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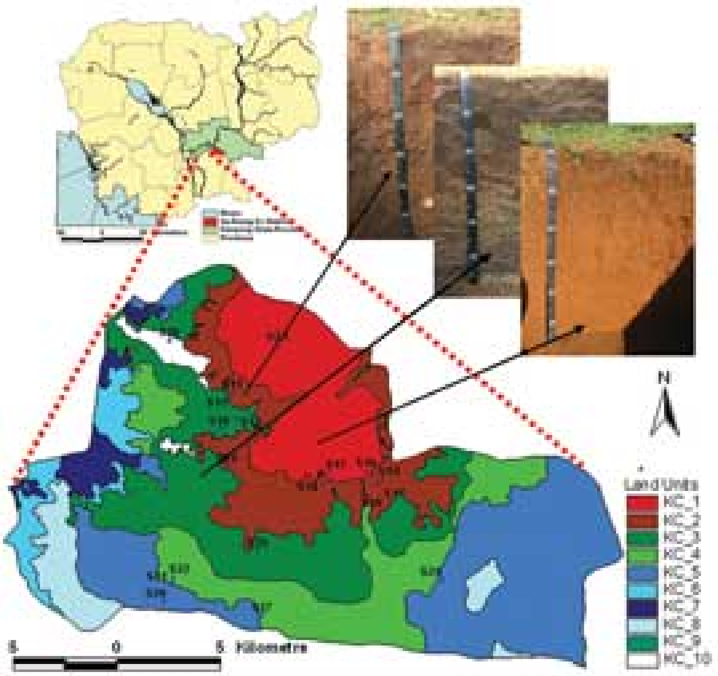

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EDITORIAL

The *Cambodian Journal of Agriculture* is proudly back and, just like before, it will be playing an important role to serve as the forum for all researchers and scientists in Cambodia, and elsewhere, to publish their findings, to share their knowledge and, to communicate more effectively with one another.

In the 21st century, more than ever before, the knowledge of people is expanding rapidly. But yet there is still lack of effective communication sharing that can help us to combat against hunger and to utterly eradicate poverty. It is a worldwide incapability syndrome but it is even more serious in the country like Cambodia where knowledge sharing is still very limited.

For this reason, bringing back the *Cambodian Journal of Agriculture* is especially important for every one to effectively share and disseminate the new knowledge to the development of the country and the social welfare of all. We are fully optimistic that the *Cambodian Journal of Agriculture* will provide significant contributions to promote better linkages, nationally and internationally, in the fields of research and education; and with its contributions we have all the confidences that agricultural productivity in the country will steadily increase. Eventually, hunger will be diminished and poverty will be ultimately eradicated. We therefore urge for your support and contribution.

Contributions of many who responsible to bring back this journal are well acknowledged. Amongst all, the support that the Australian Center for International Agricultural Research (ACIAR) has provided is highly appreciated.

Men Sarom
Editor

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CONTEMPORARY PRACTICES, CONSTRAINTS AND OPPORTUNITIES FOR NON-RICE CROPS IN CAMBODIA

Robert Farquharson, Chea Sareth, Chapho Somrangchittra, Richard W. Bell, Seng Vang, Wendy Vance, Robert Martin, Ung Sopheap and Fiona Scott*

អត្ថបទសង្ខេប

ប្រទេសកម្ពុជាបានឈានដល់ការធានាសន្តិសុខស្បៀងលើផលិតកម្មស្រូវ ដូចនេះអាចមានលទ្ធភាពក្នុងការបង្កើនការផ្តោតការយកចិត្តទុកដាក់ដើម្បីជំរុញផលិតកម្មដំណាំចំការផ្សេងៗ ដូចជាសណ្តែកសៀង សណ្តែកបាយ ពោត ល្ង សណ្តែកដី ម្មេស និងសណ្តែកអង្គុយ។ ក្នុងខណៈដែលដំណាំស្រូវនៅតែជាដំណាំចំបងនៅប្រទេសកម្ពុជា ផលិតកម្មនៃដំណាំចំការផ្សេងៗទៀត កំពុងមានការកើនឡើងយ៉ាងឆាប់រហ័ស និងមានសារសំខាន់ជាពិសេសដល់ការអភិវឌ្ឍន៏នៅក្នុងតំបន់ផ្សេងៗនៅក្នុងព្រះរាជាណាចក្រកម្ពុជា ដែលមិនមានលក្ខណៈអំណោយផលដល់វប្បកម្មដំណាំស្រូវ។ យើងធ្វើការវិភាគលើលទ្ធផលនៃការស្រាវជ្រាវពីសេដ្ឋកិច្ច-សង្គម ដែលបានធ្វើការសិក្សានៅក្នុងខេត្តបាត់ដំបង កំពង់ចាម និងតាកែវ ដើម្បីកំណត់ធនធានដែលអំណោយផល ដល់ការអនុវត្តគ្រប់គ្រង និងឧបសគ្គចំបងសំរាប់ការបង្កើនប្រព័ន្ធដំណាំចំការ។ ដំណាំទាំងអស់នេះភាគច្រើនជាដំណាំសំរាប់ប្តូរយករូបិយវត្ថុ។ ដូចនេះបញ្ហាសំខាន់ៗដែលត្រូវពិចារណាគឺការចំណេញ ការផ្លាស់ប្តូរបច្ចេកវិទ្យា និងការគ្រប់គ្រង ព្រមទាំងកត្តាគ្រួសារ និងសង្គម។ ការសិក្សាត្រូវបានធ្វើឡើងនៅស្រុកកំរៀង សំពៅលូន និងរតនៈមណ្ឌល នៅខេត្តបាត់ដំបង និងស្រុកចំការលើ ត្បូងឃ្មុំ និងអូររាំងឪ នៅខេត្តកំពង់ចាម ព្រមទាំងស្រុកត្រាំកក់នៅខេត្តតាកែវ។ នៅក្នុងការសិក្សានេះរួមមានកសិករចំនួន ១៨១គ្រួសារ នៅខេត្តបាត់ដំបង និងខេត្តកំពង់ចាម និង៥០គ្រួសារ នៅខេត្តតាកែវ។ លទ្ធផលនៃការសិក្សាបានបង្ហាញអោយឃើញថា គ្រួសារនីមួយៗ ជាទូទៅមានបុរសជាមេគ្រួសារដែលមានអាយុប្រហែល ៤៥ឆ្នាំ និងមានការសិក្សាក្នុងកំរិតបឋមសិក្សា។ ប៉ុន្តែការធ្វើសំភាសន៏ត្រូវបានធ្វើឡើងដោយចូលរួមពីសំណាក់ស្ត្រីច្រើនជាងបុរស។ ចំនួនសមាជិកគ្រួសារជាមធ្យមគឺពី ៥ ទៅ ៦នាក់ តែក្នុងនោះ ២ ទៅ ៣នាក់ មិនមែនជាកំលាំងពលកម្ម ម្យ៉ាងទៀតសមាជិកគ្រួសារមួយចំនួនតូចប៉ុណ្ណោះដែលបានទៅប្រកបរបរក្រៅពីការងារចំការ។ ផ្ទៃដីដាំដុះជាមធ្យមរបស់គ្រួសារនីមួយៗគឺប្រែប្រួលពី ២ ទៅ ៨ហ.ត។ ចំណែកឯទុន និងកត្តាផលិតកម្មកសិកម្មរួមមាន សត្វពាហនៈ រទេះ នង្គ័ល ព្រមទាំងត្រាក់ទ័រ ឬគោយន្ត។ ឧបសគ្គចំបងដែលមានឥទ្ធិពលដល់ការងារដាំដុះគឺ ទិន្នផលទាបខ្វះខាតចំណេះដឹងក្នុងការគ្រប់គ្រងកត្តាបំផ្លាញដែលបានកាត់បន្ថយប្រាក់ចំណេញ។ ភាពខ្សត់ជីជាតិនៃដី ការខ្វះខាតកំលាំងពលកម្ម ឧបករណ៏កសិកម្ម ការយល់ដឹងពីបច្ចេកវិទ្យា និងភាពប្រែប្រួលនៃអាកាសធាតុគឺជាឧបសគ្គចំបងផងដែរ។ លទ្ធផលបានបង្ហាញអោយឃើញថា ការផ្តោតលើការស្រាវជ្រាវអំពីបច្ចេកវិទ្យាថ្មី និងការគ្រប់គ្រងដែលមានឥទ្ធិពលដល់ទិន្នផល និងប្រាក់ចំណេញព្រមទាំងការបង្កើនការផ្សព្វផ្សាយបច្ចេកវិទ្យាដល់កសិករ គឺជាតំរូវការចាំបាច់ក្នុងបុព្វហេតុជំរុញបង្កើនផលិតកម្មដំណាំចំការនៅកម្ពុជា។

Abstract

Cambodia has achieved food security with respect to rice production and now has an opportunity to pay more attention to boosting production of upland crops such as maize (corn), soybean, sesame, mungbean, cassava, peanut and cowpea. While rice remains the main crop in Cambodia, the production of other crops is undergoing a rapid expansion and will be especially important for the development of those parts of the Kingdom unsuited to lowland rice. We present results from socio-economic surveys carried out in the Battambang, Kampong Cham and Takeo Provinces to identify available resources, management practices and key constraints for emerging upland cropping systems. These are mainly cash crops, so the important issues to consider are profitability, technological and management changes, and household and social issues. The surveys were conducted in the Districts of Kamrieng, Sampov Lun, Rotonak Mondol and Banan in Battambang Province, Chamkar Leu, Ou Reang Ov and Tbong Khmum in Kampong Cham Province, and Tramkak in Takeo Province. Sample sizes were 181 in Battambang and Kampong Cham, and 50 in Takeo. Generally farm families had a male head aged in the mid-40s, with 3 to 4 years of schooling. However, there are significant numbers of female farmers among survey respondents. Family size averaged 5 to 6 persons; with 2 to 3 being dependents and levels of off-farm work very low. Average farm size was 2 to 8 ha, and capital items owned included draft animals, ox carts and mouldboard ploughs, as well as tractors and disc ploughs in some areas. The main reasons given for not growing crops were poor yield performance, lack of knowledge (especially about insects), concerns about profitability, land/soil constraints, labour/equipment issues, and agronomic and climate risk (including drought). These results point to the need for focused research on new technologies and management as they affect crop yields and profits, and for increased extension of this information to Cambodian farmers.

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Keywords

Cambodia, socio-economic, survey, upland crops, research priority.

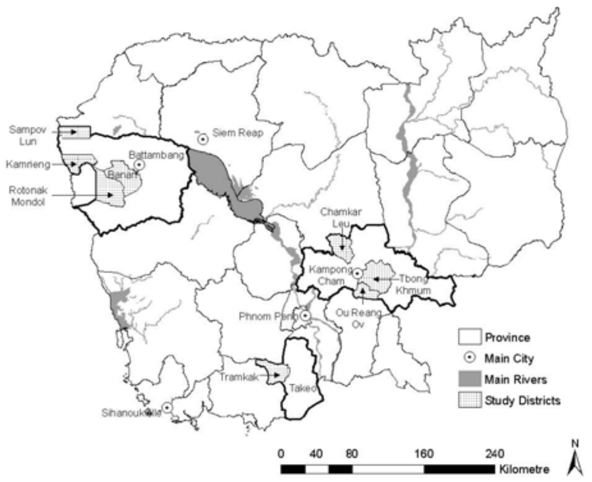

Figure 1. Administrative Provinces and study districts in Cambodia.

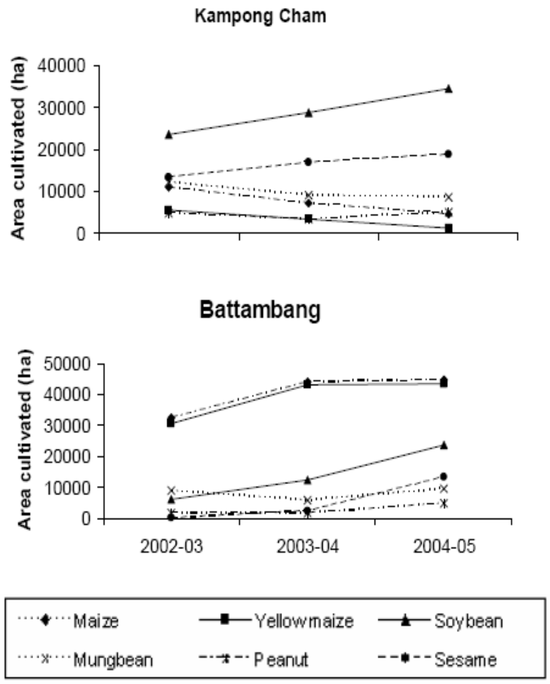

Figure 2. Recent trends in area harvested of major upland crops Source: MAFF (2003, 2004 and 2005)

Introduction

Poverty alleviation and food security are important issues for farmers in the upland cropping districts of Cambodia. In these areas non-rice (or upland) crops such as maize (corn), soybean, sesame, mungbean, cassava, and peanut are grown predominantly for cash sale, but the agronomic practices and levels of economic returns appear to be well below potential. The aim of the work reported here is to describe the farms and farm households in socio-economic terms and to identify issues that are important in developing a research agenda aiming to improve the productivity of upland cropping in Cambodia.

Due to recent socio-political history, Cambodia faces a number of human, social and economic challenges. Compared to other east-Asian and Pacific countries, Cambodia in 2004 had relatively low levels of per capita Gross National Income, literacy, birth life expectancy and access to improved water sources, and relatively high levels of infant mortality and child malnutrition, (see http://devdata.worldbank.org/AAG/khm_aag.pdf). Substantial areas of the countryside were sown with anti-personnel mines in the wars of the past 40 years and mine clearing operations continue. In population geography terms, there is a relatively large proportion of the population living in the countryside and involved in farming enterprises (19% urban population compared to 41% for east-Asian and Pacific countries (see above website)). Hence for poverty alleviation, investigations aimed at improving the conditions of Cambodian farmers are crucial. Cambodia has regained self-sufficiency in rice production since the mid-1990s and there is now a greater focus on non-rice crops through research and development activities (May 2000).

The work reported here is from three surveys conducted within two projects aimed at assessing land suitability and conducting farming systems research for crop diversification in Cambodia and Australia. In this paper, the results of these surveys provide an overview of the human and natural resources available for crop production, the socio-economic characteristics of farm families, and the current management practices used in some upland areas of Cambodia. The surveys uncovered issues that should form the core of the Research and Development (R&D) agenda for upland crops. These issues include mitigating yield losses due to drought and insects, and improving technical knowledge so farmers are better able to assess soil, climate, labour and profitability issues. The results also emphasise the need for an active extension program.

Crop production and research in Cambodia

In Cambodia rice is the most important crop grown as a human food source. In contrast, production of upland crops is less significant. Table 1 shows the areas harvested of rice and the major upland crops (maize, yellow maize, soybean, sesame and mungbean) in 2004-05 (Ministry of Agriculture, Forestry and Fisheries (MAFF), 2005).

Table 1. Crop areas in Cambodia, 2004-05

Crop	Area harvested (ha)
Rice – wet season	1,815,619
Rice – dry season	293,221
Subsidiary crops (wet season)	
- maize	71,380
- yellow maize	54,886
- mungbean	28,605
- cassava	21,380
- vegetable	20,361
- sweet potato	5,166
Industrial crops (wet season)	
- soybean	83,499
- sesame	56,814
- peanut	13,849
- sugar cane	5,133
- jute	583
- tobacco	50

Source: MAFF (2005)

Agricultural R&D has had a relatively short history in Cambodia, dating from the mid 1980s (Mak *et al*. 2000). Activities have focussed on rice for the purpose of food security. The establishment of the Cambodian Agricultural Research and Development Institute (CARDI) and associated farming systems research programs has been the most recent phase of that process (Men *et al.* 2000). Evaluations of technologies developed for dry season rice production (Vijghen 1997) and an economic impact assessment of collaboration between research and extension in the Cambodian rice sector (Young and Raab 2001) have shown the success of these R&D activities.

The alleviation of poverty for upland farmers in Cambodia depends primarily on producing more of selected crops in an efficient fashion, so that profits are improved. For all farmers there is a gap between potential and actual crop yields. Dillon and Hardaker (1993) conceptualised the yield gap between unconstrained potential yields and the best on-farm yields in a country or region as due to non-transferable technology and environmental differences (e.g. amount of solar radiation). The factors that further constrain actual farm yield below potential yield are important priorities for research; these include biological, physical-chemical and socio-economic constraints. For example, soil infertility may be a physical-chemical constraint to crop production, with the associated socio-economic constraint being a lack of credit for farmers to buy fertilizer. In the present study we focus on constraints that can be alleviated in rural Cambodia by R&D to assist upland farmers.

As will be shown, the vast majority of Cambodian farmers have access to relatively small areas of land for agricultural production, although farm size is somewhat higher than the densely settled areas of Vietnam, Indonesia and China (Pandey 2001). McConnell and Dillon (1997) listed some of the characteristics of small farms in Asia. These include managers lacking market power, the close relationship between the farm system and the farm household (so that the farm is not purely a business and the presence of non-profit activities may lead to trade-offs in management), the factors of production are often not separately supplied (so that a farmer may have difficulty in allocating priority to management versus labour), and the managers of these enterprises have generally not had the opportunity for formal education and training to develop their management skills and capacity. This general deficiency in management may be compounded by their lack of access to information and credit, and the lack of influence by farmers in setting agricultural policies and a research agenda.

What then can be done in this situation? For McConnell and Dillon (1997), the answer lies in the hands of both farmers and governments. For farmers, the challenge is to incrementally improve their own viability through observation and trials of new methods and technologies. The Government's role includes providing appropriate public infrastructure (both physical and institutional), improving liaison with farmer groups, provision of appropriate education facilities and opportunities, and provision of information through public research and extension agencies. It is at the latter objective that this work is aimed.

Materials and methods

Developing a picture of farms, families and crop management

Social and economic characteristics of farm families, and evidence of farm management and technologies used, provide an important context for upland crop improvement activities and a starting point for the development of R&D priorities. Surveys of farmers were conducted to obtain this information.

Provinces and districts surveyed

The Provinces and Districts surveyed were selected to provide a representation of upland areas where cropping practices and patterns showed differences in agronomy and crop species, and where the farming systems had been established for different periods of time. The District selection was also influenced by the perceived capabilities and likely collaboration of the extension services with farm research projects. The results of these surveys are interpreted for the Districts studied, but no wider implications of these results can be made for other upland areas.

In a study conducted in 2003 and 2004 assessing land suitability for upland cropping (Survey 1), we surveyed Districts in three Provinces – Ou Reang Ov District in Kampong Cham Province, Tramkak District in Takeo Province, and Banan District in Battambang Province. The other surveys conducted in 2004 were associated with a study of farming systems for upland crop diversification. A socio-economic survey (Survey 2) was conducted in the Districts of Kamrieng, Sampov Lun and Rotonak Mondol in Battambang Province and the Districts of Chamkar Leu and Tbong Khmum in Kampong Cham Province. A crop-check survey (CropCheck) of farmers in each of the Kampong Cham and Battambang Provinces was also conducted to investigate existing crop management practices. CropCheck (Lacy 1998) is a system of recording information from farmers' crops at 4 to 6 stages during the growth cycle to enable a comparative analysis of results and identification of yield-loss factors. A map showing the surveyed Districts within each Province in Cambodia is in Figure 1.

Representing a target group

The objective of the two projects is to investigate and promote improved crop technologies for a target group, which is the upland farm population in the Districts shown in Figure 1. In the process of conducting these surveys the aim is to derive information to describe this target population.

Anderson and Hardaker (1979) outlined three main approaches to this process. The first is a case study where one farm may be used based on its suitability for analysis as much as for its representativeness. Implicitly this approach will be justified because 'from intensive study of one or a few cases, insights of general or widespread relevance to the population of farms may be gained' (Anderson and Hardaker 1979, p.4). Second, a representative farm may be analysed if the farm (real or hypothetical) is chosen to 'represent' the population in some way. The problem with this approach is how to define the representativeness so that general solutions for the target group can be drawn. The final broad approach is to conduct a sample survey from real farms in the target population and to undertake the analysis of each of the sample farms. Statistically-derived 'raising factors' can be applied to each sample farm so that an estimate of the impact of the technology on the whole population can be made. However, the use of sampling methods will quite likely require a large number of sample farms to properly represent the population and this has implications for the amount and cost of data collection and analysis.

In this paper the survey results are interpreted as a case study for each group of farmers. The case study research strategy allows 'how' and 'why' questions to be answered where control over behavioural events is not required, while maintaining a focus on contemporary issues (Yin 1988). The interpretation as a case study is because, due to resource constraints, the sampling percentage of farms was quite low, and it was not possible to improve sampling efficiency by stratifying the sample according to farm size or another relevant characteristic. The standard errors associated with key estimates from Survey 2 were relatively large and this has implications for making valid statistical comparisons for the whole farm population. Also the surveyed farmers were relatively concentrated in a geographical sense. Hence the results are interpreted and presented as case studies, which still provide valuable information about farmers within the district, but without implying any farmer population representation.

Data collection methods

The data collection was conducted through the development and use of detailed questionnaires. Survey 1 was conducted in 2003 and 2004 to establish a baseline of current crop diversification and most common cropping practices. A pre-survey pilot test was conducted to check the questionnaire and understand the general background of the locations. The Survey 2 questionnaire was initially adapted from a Cambodian rice survey (Chea 2002), and a pilot test of a small number of farmers was conducted. The questionnaire was then revised for the full survey conducted in 2004. In both cases the interview team first approached commune and village leaders to obtain permission and cooperation for the farmer interviews. After this the farmers were chosen at random. The numbers of farmers interviewed was determined by the time and resources available to the interviewers, including proximity to main roads. The CropCheck survey was based on a questionnaire used for similar surveys in Australia. It was conducted by choosing 10 farmers in each province who grew each crop. Sixty surveys were completed in Kampong Cham and 40 were completed in Battambang. CropCheck recorded details of cropping history and crop rotations, land preparation and seeding operations, fertilizer and pesticide use, yield estimates and farmers' assessment of yield-loss factors.

Survey sample numbers

Sample numbers for the three surveys are shown in Table 2. A total of 181, 181 and 50 farmers were interviewed in the Kampong Cham, Battambang and Takeo Provinces, respectively. These were less than 1% of the farm family population in each District. Total population figures in 2004-05 were 1,720,589 (Kampong Cham Province), 1,009,955 (Battambang Province), 915,272 (Takeo province) and 13,327,946 (Cambodia) (MAFF 2005).

Table 2. Sample, farm households and total population in surveyed districts

Survey/ Year	Province	District	Sample	Farm Families (a)	Total Population (b)
1	Kampong Cham	Ou Reang Ov	50	18,388	95,227
2003,	Takeo	Tramkak	50	31,127	159,429
2004	Battambang	Banan	50	17,222	90,239
		Total	150	66,737	344,895
2	Kampong Cham	Chamkar Leu	47	22,961	122,010
2004		Tbong Khmum	24	37,928	184,202
		Total	71	60,889	306,212
	Battambang	Kamrieng	36	7,478	35,482
		Sampov Lun	24	4,489	20,313
		Rotonak Mondol	31	6,427	32,895
		Total	91	18,394	88,690
Crop	Kampong Cham	10 farmers per	60		
Check	Battambang	crop per	40		
		province			
2004		Total	100		

Source: (a) Jeff Milne and Lex Freeman (Cambodian Australian Agricultural Extension Project), (b) MAFF (2005)

Results

Household data

Tables 3 and 4 contain details of households responding to Surveys 1 and 2. The average age of the household head was consistently in the mid 40s, with the percentage of male heads of household or survey respondents between 70 and 80 in Survey 1 and between 50 and 80 in Survey 2. Average family size was consistently 5 to 6 persons, with 2 to 3 being dependents (Survey 2). The percent of income from non-farm activity in Survey 1 varied up to 60 or 70 %, but the average numbers of family members who worked off farm was very low or zero in Survey 2. Education levels for the head of farm or survey respondent were relatively low with primary school the main level achieved in Survey 1, and only 3 to 4 years of schooling on average in Survey 2.

Table 3. Household details for survey 1

	Unit	Banan	Ou Reang Ov	Tramkak
Head of farm or survey respondent				
Average age	yrs	46.1	41.9	44.2
Percent male	%	74	76	78
Average family size	no.	5.7	5.5	5.1
Percent farms with income from farm source	%	98	66	80
Percent of income from non-farm activity	% range	5-70	2-60	10-60
Schooling of head of farm or survey respondent				
Never went to school	%	30	10	10
Primary school	%	42	68	56
High school	%	24	18	32
Training course	%	4	2	0
No response	%	0	2	2

Table 4. Household details for survey 2

	Unit	Sampov Lun	Kamrieng	Rotonak Mondol	Chamkar Leu	Tbong Khmum
Survey respondent						
Average Age	yrs	43.7	46.1	46.4	45.2	43.5
Percent male	%	71	69	55	72	79
Family size	no.	5.9	6.6	5.4	5.2	5.2
Dependents	no.	2.8	3.2	2.5	2.0	2.5
Work off farm	no.	0	0	0.2	0.3	0
Schooling of survey respondent						
Years schooling	yrs	3.3	3.7	3.8	3.4	4.0

Farm areas and capital items

Average farm areas are shown in Table 5. In general, average farm areas were in the order of 2 to 8 ha. Rice was still grown on many farms in these districts, and there is some evidence of land being rented between farmers. These farm sizes are larger than the rice farms in one village surveyed by Chea (2002), who reported areas of 0.2 to 2 ha per family. The districts of Sampov Lun and Kamrieng were more recently settled and farm size tend to be larger.

Table 5. Average farm areas

Survey 1		**Banan**	**Ou Reang Ov**	**Tramkak**	
Total farm size (ha)		3.5	2.2	2.2	
Rice area (ha)		2.1	0.9	1.4	
Field crop area (ha)		1.4	1.3	0.8	
Fields rented (% farmers)		2.5	3.5	0	
Survey 2	**Sampov Lun**	**Kamrieng**	**Rotonak Mondol**	**Chamkar Leu**	**Tbong Khmum**
Land owned (ha)	9.5	5.9	3.6	3.6	1.8
Rented out (ha)	2.0	0.1	0.1	0.1	0.2
Rented in (ha)	0.0	0.1	0.4	0.6	2.8
Area operated (ha)	7.5	5.9	3.9	4.0	4.4

Capital items owned are shown in Table 6. Power for farm operations is provided by draft animals (cattle or buffalo) or tractors (smaller hand-steered or larger conventional 4-wheeled). Draft animals and ox carts are the main source of power and transport present in each district. Large tractors were reported in Sampov Lun and Tbong Khmum, with hand tractors in other areas. Disc and mouldboard ploughs were present in the districts with tractors and draft animals, respectively. Hand-held spray units were owned by a substantial number of farmers, and pumps, tubewells and threshers were owned in only some districts. Compared to most other parts of Cambodia, farming is more mechanised in the north-west districts of Battambang. There were 737, 205 and 154 private tractors in Battambang, Kampong Cham and Takeo provinces in 2002, respectively, with 165,226, 70,427 and 47,204 ha of ploughed area, respectively (MAFF 2003).

Table 6. Capital items owned

Survey 1	**Unit** [(a)]		**Banan**	**Ou Reang**	**Tramkak**	
Cattle	average		4.1	3.3	3.8	
Buffalo	average		0	0.2	0.5	
Tractor	% with		54	36	0	
Survey 2		**Sampov Lun**	**Kamrieng**	**Rotonak Mondol**	**Chamkar Leu**	**Tbong Khmum**
Draft animal	% with	21	17	81	36	50
	average	3.4	4.3	2.7	2.4	3.1
Tractor	% with	25	6	6		21
Disc plough	% with	21		3		
Mouldboard Plough	% with	4		39	19	21
Spray unit	% with	58	50	35	34	39
Pump	% with			10	6	
Tube well	% with	4	3	16	6	
Ox cart	% with	17	6	55	26	25
Thresher	% with	8			4	17
Other	% with	13	8		26	8

(a). Units are percent of sample with the item (see Table 2 for numbers of respondents per district) and average number of items per farm with the item

Debt and borrowing

The results from questions relating to debt and borrowing in Survey 2 are shown in Table 7. They relate to crop loans (size and term) and all loans categorised by source and term of the loan. An initial point to make is that 44% of the total sample reported having crop loans and 61% having loans of any type. A higher percentage of farmers surveyed reported crop loans in Sampov Lun (63%) and Kamrieng (72%) than in the other districts (around 30%). In the north-west districts Thai traders may have an influence on loans through financing the cost of hybrid maize seed and other crop inputs not normally used in other areas.

