CHAPTER 13

The Role of Irrigation in the Commercialisation of Rice Farming in Southern Cambodia

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Introduction

This chapter is based on a study to explore the key constraints to rice-based farming systems in the rainfed lowlands of Cambodia and the role of different sources of irrigation in alleviating some of those constraints (Chea 2015). The research was carried out in lowland districts in Takeo and Kampong Speu Provinces in the southern part of the Tonle Sap Basin, representing a major lowland rice-growing region with high population density, small farm sizes, and severe production constraints (Fig. 13.1). Three villages were selected with similar biophysical and socioeconomic environments but different degrees of access to irrigation:

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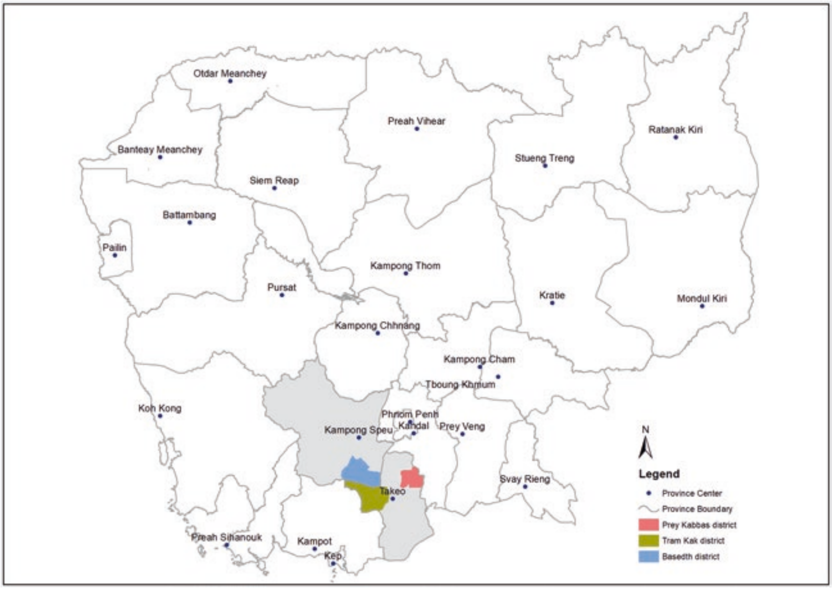

Fig. 13.1 Locations of the three study districts in Takeo and Kampong Speu Provinces. (Source: Cambodian Agricultural Research and Development Institute)

- Trapeang Run, in Tram Kak District in Takeo Province, shows the full extent of the development problem facing farm-households and villages in the rainfed lowlands, with all the constraints attributed to this zone, including very limited access to irrigation, restricted to small house-yard ponds.
- Snao, in Prey Kabbas District, also in Takeo Province, shows what options become available to farm-households with access to on-farm sources of irrigation in the form of shallow tube wells to draw on groundwater resources, in addition to farm ponds. This case also shows the potential for agricultural development with little or no intervention by government or other development agencies.
- Ta Daeng Thmei, in Basedth District in Kampong Speu Province, shows what farmers can do when they have access to a medium-scale, gravity-fed irrigation facility. Where public investment in such irrigation schemes is feasible, farming options are increased, though there are issues that must be addressed at the community level to maintain the irrigation infrastructure and manage water use.

A range of research methods were employed between 2010 and 2013 for data collection, including reconnaissance visits, household surveys (with 200 respondents across the three villages), discussions with village heads, key informant interviews, analysis of market trends, farm walks and direct observation, use of village data manuals and documents, surveys of pond-water and groundwater, analysis of rainfall data, soil surveys, and field crop experiments (Chea 2015). Each village was studied as an individual case, with cross-case comparison used to develop broader generalisations. It is this comparative analysis that is presented in this chapter.

Characteristics of Case-Study Villages

Village Settlement and Population

The main geographical and demographic characteristics of the case-study villages are shown in Table 13.1. All three villages were located 70–75 km south or south-west of Phnom Penh, but Trapeang Run was more favourably situated in terms of access to district and provincial centres for both farm transactions and non-farm employment. The settlement patterns of Snao and Ta Daeng Thmei were typical of rural Khmer communities, with houses clustered on areas of higher land which are dry year-round. However, in Trapeang Run, the houses were scattered throughout the village territory, singly or in small clusters, on or adjacent to paddy fields, giving farmers greater capacity to manage their rice and non-rice crops and livestock.

The highest population density was in Trapeang Run (700 persons per sq. km), about double that of the other two villages. However, the villages had similar areas of paddy land (90–120 ha) and there was little difference in the available paddy land per capita (around 0.1 ha). There were no major differences in the demographic characteristics of farm-households, except that the average age of household heads in Ta Daeng Thmei was 5–6 years lower than in the other two villages, consistent with a younger total village population and a high percentage aged less than 25 years. This may have been due to a lower rate of outmigration, especially when compared with Trapeang Run. Between 86% and 95% of household heads considered farming as their primary economic activity, as did their spouses. Economically active daughters (those aged 15 years and above who had

Table 13.1 Major characteristics of the case-study villages

Characteristic	*Trapeang Run (rainfed)*	*Snao (on-farm irrigation)*	*Ta Daeng Thmei (fully irrigated)*
Province	Takeo	Takeo	Kampong Speu
Distance to …			
• Phnom Penh (km)	75	75	70
• Provincial capital (km)	12	>30	>30
• National road (km)	2	15	20
Access to market	Favourable	Less favourable	Less favourable
Topography	Central plain (15 masl)	Next to floodplain (3–15 masl)	Gently sloping (27–36 masl)
Flooding regime	Flash-floods	Part flooded in WS	Flash-floods
Total land (ha)	113	451	200
Paddy land (ha)	90	120	120
Irrigation source	Small ponds	Groundwater, ponds	Reservoir
Cropping pattern (WS/DS/EWS)	Rice/fallow/rice	Rice/radish-cucumber/rice[a]	Rice/peanut-rice/rice
Settlement pattern	Dispersed	Clustered	Clustered
No. of households	157	277	158
Pop. density (pers./km^2)	697	292	372
% under 25 years	35	55	62
Paddy land (ha/person)	0.11	0.09	0.16
Household size	5.4	4.9	5.0
Family workforce	4.0	3.7	3.3
Household head			
• Age (years)	46.4	47.0	41.4
• Male (%)	89	97	92
• Education (years)	6.0	6.0	5.7
• Occupation (% farming)	86	94	93
Children's occupation			
• Female (% non-farm)	42	42	38
• Male (% non-farm)	35	22	23

[a]Cropping pattern for Snao is for WS paddy land only, excluding the DS paddy land to which some villagers had access which was flooded in the WS

finished studying) were twice as likely to be engaged in non-farm jobs as farming in all three villages. This was consistent with the predominant employment of young female workers in the nearby garment industry. Economically active sons, however, were equally likely to be employed in farming as in non-farm activities (typically, construction).

