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**Aims and Scope:**

The International Journal of Environmental and Rural Development, IJERD, is an interdisciplinary journal concerning environmental and rural development research in the education for sustainable development, ESD. The IJERD is devoted to publishing peer-reviewed research article, review article and technical report in the fields of environmental and rural development, such as education for sustainable rural development, rural development, environmental management or agricultural systems. Every article or report in IJERD must be accepted by at least 2 reviewers and an editorial member.

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***Infrastructural Systems:***
Water Resource Development, Land Reclamation, Road Construction, etc.

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*Invited article*

# Education for Sustainable Development: Challenges for Transformative Education and Research

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**Abstract** The world is experiencing tremendous challenges entering into the 21st century. The enormous growing global population is expected to use more natural resources to achieve economic growth, while imperiling moral social values and degrading the environment. These gargantuan problems cannot be solved overnight. They have to be tackled collectively by all sectors of society, and the consensus is that Education for Sustainable Development (ESD) is the pathway towards a sustainable future. While there is general consensus that ESD is the way forward, instilling this new educational paradigm into peoples' minds and hearts is a gigantic task. Higher education institutions, as well as research institutions, together with non-formal education institutions, have important roles to play in this defining human endeavor. In response to the United Nations Decade of Education for Sustainable Development (UN DESD 2005-2014), the United Nations University (UNU), collaborates with UNESCO, the lead UN agency for the UN DESD Implementation, and other UN agencies and international organizations, in spearheading the promotion and development of Regional Centres of Expertise (RCEs) on ESD worldwide. An RCE is a network of existing formal, non-formal and informal education organizations, mobilized to deliver ESD to local and regional communities. An RCE builds an innovative platform for multi-sectoral and interdisciplinary information-sharing, dialogue and collaboration for promoting ESD among regional/local stakeholders, including joint efforts by stakeholders in working for transformative education and research on ESD in all levels of education and knowledge creation. It is important that the lessons learned from these RCE activities are shared globally, through the so-called Global Learning Space on ESD, as they provide inspiration and knowledge to others wanting to make contributions for a sustainable future. This paper provides an overview of sustainability, highlights the concept of RCE as a new form of networking, and provides examples of good practices of RCEs in tackling ESD issues.

**Keywords** education for sustainable development, regional centre of expertise, sustainability, transformative education and research

## INTRODUCTION

In the last two decades there have been a number of important international commitments strongly suggesting that the traditional development paradigm must change - the UN Conference on Environment and Development or UNCED (1992), the Rio Declaration and Agenda 21 (1992), the World Summit on Sustainable Development or WSSD (2002), and the UN Decade of Education for Sustainable Development or UN DESD 2005-2014, among others. In the Rio Declaration, for example, it was recognized that the current global patterns of consumption and production are not sustainable and if these continue, additional planets will be needed by 2050 and this is not possible. The world is indeed consuming more and more, faster and faster that the entire world population are living on ever decreasing natural capital. The human ecological footprint is now equivalent to consuming annually 30 percent more biological resources than the earth can produce or regenerate in one year (Global Footprint Network). As the people consume more, more species go extinct. The Living Planet Index of biosphere health fell by about 40 percent from 1970 to 2000, a period of just 30 years, and the question is what will happen in the next 30 years (Worldwatch Institute Report, 2004). The livability of the earth is getting unsustainable, and this situation must be reversed.

As proposed by the Japanese Government and nongovernmental organizations in the Johannesburg Plan of Implementation in 2002, the UN General Assembly in December 2002 adopted the UN Decade of Education for Sustainable Development during 2005-2014. The International Implementation Scheme (IIS) for DESD, with UNESCO as lead UN agency, was approved in September 2005, and Governments of UN Member States are invited to consider measures to implement DESD in their educational strategies and action plans. Sustainable Development - one which meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987) - must be adopted and integrated into educational context. The vision of the UN DESD is to create a world where everyone has the opportunity to benefit from education and learn the values, behaviors, and lifestyles required for a sustainable future and for positive societal transformation.

## EDUCATION FOR SUSTAINABLE DEVELOPMENT

Education for Sustainable Development (ESD) is about learning rather than teaching and therefore requires reforming the structure and nature of basic education, reorienting existing education programs, developing public awareness about what sustainability means, and building capacity within education systems and across all other ESD partners. The three pillars of sustainability are Society, Environment, and Economy, with Culture as an underlying and critical dimension. There is a need to understand the social institutions and their role in change and development. There should be awareness of natural resources and the fragility of the physical environment. There must also be sensitivity to the limits and potential of economic growth and its impact on society and on the environment. All of these must be embedded in ways of behaving, and acting which differ according to context, history and tradition.

ESD is interdisciplinary, holistic and values-driven, promoting the ideals of gender equity, just and peaceful societies, human rights, environmental preservation and restoration, cultural diversity, and poverty alleviation, and focusing on critical thinking and problem-solving, multi-methodological in approach, participatory in decision making, and locally relevant. Sustainability is not only a “what” but it is more a “how”; it is a decision-making framework for continuous improvement for creating a sustainable future. For each and every planned action, it is imperative to ask and answer the big question - How will this action impact people, the environment, and the economy?

ESD research and development deals with longitudinal studies to evaluate the effects of ESD programs implemented. It is designed to advance the conceptual and theoretical development of ESD and identity appropriate ESD pedagogy, as well as research on quality teaching and learning approaches for ESD. Research on and on topics related to Sustainable Development (SD) must be demonstrated and put into education context so that they can be cases of good practices for the education sector - both formal and nonformal - to use and learn from them. Not only that theory must be put to practice, but that also practice - sustainability practice, that is - must be contextualized in educational curricula and programs.

## DEVELOPMENT PARADIGM SHIFT TOWARDS SUSTAINABILITY

There is a need to effectuate change in peoples’ living and working styles, in enterprises doing business, and on the whole towards sustainable consumption and production. These changes entail exercise of leadership by all people in all segments of society. The change is everybody’s business, in bringing the present state, which is basically unsustainable, into a desired future state, which is and must be sustainable. The past cannot be undone, but it can be analyzed and lessons learned from for purposes of designing a sustainable future. The desired future state is undoubtedly to attain the goals of sustainable development - e.g. those articulated in the Millennium Development Goals (MDGs); the Goals of Education for All (EFA); and in the Thrusts of the UN DESD. MDGs aspire for ending poverty and hunger, providing universal education, attaining gender equality, securing child and maternal health, combating HIV/AIDs, creating environmental sustainability, and achieving global partnership. EFA aims at expanding early childhood care and education, providing free compulsory education for all, promoting learning and life skills for young people and adults, increasing adult literacy, achieving gender parity, and improving quality of education.

The major thrusts of ESD under DESD is to improve access to quality basic education, reorienting existing education programs to address SD, developing public understanding, and to provide training programs for all sectors of private and civil society. In response to the UN DESD, the DESD vision of UNU is the creation of the so-called Global Learning Space (GLS) for SD. The GLS for SD encompasses advocacy and dissemination of ESD and DESD, promotion of regional centres of expertise (RCEs) and their networking, strengthening of ESD activities of higher education institutions, further development of on-line learning for ESD, and training of teachers and trainers on ESD. These thrusts constitute the UNU strategy to promote ESD.

## REGIONAL CENTRES OF EXPERTISE

A Regional Centre of Expertise (RCE) is a network of existing formal and nonformal education organizations mobilized to deliver ESD in the region or locality where it is situated. It creates a platform for dialogue among regional/local ESD stakeholders and for exchanging information, experience and good practices on ESD. It develops regional/local knowledge base and assists in promoting vertical alignment of curricula from primary through university education and in linking formal and nonformal sectors of the education community. RCEs together and their mutual relations form the Global Learning Space for SD, which is a visible output of DESD. As of November 2009, there are 74 RCEs worldwide that have been acknowledged, 28 of them are located in the Asia-Pacific region, 22 in Europe, 13 in the Middle East & Africa, and 11 in the Americas. RCE Greater Phnom Penh is one of the 8 new RCEs acknowledged in November 2009.

There are three levels of networking under the RCE framework. One is networking among RCE stakeholder organizations, called intra-networking. The next level is the networking of RCEs in the Asia-Pacific region. The widest level is networking among RCEs globally. The inter-networking among RCEs, either continentally or globally, is in the form of thematic groups such as Health and Traditional Medicine, Sustainable Production and Consumption, Youth, Teacher Education, Climate Change, Energy, Biodiversity, among other areas. All of these areas cut across the Conference theme of Environment and Rural Development. Some areas - Climate Change, and Sustainable Production and Consumption - are further considered in the subsequent sections in the context of RCE activities.

## CLIMATE CHANGE

Climate change is an issue of concern to all of humanity, and many RCEs around the world have engaged in programs and projects on this issue. Albeit the task is gigantic, it can be tackled with great impact in the long-run in the context of ESD. Climate change has serious impacts on food and water security, on ecosystems and weather conditions. It causes falling crop yields in many areas, particularly developing regions. Small mountain glaciers can disappear, threatening water supplies in several areas. There can be significant decrease in water availability in many areas, and sea level rise threatens major cities. Climate change can cause extensive damage to ecosystems and biodiversity where rising number of species face extinction. It causes extreme weather conditions - rising intensity of storms, forest fires, droughts, flooding and heat waves. There is increasing risk of dangerous feedbacks and abrupt, large-scale shifts in the climate system.

There is a need to have an integrated approach to tackle climate change, both in terms of adaptation and mitigation. Mitigation requires reducing vulnerability and impact possibly through sustainable production. Adaptation requires changes on where and how people live through sustainable consumption. Another option in combating climate change is through sequestration of greenhouse gases. These responses to climate change can be effective if they are put into education context. In this great endeavor, RCEs can play important roles.

## SUSTAINABLE PRODUCTION AND COMSUMPTION

Sustainable Production and Consumption (SPC) is another critical movement in pursuit of a sustainable future and in which RCEs can play important roles. Changing consumption and production patterns towards more sustainable ones require improving policy framework to stimulate sustainable production and consumption. The technologies, or in some cases adopting the local indigenous knowledge, and processes involved in the productive activities need to be addressed as well as on the way basic services are provided, managed and distributed to the population. There is also a need to improve the way communication and information are provided and the way consumers purchase. These changing patterns requires strategies that would change public consumption behavior, increase resource-use efficiency by the production and service sectors, and in changing the way administering and managing sustainable consumption is done in a country.

Changing consumption behavior of the public sector entails several strategic options including advocacy and public awareness on product and service selection, dissemination of information from the government sector concerning sustainable consumption, creating a mechanism to support green product and service marketing, and integrating sustainable consumption concept into academic courses at all education levels. Promoting effective use of resource-base in production and service sectors include strategies like applying the ecological footprint concept, promoting research, development and application of clean and green technologies, promoting green design, strengthening a recycle market for industry, and promoting a product design for recycle, to mention some. Administering and managing for SPC should necessarily develop a strategy to take care and protect the resource-base in the country. It should develop a mechanism to make a balance between the use of renewable resource and restoration of ecological system of the resource that has been used. It should also involve increase efficiency of the use of non-renewable resource and develop other alternative resources, assign sustainable consumption as a national agenda, and accelerate the improvement and development of laws/legislations of the government sector in supporting effective sustainable consumption.

Instruments for SPC constitute a whole range of measures from “soft” to “hard” ones. The hard measures are of regulatory type such as following norms and standards, imposition of environmental liability, and environmental control and enforcement according to laws/legislations. The soft measures are informational instruments such as eco-labeling and sustainability reporting. The so-called in-betweens, from harder to softer in that order, are economic, research, educational, and cooperation instruments, such as environmental taxes, environmental financing, green public procurement, research & development, education & training, technology transfer, and voluntary agreements.

## SOME RCE GOOD PRACTICES ON ESD IN ASIA-PACIFIC

What follows are some examples (not exhaustive) of RCE education and research activities on ESD in the region. These were contributed by the respective RCEs for presentation at the 2nd ASEAN+3 Leadership Programme on Sustainable Production and Consumption organized by UNU-IAS, the ASEAN Secretariat, and the Ministry of Natural Resources and Environment of Thailand, 8 August 2009, Cha-am, Petchaburi, Thailand.

- *RCE Tongyeong, South Korea:* As an example of a practical approach to ESD, the network introduced values education through “Clean Plate Movement”. In the environmental context, the movement conserves food resource and save cooking energy. It contributes towards reducing carbon emission from cooking and transport; it leads to green consumption, and forest cultivation. From the economic standpoint, the movement decreases unnecessary food waste, activation of safe organic farming industry, and decreases food price at the international market. From the societal and cultural perspectives, the movement can prevent conflict instigated by food shortage; it enhances safe and healthier food security, respect for various food culture, and healthier eating manner by only eating moderate amount. The movement has impacted a large number of the local population.

- *RCE Anji, China*: The Anji County of Zhejiang Province of China is richly endowed with bamboo resources. About 70 percent of its land area is covered with forest, most of them by bamboo plantations. This is an example of utilizing its indigenous natural resource to propel the local economy through the concept of sustainability from consumption to production. The County has been awarded by the Government of China as an Eco-county, which practices the concepts of sustainability. Bamboo forest is considered as among those with high carbon sequestration capacity. The RCE helps promote ESD through the sustainable bamboo economy as example.
- *RCE Bogor, Indonesia*: The RCE contributes towards tissue culture training, engaging in rice organic farming pilot project, and entrepreneurial training and practices. The target groups are teachers, students and the community. Entrepreneurial practices include fruit chips, aromatic oil distillation, mushroom production, and herbal drink production.
- *RCE Trang, Thailand:* The RCE engages in biodegradable packaging. The process is from sugarcane to bagasse pulp to biodegradable tableware, to compost in landfill, and back to fertilize sugarcane plantation again. Products include common-use things such as bowl, box, plate, tray, and biofoam. Promoting the use of biodegradable packaging is done in traditional festivities including the municipality's vegetarian festival.
- *RCE Cha-am, Thailand:* The Philosophy of Sufficiency Economy of His Majesty, The King of Thailand calls for a balanced and sustainable development at all levels. The theory is to make the agricultural producers or farmers more self-reliant through a holistic management of their land, while living harmoniously and within society. The RCE is engaged in promoting this sustainable philosophy in the locality. Sustainable production includes rice farming, livestock, mushroom culture, organic farming, solid waste disposal technology production, biological fertilizer production, and water bio-fermentation.
- *RCE Kitakyushu, Japan:* The RCE is engaged in demonstrating an example of adopting a circular society through cardboard compost. Domestic garbage from households is put in the compost, the compost is put in the field, then planting, and then harvesting. There were lessons learned from the project including habit-forming behaviors such as - to stop throwing garbage as disuse; getting into the habit of garbage compost; the pleasure of growing vegetables; learning the circular system, etc. For the activity of using compost fertilizer for rice cultivation, lessons learned include the pleasure of youth and adults working together, the fun and difficulties of rice-making, knowing about the animals and plants in the rice fields, and sensing a good taste of rice.
- *RCE Cebu, Philippines*: The RCE adopts corporate social responsibility (CSR) by a cluster of business enterprises working together for a common purpose. Consideration of the environment is addressed through solid waste management which includes activities such as segregation, garbage collection, composting, biodiversity conservation, and watershed management. Entrepreneurship is demonstrated through recyclable collections in the form of cash-from-trash project, product-from-waste project, waste exchange and seed bank project. Education is impacted by the adopt-a-library project, vocational scholarship, and tutorials. The movement also serves as a manpower source for the participating businesses. The movement also contributes to peace and order through emergency preparedness activities. It also impacts health through feeding programs, medical mission, and health center project. All of these are through the initiative of the RCE with the participation of a group of companies working together for ESD.

## CONCLUDING REMARKS- ROLE OF HIGHER EDUCATION INSTITUTIONS

It is imperative that education institutions, especially higher education institutions (HEIs), integrate SD philosophy into curricula as well as mainstream the sustainability paradigm in academic programs. Research must be reoriented and new knowledge developed based on SD. There is also a need to develop new technologies, methods, tools and techniques to embrace SD.

There are obviously questions of competencies, however, which are critical. The focus must not only be on teachers and students in formal education but also those in nonformal education organizations engaged in teaching diverse fields. Training must also be in-service, not only pre-service teaching, at the inter- and multi-disciplinary nature of ESD. ESD must be learned as a general concept that allows for its adaptation to national and local needs and priorities.

As part of its Education for Sustainable Development Programme, UNU-IAS has under its auspices, spearheaded the establishment of the Promotion of Sustainability in Postgraduate Education and Research Network (ProSPER.Net) in Asia-Pacific. Members of the alliance, currently 19 reputed higher education institutions, have committed to working together to integrate SD into postgraduate courses and curricula as well as in research programs. The network is a platform of collaboration for members to pursue postgraduate education and research on SD with an emphasis on ESD. The process and content of education must change to be able to reach the goals of sustainability.

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*Invited article*

# Establishment of RCE Greater Phnom Penh for Promoting ESD in Cambodia

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**Abstract** Rapid development of agricultural technologies in Greater Phnom Penh has significantly increased agricultural production. The majority of farmers apply agricultural chemicals. Agricultural chemicals released from farmlands to downstream cause various environmental problems. So, the education for sustainable development (ESD) was focused on agricultural sector. Especially, the students in the elementary schools were prioritized as they will become farmers in the future. Forming RCE is expected to increase the opportunity to build the public awareness and perception of the importance of making harmony between farming practices and natural environment. This report deals with the background of RCE Greater Phnom Penh in Cambodia and its challenges. One of the challenges in the RCE is enhancing the food, agriculture and environment education for elementary schools through the organic farming activities at elementary schools and the facilitator training of elementary school teachers under the collaboration among government, university, local NGO and local community.