For all loans 79% and 97% reporting loans in Sampov Lun and Kamrieng respectively, and 45%, 51% and 29% in Rotonak Mondol, Chamkar Leu and Tbong Khmum, respectively. Farmers with larger farm areas (Sampov Lun and Kamrieng) appeared to have more and larger loans. Crop loans were generally short term (averaging less than 12 months). Evidence of interest rates paid by farmers was found to be unreliable from this survey. Other information of the interest rates paid by Cambodian upland farmers indicates that they pay a minimum of 3% per month (Farquharson *et al*. 2006), even for concessional finance from non-government organisations. Information collected for all loans indicates that those borrowing often did so each year, but that the amount generally differed. There seemed to be some choice of lenders, i.e. borrowers did not always use the same lender. Interest rates seemed to vary both within a season and between years.

Table 7. Loans and borrowing, average per farm with loans, Survey 2

	Unit [(a)]	Sampov Lun	Kamrieng	Rotonak Mondol	Chamkar Leu	Tbong Khmum
Crop loans						
Prioportion of sample	%	63	72	32	30	29
Size of loan	‘000 R	3403	1755	670	390	400
Average Term	mths	11	10	8	6	6
All loans						
Proportion of sample	%	79	97	45	51	29
Each year?	% yes	46	66	36	50	71
Same amount?	% yes	13	26	14	13	14
Same lender?	% yes	29	29	43	45	71
Rates vary seasonally?	% yes	50	43	14	27	0
Rates vary annually?	% yes	17	49	0	18	0

(a) R – Riel, 4000 R approximately to US$1

Crops grown and planting intentions

Information on crops grown and planting intentions is shown in Table 8. Historically farmers in Banan, Ou Reang Ov and Tramkak have grown a range of field crops; however in 2004 a restricted range of crops was planned. For Survey 1 districts, the most popular crops grown in 2004 were sesame and peanut in Ou Reang Ov; peanut, mungbean and maize in Tramkak; and mungbean and chilli in Banan. From Survey 2 results, crop planting intentions for 2004 were soybean and mungbean in all districts, maize in all districts except Tbong Khmum, peanut in Kamrieng and Rotonak Mondol, sesame in Kamrieng, Tbong Khmum, Rotonak Mondol and Sampov Lun, and cowpea only in Chamkar Leu.

Table 8. Crops grown and planting intentions

Survey 1		Ou Reang Ov	Tramkak	Banan	
Field crops grown 2004 (percent of sample)					
Soybean		9	0	6	
Sesame		20	0	2	
Peanut		18	46	6	
Maize		5	26	6	
Mungbean		4	32	48	
Chilli		0	2	38	
Survey 2	**Sampov Lun**	**Kamrieng**	**Rotonak Mondol**	**Chamkar Leu**	**Tbong Khmum**
Planting intentions in 2004 (percent of sample)					
Rice	8	78	68	32	63
Maize	96	94	65	28	8
Soybean	100	92	71	96	96
Mungbean	58	78	71	70	87
Peanut	8	22	32	11	0
Sesame	25	89	35	17	54
Cowpea	0	19	0	64	4

Crop production and prices

Crop figures (yield, area and price) within each district are shown in Table 9. The reported crop yields appear to be consistent over the surveys. The patterns emerging are for maize yields being generally higher (2.6 to 5 t/ha) than the soybean yields (1.0 to 1.6 t/ha) and mungbean yields (0.1 to 0.7 t/ha). Maize prices varied from 300 to 400 Riel (R)/kg in each district. Generally no maize seed was kept for the next year's crop. Yields of the other crops were generally low – 0.3 to 0.4 t/ha for cowpea, 0.7 to 1.7 t/ha for peanut, and 0.3 to 0.7 t/ha for sesame. Prices for these three crops ranged from 1100 to 2000 R/kg, with one higher average peanut price (2600 R/kg in Rotonak Mondol).

Table 9. Average crop yield, area sown and price received by district

Survey 1Crop yields	**Unit**		**Ou Reang Ov**	**Tramkak**	**Banan**	
Maize	t/ha		0.3	0.1	0.3	
Soybean	t/ha		1.0	-	1.3	
Sesame	t/ha		0.4	-	0.5	
Peanut	t/ha		1.0	0.2	1.6	
Mungbean	t/ha		0.3	0.1	0.4	
Chilli	t/ha		-	0.2	1.8	
Survey 2Crop/item		**Sampov Lun**	**Kamrieng**	**Rotonak Mondol**	**Chamkar Leu**	**Tbong Khmum**
Maize						
Area sown	ha	6.3	4.2	1.4	1.2	-
Yield	t/ha	4.8	3.7	2.6	5.0	-
Price	R/kg	317	295	330	418	-
Soybean						
Area sown	ha	3.8	0.9	1.7	1.9	3.1
Yield	t/ha	1.0	1.2	1.0	1.2	1.2
Price	R/kg	1072	1114	941	1028	1063
Mungbean						
Area sown	ha	1.4	1.2	0.9	1.4	2.9
Yield	t/ha	0.7	0.5	0.3	0.2	0.2
Price	R/kg	1204	1332	1043	1089	1119
Peanut						
Area sown	ha	-	0.6	0.7	1.0	-
Yield	t/ha	-	0.7	1.7	1.0	-
Price	R/kg	-	1907	2667	1200	-
Sesame						
Area sown	ha	-	1.3	1.4	1.2	1.4
Yield	t/ha	-	0.3	0.4	0.5	0.7
Price	R/kg	-	1974	1275	1565	1420
Cowpea						
Area sown	ha	-	1.2	-	1.0	-
Yield	t/ha	-	0.3	-	0.4	-
Price	R/kg	-	1188	-	1137	-

As a comparison with the case study results, agricultural statistics for 2004-05 from the Cambodian Government (MAFF 2005) are presented in Table 10. Area, production and yield information for particular crop and province combinations are shown. In comparison with these statistics, the average yields in 2004 from Table 9 appear to be higher in Battambang and Kampong Cham for maize, and generally equivalent for other crops.

Trends in areas harvested of some upland crops from 2002-03 to 2004-05 (MAFF 2003, 2004, 2005) in Kampong Cham and Battambang Provinces are shown in Figure 2. Rising trends over this period are apparent for soybean and maize in Kampong Cham and for maize, yellow maize, soybean and sesame in Battambang.

Table 10. Selected Cambodian wet season crop statistics 2004-2005

Crop	**Province**	**Harvested area**	**Yield**	**Production**
		ha	**tonne/ha**	**tonnes**
Maize	Kampong Cham	4,628	1.22	5,657
	Battambang	35,609	4.32	153,917
Maize	Kampong Cham	1141	1.22	1396
(yellow)	Battambang	34,264	4.39	150,409
Soybean	Kampong Cham	34,490	1.2	41,388
	Battambang	23,545	1.38	32,430
Mungbean	Kampong Cham	8,514	1.11	9,451
	Battambang	8,810	0.85	7,490
Peanut	Kampong Cham	4,985	0.74	3,676
	Battambang	4,827	1.57	7,598
Sesame	Kampong Cham	17,733	1	18,733
	Battambang	7,313	1.05	7,668

Source: MAFF (2005)

In Survey 1, respondents were asked to rank their income from field crops and recent changes in their living standards (Table 11). Most respondents reported that their living standards had been either not changed or decreased in the last 12 months, but that returns to field crops were good or acceptable. This implies that some other change (eg in off-farm work) has been occurring.

Table 11. The rank of income from field crops and the change to living standards in the previous 12 months, Survey 1

	Ou Reang Ov	Tramkak	Banan
Rating of change to living standards in last 12 months (percent)			
Increased	4	14	10
Unchanged	38	44	32
Decreased	48	32	34
Very decreased	10	10	24
Rating of income from field crops (percent)			
Very good	0	0	0
Good	64	44	48
Acceptable	34	56	48
Break even	2	0	4
Uneconomic loss	0	0	0

Reasons for not growing crops

In Survey 1, the main factors impeding crop production were yield performance, drought, insect problems, small land area and low market demand (Table 12). The major reasons for not growing crops in Survey 2 were, in order of importance: lack of knowledge; concerns about profitability; land/soil constraints; labour/equipment issues; and agronomic and climate risk.

Table 12. Major factors impeding production of crops and reasons for not growing upland crops in selected districts of Cambodia

Survey 1	Maize	Soy bean	Mungbean	Peanut	Chilli	Sesame
Factors impeding crop production						
Low yield	1	1	1	1	2	1
Drought	2	2	2	4	3	2
Small area		4				
Seed cost				4		4
Seed shortage		4				4
Insect problems	4		2	2		3
High labour cost				3		
Soil infertility	3		3			
Unsuitable time			4			
Management					4	
No irrigation					1	
Low market demand	4				4	
Not popular crop		3				
Survey 2: 2003	**Maize**	**Soy bean**	**Mungbean**	**Peanut**	**Cowpea**	**Sesame**
Reasons for not growing crops						
Marketing 3 Profitability	2		2	1	2	
Seed costs				2		
Capital constraint						
Labour/equipment		2	4	4		3
Agronomic risks			1		4	3
Lack of varieties						
Climate/drought		1	3			
Agronomy constraint						
Theft	1					
Lack of knowledge	1	3			1	1
Land/soil constraints	3	4		3		2

1 = highest, 4 = lowest

Detailed crop information

Crop activity information for Kampong Cham

In Table 13 the CropCheck data are presented for Kampong Cham Province. Soils were generally clay/loams of red, grey and black colours with moderate fertility and structure. Land preparation varied from 2 to 4 workings but fertilizer was used on only one farm of the 60. No pesticides or chemicals were used, and legume seeds were not treated or inoculated. Marketing grades of crops were assessed by the farmers as good (80 to 90%), all crops were sold privately for cash, but some maize, mungbean and cowpea seeds were kept for family use. Prices received for red maize were lower (around 500 R/kg) than the other crops (1300 to 3000 R/kg). Crop yields compared to the Provincial averages for 2004-05 (Table 10) were higher for maize, soybean and peanut but lower for mungbean and sesame.

Table 13. CropCheck data, 10 farms per crop, Kampong Cham Province

Reason	Maize	Soy bean	Mung bean	Peanut	Cowpea	Sesame
Soil – texture	C/L	C/L	C/L	C	C/L	C/L
-colour	Gr/R	R/B	R/Gr	R	R/B	R
-structure	M	M	M	M	M	M
-N fertility	M	M	M	M	M	M
No. tillage operations	3	3.3	3.9	2	3.2	3
Fertilizer (# farms)	1	0	0	0	0	0
Pesticides (# farms)	0	0	0	0	0	0
Seed - inoculated	0	0	0	0	0	0
-treated	0	0	0	0	0	0
Chemicals used	0	0	0	0	0	0
Recorded annual rainfall (mm)	908	1102	908	1067	908	1068
Marketing – grade %	93	83	90	G	83	G
-% sold	62	100	83	100	64	100
-% family use	38	0	17	0	36	0
-% sold for cash	100	100	100	100	100	100
-selling option	Pr	Pr	Pr	Pr	Pr	Pr
Yield (t/ha)	2.2	1.5	0.8	0.9	0.7	0.7
Price (R/kg)	505	1309	1285	1450	1415	2890

C Clay, L Loam, S Sand, G Good, M Moderate, P Poor, R Red, Gr Grey, B Black, Br Brown, Pr Private

Crop activity information for Battambang

In Table 14 the CropCheck data for four crops are presented for Battambang Province. Soils were clay/loams of red, brown, grey and black colours with moderate to good structure and moderate fertility. Land preparation varied from 3 to 4 workings and fertilizer was used on eight farms of the 40. Pesticides were used on all farms, but again legume seeds were not treated or inoculated. Marketable grades of crops ranged from 83 to 87% of total production. All crops were privately sold for cash, and only a small amount of mungbean was kept for family use. Prices received for maize were lower (around 280 R/kg) than the other crops (880 to 1720 R/kg). Crop yields compared to the Provincial averages for 2004-05 (Table 10) were lower for all crops.

Table 14. CropCheck data, 10 farms per crop, Battambang Province

Reason	Maize	Mung bean	Peanut	Sesame
Soil – texture	C/L	C/L	C/L	C/L
- colour	R/Gr/B	R/Br/Gr	R/Br/Gr/B	Br
- structure	M	M	M/G	G/M
- N fertility	H/M	M	M	M
No. tillage operations	3.8	3.7	3.3	3
Fertilizer (# farms)	2	3	2	1
Pesticides (# farms)	10	10	10	10
Seed - inoculated	N	N	N	N
- treated	N	N	N	N
Chemicals used	0	0	0	0
Recorded annual rainfall (mm)	908	908	1102	1057
Marketing – grade %	83	85	83	87
- % sold	100	96	100	100
-% family use	00	4	0	0
- % sold for cash	100	100	100	100
- selling option	Pr	Pr	Pr	Pr
Yield (t/ha)	3.5	0.5	0.7	0.4
Price (R/kg)	282	1300	881	1720

Land slope and erosion

Survey 1 collected information on the slope of land and evidence of erosion (see Table 15). Generally fields were reported to be flat or have very gentle slope (<5%). Some fields in Banan were of gentle slope (5-10%) and some in Ou Reang Ov were of gentle or moderate slope (up to 30%). Thirty-two percent of fields in Tramkak were assessed to be prone to erosion, but most land in other districts was considered not to be prone to erosion. Most land was considered by farmers to have never been eroded in the past 5 years, apart from some fields in Tramkak.

Table 15. Slope of land and evidence of erosion, Survey 1

	Ou Reang Ov	Tramkak	Banan
		Percentage of farms	
Slope of fields			
Flat (<2%)	24	70	40
Very gentle (2-5%)	34	30	42
Gentle (5-10%)	32	0	18
Moderate (10-30%)	10	0	0
Steep (>30%)	0	0	0
Soil erosion condition			
Prone to erosion[a]	2	32	6
Currently eroded[b]	0	10	4
Previous erosion – [b]	98	74	94
-[c]	0	0	2
-[d]	0	8	2
-[e]	2	18	2

(a). % yes, **(b).** zero years in 5, **(c).** 1 year in 5, **(d).** 2 years in 5, **(e)**. 2 years in 5

Droughts and floods

Fields were assessed in Survey 1 for drought and flood prevalence based on farmers' reporting (see Table 16). Droughts are more frequent than floods in these upland districts of Cambodia. Between 1 and 2 years in 10 were classified by farmers as severe drought (>50% yield loss), with another 1 to 2 years in 10 being moderately drought affected (15-50% yield loss). Another 1 to 3 years in 10 were affected by slight drought (<15% yield loss) so that a total of 4 to 7 years in 10 were estimated to limit crop production by drought of varying severity. Floods were less of a problem, with less than 1 year in 10 experienced severe floods (>50% yield loss) and up to 3 years in 10 being affected by floods of some size. These results emphasise the importance of climate risk (dry periods or mini droughts in the early wet season) in limiting crop yields for Cambodian farmers.

Table 16. Drought and flood experiences over last 10 years, Survey 1

	Ou Reang Ov	Tramkak	Banan
		Average number of years in 10	
Severe drought[a]	1.8	1.2	1.8
Moderate drought[b]	1.9	0.9	1.0
Slight drought[c]	3.3	2.4	1.3
Total years of drought	7.0	4.5	4.1
Severe flood[a]	0.2	0.8	0.5
Moderate flood[b]	0.1	0.3	0.3
Slight flood[c]	0.5	1.6	0.8
Total years of flood	0.8	2.7	1.6

(a). 50% yield loss, **(b).** 15-50% yield loss, **(c).** 1-15% yield loss

Yield potential

Like all farmers, but especially for those with small farms, the achievement of improved income security depends primarily on producing more of a crop in an efficient fashion, so that profits are improved. In considering the case study results presented here, an initial question is how these reported yields match with potential yields or inherent productivity. Potential yields for any particular location depend on a range of management practices being adequate, from properly fertilized soil growing a crop free of weeds, pests and diseases in a timely fashion to make most use of available rainfall, to having the best available crop varieties and being able to deliver a crop product which is of good quality and for which a fair market price is paid. At this stage, it is still unclear what potential yields are likely to be in the Cambodian upland context.

With respect to the potential yield gaps mentioned above, two methods were used to derive estimates of the maximum potential crop yields and Cambodian potential farm yields (Table 17). One set of estimates was derived by personal communication with John Holland (New South Wales Department of Primary Industries, Australia), and Dr Graeme Wright (Queensland Department of Primary Industries, Australia). Other estimates from Sys *et al*. (1993) involved a synthesis of various observations in tropical countries. The maximum potential yields are worldwide, given optimal climatic and unconstrained soil and nutrient conditions.

The Cambodian potential farm yields are lower, primarily due to solar radiation and temperature factors (John Holland, New South Wales Department of Primary Industries, personal communication). In Cambodia the effect of these factors is to reduce crop maturity times and lower the amount of solar radiation available to the crop. Also, some short-duration crop varieties with lower yield potential are often grown to reduce crop losses from drought.

The potential Cambodian farm yields in Table 17 can be compared with the recorded yields in Tables 9, 13 and 14. For maize the surveyed yields are less than half the potential yield of 10 t/ha, except in Sampov Lun and Chamkar Leu where yields were up to 60% of potential. Surveyed soybean and mungbean yields were also less than half the potential yield, substantially so in some cases. Peanut, cowpea and sesame yields are very low compared to the potential farm yield. These comparisons indicate the substantial potential for farming systems research to contribute to improved performance of upland Cambodian farms and increased farm-family well being.

Table 17. Estimates of maximum potential and Cambodian farm potential yields

Crop	**Maximum potential yield[a]**	**Cambodian potential yield[a]**	**Cambodian potential yield[b]**
	t/ha	t/ha	t/ha
Maize	15	10	6 - 9
Soybean	6	3	1.5 – 2.5
Mungbean	3	2	2 – 2.7
Peanut	9 -10	5-6	2 – 3
Sesame	2	1.5	1.2 – 1.5
Cowpea	3	2	

(a) John Holland (New South Wales Department of Primary Industries, Australia) and Dr Graeme Wright (Queensland Department of Primary Industries, Australia), personal communication, July 2005

(b) Sys *et al.* (1993)

Discussion

Results from these surveys are valuable in showing the resources available to farmers in representative upland districts, as well as characteristics of the farm household. An initial result from the survey is the substantial proportion of female heads of farm or survey respondents (between 20 and 50% in different Districts). This can have a major impact on management practices and adoption of new technologies in Cambodia. Catalla *et al.* (2001) noted that there are different roles, rights and responsibilities of women and men in various aspects of agricultural production. Norris (2001) pointed out that women play a significant role in labour supply and management of agriculture in Cambodia, and that women's access to and utilisation of new agricultural technologies are essential for rural economic growth and the equitable distribution of benefits from that growth. Another aspect of the power of knowledge was noted by Vijghen (1997) who found that power structures and access to knowledge about improved agricultural technologies, and to training, can be allocated unfavourably or inequitably between the sexes. This can be a barrier to dissemination of information and adoption.

Other survey results show that farms are relatively small and farmers have limited resources in terms of management knowledge and technical expertise. The yield data collected indicated that potential yields were not being achieved, so that there is an opportunity for improvements in the technical knowledge of farmers.

As well as the technical production issues canvassed, the resource information collected by Survey 1 pointed to the need to consider other issues. While land slope and erosion potential do not seem to be a general problem, there are some areas of the countryside where cropping is undertaken on land of relatively steep slope. This is an issue of concern which needs to be communicated to the farmers involved. Evidence of variation in soil type and fertility status provides valuable information on how R&D activities can be adapted. The information from surveyed farmers of the prevalence of drought and relative rainfall deficiency also provide an important focus for R&D activities.

The surveys showed which issues should form the core of a substantial R&D agenda for upland crops. These issues include the importance of improving yields in a drought-prone environment for these upland farmers (Survey 1). Yield losses due to insect problems were also important. From the Survey 2 results the R&D priorities were lack of knowledge about crop agronomy, concerns about profitability, land/soil constraints, labour/equipment issues, and agronomic and climate risk.

Other issues for encouraging change in upland crop management to improve income security have become apparent to the authors in the course of these surveys and the project work. These relate to the extension of R&D results and best management practice to the target farmer populations. A specific issue relates to information available to farmers on the application of crop protection products or fertilizers to their crops. In most cases these crop inputs are imported from Thailand or Vietnam and the instructions are written in those languages. Cambodian farmers often are unaware of recommended application rates or safe handling instructions. There appears to be an urgent need for a translation of product labels into the Khmer language and an education program on the application and use of these crop inputs.

A more general point about information dissemination is that the R&D results from these and other projects need to be relayed to the upland farmers in specific agricultural extension programs. The use of farmer field trials and demonstrations of improved technology and practice can provide a ready focus for such programs, but other information including fact sheets and technical guides (eg for identifying insects, weeds and crop diseases) need to be developed to assist extension workers. In addition, financial budgets of the potential profit advantages from changing management need to be developed. The existing group of agricultural extension officers in the Provincial Departments of Agriculture are an obvious group to be involved with these projects and trained to advise farmers about the possible benefits from the technologies developed in these projects. They need to be actively involved in such activities.

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ការវិភាគរចនាសម្ព័ន្ធដំណុះព្រៃ សម្រាប់ការស្តារឡើងវិញលើព្រៃដែលប្រមូលផលរួច-ករណីសិក្សានៅកម្ពុជា

THE STAND STRUCTURE ANALYSIS FOR THE REHABILITATION OF LOGGED-OVER FOREST - A CASE STUDY IN CAMBODIA

Ouk Syphan

អត្ថបទសង្ខេប

គោលបំណងនៃអត្ថបទស្រាវជ្រាវនេះ គឺបង្ហាញនូវការសិក្សាលើការវិភាគ សង្គមសាស្ត្រ រុក្ខជាតិ និងវាយតម្លៃមជ្ឈដ្ឋាន ព្រមទាំងរចនាសម្ព័ន្ធរបស់ដំណុះព្រៃដែលបានប្រមូលផលរួច។ ការសិក្សាបានផ្តល់នូវព័ត៌មានអំពីរចនាសម្ព័ន្ធដំណុះព្រៃ ភាពសម្បូណ៌នៃប្រភេទ និងរបាយនៃឯកត្តៈ ដើមមេ និងតំណពូជ របស់គ្រប់ទម្រង់ជីវសាស្ត្ររុក្ខជាតិនៅក្នុងដំណុះព្រៃដែលប្រមូលផលរួច។ ការវិភាគបានបង្ហាញថាប្រភេទមានតម្លៃពាណិជ្ជកម្ម ស្ថិតនៅក្នុងលំដាប់បរិមាណទាប ហើយដូចគ្នាចំពោះដង់ស៊ីតេដើមឈើមេ និងកូនដំណុះ។ ផ្ទុយទៅវិញតំណពូជនៃកូនដំណុះរបស់ប្រភេទមានតម្លៃទាបក្នុងទម្រង់ជីវសាស្ត្រ ដើមឈើតូច និងមធ្យមមានដង់ស៊ីតេខ្ពស់ ប៉ុន្តែដង់ស៊ីតេនៃដើមឈើមេរបស់វាមាន លំដាប់ទាបដូចគ្នា។ ករណីនេះសបញ្ជាក់ឱ្យឃើញថាដំណុះព្រៃដែលប្រមូលផលរួច បានបន្សល់នូវស្រទាប់ក្រោមនូវការគ្របដណ្តប់នៃប្រភេទឈើទំហំមធ្យម តូច និងកូនដំណុះរបស់វា អាស្រ័យដោយការបើកចំហរគម្របព្រៃ ដោយមូលហេតុការកាប់រំលំហួសហេតុ។ ក្នុងករណីសិក្សាប្រៀបធៀបចំពោះប្រភេទនៃព្រៃដូចគ្នាដែលមិនបានប៉ះពាល់ឃើញថាដង់ស៊ីតេនៃក្រុមប្រភេទ Dipterocarps មានតម្លៃទ្វេរដង ចំពោះក្រុមប្រភេទដូចគ្នាដែលបន្សល់នៅក្នុងដំណុះព្រៃប្រមូលផលរួចដែលបានសិក្សានេះ (៤/៩ ប្រភេទ)។ អថេរភាពនៃអំបូរ និងប្រភេទនៃក្រុមមិនមែន Dipterocarps នៅក្នុងដំណុះព្រៃប្រមូលផលរួចនេះ មានតម្លៃខ្ពស់ជាងអ្វីដែលស្ថិតនៅក្នុងដំណុះព្រៃដែលគ្មានការប៉ះពាល់ (២២ អំបូរ/១៨ និង ៤១/២៧ ប្រភេទ)។ នេះគឺជាការវិវត្តន៍បឋមនៃប្រភេទព្រៃស្រោងបៃតងជានិច្ច ដែលបន្សល់ទុកនូវដើមឈើមេនៃប្រភេទពាណិជ្ជកម្មនៅក្នុងសមាសភាគទាបបំផុត និងគ្មានសម្បទានដើម្បីផលិតគ្រាប់ពូជឡើយ។ ទស្សនទានសម្រាប់ការស្តារឡើងវិញនូវដំណុះព្រៃដែលបានធ្វើការប្រមូលផលរួចនេះគឺការបញ្ចូលនូវបច្ចេកទេសដាំធ្វើឱ្យសម្បូណ៌នៃក្រុមប្រភេទដើមកំណើតសំខាន់គឺក្រុម Dipterocarps ដែលអាចឆ្លើយតបទៅនឹងលក្ខខណ្ឌមជ្ឈដ្ឋាន និងជីវសាស្ត្រនៅក្នុងប្រព័ន្ធមជ្ឈដ្ឋានរបស់វា។ ក្នុងករណីនេះកូនឈើប្រភេទមិនសូវចូលចិត្តពន្លឺថ្ងៃ ត្រូវបានជ្រើសរើសដើម្បីឆ្លើយតបទៅនឹងលក្ខខណ្ឌម្លប់នៅក្នុងដំណុះព្រៃ។ វិធីសាស្ត្រ "ប្រព័ន្ធប្រលោះព្រៃ" គួរត្រូវបានអនុវត្តដែលអាចផ្តល់នូវកិច្ចប្រតិបត្តិល្អ សម្រាប់ការដាំធ្វើឱ្យសម្បូណ៌ក្រោមគម្របព្រៃដែលប្រមូលផលរួច និងផ្តល់នូវលក្ខខណ្ឌសមស្របចំពោះកូនឈើប្រភេទមិនសូវចូលចិត្តពន្លឺថ្ងៃនៃក្រុមប្រភេទមានតម្លៃពាណិជ្ជកម្ម នៃពួក Dipterocarps នឹងអាចកាត់បន្ថយផលប៉ះពាល់ដល់មជ្ឈដ្ឋាននៅក្នុងពេលដាំដុះផងដែរ។

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Abstract

The aim of this paper is to present a study on phytosociology analysis and assessment on site and structure of logged-over forests. The study shall provide the information on stand structure, Species richness and the distribution of the mature and Regeneration individuals of all liveforms within the logged-over forest. The analysis showed that the merchantable Species Contain in low range as well as their density of mature and regeneration trees. Oppositely, the regeneration of small and medium less value tree species contain higher density but their mature are low. It proved that the logged-over forest retained a dominated stratum of medium and small trees species and their new regeneration due to opened canopy caused of over-felling. There are double density of Dipterocarps Species within the Non-Disturbed forest, if comparing with this logged-over forest study area (4/9 species). The variation of families and Species of Non-Dipterocarps group within logged-over forest is higher than Non Disturbed forest (22 families/18, and 41/27 species). That is the first evolution of the original Dense evergreen forest, that left the mature trees of merchantable species in very low component and had no ability to reproduce seeds. The concept for rehabilitation of this logged-over forest is to introduce the enrichment plantation of the indigenous main Dipterocarps species, which could correspond to the site and its biological conditions within the ecosystem .In this case, the sciaphyle seedling should be selected to match the shade conditions within the stand .The “Gap System” method should be implemented which may provide a good practices for enrichment plantation under logged-over forest canopy and favorable condition for sciaphyle seedling of the major merchantable Dipterocarps Species and could also reduce the site impact during plantation.

Keywords

Phytosociology, Species richness, Logged-over forests, Stand structure, Liveforms, Forest rehabilitation, Enrichment plantation.

Introduction

The forest of Cambodia is a significant economic renewable natural resource for the country. The forest ecosystem is rich in biodiversity as evidenced by species richness and endemism. Unfortunately, as the result of the long social unstability and the fast growing population, which caused to suppress the forest resources due to the requirement of timber for the rehabilitation of socio- economy and national infrastructure.. The intensive reduction in forest cover has been observed during 1992-1997 which was about 1.55 % per annum, compared to about 0.56 % for the last two decades reduction (1972-92). The consequence of such circumstance shall result to lose the genetic resources of forest flora, to modify the forest structure and to decrease species richness of flora and also fauna.