Land Resources

Trapeang Run occupied a level plain and experienced only very short periods of flash-flooding (Table 13.1). Snao occupied a level plain adjacent to the Tonle Bassac floodplain, and hence some of the lower paddy land was subject to wet-season (WS) flooding while the upper paddy land was subject to drought. Some households in the village also had access to floodplain land that was uncultivable in the WS due to flooding but highly suitable for a dry-season (DS) rice crop—that is, flood recession rice. Ta Daeng Thmei was located on a gently sloping plain downstream of low hills and below a dam providing gravity-fed irrigation. It was only subject to flash-flooding when excess water was discharged from the reservoir.

All three villages had access to three land types—WS paddy land (cultivable in wet and dry seasons), upland used for non-rice crops and residential upland—and (as noted above) some households in Snao had access to DS paddy land (only cultivable in the dry season). The WS paddy lands in all villages were of the Prateah Lang soil type—the infertile, sandy soils that predominate in the lowland rice-lands of Cambodia. However, the DS paddy land to which some villagers in Snao had access were highly fertile alluvial soils. Almost all survey households in the three villages owned WS paddy fields. The mean area of WS paddy land was lowest in Snao (0.6 ha), intermediate in Trapeang Run (0.9 ha), and highest in Ta Daeng Thmei (1.3 ha). However, nearly 50% of households surveyed in Snao owned on average 0.85 ha of DS paddy land in addition to their WS land.

All villages showed the spatial dispersion of paddy landholdings arising from the land reform of the late 1980s and the subsequent fragmentation of land through equal inheritance among children. However, paddy land was more dispersed in Ta Daeng Thmei, averaging 5.7 plots per household, than in Trapeang Run (3.3 plots) and Snao (2.5 plots). The more recent settlement, larger average landholding, and access to irrigation could have influenced the greater degree of land fragmentation in Ta Daeng Thmei.

Water Resources

Households in Trapeang Run had established small ponds close to the house for their domestic water supply, which were also used to a small extent for the irrigation of vegetables in the house-yard, and irrigation of field crops on small plots of paddy land adjacent to the house (Table 13.1).

Pond-water was also used to supplement the water needs of rice seedlings when rainfall was inadequate early in the WS. The minimal use of ponds for agriculture was because of their limited storage capacity, such that they could potentially become dry early in the DS. Households in Trapeang Run also accessed groundwater through open wells and tube wells, but only for domestic use. Hence in terms of water resources for agriculture, it is accurate to characterise Trapeang Run as a purely rainfed village.

Households in Snao also had access to small ponds, sometimes in the farm (Fig. 13.2). However, the village had made the important change to extracting groundwater through tube wells in the farms for irrigation, after which farmers have made little use of ponds for irrigation (Fig. 13.3). The use of groundwater was reflected in the much higher incidence of pump ownership in this village (90%). Groundwater was a highly reliable irrigation source, sufficient to fully irrigate two DS crops of radish or cucumber, as well as provide supplementary irrigation for the early-wet-season (EWS) and WS rice crops. Despite increasing extraction over the past three decades, the water table had shown no sign of a significant drawdown. Although there was sufficient groundwater for a large irrigated

Fig. 13.2 Farm pond with portable pump in Takeo. (Source: Rob Cramb)

Fig. 13.3 Farmer in Takeo with tube well and pump. (Source: Rob Cramb)

area, only part of the paddy land could be irrigated because the land was fragmented and financial constraints restricted households from installing tube wells in every plot.

Ta Daeng Thmei had a community irrigation scheme, drawing water from a large reservoir, which also supplied five neighbouring villages.[1] The water level in the reservoir decreased late in the DS due to intensive irrigation and lack of rainfall. Hence the irrigation supply could be unreliable for up to two months but gradually recovered from late May because of the large catchment area to the north. The slight slope of paddy land from north to south permitted a gravity-fed irrigation system, but some households occupied paddy lands that could not be reached in this way. Hence portable pumps were used in these cases to get water from the main canals to farmers' fields, but at a higher cost that limited the options for these less favourable plots.

Village Characteristics in Context

The characteristics of the three case-study villages can be seen in the context of the general features of the lowland plain. All the villages had high population densities, characteristic of the rice-lands of south and south-eastern Cambodia. Hence all were experiencing the long-term rural-rural (e.g., to north-east and north-west Cambodia) and rural-urban (to Phnom Penh) migration that has been a feature of the south and south-east in recent decades. That the population density of Trapeang Run was twice as high as in the other two villages implies greater pressure to migrate, explaining the low proportion of the village population aged less than 25 years. The potential for agricultural development in all lowland villages in the south needs to be seen against this backdrop of continuing out-migration.

All the case-study villages had reasonable access to Phnom Penh, the largest and fastest-growing agricultural market in the country, as well as having close proximity to Vietnam. Hence future expansion of agricultural production was unlikely to encounter a market constraint. However, Trapeang Run also had particularly good access to district and provincial centres, giving it an advantage in terms of supplying fresh produce to these markets, as well as engaging in business activities, non-farm employment, and higher education, including high school and university. This was reflected in the generally higher grades of school-age children. The greater distance from national roads and market centres seen in Snao and Ta Daeng Thmei was more typical of rainfed lowland villages. Nevertheless, the widespread improvement in transport infrastructure in the southern lowlands in the past decade has created significant new market opportunities, even for these relatively remote villages.

While the dispersed settlement pattern of Trapeang Run was also atypical, it could indicate the future pattern for lowland villages as the population grows and farming becomes more intensive and diverse. The traditional Khmer pattern of clustered housing in a village centre was already beginning to change in the other two villages as a number of young farm families had settled on their inherited paddy land rather than adjacent to the parental household.

The three villages' reliance on WS paddy land with infertile, sandy soils, and only small upland plots used for house-yards and non-rice crops, was representative of the general situation in the rainfed lowlands. The land potential of Trapeang Run was more typical in that paddy lands made up most of the village area apart from residential land, whereas the other two villages had greater access to uplands for cropping and some in Snao had access to DS paddy land beyond the village boundary (not a general feature of the rainfed lowland zone).

