after the period that the French administered present-day Laos as part of French Indochina. However, this information has, until recently, not been systematically processed, and its use for agricultural planning and management purposes has therefore been very limited. During the second half of the 1990s and early 2000s, several organizations, working in collaboration with the National Agriculture and Forestry Research Institute (NAFRI) within the Ministry of Agriculture and Forestry (MAF) of Laos, have worked on developing a database inventory for the country using available information on soils, topography, land use, and climate. This

Table 1. The response of the rice plant to varying daily mean temperature at different growth stages.

Growth stages	Critical temperature (°C)		
	Low	High	Optimum
Germination	10	45	20–35
Seedling establishment	12–13	35	25–30
Rooting	16	35	25–28
Leaf elongation	7–12	45	31
Tillering	9–16	33	25–31
Primordia initiation (panicle)	15	–	22–23
Panicle differentiation	15–20	38	–
Anthesis	22	35	30–33
Ripening	12–18	30	20–25

Source: Yoshida (1981).

chapter summarizes efforts to develop a series of agro-climatic maps for Laos focused on the rice-producing environments of the country.

A proper understanding of climatic variation across a country is essential in helping predict the weather pattern during periods of crop growth in a country like Laos, both in the wet season under monsoonal rainfall conditions and during the dry season in the irrigated environment. Although long-term climatic data are being used for predicting weather changes, the occurrence of drought in the rainfed cropping environments of Laos remains unpredictable. Rainfall, temperature, and solar radiation influence rice production through their direct effects on the physiological processes involved in growth and development of the rice plant, and indirectly through the influence on environmental factors that affect the incidence of pests and diseases. Climate and soil variation are the two most important factors that determine variation in yield throughout the region.

Temperature

Temperature and growth of the rice plant

Table 1 summarizes the response of the rice plant to varying temperature at different stages of growth. A mean temperature above 20 °C throughout the growing period is required for good germination, growth, and grain-filling processes. The rice crop can tolerate daytime maximum temperatures up to 45 °C and nighttime minimum temperatures as low as 7 °C. However, for seedbed seedling establishment, minimum temperatures in excess of 12 °C are required. The optimum temperature for panicle initiation is 22–23 °C, and for grain ripening 20–25 °C. Temperatures above 22 °C tend to accelerate the process of respiration and, as a result, the grain-filling period is reduced.

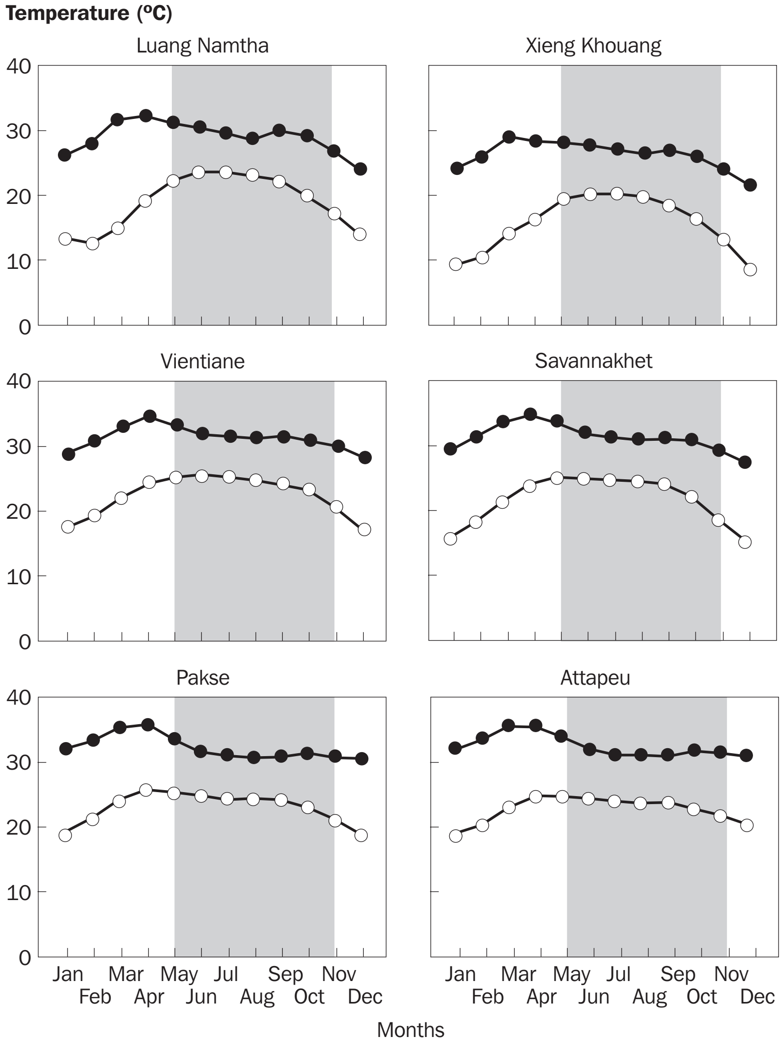

Fig. 1. Temperature distribution (monthly mean minimum and monthly mean maximum) in the wet and dry seasons in some rice-growing areas in provinces in the northern (Luang Namtha and Xieng Khouang), central (Vientiane Municipality and Savannakhet), and southern (Pakse and Attapeu) agricultural regions of Laos (the wet season is represented by the shaded area).