The research on flora resource in Cambodia has been promoted since the time of French colonialism whether with the three countries of Indochina Peninsular during 1908 -1942. The document on "General Flora of Indochina" which contained about 8,000 species has been developed. The research has been continued to review in 1960 by the Museum of Natural History in Paris and has been documented "the Flora of Cambodia, Laos and Vietnam" which described about 71 to 164 plants families in Cambodia. Dy Phon (1982) on "The Flowering plants of Cambodia" showed that Cambodia contained about 2,308 species from a total of 8,000 species found in General flora of Indochina. Those include Gymnosperms plants, 07 Genus and 14 species; the Angiosperms plants that composed into Monocotyledons plants are 219 genus and 488 species and Dicotyledons plants are 626 Genus and 1,806 species, within them the endemic plants are 214 species which have the unique areal in Cambodia. A unique reference researched and developed by M. Bejaud (1932) on Forest plants species in Cambodia indicated that the Forest flora in Cambodia contained 1,021 forest plants species consisted of 862 trees and shrubs species, of 22 bamboo species, of 74 lianes and Wines Species and about 34 species of other wild plants species.

Lack of knowledge of stands structure analysis and the component of mature and regeneration stands of all live-forms within the stands might be one of the causes of the mis -rehabilitation of logged-over forest. The need of reforestation and rehabilitation of degraded forest is the important task, but the mispractice of clearing the original vegetation is a technical ignore, that can lead to the failure and modify the forest ecosystem which could not be able to restore. Therefore, the objective of this study is to explore the stand structure of dense evergreen logged-over forest through Phytosociology analysis and site assessment in order to have basic information before setting any technical measures for the rehabilitation of Cambodia's logged-over Forest.

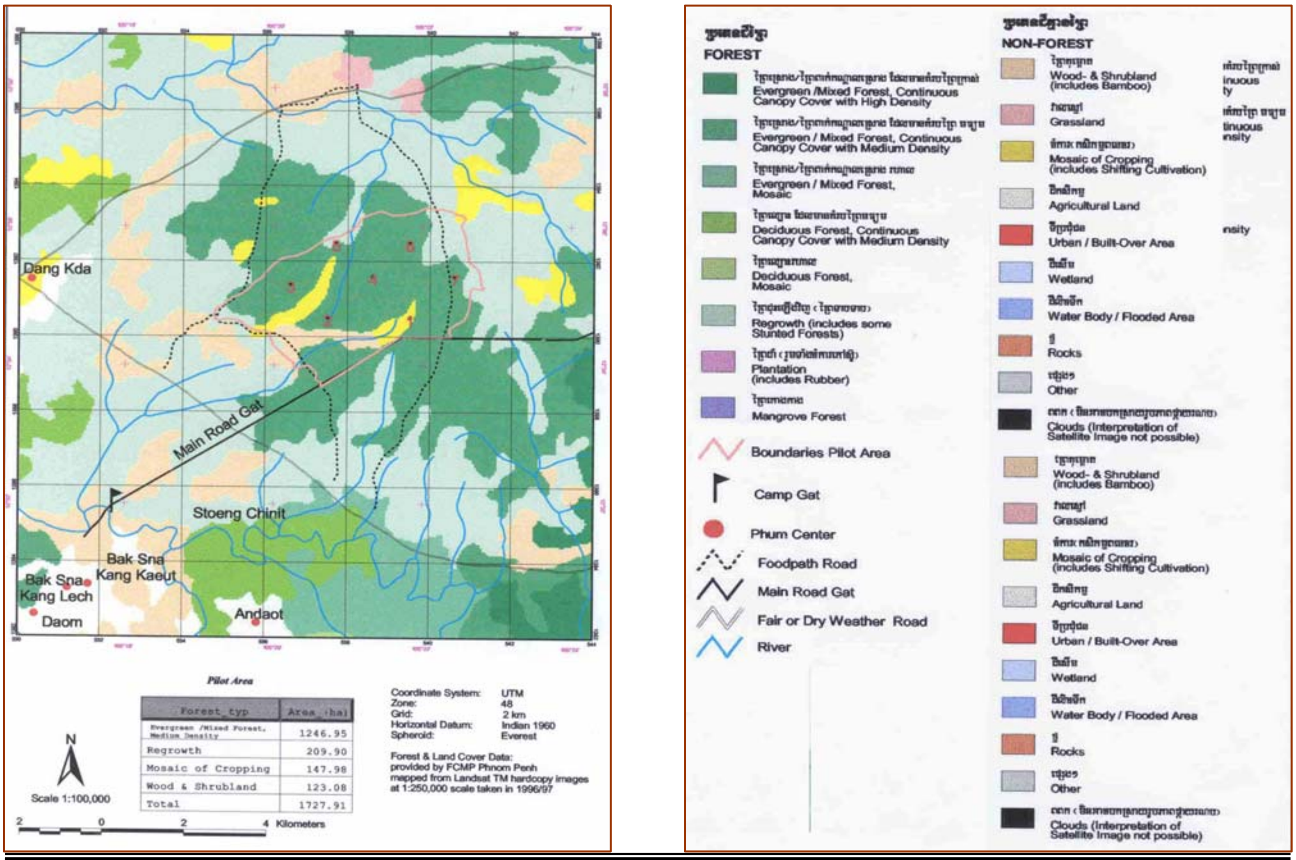
An overview of study area

A pilot area covered about 1,700 ha has been selected, which is located in Forest concession of Komgpong Thom Province, Cambodia.

Before 1990, the vegetation of this area covered by dense moist evergreen forest with high density and was rich in floristic composition, especially main commercial Dipterocarps species. Up to now, caused of uncontrolled and anarchic logging this area has modified and only the vegetation of dominated and lower stratum have been remained, and other vegetation such as secondary forests and abandoned shifting cultivation fields.

The study area located about 10 km from Baksna Village, which consists about 270 Households or 1415 people including 50 % of women. Most people are ethnic and depending on forest resources as their customary use for daily subsistence such as poles, firewood, tree leaves, all edible flora, bamboo, Medicinal plants, résins and others. The main sources of their incomes are Shifting Cultivation (30 - 40 %), traditional pasture, and collecting NTFPs as supplemently for their daily subsistence.

Map 1: Pilot Area For Phytosociology Analysis And Rehabilitation Of Logged-over Forest, Kampong Thom Province

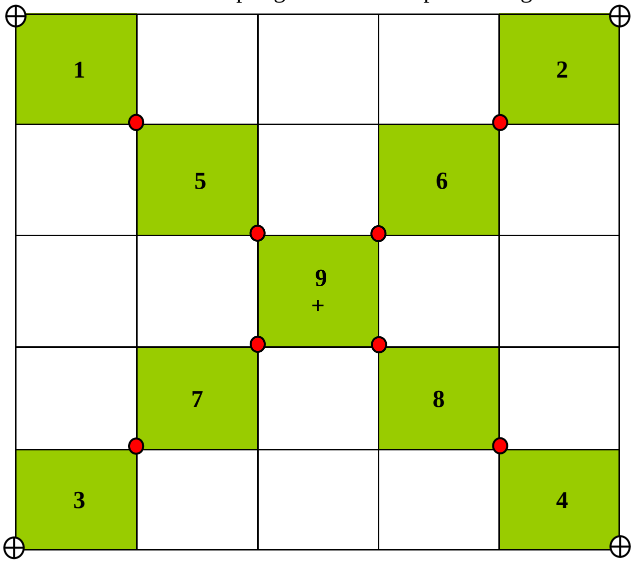


Study method

Sampling design

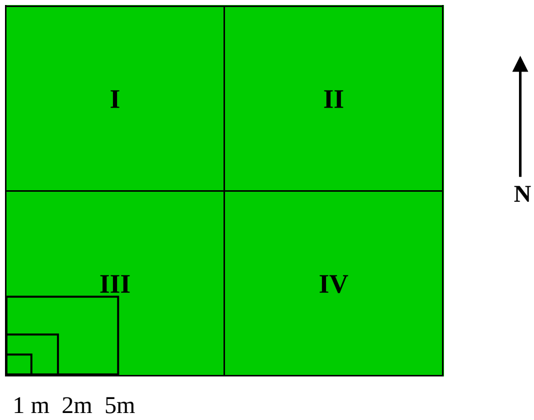
Based on Specific Phytosociology study, Random Sampling has been introduced. The pilot area are allocated into equal size units (1 x 1 km). Within them, 07 Primary Sampling Units are selected randomly, which the centre points shall be the centre of 07 Sampling plots of (100 x 100 m). Within the sampling plots we allocate subplots of (20 x 20 m), but only 09 subplots are distributed by the intersection of diagonals are selected for enumeration. Within the 09 subplots, we allocate subsequently the secondary subplots, which the size are respectively 10 x 10 m, 5 x 5 m, 2 x 2 m, and 1 x 1 m.

Picture 1: Simpling Plots and Subplots Design



Legend: + :Sampling plot centre.
⊕ :The four right angles of sampling plot.
● :Start point of subplots location.'
■ :Subplot

Picture 2: Secondary Subplots Design



Legend:
I, II, III, IV: Secondary subplots quadrants

Species and individuals enumeration

All Species and Individuals are enumerated in subsequent Sampling plots, subplots and secondary subplots as shown in the table 3.1 below:

Table 3.1: The Distribution Of Plots And Subplots Size related with Height Stratum And Liveforms

Plots and Subplots Forms	Plots and Subplots Size (ha)	Height Stratum (m)	Liveforms
100 x 100 m	1.00	> 30	A – Big tree
20 x 20 m	0.04	15 – 30	a – Medium tree
10 x 10 m	0.01	7 – 15	aa – Small tree
5 x 5 m	0.0025	4 – 7	ab – Shrub abr – Bush Pe – Tree regeneration of "Perchis" size
2 x 2 m	0.0004	1 – 4	ab_1 – Small shrub abr_{1-} – Small bush Ga – Tree regeneration of "Gaulis" size He_1 – Big herbaceous plants
1 x 1 m	0.0001	< 1	Pt – Tree regeneration of "seedling" He_2 – Medium herbaceous plants He_3 – Small herbaceous plants

Data analysis

The Data on Species and Individuals and their characteristics are recorded in the Phytosociology analysis sheets showing their height Stratum, Richness, Recovery %, Repartition, Phenology, Viguor and Liveforms. The Information on Vegetation and Site are recorded in particular relevant Sheets. The data are analysed as Species richness, Chao Index, and Diagram of Commercial Species richness mature and regeneration distribution and distribution of Individuals by liveforms class, distribution of Dipterocarps and Non Dipterocarps species and its comparative study with non disturbed forest. All data analysis are evaluated for discussion and conclusion.

Analytical results

Species richness analysis

Followed the data analysis, the component of Species and particularly the merchantable Species remained in the studied area are as below:

(1). Within 16 plants liveforms by each Sampling plot, the component of plants families are in the range of 32 to 45 and for Species, are 59 to 72.

(2). Due to different Opened degree, the individuals by each Sampling plot are in the range of (100,000-200,000 Individuals). They cumulated on "Small bush" or the regeneration of non-merchantable Species, which specified the modification of the vegetation.

(3). The merchantable Species by each plot are in low range (0,14% to 6,50%). This component is mostly Secondary merchantable Species (Vatica cinerea ,king- Dipterocarpaceae).

Table 4.1: Species Richness

Relevant plots	Liveforms	Families	Species	Individuals	Merchantable species	
					Number	Frequency %
1	16	43	64	95.255	7	1.940
2	16	45	68	128.731	6	0.530
3	16	42	59	165.794	5	3.630
4	16	32	62	214.712	8	0.140
5	16	44	62	218.209	5	0.980
6	16	42	63	201.921	8	0.260
7	16	44	72	170.098	7	6.506

CHAO Index

The definition of CHAO Index is to show the total number of species enumerated in an area unit, which is adjusted by adding the index of rare species calculated by the formula as below:

$$S_{chao} = S_{obs} + \frac{a^2}{b^2}$$

Where S_{obs} : Total number of species and enumerated.
a : Number of species represented by 01 individual.
b : Number of species represented by 02 individuals.

The data analysis in the table below showed that, the Scarcity of Species are in low range, because the mean of Species represented by one and two individuals are respectively 1 and 8.

Table 4.2. CHAO Index by plots

Plot	S_{obs}	A	b	S_{chao}
1	64	2	3	64.444
2	68	2	12	68.028
3	59	2	11	59.033
4	62	1	5	62.040
5	62	0	8	62.000
6	63	3	9	63.111
7	72	0	11	72.000
7 plots	**450**	**10**	**59**	**127.034**
Mean by plot	**64**	**1**	**8**	**64.125**

Distribution of individuals by liveforms

There are 16 liveforms to be classified and represented the flora diversity in the studied area. The main components of stand structure are distributed by liveforms as below:

- **Big trees stratum (A):** the component of Big tree liveforms either the mature (A) or medium Ga (A) or big regeneration Pe (A) individuals have too low range (0.09%-0.16%). For the seedlings of this component Pt (A) obtained 1.17 %.
- **Medium trees stratum (a):** the component of Medium tree either the mature (a) or big regeneration Pe (a) have too low range (0.22%-0.32%), but for the Medium regeneration Ga (a) and Seedlings Pt (a) obtain respectively 2.57% and 25.94%.
- **Small trees Stratums (aa):** the component of small trees stratum both for the mature trees (aa) and the big regeneration Pe (aa) are in the range of 0.18%-0.62%, but for the medium regeneration Ga(aa) and their seedling Pt(aa) obtain respectively (3.18% and 31.41%).
- **Shrub and Bush stratum (ab-abr):** the component of this mature liveforms distributed the density about 3.22% (ab-abr) but for the small Shrub and Bush (ab_1-abr_1) increased to 19.08%.
- **Lianes and Herbaceous stratum (Ln-He):** the presence of Herbaceous plants and Lianes are counted respectively 1.65% and 10.10%.

Table 4.3: Mean density by liveforms (7 plots)

Liveforms	Mean	%
Pe (A)	157	0.09
A	186	0.11
Ga(A)	277	0.16
Aa	312	0.18
A	391	0.22
Pe(a)	566	0.32
Pe(aa)	1086	0.62
Pt(A)	2063	1.17
He	2897	1.65
Ga(a)	4518	2.57
Ga(aa)	5589	3.18
Ab-abr	5662	3.22
Ln	17774	10.10
Ab1-abr1	33572	19.08
Pt(a)	45645	25.94
Pt(aa)	55275	31.41
	175970	**100**

Graph 4.1: Distribution of individual by density class

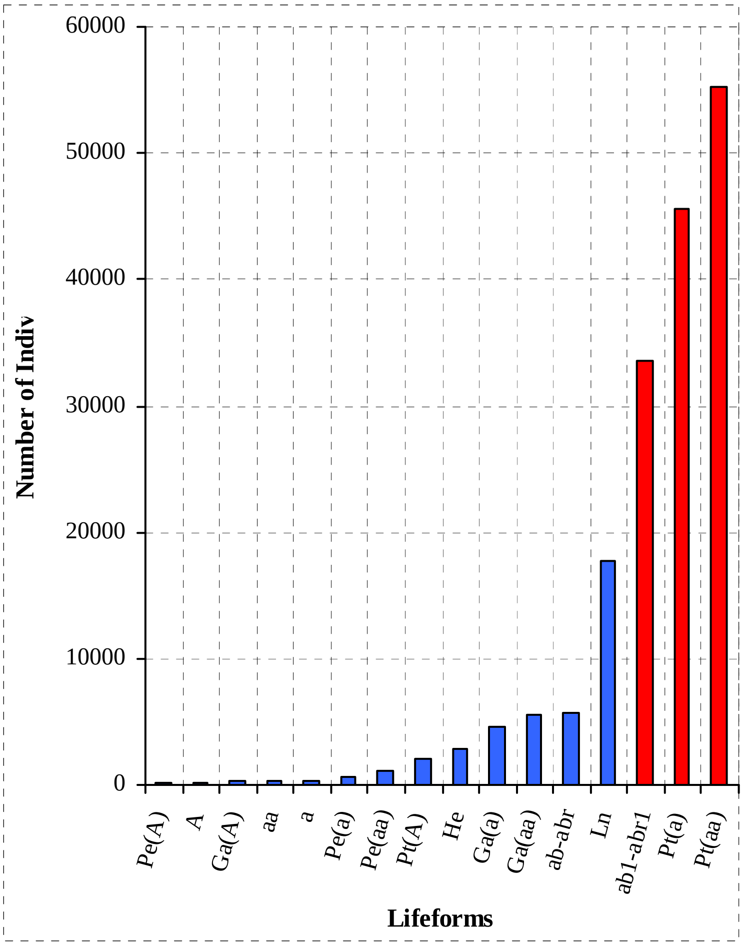
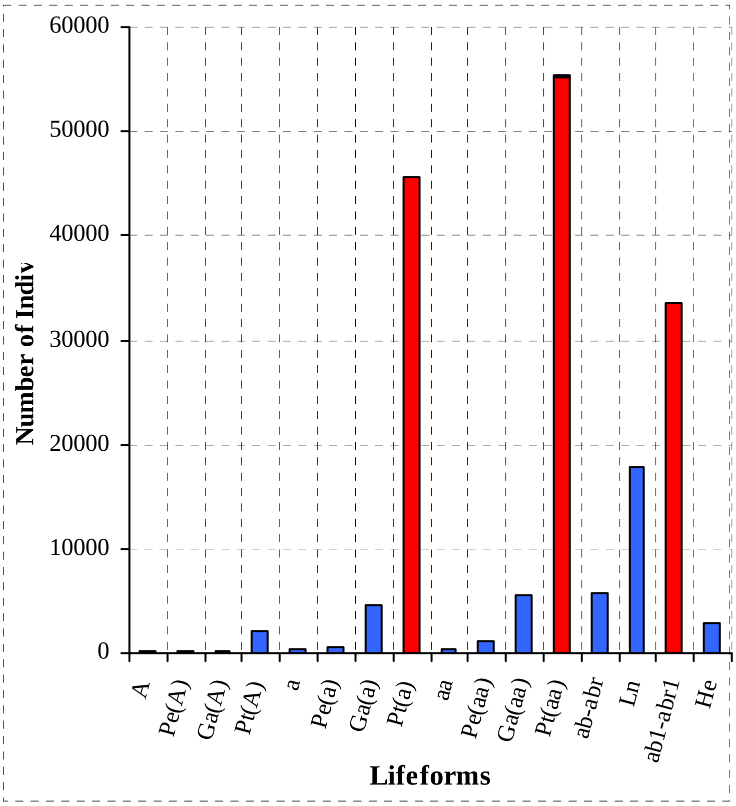


Table 4.4: Mean density by lifeform (7 plots)

Lifeform	Mean	%
A	186	0.11
Pe(A)	157	0.09
Ga(A)	277	0.16
Pt(A)	2063	1.17
A	391	0.22
Pe(a)	566	0.32
Ga(a)	4518	2.57
Pt(a)	45645	25.94
Aa	312	0.18
Pe(aa)	1086	0.62
Ga(aa)	5589	3.18
Pt(aa)	55275	31.41
Ab-abr	5662	3.22
Ln	17774	10.10
Ab1-abr1	33572	19.08
He	2897	1.65
	175970	**100**

Graph 4.2: Distribution of individual by lifeforms class



Regeneration and mature stands distribution of main commercial species

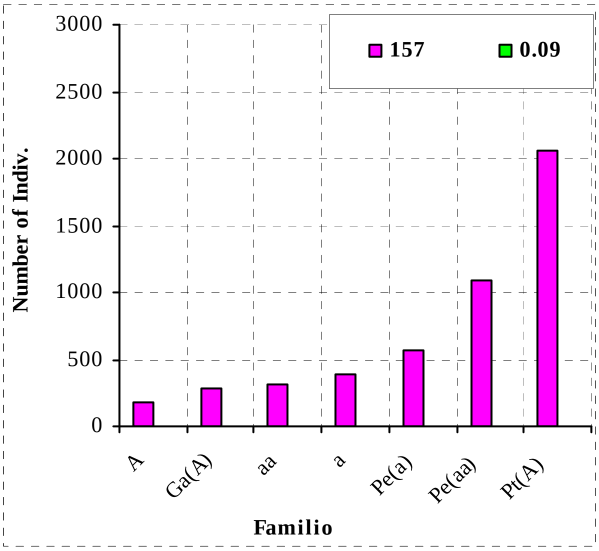
There are only seven plant families which are distributed the main commercial species in the studied area. The regeneration is in very low range (0%-2.047%) except family DIPTEROCARPA-CEAE (2.047%). Mostly of Dipterocarpaceae family are cumulated on species Vatica cinerea, King., which the liveforms is small tree (aa) and the main use is pole but not timber.

The mature trees are also cumulated in three families: Dipterocarpaceae (0.058%), Caesalpiniaceae (0.011%) and Lythraceae (0.013%).

Table 4.5: Frequency of mature and regeneration

Familio	Mat.	Reg.	% Frequ. of Mat.	% Frequ. of Reg.
Anacardiaceae	10	1111	0.001	0.090
Caesalpiniaceae	134	220	0.011	0.018
Dipterocarpaceae	719	25213	0.058	2.047
Lythraceae	161	88	0.013	0.007
Rosaceae	40	44	0.003	0.004
Rubiaceae	2	0	0	0
Sterculiaceae	95	88	0.008	0.007
	1161	**25764**	**0.094**	

Graph 4.3: Main Commercial Species Richness



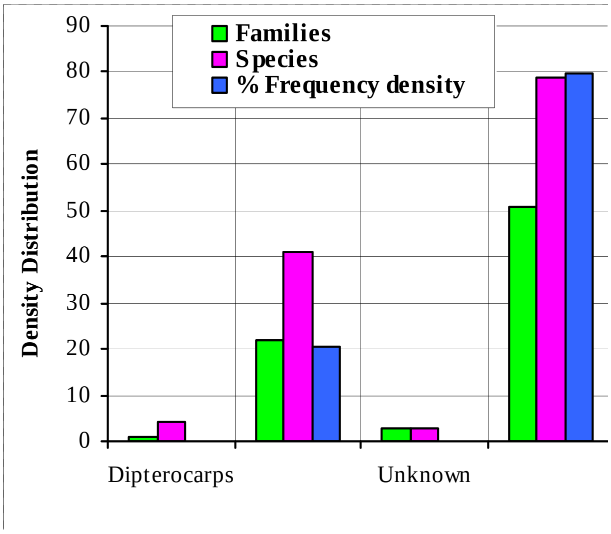
Distribution density of dipterocarps, non-dipterocarps and unknown tree species

Followed the analytical result, the family DIPTEROCARPACEAE are represented by 04 species and distributed 0.058% of total density frequency. For Non-Dipterocarps are represented by 22 families and 41 species, and distributed 20.379% of density frequency. The Unknown trees are represented by 03 families and 03 species, and distributed 0.043% of total density frequency. Besides the trees species component, the studied area also distributed by other Non-trees stratum including regeneration stands such as Shrub, Bush, Herbaceous vegetation which are represented by 51 families, 79 species and distributed 79.520% of the whole flora frequency.

Table 4.6: Frequency density of group species

Families		Species	% Frequency density
Dipterocarps	1	4	0.058
Non-Dipterocarps	22	41	20.379
Unknown	3	3	0.043
Non tree Stratum	51	79	79.520
Total	**77**	**127**	**100**

Graph 4.4: Distribution Density Of Dipterocarps, Non-Dipterocarps And Unknown Tree Species



Comparative study with non-disturbed forest

There is poor information on Floristic composition or stand distribution of Non-disturbed forest in Cambodia. Only the table was done by Bernard Rollet during his research by the year 60's in the similar condition area of Dense Humid Semi evergreen forest on "Grey soils", which could be used as comparative data with the study area.

Followed the table 5.1, There are double density of Dipterocarps Species within the Non-Disturbed forest, if comparing with this logged-over forest study area (4/9 species). The variation of families and Species of Non-Dipterocarps group within logged-over forest is higher than Non Disturbed forest (22 families/18, and 41/27 species).

Table 5.1 Floristic composition per ha of typical dense humid evergreen forest on "Grey soil"

Scientific Names	Numbers of trees by species and diameter class, cm											Total /1 ha	% Frequency by group
	20 29	30 39	40 49	50 59	60 69	70 79	80 89	90 99	100 109	110 119	120 129		
I-Dioterocarps													
1. Hopea odorata	2	-	1	-	-	-	-	-	-	-	-	3	
2. Dipterocarpus dyeri	1	1	1	-	1	-	-	3	-	-	1	8	
3. Dipterocarpus costatus	-	1	1	1	-	1	1	1	-	-	-	6	
4. Dipterocarpus turbinatus	1	-	-	-	-	-	-	-	-	-	-	1	
5. Anisoptera cochinchinensis	2	1	-	1	1	-	-	-	-	-	-	5	
6. Shorea hypochra	1	-	1	-	-	-	-	-	-	-	-	2	
7. Shorea thorelii	-	-	-	-	-	-	-	-	1	-	1	2	
8. Shorea vulgaris	4	7	1	-	1	-	2	-	-	-	-	15	
9. Vatica cinerea	52	12	1	-	-	1	-	-	-	-	-	66	
Sub Total	63	22	06	02	03	02	03	04	01	0	02	108	50 %
II-Non-Dipterocarps													
10. Sindora cochinchinensi (Caesalpiniaceae)	1	1	2	-	2	1	-	-	1	-	-	8	
11. Dialium cochinchinensi(Caesalpiniaceae)	-	1	-	-	-	-	-	-	-	-	-	1	
12. Tarrietia javanica (Sterculiaceae)	-	-	2	-	-	-	-	-	-	-	-	2	
13. Sterculia lichnophora (Sterculiaceae)	-	1	-	-	-	-	-	-	-	-	-	1	
14. Parkia streptocarpa (Mimosaceae)	1	-	-	-	-	-	-	-	-	-	-	1	
15. Aglaia odorata (Meliaceae)	2	-	-	-	-	-	-	-	-	-	-	2	
16. Cleistanthus eburneus (Euphorbiaceae)	1	-	-	-	-	-	-	-	-	-	-	1	
17. Cleistanthus sp. (Euphorbiaceae)	2	-	-	-	-	-	-	-	-	-	-	2	
18. Diospyros bejaudii (Ebenaceae)	3	1	-	-	-	-	-	-	-	-	-	4	
19. Diospyros nitida (Ebenaceae)	9	4	-	1	-	-	-	-	-	-	-	14	
20. Maba costanea (Ebenaceae)	2	-	-	1	-	-	-	-	-	-	-	3	
21. Haasia cuneata (Lauraceae)	5	3	4	-	-	-	-	-	-	-	-	12	
22. Popowia diospyrifolia (Annonaceae)	2	-	1	-	-	-	-	-	-	-	-	3	
23. Mitrephora thorelii (Annonaceae)	-	1	-	-	-	-	-	-	-	-	-	1	
24. Xylopia sp. (Annonaceae)	2	-	-	-	-	-	-	-	-	-	-	2	
25. Garcinia schomburchiana (Clusiaceae)	4	1	-	-	-	-	-	-	-	-	-	5	
26. Garcinia ferrea (Clusiaceae)	1	1	-	-	-	-	-	-	-	-	-	2	
27. Griwia paniculata (Tilliaceae)	2	-	1	1	-	-	-	-	-	-	-	4	
28. Pentace sp. (Tilliaceae)	1	-	-	-	-	-	-	-	-	-	-	1	
29. Mangifera indica (Anacardiaceae)	1	1	-	-	-	-	-	-	-	-	-	2	
30. Eugenia sp. (Myrtaceae)	3	7	1	1	1	1	-	-	-	-	-	14	
31. Corallia lucida (Rizhophoraceae)	2	-	-	-	-	-	-	-	-	-	-	2	
32. Schima crenata (Terstroemiaceae)	-	1	-	-	-	-	-	-	-	-	-	1	
33. Irvingea oliveri (Irvingiaceae)	1	1	-	-	-	-	-	-	-	-	-	2	
34. Parincrium annamense (Rosaceae)	2	-	1	2	-	-	-	-	-	-	-	5	
35. Nephelium sp. (Sapindaceae)	1	1	-	-	-	-	-	-	-	-	-	2	
36. Ardisia sp. (Myrzinaceae)	1	-	-	-	-	-	-	-	-	-	-	1	
Sub Total	49	25	12	06	03	02	0	0	01	0	0	98	45 %
III-Unknowns													
37. Srangol	1	-	-	-	-	-	-	-	-	-	-	1	
38. Dol moon	1	-	-	-	-	-	-	-	-	-	-	1	
39. Ke mong	3	1	-	1	-	-	-	-	-	-	-	5	
40. cheng	1	-	-	-	-	-	-	-	-	-	-	1	
41. Chbeam tukké	1	-	1	1	-	-	-	-	-	-	-	3	
Sub Total	07	01	01	02	0	0	0	0	0	0	0	11	05 %
Total	**119**	**50**	**19**	**10**	**6**	**4**	**3**	**4**	**2**	**-**	**2**	**217**	**100 %**

By Bernard Rollet (1972), La végétation du cambodge.