Establishing small ponds in house-yards has long been a practice in lowland villages, though they are mainly used for domestic purposes, as in Trapeang Run. Likewise, accessing groundwater through open wells is a traditional practice, but not generally for irrigation. However, the case of Snao, with widespread on-farm irrigation based on groundwater, reflects an emerging trend in parts of the southern and south-eastern provinces. As in Trapeang Run and Snao, there is limited potential in the lowlands for the kind of canal irrigation development seen in Ta Daeng Thmei.

The variation in ownership of WS paddy land is a feature of the lowlands and a critical determinant of economic differences between households. However, the generally small landholdings seen in the case studies, even the very low mean of 0.6 ha in Snao, are common for the southern lowlands. The fragmentation of paddy land that was seen in all three villages, influenced by the 1980s land reform and the pattern of land inheritance, was also a general phenomenon in the lowlands, potentially hindering the adoption of both mechanisation and irrigation.

The increasing engagement of household members in non-farm employment in all three villages was characteristic of the lowlands, despite varying distances from Phnom Penh. In particular, the garment industry in Phnom Penh employs around 650,000 young female workers from a wide range of rice-growing areas. In each of the study villages, young women were twice as likely to be engaged in non-farm work as in farming. While young women from more favourably located villages could commute to the factories, many others still opted to take up this employment and reside in Phnom Penh rather than focus on farming. Many young men from the lowlands also took up employment in Phnom Penh, mainly in construction, but in the study villages they were just as likely to be engaged primarily in farming. In Trapeang Run, with its better access to local markets, young men and some older household members were also engaged in local trade, business, and wage employment.

Comparative Analysis of Wet-Season Rice Production

WS rice was the traditional mainstay of the farming system, being cultivated by every survey household in the three villages as the main or only source of household rice supply, as well as a potential source of cash income (Table 13.2). In each village, the available paddy land was fully cultivated. The mean cultivated area was the lowest in Snao (0.6 ha), but even in Ta Daeng Thmei, where the cultivated area was more than twice

Table 13.2 Characteristics of WS rice cultivation in the case-study villages

Practices	*Trapeang Run* (n = *79)*	*Snao* (n = *62)*	*Ta Daeng Thmei* (n = *59)*
Mean area (ha)	0.9	0.6	1.3
No. of traditional varieties	15	3	9
No. of modern varieties	5	3	1
Varieties/household	2.4	1.2	2.0
Land preparation	Draught animal, plough, and harrow	Draught animal, plough, and harrow	Draught animal, plough, and harrow
Establishment method	Transplanting	Transplanting	Transplanting
Main water source	Rainfed	Rainfed	Rainfed
Supplementary irrigation	Small ponds	Groundwater	Reservoir
Irrigate nursery (%)	39	77	29
Irrigate main field (%)	16	71	25
Manure nursery (%)	100	77	93
Manure main field (%)	85	66	34
Fertilise nursery (%)	22	79	54
Fertilise main field (%)	95	82	100
Weeding (%)	89	71	25
Weeding method	Manual	Manual	Manual
Harvesting method	Sickle	Sickle	Sickle
Threshing method	Manual and thresher (11%)	Manual and thresher (35%)	Manual
Transport of paddy	Oxcart and shoulder pole	Oxcart and shoulder pole	Oxcart and shoulder pole
Drying paddy	Sun drying	Sun drying	Sun drying
Storage of paddy	Rice barn and bags	Rice barn and bags	Rice barn and bags

this figure, there was adequate labour to fully utilise the available land, even without mechanisation.

As elsewhere in the lowlands, traditional rice varieties were preferred in the WS, despite low yields, because of their good grain quality and adaptability to abiotic stress (Javier 1997). Lowland farmers were still unwilling to adopt modern IR varieties (derived from the International Rice Research Institute) for the WS crop, despite their higher yield potential, because of their inferior eating quality. There were up to 15 different traditional varieties in a village, but the suite of varieties (at least, as identified by farmers) differed between villages; only the *Srau Kraham* (Red Grain) variety was reported by every village. A few modern varieties were also grown but on no more than 5% of the total cultivated area in a village.

All activities from land preparation through to storage of the paddy were very similar across the three sites. Land preparation was undertaken with a pair of draught cattle and a traditional plough and harrow, as has been the practice for centuries. The low level of mechanisation reflected the general situation in the lowlands. In Takeo Province, the ratio of cultivated rice area to two-wheeled tractors is 23.5 ha per unit and in Kampong Speu, 14.7 ha per unit (MAFF 2011–2013). In the WS, farmers had an extended window for land preparation (June–September) and in any case farms were small. Moreover, households mostly owned enough draught cattle to manage land preparation and did not want to outlay the money to buy a tractor, or even to hire one from the few tractor-owners in each village.

The traditional labour-intensive transplanting method was used in all villages. Direct seeding by dry-seed broadcasting has been practised in north-western provinces such as Battambang and Banteay Meanchey, with larger farms, more fertile soils, and distant field locations, but there was no apparent trend to direct seeding in the south and south-east. This was presumably because the population density was higher, farm sizes smaller, and the household labour supply not yet limiting.

Supplementary irrigation was used for the seedling nursery and the transplanted crop. The incidence was much higher in Snao (over 70%) because of the ease of irrigating from tube wells. There was a low incidence of manual weeding in Ta Daeng Thmei (25%), reflecting a greater ability to maintain an adequate level of standing water in the paddy field. The incidence of weeding in the other two villages (70–90%) was high compared to other rainfed lowland areas (Rickman et al. 1997). Both farmyard manure and mineral fertiliser were widely applied in all villages.

In Snao, there were also probably carryover effects from the heavy application of nutrients to the DS crops grown on the same land.

The harvest and post-harvest activities largely followed conventional practice across the rainfed lowlands, relying on manual techniques using family, exchange, and, in some cases, hired labour. In the 1990s there was not a single mechanical harvester or thresher used in paddy fields in Cambodia (Rickman et al. 1997). Though the numbers of reapers, threshers, and combine harvesters have grown dramatically since then, especially for commercial DS rice, every case-study village harvested the WS crop with sickles. In Ta Daeng Thmei all farmers also threshed manually, but in the other two villages a minority hired mechanical threshers. The harvest was brought back to the homestead by a cattle-drawn cart or carried on shoulder poles, with a few using two-wheeled tractors. The paddy was commonly dried on palm-leaf mats for two to three days after threshing and stored in sacks (if intended for sale) or in the household's rice barn.