Temperature variation in Laos

The pattern of monthly mean temperature (minimum and maximum) distribution varies across central, southern, and northern Laos (Fig. 1).

In the central and southern regions, peak monthly maximum temperatures are recorded in April, immediately before the onset of the wet-season rains. Maximum temperatures increase gradually from their lowest of around 28–30 °C in January to

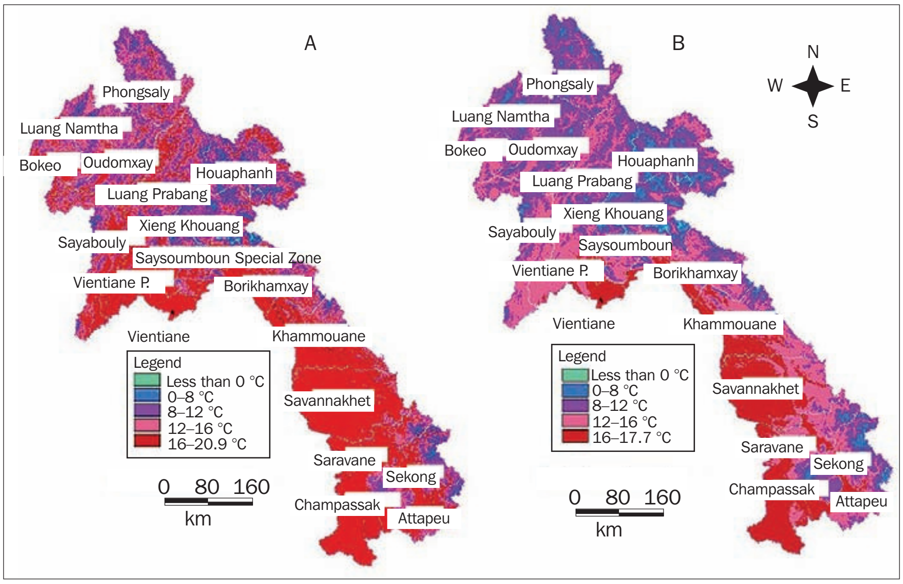

Fig. 2. Mean minimum temperature in November (A) and January (B) for Laos, predicted from altitude-temperature relationships.

about 35 °C in April. The temperature remains above 30 °C between April and October, and starts to decline from late October. Minimum temperatures also follow the same pattern, while the daily temperature variation becomes smaller (<10 °C) during April to August (Chanphengxay et al 2003).

Recent work on agro-climatic characterization reported by Inthavong et al (2001) has produced monthly minimum and maximum temperature maps for Laos. Digitized historical data on maximum and minimum temperatures were used to develop temperature distribution maps for each month. Altitude and temperature relationships were used to develop GIS-based temperature maps for the whole country. Examples of these maps showing the mean monthly minimum temperatures for November and January appear in Figure 2.

Temperature as a limitation to rice production in Laos

Generally, temperature is not a constraint to rice cultivation during the wet season. An exception to this general situation exists for flood-prone areas adjacent to the Mekong River in the provinces of Borikhamxay and Khammouane in the lower part of the central agricultural region. In this area, transplanting of the wet-season crop can be delayed beyond the normal time of late June or early July to August or September, with flowering occurring in December when the temperature is around 16 °C.

In contrast to wet-season cultivation, low temperature can potentially be a major production constraint for dry-season irrigated rice crops, particularly in some provinces in the northern agricultural region (Fukai 2001). In this region, for the coldest

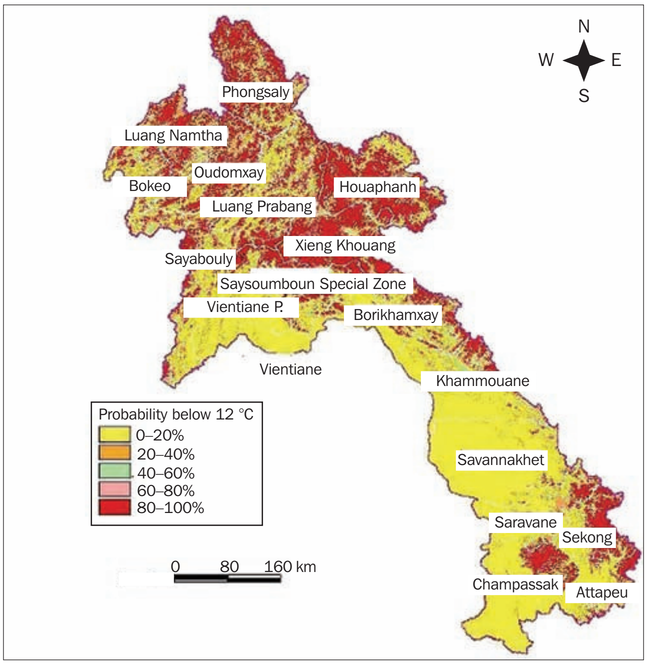

Fig. 3. Low-temperature probability map for a monthly mean minimum temperature of less than 12 °C during December throughout Laos.

months of December to January, mean monthly maximum temperature ranges from 22 to 26 °C, while mean monthly minimum temperature for the same period ranges from 8 to 12 °C. Dry-season rice crop establishment usually coincides with the period of lowest temperature. Seedling nursery establishment during November to January in some parts of the north can fail, as germination and seedling growth can be severely affected by low temperature, particularly at high elevation.