The vegetable and site analysis

Followed the vegetation and site information, the opened degree of the main stratum is ranging from sub-opened to semi-opened and opened. The retained stand is low woody vegetation formation with high degree of artificialisation, but in general they are still sound vegetation, which could be improved. The majority of component are small trees stratum of 10-15 m height of minor merchantable dominant species such as Vatica cinerea,King., Peltophorum dasyrachis,(Miq) Kurz, Dialium cochinchinensis, Pierre. Herritiera javanica, (Blume) korstern., Lagerstroemia spp etc., particularly, the main merchantable species had been extracted through over-logging such as: Anisoptera glabra, Dipterocarpus alatus, Roxb., D. costatus, CF. Gaerth., D. dyeri, Pierre., D. turbinatus, Shorea guiso, (Blanco) Blume., Hopea odorata, Roxb., Shorea hypochra, Hance., etc.

The site is still fair, plat area, non inundated, non hydromorphed, especially the areas are covered by organosoil substratum with mull cover on the top layer. Otherwise the presence of major lianes component and minor Herbacoeus plants component revealed that the original stands structure did not rootly degraded yet, because the Forest Stands still keep their crown canopy or it just lose some main dominant trees layer of major merchantable species.

Table 6.1 Main information on vegetation and site

Informations	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7
Opened Degree of Main Stratum	Opened	Semi-Opened	Opened	Semi-Opened	Semi-Opened	Opened	Sub-Opened
Degree of Artificialisation	High	High	High	High	High	High	High
Vegetation Formation	Low woody Veget. Formation	Low woody Veget. Formation	Low woody Veget. Formation	Low woody Veget. Formation	Low woody Veget. Formation	Low woody Veget. Formation	Low woody Veget. Formation
Dominant Species	1-Dialium cochinchinensis 2-Lagerstroemia spp	1-Vatica cinerea 2-Peltophorum Dasyrachis	1-Vatica cinerea 2-Dialium cochinchinensis	1-Vativa cinerea 2-Khla tas	1-Vatica cinerea 2-Cratoxylon Formosum	1-Hasia cuneata 2-Vatica cinerea	1-Tarietia javanica 2-Vatica cinerea
Forest Exploitation	Anachic Logging	Anachic Logging	Anachic Logging and Shifting Cultivation	Anachic Logging	Anachic Logging and Shifting Cultivation	Anachic Logging and Shifting Cultivation	Anachic Logging
Accidents	Sound	Sound	Infection on Stems & Branches	Sound	Sound	Sound	Sound
Slope	0 – 1 %	0 – 1 %	0 – 1 %	0 – 1 %	0 – 1 %	0 – 1 %	0 – 1 %
Exposition	Plat Area	Plat Area	Plat Area	Plat Area	Plat Area	Plat Area	Plat Area
External Drainage	Null	Null	Null	Null	Null	Null	Null
Submersion	Non Inundated Unit	Non Inundated Unit	Non Inundated Unit	Non Inundated Unit	Non Inundated Unit	Non Inundated Unit	Non Inundated Unit
Hydromophy	Non Hydromorphy	Non Hydromorphy	Non Hydromorphy	Non Hydromorphy	Non Hydromorphy	Non Hydromorphy	Non Hydromorphy
Substratum	Organo-Soil	Soil	Organo-Soil	Organo-Soil	Soil	Graveo-Stony	Organo-Soil
Nature of Humus	Mull	Mull	Mull-Moder	Mull	Mull-Moder	Mull	Mull

Discussion and conclusion

Based on analytical results, the “BAKSNA” Forest, a typical studied area of logged-over Dense moist evergreen forest of the North Great Lakes plain, has been characterized generally by optimum Species richness indicated by mean CHAO index Schao = 64.125, but the distribution of density frequency are cumulated mostly on non-tree Stratum (34.05% of density frequency by liveforms) and the regeneration of less merchantable tree Species (57.35% of density frequency by liveforms). The merchantable species are represented by 07 families only among 45 plants families counted in the area, and its density frequency ranging from 0.14% to 6.50%. The component of the big trees stratum whether their mature (A) or regeneration trees [Ga(A)] distributed in very low range. It mean that the big trees liveforms represented by major merchantable species had been loss their mother stands which were the seeds source of next regeneration, and particularly their medium Ga(A) and big Pe(A) regeneration stands which were the Future trees of the forest structure were also insufficient.

The component of the seedlings of Medium trees Pt(a) and small trees Pt(aa) distributed in very high range (25.94% - 31.41%). Oppositely, the distribution of their mature Stands (a) and (aa) and also their medium and big regeneration stands (future trees) are ranging very low frequency. So, the retained forest stand structure has been left mostly the Dominated tree Stratum, composed majorly by medium and small tree liveforms. That is the primary evolution of the original dense moist evergreen forest vegetation, because the component of merchantable species represented by the mature trees (A) distributed extremely low range and were defected stands, which had no ability for seeds production. The Dipterocarps Species either the mature stand or Regeneration are cumulated on Species “Vatica cinerea” which are the Indicators Species for Dominated stratum of Dense Humid Evergreen forest. The component of Dipterocarps Species represented extremely low range (0.058%), if comparing with the non-disturbed forest of the similar conditions, which contains about (50%). So it proving that the Stands Structure of Forest studied area is modifying resulted from repeated and over logging. For such typical logged-over forest any more extraction of timber should be prohibited and it must be managed as the forest reserves for at least another 30 years cutting cycle or could be rehabilitated through Enrichment plantation by introducing under retained forest canopy the main indigenous merchantable species. The selection of Species for enrichment plantation should correspond to the site and its biological condtions within the ecosystem .In this case, the sciaphyle seedling should be selected to match the shade conditions within the stand . Species that should be selected include the group of Dipterocarpus spp, Anisoptera glabra, Korth., Hopea spp, Shorea guiso, (Blanco) Blume., S. hypochra, Hance., Herritiera javanica, (Blume) Korstern., etc. The "Gap System" method should be implemented which may provide a good practices for enrichment plantation under logged-over forest canopy and favorable condition for sciaphyle seedling of the major merchantable Dipterocarps Species and could also reduce the site impact during plantation.

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នយោបាយធារាសាស្ត្រ និងប្រព័ន្ធស្រោចស្រពសហគមន៍នាពេលបច្ចុប្បន្ននៅកម្ពុជា

RECENT IRRIGATION POLICY AND COMMUNITY IRRIGATION SYSTEM IN CAMBODIA

Chea Sareth and Kumi Yasunobu*

អត្ថបទសង្ខេប

នយោបាយធារាសាស្ត្រថ្មីរបស់រាជរដ្ឋាភិបាលកម្ពុជា បានបង្កើតសហគមន៍កសិករប្រើប្រាស់ទឹកនៅចំនួន ១៣ខេត្ត នៅទូទាំងប្រទេស ចាប់តាំងពីឆ្នាំ២០០៣ ដើម្បីដាក់អោយដំណើរការ និងគ្រប់គ្រងប្រព័ន្ធស្រោចស្រពដែលមានស្រាប់ និងប្រព័ន្ធធារាសាស្ត្រដែលទើបអភិវឌ្ឍន៍នៅពេលបច្ចុប្បន្ន។ ការបង្កើតសហគមន៍កសិករប្រើប្រាស់ទឹក គឺជាដំណើរការផ្ទេរពីរាជរដ្ឋាភិបាល ទាំងចំណាយក្នុងការដំណើរការ និងការគ្រប់គ្រងនៃប្រព័ន្ធធារាសាស្ត្រទៅអោយសហគមន៍កសិករ ក្នុងគោលបំនងអនុវត្តនយោបាយធារាសាស្ត្រប្រកបដោយនិរន្តភាព។ ការសិក្សាត្រូវបានធ្វើឡើងនៅប្រព័ន្ធធារាសាស្ត្រប្រវត្តិសាស្ត្របារាយណ៏នៅខេត្តសៀមរាប ដែលជាសហគមន៍មួយក្នុងចំណោមសហគមន៍ប្រើប្រាស់ទឹកផ្សេងៗនៅកម្ពុជា ដើម្បីធ្វើការវិភាគពីផលិតកម្មស្រូវប្រាំង និងការគ្រប់គ្រងប្រព័ន្ធធារាសាស្ត្រដែលមានការចូលរួមពីសហគមន៍កសិករ។ ការសិក្សាក៏បានផ្តោតទៅលើការគ្រប់គ្រងការស្រោចស្រព ការអភិវឌ្ឍន៍ដំណាំស្រូវប្រាំង និងនយោបាយធារាសាស្ត្រនៅកម្ពុជាផងដែរ។ ការប្រមូលព័ត៌មានត្រូវបានធ្វើឡើងតាមរយៈការសម្ភាសន៏ជាលក្ខណៈឯកត្តជន និងការប្រជុំពិភាក្សាជាក្រុម។ លទ្ធផលបឋមបានបង្ហាញអោយឃើញថាសហគមន៍កសិករប្រើប្រាស់ទឹកបានជំរុញការដាំដុះស្រូវប្រាំងតាមរយៈការបែងចែកទឹកដ៏សមស្រប។ ស្វ័យហិរញ្ញកិច្ចរបស់កសិករ និងការគ្រប់គ្រង ដោយមានការចូលរួមពីសហគមន៏បានចូលរួមចំណែកក្នុងការថែរក្សាហេដ្ឋារចនាសម្ព័ន្ធប្រព័ន្ធធារាសាស្ត្រ។ ក៏ប៉ុន្តែបញ្ហាជាក់ស្តែងមួយចំនួនដែលជាឧបសគ្គ ដូចជាការខកខានក្នុងការបង់ថ្លៃទឹកស្រោចស្រព ការខកខានក្នុងការចូលរួមចំណែកការងារសហគមន៏ ការដណ្តើមទឹកគ្នា ការគិតតែពីផលចំណេញរបស់សមាជិក ជម្លោះ ភាពខ្វះការទទួលខុសត្រូវ និងការខ្វះខាតទឹកបានកើតឡើង និងអាចមានផលអវិជ្ជមាននៅក្នុងសហគមន៏។

Abstract

New irrigation policy to form a Farmer Water User Community (FWUC) is introduced by the Cambodian Government in 13 provinces across the country since 2003 to function and manage both existing and new irrigation systems. The formation of FWUC is to transfer the function and management of irrigation systems to farmer communities from the government for the sake of implementing sustainable irrigation policy. The study was conducted in a historical Baray Irrigation Scheme located in Siem Reap Province, one of the FWUC in Cambodia, to analyze dry season rice production, and irrigation management and participation from the community. A review of irrigation management, dry season rice development and irrigation policy itself were briefed. Survey and focus group discussion approach were carried out to collect information from farmers in two communes where FWUC was established. It can be initially assessed that the community could improve dry season rice through appropriate irrigation water distribution. Irrigation infrastructures could be maintained by farmer self-finance and participatory management. Nevertheless, such certain constraints as failure to pay water fee and to attend community's activities, water competition, selfishness of members, conflicts, lack of responsibility and water shortage were observed.

Keywords

Participatory Irrigation Management, Water user community, Common resource management, Irrigation policy

Introduction

Efficient water uses for irrigated rice of Asian monsoon region are able to feed 54 % of the world's population with only 14 % of the world's land (Takase, 2004). The supply of water is the most important factor that can control the production of field crops in the tropics (Brady, 1978). Cropping intensity and diversity can be carried out where water supply can be dependable and controllable. Of the field crops, rice is most water supply dependant crop and requires most controllable irrigation water. If there is a shortage of water at any stage of its life cycle, potential yields will be affected severely (Javier, 1997). According to Greenland (1997) the rice crop requires more water than any other major crop, which was estimated 4,000 tones of water are required to produce one ton of rice. The requirement of water for rice cultivation varies widely according to planting season, rice varieties, weather, landscape position, soil drainage characteristics, and the management of the water supply.

The irrigation system is not just for rice crop itself but also can support, maintain and even improve soil fertility. The cultivation of rice absorbed huge amount of available nutrients in the soil every year. Even though the supply of nutrients is practiced yearly, there would be no balance between absorbing of rice plant and application because rice farmers in Cambodia are still under poor so that they cannot afford to buy sufficient fertilizers. Furthermore it is impossible for farmer to be aware that the suitable quantity fulfills the lost. Therefore irrigated rice field is generally rich soil fertility and good soil structure and texture compared to rainfed lowland field condition because supply water contained high content of nutrient in particular rich deposit of

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silt from river source. Even other source of water supply may not be very rich in silt and nutrients, it remains high content of plant required substances compared to rainfall.

The development or establishment of irrigation systems requires huge capitals and years but the supply of water is not efficiently used and the project is not sustainable if a proper operation and maintenance is not taken into considered. If the condition of irrigation systems are well-conceived and efficiently managed, one year round cultivation is possible where water supply is dependable and controllable (Brady, 1978). The lack of the conceptualization and management of irrigation systems has adverse impact on full food-production potential even the water supply is favorable. Concerning irrigation, proper water management is the most important measure and has become generally accepted in Southeast Asian farming societies (Wickham and Valera, 1978).

Apart from project sustainability, good management of irrigation water benefits both users and providers (Wickham and Valera, 1978). Good water management can supply rice grower with full water sufficiency from seedling to harvesting and further offer opportunity to grow second or third crop within one year. Good water management of the operator or provider means appropriately application of water to rice field to minimize over-irrigation and consequent drainage losses that is reduce current water supply to irrigated land can save water for a potential larger area. Wickham and Valera (1978) state that the aspects of good water management are critical to enhance agricultural output by achieving either higher yields or larger irrigated areas. In order to manage irrigation water efficiently, certain activities and factors need to be taken into account. Recent studies in Cambodia emphasized that the link with the local institutions and appropriate strategies are essentials to be functioned the farmer water users group in participatory management (Prera, 2006).

The aims of this paper are to depict the recent agricultural irrigation policy in Cambodia and to analyze a case of irrigation water usage in community level, which is reflecting the concept of well irrigation water management contributing to better life through safe agricultural production. In the next section, introduction of recent irrigation policy related to farmer associations is outlined, followed by the survey results of community irrigation systems in Siem Reap is presented. The paper will show the actual situation of water users group in Cambodia from field survey under the complex, though it is rather real, water usage situation and issues.

Method of the research

The analysis started from collecting related information from the Ministry of Water Resources and Meteorology (MOWRAM) and JICA Cambodia office. The information from field study conducted in two communes located in the Baray Irrigation Scheme (BIS) area in Siem Reap Province in July 2005. The data collection in the survey site was carried out through different methods. The authors discussed with Directors and officials of Provincial Department of Agriculture, Forestry and Fisheries (PDAFF) and Provincial Department of Water Resources and Meteorology (PDWRAM) in Siem Reap, and a Farmer Water User Community's (FWUC) committee members and commune heads of the survey site. Direct observation of irrigation systems and fields were conducted by the authors. A survey using questionnaire was conducted by seven research assistants under the supervision of the authors. A random selection of 150 and 151 farm households were interviewed in Samrong Yea and Khnath commune respectively. The questionnaire focused critically on water irrigation issue and FWUC management. In order to cover broader viewpoints of respondents, six sessions of focus group discussion was also held by the authors in both communes for two farmer groups with paddy field location basis and a village head group from each commune in March 2006. In the session, details included land holding, cropping systems, rice yield and disposal, farm resource inputs and in particular constraints in rice production in the communes were discussed.

Dry season rice development in Cambodia

Irrigation water is the common resource for rice farmers. If the resource is critically scarcity condition, rice farmers have to compete and/or cooperate with each other. The necessity of collective action is determined by the quantity and quality level of resource endowment. Farmer community has a critical role to play in functioning irrigation water usage association and sustaining the water group management; and farmer water use community is influenced by social relationship because irrigation water is critically required by the whole rice grower community, especially water application is requested at the same time and long-term supply. It broadly accepted that negligence and uncooperativeness of farmers caused poor irrigation water management (Wickham and Valera, 1978).

Increasing participation and collaboration from farmers, responsibilities for water supply and irrigation facilities should largely or fully be transferred to the farmers. The farmers should be trained and educated about technical skills and valuable water resource endowment to run the source ideally. Since well cooperation from farmers influenced on successful management of water supply, the farmers should be encouraged to assume more responsibility in water management and then such responsibility as operational functions in charge by the systems' field staff can be taken over the farmers (Wickham and Valera, 1978). When farmers bear responsibility for water management, they do not just function water and facilities in reservoirs, main canal or sub-canals carefully but they also use water supply in their fields efficiently that can avoid wasting water through over-irrigation and drainage. There is different history, experience, method in irrigation water management in Asia depend on natural resources, national economy, technology development and water policy.

But the cultivation of rice in Cambodia is mainly under rainfed lowland condition that one of the factors attributed to down turns of rice production in this country. Water supply is the most severe constraint to rice production since around 84 % of rice growing area is rainfed lowlands. The total rice cultivating area in 2004 is around 2,374,000 ha and only 12 % of the total area is irrigated rice of dry season rice production. Rest 2,075,000 ha is rainfed lowland conditions (MAFF, 2005). Even though the *colmatage* irrigation system for recession rice was distinctive aspect (Takase, 2004), it was a tiny area compared to the total rice production area.

Within Southeast Asian nations and Asia as a whole, percentage of irrigated land area in Cambodia is smallest compared to other countries. Even though Cambodia produced surplus rice and was third rice exporter country during 1960s, the irrigated land was only around 2.2 % of its total cultivated land (Table 1). Besides Cambodia, several rice growing countries in Asia such as Laos, Myanmar, Bangladesh and Nepal, reported with less than 10 % of irrigated land in 1960s but then the percentage of irrigation land of all countries except for Cambodia gradually increased. Until recently, Cambodia's irrigated land remained around 7 % while other grown above 18 % though water resources of the country was considerably favorable.

Table 1: Irrigated land area/arable land area (%)

	1961	1965	1970	1975	1980	1985	1990	1995	2000	2003
Southeast Asia										
Cambodia	2.2	3.4	3.3	4.8	6.0	7.8	6.5	7.3	7.3	7.3
Indonesia	21.7	21.7	21.7	21.7	22.8	21.1	21.8	25.5	22.0	21.4
Laos	1.9	2.0	2.6	5.3	14.7	15.0	16.9	18.7	20.0	18.4
Malaysia	27.5	27.1	28.5	31.8	32.0	26.1	20.1	19.9	20.1	20.3
Myanmar	5.4	7.6	8.4	10.3	10.5	11.0	11.0	16.3	18.6	18.5
Philippines	14.1	15.1	17.7	21.4	23.3	26.9	28.3	28.2	27.4	27.2
Thailand	15.6	15.8	15.9	16.2	18.3	21.6	24.2	27.6	31.4	35.3
Viet Nam	18.0	18.0	21.3	24.6	28.6	44.5	54.3	55.5	48.4	44.9
East Asia										
China	29.4	32.8	38.1	43.8	46.9	36.9	38.8	40.2	39.7	38.3
Japan	51.9	53.7	65.7	64.1	62.7	61.1	59.7	59.3	59.0	58.9
Korea, N	23.3	23.3	23.3	40.9	49.0	55.6	62.1	60.8	56.2	54.1
Korea, S	32.0	32.5	39.4	44.4	43.3	47.2	50.6	50.9	51.2	53.3
South Asia										
India	15.8	16.8	19.0	20.7	23.6	25.8	28.7	32.8	35.4	34.8
Bangladesh	5.0	6.5	12.0	16.2	17.1	23.4	30.5	48.1	51.8	59.2
Nepal	3.9	4.8	6.0	10.5	22.9	33.2	43.1	48.8	48.8	49.5
Pakistan	64.3	60.0	67.6	69.6	73.4	78.0	77.2	82.0	84.9	93.7
Sri Lanka	56.3	43.0	57.4	51.2	53.8	59.1	59.4	65.8	74.3	81.1

Source: FAOSTAT

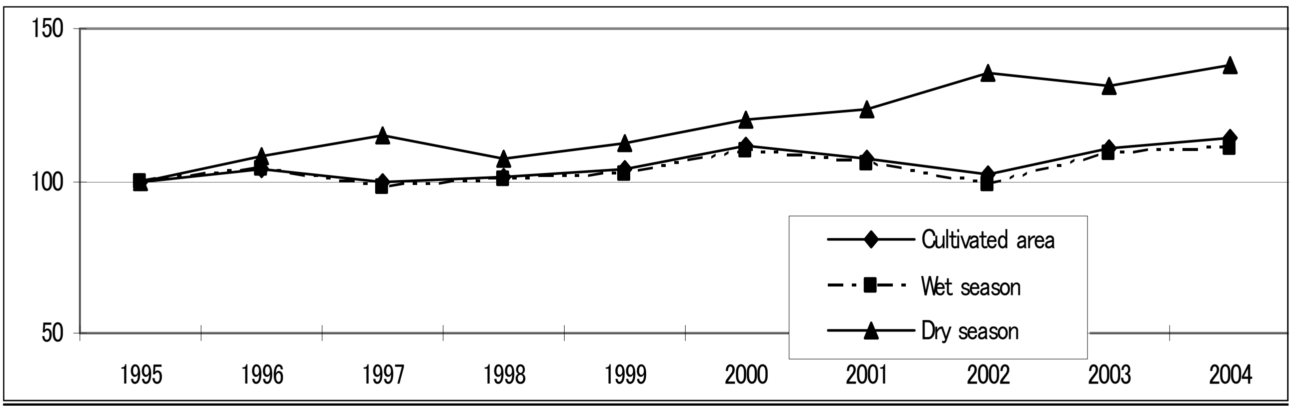
Due to the long civil war in Cambodia from 1970s to 1980s, the country was left behind the Green Revolution. Once the country enjoyed the abundance of agricultural production in 1960s but the infrastructure was totally destroyed under the Pol Pot regime in 1980s. Along the Mekong River and Tonle Sap Lake, country seems abundant of irrigation water. But actually, most of the rice field is under rainfed condition with insufficient water and especially irrigation is impossible in dry season.

In fact, there are four major irrigation methods in Cambodia and beside ordinal irrigation method by canal gravity with/without pump and utilize groundwater by using shallow tube well, two among them are unique and traditional irrigation methods in Cambodia. One is *Colmatage* and another is *Tomnub*. The former was seen at the area between Bassac and Mekong Rivers, which is known as traditional farming system used by water level changes between wet and dry season. The latter, which is presented in the study sites, referred as dam of reservoir in English and use wet season flooded water to store in the reservoir and use the water for irrigation during the dry season. But they are not favorable for major cultivated rice land in Cambodia and the irrigation infrastructures were destroyed by chronic civil war.

Therefore, the development of both small and large scale irrigation systems for crop intensification on the existing paddy lands is the critical strategy. The plan of irrigation development for the available farmland is the most suitable for improving Cambodian rice productivity. However, to develop new irrigation infrastructure requires high investment cost by the government or depend on overseas aids. It is necessary to enforce the existence facilities of both *Tomnub* and canal system with minimum cost.

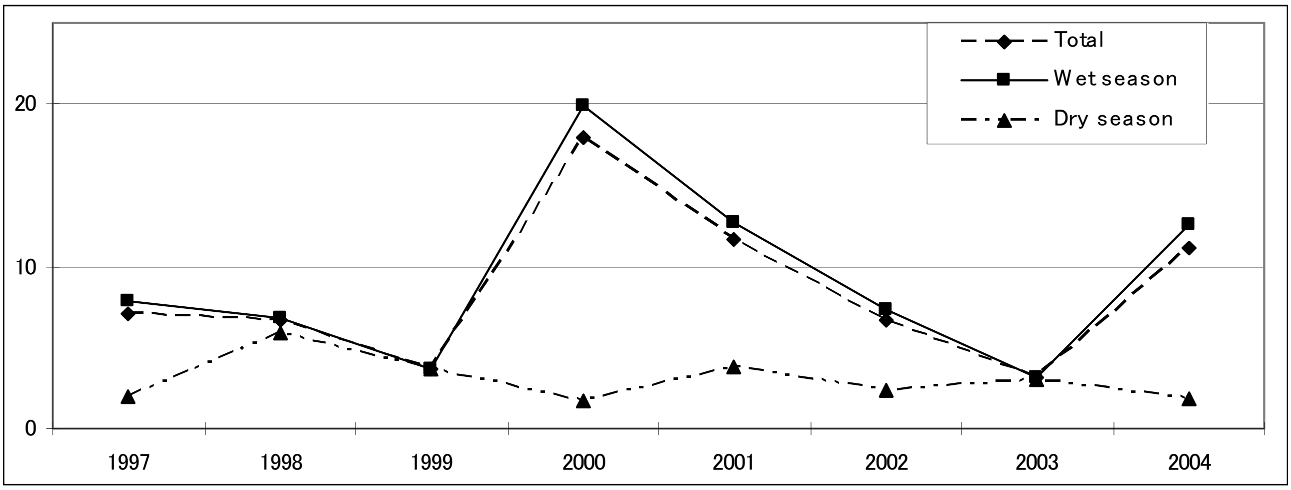
International development aids for Cambodia in agricultural sectors made great efforts to establish new irrigation infrastructure and to rehabilitate the destroyed and abandoned infrastructures. Thanks to the effort and stable peace situation, the dry season rice has been gradually increased in the past decade (Figure 1). According to the MOWRAM, some 3,291 irrigation schemes and total 1,014,300 ha area was irrigated as of 2003. From 1999 to 2003, 315 irrigation areas were rehabilitated and it covered 153,149 ha. The rehabilitation helped 113,500 ha and 16680 ha of land by protected from flooding and saline damages, respectively.

Figure 1: Development ratio of dry season rice in Cambodia, 1995-2004



Though rainfed lowland rice production transformed into the double cropping of rice, the majority of the production came from rainfed rice field in wet season and recessing rice in dry season. However, the production tends to suffer from either drought or flood or both constraints. For example, within one village, rice field located at one site of a road suffered from drought while rice crop at another site of the road was destroyed by flood. Destroyed cultivated rice area by flood and drought often reached more than 5 % of total rice cultivation area and reached 20 % of wet season rice by flood in 2000 and 13 % of wet season rice by drought in 2004 (Figure 2). The unstable rice production condition gave strong negative impact for the fragile rural poor. Development of the irrigation facilities is necessary not only for the dry season rice production but also for improving wet season rice yield through the supplementary irrigation.

Figure 2: Percentages of destroyed area of rice cultivation area in Cambodia, 1997 - 2004



Irrigation policy and farmer water user community (FWUC)

Outline of the irrigation policy in Cambodia

Recently many development and rehabilitation projects of canal based irrigation have been on going by several foreign aids including the key donors of Japan European Union countries. At the same time, the Royal Government of Cambodia which regard irrigation systems as top priority starts to implement the irrigation water usage association in rice growing area, named Farmer Water User Community (FWUC) and participatory irrigation management and development (PIMD) to let farmers have their ownership sense of the canal maintenance as well as to minimize the supporting cost from the government. Development of the irrigation facilities is necessary not only for the dry season rice production but also for stabilizing and controlling water of wet season rice cultivation. The community scale of canal based irrigation has been long history in Cambodia but participatory irrigation management is recently formed.

Since water is essential to improve food security and more importantly can contribute to the national economy in Cambodia because around 85 % of its total population are farmers, the restoration of existing irrigation systems and reconstruction of new infrastructures have been hectically worked by the Royal Government of Cambodia in collaboration with international donors, NGOs and private companies and others. There are several main tasks which need to be carried out by the government to achieve sustainable irrigation policy. First, irrigation systems are effectively used and maintained for long lasting. Using capacity and irrigating potential are also increased. Next, any misuse and destruction of irrigation systems is prohibited. International aids for the irrigation systems are targeted. And also private investment on the area is encouraged. Furthermore, farmers are encouraged to maintain the irrigation systems and take ownership responsibility. Eventually, irrigation systems management is transferred to FWUC. Hence, annual national budget can be gradually deducted and sustainable policy of irrigation systems can be successfully implemented.