**Keywords** ESD-education for sustainable development, RCE-regional centre of expertise, Phnom Penh

## INTRODUCTION

A RCE is a network among formal, non-formal and informal education organizations, mobilized to deliver education for sustainable development (ESD) to local and regional communities. A network of RCE provides the Global Learning Space for Sustainable Development. RCEs aim to achieve the goals of the UN Decade of Education for Sustainable Development, DESD, from 2005 to 2014 by translating its global objectives into the context of the local communities in which locals operate.

A RCE is expected to involve all levels as school teachers, professors at higher education institutions, environmental NGOs, scientists, researchers, governmental officers, representatives of local enterprises, volunteers, civil associations or individuals who work in the spheres of sustainable development such as economic growth, social development and environmental protection. Also, it aims to collaborate among institutions at the regional or local level in a RCE for promoting ESD jointly. Innovative platforms should be built for sharing information and experiences and for promoting dialogue among regional or local stakeholders for sustainable development. In addition, a local or regional knowledge base should be created to support ESD actors (Mochizuki and Fadeeva, 2008; UNU-IAS).

This report deals with the background of RCE Greater Phnom Penh in Cambodia, that is the first RCE established in Cambodia, and its challenges in the education for sustainable development, ESD, focusing on the food, agriculture and environment education.

## TARGET AREA

Phnom Penh is the capital of Cambodia where more than 1.3 million people are living. Phnom Penh covering an area of 290 square kilometers is located in the south-central region of Cambodia at the confluence of the Tonle Sap, Mekong and Basac Rivers. These rivers provide potential freshwater and other resources.

As shown in Fig. 1, Greater Phnom Penh covers not only Phnom Penh but also surrounding provinces, such as Kampong Cham, Kampong Chhnang, Kampong Speu, Kandal, Prey Veng and Tako. The area and population of each province are summarized in Table 1. These provinces being close to Phnom Penh have a strong relation in food demand-supply and economical aspect. Total area and population of Greater Phnom Penh is 34,641 square km and 7,250,881, respectively. Also as shown in Table 2, more than 90% of population is in rural area in surrounding provinces, although 93% of population in Phnom Penh is in urban area.


**Fig. 1 Location of Phnom Penh and Greater Phnom Penh**

**Table 1 Phnom Penh and surrounding provinces in Greater Phnom Penh**

| | Name of province | Area (Square km) | Population | Remark |
|---|---|---|---|---|
| 1 | Phnom Penh | 290 | 1,325,681 | capital |
| 2 | Kampong Cham | 9,799 | 1,680,694 | |
| 3 | Kampong Chhnang | 5,521 | 471,616 | |
| 4 | Kampong Speu | 7,017 | 716,517 | |
| 5 | Kandal | 3,568 | 1,265,085 | |
| 6 | Prey Veng | 4,883 | 947,357 | |
| 7 | Takeo | 3,563 | 843,931 | |
| | Total | 34,641 | 7,250,881 | |

The economy in Greater Phnom Penh is based on agriculture. Agriculture is one of the important sectors of the Cambodian national economy. More than 70% of the total population in Greater Phnom Penh is in the agricultural sector. Most of households in Greater Phnom Penh depend on agriculture having the relation with sub-sectors such as livestock raising, fisheries or aquaculture for their livelihood. Agriculture produces a wide variety of crops in Greater Phnom Penh. However, the major crop is paddy rice. Agricultural sector remains unpredictability, because it still depends on geographical and weather conditions.

**Table 2 Population in urban and rural areas in Phnom Penh and surrounding provinces**

| | Name of province | Population in urban area (%) | Population in rural area (%) | Remark |
|---|---|---|---|---|
| 1 | Phnom Penh | 93 | 7 | capital |
| 2 | Kampong Cham | 5 | 95 | |
| 3 | Kampong Chhnang | 8 | 92 | |
| 4 | Kampong Speu | 7 | 93 | |
| 5 | Kandal | 9 | 91 | |
| 6 | Prey Veng | 5 | 95 | |
| 7 | Takeo | 0 | 100 | |

*Source: Commune Database 2004*

## REGIONAL CHALLENGES

Phnom Penh being the capital of Cambodia is the center of economic, industrial, commercial, cultural, tourist and historical aspects. Number of people living in Phnom Penh is rising every year. Recently, rapid increase in population causes many problems in environment, life quality, education and health, etc. Although education is the key to develop the human resources, it is not easy to improve education system, because of lacking teachers, school facilities and low income of people.

A net admission ratio for elementary school is 93.3%, however a net enrollment ratio of lower secondary school is 34.8% and of higher secondary school only 14.8% based on the education statistics of MoEYS (2007/2008). Female students from rural areas or students from the poor family are all grossly underrepresented in education statistics. Big number of students who didn’t continue to secondary schools starts working in agricultural sector.

In the provinces of Kampong Cham, Kampong Chhnang, Kampong Speu, Kandal, Pray Veng and Takeo, the conditions of education are much insufficient for children comparing to that in Phnom Penh. The parents in rural area need their children to work in the farmlands. The poverty of farmers (Table 3) is a barrier for children to continue their study at elementary or secondary schools.

**Table 3 Poverty rate based on population under poverty line**

| No. | Name of province | Poverty rate (%) |
|---|---|---|
| 1 | Phnom Penh | 11.9 |
| 2 | Kampong Cham | 12.1 |
| 3 | Kampong Chhnang | 44.6 |
| 4 | Kampong Speu | 18.2 |
| 5 | Kandal | 18.4 |
| 6 | Prey Veng | 53.1 |
| 7 | Takeo | 15.2 |

*Source: WFP 2002*

Agriculture plays an important role for economic growth with reducing poverty of the people. Rapid development of agricultural technologies has significantly increased agricultural production. Currently, the majority of farmers apply agricultural chemicals, such as chemical fertilizers, herbicide or pesticide, to maintain high levels of crop yields. However, the overuse of agricultural chemicals is damaging the long-term soil fertility and productivity of farmlands. Also, agricultural chemicals released from farmlands to downstream cause the degradation of water environment. This degradation is progressively accelerated with the transport of suspended substances caused by soil erosion. It means that intensive farming practices depending on agricultural chemicals cause various problems for natural environment and human health.

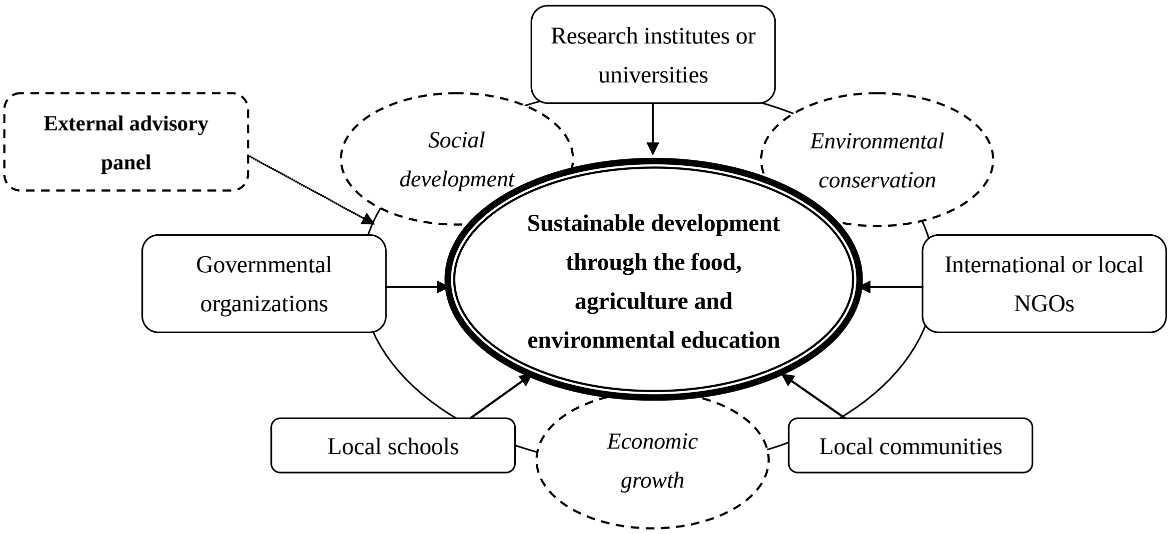


**Fig. 2 RCE Greater Phnom Penh focusing on the food, agriculture and environment education**

Accordingly, as regional challenges in the education for sustainable development (ESD), an attention has been paid to sustainable processes for rural development. Although there are some factors constituting sustainable rural development as economic growth, social development and environmental conservation, the food, agriculture and environment education was focused as a first step for approaching sustainable rural development in the area of Greater Phnom Penh as shown in Fig. 2. Especially, the students in the elementary schools were prioritized, as they will become farmers in the future. So, one of current challenges in RCE Greater Phnom Penh is enhancing the food, agriculture and environment education for elementary schools through the organic farming activities at elementary schools and the facilitator training of elementary school teachers under the collaboration among government, university, local NGO and local community.

**Fig. 3 Food, agriculture and environment education through cultivating vegetables at school organic gardens in Phnom Penh and Kampong Cham**

## ON-GOING ACTIVITIES

The program on the food, agriculture and environment education has been conducted since 2006 under the collaboration among government organizations, universities, local NGOs, local communities and elementary schools in Phnom Penh and Kampong Cham. In the initial stage of

RCE Greater Phnom Penh, all organizations in RCE Greater Phnom Penh are also involved and collaborate in the program. The contents of the program are as follows.

- To make a model for enhancing the food, agriculture and environment education for elementary schools in Phnom Penh and Kampong Cham through conducting seminars and practicing organic farming at schools.
- To publish and distribute various textbooks or guidebooks written in Khmer.
- To conduct the training courses for depper perception on the food, agriculture and environment education under the collaboration among government, university, local NGO and local community.
- To hold the workshop or conference for illuminating various ESD activities conducted not only in Cambodia but also in other countries.
- To construct the network among governments, universities, local NGOs, local communities, elementary schools and so on for managing RCE Greater Phnom Penh.

**Fig. 4 Food, agriculture and environment education through composting and students' activity report at elementary schools**

RCE Greater Phnom Penh comprises member organizations from various fields with a wide range of expertise which are engaged in ESD and its related activities. The stakeholder organizations include Royal University of Agriculture (RUA) and Institute of Environment Conservation and Rehabilitation, Cambodia Branch (CaM-ERECON), which work as coordinators of RCE Greater Phnom Penh in the Secretariat Committee, Ministry of Agriculture, Forestry and Fisheries, Ministry of Rural Development, Ministry of Education, Youth and Sports, several elementary schools in Phnom Penh and Kampong Cham and so on.

In addition, Tokyo University of Agriculture, Institute of Environment Conservation and Rehabilitation and Association of Environmental and Rural Development are in the external advisory panel of the RCE Greater Phnom Penh.

## CONCLUSION

RCE Greater Phnom Penh is established to promote ESD through the food, agriculture and environment education for sustainable development in the area of Greater Phnom Penh. This is the first RCE established in Cambodia.

In a short term for 2-3 years after the establishment of RCE Greater Phnom Penh, the food, agriculture and environment education for elementary schools is focused as a challenge of the RCE. Also, some conference or workshop is held in Phnom Penh regularly for promoting the discussion or the sharing of ideas concerning sustainable processes for rural development. This conference or workshop held in Phnom Penh is expected to increase not only the quality of educators but also the collaboration among school teachers, professors at higher education institutions, facilitators at environmental NGOs, scientists, researchers, governmental officers, representatives of local enterprises, volunteers, media, civil associations or individuals.

In a long term after 2-3 years passed from the establishment of RCE Greater Phnom Penh, the activities on the food, agriculture and environment education for elementary schools will be advanced at other provinces in Greater Phnom Penh, in addition to the activities for local communities.

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*Research article*

# Land Conservation of Upland Hills with Severe Erosion – Promoting Field Schools to Increase Farmers' Awareness

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Received 1 December 2010 Accepted 5 March 2010

**Abstract** Lack of knowledge and understanding of farmers about the risk of erosion have contributed to the rapid degradation of watersheds in Indonesia. Research was carried out to identify the topography and extent of land use in the upstream Bengawan Solo watershed to determine interactions between topographic characteristics and land use that could explain the effect of agricultural expansion in hill areas on erosion occurrence. An erosion model was applied to calculate the erosion risks using Geographic Information System (GIS). Slope and land use assessments showed that more than 60% of the soil loss occurred on upland and mixed crop areas under moderate to steep slopes. Field investigation indicated that many farmers used to grow maize and cassava in the hilly areas that are tilled repetitively and mostly left without vegetation cover. Moreover, farmers are not making efforts to use land conservation measures. Thus, these areas need immediate attention for soil and water conservation activities to prevent further land degradation. A land conservation map was created to identify land use features as well as recommended conservation measures which should be applied in order to limit further watershed degradation. Farmer field schools are proposed to increase farmer awareness on the negative effects of soil erosion and the benefits of practicing soil and water conservation.

**Keywords** upland hills, erosion, GIS, farmer field school

## INTRODUCTION

Environmental-related problems, especially erosion, are major issues faced by developing countries such as Indonesia. Increased illegal logging and inappropriate land conversion to expand the agriculture area have contributed to an increase in the number of critical watersheds in recent decades. In 1984 the number of critical watersheds in Indonesia was estimated at 22. However, according to the latest survey the number of critical watersheds has increased to 108, or 6-fold, within two decades (Ministry of Forestry, 2009).

High population growth has led to pressure on land resources. Moreover, lack of knowledge and understanding by local people about the dangers posed by the illegal exploitation of forests and ways of ignoring the rules of land conservation have also accelerated land degradation. This phenomenon is now faced by Wonogiri Regency which is the case study in this research. Uncontrolled land conversion in the upland and hilly areas has accelerated the occurrence of landslides, floods and droughts in downstream areas. In addition, agricultural practice in the upland and hilly areas has led to a decline in the productivity of upland fields as cropland is more prone to erosion because they are tilled repetitively and mostly left without vegetation cover. Soil erosion levels in this area are still high and farmers are not making efforts to construct or maintain soil and conservation works. The Regional Development Agency of Wonogiri Regency has reported a strong relationship between forest conversion and erosion, explaining the need to detect and assess land conversion systems as a first step in erosion evaluation.

In the present work, an attempt is made to assess the topography and extend of land use over the watershed in order to find the relationship between topographic characteristics and land use that could explain the effect of land conversion on erosion occurrence. Furthermore, farmer field schools are proposed to increase farmer awareness of the negative effects of soil erosion and the benefits of soil and water conservation.

## MATERIALS AND METHOD

Because of the high erosion levels, a research area was selected in the Wonogiri Regency of Indonesia. Wonogiri is located between latitudes 7º 32' S and 8 15' S and longitudes 110º 42' E and 111º 18' E. A map of the study area is shown in Fig. 1. This area has a monsoon climate with an average annual precipitation of 2773 mm. Topography of the area includes elevations from 115 to 1300 m. Major soil types are Latosol, Meditreran, and Andosol (Soewarno and Hardjosuwarno, 2008). Dry land farming, paddy field and forest dominate the land use system in the river basin, which account for more than 70% of the area. Widespread soil conservation measures have been implemented in the area but these are in a poor state due to a lack of maintenance by farmers who are expecting local government assistance.

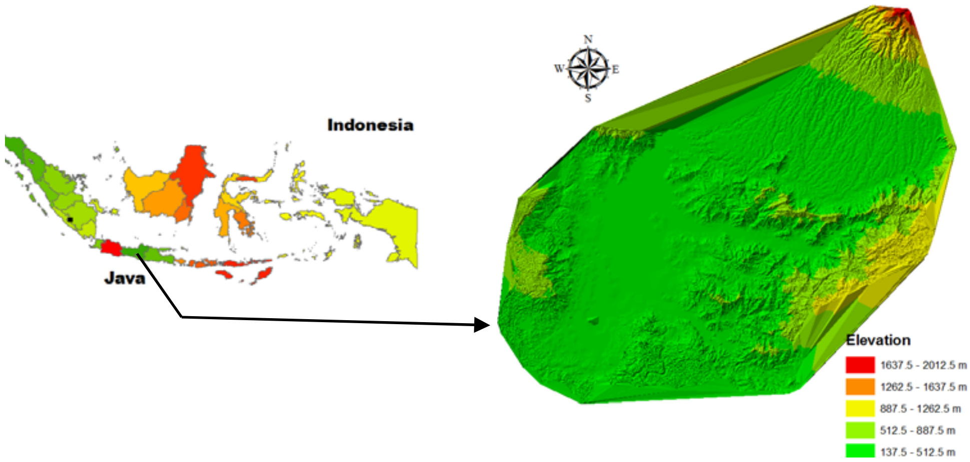


**Fig. 1 Map of the study site under consideration**

A survey was undertaken from January to May 2009. Various types and sources of data were collected including satellite image soil attribute data from the National Soil Survey Office, land use and climate data. This information was used to identify the source of erosion as well as to develop conservation strategies. Interviews were also conducted with local farmer about their perceptions of soil erosion and the constraints of the present existing soil and water conservation measures.