One method of quantifying the risk of low-temperature effects on seedling establishment is to estimate the probability of occurrence of critical temperatures during the period of seeding using historical temperature data. In formulating these low-temperature probability maps, a minimum monthly temperature below 8 °C was considered to be a severe limitation to rice establishment. Areas where the minimum monthly temperature is in the range of 8–12 °C, 12–16 °C, and above 16 °C were considered high, medium, and no low-temperature risk, respectively (Basnayake et al 2003). Temperature probability maps showing areas of the country potentially affected by low temperature are now available (Inthavong et al 2001). The higher altitude (>600 m) areas in northern Laos have been identified as high-risk areas, particularly for sowing in December and early January. Figure 3 illustrates the probability of monthly mean minimum temperature falling below 12 °C in December throughout Laos. There is a 80–100% probability of the mean minimum temperature being below 12 °C in some parts of the northern provinces of Xieng Khouang and Houaphanh. Other parts of these provinces show a less than 20% probability of having a monthly mean minimum temperature of at least 12 °C. Other provinces in the north that also show varying degrees of low-temperature effects on rice crop establishment and growth are Luang Namtha, Phongsaly, Oudomxay, and Luang Prabang. For the central and southern regions of the country, there is almost no risk of low-temperature effects on seedbed establishment in November to January for dry-season irrigated rice crops. However, there can be an exception to this at higher altitudes in some provinces (mountain areas in Khammouane and Champassak), where monthly mean minimum temperatures can fall below 12 °C (Fig. 3).

The temperature maps for Laos have been published (Inthavong et al 2001) and an interactive CD featuring these maps is currently available through the National Agriculture and Forestry Research Institute within the Ministry of Agriculture and Forestry of Laos.

Daylength variation across Laos

The life cycle of many plants is synchronized to the changing seasons. This relationship ensures that developmental transitions, such as the onset of flowering, occur under the most appropriate environmental conditions. Fluctuations in daylength (or photoperiod) provide the information used by plants to synchronize these developmental adaptations to the seasons (Garner and Allard 1920). Rice is a short-day plant and it progresses quickly toward flowering and reproduction in response to the shortening of daylength.

Daylength variation throughout the year in Laos is relatively small when compared with that of the rice-growing areas in many other countries. This reflects the fact that Laos is located near the equator. Generally, daylength ranges from 10 h 45 min to 11 h 15 min in different parts of Laos for December to between 12 h 45 min and 13 h 15 min in June (Fig. 4). Phongsaly (21°42′N, 1,000 m) in the north has the maximum daylength variation between January and June (2 h 30 min), whereas Attapeu in the south (14°48′N, 105 m) has the lowest (1 h 30 min). Vientiane (17°57′N and 178 m) has an intermediate daylength variation.

The short daylength in the wet season is conducive to flowering in many rice-growing areas of Laos. Generally, traditional rice varieties of Laos, which are usually highly photoperiod-sensitive, flower from late September to mid-October when daylength is shorter than 12 hours. Flowering of photoperiod-insensitive cultivars (into which category most improved Lao varieties released since 1993 fall) depends on time of sowing. If seedbed sowing is delayed as a result of early wet-season drought, to July or possibly early August, this would result in late flowering in November or December. However, photoperiod-sensitive cultivars that flower in mid-October (early) or early November (late) do not reflect any influence of time of sowing on flowering time. Photoperiod sensitivity is an advantage where the time of sowing needs to be adjusted on account of other resource limitations, such as lack of water availability. Early sowing provides a potentially long vegetative period, whereas late

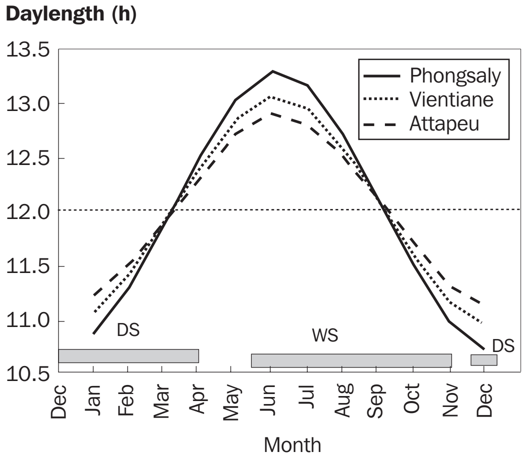

Fig. 4. Monthly mean daylength variation in three provinces (Phongsaly, northern region; Vientiane, central region; Attapeu, southern region) of Laos. The shaded areas indicate the normal growing periods for rice in the dry season (DS) and wet season (WS).

sowing shortens the vegetative period in photoperiod-sensitive cultivars grown in the wet season. Most wet-season rice-growing areas of Laos experience short days (<12 hours) during the flowering period. Dry-season crops flower in February and March. However, there is a risk to the sowing of photoperiod-sensitive rice cultivars in the dry season because daylength is too long for these cultivars to flower during this period of the year. Generally, photoperiod-insensitive cultivars are grown in the dry season.

Solar radiation

As with temperature, the solar radiation requirement of the rice plant varies for different growth stages. Low-intensity solar radiation generally reduces photosynthesis in crop plants. Reduced photosynthesis results in lower crop yields. Low radiation during the early vegetative stage generally does not have a significant effect on yield and yield components. However, low radiation levels during the reproductive phase can have a detrimental effect on spikelet number and subsequent grain yield. A yield reduction of more than 50% has been measured in response to 75% shading in the reproductive stage (Yoshida 1981, Monteith 1972). Low radiation during the ripening stage also reduces grain yield. On the contrary, varieties with a high yield potential can produce higher yields if daily radiation exceeds 20 MJ m^{-2} during the ripening stage.