Though cultural practices were common, there were differences in the level of material and labour inputs, as summarised in Table 13.3. All villages used cattle manure, averaging about 6 t/ha in Trapeang Run and Snao, but only 2 t/ha in Ta Daeng Thmei. The lower rate in Ta Daeng Thmei probably reflected the larger cultivated area and the high application of manure for DS peanut cultivation (7 t/ha). Farmers in Snao used the highest rates of seeds and mineral fertilisers, whereas these rates were not very different between the other two villages. This probably reflected the smaller cultivated area in Snao, hence both the ability and the need to intensify the use of inputs, as well as a higher cash flow (see below). Snao also had a higher average use of fuel for supplementary irrigation. With home consumption as the main objective of WS rice production, farmers

Table 13.3 Average material and labour inputs for WS rice cultivation in the case-study villages

Input	*Units*	*Trapeang Run (n = 79)*	*Snao (n = 62)*	*Ta Daeng Thmei (n = 59)*
Seed	kg/ha	81	101	71
Fertiliser	kg/ha	124	166	125
Fuel	l/ha	13	59	29
Cattle manure	t/ha	6.2	6.0	2.3
Labour	days/ha	132	97	83

appeared to utilise all available household resources to the full, but to minimise the cash outlay (e.g., in comparison with EWS and DS rice and other cash crops) because they anticipated little or no cash return from this crop (though the subsistence value of the crop, hence the saving in expenditure, was around USD 350 per year).

Although material inputs were used more intensively in Snao, it was Trapeang Run that had the highest labour use (132 days/ha), 35–60% more than the other villages. However, Ly et al. (2012) also found labour inputs for WS rice cultivation in Takeo and Kampong Thom Provinces ranging from 78 to 127 days/ha; all farmers in that study used transplanting for their WS rice crops, but land preparation performed by two-wheeled tractors was found to save up to 6 days/ha. The additional labour input in Trapeang Run was spread over the activities of land preparation, pulling, transplanting, weeding, harvesting, threshing, and transport. The limited supply of irrigation water may have added to the time needed for ploughing and transplanting, because of drier, harder soil, and may have also added to the weed burden. It is also possible that the higher labour input reflected a somewhat older farm workforce with lower daily productivity, given the demographic characteristics described above.

The unit costs and returns for WS rice production are summarised in Table 13.4. Snao, with the smallest cultivated area and the highest seeding and fertiliser rates, produced the highest mean yield (2.8 t/ha), around

Table 13.4 Average unit costs and returns for WS rice production in the case-study villages

Item	*Trapeang Run* (n = *79)*	*Snao* (n = *62)*	*Ta Daeng Thmei* (n = *59)*
Yield (t/ha)	2.2	2.8	2.4
Net output (t/ha)	2.1	2.7	2.3
Net output per capita (kg)	392	552	456
Rice-deficit households (%)	41	18	15
Households selling paddy (%)	47	24	90
Mean quantity sold (kg)	313	200	1100
Farm-gate price (USD/kg)	0.28	0.28	0.28
Gross income (USD/ha)	592	757	639
Input expenses (USD/ha)	90	176	70
Net return to household (USD/ha)	502	581	569
Total labour (days/ha)	132	97	83
Net return to labour (USD/day)	4.0	6.8	7.7

20–30% higher than the other two villages; this difference was significant at the 10% level. Snao also had the highest output per capita, while Trapeang Run had the lowest at 390 kg, though this output was above the assumed per capita consumption requirement of 250 kg. Trapeang Run also had the highest incidence of rice-deficit households (41%), despite cultivating a 50% larger area than Snao, reflecting the fact that the lower yield affected the household rice supply. Moreover, households in Trapeang Run did not have the same degree of back-up from EWS rice as in the other two villages. On the other hand, the potential of the traditional WS rice crop as a source of cash income was shown in the case of Ta Daeng Thmei, with its larger area more than compensating for a lower yield. Hence 90% of Ta Daeng Thmei households sold WS paddy, with a mean of 1.1 t being sold, more than a third of mean production.

Applying a farm-gate price of USD 0.28/kg across the three villages, the differences in gross income reflected the differences in yield. However, as noted above, input expenses (especially fertiliser) were highest in Snao (USD 176/ha), significantly higher than the other two villages (at the 1% level). This reduced the advantage of Snao in terms of the mean net return to household resources (USD 581/ha), although this was still the highest return of the three cases. The lower yield and gross income, and higher labour input of Trapeang Run, gave it a significantly lower net return to labour (USD 4/day), well below the return of USD 7–8/day in the other two villages and not greatly above the opportunity cost of labour (USD 3/day).

Though traditional farming practices predominated in all three villages, certain key factors gave farmers in Snao and Ta Daeng Thmei an edge over farmers in Trapeang Run, who more closely represented the majority of WS rice farmers in the rainfed lowlands:

- Access to adequate supplementary irrigation in Snao and Ta Daeng Thmei was important to save the crop from drought periods during the WS, whereas the small ponds in Trapeang Run were only sufficient to protect the crop at the nursery stage.
- Snao farmers used only three traditional varieties, suggesting that they had selected a small number of higher-performing varieties and avoided using low-yielding varieties. Trapeang Run farmers used 15 traditional varieties, most of them yielding less than 2 t/ha.
- Higher rates of input use, including seeds, fertilisers, and fuel (for irrigation), along with better varieties, helped give Snao farmers a significantly higher yield than the other two villages.

- The small landholdings in Snao pushed farmers to intensify and diversify their cropping system, with farmyard manure, fertilisers, and on-farm irrigation being used to support up to four crops per year, thus improving the soil fertility in the WS rice fields. In contrast, in Trapeang Run, with only a single rice crop, the paddy land was baked hard by the strong sun for half the year, degrading soil properties.
- It may have also been a factor that an older farm workforce and involvement in local non-farm activities in Trapeang Run helped to drag out the duration of transplanting, fertiliser application, weeding, and harvest activities, reducing the timeliness of these operations and thus decreasing yield.

The integration of traditional and improved practices for WS rice cultivation in Snao could indicate a possible future pathway for resource-poor lowland households, such as those in Trapeang Run. Even with small paddy holdings, Snao farmers were mostly self-sufficient in rice and could earn some cash income from the WS crop. With somewhat larger holdings, though still only 1.3 ha on average, farmers in Ta Daeng Thmei could produce substantial surplus paddy to sell. The case studies show that there is potential to improve the productivity of WS rice within the context of a more intensive and diversified farming system with access at least to on-farm irrigation.