Data processing was implemented using the Revised Universal Soil Loss Equation (RUSLE) in a GIS raster system. RUSLE computes the average annual erosion expected on hillslopes by multiplying several factors together as: A = R.K.L.S.C.P, where A is the computed annual soil loss (t/ha/yr); R is the rainfall erosivity factor (MJ mm/ha h); K is a soil erodability factor (t/ha/MJ mm); L is a slope length factor; S is a slope steepness factor; C is a cover management factor; and P is a supporting practices factor. The values of these factors are determined from field and laboratory experiments (Renard et al., 1997; Lal, 2001).

After obtaining information on the relative magnitude and spatial distribution of soil erosion and potential soil erosion sites, we expand the analysis to create a land conservation map to protect the watershed from degradation.

## RESULTS AND DISCUSSIONS

### Farming practice on slope areas and its effect on soil erosion

Soil erosion in this study area has become one of the important factors affecting land degradation and sedimentation deposition on the river. The results indicated that some regions of the watershed have been identified as high erosion potential zones. To distinguish the level of erosion based on the slope steepness the area was classified into four classes, namely 1. gentle slope (0-25%), 2. moderate slope (25-35%), 3. steep slope (35-50%), and 4. very steep slope (>50%). Through slope assessment in the GIS environment, the estimated distribution of erosion by soil class is shown in Table 1.

**Table 1 Soil loss and coverage area under different slope class**

| Slope class | Soil loss ( ton/ha/yr) | Percent (%) | Coverage area (ha) | Percent (%) |
|---|---|---|---|---|
| Gentle | 53.75 | 9.17 | 133410 | 72.49 |
| Moderate | 185.36 | 43.38 | 45393 | 24.66 |
| Steep | 207.73 | 35.43 | 3565 | 1.94 |
| Very steep | 70.51 | 12.03 | 1676 | 0.91 |

Most of the Wonogiri watershed has erosion values of 53.75-207.73 ton/ha/yr, with most values in the range 185.36-254.31 ton/ha/yr, having a climatologically moderate to high erosion potential. In addition, more than 60% of the total amount of erosion occurred on the moderate and steep slopes. Most of the erosion occurred from November to March as this area is tropical where monsoon winds bring heavy rainfall during that period. During these months rainfall intensity reaches 150-200 mm/day, which can cause considerable soil erosion.

As land use practice has a strong relationship with the erosion occurrence the five land uses, i.e. mixed agriculture, settlement, upland crop, paddy field, and forest, were investigated to determine the effect of land use on soil erosion, as shown in Table 2. The computed soil erosion decreased in the following order: upland crop, mixed agriculture, settlement, forest and paddy field. The average computed amount of soil erosion under upland crop and mixed agriculture contribute more than 90% of the total soil loss.

**Table 2 Soil loss and coverage area under different land use**

| Land use | Soil loss (ton/ha/yr) | Percent (%) | Coverage area (ha) | Percent (%) |
|---|---|---|---|---|
| Upland crop | 223.12 | 52.26 | 20854 | 12.12 |
| Settlement | 6.45 | 1.71 | 28990 | 16.85 |
| Mixed agriculture | 143.96 | 38.24 | 67115 | 39.02 |
| Paddy field | 2.96 | 0.79 | 30318 | 17.44 |
| Forest | 3.00 | 0.80 | 25041 | 14.55 |

The major reason for high erosion in the area of upland and mixed agriculture was the rapid expansion of agricultural activities in hill areas (Veldkamp and Verburg, 2004). Most of the crops (upland and annual) were cultivated in hill areas which are more prone to erosion. Rapid population growth and reduced land availability in the flat areas have forced cultivation of crops (including maize, cassava and beans) in areas of moderate to steep slopes. In addition, high profits due to increased upland crop market prices have attracted more farmers to cultivate land more intensively, shorten the fallow periods and till the land repetitively. This results in land left without vegetation cover that accelerates soil erosion.

## Proposed land conservation area map

One of the challenges for the farmers living in the watershed is how to best manage their land without adverse effects on the environment. To help farmers limit or reduce further land degradation and its depleting effect on productivity, a proposed land conservation map has been created through overlaying erosion risk on land use maps. Risk assessment using GIS was conducted to classify five conservation areas, namely A, B, C, D and E as shown in Fig. 2 and Table 3.

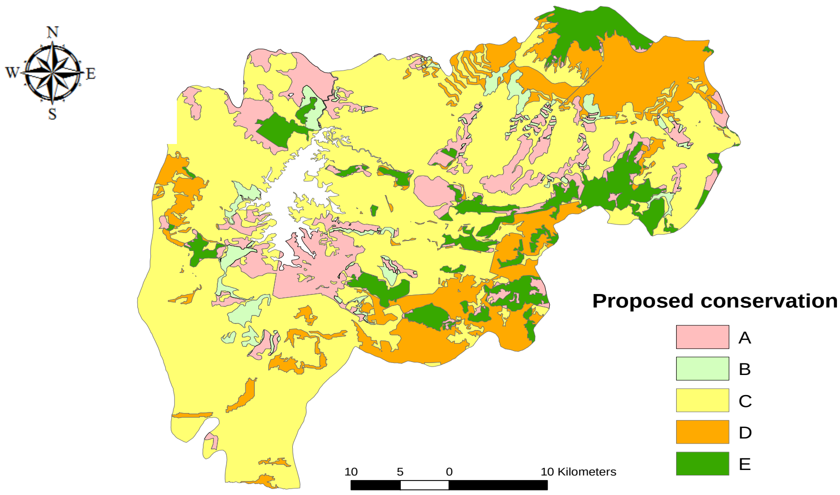


**Fig. 2 Recommended land conservation for the study area**

**Table 3 Proposed land conservation map for the study area**

| Land type | Existing land features | Area (ha) | Recommended land use/land conservation |
|---|---|---|---|
| A | Very low erosion level | 22891 | No specific conservation efforts required |
| B | Settlement areas with low to moderate erosion level | 6412 | • A grassed waterway to reduce erosion and catch nutrients<br>• Carry out settling ponds construction in the drainage area<br>• Individual terrace construction |
| C | Agricultural areas with low to moderate erosion level | 106783 | • Cover crop-any annual plant grown as monoculture<br>• Crop rotation or Crop sequencing- growing dissimilar types of crops in sequential seasons<br>• Ridge terrace construction |
| D | Agricultural areas with high to severe erosion level | 31085 | • Strip farming-alternate strips of closely sown crops with strips of row crops<br>• Contour farming- practice across a slope following its elevation contour lines<br>• Drop structure construction<br>• Community based soil erosion management program should be introduced |
| E | Agriculture on mountainous areas and forest | 16969 | • Change upland agriculture into agroforestry<br>• Reforestation of the very steep area (slope>50%)<br>• Engineering construction such as check dam and gully control<br>• Community based soil erosion management program should be introduced |

In Table 3 each different type of conservation contributes to a specific type of treatment. However, attention should be paid to land types D and E as these areas are the most critical, and should be treated immediately in order to maintain the sustainability of hydrological function. Farmers growing upland crops (mainly maize) in these areas are advised to practice strip or contour farming across a slope, as this system helps to stop erosion by creating natural dams for water and preserving the strength of the soil. In addition, drop structure construction helps to stabilize steep waterways and reduce gully erosion.

In addition, areas of land type E should be restricted from any upland farming activities such as maize or cassava. Instead, local farmers may be advised to pursue a practice encouraging environmental sustainability such as agroforestry in the border forest areas which buffer the more intensively deforestation. Furthermore, very steep areas (slope >50%) should be reforested to recover destroyed forests.

**Enhancing farmer awareness through farmers field schools**

The best way to permanently conserve eroded land is to work closely with an established education program in farming communities. Farmers field schools (FFSs) on soil and water conservation are proposed to help farmers obtain a deeper understanding of environment problems and their causes. This program brings together concept and methods from agro-ecology, experimental education and community development (FAO, 2002; Ministry of Agriculture, 2008).

The FFS is a group-based learning process with activities involving simple experiments, regular field observation and group analysis. The knowledge gained from these activities enables farmers to make their own locally-specific decisions about environmentally friendly crop management practices. The curriculum of FFS involves a wide range of environmentally friendly crop management such as tillage practices (direction and conservation tillage), crop rotations, use of organic fertilizer to manage soil fertility, use of crop residues, and soil and water conservation structures (terraces, drop structure). This curriculum is built on the assumption that farmers can only implement conservation measures once they have acquired the ability to carry out their own analysis. Organizing FFS requires a facilitator for the activities associated with farming practices. A flow diagram of FFS implementation is shown in Fig. 3.

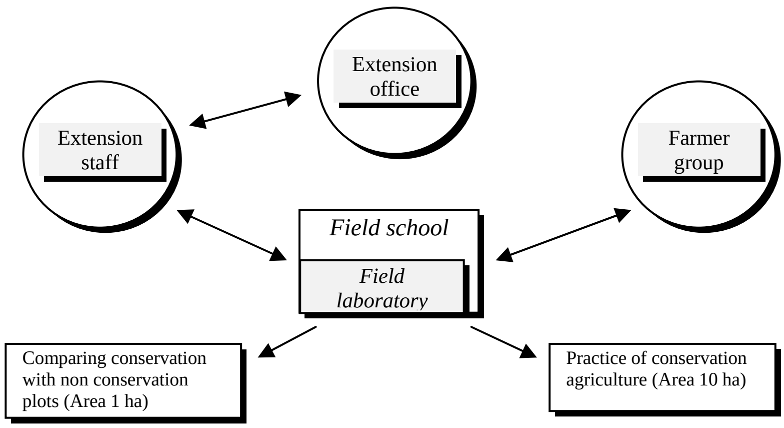


**Fig. 3 Flow diagram of FFS on soil and water conservation**

Fig. 3 details the role of a facilitator in the various FFS activities. In general, the facilitator introduces an activity, clarifies the process, sets participants to work, asks questions as groups make their presentations, and summarizes presentations underlining the important points that were learned during the exercise. The field facilitator (extension or researcher) organizes all activities from beginning to the end of the crop season. Participants of FSS are farmers living within the area around 10 ha. Farmers are divided into several small groups of 15 to 20 to maximize participation. Of the 10 ha of FFS land, 9 ha will be managed by farmer groups and the remaining 1 ha is used as a field laboratory with field guides managed by the extension/researcher.

Working with 15 to 20 member teams, farmers enter and make observation/experiment in the field laboratory plot (±1 ha). Once a week, participating farmers will come to the field laboratory to make observations and analyze the problems occurred. They are expected to compare these problems with the existing realities in the field. If there are differences in appearance between the conditions in a field laboratory with the field school, farmers are expected to have been able to explain. At harvest, the participants compare the crop yield or other conservation measures (e.g. erosion rate, soil quality) of the study samples (field laboratory) with the larger field (field school) in which the supporting study is conducted. Thus, the experience and lessons gained from the field laboratory can be a reference for farmers and motivate them to continue applied conservation measures in their own fields.

## CONCLUSION

Agricultural practices in upland and hilly areas have resulted in seriously declining land productivity as cropland is more susceptible to soil erosion. The erosion model was applied to assess the effect of farming practice in slope areas on the occurrence of erosion. Through slope and land use assessments we found that more than 60% of the soil loss occurred on upland crops and mixed agriculture under moderate to steep slopes. Field investigation indicated that many farmers grow maize and cassava in the hilly areas that are tilled repetitively and mostly left without vegetation cover. Moreover, farmers are not making efforts to maintain land conservation measures. Thus, these areas need immediate attention for soil and water conservation activities to prevent further land degradation. One of the challenges for the farmers living in the watershed is how to best manage their land without any adverse effect on the environment. A land conservation map was created to localize land use features and recommended conservation measures which should be applied in order to limit further watershed degradation, as well as depleting agricultural productivity. Farmers field schools are proposed to increase farmer awareness of the negative effects of soil erosion and the benefits of practicing soil and water conservation.

## ACKNOWLEDGEMENTS

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*Research article*

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## INTRODUCTION

Environmental-related problems, especially erosion, are major issues faced by developing countries such as Indonesia. Increased illegal logging and inappropriate land conversion to expand the agriculture area have contributed to an increase in the number of critical watersheds in recent decades. In 1984 the number of critical watersheds in Indonesia was estimated at 22. However, according to the latest survey the number of critical watersheds has increased to 108, or 6-fold, within two decades (Ministry of Forestry, 2009).

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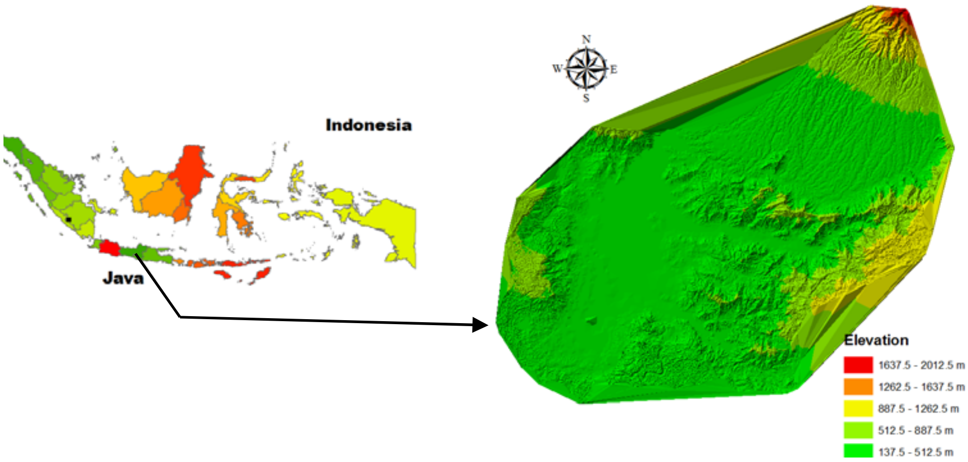


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## Proposed land conservation area map

One of the challenges for the farmers living in the watershed is how to best manage their land without adverse effects on the environment. To help farmers limit or reduce further land degradation and its depleting effect on productivity, a proposed land conservation map has been created through overlaying erosion risk on land use maps. Risk assessment using GIS was conducted to classify five conservation areas, namely A, B, C, D and E as shown in Fig. 2 and Table 3.

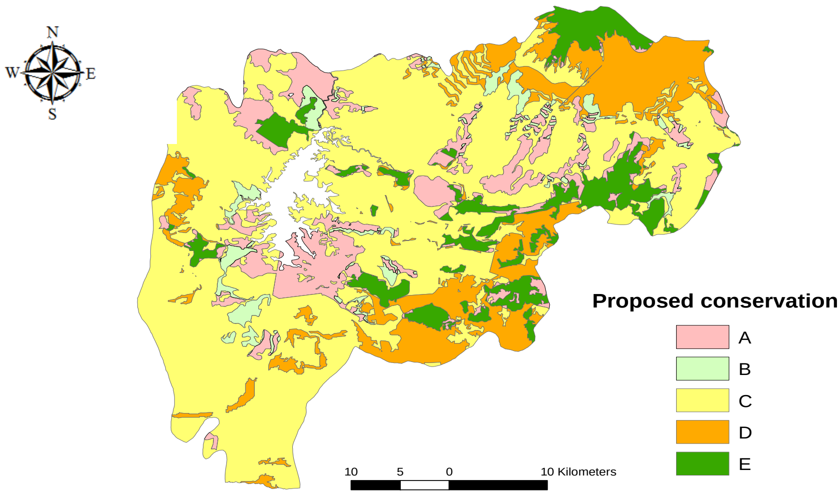


**Fig. 2 Recommended land conservation for the study area**

**Table 3 Proposed land conservation map for the study area**

| Land type | Existing land features | Area (ha) | Recommended land use/land conservation |
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| A | Very low erosion level | 22891 | No specific conservation efforts required |
| B | Settlement areas with low to moderate erosion level | 6412 | • A grassed waterway to reduce erosion and catch nutrients<br>• Carry out settling ponds construction in the drainage area<br>• Individual terrace construction |
| C | Agricultural areas with low to moderate erosion level | 106783 | • Cover crop-any annual plant grown as monoculture<br>• Crop rotation or Crop sequencing- growing dissimilar types of crops in sequential seasons<br>• Ridge terrace construction |
| D | Agricultural areas with high to severe erosion level | 31085 | • Strip farming-alternate strips of closely sown crops with strips of row crops<br>• Contour farming- practice across a slope following its elevation contour lines<br>• Drop structure construction<br>• Community based soil erosion management program should be introduced |
| E | Agriculture on mountainous areas and forest | 16969 | • Change upland agriculture into agroforestry<br>• Reforestation of the very steep area (slope>50%)<br>• Engineering construction such as check dam and gully control<br>• Community based soil erosion management program should be introduced |

In Table 3 each different type of conservation contributes to a specific type of treatment. However, attention should be paid to land types D and E as these areas are the most critical, and should be treated immediately in order to maintain the sustainability of hydrological function. Farmers growing upland crops (mainly maize) in these areas are advised to practice strip or contour farming across a slope, as this system helps to stop erosion by creating natural dams for water and preserving the strength of the soil. In addition, drop structure construction helps to stabilize steep waterways and reduce gully erosion.

In addition, areas of land type E should be restricted from any upland farming activities such as maize or cassava. Instead, local farmers may be advised to pursue a practice encouraging environmental sustainability such as agroforestry in the border forest areas which buffer the more intensively deforestation. Furthermore, very steep areas (slope >50%) should be reforested to recover destroyed forests.