Under tropical conditions, solar radiation levels are higher in the dry season than in the wet season. During the wet season, radiation interception by cloud cover is greater than in the dry season. Long-term solar radiation data for Laos are not available. The solar radiation information presented here is based on records of sunshine hours from several meteorological stations across the country for a period of 5 years (1996-2000).

The variation (weekly) in solar radiation across Laos (for two locations for each of the northern, central, and southern regions) is shown in Figure 5. In the northern region, the two provinces of Luang Namtha and Xieng Khouang receive an annual mean radiation of 18 MJ m^{-2} day^{-1}, with a range of 16 to 21 MJ m^{-2} day^{-1} for the wet and dry seasons, respectively. The central and southern regions receive mean annual radiation of 20 MJ m^{-2} day^{-1}, with a range of 18 to 24 MJ m^{-2} day^{-1} for the wet and dry seasons, respectively. Potential solar radiation ranges from 12 to 23 MJ m^{-2} day^{-1} in the north to 15 to 24 MJ m^{-2} day^{-1} in the south. Also represented in Figure 5 is the solar radiation that could be received without the interception effects of cloud cover during the year. Clouds mostly affect incoming radiation during the wet season, reducing the incident radiation level to 15 MJ m^{-2} day^{-1} in the month of peak rainfall, September. Generally, the potential effects on rice grain yield are greatest by a reduction in solar radiation levels during the last two months of growth, during the period of flower primordia initiation and maturation. For wet-season crops, this period of development occurs in September-October, when the solar radiation level can fall to less than 20 MJ m^{-2} day^{-1}. For dry-season crops, the incoming radiation level varies from 20 to 25 MJ m^{-2} day^{-1} in March and April, corresponding with the flower primordia initiation to maturation periods. In the absence of other constraints, dry-season rice crops should be able to yield more than wet-season crops on account of the difference in radiation levels between seasons. For wet-season crops, early-flowering cultivars (August) will generally result in lower yields than later-flowering (October) cultivars because of the impact of differences in radiation levels at the time of flowering. However, independent of the effects of solar radiation, yields of later-flowering rice crops can be limited by a lack of water in the rainfed lowland environment.

Rainfall

Water and the rice plant

Rice can be grown as a lowland crop with standing water as well as an upland crop without standing water, although genotypes generally differ in relation to the growing environment to which they are best adapted**.** The water requirement of the rice plant varies according to its growth phases. Generally, 200 mm of monthly rainfall for lowland rice and 100 mm of rainfall for upland rice are required during the establishment phase. For the vegetative stage, the crop requires a minimum monthly rainfall of 125 mm. At the ripening stage in lowland crops, no standing water is required, but the soil moisture content should be retained close to field capacity.

Interruptions to the regular monsoon rainfall can result in moderate to severe moisture stress for the rice plant. Moisture stress can cause the retardation of both root and shoot development, delay flowering or cause poor floral development, affect pollination and fertilization, and affect grain filling, all of which can affect final grain yield. Excessive rainfall can also cause severe problems in rice production. It can interfere with many farming operations such as seedbed preparation, sowing,