MOWRAM has an important role to play to carry out the sustainable policy of irrigation systems. MOWRAM submitted to the parliament the Law on Water Resource Management in April 2004 which is currently still under reviewing process (as of June 2005 from personal communication with a MOWRAM officer). Chapter IV (Article 19) in the draft of the law refers to the collective effort by farmers for irrigation water usage hence the government prepared sub-decree of the FWUC. There are many different kinds of group activities regarding irrigation water in Cambodia funded by different organizations, such as international organizations and NGOs. MOWRAM needs to conduct study in order to assess irrigation systems across the country to achieve the sustainable policy of irrigation. The ministry needs to design and construct the irrigation systems and infrastructure to guarantee that farmers can access irrigation water. Preparation of statute for FWUC and formation of FWUC are carried out by the ministry in collaboration with other involved authorities.

According to the report from MOWRAM, some 66 FWUC were established in the 13 provinces (Table 2). Even though the formation of this association commenced in 2000, the majority of FWUC was completed in 2003 and other was also on forming. The number of FWUC was quite variation from one province to another, e.g., there was 10 communities in Kampong Cham compared to only one community in Sihanouk Ville. The number of FWUC may not correlate to the number community member except for Takeo Province because locations with more communities had fewer members than less community locations. This would result from different land size holding of individual household in different provinces. The total area covered by FWUC was almost 90,000 ha including around 37,000 ha of dry season rice area. Every FWUC could not be operated for both dry and wet season. According to the report, of the total communities only 16 could supply both seasons while 30 were the sources of dry season only and 19 were using as supplementary of wet season rice.

Table 2: The establishment and operation of water use communities

Province	No of FWUC	Established year				Operating season			Total Number of members	Average Number of members	Area covered (ha)		
		before 2001	2002	2003	On forming	Dry only	Wet only	Both			Dry season	Wet season	Total
Banteay Meanchey	6	1	0	3	2	1	2	3	3,434	572	7,654	7,891	15,545
Battambang	5	0	4	1	0	0	3	2	5,361	1,072	800	15,388	16,188
Kampong Cham	10	0	3	7	0	4	3	3	5,731	573	7,100	2,000	9,100
Kampong Chnang	3	0	0	3	0	0	2	1	12,924	4,308	540	2,200	2,740
Kampong Speu	4	1	1	2	0	1	0	2	3,487	1,162	1,900	700	2,600
Kampong Thom	3	0	0	1	1	1	2	0	450	150	350	500	850
Kandal	3	1	2	0	0	3	0	0	1,086	362	2,396	0	2,396
Posath	4	0	0	2	2	0	3	1	2,000	500	300	4,735	5,035
Prey Veng	8	2	1	4	1	7	0	1	4,075	509	1,743	500	2,243
Seam Reap	4	0	0	4	0	2	1	1	2,756	689	4,127	8,202	12,329
Sihanouk Ville	1	1	0	0	0	0	1	0	6,655	6,655		8,800	8,800
Svay Rieng	6	0	1	4	1	3	2	1	4,938	823	2,800	950	3,750
Takeo	9	1	3	6	0	8	0	1	27,765	3,085	7,592	50	7,642
Total	66	7	15	37	7	30	19	16	80,662	1,222	37,302	51,917	89,219

(Source): MOWRAM (2004) Report in the activities in the ADB loan project No 1445-CAM(SF) of the Ministry of Water Resource and Meteorology from January to June 2004

The statute/regulation of FWUC including 8 chapters and 40 articles was developed as the standard across the country in order to be effectively implemented. The key points of the statute are name and objectives of each FWUC, criteria of membership, committee members' term and roles, costs and returns, actions, orders and fine/penalty. Besides implementing the statute, the committee of FWUC has to organize and operate the community well with self responsibility. The committee has to solve any crisis resulted from irrigation water use. Most importantly, the group has to collect money from all members defined by the committee.

The sustainability of FWUC depends on certain of main factors but financial issue is likely to be the most important point to support the community (Perera, 2006). Concerning long-term running of the community together with limited budget from the government, five-year descent subsidy is paid by the government commencing from the year of formation. According to MOWRAM, within the first year of the community establishment, government supports 80 % of the maintenance cost of irrigation facilities, then every year reduced by 20 % each, then in the fifth year and after, member farmers paid 100 % of the cost by themselves. The members of FWUC have to pay for full fee, cost USD 10/ha, from the fifth year in order to keep operating of the association. Defining water fee was the result of yield analysis indicating that 20 % yield increase after the operation of irrigation systems. The operating costs are allocating for maintenance, fuel, committee members' incentive, and administration and overhead costs. However, the bequeathing the management autonomy by sharing the cost sometimes may face difficulties because most of the subsistence farmers could not afford to pay for irrigation fee especially crop failure by frequent flood, drought and severe pest constraint even though the regulation is under enforcement.

Besides natural constraint, management and technical issues are also generally recognized as critical problem (MOWRAM, 2003). Water distribution can be affected by shallow/disrepair canal, broken dam/bank and field location. Schedule, time and quantity of water delivery can lead to water competition or taking advantage and conflict eventually. Furthermore, it is widely recognized that the management would be difficult for irrigation systems with large reservoirs, cover large area of paddy and numerous members. There would be conflict between farmers and committee of FWUC/government if there is too much pressure of water payment from the latter while the former harvest very poor or no yield. But controversial issue may also happen if the farmers are excluded from FWUC members because they keep declining to pay water fee consecutively. In contrast, FWUC would become inactive or collapse if no measure is taken to water fee collection due to no subsidy from government. How to activate FWUC substantially seems the major concern for the Cambodian government.

Therefore law alone without understanding and participating from implementers/users may not be enough to keep irrigation systems sustainable. The Ministry has tried to uniform these different management systems to consolidate under unified regulation in which concept was based on participatory irrigation management. It is critical for farmers to understand the purposes of FWUC formation and fully collaborate with committee members. An analysis of situation, ex-ante and ex-post the establishment of FWUC need to be widely extend to farmer circle. Capacity building of FWUC needs to be provided to both farmers and committee members that enable them to be functioned irrigation systems and infrastructures effectively (MOWRAM, 2003). They also need to be trained to define, analyze and solve problem by themselves. The formation of FWUC is hypothesized to implement sustainable water policy.

Irrigation water usage situation in the case study site

The community of Baray Irrigation Scheme (BIS) was established in 2002 and first election for selecting FWUC committee members was held in 2003. Though the year of community establishment was quite recently but East Baray reservoir was constructed in the Angkor era (around 890AD). Main canal is 2.9km followed by secondary 59.2km and tertiary 150km canal. Secondary and tertiary canal was rehabilitated in 1975 however, there were so many conflict/fighting/arguing cases happened especially before forming the community. Though both main and tertiary canals have been restored in this area, there is not enough water in the both dry and wet season due to the poor canal physical condition.

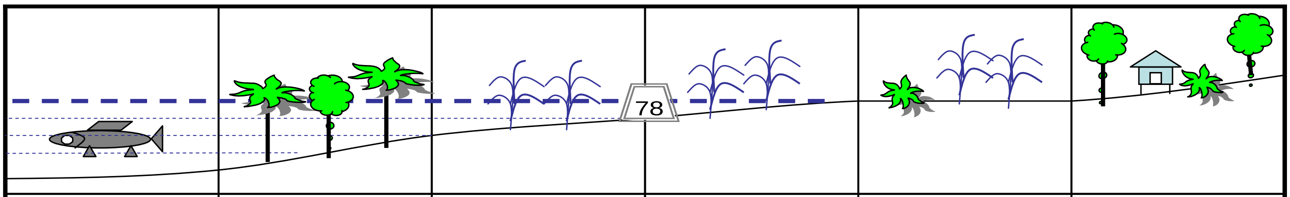
In order to manage irrigation system, well maintain infrastructure, solve conflicts and well operate irrigation water distribution, FWUC of BIS located in Khnath Commune, Pouk District of Siem Reap Province was officially formed in August 2004 after the committee member were elected, and the new FWUC got the approval from MOWRAM. The committee comprised of one head, two deputy heads responsible for planning, repairing and water delivery, one accountant and all heads of farmer water use groups as members. The committee consisted of six group farmers and 27 subgroups with village base because of field location conditions. However, the actual activities such as collecting irrigation fee and/or maintaining canal are carried out by village (*Phum*) based. The management and implementation of Baray irrigation scheme is based on the statute/regulation.

Inundated water from Tonle Sap Lake in the wet season is reserved inside dams and it is used for especially at the beginning of the dry season rice production while the source of BIS is irrigated from the second irrigating until harvesting. Ending wet season enter into dry season, farmer used the land inside the main dam constructed during the Pol Pot time for rice cultivation according to the water receding, named recession rice. Though BIS has canals, the rice farmers in the area face chronic water shortage of irrigation water so that they also use *Tomnub* (dam reservoir) water. One of the main dams is named "*Tomnub* 78" which build in 1978.

From field observation, discussion with commune councils and maps, the study sites can be divided into six distinguished sections with the differences of topography, land elevations, flood water regime of Tonle Sap Lake and agro-ecosystems through the cross sectional view (Figure. 3). There was flooding whole year round in the Tonle Sap Lake region though it is shallow during dry season or even only muddy at certain places. The area is quite rich of fish and it was fishing zone in dry season. Flood forest zone or wet land area, where flood only in wet season, is next to Tonle Sap Lake. This area is covered by small trees or bushes which are resistant to flood for several months. Even though dry season rice production is encouraged, clearing bush in the zone is prohibited because it affects both fish laying egg hosts and environments. The zone followed by dry season rice area also flooded in wet season. Soon flood water recede, farmers commence to sow rice seed as dry season rice cultivation using both flood water at early stage and BIS water at later phase. Between dry season rice and recession rice area are separated by *Tomnub* 78. Rice cultivation in this area was also at the start of flood receding but a couple of weeks earlier. Farmers in the study sites considered as recession rice rather than dry season rice. In the same section, early harvest wet season rice is also cultivated.

Photoperiod-insensitive short duration variety is transplanted at the beginning of wet season and harvested just before rising flood. Next to recession rice area is rainfed lowland rice area where flood of Tonle Sap could not be reached. Photoperiod sensitive traditional variety is favorable for cultivating in the area. Other cash crops, corn, sugarcane, mungbeans and vegetables, are grown in dry season using BIS for irrigation. Last zone of transect in the Figure 3, the highest land elevation in the locations, is residential area where vegetables and fruit trees were cultivated for home consumption and additional household income.

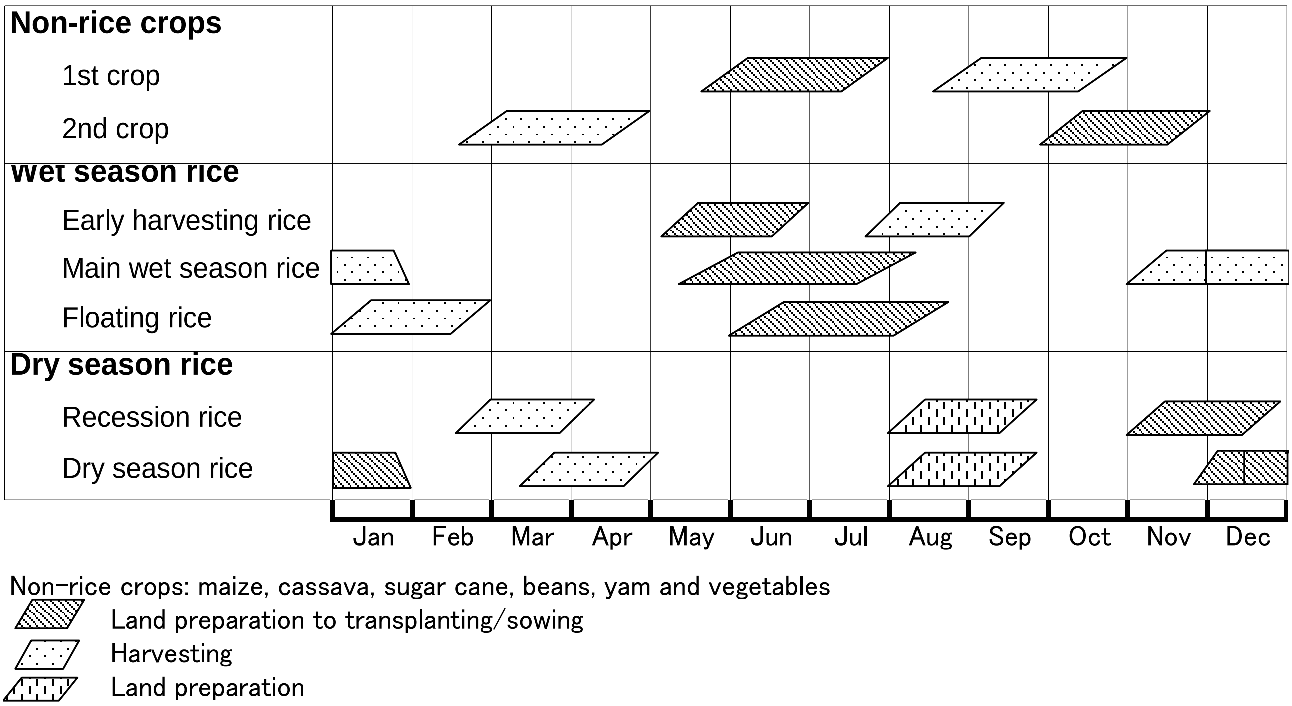
Figure 3: Transect of survey sites



Tonle Sap Lake	Flood forest area	Dry season rice (Outside dam 78)	Recession (Inside dam 78)	Rainfed lowland rice	Villages
- Flooded whole year - Fishing zone in dry season	- Flood in wet season - Fish feed source and lay egg in wet season	- Flood in wet season - Dry season rice in dry season	- Flood in wet season - Recession rice in dry season rice	-Rainfall -Wet season rice - Cash crop in dry season	- Residential area - Vegetables and fruit trees

Figure 4 shows the cropping calendar representing the cropping system in the study area. As for the rice, farmer's identified five types of cropping patterns though floating rice is rarely shown in the survey sites. Three main cropping patterns, non-rice crops, wet season rice and dry season rice, can be identified from the study sites. The main non-rice crops include maize, cassava, sugarcane, beans, yam and vegetables. There are two non-rice crops per year, wet season and dry season but the majority is cultivated in wet season. The cultivation of first crop kick off in May completed in June and harvested between August and October. The second crop starts during October and November and need to be harvested in March and April. Wet season rice comprises of three patterns, early harvesting rice, main wet season rice and floating rice. The first two patterns are began to cultivate at similar period, May and June but one crop is harvested shortly before coming flood in August and September while November and January are the harvesting time for main wet season rice. Floating rice can be started a bid late and harvested until flood receding. As mentioned earlier, there are two crop patterns in dry season due to the different times of cultivation and harvesting and field conditions. Farmers conduct land preparation for both crops in August and September but one crop could be sown and harvested around one month earlier, that is, between November and March, named recession rice, and between October and April, named dry season rice.

Figure 4: Crop calendar in survey site

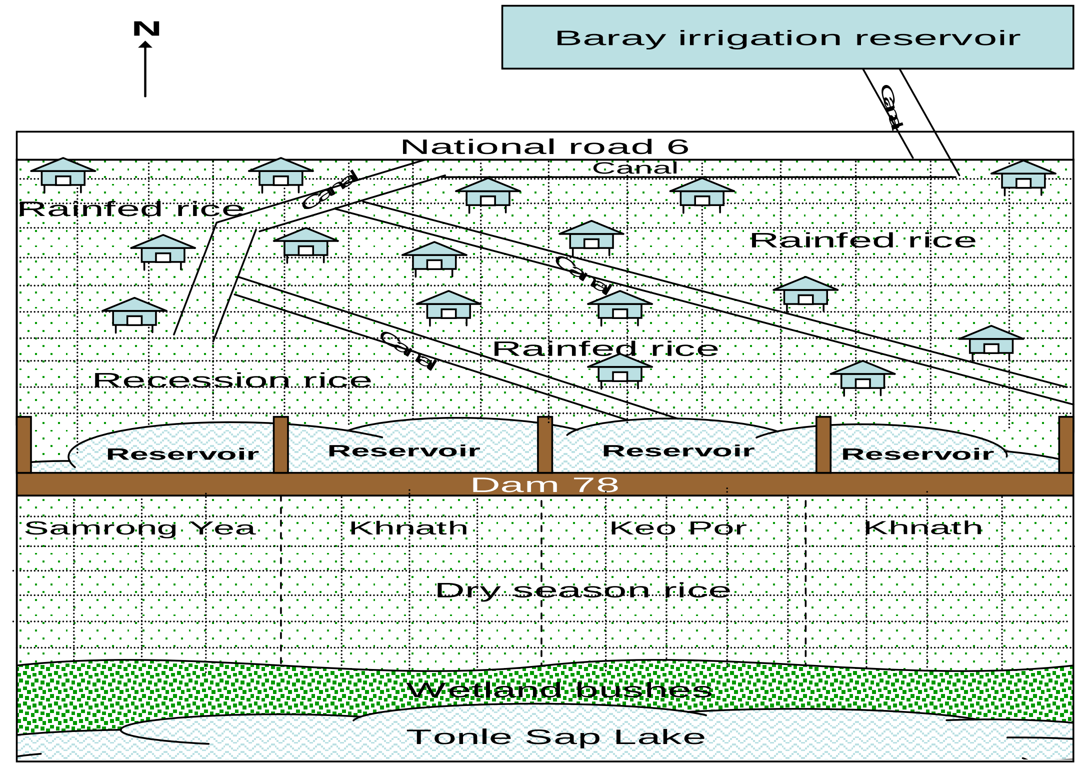


Case study: Two communes in baray irrigation scheme

Outline of the respondents

To identify the issues on irrigation situation in the survey sites, two communes, namely Samrong Yea and Khnath was selected with 150 and 151 farm household respectively for interviewing. The BIS covers 8 communes and 1400ha of land. Among the 8 communes, three communes including Samrong Yea and Khnath have dry season rice (Fig 4). It means these three communes can use both Baray water through canal for wet season rice and *Tomnub* water for the dry season rice. We selected two of them to identify the water usage situation in the both seasons. Figure 5 shows the outlay of the study communes and their land use situation in wet and dry season.

Figure 5: Location of the survey communes



The age of respondents of both communes was quite close, only two years different in average with comparable median and standard deviation and similar range (Table 3). In overall, the age of the interviewees was 44 even if there was quite broad gap between the oldest and the youngest interviewees, 83 and 17 but this was only few cases according to the standard deviation. Since the respondents and household heads could be different, the age of household head was older than the respondent with an average of 47 years old because the interviewees could be wife and other young family member. Even though the interview was randomly conducted, the proportion between male and female respondent was fairly equal, especially number of female was higher than male respondents in Samrong Yea Commune, 79 to 71. It was very common in Cambodia that household head was male but at 39 and 30 out of 150 and 151 in Samrong Yea and Khnath respectively were female household heads. According to the average age and ratio between male and female, they were appropriate source of information for the study because the respondents were enough experienced people in farming. The information collected can represent common practices in the area.

Table 3: Outline of the survey respondents

Location		Respondents age	Household head age	Sex	Respondent	Household head
Samrong Yea	Average	43.05	47.64	Male	71	111
	Std Dev	13.97	12.52	Female	79	39
	Median	44.00	47.00	Total	150	150
Khnath	Average	45.41	47.58	Male	86	121
	Std Dev	13.76	11.84	Female	65	30
	Median	45.00	46.00	Total	151	151
Total	Average	44.24	47.61	Male	157	232
	Std Dev	13.89	12.16	Female	144	69
	Median	44.00	46.00	Total	301	301
	Max	83.00	79.00			
	Min	17.00	22.00			

The average household size of the two locations was almost the same, around 6 persons per household but few households could have as many as 13 members while few other as less as 1 (Table 4). Average size of owned land was 1.9 ha and 1.7 ha in Samrong Yea and Khnath Commune, respectively. Some 24 % of respondents are classified under size of 1.0-1.5 ha followed by 21 % under 1.5-2.0 ha. The total land the farmers owned was divided into four different categories according to field conditions and crop cultivations, rice and non-rice in wet season and rice and non-rice in dry season. Both operated land and land owned, dry season rice area was larger than wet season rice area for both communes. Concerning non-rice crops, there was only 0.2 ha in average for cultivation and some farmers even used wet season rice field for the field crops in dry season. Therefore, the total land owned tended to be smaller than the sum of operated land. Dry season field was classified into two categories by *Tomnub* 78. Due to land elevation, flooding period and cultivating time, inside dam field was named recession rice (early dry season rice) and late dry season rice for outside dam area. The average field plot outside dam was larger than that of inside dam in particular Khnath Commune 0.75 ha compared to 0.22 ha. Total land holding of the study was fairly large, almost 2 ha, compared to other rainfed lowland area in Cambodia but the standard deviation was larger was 1.2 ha. Hence, with considerably household size, it would be difficult for farmers to produce surplus output without increasing crop cultivation per year. Since most of rice field flooded in wet season and only some farmer owned small favorable plot for non-rice crops, dry season rice would be the most important crop in the areas.

Table 4: Relations between household size and land holding and operated field

Commune		House hold size (person)	Cultivating area (ha)					Total owned land (ha)
			Wet season 2004		Dry season 2004/05			
			Rice	Non-rice	Rice (outside dam)	Rice (inside dam)	Non-rice	
Samrong Yea	Average	6.30	0.95	0.23	0.96	1.09	0.32	1.91
	Std Dev	2.06	0.70	0.30	0.75	0.78	0.27	1.30
	Median	6.00	0.80	0.15	0.71	1.00	0.20	1.68
Khnath	Average	6.24	0.67	0.27	1.00	0.83	0.23	1.72
	Std Dev	2.08	0.61	0.35	0.77	0.45	0.13	1.10
	Median	6.00	0.50	0.15	1.00	1.00	0.20	1.50
Total	Average	6.27	0.81	0.26	0.98	1.00	0.26	1.82
	Std Dev	2.07	0.67	0.33	0.76	0.70	0.20	1.20
	Median	6.00	0.60	0.15	1.00	1.00	0.20	1.53
	Max	13.00	4.00	2.00	6.00	4.00	1.00	11.00
	Min	1.00	0.02	0.02	0.04	0.04	0.01	0.10

Irrigation facilities and usage of water

Since the question of paper was address to irrigation policy and its management as main topic, irrigation facilities and sources were needed to be outlined. Baray reservoir and river-flood were the most important irrigation sources for farming especially dry season rice. Regardless of Baray or river-flood, irrigation was generally carried out by gravity canal but some 17 and 4 from Samrong Yea and Khnath respectively reported that they need to pump from canal (Table 5). Concerning river-flood, small or large dams were used to store water in wet season and irrigate in dry season. However, other sources of irrigation such as underground water or shallow tubewell using pump was also reported by 24 farmers from both communes. Not all but some farmers owned irrigation pump and some other also rent pump if it was necessary for their farming. Irrigation pump would not be important facility for irrigation especially dry season rice production but rather for seedbed and field crops such as corn and sugarcane cultivated where gravity was not applicable. It would be also used for upper wet season rice fields when drought occurred. The condition of irrigation system was quite favorable for dry season rice because there were two sources of irrigation water and they were done by gravity. River-flood was supplied for early phase of rice crop and followed by Baray reservoir before harvesting time. However, the condition would be critical if the river-flood could not reach paddy fields and precipitation was very low.

Table 5: Number of farmers by irrigation sources for both wet and dry season rice and other crops

Commune	Irrigation sources					Owned irrigation pump
	Irrigation canal		Underground or shallow tube well	River or creek	Reservoir or dam	
	by gravity	by pumping				
Samrong Yea (n=150)	145	17	10	41	54	12
Khnath (n=151)	137	4	14	50	44	16
Total (n=301)	282	21	24	91	98	28
%	93.7	7.0	8.0	30.2	32.6	9.3

Irrigation fee payment situation

Concerning irrigation fee paid last year, around 140 and 120 farmers in Samrong Yea and Khnath respectively paid the water fee for dry season rice while some other reported paying for wet season rice as well. Even though number of farmers paid for water fee was high last year, number of farmer who have experienced a failure to pay the fee over a period of time was also considerably high. The payment of water fee could be in cash and in-kind depend on irrigation sources the farmers used. Payment was collected by FWUC members in cash after harvesting for those who was able to access BIS. Since the communes were under the same FWUC, average water fee was not much different, approximately 9,000 riel/ha with the standard deviation of 3,000 riel (Table 6). But the payment was negotiable between individual farmer and water fee collector due to different reasons hence the variation of the cost was very large ranging from 1500 to 20,000 riel/ha.

Table 6: Different kinds of irrigation fee payment for both BIS and dam guardians

Location	In cash payment for canal water from BIS		In kind payment for dam guardians in dry season		
	Riel/ha		Medium of payment	No of cases	average (kg or riel)
Samrong Yea	Average	8,831	Pay in kg basis	24	21.6
	Std Dev	2,802	Pay in riel basis	16	6875.0
	Median	10,000			
Khnath	Average	9,161	Pay in kg basis	24	35.4
	Stdev	3,211	Pay in riel basis	1	5857.1
	Median	10,000			
Total	Average	8,976	Pay in kg basis	48	28.5
	Stdev	2,988	Pay in riel basis	23	6565.2
	Median	10,000			
	Max	20,000			
	Min	1,500			

The payment for reservoir water of river-flood source such as *Tomnub* 78 and other reservoirs was mainly by in-kind except some farmers paid in cash. It was paid for dam guardians and not for FWUC. Water fee for this source seemed to be household basis annually with an average payment of 22 kg and 35 kg per household in Samrong Yea and Khnath respectively. Cash payment was also not a hectare basis, that is, one farm family paid about 7000 riel in Samrong Yea and 6000 riel in Khnath.

Failure to pay and insufficient amount of payment of annual irrigation fee were caused by variety of factors reported by the respondents. More than 50% of the farmers who failed to pay irrigation fee, total of 42 respondents with 19 farmers from Khnath, was reasoning that their crop was destroyed and further they spent much cost on labor. Some 12 farmers in both communes mentioned that they would pay but it was late due to the paddy was not yet sold. The rest indicated that the payment was done according to quantity yield harvested.

Meanwhile almost 60 interviewees claimed that water fee was always paid to FWUC because of many different reasons but main factors can be summarized that: the fee was paid but it depend on harvest yield quantity and it was accepted by FWUC. Reasons were also raised that payment was in exchange for water and the fee was used for constructing water gate which was for their own benefit. Without water, crop was destroyed hence water for irrigating was needed. Some farmers implied that if failure to pay this year, they would not be allowed to access irrigation water next year. Reasons were reported that water was needed so the fees need to be paid to the government. On the other hand, sooner or later payment was done at home rather than at FWUC. It was also argued that the water fee was used for maintenance and construction of irrigation facilities but if it failed to pay, it would lead to shut the water gate. The money was an exchange for water with the government and this was a contribution to the government.

Even larger number reported that they always paid the irrigation fee, water payment seemed to be one of complicated issues of irrigation community. Farmers' contribution was very important because the supports from the government have been deducted from the second year and are zero from fifth year onward. Though reasons were explained by water users, failure to pay or insufficient payment could have adverse impact on FWUC's policy and management in the long run. We have to take into consider the fact that farmers seemed to aware the importance of payment, however, rationale behind the unwillingness to pay of water fee are caused by the low and unstable productivity.

Chronicle water shortage problem

Since crop damaged/destroyed was closely related to payment of water fee – fully pay, insufficiently pay and failure to pay, constraints attributed to poor yielding was taken into considered. Of the constraints, drought and flood were the main factors affected the crop yield and submergence was also reported. In Samrong Yea, around 33 % of crop was severely damaged by both flood and drought and 23 % and 19 % were destroyed by individual factor of flood and drought respectively (Table 7). But almost 54 % of the crop was severely experienced by drought alone in Khnath. Both flood and drought seriously affected the crop but flood alone was unlikely the main risk. Furthermore, water shortage was directly concerned with water fees though it would not severely affect the crop. Some 45 % and 56 % of respondents in Samrong Yea and Khnath respectively reported that they experienced water shortage.

Table 7: No of claiming about damaged by flood, drought and submergence

Damaged by	Samrong Yea		Khnath		Total	
	No of farms	%	No of farms	%	No of farms	%
Drought	29	19.3	81	54.4	110	36.8
Flood & drought	49	32.7	39	26.2	88	29.4
Flood	35	23.3	5	3.4	40	13.4
No problem	15	10.0	14	9.4	29	9.7
Flood, submergence & drought	10	6.7	2	1.3	12	4.0
Drought & submergence	4	2.7	3	2.0	7	2.3
Submergence	1	0.7	0	0.0	1	0.3
Flood & submergence	1	0.7	0	0.0	1	0.3
Not specify	6	4.0	5	3.4	11	3.7
Total	**150**	**100.0**	**149**	**100.0**	**299**	**100.0**

Water shortage was not only caused by water itself but also resulted from management, participation and responsibility of all parties involved. Even many questions were raised by the farmers in both locations; farmer community was main root to water shortage in the two communes. Total of 20 farmers, 16 from Khnath, stressed that water shortage resulted from upper stream farmers took advantage by shutting the gate to irrigate their fields. Other 17 farmers from Khnath as well pointed out that shallow and small canals led to water shortage for them too. So farmers in this commune would own paddy field at lower part or far end of the canals. Number of 9 farmers from the same commune reported that severe water shortage occurred in late season, sometime in March, in 2003 and 2004. This argued that shortage was not always taken place but in particular year and month. Other difficulties identified by some farmers in both places were very distant fields from canal, dry season cultivation, higher field with un-leveling, poor reservoir condition and problems related to collaboration among the farmers and water distribution.