Comparative Analysis of Early-Wet-Season Rice Production

Between 55% and 65% of households interviewed in the three villages planted an EWS rice crop, even though the WS rice crop was generally sufficient for their domestic needs (Table 13.5). The EWS crop provided an additional source of cash income for those households that were already self-sufficient in rice and a supplement to the domestic supply for rice-deficit households. Even without irrigation, the incidence of EWS rice cultivation was highest in Trapeang Run, but the small cultivated area (0.15 ha) was clearly restricted by the lack of irrigation. For the two villages with irrigation, the EWS rice area appeared to be in inverse relationship to the WS rice area. Snao, with a smaller WS rice area (0.61 ha) had a larger EWS rice area (0.37 ha), while Ta Daeng Thmei, which had double the WS area (1.3 ha), had a smaller EWS area (0.21 ha).

Table 13.5 Characteristics of EWS rice cultivation in the case-study villages

Practices	*Trapeang Run* (n = *79)*	*Snao* (n = *62)*	*Ta Daeng Thmei* (n = *59)*
% of households	62	65	56
Mean area (ha)	0.15	0.37	0.21
Rice variety	Modern (IR)	Modern (IR)	Modern (IR)
Land preparation	Draught animal	Draught animal	Draught animal
Crop establishment	Transplanting	Direct seeding	Transplanting
Source of irrigation	Rainfed and ponds	Rainfed and groundwater	Rainfed and reservoir
Weed control	Manual	Manual and herbicides	Manual
Harvesting	Manual	Mechanised and manual	Manual
Threshing	Manual	Mechanised and manual	Manual
Transport of grain	Oxcart and shoulder pole	Oxcart and trailer	Oxcart and shoulder pole
Drying	Sun	Sun	Sun
Storage	Bags	Bags	Bags

Three photoperiod-insensitive rice varieties were reported in Trapeang Run—the Cambodian-released varieties of IR66 and Senpidao, and the variety introduced by Vietnamese traders, IR504. However, most of the production in this village was for household consumption. In Snao and Ta Daeng Thmei, IR504 was the most widely cultivated, with a smaller number of farmers planting IR66 in Snao, and Senpidao in Ta Daeng Thmei. The cultivation of IR504 indicates that the harvest was all sold to the Vietnamese rice traders.

The EWS crop relied heavily on early rainfall in Trapeang Run, despite the availability of small household ponds, but the crop was secured by on-farm irrigation in Snao and reservoir water in Ta Daeng Thmei. Certain cultural practices in Snao were noticeably different from the other two villages. Direct seeding, the application of herbicides, and the use of machinery for harvesting and threshing were carried out only in this village. The paddy grain was stored in plastic bags rather than in barns where the WS crop was mostly stored, which usually indicated an intention to sell the EWS produce. Following the operation of the combine harvesters or reapers in Snao, the paddy was commonly sold directly to the rice traders without being transported home.

The material and labour inputs for EWS rice cultivation are compared in Table 13.6. Snao stands out as using higher rates of all material inputs (seeds, manure, fertilisers, fuels, and herbicides). Because farmers in Snao used direct seeding, they used more than three times the seeding rate of the other two villages (380 kg/ha). The practice of direct seeding with a high seed rate, as observed in Snao, can increase crop yield through a high density of plants and hence panicles per unit area, compared with the minimal tillering of short-duration varieties using the transplanting method. Many farmers in the Mekong Delta in Vietnam broadcast at up to 300 kg/ha to ensure crop establishment and minimise weed infestation, with yields of 4–6 t/ha (Nguyen and Vo-Tong 2002).

Snao farmers also used nearly twice the rate of mineral fertilisers and applied much more cattle manure than in the other two villages. Every farmer cultivating EWS rice in Snao required fuel for pump-irrigation, averaging five times the mean fuel input in Trapeang Run, where only 43% of EWS rice growers used fuel. Farmers in Ta Daeng Thmei did not require fuel because they had access to gravity-fed irrigation; if not, they did not cultivate those plots in the EWS to avoid pumping costs. Snao farmers also incurred USD 100/ha for spraying herbicides and pesticides to control weeds and/or insects but the other two villages reported no cash outlays on agrochemicals.

The use of direct seeding, chemical weed control, and mechanised harvesting and post-harvest operations in Snao meant that the total labour requirement was very low (32 labour-days/ha), almost one-fifth that of Trapeang Run and one-third that of Ta Daeng Thmei. Trapeang Run had the highest labour input across all the activities—seedbed, pulling, transplanting, weeding, and harvesting—45% more than in Ta Daeng Thmei. As discussed in relation to the WS rice crop, one reason for this difference could be the lack of irrigation in Trapeang Run, which meant

Table 13.6 Material and labour inputs for EWS rice cultivation in the case-study villages

	Trapeang Run (n = *49)*	*Snao* (n = *40)*	*Ta Daeng Thmei* (n = *33)*
Area (ha)	0.15	0.37	0.21
Seed (kg/ha)	114	377	106
Fertiliser (kg/ha)	151	265	151
Fuel (l/ha)	34	171	0
Herbicides (USD/ha)	0	103	0
Cattle manure (t/ha)	6.9	8.7	3.4
Labour-days/ha	153	32	105

there was a firm soil surface, increasing the labour-days needed for seedbed management, pulling seedlings, and transplanting. This also provided favourable conditions for weed infestation, increasing the labour input required for weeding. In addition, the engagement of younger family members in daily non-farm activities, and reliance on older family members for farm work, could have increased the number of work-days for a given task.

Both Trapeang Run and Ta Daeng Thmei used slightly more labour per hectare on the EWS crop than for their respective WS crops. The EWS rice crop required four to five more labour-days than WS rice for irrigating in the two villages. The firm soil surface in the EWS also doubled the labour-days required to pull young seedlings in Trapeang Run (21 labour-days, compared with 10 labour-days for WS rice). Ta Daeng Thmei also needed an extra three labour-days for pulling seedlings. However, the small cultivated area made these per hectare differences less significant.