**Enhancing farmer awareness through farmers field schools**

The best way to permanently conserve eroded land is to work closely with an established education program in farming communities. Farmers field schools (FFSs) on soil and water conservation are proposed to help farmers obtain a deeper understanding of environment problems and their causes. This program brings together concept and methods from agro-ecology, experimental education and community development (FAO, 2002; Ministry of Agriculture, 2008).

The FFS is a group-based learning process with activities involving simple experiments, regular field observation and group analysis. The knowledge gained from these activities enables farmers to make their own locally-specific decisions about environmentally friendly crop management practices. The curriculum of FFS involves a wide range of environmentally friendly crop management such as tillage practices (direction and conservation tillage), crop rotations, use of organic fertilizer to manage soil fertility, use of crop residues, and soil and water conservation structures (terraces, drop structure). This curriculum is built on the assumption that farmers can only implement conservation measures once they have acquired the ability to carry out their own analysis. Organizing FFS requires a facilitator for the activities associated with farming practices. A flow diagram of FFS implementation is shown in Fig. 3.

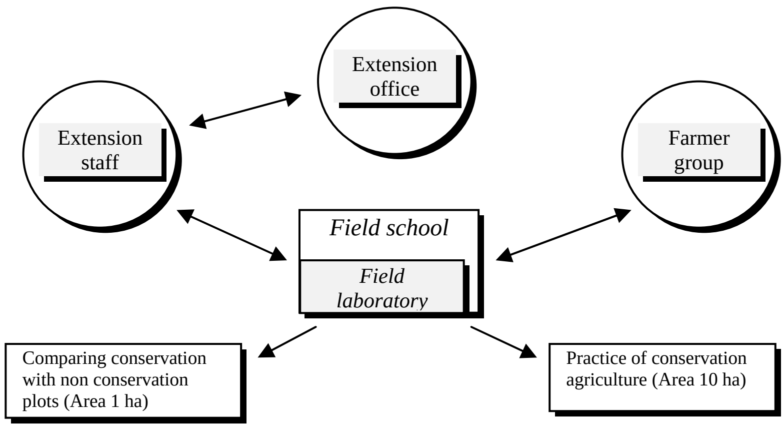


**Fig. 3 Flow diagram of FFS on soil and water conservation**

Fig. 3 details the role of a facilitator in the various FFS activities. In general, the facilitator introduces an activity, clarifies the process, sets participants to work, asks questions as groups make their presentations, and summarizes presentations underlining the important points that were learned during the exercise. The field facilitator (extension or researcher) organizes all activities from beginning to the end of the crop season. Participants of FSS are farmers living within the area around 10 ha. Farmers are divided into several small groups of 15 to 20 to maximize participation. Of the 10 ha of FFS land, 9 ha will be managed by farmer groups and the remaining 1 ha is used as a field laboratory with field guides managed by the extension/researcher.

Working with 15 to 20 member teams, farmers enter and make observation/experiment in the field laboratory plot (±1 ha). Once a week, participating farmers will come to the field laboratory to make observations and analyze the problems occurred. They are expected to compare these problems with the existing realities in the field. If there are differences in appearance between the conditions in a field laboratory with the field school, farmers are expected to have been able to explain. At harvest, the participants compare the crop yield or other conservation measures (e.g. erosion rate, soil quality) of the study samples (field laboratory) with the larger field (field school) in which the supporting study is conducted. Thus, the experience and lessons gained from the field laboratory can be a reference for farmers and motivate them to continue applied conservation measures in their own fields.

## CONCLUSION

Agricultural practices in upland and hilly areas have resulted in seriously declining land productivity as cropland is more susceptible to soil erosion. The erosion model was applied to assess the effect of farming practice in slope areas on the occurrence of erosion. Through slope and land use assessments we found that more than 60% of the soil loss occurred on upland crops and mixed agriculture under moderate to steep slopes. Field investigation indicated that many farmers grow maize and cassava in the hilly areas that are tilled repetitively and mostly left without vegetation cover. Moreover, farmers are not making efforts to maintain land conservation measures. Thus, these areas need immediate attention for soil and water conservation activities to prevent further land degradation. One of the challenges for the farmers living in the watershed is how to best manage their land without any adverse effect on the environment. A land conservation map was created to localize land use features and recommended conservation measures which should be applied in order to limit further watershed degradation, as well as depleting agricultural productivity. Farmers field schools are proposed to increase farmer awareness of the negative effects of soil erosion and the benefits of practicing soil and water conservation.

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*Research article*

# People's Livelihoods in the Suburbs - A Case Study at a Community of Ho Chi Minh City

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**Abstract** The study focuses on the analysis of the effects of urban growth and land tenure policies on access to the land and livelihoods of the people. In the process of urbanization, suburbanization, and changes in land tenure status, practical evidence shows that the households' situation has improved. The problem, however, is whether everybody is benefiting equally. In order to understand the problem, the following questions need to be answered: How do policies impact on the livelihoods of the households? How do people in the community have to change their livelihoods to adapt to the new circumstances. The study employed various participatory research methods, both quantitative and qualitative. Semi-structured interviews, In-depth interviews, Focus-group discussion, Participant observation, and Secondary data were used in the study. The results indicate that the most successful households are those that are characterized by multi-activity and risk-spreading. This is achieved by exploiting rural and urban opportunities simultaneously. The least successful and poorer households are generally those with non-diversified income-earning activities and/or which do not attempt to maximize the utilization of rural and urban resources. It seems that farmers are not well-prepared for the transition from rural to urban living. Lack of skills and formal training prevent them from exploiting opportunities to adjust to rapid changes. Thus, we can now observe a new group of people who have fallen into poverty. Tenure transformation in the suburban areas due to rapid urbanization has created more hardships, in social and economic terms, for the most vulnerable in society. Given the limited availability of land, farmers in the community generally have three means of maintaining and improving their livelihoods. First, they can increase the use of agricultural inputs. Second, they can migrate to areas where agricultural land is available or where non-farm employment offers higher wages. Third, they can establish themselves in a local off-farm occupation. Each of these strategies can be carried out alone or in combination.

**Keywords** urbanization, livelihood, suburbs, skills, Ho Chi Minh

## INTRODUCTION

Ho Chi Minh City, considered as one of Vietnam's fastest growing cities, is the largest metropolitan area of the country, with 22 districts, 17 urban districts (quan), and 5 rural districts (huyen). It is the economic, industrial, financial, cultural, and tourist center of the country, which perhaps could explain partly the constant increase in population. In 1940, there were only 0.5 million people living in the city. This grew to 2.3 million some 20 years later, and then to 5 million by the year 2000, a tenfold increase within 60 years (Table 2). This growth of the population has resulted in dynamic suburban development and intense competition for sites of industry, housing, commerce, and public utilities. Rapid economic development in recent years has caused a shift in the spatial pattern of industry within the city. Factories have decentralized increasingly to peripheral industrial suburbs, industrial estates, and more extensive sites with lower land values.

This study focuses on the changing socioeconomic characteristics of households in the suburbs. The main question to be answered is "How do people in the community change their livelihoods to adapt to the new circumstances?" In the process of urbanization, suburbanization, and changes in land tenure status, practical evidence shows that the households' situation has improved. The problem, however, is whether everybody is benefiting equally. Who are the "winners" and "losers" in this system? What groups of people tend to win more?

## METHODOLOGY

This study is descriptive in nature. To draw a wide range of information, it employed various participatory research methods, both quantitative and qualitative (i.e., secondary data collection, interviews, household livelihood analysis). The following techniques were used for data collection: Semistructured interviews, In-depth interviews, Focus-group discussion, Participant observation, and Secondary data.

## RESULTS AND DISCUSSION

This study looked more intensively into the livelihood strategies of three types of households classified according to access to land; households whose land was wholly expropriated; households whose land was wholly or partly sold; and households who still cultivate the lands (landed households), as well as those engaged in non-farm and off-farm livelihood activities.

### Changes in livelihoods and livelihood strategies of households in Vinh Loc A

Because each person's most important productive asset is the land; there is an evident link between loss of land and livelihood. The impact on livelihoods is devastating especially for the asset-poor households. Before 1996, there were no landless farmers; even though some owned as little as 2,000 sq m of land. People mostly relied on agriculture for their livelihoods. The wealth and income gap between the rich and the poor was relatively small. Most owned about the same size of land and pursued similar economic activities. Most if not all farmers were owner-operators of small landholdings, possessing nearly the same basic productive skills and independently managing their own land and money.

By the year 2000, the land-use pattern had changed; farming had ceased to be the backbone of people's livelihoods. There was an increase in the number of landless farmers. The gap between the rich and the poor households also widened. Unemployment and underemployment has become a major problem and those who can find jobs in the city or industrial zones nearby have to support a much larger number of relatives than before.

The chief and elders (of the households?) estimate that only about one-third of the households are still earning part of their livelihoods from farming and those still farming are doing so on a much reduced scale. Moreover, income from the farm has become only a secondary source. Farmers have also become vulnerable to losing the land they still held. Interviews with farmers reveal that whether a farmer is eager or reluctant to sell land depends mainly on his/her ability to find other occupations and opportunities for investment for the household.

To obtain a secure livelihood, in the context of an urbanized commune like Vinh Loc A, people are forced to choose a livelihood strategy that combines agriculture, industry, and service sectors. Most if not all successful households or households with secure livelihood in this suburban area does not depend exclusively on agriculture for their livelihood. Services and trading provide additional sources of earnings for local residents. It should be noted that occupational diversification has a long history. The trend towards occupational diversification within lower-income households more recently is the result of an expansion of livelihood possibilities accompanying changes in the commune's economy. It is important to acknowledge that the process of occupational diversification is one in which households play an active part. Nonetheless, for those whose lands were expropriated by the State, some difficulties are found in the process of change in occupation. In this case, households play a passive part. Their social capital (e.g., membership in farmers' association) gained through the holding of land is suddenly became disrupted when land was lost. These households can be portrayed as victims of lost land and of the encroachment of the city upon the suburbs.

**Livelihood diversification**

In relation to the livelihood strategies, people in the area follow a pattern of production dependent on income from both the land and urban development so that family incomes are likely to be the sum of several activities - agricultural and commercial activities and urban employment within the city. In other words, people depend on a combination of on-farm, off-farm, and non-farm income sources. Many households earn some income from the farms but also earn substantial income from other sources. Certain members of the households may have part-time or even full-time employment off the farm, or engage in cottage industries at home for part of the time. The principal activity is small-scale farming while livestock serve to reduce risks. For some households, livestock raising, particularly dairy cattle, has become a reliable income source.

The economy of households in the commune is tied to the economy of the metropolis, and their production strategies are developed in response to changing market conditions. Well after factories and industrial zones encroach into the formerly rural landscape of the commune, these households had become occupationally diversified. People who settle near main streets or the Vinh Loc industrial zones (commercial and industrial activities) have built their own small business such as retail business, coffee shops, and workshops in a portion of their dwelling space. Alternatively, they rent out space to others for those purposes or build houses for rent to workers.

The practice of diversifying the households' occupation into various nonagricultural sectors could be seen as a strategy of survival as much as status acquisition and maintenance. Nonetheless, the adaptation and the ability to diversify occupation and sources of livelihood of people in the commune vary significantly between groups. The analysis of the household's livelihood strategy in the previous section indicates that the households in Case 1, 4, and 5 have chosen different strategies depending on their asset statuses. Those who have more assets can diversify their source of livelihood from among the three economic sectors such as industry, services, agriculture, or a combination of these sectors. Thus, it can be stated that the better the ability to access capital, the better the adaptation.

**Opportunities and challenges faced by different groups**

Research in the commune has brought to light cases of both successes and failures. In terms of livelihood opportunities, landed households have a wide range of choices. They can either continue to engage in farming with additional income from small services, or they can decide to sell land and become totally nonagricultural households. Otherwise, they can sell part of the land and invest the money in animal husbandry and intensively cultivate the land with new varieties and techniques.

In contrast, land-lost households, in general, are not only unable to take advantage of this opportunity but in many cases lose a well-established job with the disappearance of agricultural land, which in the past had provided them with employment as agricultural workers or self-employment. Among the land-lost house-holds, those whose lands are expropriated face more hardship than their counterparts primarily because they are not prepared for the transition. They are totally forced to seek other livelihood sources outside their traditional agricultural occupations that have long been established in history. Clearly, the gravity of the consequences of such a loss depends, for individual households, on the ability of its members to obtain other forms of livelihood.

However, the effects are not entirely negative for all land-lost households. As mentioned elsewhere in this study, a new environment also provides new opportunities for households to move up. More jobs are being created in and around the commune, especially in and around the Vinh Loc Industrial Zone, especially since the Zone has become fully operational. With the demand for more services, from a growing population of industrial workers, shops can be set up to meet the diverse needs of these workers in the area. Nevertheless, new job opportunities are not being created at a sufficient rate to provide employment for the expanding labor force in the commune and the increasing income needed to support large households. And even if employment opportunities are available, indigenous workers cannot efficiently compete with migrant workers by reason of inadequate technical skills and lower education level. Thus, migration to other areas in search for work, especially manual work, becomes an option taken by a growing number of landless and near land-less households.

To obtain a secure livelihood, in the context of an urbanized commune like Vinh Loc A, people are forced to choose a livelihood strategy that combines agriculture, industry and service sectors. Most if not all successful households or households with secure livelihood in this suburban area does not depend exclusively on agriculture for their livelihood. Services and trading provide additional sources of earnings for local residents. It should be noted that occupational diversification has a long history. The trend towards occupational diversification within lower-income households in more recent times is the result of an expansion of livelihood possibilities accompanying changes in the commune's economy. It is important to acknowledge that the process of occupational diversification is one in which households play an active part. Nonetheless, for those whose lands were expropriated by the State, some difficulties are found in the process of change in occupation. In this case, households play a passive part. Their social capital (e.g., membership in farmers' association) gained through the holding of land is suddenly disrupted when land was lost. These households can be portrayed as victims of lost land and of the encroachment of the city upon the suburbs.

In many cases, like the ones cited above, the loss of agricultural land poses a threat to the livelihood of Vinh Loc A farmers, especially farmers with little or no assets. Earning a livelihood becomes an increasingly arduous task for farmers because of intense competition for employment and access to land. Farmers fear that this land is being lost to urbanization which, once lost, usually cannot be regained. Very few landless households can expect any access to additional land, either because all available land is now in use or highly priced. Not only do farmers depend on this land to produce their food, it is also a major economic sector in the commune. When farmers lose their lands, lack of access to credit is an inescapable consequence since land is the only meaningful collateral accepted by agricultural banks. Households that have not considered starting a non-farm business usually cite the lack of capital or financing as the chief reason why they have not done so. The other most common responses for not diversifying are age and ill health.

**Roads to achieve secure livelihoods**

When land, a natural capital, is lost, lack of human capital is one of the greatest difficulties that Vinh Loc A households have to face. The majority of the households have been engaged in agricultural work. Now that agricultural land is no longer available, they are forced to find other jobs to earn a living. However, the requirements to be employed in other sectors are not the same as in agriculture. Technical and scientific skills are needed if one wants to be employed in the industrial zones or in the industrial sectors. The loss of land for some households whose main source of income is based on the farm can be seen as an adverse shock.

In fact, households who have sold land are not necessarily poor. They may have spent substantially on building and repairing houses, purchasing consumer goods for their families, or depositing savings in bank accounts to draw interest for consumption. Investments in production, animal breeding, or professional training are still low. This constitutes another contradiction to be settled and to draw lessons from in order to shift actively the attitudes and behavior patterns of residents in these areas. Improving the people's technical skills and education levels would help solve the problem. With good human capital, people can easily capture opportunities when available to improve their status.

In the process of adaptation to the new environment, there is a general pattern easily observed in the commune; most farmers having low education are old age and have no technological skills and therefore they face more hardships. Occupational training for farmers in the process of transformation also has many difficulties. Old farmers face health and aging problems. For the younger generation, education is a major constraint. Interviews with the young people reveal that they prefer short-term training of about 2-5 months to be employed at the Industrial Zones. Those whose parents have cash from selling land or whose land was expropriated often are not interested in job training when they consider the low salary that can be gained with the money they have.

Interviews have shown that many young people lack the education and skills needed to benefit from new economic opportunities. Farmers are particularly ill equipped for the urban transition. Several reports from the Districts admit that job training, vocational guidance and job creation for households whose lands were expropriated have not been effective. Almost all the adjustment strategies depend heavily on the households. In short, these households receive little help from the government.

The loss of land will likely create a sense of confusion among many farmers who presently make a living in agriculture. While agriculture certainly does not bring them much money, many farmers cannot instantly adjust to new circumstances. Most of them still rely on agriculture despite having smaller plots of land and other difficulties. As a result, the poor have become poorer, and there are many new poor households that have been pulled further below the poverty line.

In many cases, non-farm and off-farm activities were essential components in the household economies of the commune. Data collected for this study show that the most successful households are those that are characterized by multi-activity and risk-spreading. This is achieved by exploiting rural and urban opportunities simultaneously. The least successful and poorer households are generally those with nondiversified income-earning activities and/or which do not attempt to maximize the utilization of rural and urban resources. These households still do not have an opportunity to move away from rice farming.