Management issues of FWUC

Concerning problems within the irrigation water community, similarly farmers mentioned the issues of irrigation physical condition, farmer collaboration and management. At least 27 respondents implied that there were problems in the irrigation water community but they did not give any specific reason or hesitated in interviewing (Table 8). When it was involved management work, farmers did not want to express own views or they were cautious. Apart from management, such problems as poor canal condition and field condition and location, and collaboration were the key issue led to further obstacles and even conflicts. Lack of responsibility and cooperation among farmers in maintaining irrigation facilities such as deepening canals, building canal and taking care of water gates, pipes and bridge could lead to poor water distribution. Late water supply, unequal and irregular water distribution by FWUC brought about to water competition, argument and eventually conflict among the farmers. Contribution from community members to FWUC seemed to be very limited. It was not just financial capital but also human and social capital which were essential for the community.

Table 8: Problems regarding FWUC

Do you find any problems about the irrigation water community Answer "Yes"	Samrong Yea	Khnat	Total	%
Upper stream farmers shut gate/Located lower stream	8	26	34	22.7
There are problems (hesitate to tell specifically)	15	12	27	18.0
Water shortage problem (not specific reasons are given)	10	15	25	16.7
Water supply is not smoothly done/ Late delivery	17	2	19	12.7
Distribution is not equal	2	11	13	8.7
Water competition	7	5	12	8.0
Insufficient canal system (shallow, destroyed)	3	3	6	4.0
Filed location (higher field)	4	1	5	3.3
No Cooperation among users	2	2	4	2.7
FWUC did not help	2	0	2	1.3
Others	1	2	3	2.0
Total	71	79	150	100.0

Some 78 and 80 interviewees indicated that there was general problem within FWUC in Samrong Yea and Khnath respectively (Table 9). Of the four main issues raised, competition over water and being taken advantage were predominant cases in both locations followed by participation in activities and water fee payment failures. Water competition and taking advantage could lead to argument or even conflict among community members. In Samrong Yea, there were 51 respondents who reported that argument for water occurred and other 17 farm households claimed that argument was sometimes as severe as quarrel and insult each other (Table 10). Further more, at least one farmer revealed that the water competition led to fighting among the villager when rice crop was in critical condition due to drought. Similarly, of interviewing farm households, 45 and 16 respondents of Khnath mentioned that argument and serious argument with quarrel respectively took placed.

Table 9: Number of farmers who claim the problems regarding FWUC management and among members

		Any problems about FWCU	Competition over water	Being taken advantage	Failure to pay irrigation fee	Failed to participate in activities
Samrong Yea	Yes	78	84	88	37	45
	No	69	66	62	113	105
	No specify	3	0	0	0	0
Khnath	Yes	80	68	83	49	64
	No	47	79	61	101	86
	No specify	24	0	7	0	0
total	Yes	158	152	171	86	89
	No	116	145	123	214	191
	No specify	27	0	7	0	0

Table 10: Experiences of argument toward water usage among farmers

	Samrong Yea	Khnath	Total	%
Argument	51	45	96	64.9
Argument and quarrel	15	16	31	20.9
Argument and insult each other	2	0	2	1.4
Fighting	1	0	1	0.7
No specify	13	5	18	12.2
Total	82	66	148	100.0

Other difficulties within FWUC were the participation and contribution from community members. Almost 40 farmers from the communes reluctantly replied that they failed to participate in community activities because of different reasons. Most farm household who failed to attend the community's gathering indicated that they were busy with field work, other work or labor-less due to schooling children. Some other also gave reasons that they were sick and they paid in cash alternatively or their kids went instead. Few others also blamed the village or commune heads for failing to invite them to community's activities.

However, many other respondents stressed that they contributed to the community's activities through household resources and labor input. A similar answer from whom if failed to attend, paid cash to community and hired labor to work for them were the response of 15 farmers (Table 11). Another group of interviewee pointed out that their participation was to improve the canal such as deepening canal because they need water for irrigation and it was also common benefit. Failure to work for the community resulted in stopping accessing irrigation water and working alone later on could push them to participation. The purposes of learning from community, equal water distribution, peaceful solution to water competition, taking advantage and conflicts were also encouraged the farmers to joint the activities. Several negative points occurred in the irrigation community gave rise to water shortage or own benefit. Conflict among members themselves and members and leaders was the most sensitive subject because it weakened the community where collective action was newly introduced.

Table 11: Reasons why attended the FWUC activities

Reason why attended the community activities	Samrong Yea	Khnath	Total	%
Have to pay fine for absence or work later	3	18	21	23.3
Because water is important resource	8	6	14	15.6
Deepened canal together	4	6	10	11.1
I want to know the canal maintenance / irrigation systems	6	2	8	8.9
I want to share water equally	4	3	7	7.8
It was for both my own and common benefit	5	1	6	6.7
I was afraid of not allow to use water next season	1	5	6	6.7
I want to know the community's activities and its planning	3	2	5	5.6
I wanted to know how to avoid taking advantage	0	4	4	4.4
In order to solve problem peacefully and exchange idea	1	2	3	3.3
To avoid criticize / conflict from others	0	2	2	2.2
Others	1	3	4	4.4
Total	36	54	90	100.0

Recap of the focus group interviews

To clarify the above mentioned farmers' interview, focus group interview for the three groups from each commune was held. The six groups of discussions stated similar problems in their rice production that was water shortage and insects such as stem borer and thrips though severity level of affect was different. But water shortage was likely the critical issue among the identified constraints. The groups presented different causes of water shortage such as slow/late water distribution as dikes/banks of main canal were destroyed. The water gates located in lower stream of main canal were shut while main gate was opened hence volume of water in the canal increased and overflowed the banks/dikes with strong current that led to cut off banks/dikes easily. Shutting gates was committed by unknown people because the gates were not properly locked. Even though there was no evidence, this violation was purposely done in order to wet the fields around the broken banks/dikes. These responses from focus group discussions consisted with the response of the field survey interview from farmers.

Another group pointed out the broken canal banks but it was disturbed by cattle, buffalo and duck flocks when water level increased to overflow the dikes. The soft soil was prone to erode due to the heavy track of animals. Dike erosion was also disclosed by the group of village head and FWUC members but this group also blamed that the secondary canal flowed across another commune so it led to late water delivery if water was shortage. Few members of this group mentioned that it was difficult to collect water fee from farmers because farmers declined to full irrigation fee by giving reason that rice was damaged. They blamed the neighboring commune that their new bridge construction, clearing bushes in canals and taking water in the upper stream. Water gate was shut to construct bridge or repair canals while water was required critically for rice crop. They were likely to blame another commune located at upper stream of the canal for the matter.

Even though the groups indicated different explanations attributed to water shortage, irrigation infrastructures and community members as whole were the main factors to the constraints. Budget was unquestionably essential resource for water irrigation scheme but participation and responsibility of community member were inevitable to well operate the irrigation systems. Linkage and talk between neighboring communes will be helpful to understand each other to get them in the right mood for cooperation.

Conclusion

Introduction of recent irrigation policy and community-based irrigation management in existing Cambodian irrigation is analyzed in the paper. Irrigation water remains the essential factor in rice production since this crop requires most controllable water at all stages of crop cycle even though new technologies – rice varieties, planting methods and crop management, have been introduced by rice researcher. The potential yield can be severely affected when the crop experienced water shortage or drought at any growing stage. More importantly, irrigation system is also a rich source of nutrients that can maintain and improve soil fertility. But the establishment of irrigation is very costly and time consuming for developing countries such as Cambodia.

Collective action is extremely important for irrigation water management because it is the common resource endowment. This resource is usually required by the whole rice farmer community at the same time and in the long run. Fully participation and closed collaboration from the community are desperately needed to manage the resource efficiently. All water user members need to bear responsibility for water management and equally benefit from the resource. The development of irrigation system is a great task but operation and management the systems is even greater task because the latter requires participation, collaboration and responsibility of the whole group. Further more, the project seems to be no limit time.

Recently Cambodian government has introduced a new policy on irrigation after many development and rehabilitation projects of canal based irrigation have been financially and technically supported by several foreign aids including the key donors of Japan European Union countries. The commencement of irrigation water usage association in rice growing area or Farmer Water User Community (FWUC) and participatory irrigation management and development (PIMD) is to let farmers have their ownership sense of the canal maintenance as well as to minimize the supporting cost from the government. The bequeathing the management autonomy by sharing the cost certainly faces difficulties because most of the subsistence farmers could not afford to pay for irrigation fee especially crop failure by frequent severe risks.

A field study was conducted in Baray Irrigation Scheme (BIS) of Siem Reap Province to analyze the situation and evaluate the community based irrigation maintenance and operation. Most of the respondent could pay fully or partially of the irrigation fee in the study site last year. But the number of paid farmers was inconsistent over a couple of years because farmers who have experienced a failure to pay the fee over years were also considerably high. Farmers' contribution is critical because there is no longer support from the government after fifth year of planning.

However, rationale behind the unwillingness to pay water fee was crop failure. This consequence gave rise mainly to drought and flood constraint. But the majority of production was severely affected by drought. Further, the factor of water shortage discouraged farmers from paying water fee. More importantly, water shortage resulted in deteriorating relationship among the farmers. When there was water shortage during the critical period for the crop, water competition, taking advantage, argument and eventually conflict occurred among the farmers. Besides, it was also ground that farmers failed to participate in the community's activities.

Physical condition of irrigation systems seemed to be one of the factors attributed to water shortage. Poor condition of irrigation infrastructure included shallow canals, water gates, pipes, canal banks/dikes and small canals. Even irrigation water was available, if irrigation systems and structure were in poor condition, irrigation could not be efficiently distributed. However, human factor also need to be taken into account to run this common resource. Well management, active participation, closed collaboration and full responsibility of all parties involved have important role to play in community irrigation.

The formation of FWUC, thus far, has been a step forward to improve both irrigation systems and farming in the area. Irrigation infrastructures have been repaired and improved otherwise the facilities were rapidly degraded and eventually useless. Moreover, operation and management were involved by all member farmers and they partly supported financial input and will take over the responsibility fully. Household economics could be improved through the recent irrigation policy because the condition of area is not favorable for wet season rice hence only dry season rice production was major source of income for the community. However, the consequents of implementing the new irrigation policy should be cautiously taken into consideration because this is just the second year of FWUC. Failure to pay irrigation fee, insufficient payment and large variation of payment among water users have an adverse impact on the financial issue because the community will be self-finance after withdrawal of the government's supports. Taking advantage, water competition, argument and conflict which gave rise to the constraint of water shortage would affect relationship within the community as a whole. Participation in community's activities and responsibility were not strongly committed by the community members. The drawback is fairly sensitive for the development of new irrigation policy at the commune level.

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ផែនទីកំណត់ទិន្នផលស្រូវ និងចម្លើយតបរបស់វាទៅនឹងការប្រើប្រាស់ជី នៅក្នុងខេត្តតាកែវ

Mapping Rice Yield and Its Fertilizer Response at Provincial-Scale in Takeo, Cambodia

Richard W. Bell, G. Pracilio, S. Cook, Ros Chhay and Seng Vang*

អត្ថបទសង្ខេប

យើងបានធ្វើការសិក្សាដើម្បីកំណត់តំបន់ឆ្លើយតបនៃដំណាំស្រូវទៅនឹងជីអាសូត (N) ផូស្វ័រ (P) និង ប៉ូតាស្យូម (K) នៅក្នុងខេត្តតាកែវ តាមរយៈលទ្ធផលដែលទទួលបានពីការពិសោធន៍ចំនួន ២៣៣៦កន្លែង។ ការវិភាគស្ថិតិវិទ្យា បានបង្ហាញនូវលំដាប់លំដោយនៃកត្តាសំខាន់ៗ ដែលធ្វើឱ្យមានបម្រែបម្រួលទិន្នផលស្រូវលើស្រែកសិករគឺ រដូវដាំដុះ ទីតាំង ជី និងប្រភេទដី។ ការវិភាគស្ថិតិលើទិន្នន័យដដែលបានបង្ហាញថា យើងត្រូវការគម្លាតអតិបរមា ១២គ.ម ពីចំនុចមួយទៅមួយ ដើម្បីធ្វើផែនទីទិន្នផលស្រូវទូទាំងខេត្តបាន។ ប៉ុន្តែបើបំបែកទៅតាមចំណាត់ថ្នាក់ចម្លើយតបនឹងជី N យើងអាចបន្ថយគម្លាតអតិបរមានេះមកនៅត្រឹម ៨គ.ម។ ផែនទីដែលបានធ្វើបង្ហាញពីតំបន់ដែលទំនងជានឹងមានការឆ្លើយតបទៅនឹងការប្រើជី។ ចម្លើយតបទៅនឹងការប្រើជី N និង K មានការប្រែប្រួលជាងចម្លើយតបទៅនឹងការប្រើជី P ដែលមានលក្ខណៈស្មើតែឯកសណ្ឋាននៅទូទាំងខេត្ត។ លទ្ធផលនៃការសិក្សាបង្ហាញនូវការឆ្លើយតបយ៉ាងខ្លាំងទៅនឹងការប្រើ N ជាពិសេសនៅតំបន់កណ្តាលនៃខេត្ត។ លទ្ធផលក៏បានបង្ហាញផងដែរនូវឥទ្ធិពលអវិជ្ជមាននៃការប្រើជី N កំរិតខ្ពស់នៅលើប្រភេទដីដែលសំបូរជីជាតិ (ក្រុមដីក្បាលពោធិ និងក្រគរ) នៅតំបន់ខាងកើតនៃខេត្ត និងនៅលើក្រុមដីប្រទះឡាង និងគោកត្រប់ នៅតំបន់លិចទឹកភាគអគ្នេយ៍នៃខេត្ត។ ផែនទីដែលបានធ្វើថ្នាក់ខេត្ត បានកំណត់នូវតំបន់នានា សម្រាប់ពង្រីកការផ្សព្វផ្សាយទៅកន្លែងដែលមានប្រសិទ្ធភាពបំផុត និងកន្លែងដែលតម្រូវឱ្យធ្វើការសិក្សាបន្ថែមទៀតដើម្បីកំណត់មូលហេតុនៃការមិនសូវឆ្លើយតប។ ដូចនេះវាអាចជួយពង្រឹងសមត្ថភាពធ្វើផែនការយុទ្ធសាស្ត្រ ដើម្បីផ្តល់នូវសេវាកម្មផ្សព្វផ្សាយ និងធនធានជីដល់កសិករ។

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Abstract

Our objective was to identify responsive areas for nitrogen (N), phosphorus (P) and potassium (K) fertiliser use on rice (*Oryza sativa* L.) within Takeo province from trial results obtained at 2336 sites. Regression tree analysis identified in order of decreasing importance the following factors which explained the variation in yield from on-farm experiments: season, location, fertiliser, soil type. Semi variograms of the same data set indicated that a maximum spread of 12 km in datum points was required to map yield across the province. Separating the results into N response classes decreased the maximum spread of datum for mapping to only 8 km. The maps generated indicated areas in which response to fertiliser is more or less likely. Whereas P responses were predicted to be relatively uniform across the province, N and K responses were more varied. Results suggest a very strong positive response to N, particularly on the central-west of the province. They also suggest negative effects of high N rates on the most fertile soils (Kbal Po, Krakor) in the east of Takeo, and in the Prateah Lang and Koktrap soils in the flooded areas of the south east of Takeo. At the provincial scale, the maps identified areas that can be used to target extension effort to where it is likely to be most effective, and areas where further research is needed to clarify reasons for poor responses. This should enhance the strategic planning capability for delivery of extension services and fertiliser inputs.

Keywords

fertilizer, location, mapping, rice, season, soil type, yield.

Introduction

In Cambodia, as in most parts of the world, national research programmes have developed nutrient management advice based on fertiliser recommendations that are generalised to soil types (e.g. White et al. 1997a,b). Traditionally fertiliser recommendations have been based on mean responses for particular soils and ecosystems (Dobermann and White 1999), derived from responses for a number of experiments, replicated across locations and seasons. The variability of the responses is often not reported or not emphasised. However, farmers' make decisions about fertiliser based among other things on specific responses expected on their land, and for their decision making the variability is as important as the mean response.

Avoidance of risk occupies a more important position in the decision making of rainfed farmers than for irrigated farmers (Ziegler and Puckridge 1995). Farmers in the rainfed lowlands have traditionally used little fertiliser, and it is suggested that their risk aversion behaviour is a major factor governing their decision not to adopt fertiliser. Support for this notion is provided by Pandey (1998) who reported that rates of NPK fertiliser use across Asian countries are correlated positively with the % of the rice crop that is irrigated. Jahn et al. (1997) conducted surveys in Cambodia which showed that only 27 % of rainfed farmers used inorganic fertilisers compared to 70 % of dry season farmers who have access to irrigation. However, in Takeo in 2000, close to 100 % of rice farmers in 3 villages were using inorganic fertilisers (Ieng et al. 2002). These villages were selected to represent rainfed, rainfed-irrigated and receding floodwater rice ecosystems and each involved surveys of 50 farmers. Hence in Takeo province at least, there is evidence of a rapid shift in adoption of fertilisers over a 5 year period. Ieng et al. (2002) suggested that a key priority with nutrient management advice in Takeo in future was not the promotion of the use of fertiliser to farmers, since use is already widespread, but rather to increase a recognition of how fertiliser requirements vary with soil type and with seasonal variations in soil water regimes.

There are a number of agencies that provide nutrient management advice to farmers in Cambodia, including CARDI, Department of Agronomy and Agricultural Land Improvement, Provincial and District Agriculture Offices and NGO's. These agencies may also carry out their own research to develop fertiliser recommendations. Some duplication of information is inevitable, but perhaps more importantly an opportunity exists to improve the quality of information provided to farmers about nutrient management by integrating the various data sets.

The central premise of this project is that fertiliser is under-used by farmers or the balance of nutrients applied is inappropriate because of gaps in communication between researchers who indicate a significant benefit of fertiliser use and growers who are expected to risk buying it. We examined the problem at provincial scale in Takeo, south east Cambodia, where several sources of research information existed across several agencies. By bringing these data sources together, maps which represented yield and yield response could be more reliably produced. The objective of producing maps was to help provincial and district advisers and fertilizer distributors answer the following sorts of questions:

1). where is rice yield inherently high or low?

2). where is rice likely to respond to fertiliser and by how much?

Materials and methods

An initial data set of 748 samples, comprising 82 % wet season sites, was obtained from simple field trials on farmer fields conducted by FAO and the Cambodia-IRRI-Australia Project (CIAP). Most of the initial data set (referred to as the partial data set) was located in central and northern districts of Takeo province (Figure 1). A more complete data set was obtained by adding sites from the Cambodia-Australia Agricultural Extension Project (CAAEP) and PRASAC (Table 1). All results presented, use the complete data set. The complete data set had better presentation over the whole province (Fig. 1) but comprised only 65 % wet season sites. A range of attributes for each site were reported including: village and commune location, soil type, season, field type. Each site had fertilizer treatments applied and rice yields recorded. In addition observations recorded about each crop included: variety, insect damage, disease, drought, flood.

When samples were located onto a map of Takeo Province using the recorded GPS coordinates, many fell outside the province. This was attributed to the use of an incorrect datum when the GPS coordinates were recorded. To correctly locate sites, it was necessary to relate location of a site to the known coordinates of the nearest village using

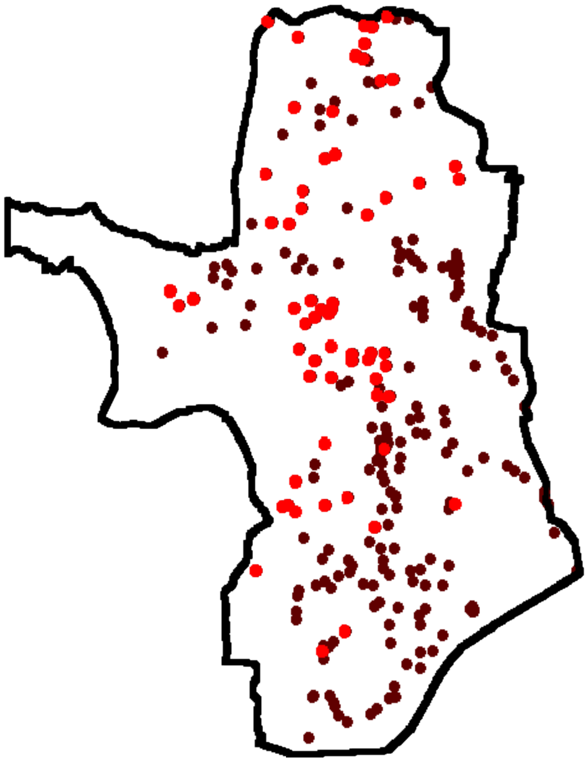

Figure 1. Takeo province map showing locations of on-farm trial sites with records used in data set. Partial data set from FAO and CIAP; Full data set from FAO, CIAP, CAEEP and Prasac.

Table 1. Source of data in the partial and complete data set for Takeo province

Data Provider[1]	Number	% of wet season samples
	Partial data set	
CAAEP	0	0
CIAP	246	33
FAO	502	67
PRASAC	0	0
Total	748	56
	Complete data set	
CAAEP	205	9
CIAP	246	11
FAO	502	21
PRASAC	1383	59
Total	2336	41

[1]CAAEP - Cambodia-Australia Agriculture Extension Project; CIAP - Cambodia-IRRI Australia Project; FAO- Food and Agriculture Organisation; PRASAC-

the Department of Geography database.

Regression tree analysis

Regression tree analysis was used to predict factors affecting yield from the Takeo on-farm trial data and more importantly to understand the structural relationships between yield and trial site parameters. The regression tree analysis has the advantage of scale independence, easy-to-interpret rules and use of both continuous and categorical data (Breiman et al. 1984, Venables and Ripley 1997, MathSoft 1997).

S-PLUS was used to create regression tree models. The end point of a tree (leaf and terminal node) is a partition of space, where the dependent variable (rice yield) is predicted (Breiman et al. 1984). An iterative process of splitting nodes constructs the tree model by a series of binary splits. The split chosen is based on a goodness of fit criterion. See Breiman et al. (1984); MathSoft (1997) and Venables and Ripley (1997), for more details.

Minimum deviance was set to 0.01 to control the threshold for splitting nodes. Minimum size and minimum cut, which control size thresholds, were set to 10 and 5, respectively. Each regression tree figure was plotted using the non-uniform spacing option to represent node importance. In addition, yield (t/ha) was predicted at each terminal node. For each chosen variable, increasing length represents greater importance. Hierarchy within the tree and the length of the tree branch determined the variables most important to yield.

Spatial analysis of rice yield and fertiliser response

The aim of this analysis was to use spatial visualisation to highlight broad effects of fertiliser: nitrogen (N), phosphorus (P) and potassium (K). Yield data from the complete data set was also interpolated using kriging in VESPER (Variogram Estimation and Spatial Prediction with ERror) which is available as a shareware program (Minasy et al. 2002).

Analysing the fertiliser response data in original format was too complex because of unbalanced or uneven treatments. A pragmatic approach was therefore to create maps of each level of fertiliser and simply compare these. This gives no information about the shape of the response curve, or the interaction between fertilisers. However, as a visualisation tool this is a useful start. ArcView 3.2 with the Spatial Analyst extension, was used to visualise and process the data. An example of the procedure is as follows:

- Sort the database (containing at least fertiliser, yield, Eastings, Northings and other explanatory variables such as season) according to N rate;
- Plot the frequency distribution of N rates to determine reasonable classes for calculating N response effects. For N, these were selected as: <10 kg/ha (zero); 10-50 kg/ha (medium); > 50 kg/ha (high);
- Map (interpolate using VESPER) yield for each N rate class;
- Using simple map algebra, identify the apparent effect of N as:
  N effect = (Yield with high N) – (Yield with zero N);
- N effects calculated were medium - zero; high- zero and high-medium.

Only two classes of K fertiliser were created; zero (including all cases with < 8 kg K/ha) and plus K (including all cases with >12 kg K/ha).

Sensitivity analysis of yield and fertiliser response data

The aim of this activity was to identify the number of data points sufficient for provincial scale yield and fertiliser response mapping. The analysis concentrated on yield and medium nitrogen (N) response. Random samples of 2336 yield observations were taken using ArcView. Data was sampled at 10 % of the complete data set and then at 10 % increments to 90 %. The minimum sample size was determined by plotting descriptive statistics with increasing sample size and calculating the mean MSE of grids with increasing sample size.

Results and discussion

Regression tree analysis

A number of regression tree models were examined starting with simple models using only N, P and K as explanatory parameters, through to as many as nine parameters in a model (Table 2).

Table 2. Regression tree analysis models showing parameters tested in order of decreasing importance.

No.	Parameters
1	X*, soil, variety, y*, K, P, N, year
2	N, P, K
3	Soil, N, year
4	Season, N, soil
5	Season, soil
6	Season, y, x, N, soil
7	Season, y, x, N, K, P, soil, variety, year

*x east- west coordinate for location; y north-south coordinate for location

The most dominant factor identified was season or rice ecosystem (Figure 2). It was the primary parameter of all regression trees in which it was included and had precedence over location, the next most dominant parameter (Table 2). Season was expected to be a primary factor since dry season crops are generally higher yielding due to improved water control, higher solar radiation and the use of modern varieties (Nesbitt 1997). For future mapping and in order to account for yield variance associated with different ecosystem conditions, the database and analysis could be separated into season accordingly. However, using this approach it may not be possible to produce a map for the whole province since there is limited dry season cropping in the western half of Takeo province and limited wet season cropping in the flooded eastern half (Figure 1).

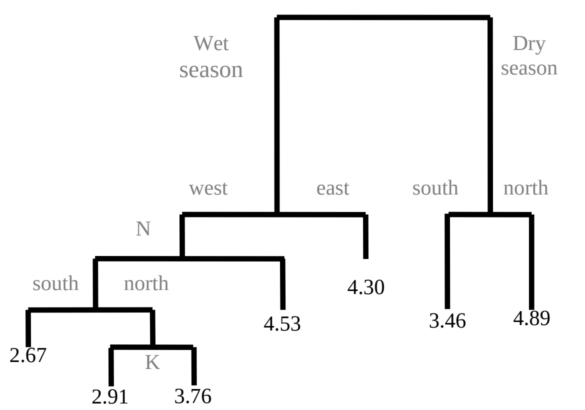

Figure 2. Trimmed regression tree for yield (t/ha) as a function of all variables assessed (model 7, Table 2). Variables were season, soil, N, P, K, variety, year, x, y location. Season is the most dominant factor, followed by location, N then K.

The location parameter in the regression tree model represented a regional yield trend, east to west, of high and low yields, respectively (Figure 3). It was an unexpected parameter for yield prediction, since only indirect relationships exist between yield and location. Location apparently summarised, at the scale of mapping used, the chemical, physical, social and crop factors directly related to yield in the areas studied. For example, the soils in the west are poorer with sandy surface texture more common and a higher proportion of sites are on high fields that are more drought-prone (Figures 3, 4). Socio-economic differences along E-W and N-S gradients within Takeo may also explain why location is a significant variable. For example, areas in the west of Takeo were until the late 1990's insecure which may account for a more recent introduction to modern rice growing technologies. Rainfall decreases along W-E and S-N gradients within Takeo (see Javier 1997) but as this would imply a decrease in rice yield with increasing rainfall it does not explain the importance of the location variable. Completeness of the picture in regression tree analysis is dependent on the data input (Breiman et al. 1984). For subsequent analyses additional parameters affecting yield such as site rainfall, drought, flood, geology, geomorphology, disease and pests are recommended.