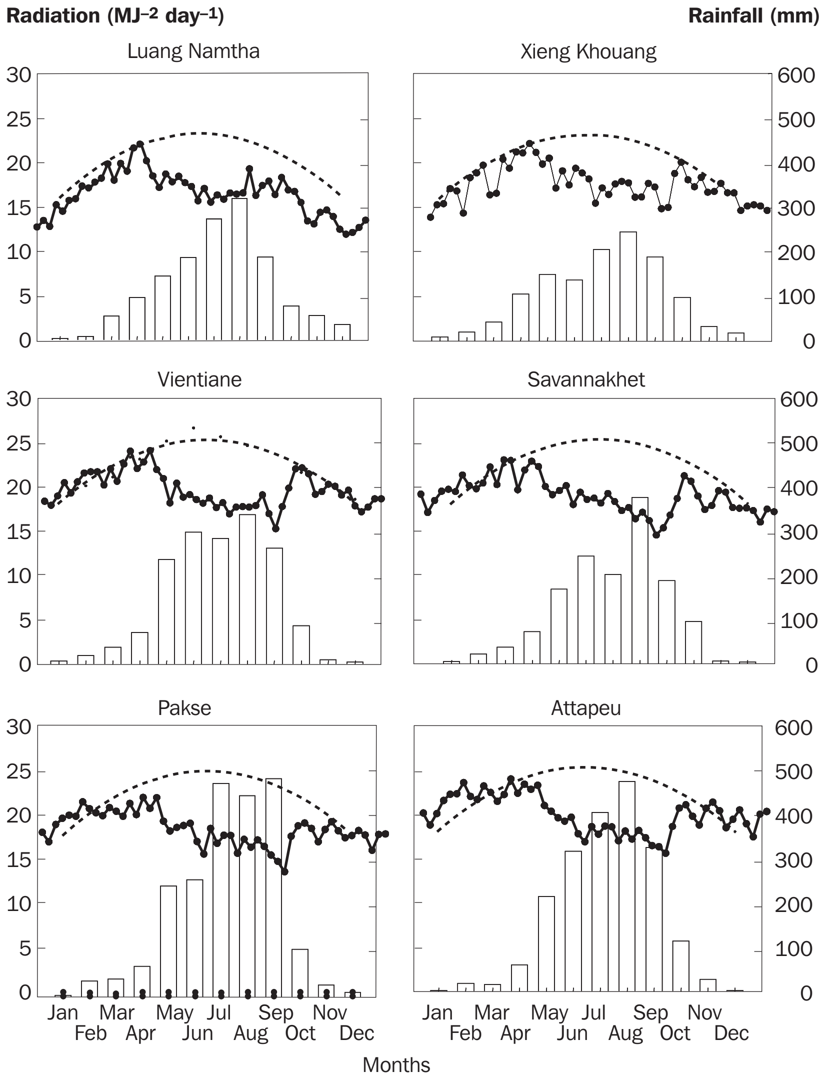

Fig. 5. Weekly mean incoming solar radiation and monthly rainfall across six rice-growing areas during a 12-month period. The dotted lines indicate the pattern of incoming radiation if there is no radiation interception by clouds during the rainy season.

Table 2. Rainfall distribution (mm) in selected provinces of northern, central, and southern Laos.

Region/province	Dry-season[a] rainfall (mm)	% rainfall	Wet-season[b] rainfall (mm)	% rainfall	Annual rainfall (mm)
Northern					
Phongsaly	251	16	1,329	84	1,580
Luang Namtha	258	17	1,272	83	1,530
Oudomxay	213	15	1,221	85	1,434
Luang Prabang	214	15	1,192	85	1,406
Sayabouly	224	17	1,060	83	1,284
Xieng Khouang	303	20	1,180	80	1,483
Central					
Vientiane	197	11	1,594	89	1,791
Savannakhet	197	13	1,286	87	1,483
Savannakhet (Seno)	120	11	1,011	89	1,131
Southern					
Saravane	197	9	1,908	91	2,105
Pakse	195	9	2,022	91	2,217
Paksan	467	14	2,893	86	3,359
Attapeu	252	11	2,041	89	2,292

[a]The dry season starts in November and ends in April. [b]The wet season starts in May and ends in October.

harvesting, threshing and processing, and seed drying. High rainfall can also cause flooding, with resulting yield reduction or crop loss. Further, continuous rain during the flowering period can affect fertilization and grain formation. Excessive rain can also favor an increased incidence of plant diseases and pests, resulting in lower crop yields. The frequent occurrence of both drought and flooding in many rice-growing areas of Laos has been summarized by Schiller et al (2001).

Rainfall in Laos

Annual rainfall distribution is highly varied across the northern, central, and southern agricultural regions of Laos. Provinces in the northern region generally receive less rainfall than the central and southern regions, with small variations (1,566 ± 247 mm annum^{-1}) across provinces. The northern provinces of Sayabouly and Luang Prabang have the lowest mean annual rainfall, with 1,284 and 1,406 mm, respectively. The highest annual rainfall is received in provinces in the southern region (2,237± 426 mm annum^{-1}), with a higher variation across provinces within this region than in other regions. The provinces with the highest annual rainfall are Saysoumboun Special Zone and Borikhamxay, with 3,231 and 3,107 mm, respectively. The proportion of total rainfall received in the wet season (north to south) varies from 84% to 90% across the three regions (Table 2).

The annual rainfall distribution for Laos is illustrated in Figure 6. The temporal pattern of rainfall distribution is depicted in Figure 7 for weeks 15 (second week of April), 25 (third week of June), 35 (first week of September), and 40 (first week of

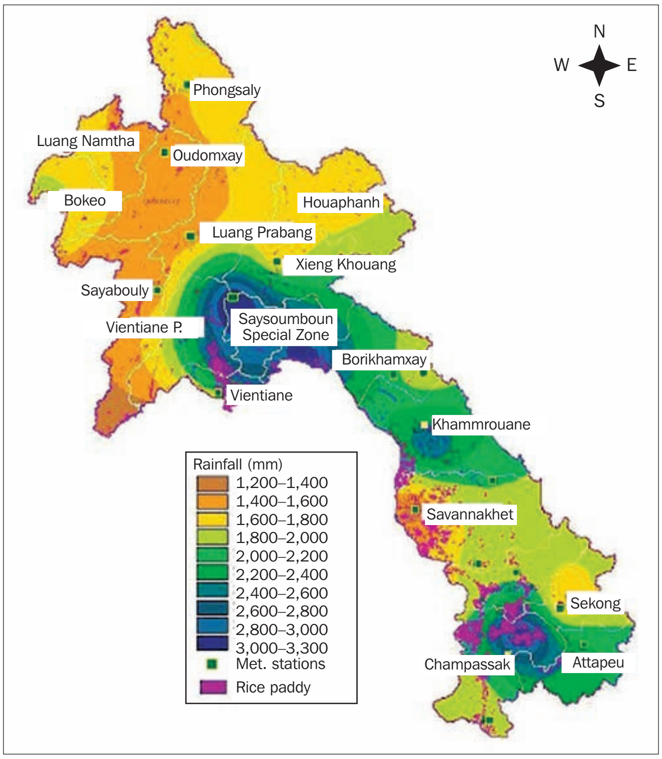

Fig. 6. Mean annual rainfall map for Laos generated with the interpolation of rainfall data.

