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Authors: Wang, Huaiyu, Pandey, Sushil, Hu, Fengyi, Xu, Peng, Zhou, Jiawu, et al.

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Farmers' Adoption of Improved Upland Rice Technologies for Sustainable Mountain Development in Southern Yunnan

Huaiyu Wang[1], Sushil Pandey[1], Fengyi Hu[2], Peng Xu[2], Jiawu Zhou[2], Jing Li[2], Xianneng Deng[2], Lu Feng[2], Lu Wen[3], Jian Li[4], Yun Li[5], Lourdes E. Velasco[1], Shijun Ding[6], and Dayun Tao[2]**

*Corresponding authors: h.wang@irri.org (H.W.); taody12@public.km.yn.cn (D.T.)
[1] International Rice Research Institute, DAPO 7777, Metro Manila, Philippines
[2] Yunnan Academy of Agricultural Sciences, Kunming, 650205, P. R. China
[3] Puer Agricultural Research Institute, Puer 665000, P. R. China
[4] Xishuangbanna Seed Management Station, Jinghong 666100, P. R. China
[5] Wenshan Agricultural Research Institute, Wenshan 663000, P. R. China
[6] Zhongnan University of Economics and Law, Wuhan 430074, P. R. China

An analysis of the patterns of technology adoption by upland rice farmers in southern Yunnan and of the impact of technologies was conducted using farm–household data collected during 2005. The technologies considered were improved upland rice varieties and terraces. The results indicate that these technologies are now spreading in upland areas. Farmers who have adopted both technology components have been able to increase the upland rice yield substantially. Income from rice production was similarly found to be higher for adopters than for nonadopters. In addition, there was evidence that increased rice yield helped reduce the pressure from intensifying food production in these fragile uplands because farmers were able to meet their food needs from smaller areas. Implications of these findings for sustainable development of uplands in Yunnan and in countries in the region are drawn.

Keywords: *Upland rice; adoption of improved technologies; sustainable mountain development; Yunnan; China.*

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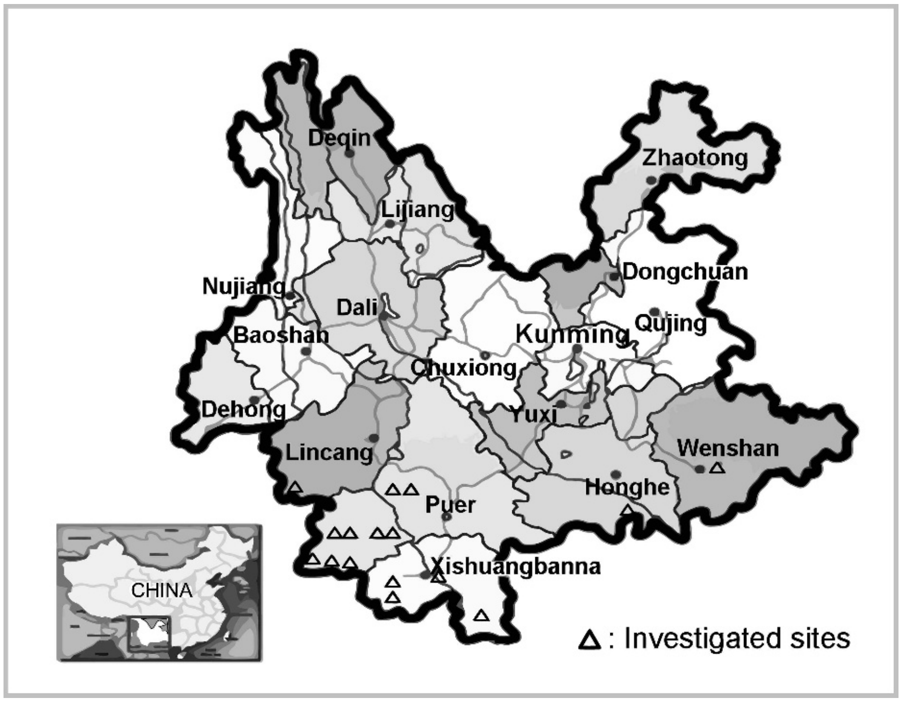
Introduction