An economic analysis of EWS rice production in the three villages is presented in Table 13.7. Though the yields for Trapeang Run and Snao relate to the 2011 harvest, and for Ta Daeng Thmei to the 2010 harvest, the provincial yields varied little between these years (MAFF 2011–2013), consistent with the close to average rainfall in both years. Snao had a significantly higher yield (4 t/ha) than the other two villages, despite cultivating the same IR rice varieties (mainly IR504), presumably reflecting the high seed rate and higher rates of nutrient application. Also, the intensive utilisation of the paddy fields throughout the year in Snao meant there was a likely carryover effect of mineral and organic nutrients applied in each season. Poor inherent soil properties had also been improved, with

Table 13.7 Average unit costs and returns for EWS rice production in the case-study villages

Item	*Trapeang Run* (n = *49)*	*Snao* (n = *40)*	*Ta Daeng Thmei* (n = *33)*
Yield (t/ha)	2.6	4.0	2.2
Net output (t/ha)	2.5	3.7	2.1
Farm-gate price (USD/kg)	0.24	0.23	0.24
Gross income (USD/ha)	602	843	505
Input expenses (USD/ha)	125	501	79
Net return to household (USD/ha)	490	342	425
Total labour (days/ha)	153	32	105
Net return to labour (USD/day)	3.50	11.70	4.50

manure and crop biomass frequently being incorporated in the course of successive cultivations, and the soil was protected by almost continuous crop cover. The EWS yield in Snao was also significantly higher than the WS yield in the same village—a result of the higher yield potential of the modern varieties.

The gross income per hectare in the three villages followed the same pattern as the yields. The higher expenses in Snao (USD 500/ha) reduced the net return to household resources to USD 340/ha, significantly lower than the other two villages. However, the use of labour-saving innovations (direct seeding, herbicides, and mechanised harvesting) significantly reduced the labour input, enabling farmers in Snao to achieve the highest net return to labour (USD 12/day), about three times the return in the other two villages. This return was also double the labour return for the WS crop in Snao.

EWS rice production had been adopted in 16 of 24 provinces in Cambodia by 2012, accounting for 8% of the total harvested rice area, and the equivalent of 50% of the area used for DS rice (MAFF 2011–2013). The EWS rice area (242,113 ha) had more than doubled over the previous three years. Takeo had the second largest area of EWS rice (47,764 ha) but Kampong Speu had only 1770 ha. It is likely that the area and output of EWS rice will continue to expand, both to supplement subsistence production and generate cash income. The case-study villages illustrate this trend. The main purpose of EWS rice cultivation in Snao and Ta Daeng Thmei was to generate cash income and, in Trapeang Run, to supplement domestic rice supply.

In particular, though most farmers in each village cultivated EWS rice, Snao farmers cultivated the largest area and the highest proportion (about two-thirds) of their paddy holdings to EWS. The motivation was the small area available for WS rice production and the availability of on-farm irrigation. EWS cultivation in Trapeang Run was restricted by the lack of irrigation and only some plots in Ta Daeng Thmei were favourable for gravity-fed irrigation. Moreover, with a large surplus of WS rice, there was less incentive for farmers in Ta Daeng Thmei to spend money on fuel to increase the EWS rice area.

A number of specific approaches had been adopted in Snao to boost the EWS rice yield and net returns to family labour. The key cultural practices comprised mechanised land preparation, harvesting, and post-harvest operations, direct seeding, and applying herbicides, significantly reducing the total labour input. The crop also received high levels of material inputs including seed, manure, mineral fertilisers, and fuel to improve the crop yield. The yield was certainly improved by the reliable supply of on-farm irrigation. These practices suggest a way forward for less-productive rainfed villages such as Trapeang Run.

Comparative Analysis of Non-rice Crops

Apart from cultivating rice in the WS and EWS, non-rice crops were also cultivated in the DS within all three villages, mainly to produce cash income but also for household consumption. Table 13.8 summarises the major crops and farming practices in each village.[2] The various non-rice crops in Trapeang Run comprised watermelons, cucumbers, pumpkins, mung beans, and convolvulus. In Snao, radish was the dominant crop, with some cucumber cultivation, and in Ta Daeng Thmei peanuts were the major DS crop. The radish crop was cultivated on raised beds and peanuts on slightly raised beds, but most other crops were planted on flatbeds. Because radish cultivation involved intensive cropping, a power tiller was necessary to prepare the land but draught animal power with a conventional mouldboard plough was used to raise the beds (Fig. 13.4). Trapeang Run depended on small household ponds to irrigate the DS

Table 13.8 Characteristics of DS non-rice crop cultivation in the case-study villages

Practices	*Trapeang Run*	*Snao*	*Ta Daeng Thmei*
Crops	Various	Radish, cucumbers	Peanuts
Land preparation	Draught animals	Two-wheel tractor/draught animals	Draught animals
Cultivation method	Flatbed	Raised bed	Low raised bed
Irrigation source	Pond	Groundwater/pond	Reservoir
Water requirement	Daily/occasional	Daily	Three to four times per season
Pest control	Chemicals	Chemicals	n.a.
Weed control	Manual	Manual	Manual
Harvesting	Manual	Manual	Manual
Threshing	n.a.	n.a.	Manual
Transport	Bicycle/oxcart	Transported by buyer	Bicycle/shoulder pole
Drying	n.a.	n.a.	Sun
Storage	Sold at harvest	Sold before harvest	Bags

Fig. 13.4 Farmer in Snao preparing paddy field for radish cultivation in the dry season. (Source: Rob Cramb)

crops but, as already noted, Snao had access to a reliable groundwater supply and Ta Daeng Thmei to surface irrigation.

Radish cultivation required considerably more material inputs and labour-days than the crops in the other two villages (Table 13.9). The use of mineral fertilisers, cattle manure, fuel, and pesticides was much greater for radish cultivation than for peanuts or the other non-rice crops. The cucumber crop appeared to require little cattle manure because the application was made precisely in the planting holes rather than being spread across the entire planted area. The crops requiring daily watering were radish, cucumber, and convolvulus, with Snao farmers pumping groundwater for radish and cucumber for 1–2 hours/day and Trapeang Run farmers mostly fetching water from ponds to the cropped plots by watering can. Gravity-fed irrigation was applied three to four times for the peanut crop in Ta Daeng Thmei. Watermelon, pumpkin, and mung bean cultivated in Trapeang Run were watered only at planting time, with possibly one to two more supplementary waterings. The labour input for planting radish and cucumber was comparable to the input for other non-

Table 13.9 Material and labour inputs per ha for DS crop cultivation in the case-study villages