Interviews with KIs and households have demonstrated that the biggest losers in the process of land use changes and loss of land are the farmers, who are dependent mainly on agricultural work for their livelihood and who have little formal education and experiences (human capital) that might offer opportunities in the urban economy. The most economically successful and secure group of households are those that, after the loss of land in the commune, used profit from the land (in terms of compensation and proceeds from land sale) to purchase land in other areas where agricultural land was cheap, or to invest in room-for-rent services or other nonagricultural productive activities. Their strategy is a combination of crop production and marketing, with a variety of non-farm and off-farm income-generating activities.

By analyzing the livelihood strategies of selected households, the study found that the success or failure of households in the commune depends on a composite of personal and nonpersonal or institutional situations. On the personal level, it means the ability of the individual or household to acquire the basic necessities of life such as food, shelter, and clothing. On the nonpersonal level, it means the ability of the State and other socioeconomic institutions to provide assistance to people in terms of access to education, vocational training, health, information (including labor market information and urban planning information), job attainment, and loans among others. Good personal ability combined with a favorable institutional situation would likely provide people with better and more secure livelihoods and vice versa. The absence of one of these two components would cause difficulties for households in obtaining a secure, sustainable livelihood.

## CONCLUSION

It is obvious that suburbanization is not entirely beneficial to all suburban people. Many problems remain, some of which have been in existence for a long time, while others have recently emerged but for which no absolute solutions have yet been found. Based on the findings of the research, tI provides some recommendations for improvement of people's livelihoods. The following recommendations are based mainly on the notion that the biggest problem for the people in the commune is the availability of assets, both tangible and intangible: 1. Providing nonagricultural income sources and assisting farmers in improving cultivate productivity efficiently; 2. Protecting agricultural land and livelihood; 3. Investing in human capital through education and vocational guidance; 4. Accessibility to information, especially planning information; 5. Participation of people in project planning that directly affects their lives; 6. Investment in infrastructure (physical assets). For those whose lands were lost, their future lies increasingly in labor-force participation outside agriculture. How to move people from the agricultural sector to other sectors of the economy is the chief objective of State policy. To accomplish the objective of moving agricultural workers to other nonagricultural sectors, improving educational levels and occupational skills is vital in order to give people the means to obtain sufficient income for their households. Training in nonagricultural skills is a critical factor in increasing the ability of farmers to take on off-farm work. Those whose agricultural lands are to be affected by planned urban development should be given a higher priority in job training and vocational guidance, as well as in employment in the industrial zone built on their land. However, this would require more support from the government at all levels. Improving education would help people recognize the new challenges they are facing in the urban environment so that they would develop coping and adaptive mechanisms to ensure a stable livelihood.

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*Research article*

# Rubber Farmers' Perception of Rubber Technologies in Dambae and Peam Cheang, Kampong Cham

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**Abstract** The main objectives of the study were to 1) determine the level of the farmers' awareness of recommended technologies related to rubber tapping and 2) identify the farmers' perceptions of rubber technologies. A multistage random sampling technique was used to select the sample of 92 rubber smallholders from Dambae, a non traditional rubber region, and Peam Cheang, a traditional rubber region. Data were collected through pocket voting and preference ranking which are the tools of participatory methodology. Friedman's test and multiple comparisons were used to analyze the data. The study showed that rubber farmers were not well aware of recommended technologies related to rubber tapping, for instance required girth (23%), height of measurement (34%), cup hanging (46%), thickness of tapping (21%) and tapping angle (21%). However, the awareness of tapping panel marking was high (97%). It was discovered that there were significant differences in the participants' rank ordered preferences for techniques, during immature and mature stages, related to rubber collection works and dissemination media ($p<0.001$). Establishment of cover crop, land preparation, correct tapping method and latex preservation methods were considered by the rubber smallholders as the most important techniques ($p<0.05$) that they need the extension officers to address in designing extension activity programs for these regions. Workshop was the most preferred area ($p<0.05$) of dissemination media through which the rubber farmers need the researchers and extension officers to transfer information and knowledge.

**Keywords** pocket voting, preference ranking, participatory method, Friedman's test

## INTRODUCTION

Participatory Rural Appraisal (PRA) is a family of approaches and methods to enable local people to present, share and analyze their knowledge of life and conditions in order to plan, to act, to monitor and evaluate the situations. There has been increasing interest in PRA as it has been successful on many occasions in planning and decision support since its development in the late 1980s. An extensive review on the evolution, methods and practices of PRA can be found in Chambers (1994). Unfortunately, PRA has not been used for research on rubber smallholding in Cambodia. It has been found that the Cambodian smallholder rubber yield is very low (845 kg/ha/year) compared with the average smallholder rubber yield of other countries (Sovann, 2009). Malaysian smallholder rubber yield is 1047 kg/ha/year and for Thailand, 1530 kg/ha/year

(Pondikou, 2005). The low rubber yield is attributed to poor plantation management, use of conventional clones, low fertility of soil, use of old tapping systems, poor skill of the tappers and poor knowledge of rubber smallholders on rubber management techniques. To improve the knowledge of rubber smallholders' onrubber management techniques is an important factor in increasing the rubber yield. A better result can be achieved by collaboration with the farmers and by means of understanding their needs. Therefore, the topic "Rubber farmers' perception of rubber technologies in Dambae and Peam Cheang, Kampong Cham" is an important study.

The specific objectives of the study were 1) to determine the level of farmers' awareness of recommended technologies related to rubber tapping and 2) to identify farmers' perceptions of rubber technologies.

## METHODOLOGY

This study was conducted in Peam Cheang and Dambae regions. Peam Cheang is located on the southern side of Kampong Cham and Dambae is on the Northern side of this province. A total of 92 rubber smallholders were selected. A multi-stage random sampling technique was used for sample selection from the two regions. Actual data collection used a variety of participatory methods such as, pocket voting and preference ranking. The study was conducted from September 16 to November 25, 2008.

Pocket voting was used to find the level of the smallholders' awareness of recommended technologies related to rubber tapping. Awareness on correct tapping practices among the smallholders was assessed using 12 questions with multiple choice answers. When all had voted, the slips were taken out from each pocket and the votes were registered (Wasana et al., 2006). Preference ranking was used to identify the farmers' perception of areas for which the techniques were needed and preferred dissemination media. Preference ranking was done by individual farmers, where a set of options was ranked according to their perception.

All data gathered from the pocket voting were analyzed using frequency and percentage statistics. Number of votes for the correct answer was awareness on correct tapping practices. Friedman's test (Fr.) was used for the analysis of preference ranking. When the number of rows and/or columns is large, it can be shown that the statistic Fr. is distributed approximately as chi-square ($\chi^2$) with d.f. = k-1 (Abeyasekera, 2001). SPSS version 12 was employed in this analysis. For the options above the null and alternative hypotheses are given below:

H0 = There is no difference in the participants' rank ordered preferences for techniques during each stage of rubber and dissemination media.

H1 = There is a difference in the participants' rank ordered preferences for techniques during each stage of rubber and dissemination media.

Afterwards, multiple comparisons were made using the following inequality (Siegel and Castellan, 1988).

## RESULTS AND DISCUSSION

### Farmers' awareness of recommended technologies related to rubber tapping

According to the results given in Fig. 1, the farmers' overall awareness of recommended technologies related to rubber tapping was moderate (54 %). The overall awareness of Sri Lankan rubber farmers of recommended rubber technologies of 55% to 58% was similar (Wasana et al., 2006). The plausible reasons for this moderate awareness could be traced to: a) the very low intensity of extension services provided by relevant research and development bodies. 83% of the rubber farmers responded that researchers and extension workers had never visited their regions (Sovann, 2009); b) Lack of funds to support the institutions related to the rubber smallholder development. The rubber farmers lacked the necessary knowledge of tapping techniques especially bark thickness of tapping and tapping angle (21%). When bark consumption has been excessive, capital value is lost through reduced economic life span of trees.

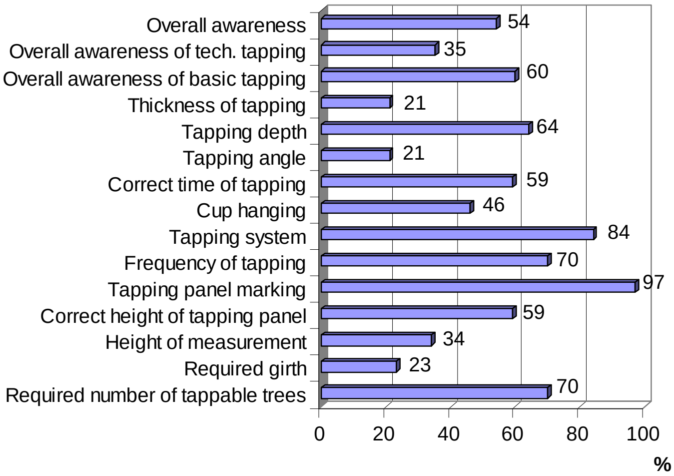


**Fig. 1 Farmers' awareness of aspects of tapping technologies**

**Farmers' perceptions of rubber technologies during the immature stage of rubber trees**

The rubber techniques used during the immature stage of trees that the smallholders selected for extension activity were land preparation, establishment of cover crops, fertilizer application, weeding and disease control. It was found that at least one treatment comparison was significantly different ($\chi^2$ =73.63, d.f =4, p<0.001, Table 1). The rubber farmers considered that land preparation and the establishment of cover crops were the most important techniques (lowest rank sum) and weeding was the least important (highest rank sum) during the immature stage that they needed to know (p< 0.05, Table 2).

**Table 1 Friedman's Test of smallholders' rank of techniques in different stages and dissemination media**

| Parameter | Immature stage | Mature stage | Collection works | Dissemination media |
|---|---|---|---|---|
| N | 92 | 92 | 92 | 92 |
| Chi-Square | 73.630 | 101.496 | 31.370 | 122.922 |
| d.f | 4 | 4 | 2 | 4 |
| Asymp. Sig | 0.000 | 0.000 | 0.000 | 0.000 |

**Table 2 Rank sums of smallholders' perception of different techniques during the immature stage of rubber**

| Technique | Mean rank | Sum of ranks* | |
|---|---|---|---|
| 1 Land preparation | 2.20 | 202 | a |
| 2 Cover crop | 2.68 | 247 | ab |
| 3 Fertilizer application | 2.83 | 260 | ab |
| 5 Disease control | 3.21 | 295 | b |
| 4 Weeding | 4.09 | 376 | c |

**Sums of ranks with different letters are significantly different (p<0.05)*
*Highest priority for the lowest rank sum*

This was consistent with Wasana et al. (2006) who reported that land preparation was also considered as important by the rubber smallholders in the Badalkumbura area of Sri Lanka. In 2005, the International Rubber Research and Development Board recommended zero burning concepts for rubber plantation establishment (Abdul, 2005). Burning the field causes the microbial populations to die and loss of organic matter in the vegetation. Farmers therefore wanted to know more about the zero burning method for establishing the rubber plantation. At the immature period, the rubber trees are not yet tapped and the rubber farmers do not have income, so it is only the cover crops planted between the rows of rubber trees that the rubber farmers can earn money from. In addition, farmers want to know which cover crops give the biggest profit and the impact of the cover crops has on the rubber growth. Accordingly, land preparation and establishing of cover crop were priority techniques.

**Farmers' perceptions of rubber technologies during mature stage of rubber**

The management techniques during the mature stage of rubber that the smallholders selected for extension activity programs included marking panel, correct tapping method, fertilizer application, weeding and disease control. It was found that at least one treatment comparison was significantly different ($\chi^2$ =101.496, d.f =4, p<0.001, Table 3). According to multiple comparisons, the rubber techniques used during the mature period can be categorized into 3 groups as proposed in Table 3 (p<0.05). The rubber smallholders have considered correct tapping method to be the most important technique (lowest rank sum) and fertilizer application to be the least important (highest rank sum). The main reasons for choosing correct tapping method were sustainable production, good health of rubber trees, reasonable consumption of bark and high quality of rubber. Alcala et al. (2005) concluded that a poor tapping system was also the most important factor to make rubber tree yield very low in the Philippines.

**Table 3 Rank sums of smallholders' perception of different techniques during the rubber mature stage**

| Technique | Sum of ranks* | | Priority |
|---|---|---|---|
| 2 Correct tapping method | 157 | a | High |
| 1 Marking panel | 275 | b | Moderate |
| 5 Disease control | 275 | b | Moderate |
| 4 Weeding | 306 | b | Moderate |
| 3 Fertilizer application | 367 | c | Low |

**Sums of ranks with the different letters are significantly different (p<0.05)*
*Highest priority for the lowest rank sum*

**Rubber collection works**

The techniques related to rubber collection that the smallholders selected for extension activity programs included preservation method, coagulation method and stocking method. It was found that at least one treatment comparison was significantly different ($\chi^2$ =31.37, d.f = 2, p<0.001, Table 1). According to multiple comparisons, the management techniques related to the rubber collection can be categorized into 2 groups as proposed in Table 4 (p<0.05). The rubber smallholders considered latex preservation method as the most important technique (lowest rank sum) that they need to know, and stocking and coagulation methods as the least important (highest rank sum). The main reasons for choosing the latex preservation method as most important were price of latex and the distance between their rubber plantations and the rubber processing factory.

**Table 4 Rank sums of smallholders' perception of different techniques related to the rubber collection works**

| Technique | Sum of ranks* | | Priority |
|---|---|---|---|
| 1 Preservation method | 143 | a | High |
| 3 Stocking method | 191 | b | Low |
| 2 Coagulation method | 218 | b | Low |

**Sums of ranks with the different letters are significantly different (p<0.05)*
*Highest priority for the lowest rank sum*

Farmers still think that the rubber coagulum they sold is not rated on the quality but its weight. It was the same in Indonesia (Akiefnawati and Joshi, 2006). It was for this reason, that smallholders in these study regions considered that the coagulation method and the stocking method were the least important techniques.

## DISSEMINATION MEDIA

The media that the smallholders preferred for dissemination were lectures, workshops, video documentary, radio programs and newspaper supplements. It was found that at least one treatment comparison was significant difference ($\chi^2$ = 122.922, d.f = 4, $p<0.001$, Table 1). According to multiple comparisons, the dissemination media can be categorized into 3 groups as proposed in Table 5 ($p<0.05$). The rubber smallholders considered workshops as the most preferred type (lowest rank sum) of dissemination media and radio programs as the least important (highest rank sum). The rest of the dissemination media were considered as moderately important. It was the same in Sri Lanka (Wasana et al., 2006). The main reasons for not preferring mass media were due to absence of discussion, inappropriate time of broadcasting and lack of delivery means. The rubber smallholders preferred workshops because they thought that in workshops they could easily discuss their specific problems and share their knowledge and experience.

**Table 5 Rank sum of smallholders' perception of different dissemination media**

| Dissemination media | Sum of ranks* | | Priority |
|---|---|---|---|
| 2 Workshops | 150 | a | High |
| 5 Newspaper supplements | 260 | b | Moderate |
| 3 Video documentary | 276 | b | Moderate |
| 1 Lectures | 317 | bc | Moderate |
| 4 Radio programs | 377 | c | low |

**Sums of ranks with the different letters are significantly different (p<0.05)*
*Highest priority for the lowest rank sum*

## CONCLUSION

The study showed that the rubber farmers' awareness of tapping techniques was poor. The awareness of tapping angle and bark thickness of tapping was only 21%. This poor awareness has made an impact on the economic life span of rubber trees, yield and income stability. This study has opened up the need for an awareness program on tapping rubber trees. Following analysis of results, it was concluded that there were differences in the participants' rank ordered preferences for techniques during each stage of rubber growth and for dissemination media ($p<0.001$). At the immature period, the rubber farmers considered that land preparation and the establishment of cover crops were the most important techniques that the rubber smallholders need to know about. The smallholders gave least priority to weeding. According to the study on smallholders' perception of different techniques during rubber mature stage, the smallholders considered correct tapping method as the most important technique. Fertilizer application has been considered by the farmers as the least important. Among the techniques related to rubber collection methods, the smallholder considered the latex preservation method as the most important technique that required awareness raising. Rubber stocking and coagulation methods were considered by rubber smallholders as less important areas for awareness raising. Based on the results of the study, workshops were nominated by the rubber farmers as the most preferred area of dissemination and radio programs were considered as the least important. Establishment of cover crop, land preparation, correct tapping method and latex preservation method were the most important techniques which should be addressed in designing extension programs for the study areas. Workshops were the most preferred area of dissemination media through which researchers and extension officers can transfer the above techniques to farmers.

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Research article

# Development of the Indigenous Chironomid Species as Ecotoxicology Test: Tool for Water Quality Management in Thailand

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**Abstract** In Thailand, heavy metal contamination of the aquatic ecosystem is of concern because of the effect on water quality and toxicity to aquatic biota. The aim of this study was to develop ecotoxicology test protocols using a standard test organism the midge, *Chironomus striatipennis* Kieffer for measuring acute and chronic toxicology.. This species is an important indigenous freshwater invertebrate in Thailand. The acute effects of cadmium using cadmium chloride and lead as lead nitrate on midge larvae were investigated by static bioassay under laboratory conditions. The observed mortality data of the acute test for median lethal concentration 48 h $LC_{50}$ of cadmium chloride on first, second, third and fourth instars of midge larvae were 25.1 (14.6-40.7), 201 (60.1-367), 579 (537-620) and 641 (564-717) mg/L, respectively. The 48 h $LC_{50}$ of lead on first, second, third and fourth instars of midge larvae were 99.9 (14.7-209), 55.5 (266-897), 1,540 (1,200-1,870) and 3790 (2,890-4,410) mg/L, respectively. The results showed that cadmium chloride and lead nitrate were highly toxic to the first instar larvae followed by second, third, and fourth instar larvae, respectively. Sublethal studies of cadmium and lead on midge showed that both cadmium and lead had effects on the body length of larvae, the development time of larvae, dry weight and the number of female and male adults. The results from this study would be useful for developing a biomonitoring tool for heavy metal contamination assessment in freshwater ecosystem and water quality management in Thailand.