Globally, extreme poverty continues to be a rural phenomenon (Anriquez and Stamoulis 2007). The incidence and severity of poverty are much higher in tropical and subtropical mountainous regions, which are often poorly connected with markets and are inhabited mainly by ethnic minorities (CPRC 2005, 2008). Poverty is recognized as a significant constraint to agricultural growth in upland areas because of poor people's need to concentrate resources on lower-value food crops to ensure subsistence security and their difficulties in mobilizing production and investment resources (Scherr 2000). Thus, people in mountainous areas tend to be poorer and more food insecure than in comparable flat areas (Templeton and Scherr 1999).

The production system tends to be largely subsistence oriented in the remote upland areas of Asia, where rice is a major staple. Farmers traditionally grow upland rice in a swidden system, which basically involves clearing the forest vegetation by burning and subsequently growing upland rice in cleared fields for 1 or 2 years. The land is then left fallow for 15–20 years or longer while new areas are opened up for rice cultivation by burning. Farmers eventually return to the same field, clear the fallow vegetation by burning, and grow rice again, thus completing the full cycle. But these traditional swidden systems based on long fallow periods are no longer viable because of rising population pressure. The fallow period has become shorter in response to increased pressure on the land, resulting in a loss of productivity over time (Maclean et al 2002; Linquist et al 2007). Overall, increasing pressure on the marginal uplands has contributed to environmental degradation as farmers reduce fallow periods even more and exploit fragile sloping land in the forest margins (Valentin et al 2008). In essence, the upland areas of Asia are caught in a vicious circle of low productivity, poverty, and environmental degradation (Asai et al 2009; Pandey 2009).

Improvements in technologies that raise the productivity of land and labor can be seen as an important entry point to break out of this vicious circle (IFAD 2001; Pandey 2009). However, improved technological options suitable to upland conditions have

FIGURE 1 Distribution of study samples in southern Yunnan, China. (Map by Wei Yang)



not been available until recently because of inadequate investments in agricultural research and development targeted to these poor areas. The situation has changed in more recent years, however, as national governments are increasingly recognizing the importance of upland development for poverty reduction and environmental protection (Pandey 2009).

In China, southern Yunnan is an important upland area where the problem of high incidence of poverty and environmental degradation has been a major concern of both the central and provincial governments. The development of improved technologies for upland rice production has been one of the key interventions aimed at improving the productivity and sustainability of upland systems in Yunnan (Fan 1991; Lin 1991; Huang and Scott 1996; Fan 2000). The Yunnan Academy of Agricultural Sciences developed and validated several improved upland rice varieties that outyield traditional varieties. The government of Yunnan has actively promoted these varieties over the last 15 years. In addition, the government promoted the construction of terraces in sloping fields to stabilize the land and reduce soil erosion that occurs when upland rice is grown in sloping fields. These technologies have now been promulgated in upland areas. However, no assessments of the patterns of technology adoption and its impacts have yet been conducted.

The objective of this paper is to assess the extent of the adoption of improved upland rice technologies, the yield and income gains resulting from technology adoption, and the impact of improved technologies on the area devoted to upland rice production.

Background information on Yunnan

Yunnan Province, which is located in southwestern China and has borders with Myanmar, Laos, and Vietnam, is home to around 46 million people. In 2003, the incidence of poverty in Yunnan was high (23.3%) compared with the national average (9.1%), and it accounts for 9.6% of the poor people in the country. Most of the poor people in Yunnan are clustered in upland regions and belong to ethnic minority groups (NDRC 2008).

Upland areas in Yunnan are characterized by rugged terrain, poor access to markets, environmental degradation, and high incidence of poverty. Upland rice is typically grown by farmers with inadequate resources in sloping fields under the shifting cultivation or swidden system for subsistence (Maclean et al 2002; Linquist et al 2007). In the shifting cultivation system of Yunnan, the fallowing cycle has become shorter over time in response to rising population pressure and government restrictions on the agricultural use of land (Pandey and Minh 1998; Asai et al 2009). As a result, upland rice yields have remained stagnant, and shifting cultivation has been identified as an important factor in human-induced land degradation (Baren and Oldeman 1998).