	Trapeang Run	*Snao*	*Ta Daeng Thmei*
Households (%)	44	82	80
Crop cycles	1	2	1
Area (ha)	0.13	0.36	0.19
Seed (kg/ha)	n.a.	6	200
Fertiliser (kg/ha)	35	385	100
Fuel (l/ha)	15	367	n.a.
Pesticides USD/ha	31	275	0
Cattle manure (t/ha)	3	12	7
Labour-days/ha	215	241	95

Table 13.10 Average unit costs and returns for DS non-rice crop production in the case-study villages

Measure	*Trapeang Run (various crops)*	*Snao (radish)*	*Ta Daeng Thmei (peanut)*
Yield (kg/ha)	a	b	1214
Seed (kg/ha)	a	6	204
Output (kg/ha)	a	b	1010
Farm-gate price (USD/kg)	a	b	1.0
Gross income (USD/ha)	454	2760	1010
Input expenses (USD/ha)	92	1018	57
Net returns to household (USD/ha)	362	1742	953
Total labour (days/ha)	215	241	95
Net returns to labour (USD/day)	1.70	7.30	11.00

Notes: a. There were many crops grown on a small scale and intermixed on the same plot, hence it was not possible to determine yield, seed, output, and price; b. The radish crop was bought before harvest by the trader who harvested the crop, hence only gross income is known, not the physical yield and output

rice crops in Trapeang Run (over 200 labour-days/ha), but more than twice that for peanut cultivation.

An economic analysis of DS non-rice crops in the three villages is summarised in Table 13.10. The radish cultivation in Snao produced the largest gross income (USD 2760/ha), six times that of the various crops in Trapeang Run and three times that of the peanut crop in Ta Daeng Thmei. Cucumber, cultivated by some non-radish farmers in Snao, provided around half the gross income of radish. However, radish production had much higher input expenses. As well, planting, watering, and weeding for the radish crops all required a high labour input with a high concentration, necessitating the use of hired or exchange labour. The lower labour concentration for cucumber, peanut, and other crops meant they could be managed by the farm family; for example, the harvest of cucumber was carried out daily by one or two family workers over a period of about 20 days.

Despite the high expenses, radish cultivation still provided the highest net return to household resources (USD 1740/ha), five times that of Trapeang Run crops and double the returns of peanut and cucumber cultivation. However, the high labour input reduced the net return to labour to about USD 7/day for radish, compared with USD 11/day for peanuts. Cucumbers (USD 4/day) and the non-rice crops cultivated in Trapeang Run (USD 2/day) gave significantly lower returns to labour, in the latter case less than the presumed opportunity cost of labour (USD 3/day). Most of the households in Trapeang Run produced very small outputs for their own consumption; only a quarter of the DS crop growers were able to generate some cash income from their crops.

Over a decade ago, Pingali (2004: 43) made the assessment that "dry-season cropping activities in the rainfed [rice-growing] areas [of South and Southeast Asia] are limited because of technical problems related to timely and effective crop establishment, limited moisture (or excessive moisture in some cases), and generally modest or high yield instability". However, the three case-study villages show that WS paddy land has potential for the cultivation of non-rice crops in the DS, both to improve household cash income and supply domestic consumption. The crops were able to be grown under a range of irrigation conditions, from small ponds to a large-scale reservoir. The crops cultivated also had different water requirements, ranging from daily watering to two to three irrigations per crop. However, the key to obtaining viable returns was a reliable irrigation source as in Snao and Ta Daeng Thmei. The limited water supply in Trapeang Run provided negligible returns and risked wasting production inputs. The improvement of on-farm irrigation would be necessary for Trapeang Run and other rainfed lowland villages to produce a significant household cash income from the cultivation of non-rice crops in the DS.[3]

Given an adequate supply of water, villages such as Trapeang Run could be expected to replicate the success of radish growers in Snao and peanut growers in Ta Daeng Thmei. To viably adopt the Snao radish cropping system, farm-households would also need to have suitable soils, an available market, sufficient working capital, and an adequate supply of family labour to undertake the intensive operations required. The lower requirements for water, cash outlays, and labour for the peanut system in Ta Daeng Thmei make this a more feasible DS cropping option for resource-poor farmers and those with other non-farm employment options in villages such as Trapeang Run.

Comparative Analysis of Cropping Systems in the Three Villages

Representative farm budgets were constructed to reflect the whole-year cropping system of typical households in the three villages (Table 13.11). Trapeang Run, with only small ponds to provide supplementary irrigation, was restricted to an annual cultivated area of 1.2 ha per household, not much more than the mean farm size of 0.9 ha. Snao, despite a small farm size of 0.6 ha, could draw on groundwater to achieve an annual cultivated area of 1.4 ha from the same land (DS rice-land was excluded from the representative budget). Ta Daeng Thmei, being fully irrigated, could crop a total of 1.7 ha for a farm size of 1.3 ha.

Given the higher cropping intensity of the representative farms in Snao and Ta Daeng Thmei, these farms achieved higher paddy output (3.2 and 3.5 t, respectively) and greater paddy surpluses (1.8 and 2.3 t, respectively) than the Trapeang Run representative farm, which was much more dependent on the WS rice crop. The higher output from Snao also reflected higher yields in both the WS and the EWS, probably due to the higher year-round input of organic and inorganic nutrients. Each of the three budgets indicates household self-sufficiency in paddy, though the lower surplus in the Trapeang Run case (1 t) reflects a greater incidence of rice-insufficiency within that village population.

The Snao farm had the highest annual expenditure, mainly for the DS radish and EWS rice crops, although the WS rice crop also incurred higher expenditure than in the other two villages. Fertiliser, fuel, and pesticide were all large items of expenditure in this case. In the other two villages the major expenses were for the fertiliser input for the WS rice crop, with relatively less expenditure on the EWS rice and DS non-rice crops. As noted above, the application of farmyard manure was two to three times higher in the Snao farm (11 t/year), nearly 70% of which was applied to

Table 13.11 Annual inputs, outputs, and net cash flow of representative cropping systems in the case-study villages