**Keywords** ecotoxicology test, heavy metal, freshwater management

## INTRODUCTION

Aquatic ecosystem contamination with heavy metals has been an increasing concern in Thailand, due to their persistence and high toxicity to many living organisms when they exceed threshold concentrations (Chen et al., 2007; Be´chard et al., 2008). The impact of heavy metals on the ecosystemare significant as they cannot be completely removed from water by natural self purification in aquatic ecosystems and could accumulate in overlay water and in sediment and thus enter the food chain (Loska and Wiechuła, 2003) and subsequently cause ecotoxicological problems and then affect human health. Because of the great importance of this issue, there is an urgent need to have practical tools for water quality management and ecological risk assessment in Thailand. However, the study of ecotoxicology is quite new and has many limitations, especially the availability of ecotoxicological data on aquatic organisms in Thailand. As with many developing countries, we have relied upon overseas data (US.EPA, ATSM, OECD, etc.) for developing ecotoxicology test guidelines. However, these guidelines may not be suitable for Thailand. Because indigenous aquatic organisms in Thailand may be more or less sensitive to contaminants than surrogate species, the characteristic of sediment and water in Thai river systems may differ from other temperate locations.

Chironomid species have been adopted as test species for ecotoxicological assessments because they are an important component of freshwater ecosystems and represent one of most widely distributed group of benthic organisms. They are adapted to almost every type of aquatic ecosystem (Vos, 2000). These species are important as prey for juvenile and adult fish and aquatic birds and can be easily cultured under laboratory conditions with a relatively short life cycle (Taenzler, 2007). Two species of *Chironomus* are typically used in ecotoxicity testing: these are *C. tentans* and *C. riparius* (Watts and Pascoe, 2000). Unfortunately, these species are few in number in Thailand freshwater ecosystems. Therefore, the use of indigenous species to assess contaminated aquatic ecosystems should be investigated because the toxic response of such species represents more accurately the adverse effect of pollution on the tropical invertebrate species in Thailand. In addition, standardized protocols for acute and chronic aquatic toxicity testing should be developed using indigenous species.

The aim of this paper is to study the ecotoxicology of cadmium and lead on the indigenous freshwater invertebrate *Chironomus striatipennis*, a non-biting midge (Diptera; Chironomidae) found in Thailand. The result would be a useful component in developing a biomonitoring tool using an indigenous species test for evaluation heavy metal contamination in aquatic ecosystems and provide useful information for pollution control authorities involved in water quality management in Thailand.

## MATERIALS AND METHODS

### Test organism

Initially, a local chironomid species was found in Thailand, *Chironomus striatipennis* Kieffer, isolated from the field and cultured under control laboratory conditions at the Ecotoxicology and Environmental Sciences Laboratory, Faculty of Agriculture, Khon Kaen University, Thailand. *C. striatipennis* were cultured in 3 L glass tanks of 15 x 30 x 30 $cm^3$ in the aquarium and covered with netting to trap the emerging *C. striatipennis*. Overlying water was replaced every three days. Each egg mass was collected and placed in a 1 L beaker containing 500 mL of aerated water. When all eggs hatched, larvae were transferred in to a clean beaker and cultured until the larvae reached a suitable stage and were ready for use in experiments. The test species was given fish food at a rate of 0.5 g/L for food and conditions were maintained at 23±2 $^{o}$C, on a 16:8 h light: dark regime with pH of 7-8 and a dissolved oxygen (DO) concentration of 5-7 mg/L.

### Test chemicals

The test heavy metals were cadmium chloride ($CdCl_2$ 99.5%) and lead nitrate ([$Pb(NO_3)_2$] 99%). Stock solutions were prepared by dissolving the heavy metal directly in distilled water and test solutions were prepared by appropriate dilution immediately before each experiment.

### Acute toxicity test

Acute toxicity tests were conducted in order to calculate the Cd and Pb $LC_{50}$ data of first, second, third and fourth instars of midge larvae. All experiments were performed according to the US.EPA (1991) method for determining 48 h $LC_{50}$ values for *C. striatipennis*. Five dilutions were prepared for Cd: 200, 400, 600, 800 and 1,000 mg/L, and 6 for Pb: 100, 200, 300, 400 and 500 and 1,000 mg/L. Three replicates of 10 midge larvae per treatment plus a control were used. The larvae were exposed in 20 mL glass beakers containing 10 mL for each test concentration and control and were undertaken as static bioassay under laboratory conditions. Test organisms were not fed during the testing period. Observations were made after 24 and 48 h, and results recorded. For water quality purposes DO, pH, electrical conductivity (EC) and temperature were monitored at the beginning and end of the test. Mortality data were used to calculate 48 h $LC_{50}$ values and 95% confidence intervals by Probit analysis with the Statistical Analysis System (SPSS) Version 12 statistical software.

### Chronic toxicity test

Chronic toxicity testing for heavy metal effects on midge larvae followed the procedure recommended by USEPA document 6004-91/002 (1994). Based on the acute toxicity result, *C. striatipennis* were exposed to Cd concentrations of 0, 0.5, 2.5 and 5.0 mg/L. Lead concentrations of 0, 5, 25 and 50 mg/L were used.

The effects of Cd or Pb on the growth of midge larvae were evaluated by using 60 midge larvae and 300 eggs to study the effect on emergence of adult, length, the development time and dry weight of larvae. These were randomly sampled from each treatment and control and were exposed in 500 mL glass beakers for static bioassays containing 300 mL for each test concentration. Test organisms were fed with fish food 0.5 g/L. The water quality at the beginning and end of the test on control and treatments were measured. Data from chronic tests were analyzed using analysis of variance (ANOVA) to detect significant differences between treatment and control. Statistical analysis was performed using SPSS Version 12 statistical software.

## RESULTS AND DISCUSSION

### Acute toxicity

Table 1 shows the estimated 48 h $LC_{50}$ for Cd and Pb that were calculated from standard toxicity tests on the first, second, third and fourth instars of *C. striatipennis*. The results of this investigation demonstrated that the 48 h $LC_{50}$ values of first to fourth instars of *C. striatipennis* for Cd concentrations were between 25.1 - 641 mg/L and for Pb concentration between 99.9 - 3,720 mg/L, respectively. The 48 h $LC_{50}$ value of Cd on second, third and fourth instars of *C. striatipennis* were 8, 23 and 25 greater than for first midge larvae, respectively. The 48 h $LC_{50}$ value of Pb on second, third and fourth instars of C. striatipennis were 6, 15 and 31 fold greater than for first midge larvae, respectively.

On the basis of the experimental $LC_{50}$ values from this study, *C. striatipennis* were more tolerant to the heavy metals Cd and Pb than some other Chironomid species (Bechard et al., 2008; CCME, 2006; Milani et al., 2003; USEPA, 1996; Watts and Pascoe, 2000). Comparison of the $LC_{50}$ values showed that *C. striatipennis* was more sensitive to Cd and Pb than other aquatic insects such as stonefly and mayfly (William et al., 1985). Acute toxicity results from this study showed higher Cd toxicity on *C. striatipennis* than found for Pb and $LC_{50}$'s in similar reported findings (CCME, 2006; Suedel et al., 1997; US.EPA, 1996). The observed $LC_{50}$ values of Cd and Pb showed high toxicity to the the first instar larvae followed by the second, third, and fourth instar larvae, respectively. The results were similar to other reported findings (Gills and Wood, 2007; Hooftman et al., 1989). This study showed that the second instars of midge larvae were a suitable stage organism to assess the ecotoxicology test because of its sensitivity as a test organism, suite size and being stronger than other instars of midge larvae. Williams et al. (1986) also reported that the second instar of midge was useful to assess the ecotoxicological test.

### Chronic toxicity

Table 2 shows that the effect of sublethal Cd and Pb concentrations on emergence of the adult were reduced significantly ($P<0.05$) and that the number of females and males at 2.5 mg Cd/L and 50 and 5 mg Pb/L, respectively, were reduced. The LOEC of the number of emergent female and male was 2.5 mg Cd/L and NOEC was 0.5 mg Cd/L. The LOECs of Pb concentration for the number of emergent females and males were 50 and 25mg Pb/L; a NOEC of 25 mg Pb/L was obtained for the number of emergent females.

**Table 1 Acute toxicity (Medium lethal concentration [$LC_{50}$]) of Cd and Pb on larvae of *C. striatipennis* at 48 h**

| Larvae instar | 48h $LC_{50}$ of Cd (95% C.I) | 48h $LC_{50}$ of Pb (95% C.I) |
|---|---|---|
| First | 25.10 (14.61 - 40.67) | 99.89 (14.68 - 209.13) |
| Second | 201.30 (60.05 - 367.03) | 555.49 (265.69 - 896.62) |
| Third | 579.31 (536.74 - 620.07) | 1,539 (1,201- 1,874) |
| Fourth | 641.12 (564.30 -717.21) | 3,720 (2,890 - 4,405) |

**Table 2 Effect sublethal Cd and Pb concentrations on the number of female and male *C. striatipennis* (n=300)**

| Chemical | Concentration | Number of emergence (number) | | Emergence (%) | |
|---|---|---|---|---|---|
| | (mg/L) | Female | Male | Female | Male |
| Cd | Control | 6.83±0.75$^{c}$ | 7.17±0.75$^{b}$ | 2.2 | 2.39 |
| | 0.5 | 6.50±1.05$^{c}$ | 6.83±1.17$^{b}$ | 2.17 | 2.28 |
| | 0.6 | 5.50±0.55$^{b}$ | 5.33±0.82$^{a}$ | 1.83 | 1.78 |
| | 5.0 | 4.50±0.55$^{a}$ | 5.50±0.84$^{a}$ | 1.50 | 1.83 |
| Pb | Control | 6.83±0.75$^{b}$ | 7.17±0.75$^{bc}$ | 2.28 | 2.39 |
| | 5 | 6.83±1.47$^{b}$ | 7.50±1.05$^{c}$ | 2.28 | 2.50 |
| | 25 | 6.67±0.82$^{b}$ | 6.33±0.82$^{ab}$ | 2.22 | 2.11 |
| | 50 | 4.83±0.75$^{a}$ | 5.50±0.55$^{a}$ | 1.61 | 1.83 |

*Note: Values are mean ± standard deviation. Means with the same letter in the same column are not significantly different (P>0.05)*

The effect of sublethal Cd and Pb concentrations on length, development time and dry weight of *C. striatipennis* are shown in Table 3. Length of midge larvae in the control and 3 additional concentrations of 0.5, 2.5 and 5 mg Cd/L and 5, 25 and 50 mg Pb/L showed no significant reduction (P>0.05) in length of the first to fourth instars of *C. striatipennis*.

The development time of the second, third and fourth instars of *C. striatipennis* was reduced significantly (P<0.05) at 0.5 mg Cd/L and higher concentrations. Lead concentrations at 0.5, 5 and 25 mg/L significantly reduced (P<0.05) the development time of the first, third instars, and second and fourth instars of *C. striatipennis*, respectively (Table 3). The development time is also an important endpoint for the chironomid as it reflects larval growth to development emergence data that were also similar to those found in other studies (Sikanchadra and Crane, 2000; Suedle et al., 1997). For the development time at each Cd concentration on the second, third and fourth instar of *C. striatipennis*, a lowest observed concentration (LOEC) of 0.05 mg/L was obtained and for Pb concentrations on the second and third instars, a LOEC of 5 mg and 50 mg/L was found while the LOEC of the third instar was 50 mg/L and no observed effects of concentration (NOEC) for Pb at 25 mg/L were obtained.

No difference in reduction of the dry weight (P>0.05) of *C. striatipennis* was observed between control and treatment with Cd concentration but in the fourth instars of *C. striatipennis* there was a significant reduction on dry weight (P<0.05) with Pb at 5 and 25 mg/L (Table 3). The LOEC of Pb concentration on fourth instar was 50 mg/L.

Table 3 shows that the effect of sub lethal Cd and Pb concentrations significantly reduced emergence of the adults (P<0.05) and that the number of females and males at 2.5 mg Cd/L and 50 and 5 mg Pb/L, respectively, were reduced. The LOEC of the number of emergent females and males was 2.5 mg Cd/L and NOEC was 0.5 mg Cd/L. The LOECs of Pb concentration for the number of emergent of female and male were 50 and 25mg Pb/L; a NOEC of 25 mg Pb/L was obtained for number of emergent females.

**Table 3 Effect of sub lethal Cd and Pb concentrations (mg/L) on the body length (mm), the development time (days) and the dry weight (mm) of instar larvae of *C. striatipennis***

| (Effect) | Concentration of Cd (mg/L) | | | | Concentration of Pb (mg/L) | | | |
|---|---|---|---|---|---|---|---|---|
| Instar | Control | 0.5 | 2.5 | 5 | Control | 5 | 25 | 50 |
| **(Length)** | | | | | | | | |
| 1st | 2.21±0.46 | 1.21±0.30 | 1.17±0.24 | 1.20±0.30 | 1.18±0.25 | 1.21±0.29 | 1.13±0.22 | 1.04±0.13 |
| 2nd | 3.88±1.17 | 2.31±0.42 | 2.16±0.41 | 2.27±0.40 | 2.21±0.46 | 2.24±0.37 | 2.06±0.31 | 1.88±0.34 |
| 3rd | 8.60±1.83 | 4.00±1.26 | 3.41±0.73 | 3.61±1.14 | 3.88±1.17 | 3.68±1.06 | 3.24±0.78 | 3.01±0.51 |
| 4th | 6.65±0.47 | 8.72±1.80 | 7.91±2.03 | 8.17±2.08 | 8.60±1.83 | 8.22±1.95 | 7.61±2.16 | 7.59±2.09 |
| **(Development time)** | | | | | | | | |
| 1st | 6.65±0.47 | 6.63±0.66 | 6.62±0.51 | 6.62±0.42 | 7.00±0.47[d] | 6.50±0.50[c] | 6.00±0.23[b] | 5.00±0.12[a] |
| 2nd | 3.17±0.38[a] | 3.50±0.50[b] | 3.50±0.50[b] | 3.50±0.50[b] | 3.17±0.38[b] | 3.00±0.12[a] | 3.00±0.00[a] | 3.15±0.36[b] |
| 3rd | 4.33±0.48[d] | 4.00±0.22[c] | 3.83±0.13[b] | 3.67±0.48[a] | 4.33±0.48[b] | 4.33±0.75[b] | 4.17±0.91[b] | 3.67±0.48[a] |
| 4th | 8.67±0.75[c] | 8.17±0.38[b] | 7.50±0.97[a] | 7.33±1.11[a] | 8.67±0.75[c] | 7.17±0.38[b] | 7.00±0.11[a] | 7.18±0.39[b] |
| **(Dry weight)** | | | | | | | | |
| 1st | 0.03±0.01 | 0.03±0.00 | 0.04±0.00 | 0.04±0.01 | 0.03±0.01 | 0.03±0.01 | 0.04±0.00 | 0.05±0.00 |
| 2nd | 0.10±0.00 | 0.07±0.02 | 0.15±0.06 | 0.11±0.05 | 0.10±0.01 | 0.05±0.01 | 0.08±0.01 | 0.08±0.01 |
| 3rd | 0.11±0.03 | 0.16±0.00 | 0.12±0.05 | 0.10±0.00 | 0.11±0.03 | 0.16±0.03 | 0.26±0.01 | 0.17±0.11 |
| 4th | 0.30±0.01 | 0.26±0.02 | 0.24±0.02 | 0.21±0.10 | 0.30±0.01[a] | 0.21±0.10[b] | 0.31±0.00[a] | 0.42±0.05[b] |

*Note: Values are mean ± standard deviation. Means with the same letter in the row are not significantly different to control* ***(****P>0.05****)***

## CONCLUSION

The development of a method using an indigenous Chironomid species, *C. striatipennis*, as a bioindicator and aquatic organism for ecotoxicology tests is reported as a biomonitoring tool for evaluation of heavy metal contamination in the aquatic ecosystem of Thailand. Compared to lead, cadmium had higher acute toxicity to the first instar larvae followed by second, third, and fourth instar larvae of *C. striatipennis*, respectively. Sub lethal effects of Cd and Pb concentration significantly reduced the length of larvae, the development time for larvae, dry weight and the number of emergent females and males. These endpoints are also important for Chironomids because they reflect larval growth and the development of the emergent Chironomid species and its abundance in the aquatic ecosystem.

The results showed that *C. striatipennis* was sensitive to Cd and Pb concentrations. Thus this species is suitable as a bioindicator and as a test organism for aquatic ecosystem assessment. However, revision of water quality guidelines is required to provide more precise and conclusive toxicology data for heavy metals on other indigenous aquatic organisms.