Since the mid-1980s, upland farmers, especially minorities, have been under pressure to abandon swidden agriculture in favor of cash cropping (Yin 2000; Xu 2006). The swidden system is giving way to permanent agricultural systems in response to increased population pressure, the availability of improved technologies, and

TABLE 1 Sampling scheme.

Prefecture	County	Village	No. of households
Honghe	Pingbian	Cangfang	30
Lincang	Cangyuan	Tuanjie	30
Simao	Lancang	Fotang	22
		Laomian	26
		Xiaohuilong	36
		Xiyun	35
	Menglian	Bansong	36
		Guangsan	32
		Hani	35
		Laomianzhai	34
		Mangnuo	23
Wenshan	Wenshan	Duobaiku	34
Xishuangbanna	Jinghong	Xinzhai	33
	Menghai	Laodong	36
		Zhongzhai	31
	Mengla	Panshan	35
Total			508

new policies that have discouraged the swidden system (Xu and Wilkes 2004; Weyerhaeuser et al 2005).

Data and methodology

A case study was used to assess the extent of adoption of improved rice technologies and to measure the impact on rice yield, income from rice, and area planted of upland rice. In addition to analyzing time-series data on rice yield and area at the prefecture level, we organized 2 household surveys to collect detailed farm-level information. These surveys were carried out in May and October 2005. Farm and household-level information was collected in the first survey (sample size 508), whereas the second intensive survey (sample size 182) focused on detailed plot-level information on crop yield, variety, and input use. The survey covered all 5 prefectures in southern Yunnan (Figure 1): Honghe, Lincang, Simao, Wenshan, and Xishuangbanna. The sampling scheme is summarized in Table 1.

The survey was based on a structured questionnaire that was developed in consultation with agricultural experts and was pretested before implementation. In addition to quantitative information on variables such as household characteristics, farm size, production, input use, and income, the survey included several open-ended questions to elicit farmers' perceptions regarding technology and the broader changes in their welfare. We relied on farmers' memories to obtain information on how technology adoption has altered their land-use patterns over time.

Key informant interviews that included local government officials, extension workers, upland agricultural researchers, and experienced farmers were also conducted to generate in-depth understanding of the patterns of technology adoption and recent changes in upland systems. Open-ended guide questions and checklists were used for these interviews.

Quantitative data were analyzed using various statistical tools, including the comparison of means, correlations, and multivariate regressions. Qualitative data were analyzed as frequencies, and descriptive analyses were also carried out.

Results and discussion

Most of the surveyed households produced both food crops (mainly upland rice and maize) and cash crops (for example, sugarcane, tea, and rubber). The average area per household allocated to the production of food and cash crops was 0.89 and 0.53 ha, respectively (Table 2). These areas vary quite substantially across locations.

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TABLE 2 Overview of survey results per sampled village.[a)]

County	Village	Average upland area (ha/hh)	Food crops area (ha/hh)	Cash crops area (ha/hh)	Irrigated rice area (ha/hh)	Family income (yuan/hh)	Selling cash crop (yuan/hh)	Income per capita (yuan)
Pingbian	Cangfang	0.77	0.68	0.00	0.04	3343	10	748
Cangyuan	Tuanjie	0.74	0.60	0.33	0.05	2688	1586	689
Lancang	Fotang	0.65	0.50	0.03	0.16	1500	32	359
	Laomian	1.02	0.71	0.24	0.12	2418	1275	540
	Xiaohuilong	2.05	1.64	0.50	0.03	8561	2889	1816
	Xiyun	1.86	1.63	0.68	0.06	21,456	7906	4820
Menglian	Bansong	0.71	0.69	0.28	0.08	2487	26	525
	Guangsan	2.72	1.92	0.81	0.20	11,554	7756	2772
	Hani	1.00	0.59	0.52	0.16	2992	1925	739
	Laomianzhai	1.73	1.19	0.57	0.16	6101	3743	1393
	Mangnuo	1.29	0.83	0.31	0.00	4648	2244	1022
Wenshan	Duobaiku	0.56	0.40	0.28	0.01	9430	7507	2023
Jinghong	Xinzhai	1.57	0.40	1.60	0.00	17,941	17,122	3368
Menghai	Laodong	0.66	0.78	0.12	0.15	2512	53	507
	Zhongzhai	1.08	0.37	0.79	0.01	4480	2365	927
Mengla	Panshan	5.79	1.03	1.31	0.14	8389	7059	1763
Total		1.52	0.89	0.53	0.09	7149	4096	1557

[a)] ha/hh, hectare per household.