October). Week 15 (mid-April, Fig. 7A) marks the beginning of the wet season. Within the main lowland rice-growing areas along the Mekong River, Borikhamxay and the northwestern part of Khammouane in the central region, together with Saravane and the northwestern part of Champassak in the south, receive good rainfall early in the wet season. In contrast, the western part of Savannakhet remains relatively dry at this time of the year.

By week 25 (late June, Fig. 7B), most of the area of central and southern Laos bordering the Mekong River receives about 50 mm of rain per week (50 mm per week is considered adequate for rainfed lowland rice). In contrast, in late June, most rice-growing areas of northern Laos still receive less than 50 mm of rainfall per week, insufficient for rainfed lowland rice cropping.

In week 35 (early September, Fig. 7C), rainfall registrations are high (more than 50 mm) throughout most of the country. Thereafter, rainfall decreases sharply and, by week 40 (mid-October, Fig. 7D), the southern part of Borikhamxay and Khammouane and Savannakhet in the lower central agricultural region receive less than 50 mm per week, while rainfall still exceeds 50 mm in some parts of Vientiane Municipality and Champassak in the south. In Savannakhet and Khammouane, in early October, there

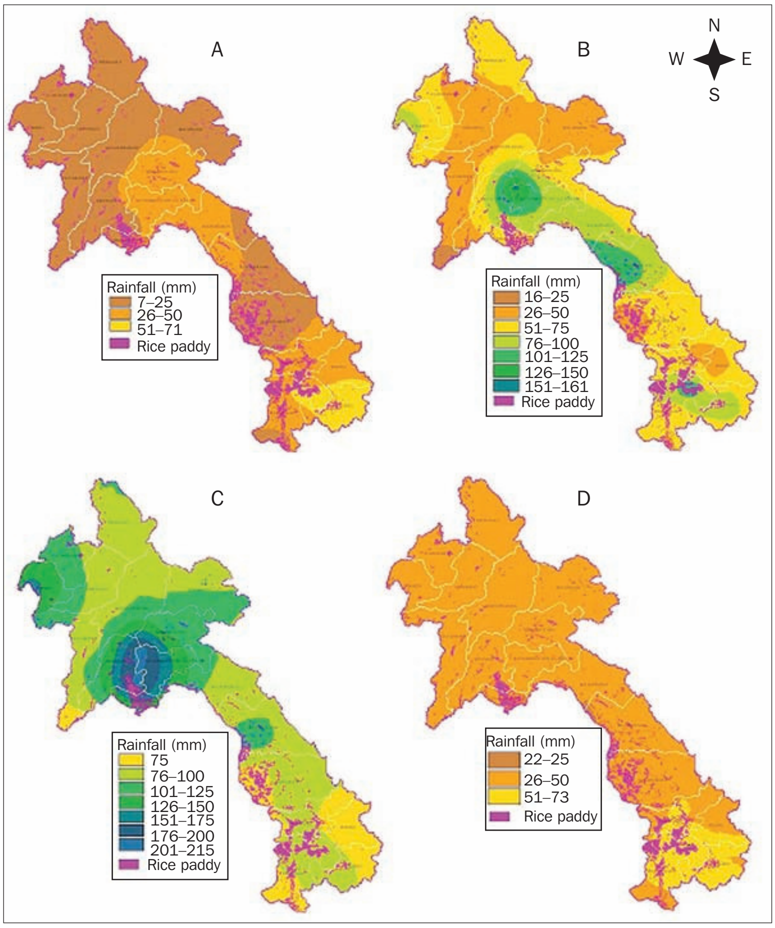

Fig. 7. Rainfall distribution maps for week 15 (mid-April), 25 (late June), 35 (late August), and 40 (early October) in Laos.

is a trend of increasing rainfall (from about 20 mm to 40 mm per week) from the west to the east in each province. There is little rainfall throughout the country from November to April. Full irrigation is usually required for dry-season rice cultivation during this time of the year.

Potential evapotranspiration and length of growing period

Potential evapotranspiration (PET) is a measure of the ability of the atmosphere to remove water from the plant and soil surface through the processes of evaporation and transpiration, assuming no limitation of water supply. The concept of PET was first introduced in the late 1940s and '50s by Penman, and is defined as "the amount of

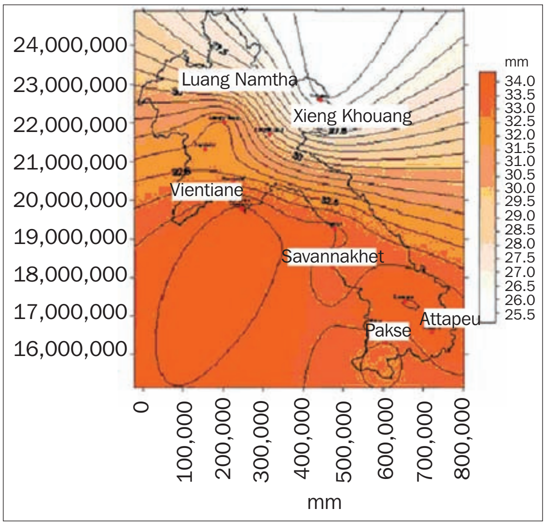

Fig. 8. Map of potential evapotranspiration (mm week^{-1}) in mid-October (week 40) throughout Laos. (X and Y coordinates are universal transverse mercator, UTM.)

water transpired in a given time by a short green crop, completely shading the ground, of uniform height, and with adequate water status in the soil profile." In the definition of potential evapotranspiration, the evapotranspiration rate is not related to a specific crop. PET is an important determinant of rice plant growth, as the effectiveness of rainfall depends upon the level of PET. If the PET is higher than the rainfall, an input of irrigation water is required for optimum plant growth.