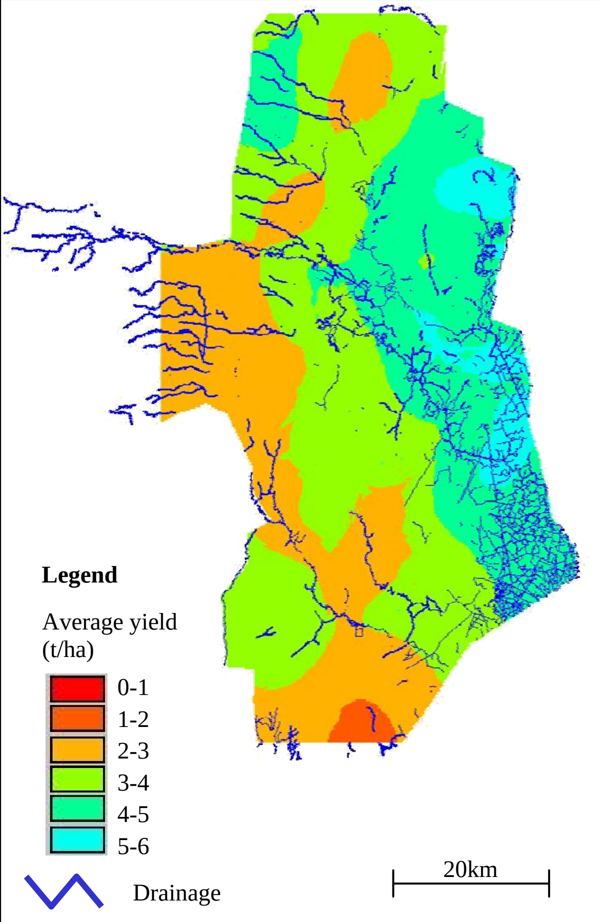

Figure 3. Mapped rice yield class for Takeo with drainage overlaid.

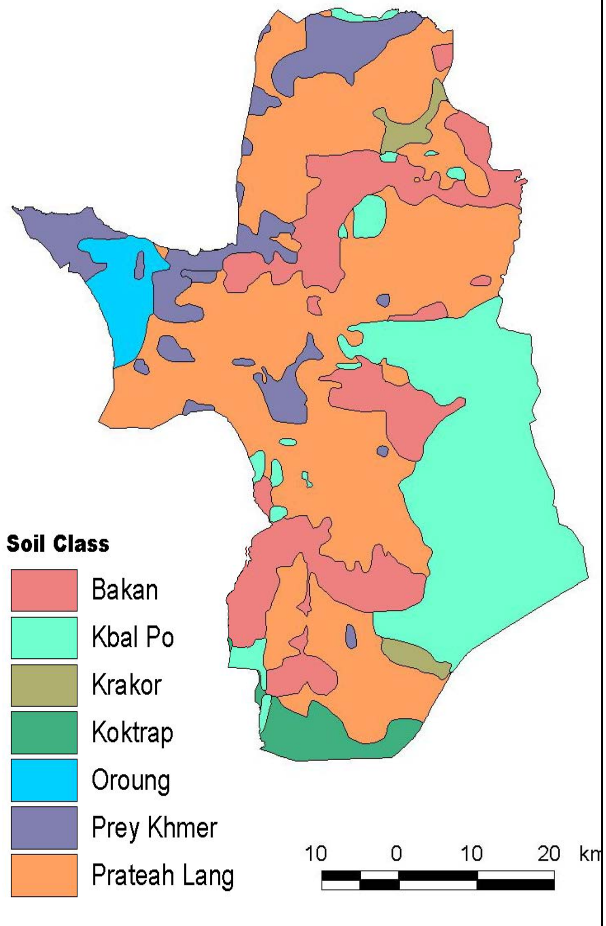

Figure 4. Soil group map for Takeo province (Oberthur et al. 2000b).

The dominance of location in the regression tree results represents *regional* trends in yield that were also evident in the yield map (Figure 3). Soil was a reasonable predictor for yield (Table 3), secondary to location (Table 2). This suggests that within these locations, the soil classification explain some of the structural relationships related to yield. The Cambodia Agronomic Soil Classification is based on soil properties that affect rice yields (White et al. 1997), and generally the yields in field experiments are closely correlated with soil groups so defined (White et al. 2000; Oberthur et al. 2000). The analysis differentiated soil into two productivity groups based on season (Table 3). Although the soils within these groups were consistent with previous field trial data (White et al. 1997; White et al. 2000), the notable exceptions were yields on Bakan and Krakor soils (albeit with small sample sizes in the wet season). In addition, by managing fertiliser input, yields within poor soils increased to levels comparable with productive soils (Table 2, model 4, 6 & 7). Recent field work in Takeo province suggests that some soil types are incorrectly located on the soil map of Oberthur et al. (2000). For example, the Oroung soil has not been located in the region shown in western Takeo province (N Schoknecht, personal communication). This error in the soil map would also weaken the apparent relationship between soil type and rice yield in the regression tree models.

Table 3. Predicted yield as a function of season and soil (averaged across fertiliser treatments, varieties), from regression tree model 5 (see Table 2). Average yields from white et al. (2000) were from field experiments conducted across Cambodia.

Season	Soil group	No. of samples	Predicted yield (t/ha)	Average reported by White et al. (2000)
Wet	Oroung	6	1.91	-
	Krakor	8	2.73	-
	Koktrap	13	3.06	1.4
	Bakan	9	3.08	3.1
	Prateah Lang	838	3.21	2.8
	Prey Khmer	43	3.22	2.5
	Kbal Po	81	4.02	-
	Toul Samrong	20	4.03	3.6
Dry	Prateah Lang	149	3.94	-
	Krakor	51	4.09	-
	Kien Svay	4	4.09	-
	Kbal Po	427	4.52	-
	Bakan	178	4.57	-

From the regression tree analysis, N, P, and K had a similar overall effect on yield when other parameters were included. Potassium was subsidiary to N as a factor explaining yield differences and only important in the wet season crops. This is consistent with the greater prevalence of dry season crops on the heavier textured soils in the east of Takeo where K response is less likely (White et al. 1997a,b). One interesting spin-off is that the analysis suggests that N fertiliser rates on poor soils could be revised upwards to 80 to 90 kg N/ha compared to current recommendations of 30-75 kg N/ha (Seng et al. 2001). The failure of P rates to explain a significant amount of yield variation can be understood by examining the P effect in Figure 5. It is obvious that most of Takeo province is expected to respond to P fertiliser addition by increases in yield >1 t/ha. Since regression tree analysis is most useful in identifying parameters that discriminate amongst sites those that exhibit uniform responses to treatments like P may be overlooked in the analysis.

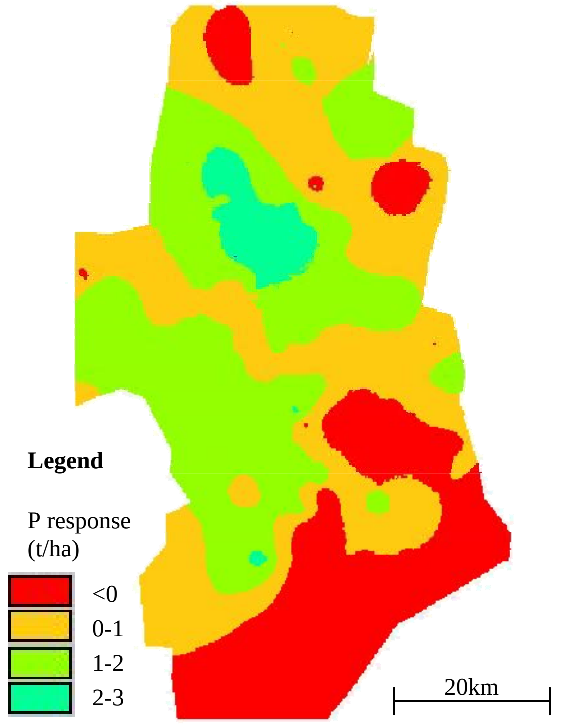

Figure 5. Phosphorus response calculated from on-farm experiments as the difference between yield with and without P added.

Variety was important to yield in the eastern areas, although this may be related to season and needs to be further examined. Yearly events influenced yield on less productive soils although fertiliser may negate some of these effects. The low yield years for 1993 and 1994 were possibly related to residual political uncertainty that discouraged farmers from significant investment in inputs to the on-farm trials.

Mapping yield data

A feature of the on-farm trial data set was the rarity of areas (from plots) with yield <1.5 t/ha (Table 3). The average yield with low fertiliser N applied was 2.9 t/ha, which contrasts with the average from crop yield census data for Takeo province of 2.2 t/ha in 1999-2000 (Table 4). However, despite the higher yields in the database than averages for the province, the relative yields for soil types are generally in the expected order as ranked in Table 3 (White et al. 2000) and hence the relative differences mapped are expected to be accurate.

Table 4. Rice yields (t/ha) reported for the whole of Cambodia

	Wet season	Dry season	Source
Cambodia	1.81	3.04	1
Takeo: this study	3.28	4.39	2
Takeo: province	2.20	3.00	3
Takeo: Farmers' survey in 3 villages	1.81	4.33	4

1. MAFF (1999-2000)
2. This study
3. MAFF (1999-2000)
4. Ieng et al. (2001)

There are several obvious explanations for higher field trial yields than the province average. Firstly, moisture content of paddy rice was probably > 14 % (the standard for reporting) in on-farm trials since it was not dried to standard moisture content before weighing and secondly, straw and other non-grain components were not thoroughly cleaned from the sample. Collectively these could account for 10-20 % over-estimation of yield. The tendency for farmers to control weeds and insects better in trial plots than the average rice field may contribute to higher yields, as will the tendency for researchers to locate experiments where supplementary irrigation can be applied as necessary. Researchers tend not to report failed experiments which results in the reported statistics over estimating the potential yield. By contrast, national statistics on yield do not report actual crop area in that year but rather the potential area, depressing the average. Finally, the fact that 59 % of the database in this study was for the dry season, which has higher average yield, in contrast to actual production which is mostly from the wet season, would increase the calculated average.

Mapped N-effect results suggest a very strong positive response to N, particularly on the central- western region of the province (Figure 6). They also suggest possible negative effects of high N rates on the most fertile soils (Kbal Po, Krakor) in the eastern part of Takeo, and in the Prateah Lang and Koktrap soils in the flooded areas of the south east of Takeo. The decline in yield of N fertilized sites appears to be explained by increased damage from stem borers which was reported on the trial site records to be very damaging at 2 out 4 sites. This suggests that further attention needs to be given to studying the conditions under which N fertiliser increases stem borer damage, because this effect was not evident in the N responses on other soils. The effect of N fertiliser on incidence of other insects and on disease also perhaps needs attention. However, there were relatively few on-farm trials in the eastern Takeo province with N fertiliser treatments, and hence the negative effect of N fertiliser may be biased by the results from a few atypical sites. Thus the decline may also be because the maximum spread of data points exceeded the maximum range for mapping based on the semi-variogram (see below). Further on-farm experiments to confirm that N fertiliser increases stem borer damage seem warranted.

Positive yield responses to K were mostly in the range 0-1 t/ha and occupied about half of the province. Visual interpretation suggests no K response on flooded-prone zones in eastern and southern Takeo (Figure 7). These are the areas with a prevalence of Kbal Po and Krakor soils which generally do not require K fertiliser (Seng et al. 2001). Another zone with no K response appears to loosely correlated with Prey Khmer soils in the north west of Takeo. Responses to K fertiliser are expected on Prey Khmer soils (Seng et al. 2001), but the sandy texture of these soils, and the prevalence of multiple nutrient deficiencies means that balanced nutrient supply is essential to achieve positive fertiliser responses (White et al. 1997a,b). Hence in the on-farms trials that included K treatments, inadequate N or P supply at a particular site could prevent a positive response to K. Alternatively excessive leaching of N or K after basal fertiliser application may prevent fertiliser response. And finally loss of soil water saturation during the growing season may decrease the availability of N or P and hence prevent responses to fertilisers (Bell et al. 2001).

Positive response to P is almost certain over the entire province (Figure 5) except for eastern and south eastern regions and two other isolated areas in the north west and north east. Very little of the province is expected to respond negatively to P. Phosphorus response peaked in central Takeo province. High flood risk seems to reduce the P response probably because of frequent replenishment of soil P in alluvial soils from fresh sediment. White and Seng (1997) note that P responses are less prevalent on the clayey alluvial soils.

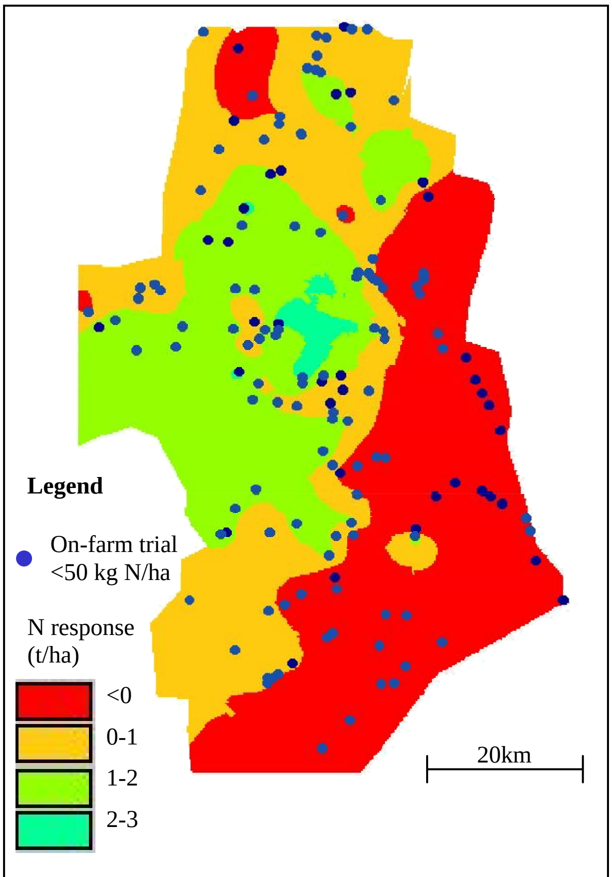

Figure 6. Nitrogen response calculated from on-farm experiments as the difference between yield with 10-50 kg N/ha and with < 10 kg N/ha added.

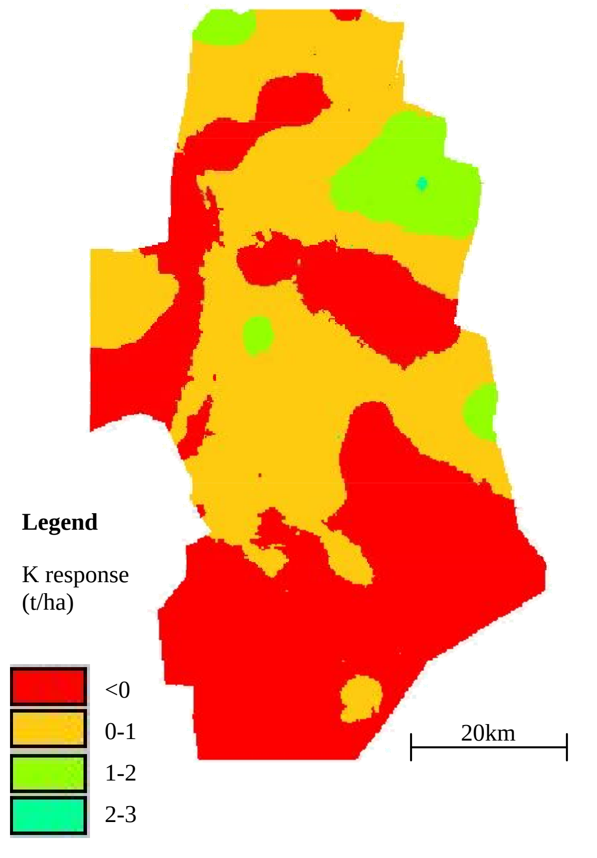

Figure 7. Potassium response calculated from on-farm experiments as the difference between yield with and without K added.

Sensitivity analysis of yield and fertiliser response data, Takeo province

For yield, the mean, confidence interval (CI) and the MSE results stabilise at 40 % of the data set, or 934 samples (Figure 8). This minimum data set exceeds the number of points in the partial data set. Takeo covers 3490 km^2 and 934 samples equates to 2.7 every 10 km^2. Dent and Young (1981) recommended one sample every 25 ha to map landforms for regional land use planning at 1:50,000 scale. This is fourteen times more intense than the rice yield sample density. The recommended sampling density for rice yield estimation is more comparable to the intensity of sampling for 1:250,000 scale for national land system applications.

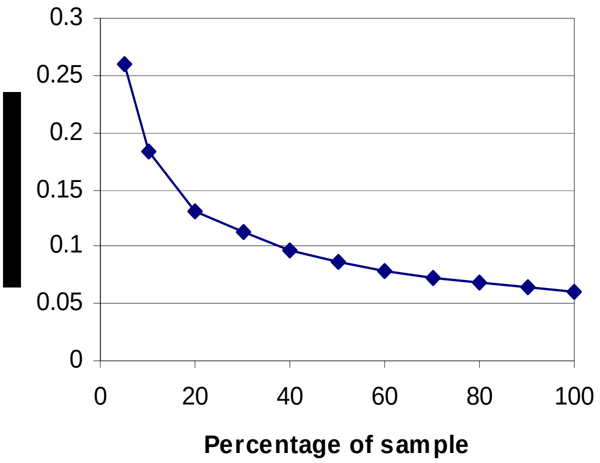

Figure 8. Confidence interval of yield data with increasing sample size for full data set.

When data was separated into N treatments, only yields with 50 to 80 kg N/ha reached a CI of 0.10 t/ha (Figure 9). This was due to the larger total sample size at 730 for this range of fertiliser N levels. The minimum number of samples to achieve the same CI (0.1 t/ha) was 20 % lower than when all yields were analysed. Presumably separating the data into fertiliser application rates takes into account some of the yield variation and thus the CI was reached at a smaller sample size. The results indicated that for 0-10 kg N/ha 5.7 samples per 100 km^2 and for 10-50 kg N/ha 9.4 samples per 100 km^2, was sufficient for a CI of 0.2 t/ha or less. From these results, 6 to 9 samples per 100 km^2 are recommended to estimate fertiliser response with a CI of 0.2 t/ha.

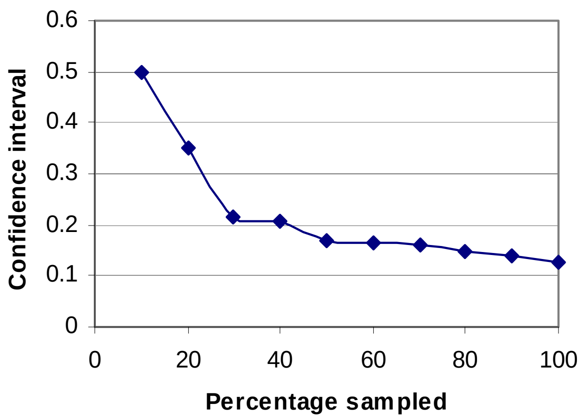

Figure 9. Confidence interval of yield data with increasing sample size for 10-50kg N/ha data set.

The sample number required for sufficient histogram and variogram modelling both occur at around 100 data points, for the 0-10 and 10-50 kg/ha N fertiliser ranges. This represents a minimum number of sample points per fertiliser input interval for semi-variogram modelling and histogram analysis. Data spacing also needs to be considered in sampling programs. This should not be greater than the range of influence obtained from the semi-variogram analysis. Investigation of the results indicates a maximum range of influence of 8 km for N-response data. This is a conservative estimate as results stabilise around 12 km with larger sample sizes when yield was estimated spatially. If sample points are located greater than 8 km apart, the data is likely to be unreliable for mapping at the provincial scale. The results from this section can act as guides to determine sampling requirements for spatial mapping in other areas of similar environment and rice production practices.

General discussion

The data used in the present study was generally filed as hard copy and put to little on-going use. In the past, data from the CIAP and FAO databases has been subject to critical analysis to derive fertiliser recommendations (White et al. 1997; Seng et al. 2001). Informally some joint consideration of these two databases has informed the development of CARDI fertiliser advice (P. White, personal communication). The present project adds value to previously collected experimental data by combining the databases from four agencies to generate results from 2336 sites with good spatial coverage in the province of Takeo. Consideration of the combined data set appears to generate new information not previously recognised in individual databases. Most significant amongst these is the effect of N fertiliser on insect damage levels in Kbal Po and Krakor soils, and the poor responses to fertilisers in general on the flood-prone acid sandy soils of south east Takeo belonging predominantly to the soil groups Koktrap and Prateah Lang. As new field trial data becomes available, maps can be up-dated to explore changes in patterns of response. Similarly as farmers' fertilizer practice changes this may be reflected in the trial data.

Maps of the sort produced in this project help to target decisions and actions for planners, investors, extension agencies and researchers. Using maps, planners can estimate how rice yield would respond across the province to the adoption of the recommended fertiliser rates. By knowing what extra yield could be produced in each district, plans can be make for the appropriate development of infrastructure to support the transport and storage of grain. Investors in rice milling and in fertiliser and pesticide products can use the predictions to identify the magnitude of markets, estimate likely sales, and decide on where to locate depots for fertiliser stocks and fertiliser sales points. Extension agencies can use maps to develop targeted advice for particular districts and communes as part of the agro-ecosystem analysis framework. There are indications that fertiliser use is a better and more reliable investment at present in some areas than in others. In areas where strong reliable response to fertilisers can be obtained using current technologies, extension programmes can be confidently mounted. In other areas, more cautious advice on fertilizers is appropriate until further research identifies the constraints to fertilizer responses.

A number of significant messages emerge for the present research. A map is a medium for dialogue on results and knowledge gaps. In the eastern, flood-prone areas there appears to be a risk of decreased rice yield when N fertiliser is added. Here the effect of N on insects warrants further examination. The severity of insect damage on yield may vary with the timing of the infestation as well as the level of N. Weather conditions may also affect the likelihood of insect populations building to levels that can cause crop damage. From this research, recommendations may emerge that N fertiliser should be applied only when effective insect control is planned by farmers. Alternatively lower than recommended rates of N fertilizer may be a prudent strategy for farmers who are unable to or choose not to use insecticides. The latter approach is consistent with the findings of Ieng et al. (2001) for farmers in Treang village, eastern Takeo where farmers in the receding floodwater rice ecosystems used lower N fertiliser than recommended.

In another study of farmers' perceptions of rice yield response to fertiliser in Takeo, it was found that the expected yield response to fertilizer in a rainfed rice ecosystem was only about 0.1 t/ha (Ieng et al. 2001). In this village in Tramkak district, 50 % of farmers' expected no response or a decrease in yield when fertiliser was added. This is at variance with the predictions from the trials reported by White et al. (1997), and from the on-farm yield responses reported here. Phosphorus and K deficiency appears to be widespread in Takeo (Figures 5,7; White et al. 1997). Further investigation is needed to verify why farmers have such modest expectations for yield increase with fertiliser use. Clearly adoption of fertiliser recommendations is likely to be impeded whilst farmers hold their present perceptions. The maps presented in the present paper may be a useful way to represent to farmers the prospects for fertilizer responses in their particular district or commune.

Finally and importantly, there is a need for a formal and organised system whereby knowledge and experience about soil fertility and fertiliser response can be stored and shared at all levels within the agriculture sector. The present study illustrates the advantages of pooling data from on-farms trials conducted by several agencies. Mining information from existing data maximises the investment in the original research and avoids the unnecessary expense of new experiments. The maps produced in this study can be updated as new research data becomes available. However, not all provinces in Cambodia will have the density of on-farm experimental data that exists in Takeo. The present authors have developed a system of predicting rice yield response in Takeo that integrates information from a range of sources, including farmer's experience (Bell et al. 2004). The spatial model developed will predict the likely yield given soil type, flooding risk and expected N fertiliser response. Hence, the aim is to be able to generate maps such as those produced here in provinces of Cambodia where the data is more limited and patchy in distribution. Through better targeting of advice, the use of the maps aims to facilitate the improved adoption of fertiliser technology by farmers. This will also contribute to improved strategic planning on a provincial and district basis.

Conclusions

Provincial scale maps of yield response to fertiliser can target extension effort to areas where yield is likely to be most responsive to fertiliser application. The work also highlighted the need for further research to clarify reasons for effect of N fertiliser on insect damage levels on fertile soils (Kbal Po, Krakor) and poor responses on flood-prone acid sandy soils (Koktrap and Prateah Lang). These outcomes could enhance the strategic planning capability for delivery of extension services and fertiliser inputs. In addition, the compilation of data and subsequent mapping demonstrated the value added to existing data, emphasising the importance of efficient data and information management systems in agricultural research and the sharing of information amongst agencies.