Irrigated rice area is very limited in these mountainous regions, and most of the households do not have irrigated land. Average per capita income is estimated to be RMB 1557 (1 US$ = 8 RMB in 2004). This is only slightly above the poverty line of RMB 882, indicating that farmers are generally very poor. The estimated incidence of poverty using the state-level poverty line is 48%.

Patterns and rates of adoption

Two major component technologies promoted in the uplands of Yunnan were improved upland rice varieties and terraces. With these 2 technologies, 4 possible combinations of adoption patterns can be identified (Table 3). Most farmers adopted one of the component technologies (mostly improved varieties), although some adopted both. Overall, 32% of the farmers did not adopt either of the technology components, but 38% adopted both components. The remaining farmers adopted one or the other component only. In terms of area, the terrace plus improved variety combination accounted for 20% of the upland rice area.

Improved rice technologies suited to these southern Yunnan upland conditions were developed during the mid-1990s and were actively promoted (Tao et al 1996). As a result, adoption increased over time. The adoption rate, however, varied quite widely across villages and between the 2 technology components (improved varieties and terraces). For example, the adoption rate of improved varieties was very high in villages such as Hani, Laomian, and Xinzhai. On the other hand, villages such as Fotang, Panshan, and Zhongzhai had almost no adoption of improved varieties. The main reason for the nonadoption of improved varieties in those villages was the lack of technology promotion programs targeted to those villages. As a result, farmers simply did not have access to these improved varieties.

The adoption rate as measured by the percentage of farmers adopting improved varieties was found to be higher, in most cases, than the percentage of area using improved varieties (Table 4). This indicates that farmers grew improved rice varieties in part of their upland rice area only and continued growing traditional varieties in the remaining area. Full adoption of improved varieties has apparently not yet taken place. This may be due to the usual lags in the adoption process and/or the unsuitability of improved rice varieties promoted for all upland rice

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TABLE 3 Adoption patterns: percentage of households planting traditional and improved varieties, with percentage of area covered for each variety, with and without terraces.

		Slope	Terrace
Traditional varieties	Households (%)	32	12
	Area (%)	56	10
Improved varieties	Households (%)	18	38
	Area (%)	15	20

areas. Indeed, according to the interviews, local technicians perceive that it usually takes 3 years or more for farmers to accept a new technology for agriculture, and the poor may need an even longer time.

Overall, the adoption rate of terraces for rice production is much lower than the adoption rate of improved varieties. This is to be expected because terracing involves an initial construction cost whereas improved varieties can be adopted without any additional costs. Farmers who were not able to incur these additional construction costs or those who considered that their land does not need terracing did not adopt terraces.