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*Research article*

# Earthworm Distribution under Different Land Use Systems in Northeast of Thailand - Benefit for Land Resource Reclamation

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**Abstract** The aims of this paper were to study the influence of land use system type on earthworm distribution in Northeast Thailand. The experimental systems were a natural forest, a eucalyptus plantation and an organic agricultural and a conventional agricultural farming system. The effects of land use systems and their management on the distribution and characteristics of the earthworm, *Pheretima* sp. on related soil properties were investigated in the rainy season (August-September 2008) and the dry season (December 2008-February 2009) in Baan None Daung Mun, Tumbon Sa-Ead, Amphur Muang, Khon Kaen, Northeast Thailand. Earthworm populations varied and there were significant differences between systems ($p<0.05$). Numbers were highest in the natural forest followed by the organic agricultural system, lower in the conventional agricultural system and lowest in the eucalyptus plantation in the rainy season. The same result was found in the dry season but the organic agricultural system had a higher number of casts than in the natural forest. The same trend was found for earthworm cast height and cast width. The results showed that the earthworm cast width in the eucalyptus plantation was lowest in the rainy season but not significantly different in the dry season between land uses. These results suggest that land use type strongly influences the abundance and characteristics of earthworm casts in the various soil ecosystems. The results of soil analyses showed that the biological soil quality, measured as soil respiration, in soil samples from each land use type were not significantly different ($p<0.05$) from each other but was highest in the organic agriculture system and lowest in the eucalyptus plantation. The soil respiration in earthworm's casts was higher than in soil in the rainy season. The results showed that the soil properties of earthworm casts were different in each land use system. Particularly, the increase of % silt and % clay and an associated decrease of % sand was found in the earthworm cast compared with the surrounding soil in every land use system. The results for soil quality showed that the earthworm casts had higher electrical conductivity (EC), organic matter, cation exchange capacity (CEC), total nitrogen, available phosphorus, and calcium and magnesium concentrations than found in soil especially the level of available phosphorus in casts.

**Keywords** earthworm, land use systems, land resource reclamation

## INTRODUCTION

Soils of Northeast Thailand generally have low fertility due to their coarse texture and low organic matter content. Organic matter plays a useful function in supporting plant growth and sustainability of a land-use system. The earthworm as a soil invertebrate plays an important role in cycling nutrients within the terrestrial ecosystem by decomposing organic matter, nutrient cycling and energy transformation within the food web. The changes of land use from forest to agriculture affect the biodiversity of soil invertebrates. Soil degradation is related to a decline in activity and diversity of soil fauna among other aspects. The soil biota including soil microbial biomass and soil fauna provide a means of regulating the transformation of organically bound nutrients into plant-available forms through mineralization. Dispersion of agrochemical residues from conventional agriculture into the environment has attracted a great deal of public interest over the past few decades. The widespread use and misuse of persistent pesticides has resulted in their occurrence throughout the biosphere. Contamination of land from indiscriminate use of agrochemicals has been a significant issue for Thailand. Because earthworms play a significant role in soil functioning and soil fertility, their ecological and physiological features make them excellent indicators of soil pollution compared to other terrestrial invertebrates (Bunning, 2003). However, limited study has been undertaken to monitor the ecological significance of the influence of land use systems on the earthworm distribution in Northeast Thailand. The distribution, chemical and physical properties of earthworm casts as compared to bulk soil under a range of different land use systems in Northeast Thailand was studied in this paper.

## OBJECTIVE

The objective of this paper was to study the influence of four land use systems on the earthworm distribution in Northeast Thailand: (i) to investigate the potential of the earthworm as a bioindicator for the change of land use in Thai soil ecosystems; and (ii) to investigate the chemical and physical properties of earthworm casts as compared to bulk soil under a range of different land use systems as related to the distribution of the earthworm *Pheretima* sp.

## MATERIAL AND METHODS

The experimental systems included in this study were a natural forest, a eucalyptus plantation, an organic agricultural and a conventional agricultural system. The effects of land use systems and their management on the distribution and characteristics of the earthworm, *Pheretima* sp. on related soil properties were investigated in the rainy season (August-September 2008) and the dry season (December 2008-February 2009) in Baan None Daung Mun, Tumbon Sa-Ead, Amphur Muang, Khon Kaen, Thailand (Fig. 1).

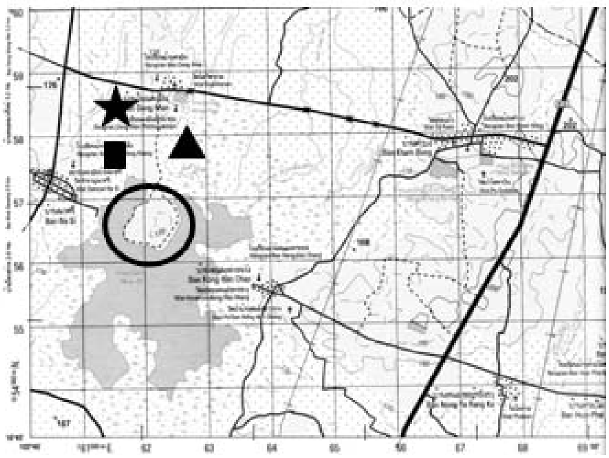

**Fig. 1 Study site in Khon Kaen, Northeast Thailand, ○ natural forest, ▲ eucalyptus plantation, ★ an organic agricultural and ■ a conventional agricultural system**

Soils and earthworms were collected at the four different land use systems during 2008-2009. The study area was selected from paired farms, with one utilizing organic practices (as an organic agricultural land use) and a second adjacent farm using conventional methods (as a chemical-agricultural land use). Pair-wise comparisons of two study sites were made for the agro-ecosystems in Northeast Thailand within 50 km of the city of Khon Kaen, 450 km NE from the capital Bangkok. Natural forests and eucalyptus plantations were also used as comparisons. The four different land use systems were chosen because of their similarity with respect to the pedalogical conditions and soil characteristics except for agrochemicals used, agricultural practices and management systems. Soil samples were collected and analysed for pesticide residues (organochlorine, organophosphate, carbamate and pyrethroid groups) and measurements were taken of physical and chemical properties of soil and earthworm casts. A survey of earthworm populations was conducted at each land use management site. The sampling site for each experimental system (natural forest, eucalyptus plantation, an organic agricultural and a conventional agricultural system) included 27, 9, 9, and 9 sampling sites, respectively.

## RESULTS

Earthworm populations were significantly different between systems (P<0.05). They were highest in the natural forest followed by the organic agricultural system and lower in the conventional agricultural system. The lowest population was in the eucalyptus plantation in the rainy season. The same result was found in the dry season but the organic agriculture system had the highest number of casts compared with the natural forest. The same trend was found with the earthworm cast height and width (Table 1). Earthworm cast width in the rainy season was significantly greater in the natural forest and organic system compared to the conventional agricural system and the eucalyptus plantation was lowest of all. Earthworm cast width in the dry season was snot significantly different for land use excepting for the eucalyptus plantation site which was significantly lower. These results suggest that land-use types are strong factors for determining the abundance and characteristics of earthworm casts in Thai soil ecosystems.

**Table 1 The number, height and width of earthworm cast of *Pheretima* sp. per square meter in different land use system and agricultural practices**

| Land use system | Number of earthworm cast per square meter | | Earthworm cast height (cm) | | Earthworm cast width (cm) | |
|---|---|---|---|---|---|---|
| | Rainy season | Dry season | Rainy season | Dry season | Rainy season | Dry season |
| Natural forest | 20.3±1.5[a] | 16.3±3.9[b] | 11.3±2.0[a] | 10.8±2.6[a] | 3.4±0.5[bc] | 4.6±0.9[a] |
| Organic agricultural system | 9.4±1.9[c] | 19.6±3.8[a] | 9.4±1.1[ab] | 8.0±1.8[b] | 4.4±0.6[ab] | 5.3±0.3[a] |
| Conventional agricultural system | 3.2±0.3[d] | 2±0.5[d] | 7.2±2.4b[bc] | 5.0±1.4[cd] | 4.8±1.1[a] | 5.2±1.0[a] |
| Eucalyptus plantation | 3.67±0.6[d] | 2.3±1.2[d] | 4.5±0.4[**d**] | 4.1±0.2[d] | 2.3±0.3[d] | 2.6±0.5[cd] |

*Data are expressed as mean ± se (n= 20).Values indicated by different letters are significantly different (p ≤ 0.05)*

The results showed that the biological soil quality expressed in terms of soil respiration in the four land use systems was not significantly different (P<0.05). However, the trend was for highest soil respiration in the organic agriculture system and lowest in the eucalyptus plantation. The soil respiration in earthworm casts was higher than in soil in the rainy season. The results showed that the soil properties of earthworm casts were different in each land use system. An increase in the % silt and % clay and decrease of % sand was found in earthworm casts compared with surrounding soil in all land use systems. As for chemical properties, the results showed that the soil in the earthworm cast had higher EC, organic matter, CEC, total nitrogen, available phosphorus, and calcium and magnesium concentrations than in soil and especially higher levels of available phosphorus. The characteristics of the soils and earthworm casts were comparable (Table 2 and 3).

**Table 2 The physical soil properties of soil and earthworm cast in rainy season in different land use systems**

| Land use system | Bulk density ($g/cm^3$) | | Saturated hydrolic conductivity (cm/h) | | Particle density ($g/cm^3$) | | Porosity (%) | | Soil Moisture (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | soil | cast | soil | cast | soil | cast | soil | cast | soil | cast |
| Natural forest | 1.40±0.19[a] | 1.39±0.04[a] | 0.33±0.29[a] | 0.47±0.49[c] | 2.54±0.05[ab] | 2.62±0.09[ab] | 45±0.07[a] | 47±0.03[a] | 20.61±4.75[ab] | 28.30±4.44[a] |
| Organic agricultural system | 1.49±0.07[a] | 1.45±0.12[a] | 0.79±0.84[a] | 0.92±0.71[bc] | 2.50±0.08[b] | 2.62±0.07[ab] | 40±0.03[a] | 45±0.05[a] | 22.84±2.71[a] | 26.96±6.22[a] |
| Conventional agricultural system | 1.49±0.09[a] | 1.36±0.08[a] | 1.62±2.48[a] | 2.66±2.32[a] | 2.54±0.12[ab] | 2.60±0.06[ab] | 41±0.06[a] | 48±0.03[a] | 18.64±2.55[ab] | 31.95±4.20[a] |
| Eucalyptus plantation | 1.58±0.05[a] | 1.35±0.13[a] | 1.16±0.54[a] | 2.98±2.22[a] | 2.53±0.06[ab] | 2.68 ±0.03[a] | 41±0.01[a] | 47±0.03[a] | 12.81±6.30[b] | 23.43±3.43[a] |

**Table 3 The chemical soil properties of soil and earthworm cast in rainy season in different land use systems**

| Land use system | pH (1:1) | | EC(1:5) dS/m | | OM (%) | | T-N (%) | | Avail.P (ppm) | | Exch.K (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | soil | cast | soil | cast | soil | cast | soil | cast | soil | cast | soil | cast |
| Natural forest | 5.14±0.75[a] | 5.41±0.62[a] | 0.03±0.01[a] | 0.05±0.00[a] | 1.60±0.21[a] | 2.96±1.05[a] | 0.08±0.01 [a] | 0.15±0.05[a] | 8.38±2.38[ab] | 9.46±3.12[b] | 32.67±5.69[a] | 42.67±4.16[a] |
| Organic agricultural system | 5.00±0.46[a] | 6.16±0.31[a] | 0.04±0.00[a] | 0.06±0.03[a] | 1.07±0.61[ab] | 1.90±1.50[a] | 0.05±0.03[ab] | 0.10±0.07[a] | 24.36±17.97[ab] | 39.42±24.97[ab] | 47.67±26.39[a] | 119.00±25.51[a] |
| Conventional agricultural system. | 5.19±0.35[a] | 5.68±0.54[a] | 0.04±0.02[a] | 0.06±0.03[a] | 1.06±0.44[ab] | 2.63±1.34[a] | 0.05±0.02[ab] | 0.13±0.07[a] | 35.58±26.73[a] | 42.13±22.08[a] | 94.67±87.65[a] | 165.33±135.2[a] |
| Eucalyptus plantation | 4.76±0.03[a] | 5.99±0.06[a] | 0.03±0.00[a] | 0.06±0.01[a] | 0.71±0.03[b] | 1.66±0.09[a] | 0.04±0.00[b] | 0.08±0.00[a] | 3.68±0.83[b] | 9.22±0.85[b] | 42.33±3.06[a] | 77.67±4.04[a] |

## CONCLUSION

The earthworm, *Pheretima* sp., has the potential to be a soil bioindicator that can be used to assess and monitor land use change, soil pollution, soil health and ecosystem functioning under different land use systems and management practices. Chemical analysis of contaminated soil can be expensive and uninformative regarding environmental hazards associated with polluted soil. The use of biomonitoring to evaluate hazardous agrochemical contaminated sites provides a direct, inexpensive, and integrated estimate of the impact of the contaminant on the ecosystem. Therefore, the role of soil biota and biodiversity should be urgently recognized as important tools for improved knowledge and management practices for soil conservation and sustainable land use in Thailand. Sustainable agriculture involves the successful management of agricultural resources to satisfy human needs while maintaining and enhancing environmental quality and conserving natural resources for future generations. Improvement in agricultural sustainability will require the optimal use and management of soil fertility and soil physical properties. Both rely on soil biological processes and soil biodiversity. This implies that management practices which enhance soil biological activity and thereby build up long term soil productivity and health are beneficial (FAO, 2004). This study found that earthworms could improve biological, physiological and chemical properties of soil. Moreover, earthworm casts contain valuable nutrients that are very useful for increasing soil fertility and plant production. Earthworm conservation should be undertaken for beneficial land resource reclamation.

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*Research article*

# Spatial Analysis of Human Activities Performed in Cheung Ek Inundated Lake, Cambodia

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**Abstract** Cheung Ek is an important lake for the livelihood of local communities through different functions, it acts as a wetland area to control flood waters and removes pollutants from Phnom Penh city. However, industrialization, urbanization and uncontrolled human occupation on the bank of the lake has decreased the lake's surface and caused the lake to become incapable of the evacuation and retention of storm water under the conditions of heavy rain. Global Positioning System (GPS) mapping was undertaken to analyze the lake border, water spinach and water mimosa surfaces and other human activities while other surveys were conducted to understand the method of cultivation and yield estimation of the main aquatic vegetables. The surface area of Cheung Ek Lake in the dry season is 992 ha and more than 50% of the area is occupied by human activities: 429 ha of water spinach; 32 ha of water mimosa; 13.5 ha of dry season rice field; 10-20 ha of fishing activities and around 10 ha of duck raising. In Cheung Ek Lake, water spinach and water mimosa are grown in rows secured by strings between the poles to prevent the crop from floating away. During the dry season, a water spinach cultivator can obtain an average yield of 16-17 tons/ha for a six-month production cycle while a water mimosa producer obtains an average of 15.5-16 tons from a production area of 5000 $m^2$ during a five month production cycle. In conclusion, during the dry season, the lake provides from 6864-7293 tons of water spinach and 992-1024 tons of water mimosa for human consumption. However, aquatic vegetable production is also facing many problems particularly with insect damage and disease outbreaks during the production period.

**Keywords** spatial analysis, GPS, aquatic vegetable, inundated lake, Cambodia

## INTRODUCTION

The majority of untreated wastewater from the major cities in Asia is discharged into peri-urban wetlands that serve as sites for natural treatment and extensive aquatic vegetable cultivation (Marcussen et al., 2004). The cultivation of aquatic vegetables in the peri-urban wetlands is widespread throughout many cities in South and Southeast Asia and is found to a lesser extent in Africa, Europe, Latin and North America (Bunting et al., 2005). Similar to many cities in Southeast Asia, peri-urban areas of Phnom Penh are very important for food production and supply (Dalsgaard et al., 2004). The use of humid zones as a lagooning system to purify urban waste is wide spread around the world and a lot of literature is available on this topic. In Southeast Asia, lagoons are used and have been studied in Vietnam, Thailand and Cambodia (Lim and Chhouk, 2008). In Phnom Penh, Cheung Ek Lake is a large body of water that receives a major part of the wastewater from Phnom Penh's population and from industrial activities. The lake also receives rain-water run-off (Seyha and Tuan Anh, 2004). The people living around the lake mostly produce several types of aquatic vegetable, particularly morning glory which contributes to the purification of urban waste water. In Phnom Penh, aquatic vegetable production systems in peri-urban areas, especially in Cheung Ek Lake, provide many benefits, not just income for producers and low cost waste water treatment, but also the employment and income generation opportunities for many seasonally hired labourers. However, uncontrolled human occupation on the lake's bank has decreased the surface area of the lake without any compensation from year to year. Moreover, rapid urbanization and industrialization can be seen as the main future threat for the continued production of aquatic vegetables in this peri-urban waste water fed lake. Thus, the mapping of the lake's surface, the area occupied by water spinach fields and other human activities, are necessary for understanding the problems. The purpose of this paper is to describe and make reference to the human activities on the lake with particular reference to the farming of aquatic vegetable used for human consumption. This paper consists of two specific objectives: (i) to map the Cheung Ek lake border, water spinach area and other human activities in the dry season and (ii) to understand the life cycles of the aquatic vegetables (methods of cultivation and yield estimation).

## METHODOGY

### Site selection

The research was conducted at Chueng Ek lake which borders with the districts of Mean Chey, Dang kor and Takmao in the South of Phnom Penh city and about 5 kilometers from the centre of the city.