	Unit	*Trapeang Run*	*Snao*	*Ta Daeng Thmei*
Annual cultivated area	ha	1.21	1.34	1.70
• WS rice	ha	0.93	0.61	1.30
• DS non-rice crops	ha	0.13	0.36	0.19
• EWS rice	ha	0.15	0.37	0.21
Cropping intensity	ha	1.3	2.2	1.3
Paddy output	kg	2423	3230	3512
Paddy surplus[a]	kg	1081	1777	2342
Total gross income	USD	726	1847	1199
• Paddy	USD	667	829	965
• Non-rice crops	USD	59	1018	234
Total cash income	USD	351	1423	779
• Paddy	USD	292	429	584
• Non-rice crops	USD	59	1018	195
Total labour input	days	173	165	148
• WS rice	%	71	39	73
• DS Non-rice crops	%	16	52	12
• EWS rice	%	13	9	15
Labour-intensity	days/ha	186	270	114
Farmyard manure	kg	7129	11,279	5033
Total cash costs	USD	124	722	118
• Fertiliser	USD	88	272	118
• Fuel	USD	28	231	–
• Pesticide	USD	4	153	–
• Seed	USD	4	26	–
• Machinery	USD	–	40	–
Net cash flow	USD	228	701	660

[a]Surplus computed based on consumption of 1250 kg of paddy per household (assuming five household members)

the DS radish and EWS rice crops, with many radish and EWS growers buying extra farmyard manure from other nearby villages. In the other two villages, most farmyard manure was applied to the WS rice crop—81% in Trapeang Run and 60% in Ta Daeng Thmei.

The cropping systems required similar annual labour inputs of 150–175 days/year, that is, less than one full-time worker. It was estimated that cattle activities required a further 150 days/year in each village, and non-farm activities accounted for a significant proportion of household labour, especially in Trapeang Run. Though the total labour input for cropping was similar, the labour-intensity was highest for the Snao farm (264 days/ha), reflecting the small farm size and the high cropping intensity. WS rice absorbed a little over 70% of the total labour input in the Trapeang Run and Ta Daeng Thmei farms, but less than 40% in the Snao farm, where DS radish cultivation accounted for the largest share (54%).

The monthly labour profile was also similar between the Trapeang Run and Ta Daeng Thmei farms, with two comparable peak periods in July–September, when the EWS rice harvest coincided with land preparation and transplanting for the WS rice crop, and December–January, when the harvesting of WS rice and the planting of DS peanut and other non-rice crops were carried out. In the Snao farm, the labour concentration was also high in the July–September period but peaked from December to April due to the WS rice harvest and the intensive DS radish activity. Collecting native grasses for cattle in the WS increased the labour requirement in the July–September period in all three villages.

Besides the WS and EWS rice crops, the DS cultivation of radish, peanuts, and other non-rice crops contributed to farm income, especially for the representative farms in Snao and Ta Daeng Thmei. The Snao farm generated the highest gross income (USD 1820/year) and cash income (USD 1420/year), two to four times that of the other two villages. After deducting the high level of cash expenditure (USD 720/year), the Snao farm still had the highest net cash flow (USD 700), somewhat higher than Ta Daeng Thmei (USD 660) but three times the net cash flow for Trapeang Run (USD 230). The DS radish crop contributed about 90% of the net cash flow in the Snao farm, whereas the peanut crop contributed only 25% of the net cash flow in the Ta Daeng Thmei case, the majority of the cash flow coming from the sale of surplus rice from the WS and EWS. In Trapeang Run, the sale of surplus rice from the two seasons was the main source of farm cash income, the non-rice crops giving a negligible net cash return.

The representative farms in Trapeang Run and Ta Daeng Thmei experienced no land use constraint, because the cultivation of DS non-rice crops and EWS rice occupied only a fraction of the total paddy land. Even with the late harvesting of the EWS rice crop, there was little impact on the preparation of the WS rice nursery, because the area of EWS rice was only 16% of the total paddy land in each village. There was also a short break in December between the harvest of WS rice and the planting of peanuts (Ta Daeng Thmei) or other non-rice crops (Trapeang Run), due to the wet field conditions following the rainy season.

However, the small total landholding in the Snao farm and the relatively large cultivated areas of DS radish and EWS rice meant that the farmer needed to manage the restricted land resource appropriately—through timely direct seeding of EWS rice and the careful planning of WS rice activities, such as nursery plot allocation, gradual land preparation of the transplanted field, and use of varieties with a diversity of maturation periods. The early broadcasting of the EWS rice was necessary to provide a short window between the harvest of EWS rice and land preparation for WS rice. The nursery plot designated for the WS rice was not used for the EWS rice crop. The land preparation and transplanting of WS rice were gradually carried out from available plots. An early-maturing variety of WS rice was used on the land targeted for the first DS radish crop, starting from mid-December, which also minimised irrigation costs.

Conclusion

This comparison of representative cropping systems shows that, compared with the largely rainfed condition of Trapeang Run, typical of most of the lowland ecosystem, on-farm and (where feasible) canal irrigation can greatly increase the intensity, diversity, and profitability of land use. This can occur without being seriously constrained by available family labour, though in Snao there had been a move to adopt some labour-saving innovations in the DS and EWS to accommodate the tight turnarounds between successive crops on the limited paddy land. However, even in Snao, the potential for irrigated cropping had not been fully realised, due to the scattering of plots and the restricted investment in tube wells. The lands accessible to gravity-fed irrigation in Ta Daeng Thmei could also be extended, increasing further the potential cropping intensity.

Nevertheless, even these partially irrigated systems not only increased land and labour utilisation, making greater use of the limited set of household resources, but improved the physical and chemical properties of the soil, reduced the risk of a household rice-deficit, increased the production of a marketable surplus of rice, and increased the level and diversity of crop income. The resultant cash flow provided the necessary working capital to keep the cropping system turning over, with minimal need for credit, while providing income for household needs. It is significant that, on average, two-thirds of cash income in Trapeang Run came from non-farm employment, compared with only 12% in Snao and 21% in Ta Daeng Thmei.

Thus the comparison suggests a potentially feasible strategy for lowland villages like Trapeang Run to increase food security and farm and household incomes. While outmigration from the densely populated, rainfed lowlands of southern Cambodia will undoubtedly continue, the case studies show that the development of more intensive, diverse, and market-oriented farming systems, based on on-farm irrigation, can provide a promising alternative pathway for many rural households.

Notes

1. This reservoir was initially built during the Khmer Rouge era.
2. As mentioned above, half the farmers in Snao had access to floodplain land suited to DS rice cultivation but flooded and uncultivable in the WS. This option is not available to farmers in the lowland agroecosystem, which is the focus of the comparison in this chapter.
3. This need not necessarily be groundwater. An integrated farming project in central Thailand used 30% of the total farm area for pond excavation and generated an annual profit four times that of a single rice crop, thereby more than compensating for the loss of land (Setboonsarng and Gilman 2009).

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