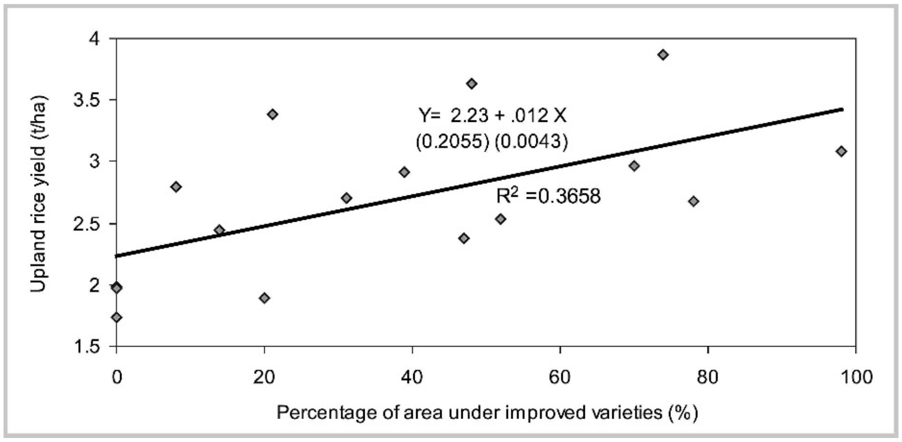
The plot-level data indicated that the average yield of improved upland rice varieties on terraces was 3.79 t/ha. This is 19% and 44% higher than the average yield of improved varieties on slopes (3.18 t/ha) and traditional varieties on slopes (2.63 t/ha). The adoption of improved varieties alone (without terracing) resulted in an increase in yield from 2.63 to 3.18 t/ha (a 21% increase). Thus, the yield effects of the adoption of terracing only or of the adoption of improved varieties only were similar. The yield increase was found to be substantially higher (44%) only when both components were adopted simultaneously. Using the aggregate village-level data,

TABLE 4 Adoption rates of improved technologies in relation to one another.[a)]

County	Village	Households adopting IV (%)	IV area to upland rice area (%)	Households adopting IV on terraces (%)	IV on terraces to upland rice area (%)
Pingbian	Cangfang	50	44	20	20
Cangyuan	Tuanjie	15	13	10	4
Lancang	Fotang	0	0	0	0
	Laomian	91	16	12	1
	Xiaohuilong	27	12	19	6
	Xiyun	38	27	23	20
Menglian	Bansong	76	43	44	16
	Guangsan	97	58	97	45
	Hani	100	82	77	66
	Laomianzhai	94	35	76	29
	Mangnuo	87	74	57	42
Wenshan	Duobaiku	59	53	32	26
Jinghong	Xinzhai	97	97	52	53
Menghai	Laodong	76	71	6	6
	Zhongzhai	0	0	0	0
Mengla	Panshan	0	0	0	0
Total		56	34	38	20

[a)] IV, improved varieties.

FIGURE 2 Relationship between upland rice yield and percentage of area under improved varieties.



average upland rice yield was found to be positively correlated with the proportionate area planted with improved varieties, indicating that the adoption of improved varieties has increased the yield of upland rice (Figure 2).

Influence of income

Did the increase in yield resulting from the adoption of improved technology translate into increased farmer income? This question can be answered by examining the net returns (gross returns net of cash input costs) associated with the use of traditional varieties and improved varieties. Compared with the use of traditional varieties on sloping land, the adoption of improved varieties resulted in an increase in net returns of 21%. When farmers adopted both improved varieties and terraces, the net returns improved by 42%. These increases in net returns are almost equal to the increases in proportionate yields, indicating that the cost increases associated with the adoption are small. (Note: These cost increases include only the variable input costs; the cost of terrace construction was not included because the information on this cost was not collected. In addition, construction of terraces is an investment that produces benefits over many years; hence, the initial investment cost needs to be amortized to annual values for such calculations.)

The survey data indicated that upland rice accounts for about 20% of the total income of households. Thus, the contribution of improved rice technologies toward total household income is estimated to be 4–8% because the increase in net income from rice for adopters of improved technology was in the range of 21–42% (depending on whether one or both components were adopted). Although this represents a relatively small proportionate increase in total income, farmers indicated that their overall food production and household-level food security improved with the adoption of these technologies. An increase in yield of 20–40% can indeed provide a substantial boost to household food security in these poor areas.

An additional impact of increases in rice yield resulting from the adoption of improved varieties is that some farmers were able to reduce their area planted with upland rice because they could meet their food needs from a smaller area. For a household that has a fixed requirement of rice for subsistence, a smaller area will be needed to produce the same amount as yield increases. The land released from rice production as a result could then be used for growing cash crops or be made available for other environmentally beneficial uses such as conversion to forest. Improved rice technologies could thus contribute indirectly to increases in farm income or to environmental protection. Field observations and key informant surveys indicated that both types of benefits were realized, although the quantification of the magnitude of those benefits is beyond the scope of this paper.