Acknowledgements

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<u>សេចក្តីជូនដំណឹង</u>

វិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៍កសិកម្មកម្ពុជា មានកិត្តិយសសូមជម្រាបជូនដំណឹងដល់ លោក លោកស្រី អ្នកនាងកញ្ញា ជាអ្នកស្រាវជ្រាវទាំងអស់ អោយបានជ្រាបថា ដោយយល់ឃើញពីគុណសម្បត្តិ និងសារប្រយោជន៍នៃទស្សនាវដ្តីកសិកម្មកម្ពុជា ក្នុងការផ្តល់លទ្ធភាពជូនអ្នកស្រាវជ្រាវខ្មែរ ទាំងឡាយឱ្យមានឱកាសបង្កើនសមត្ថភាពស្រាវជ្រាវរបស់ខ្លួនតាមរយៈការសរសេរ ការបកស្រាយ និងចូលរួមពិភាក្សានូវរាល់គំហើញវិទ្យាសាស្ត្រផ្សេងៗ ដែលជាកត្តាចាំបាច់មិនអាចខ្វះបានសម្រាប់អ្នកស្រាវជ្រាវ ដើម្បីជាការពង្រីងវិស័យស្រាវជ្រាវជាតិ ហើយក៏ដើម្បីជាកិត្តិយសដ៏ខ្ពង់ខ្ពស់សម្រាប់ប្រទេសជាតិយើងដែរនោះ វិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៍កសិកម្មកម្ពុជា បានខិតខំព្យាយាមជំរុញអោយមានការបង្កើតឡើងនូវទស្សនាវដ្តីកសិកម្មកម្ពុជានេះ និងធ្វើយ៉ាងណាឱ្យទស្សនាវដ្តីនេះបានរស់រានជីវិតឡើងវិញក្រោយពីត្រូវអាក់ខានមួយរយៈ ។

នាពេលបច្ចុប្បន្ន ក្រោយពីមានការបង្កើតឡើងជាថ្មីនូវក្រុមប្រឹក្សាពិនិត្យ (Editorial Board) របស់ទស្សនាវដ្តី ដែលមានការចូលរួមពីអង្គភាពពាក់ព័ន្ធជាច្រើន វិទ្យាស្ថានបាននិងកំពុងរៀបចំដំណើរការបោះពុម្ពទស្សនាវដ្តីកសិកម្មកម្ពុជា (Cambodian Journal of Agriculture) នេះឱ្យមានជាប្រក្រតីភាពឡើងវិញដូចដែលវិទ្យាស្ថានធ្លាប់បានធ្វើការរៀបចំ និងបោះពុម្ពផ្សាយជាហូរហែរកន្លងមកដើម្បីជាការផ្សព្វផ្សាយទាំងក្នុង និងក្រៅប្រទេស ។

អាស្រ័យហេតុនេះដើម្បីអោយទស្សនាវដ្តីនេះអាចមានសកម្មភាព និងដំណើរការទៅមុខបាន វិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៍កសិកម្មកម្ពុជា ក៏ដូចជាក្រុមប្រឹក្សាពិនិត្យនៃទស្សនាវដ្តីកសិកម្មកម្ពុជា មានក្តីសង្ឃឹមយ៉ាងមុតមាំ និងជឿជាក់ចំពោះការចូលរួមគាំទ្រពីសំណាក់ លោក លោកស្រី អ្នកនាង កញ្ញា ទាំងឡាយដែលមានបំណងចង់បង្ហាញពីការរកឃើញវិទ្យាសាស្ត្រផ្សេងៗ ក៏ដូចជាបទពិសោធន៍ល្អៗជូនដល់អ្នកស្រាវជ្រាវដ៏ទៃៗទៀត និងក៏ដូចជាចង់ជួយពង្រីងវិស័យស្រាវជ្រាវជាតិយើងផងដែរក្នុងការផ្តល់នូវអត្ថបទស្រាវជ្រាវផ្សេងៗសម្រាប់ជាការបោះពុម្ពក្នុងទស្សនាវដ្តី ។

សូមអរគុណ

ព័ត៌មានបន្ថែមសូមទំនាក់ទំនង:

វិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៍កសិកម្មកម្ពុជា

ផ្លូវជាតិលេខ ៣ សង្កាត់ប្រទេះឡាង ខណ្ឌដង្កោ រាជធានីភ្នំពេញ

ប្រអប់សំបុត្រលេខ ០១ ភ្នំពេញ

ទូរស័ព្ទលេខ: (៨៥៥-២៣) ២១៩ ៦៩២ / ០១១ ៨១៨ ៧៩៨

ទូរសារលេខ: (៨៥៥-២៣) ២១៩ ៨០០

ទូរអក្ខរ: msarom@cardi.org.kh / cc: *cja@cardi.org.kh*

ការណែនាំសម្រាប់អ្នកនិពន្ធ

គម្រូវការទូទៅ

ការបោះពុម្ពផ្សាយនៅក្នុងទស្សនាវដ្ដីកសិកម្មកម្ពុជា (CJA) អាចជារបាយការណ៍ដើមនៃលទ្ធផលស្រាវជ្រាវ (អត្ថបទ ឬ កំណត់ត្រាខ្លីៗ) អាចជាលិខិតដែលបញ្ជូនទៅអ្នកត្រួតពិនិត្យ ជាការផ្សព្វផ្សាយពាណិជ្ជកម្ម ឬការប្រកាសនូវដំណឹងនានា។ កំណត់ត្រាស្រាវជ្រាវមិនត្រូវសរសេរលើសពី ២ទំព័រទេ ឯការផ្សព្វផ្សាយវិញក៏មិនត្រូវអោយលើសពីកន្លះទំព័រដែរ។

តួអត្ថបទ ឬកំណត់ត្រា

អត្ថបទដែលបានរៀបចំត្រូវផ្ញើរមកអ្នកពិនិត្យដោយប្រព័ន្ធអេឡិចត្រូនិក (តាមរយៈទូរអក្ខរ ឬ តាមរយៈថាស) ក្នុងនោះត្រូវមាន តារាង និងក្រាហ្វិក ឯកសារយោង ចំណងជើងតារាង និងចំណងជើងក្រាហ្វិក។ រូបភាពត្រូវតែជារូបដើម ឬថតចំលង (Scan) អោយច្បាស់ដើម្បីធានានូវគុណភាពរបស់រូបសម្រាប់ទស្សនាវដ្ដី។ អត្ថបទដែលផ្ញើរមកកាន់ទស្សនាវដ្ដីកសិកម្មកម្ពុជា (CJA) អាចជាភាសាអង់គ្លេស ឬភាសាខ្មែរ។ ក្នុងករណីដែលអត្ថបទជាភាសាអង់គ្លេសត្រូវប្រើប្រភេទអក្សរ Time New Roman ដោយមានការបកប្រែជាភាសាខ្មែរនូវចំណងជើង និងសង្ខេបដោយប្រើប្រភេទអក្សរ Limon។ ចំពោះអត្ថបទជាភាសាខ្មែរត្រូវប្រើប្រភេទអក្សរ Limon ដោយមានការបកប្រែជាភាសាអង់គ្លេសនូវចំណងជើង និងសេចក្ដីសង្ខេបដោយប្រើប្រភេទអក្សរ Times New Roman ។

រចនាសម្ព័ន្ធ

ចំណងជើង : ត្រូវនៅទំព័រទី១ នៃអត្ថបទ ឬ កំណត់ត្រា។ ចំណងជើងត្រូវសរសេរអោយបានខ្លី ប៉ុន្តែច្បាស់លាស់ និងឆ្លើយតបទៅនឹងអត្ថបទ។

អ្នកនិពន្ធ : នៅខាងក្រោមចំណងជើង ត្រូវដាក់ឈ្មោះអ្នកនិពន្ធទាំងអស់ដែលពាក់ព័ន្ធក្នុងការងារស្រាវជ្រាវ។ ដកឃ្លាពីឈ្មោះអ្នកនិពន្ធមួយទៅឈ្មោះ អ្នកនិពន្ធមួយដោយប្រើសញ្ញា Comma (,) ហើយឈ្មោះអ្នកនិពន្ធចុងក្រោយគេត្រូវដាក់ឈ្នាប់ " និង " " and " នៅពីមុខ។ ឈ្មោះអ្នកនិពន្ធ/អត្ថបទនានា គួរតែមាននៅក្នុង Footnote នៃទំព័រទី១។ គួររៀបចំជាបញ្ជីនូវឈ្មោះអ្នកនិពន្ធ និងបញ្ជាក់ពីអាស័យដ្ឋាន និងឯកសារពាក់ព័ន្ធផ្សេងៗនៅក្នុងឃ្លាទី១នៃ Footnote ហើយក្នុងឃ្លាទី២ គួរដាក់បញ្ចូលនូវ ប្រភពមូលនិធិ ប្រសិនបើពុំទាន់បានបង្ហាញនៅក្នុងសេចក្ដីថ្លែងអំណរគុណ។

សេចក្ដីសង្ខេប : អត្ថបទនិមួយៗត្រូវមានសេចក្ដីសង្ខេបជាពីរភាសា គឺភាសាខ្មែរ និងភាសាអង់គ្លេស។ សេចក្ដីសង្ខេបត្រូវអោយខ្លីតែច្បាស់លាស់ហើយត្រូវសរសេរមិនលើសពី ២៥០ ពាក្យ សំរាប់អត្ថបទ និង ១៥០ ពាក្យ សំរាប់កំណត់ត្រា។ ត្រូវរៀបរាប់អំពីសនិទានភាព ទិសដៅ វិធីសាស្ត្រ លទ្ធផលគន្លឹះ និងសារៈសំខាន់របស់វា ពិសេសសំរាប់កសិកម្មកម្ពុជា។ បន្ទាប់ពីរៀបសេចក្ដីសង្ខេបត្រូវរៀបចំតាមលំដាប់លំដោយ សេចក្ដីផ្ដើម ដែលរួមបញ្ចូលនូវការវិភាគ ទៅលើបណ្ណាល័យសាស្ត្រពាក់ព័ន្ធហើយបន្តដោយខ្លីៗ សម្ភារៈ វិធីសាស្ត្រ លទ្ធផល ការពិភាក្សា សេចក្ដីសន្និដ្ឋាន (អាស្រ័យលើអ្នកនិពន្ធ) សេចក្ដីថ្លែងអំណរគុណ (អាស្រ័យលើអ្នកនិពន្ធ) និងឯកសារយោង។ លទ្ធផល និងការពិភាក្សាអាចបញ្ចូលគ្នា ហើយសេចក្ដីសន្និដ្ឋានអាចមាននៅក្នុងផ្នែកពិភាក្សា។

តារាង : តារាងទាំងអស់ត្រូវដាក់លេខរៀង ហើយត្រូវមានចំណងជើង។ Headnote ដែលមានព័តិមានផ្សេងៗពាក់ព័ន្ធទៅនឹងតារាងទាំងមូល គួរចាប់ផ្ដើមនៅបន្ទាត់ថ្មីមួយ។ តារាងគួររៀបចំទៅតាមទំហំកូឡោនគំរូរបស់ទស្សនាវដ្ដី (ទំហំ ៨ ស.ម ទៅ ២១ ស.ម) ហើយចំនួនកូឡោននៅក្នុងតារាងគួរអោយមានចំនួនតិច។ ការបំបែកចំណងជើងតូចៗ ពីចំណងជើងកូឡោនមេច្រើនពេកគឺមិនល្អទេ ហើយចំណងជើងវែងពេកក៏គួរជៀសវាងដែរ ដោយប្រើការសរសេរពន្យល់ខ្លីៗជំនួសវិញ ដែលការសរសេរទាំងនោះមានលក្ខណៈស៊ីគ្នាទៅនឹង Head note។ តួអក្សរទី១ នៅខាងដើមគួរសរសេរជាអក្សរធំ។

និម្មិតសញ្ញា នៃខ្នាតរង្វាស់ផ្សេងៗ គួរដាក់ក្នុងរង្វង់ក្រចកខាងក្រោមចំណងជើងកូឡោន។ បុព្វបទសំរាប់ឯកតាគួរជ្រើសរើសយ៉ាងណាមិនអោយមានចំនួនលេខច្រើនពេក។ ក្នុងករណីមិនអាចជៀសវាងបានគួរដាក់ចំនួននោះដោយមេគុណ ១០ នូវរាល់តំលៃទាំងឡាយក្នុងតារាង។ កំណត់សំគាល់ខាងក្នុងតារាងគួរតែរក្សាទំហំអក្សរអោយតូច និងត្រូវរក្សាទុកសំរាប់ការបរិយាយដាក់លាក់ផ្សេងៗក្នុងកូឡោន។

បន្ទាត់ផ្ដេកអាចដាក់ខាងលើ និងខាងក្រោមចំណងជើងក្រឡោន និងនៅខាងក្រោមបង្អស់នៃតារាងតែប៉ុណ្ណោះ។ ចំពោះបន្ទាត់បញ្ឈរវិញមិនគួរប្រើទេ។ រាល់តារាងនិមួយៗត្រូវឆ្លើយតបនៅក្នុងអត្ថបទ ហើយចំណុចសំគាល់តូចមួយនៅក្នុងគែមទំព័រ (Margin) គួរសរសេរបង្ហាញពីទីតាំងពិតប្រាកដរបស់តារាងនៅក្នុងអត្ថបទ។ តារាងខ្លីៗអាចដាក់បញ្ចូលទៅក្នុងអត្ថបទក្នុងលក្ខណៈជាប្រយោគ និងមិនចាំបាច់មានចំណងជើងទេ។ លើកលែងតែក្នុងករណីពិសេសប៉ុណ្ណោះដែលទិន្នន័យអាចត្រូវបានបង្ហាញទាំងក្នុងតារាង និងក្នុងក្រាហ្វិក។ បើពុំនោះទេគួរប្រើក្រាហ្វិកវិញក្នុងករណីចាំបាច់។

ក្រាហ្វិក : ក្រាហ្វិកទាំងឡាយណាដែលមិនល្អ (ឧ. ក្រាហ្វិក ស្ថិតក្នុងទ្រង់ទ្រាយពិបាកអាន/យល់) នឹងត្រូវបញ្ជូនអោយយកទៅពិនិត្យដើម្បីកែសម្រួលឡើងវិញ។ ចំពោះអ្នកនិពន្ធដែលមិនអាចរៀបចំជាក្រាហ្វិកផ្សេងៗបាន គួរទំនាក់ទំនងជាមួយអ្នកត្រួតពិនិត្យ។ សញ្ញា បូក (+) រឺ គុណ (x) គួរជៀសវាង។ ការពន្យល់ពីនិម្មិតសញ្ញាផ្សេងៗគួរតែដាក់នៅក្រោមចំណងជើងនៃក្រាហ្វិក ហើយអក្សរដែលដាក់ក្នុងក្រាហ្វិក គួរមានជាអប្បបរិមា។ អក្សរទាំងពីរនៃក្រាហ្វិក ត្រូវបញ្ជាក់ពីបរិមាណដែលបានវាស់ថ្មីៗ ឬរាប់ហើយត្រូវដាក់ឯកតា SI ក្នុងរង្វង់ក្រចក។

រូបថត : រូបថតត្រូវមានគុណភាពច្បាស់ល្អ។ លក្ខណៈសំខាន់ៗនៃរូបថតដែលត្រូវបានបញ្ជាក់គឺច្បាស់លាស់នៅក្នុងអត្ថបទ ត្រូវតែបង្ហាញអោយបានច្បាស់ (ឧ. ដាក់លេខកូដនៅពីលើអក្សរ / ដាក់សញ្ញាព្រួញ)។ រូបថតពណ៌ធម្មជាតិ នឹងត្រូវទទួលយក ប្រសិនបើវាមានសារៈសំខាន់ក្នុងការជួយអោយងាយយល់ពីលទ្ធផលផ្សេងៗ។

នាមវល្លិ៍ : ចំពោះរុក្ខជាតិ, ភ្នាក់ងារចំលងជំងឺ និងកត្តាចង្រៃផ្សេងៗ ត្រូវសរសេរជាអក្សរឡាតាំងក្នុងទំរង់ទ្រេត និងអ្នកដែលបានប្រើប្រាស់/បរិយាយមុនគេ (ឧ. rice, *oryza sativa* L.)។

ខ្នាតរង្វាស់ : ប្រព័ន្ធខ្នាតរង្វាស់អន្តរជាតិ (SI) ត្រូវយកមកប្រើប្រាស់ក្នុងរាល់អត្ថបទដែលត្រូវផ្ញើរមកទស្សនាវដ្តីកសិកម្មកម្ពុជា។ ខ្នាតរង្វាស់ផ្សេងទៀតអាចបង្ហាញនៅក្នុងរង្វង់ក្រចកខាងក្រោយខ្នាតរង្វាស់ SI បើសិនជាខ្នាតរង្វាស់ទាំងនេះអាចជួយសម្រួលអោយកាន់តែងាយយល់អំពីការងារដែលបានរៀបរាប់ពីខាងដើម។ ខ្នាតរង្វាស់ដែលត្រួតភ្ជាប់គ្នាពីរដង មិនត្រូវប្រើប្រាស់ទាំងនៅក្នុងទំរង់ជាឯកតាស្មុគស្មាញពេកទេ (ឧ.គួរប្រើ mg/sheep. day, មិនគួរប្រើ mg/sheep/day or mg $^{-1}$ sheep^{-1} day^{-1})។ ទស្សនាវដ្តីកសិកម្មកម្ពុជា ត្រូវប្រើអក្សរកាត់ "L" សំរាប់ឯកតាគិតជា លីត្រ "mL" សំរាប់ ឯកតាគិតជា មីលីលីត្រ។ ខ្នាតរង្វាស់សំរាប់ប្រើប្រាស់ក្នុងបណ្តូរអ៊ីយ៉ុង (mmol/kg) គួរប្រើចំពោះប្រភេទបណ្តូរ អ៊ីយ៉ុងទោល ឧ. Na^+, K^+, CaO.5$^+$។ ឯកតាដែលណែនាំអោយប្រើ សំរាប់បណ្តូរអ៊ីយ៉ុង និងសំរាប់សមត្ថភាពបណ្តូរអ៊ីយ៉ុង គឺ cmol(+)/kg [ឬ cmol(-)/kg] កន្លែងដែលមានបញ្ញា (+) រឺ (-) គឺសំដៅលើអាយ៉ុង និងការចុង (បន្ទុកអគ្គិសនី)។ ឯកតាដែលណែនាំអោយប្រើសំរាប់ថាមពលកំដៅ អគ្គិសនី គឺ dS/m ប៉ុន្តែខ្នាត mS/cm ត្រូវបានគេទទួលស្គាល់ជាង។

ការវាយតំលៃលើលទ្ធផល

អត្ថបទស្រាវជ្រាវត្រូវមានការពិពណ៌នាដោយសង្ខេប និងច្បាស់លាស់ ស្តីពីវិធីរៀបចំប្លង់ពិសោធន៍ និងលំអិត ក្នុងករណីដែលការវិភាគវ៉ារីយ៉ង់ ឬការវិភាគតាម Regression Models ត្រូវបានប្រើក្នុងការវាយតំលៃដើម្បីអោយអ្នកអានអាចយល់ច្បាស់អំពីវិធីគណនារកគីតលំអៀង។ ការវិភាគស្ថិតិ គួរពិពណ៌នាដោយសង្ខេប ហើយប្រសិនបើចាំបាច់ត្រូវភ្ជាប់ឯកសារយោងជាជំនួយផង។ ចំនួនឯកត្តាតម្លៃមធ្យម និងរង្វាស់អំពីបំរែបំរួលផ្សេងៗគួរត្រូវបានបង្ហាញ។

ឯកសារយោង

ឯកសារយោង : ឯកសារយោង ត្រូវបានលើកយកមកសំអាងដោយឈ្មោះអ្នកនិពន្ធ និងមានដាក់កាលបរិច្ឆេទច្បាស់លាស់ (ប្រព័ន្ធរបស់លោក Harvard) ហើយមិនត្រូវសរសេរជាលេខទេ។ រាល់ឯកសារយោងទាំងអស់នៅក្នុងអត្ថបទ ត្រូវដាក់បញ្ចូលទៅក្នុងបញ្ជីនៅទំព័រចុងក្រោយបំផុតនៃទស្សនាវដ្តី ដោយមានបញ្ជាក់ពីឈ្មោះអ្នកនិពន្ធ ដែលត្រូវរៀបរៀងតាមអក្សរក្រម។ រាល់ឯកសារយោងដែលបានបញ្ចូលទៅក្នុងបញ្ជី ត្រូវតែដូចគ្នាទៅនឹងឯកសារយោងនៅក្នុងអត្ថបទ។ នៅក្នុងអត្ថបទ ឈ្មោះរបស់សហអ្នកនិពន្ធពីរនាក់ត្រូវភ្ជាប់ដោយឈ្នាប់ "និង" ប៉ុន្តែបើចាប់ពីបីនាក់ឡើងទៅ ដាក់ឈ្មោះអ្នកនិពន្ធទី១ រួចបន្តដោយ "*et al.*"។ ចំនួនដែលមានឯកសារយោងលើសពីមួយនៅក្នុងអត្ថបទ ឯកសារយោងទាំងនោះត្រូវដាក់តាមកាលប្បវត្តិត្រឹមត្រូវ។ ចំណងជើងឯកសារនិងលេខទំព័រដំបូង និងខាងចុងបំផុតត្រូវបង្ហាញនូវក្នុងរាល់ឯកសារយោងទាំងអស់។ អត្ថបទដែលមិនបានទទួលយកទៅបោះពុម្ពមិនអាចដាក់បញ្ចូលទៅក្នុងបញ្ជីឯកសារ យោងតែអាចបង្ហាញនៅក្នុងអត្ថបទដោយពាក្យថា "ទិន្នន័យមិនបានបោះពុម្ពផ្សាយ" ឬ "ទស្សនៈផ្ទាល់ខ្លួន"។ ប៉ុន្តែការប្រើប្រាស់ឯកសារយោងទាំងនេះគឺមិនត្រូវបានលើកទឹកចិត្តអោយប្រើទេ។ អ្នកនិពន្ធទាំងអស់គួរតែយកលំនាំតាមទស្សនាវដ្តី ដែលទើបនឹងចេញផ្សាយថ្មីបំផុតនូវរបៀបបង្ហាញឯកសារយោងផ្សេងៗ ទាំងក្នុងសៀវភៅ និងក្នុងអក្សរសិល្ប៍ផ្សេងៗ។ ចំណងជើងពេញនៃសាមាយិកប័ត្រត្រូវតែដាក់បង្ហាញមកជាមួយដែរ។

ខាងក្រោមនេះនឹងបង្ហាញពីគំរូខ្លះៗ នៃរបៀបដាក់ឯកសារយោងក្នុងអត្ថបទ :

Reference Style (Journal article)

Hubick KT, Farquhar GD, Shorter R (1986) Correlation between water-use efficiency and carbon isotope discrimination in diverse peanut *(Arachis)* germplasm. *Australian Journal of Plant Physiology* **13,** 803_816.

Wagner TE (1985) The role of gene transfer in agriculture. *Canadian Journal of Animal Science* **65,** 539_552.

Reference style (Journal article)

Blackmore DJ (1996) Are rural land practices a threat to the environment? In ‘Soil science _ raising the profile’. (Ed. N Uren) pp. 22_30. (ASSSI and NZSSS: Melbourne)

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Reference style (book)

Lucas GB (1963) ‘Diseases of tobacco.’(University of North Carolina: Raleigh, NC)

Attiwill PM, Adams MA (1996) (Eds) ‘Nutrition of eucalypts.’ (CSIRO Publishing: Melbourne)

Hogan B, Beddington R, Constantine F, Lacy E (1994) (Eds) ‘Manipulating the mouse embryo _ a laboratory manual (2nd edn).’ (Cold Spring Harbor Laboratory Press: Cold Spring Harbor, NY)

Reference style (thesis)

Silver MW (1970) An experimental approach to the taxonomy of the genus Enteromorpha (L.) Link. PhD Thesis, University of Liverpool, UK.

Reference style (Report or Bulletin)

Lea HW (1957) Report on a visit to the USA and Canada, April 1 to October 2, 1957. Department of Agriculture, Orange, NSW.

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Reference style (Conference Proceedings)

Hayman PT, Collett IJ (1996) Estimating soil water: to kick, to core or computer? In ‘Proceedings of the 8th Australian agronomy conference’. Toowoomba. (Dd. M Asghar) p. 664. (The Australian Society of Agronomy: Toowoomba, Qld) Kawasu T, Koi K, Ohta T, Shinohara Y, Ito K (1990) Transformation of eucalypts (Eucalyptus saligna) using electroporation. In ‘Proceedings of the VIIthinternational congress on plant tissue and cell culture’. pp. 64_68. (Amsterdam IAPTC: Amsterdam)

ការរក្សាសិទ្ធិ

ដើម្បីផ្តល់អត្ថបទអោយមកបោះពុម្ពផ្សាយ ត្រូវធានាថាលទ្ធផលដែលបានធ្វើរបាយការណ៍មិនបាន ឬមិនធ្លាប់បោះពុម្ពផ្សាយ ឬកំពុងត្រៀមបោះពុម្ពផ្សាយនៅកន្លែងណាផ្សេង។ សេក្តីសង្ខេបលទ្ធផលនៃការរកឃើញនៃសន្និសីទ ឬនៅក្នុងអត្ថបទបោះពុម្ពផ្សាយណាមួយមិនត្រូវបានចាត់ទុកជាការបោះពុម្ពផ្សាយជាមុននោះទេ។ ទោះបីជាយ៉ាងណាក៏ដោយ ប្រសិនបើទិន្នន័យយ៉ាងច្រើនដូចជាតារាង និងក្រាហ្វិក ត្រូវបានបោះពុម្ពផ្សាយមុនហើយនោះ ការបន្ថែមទិន្នន័យខ្លះៗទៀតមិនអាចចាត់ទុកថាអត្ថបទនោះជាអត្ថបទថ្មីឡើយ។ ចំពោះអត្ថបទដែលមានអ្នកនិពន្ធច្រើនការផ្តល់នូវលំដាប់បោះពុម្ពដោយទស្សនាវដ្តី ត្រូវបានចាត់ទុកថាមានការឯកភាពគ្នារវាងអ្នកនិពន្ធទាំងនោះ។ ពេលផ្តល់អត្ថបទដល់ទស្សនាវដ្តីអ្នកនិពន្ធទាំងអស់ត្រូវចុះហត្ថលេខាលើបែបបទ "អាជ្ញាប័ណ្ណបោះពុម្ពផ្សាយ"។

អាសយដ្ឋានទំនាក់ទំនងសំរាប់ការផ្តល់អត្ថបទ

ទស្សនាវដ្តីកសិកម្មកម្ពុជា (Cambodian Journal of Agriculture)

លោកបណ្ឌិត ម៉ែន សារុម នាយកវិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៏កសិកម្មកម្ពុជា

ផ្លូវជាតិលេខ ៣ សង្កាត់ប្រទះឡាង ខណ្ឌដង្កោ រាជធានីភ្នំពេញ ព្រះរាជាណាចក្រកម្ពុជា

ប្រអប់សំបុត្រលេខ: ០១ ភ្នំពេញ ព្រះរាជាណាចក្រកម្ពុជា

ទូរស័ព្ទលេខ: (៨៥៥-២៣) ២១៩ ៦៩២

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រាល់អត្ថបទទាំងអស់ត្រូវត្រួតពិនិត្យដោយអ្នកជំនាញ យ៉ាងតិចណាស់ពី ០២នាក់ ឡើងទៅ។

SUGGESTIONS FOR CONTRIBUTORS TO THE *CAMBODIAN JOURNAL OF AGRICULTURE*

General requirement

Contributions to the *Cambodian Journal of Agriculture* (CJA) may be original reports of research (paper or note), letters to the editor, advertisements, or announcements. Research notes should not be more than two pages in length, while advertisements or announcements should not be more than ½ pages.

Manuscripts (Papers and notes)

Copies

Manuscripts should be submitted electronically, including any tables and figures, the references, table heads and figure captions. Photos must be original or scanned at magazine quality. The manuscript submitted to CJA can be in English (US) or in Khmer. In case the manuscript is in English, the test should be in Times New Roman font with a Khmer translation of the title and abstract in Limon font. For Khmer manuscript, the test should be in Limon font with an English translation of the title and abstract in Times New Roman.

Organization

Title: On the first page of either papers or notes. The title should be short but must accurately identify and describe the manuscript content. The title is, therefore, a highly condensed abstract with a maximum of 12 words.

Author(s): Below the title, list the names of all authors involved in conducting the research works. Separate the names of authors with comma (,) including before 'and' for the last author. Author/paper documentation should be included as a footnote of the first page. This should list the authors name and their complete current address and affiliation in the first paragraph. In the second footnote paragraph, the source of funding could be included if not already noted in the acknowledgements.

Abstract: Each paper must have abstracts: in both Khmer and English. It is limited in a self explanatory paragraph of not more than 250 words for papers and 150 words for notes. State the rationale, objectives, methods, key results and their significance especially for Cambodian agriculture. After the abstract the order of sections is an introduction, which includes a concise review of the relevant literature followed by materials and methods, results, discussion, conclusions (optional), acknowledgement (optional), and references. Results and discussion can be combined, and conclusions can be incorporated in the discussion section.

Style

Tables: Table must be numbered and each must be accompanied by a title. A head note containing material relevant to the whole Table should start on a new line. Table should be arranged with regard to the dimensions of the Journal columns (8 by 21 cm), and the number of column in the Table should be kept to a minimum. Excessive subdivision of column headings is undesirable and long heading should be avoided by the use of explanatory notes that should be incorporated into the head note. The first letter, only, of headings should be capitalized. Use asterisk (*, **, ***) only to indicate statistical significance at 0.05, 0.01, and 0.001 levels of probability, respectively.

The symbol of unit of measurement should be placed in parentheses beneath the column heading. The prefixes for units should be chosen to avoid an excessive number of digits in the body of the Table or scaling factors in the headings. When scaling factors cannot be avoided, the quantity expressed should be preceded by the power of 10 by which the value has been multiplied. Footnotes should be kept to a minimum and be reserved of specific items in the columns.

Horizontal rule should be inserted only above and below column heading and at the foot of the Table. Vertical rules should not be use. Each table must be referred to in the text, and a note in the margin should be indicate the preferred position of the Table in the text. Short table can frequently be incorporated into the text as a sentence or as a brief untitled tabulation. Only in exceptional circumstance will the presentation of essentially the same data in both a Table and a Figure be permitted where adequate, the Figure should be used.

Figures: Unsatisfactory Figures (i.e. in unreadable file formats) will be returned for correction. The symbols + or x should be avoided. Explanation of symbols should be given in the caption to the figure, and lettering of graphs should be kept to a minimum. Grid marks should point inwards; legends to axes should state the quantity being measured and be followed by the appropriate SI units in parentheses.

Photographs. Photographs must be of the highest quality, with a full range of tones and of good contrast. Important features to which attention has been drawn in the text should be indicated (i.e. by coded upper case letters and/ or arrows). Colour photographs will be accepted if they are essential to understanding the results.

Nomenclature: For plants, pathogens, insects and pests, give the Latin binomial in italics and the authority that first mention in the abstract or text (eg. rice (*Oryza sativa* L.).

Units of measurement: The International system of units (SI) must be used in all manuscripts submitted to the *Cambodian Journal of Agriculture*. Other units may be indicated in parentheses after the SI units if this helps in understanding the work reported. The double solidus must not be used in complex groupings of units (i.e. use mg/sheep. day, not mg/sheep/ day or mg^{-1} $sheep^{-1}$ day^{-1}). The CJA uses the abbreviation 'L' for litre 'mL' for millilitre. The units for exchangeable ions (mmol/kg) should be used for single charged ionic species, eg. N^+,K^+,CaO.5^+. The recommended unit for exchangeable ions and ion exchange capacity is cmol(+)/kg [or cmol(-)/kg], where (+)or (-) refers to a unit charge. This recommended unit is numerically equivalent to the non-SI but still widely used mill equivalents per 100g. The recommended unit for electrical conductivity is dS/m, but mS/cm is acceptable.

Evaluation of results

Research paper must contain a clear and concise description of the experimental design used with sufficient detail such that, in the case where analysis of variance or regression models are to be used in the statistical evaluation, the reader is quite clear as to how the error term was estimated. The statistical tests should be briefly described and, if necessary, supported by references. Numbers of individuals, mean values and measures of variability should be stated be made clear whether the standard deviation or the standard error has been given.

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References are cited by the author and date (Harvard system); they are not numbered. All reference in the text must be listed at the end of the paper, with the names of authors arranged alphabetically; all entries in this list must correspond to references in the text. In the text, the names of 2 coauthors are linked by 'and'; for 3 or more, the first author's name is followed by 'et al.'.

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