The following factors are important in estimating potential evapotranspiration:

1. Potential evapotranspiration requires energy for the evaporation process. The major source of this energy is from the sun. The amount of energy received from the sun accounts for 80% of the variation in PET.
2. Wind enables water molecules to be removed from the ground surface by a process known as eddy diffusion.
3. The rate of evapotranspiration is associated with the gradient of vapor pressure between the ground surface and the layer of atmosphere receiving the evaporated water.

Systematic PET data are not available for most parts of Laos; the estimates presented here have been based on meteorological information for 17 locations where daily data on sunshine hours, maximum and minimum temperature, maximum and minimum humidity, and wind speed are available. Spatial interpolation using GIS was carried out on the point-based PET estimates to produce gridded maps of weekly PET (Inthavong et al 2004). Figure 8 shows the PET surface for Laos for week 40 (mid-October). In mid-October, the highest PET is recorded in the southern agricultural region (Pakse and Attapeu), where it reaches about 34 mm week^{-1}. During the same period, PET is as low as 25 mm week^{-1} in the north and northeastern parts of the country (Luang Namtha and Xieng Khouang). Therefore, water loss in the northern region is relatively lower than in the southern region late in the wet season.

In estimating the climatic water balance, rainfall and PET for each week were used for representative locations throughout the country. The importance of water balance relates to the definition of the "length of the growing period" (LGP) for crops, where the LGP is usually defined as the period within the year when rainfall exceeds 50% PET. For Laos, where rice is the major crop, the water balance estimates were based on 75% PET (rather than 50% PET, which is the usual PET level used by FAO for upland crops, FAO 1978) because lowland rice consumes more water than most other crops. The beginning of the growing season for wet-season cropping under rainfed conditions is defined as the time when weekly rainfall exceeds 75% of the weekly PET at the end of the dry period. The first instance when rainfall exceeds 75% PET is not considered as the week of the beginning of the LGP when at least two consecutive weeks receive less rainfall than 75% PET. The end of the growing season was defined as the time when the weekly rainfall falls below 75% of the weekly PET.

The weekly rainfall, 75% of the weekly PET, and length of the growing period for six locations in Laos are shown in Figure 9. At some locations during the wet season, weekly PET falls below the weekly rainfall for 1 or 2 weeks, reflecting potential drought conditions (e.g., week 22 for Luang Namtha). If this period lasts only 1 week, it is considered to be a continuation of the period of growth (i.e., water is not considered a constraint to growth). The weekly PET together with rainfall are comparatively lower at the beginning (week 12) of the wet season in the northern region relative to the central and southern regions. However, rainfall is insufficient to begin the season for rice until weeks 17–18 (late April to early May) in both the north and central regions. Conversely, for the southern region, although PET is higher than in the northern region at this time of the year (weeks 15 and 16 in Pakse), rainfall is adequate to begin the growing season. By weeks 39–40 (late September to early October), rainfall usually falls below the 75% PET level in some locations, including Luang Namtha in northern Laos, Savannakhet in the lower central region, and Attapeu in the south (Fig. 9), and the growing season ends. However, in the area of the Vientiane Plain in the central region, the growing season extends to week 41 (mid-October), with rainfall exceeding 75% of PET until this time.

In Laos, as in most tropical and semitropical areas of Asia, the LGP for wet-season lowland rice crops is a reasonably distinct period that roughly coincides with the period of the southwest monsoon rains. Also, the LGP as estimated from the climatic water balance is not affected or modified by low-temperature constraints that might further limit the period of crop growth. The mean weekly rainfall and PET were used as inputs for the development of a climatic water balance model (rainfall minus 75% PET) to generate the LPG surfaces for Laos (Fig. 10). The start of the growing period varies throughout Laos from early April to late June (Fig. 10A), while the end of the growing period ranges from mid-September to early November (Fig. 10B).