Influence on cultivated area

Time-series data on upland rice yield and area planted with upland rice from 2000 onward were available for Simao Prefecture. These data clearly indicate a negative association between upland rice yield and area (Figure 3). It is not possible to infer causality from these aggregate data because such changes in area may be associated with numerous factors, including the recent trend toward diversification out of upland rice to the production of income-generating cash crops.

Some evidence of causality can be inferred, however, by analyzing the household-level data. During the household surveys, we elicited from farmers their reasons for reducing their upland rice area. Quite a large percentage of farmers reduced this rice area simply to diversify out of rice to cash crops for income generation. However, when we considered only a smaller set of households that had adopted both improved varieties and terraces (and obtained a 44% increase in yield on average), an important reason they gave for reducing the

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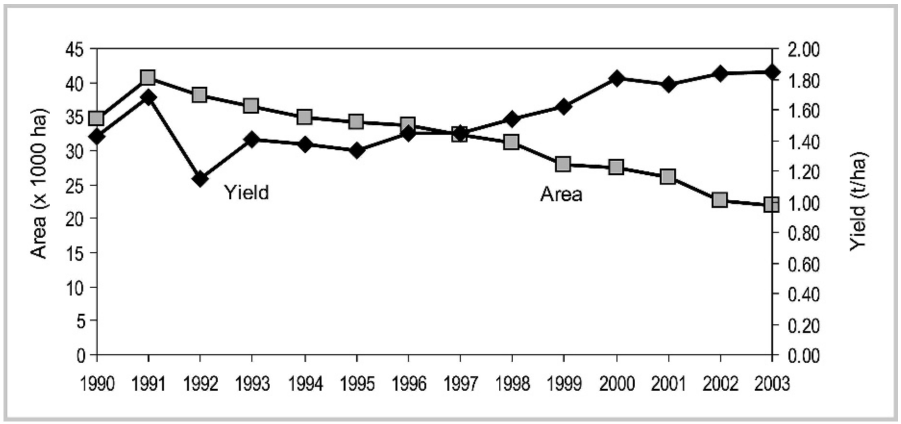
FIGURE 3 Upland rice area and yield change in Simao Prefecture.



upland rice area was that they could satisfy their food requirement from a smaller area as a result of the yield increase. Thus, there is evidence from the field surveys that an increase in the yield of a food crop can actually help reduce its area under cultivation and, in doing so, reduce the pressure on the fragile marginal land in the mountainous region.

Concluding remarks

The results of the study indicate that the upland rice production system in the mountainous areas of southern Yunnan is undergoing a transition from a low to higher productivity system, with the transition being induced by improved technologies and supportive policies. The technology combination consisting of improved rice varieties and terraces has not been fully adopted by all farmers or in all locations, but farmers who have adopted it were able to obtain higher yield and income from rice. In several cases, potential for positive environmental benefits was also indicated because higher yields have helped reduce the pressure to intensify the use of fragile uplands for food production. Thus, improved upland rice technologies have been effective as an entry point that has helped farmers break out of the vicious circle of low productivity–poverty–environmental degradation that characterizes the upland systems of Asia (Scherr 2000; Pandey 2009).

The changes in the upland agriculture of Yunnan are a part of the ongoing process of transformation that is not yet complete. Despite the increase in rice yield, improvements in food security, increases in income, and initial indications of positive environmental benefits, the problems of food insecurity and poverty persist. In addition, the pace of technology adoption and spread has not been uniform across households and communities. Obviously, more efforts are needed to help spread existing technologies and develop even better ones while providing adequate policy support to promote the sustainable use of uplands (Tao 1998). However, the fundamental lesson from this study is that an increase in agricultural productivity is critical for upland development, and improved technologies have a key role to play in this process. The relevance of individual technological components such as terracing or of a particular economic activity (such as upland rice, livestock, or forestry) is dependent on the specific context. Terracing may be a good way of improving land productivity in some locations but not in others. Similarly, improved technologies for upland rice production may serve as an effective entry point in some countries or locations, but livestock or cash crops may be more effective elsewhere. A proper mix and match of various components is needed depending on the context of upland agriculture in locations or countries that are at different levels of agricultural development.

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