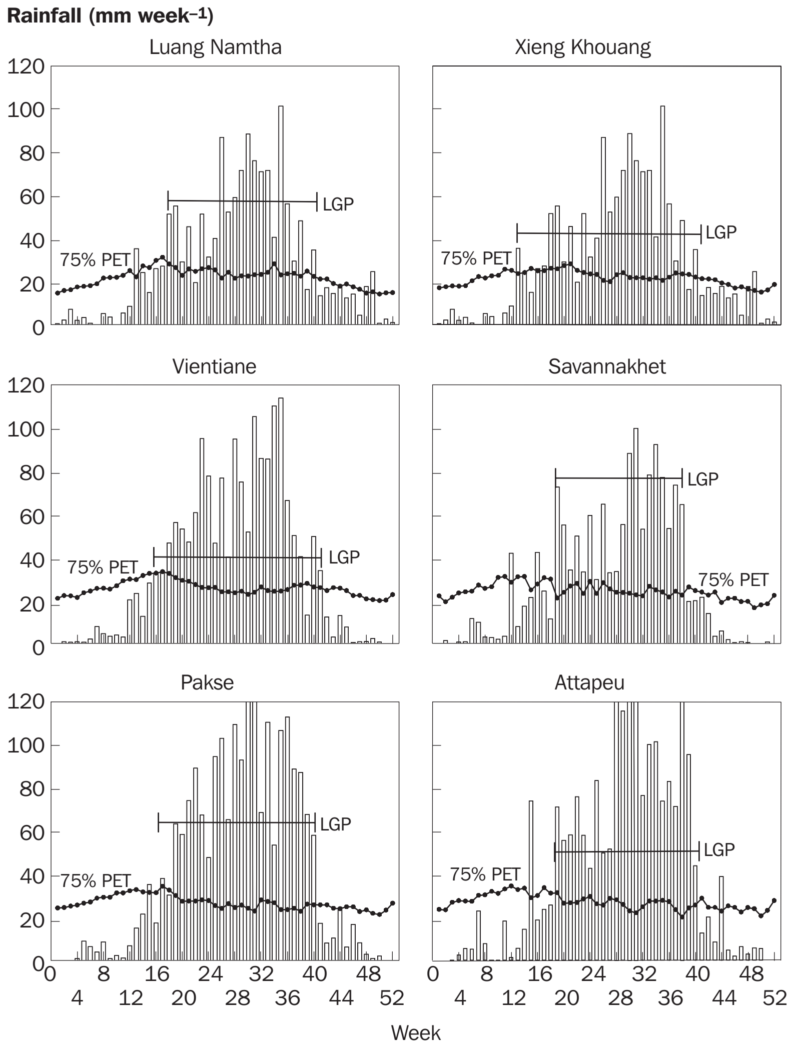

Fig. 9. Line graphs for 75% of the evapotranspiration (mm week^{-1}) and bar charts for rainfall (mm week^{-1}) in some lowland rice-growing areas in northern (Luang Namtha and Xieng Khouang), central (Vientiane Municipality and Savannakhet), and southern (Pakse and Attapeu) Laos. Horizontal lines indicate the estimated length of the growing period (LGP).

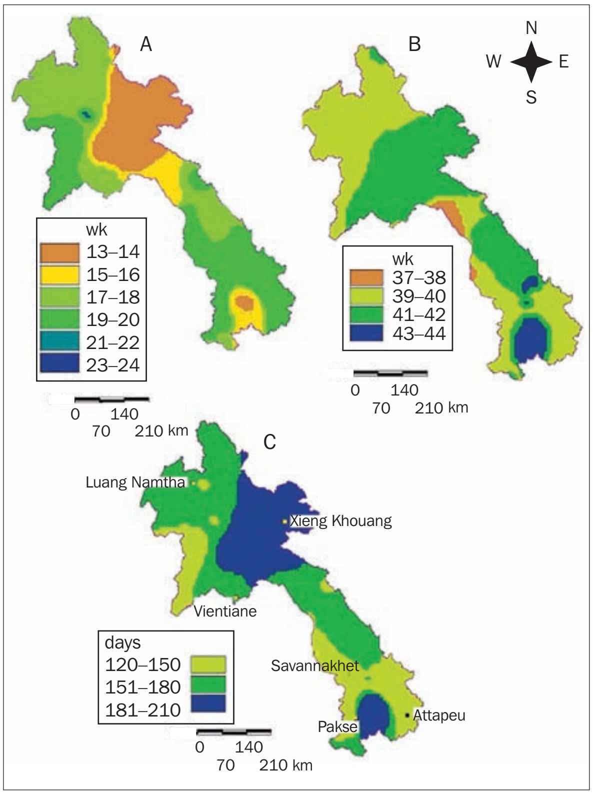

Fig. 10. Maps of Laos showing (A) first week, (B) final week, and (C) duration (in days) of the length of the growing period for wet-season rainfed lowland rice.

The LGP for wet-season rainfed lowland rice ranges from 120 to 210 days in the main rice-growing areas (Fig. 10C). The shortest LGP is in those provinces with the lowest rainfall—Attapeu in southern Laos, Savannakhet in the lower central region, and Sayabouly in the lower northern region. The areas with the longest LGP are in the rice-growing areas of Champassak near Pakse, and in the northeastern province of Xieng Khouang. Most lowland rice-growing areas in the upper north and northeast have an LGP of moderate length, from 150 to 180 days.

Conclusions

The rice production environments in Laos have enormous climatic diversity. In the main lowland rice-growing areas in the central and southern agricultural regions in the Mekong River Valley, the predominant rice production ecosystem, the rainfed lowlands often suffer from the effects of drought or flood, or a combination of both. Rice varieties can be developed for these areas that are adapted to the constraints imposed by LGP as determined by rainfall distribution, as well as showing improved adaptation to drought. Temperature is usually not a constraint to rice cropping in this environment, in either the wet season or dry season. However, low temperature can cause crop establishment failure for dry-season cropping in the northern agricultural region, particularly at higher altitudes. Recent studies and analysis of the agro-climate have provided a better understanding and delineation of the potential climatic limitations to rice production in different parts of the country; however, these studies need to be supported by further analyses (and incorporation of other factors, particularly soil-related information) and further field studies to allow more accurate mapping of potential constraints in the different agricultural environments. The results of the current analyses can be used in both rice breeding and crop management programs to better stabilize yields in many areas, as well as provide a basis for yield improvement.

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Notes

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