**Table 1 Sample size selection**

| Village | Number of households | Aquatic vegetable producers | Sample size |
|---|---|---|---|
| Prek Takong 1 | 341 | 175 | 25 |
| Prek Takong 2 | 309 | 21 | 4 |
| Prek Tanou | 416 | 10 | 2 |
| Thnoat Chhrum | 569 | 11 | 3 |
| Thnoat Chhrum 3 | 296 | 10 | 3 |
| Kvar | 749 | 48 | 10 |
| Cheung Ek | 424 | 75 | 30 |
| Total | 3077 | 350 | 77 |

### Data collection

**Secondary data collection:** Existing relevant documents were collected from research institutions, journals and information obtained from personal contact with scholars and researchers who had carried out studies in the project area to better understand the issues involved. A satellite image of Cheung Ek Lake was also obtained which was used to determine changes in the lake border and human activities compared with aerial photos taken in 2008.

**Primary data collection:** Two steps were used in primary data collection. Firstly the area of aquatic vegetable cultivation, lake border and other human activities were mapped using GPS. Secondly was an interview with key informants and farmers. A semi-structured questionnaire (a) was used for key informant interviews and a structured-questionnaire (b) was designed for a household survey which focused mainly on cultivation techniques for aquatic plants (setting-up, maintenance and harvesting).

## RESULTS AND DISCUSSION

### Human activities in the lake

Activities within Cheung Ek Lake represented an important source of household income for many households in the Phnom Penh peri-urban area. Floating vegetable production particularly water spinach and water mimosa, rice cultivation, fishing activities and duck raising contribute to the dynamic economic activities in the Cheung Ek area.

**Table 2 Area occupied by human activities at Cheung Ek Lake in the dry season**

| Human Activities | Total area (ha) | Percentage (%) |
|---|---|---|
| Water spinach area | 429 | 43.2 |
| Water mimosa area | 32 | 3.2 |
| Dry season rice field | 13.5 | 1.5 |
| Fishing activity | 15 | 1.5 |
| Duck raising | 10 | 1 |
| Other aquatic plant and water surface | 492.5 | 49.6 |
| Total lake surface | 992 | 100 |

### Fishing activity

Cheung Ek Lake is in general not used for fish production. However, fishing of wild fish species is done by men from the nearby households. A diverse range of fish *species* is caught such as common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), tilapia (*Orechromis niloticus*), Snakehead fish (*Channa striata*) and Walking catfish (*Clarias batrachus*). The fish are sold at local markets or used as a supplement in the house diet.

### Dry season rice cultivation

The people living around the Cheung Ek Lake started growing paddy rice after they returned to their village after the Pol Pot regime (1975-1979). However, by the late 1980s many families had abandoned rice farming in order to cultivate aquatic vegetables, particularly water spinach, when they could see greater market demand and higher prices for aquatic plants. Currently rice farming in the Cheung Ek lake area is only practiced in the dry season by a small number of households in the western part of the lake particularly in Kvar and Cheung Ek village for use as a daily food supply and sold in emergency cases. The area of dry season rice cultivated in the Cheung Ek area is only 13.5 ha with a high yield of 2.5 - 3 tons per hectare.

### Duck raising

Duck raising is popular within the lake surface area especially in the western part mainly in Cheung Ek village. There are around 20 households in Cheung Ek village who raise ducks on both small and large scale from 100 ducks to 1,000 ducks. The KORKY variety is most popular because it is a good egg producer, resistant to disease and adapted to the climate conditions. Duck raising helps people to improve their living standard by earning profits from sale of eggs and can be sold for meat after two years of egg production. Moreover, this animal and their eggs can be used for daily food consumption.

### Water spinach (WS) production

Water spinach is the most common species grown in Cheung Ek Lake in terms of aquatic vegetable production. It is grown in rows secured by strings between two poles to prevent the crop from floating away. Water spinach or water morning glory (*Ipomoea aquatica*) is also planted on land and watered from ponds near the village with motor pumps and hoses. These plants are raised as seedlings and planted in the lake as the water level rises. Large water surface areas around 429 ha in the north and northwest part of Cheung Ek Lake are overgrown with water spinach, covering 43% of the total lake surface in the dry season.

### Water mimosa (WM) production

Water mimosa (*Neptunia oleracea*) is the second aquatic vegetable which is grown in Cheung Ek Lake. Similarly to water spinach, it is grown in rows secured by a string between two poles to prevent the crop from floating away. Because of higher input requirements and greater technical demands compared to water spinach cultivation, water mimosa is only planted by a small number of households in the western part and northeastern part of the lake particularly in Cheung Ek and Prek tanou village. It occupies a small area of water surface covering 32 hectares equal to 3.2% of the lake surface.

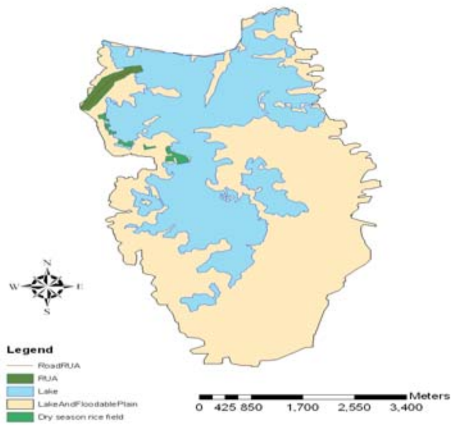


**Fig. 1 Map of Dry season rice field in the Lake**

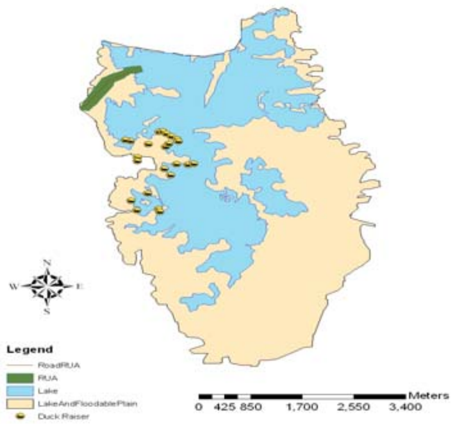


**Fig. 2 Main area of duck raising**

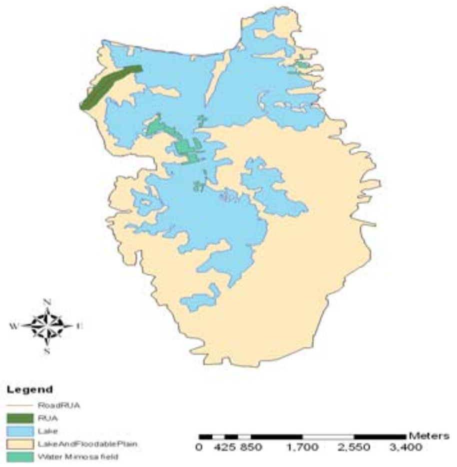


**Fig 3 Map of WM surface in the Lake**

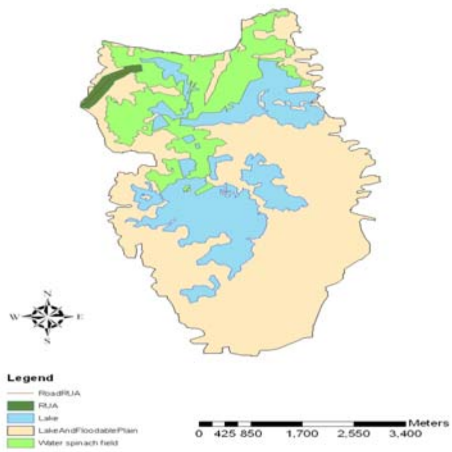


**Fig. 4 Map of WS in the Lake**

### Aquatic plant cultivation methods

### Setting up

**Seed Propagation:** Water spinach or water mimosa stems are folded into a small piece and buried into a hole in the soil of depth 20 cm width and 10cm depth, with two sides of the stems exposed to the air. The seedlings should be planted in rows with 30 - 50 cm between each seedling.

**Taking care of aquatic plant seed:** Aquatic plants are regularly taken care by removing weeds and applying pesticides in order to allow them to grow well. One week after planting the seedlings should start growing and the farmers usually apply fertilizer and pesticide at this point. In the dry season, in the absence of rain, the farmers need to irrigate the aquatic plants with water from the lake every 2 or 3 days. The seedlings can then be transferred to grow in floating rafts in the lake after 3-4 weeks of propogation on land.

**Transferring water spinach seedlings to the water:** Aquatic plants in water need to be in a raft floating on the surface, the propagated seed are bound with string tied up to poles which are already in place in the lake.

**Pole preparation:** Poles are set up in a rectanglular design of 20 to 30 meters long, depending on the length of water surface owned by the farmer, and the rows of poles should be 3 to 4 meters apart. Floating ropes are then attached to the poles.

**Water spinach Seedling braiding:** Water spinach seedlings are folded as a forearm-size plant and braided with string, with 10 to 15 cm between each plant on the string. Whereas water mimosa should be selected 3 to 5 meters long with a big trunk and many stems twisted around by big white floating sponges. Two selected seedling plants are put together facing opposite directions and braided with string with 20 to 30 cm between each knots.

### Maintenance

**Taking care of aquatic plants:** In order to make aquatic plants grow well, the farmer needs to regularly keep the floating aquatic plants bed/raft clean by removing water hyacinth and water lettuce. A suitable amount of duckweed needs to be kept to cover the open water surface but kept from growing too thickly around the water mimosa. Weeds such as water hyacinth need to be removed. Snails need to be removed as they prey on aquatic plants. The strings, ropes and poles need to be maintained and the plants need to be irrigated with lake water to prevent leaves from wilting during the dry season and especially when new buds are emerging. Pesticide and fertilizer should also be applied as required.

**Fertilization:** Fertilizer and pesticide should be applied 5-7 days after plants have been transferred to the water. By this time, most leaves have fallen off and the new buds begin to develop at the base of the plant. To make the crop grow well and resist attack from diseases and insects, the farmer usually mixes many kinds of chemicals and pesticides together in one container and sprays once. However, this is not recommended. After applying chemicals, fertilizers and pesticides, aquatic plants are left at least one week before harvesting.

### Harvesting and yield

**Harvesting:** Water spinach can be partially harvested for the first time after 3 to 4 weeks while water mimosa can reach the first harvest after 2 to 3 weeks following planting. During harvesting, farmers have to tidy up their water spinach by arranging stems into a well disciplined format, as this allows the plants to continue to grow well and avoid blocking access for boats between the rows. Farmers always use a knife or sickle to cut the stems of water mimosa from both sides of the middle knots, and leave a 20 cm interval from knots on the stems in order to let the plant grow for later harvest.

**Yield:** In the dry season, the gross yield of water spinach is estimated to be 16 to 17 tons/ha. The yield is higher than previous estimates of 12 tons/ha/year reported by Khov et al. (2005) who conducted a survey among 133 water spinach producers in Cheung Ek Lake and 15.5 tons/ha/year observed by Huy and Moustier (2005) in a survey among 400 water spinach producers. However, these yields are very low compared to the yield of 73 tons/ha/year observed by Muong (2004) in a survey carried out among 205 producers in Cheung Ek Lake. Moreover, the finding (16-17tonnes/ha in the dry season) is also very low compared to the water spinach yield using similar cultivation techniues in other cities in South East Asia.

Phuong et al. (2006) conducted a survey among 63 households producing water spinach with wastewater use in Tran Phu and Bang B villages. They showed that the average yields of water spinach were 119 and 172 tons/ha/year respectively. Another study conducted by Ruangvit et al. (2002) on the water spinach production in and around Bangkok showed that, the gross yield is estimated at around 50.0 - 62.5 tons/ha/year for a total growing period of 95 to 105 days. On the other hand the research also found that the gross yield of water mimosa was estimated to be 15.5 to 16.0 tons from a production area of 5000 $m^2$ during a production period of five months in the dry season. Unfortunately, there is no available information about the yield of water mimosa production in Cambodia from previous years. However the yields recorded in this study were very low compared to 37.50 - 46.87 tons per hectare throughout the whole cropping period of 75 - 90 days or 112.5 - 140.6 ton/ha/year reported by Ruangvit et al. (2002) for water mimosa cultivation in and around Bangkok.

**Table 3 Cropping calendar of aquatic plants (AP) in Cheung Ek Lake**

| Month and activities | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seed cultivation | | | | | | | | | | | • | |
| Taking care | | | | | | | | | | | | ━━━ |
| Fertilization | | | | | | | | | | | | • • |
| Pole design | | | | | | | | | | | | • |
| Seed braiding | | | | | | | | | | | | • |
| Seed transfer to the water | • | | | | | | | | | | | |
| Fertilization | •• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | • • • | ••• | ••• | •• |
| Taking care | ━━━ | ━━━ | ━━━ | ━━━ | ━━━ | ━━━ | ━━━ | ━━━ | ━━━ | ━━━ | ━━━ | ━━━ |
| Harvesting | • | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• |

## CONCLUSION

Cheung Ek is an important lake for local resident's livelihood as most of them practice some activities such as aquatic plant cultivation, rice cultivation, fishing and duck raising. However, rapid urbanization has caused people to move into the peri-urban area of Phnom Penh and this has decreased the lake surface from year to year. The lake surface of 992 hectare is occupied by 429 hectares of water spinach, 32 hectares of water mimosa, 13.5 hectares of dry season rice field, 15 hectares of fishing activities and around 10 hectares of duck raising. Farmers can obtain an average yield of 1105 kg/ha/harvest or 16 to 17 tons/ha of water spinach while water mimosa producers can obtain an average yield of 1217 kg/5000 $m^2$/harvest or 15.5 to 16 tons/5000 $m^2$ during the dry season. The results show that, within a similar area of water surface, mimosa producers produce double the yield of water spinach. During the dry season, the lake can provide around 7584.7 tones of water spinach and 1012.5 tones of water mimosa for human consumption. However, aquatic plant production is faced with many problems included lack of labor for harvesting, decreased production due to the increase of water pollution, insect damage and disease outbreaks during the production period. Moreover, land use change is occurring on some parts of the lake which are being reclaimed for development purposes. This is causing concern to aquatic plant producers in the Cheung Ek area.

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*Research article*

# Soil Fertility Management in Rainfed Lowland Rice Eco-systems

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**Abstract** Rice (*Oryza Sativa* L.) is a staple food of the Cambodian population and accounts for 68-70 percent of daily calorie intake. Rainfed lowland rice ecosystems are often hampered by drought, submergence and soil problems (Acid Sulphate) that are associated with low productivity and with a high incidence of poverty. A study was conducted to identify the best practices in soil fertility management and conservation on sandy soil for improving rice yield and cost effectiveness of rainfed lowland rice production systems in order to contribute to the improvement of food security and income generation of rural farmers. Three experiments were conducted in rainfed lowland rice agro-ecosystems in Champei commune, Bati district of Takeo province from the middle of 2006 to the middle of 2009: (i) assessment of agro-ecosystem analysis and rice agro-ecosystems, (ii) study on interaction and cost-effectiveness of NPK fertilizers and compost on rice yield in sandy soil in rainfed lowland production systems and (iii) on-farm adaptive research on interaction of NPK fertilizers and compost in sandy soil of rainfed lowland rice ecosystems. The results clearly indicated that the factors and parameters impacting on rice productivity and yield are poor soil fertility (sandy loam soil) and poor soil fertility management. Two options of best practices were identified for improving soil fertility management and rice yield. Firstly, for farmers raising a limited number of cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea at 44 kg, DAP 25 kg and KCl 25 kg plus 5 tones of compost per hectare. Secondly, for farmers raising more cattle and producing large amounts of compost fertilizer recommendations are the same with 10 tones of compost per hectare.

**Keywords** soil fertility, sandy soil, rainfed lowland, rice productivity, Cambodia

## INTRODUCTION

Rice, *Oryza sativa* L., is a staple food for the Cambodian population and accounts for 68-70 percent of daily calorie intake. The rice Agro-Ecosystem in Cambodia is categorized according to geographical location, ranging from mountainous to deepwater areas including upland, rainfed lowland, floating rice and dry season rice (Men Sarom, 2007). Rainfed lowland rice ecosystems are often hampered by drought, submergence and soil problems (Acid Sulphate) that are associated with low productivity and with a high incidence of poverty. These ecosystems have many factors and constraints to rice production such as poor soil quality, flood and drought, water problems, pest and diseases and crop management practices of farmers.

Recently increasing fuel and fertilizer prices have also raised concerns for farmers, especially for rice farming, to maintain the delicate balance between sufficient profitability for farmers and sufficient rice supply at affordable prices for the urban and non-farming rural poor. As fertilizer prices increase, research and extension workers often advise farmers to reduce fertilizer use to save money. However, crop yield is directly related to the amount of nutrient taken up by the crop. Use of less of fertilizer means lower crop yield and less profit for farmers. Important questions are: how much fertilizer is needed to maximize profit and how could we improve rice production under these conditions?

To address these constraints, we conducted the research study: "Strategy for Soil Fertility Management in Rainfed Lowland Rice Eco-system in Cambodia". This research aimed to identify the best practices in soil fertility management and conservation on sandy soil for improving rice yield and cost effectiveness of rainfed lowland rice production systems in order to contribute to improved food security and income generation for rural farmers. Objectives of the research were:

1. To identify the problems and constraints in rice production systems and to identify options to address these in rainfed lowland rice eco-system in Cambodia
2. To develop best practices for effective application of NPK fertilizers and compost on rice yield and cost-effectiveness in sandy soil under rainfed lowland production systems in Cambodia
3. To identify the best practices of appropriate fertilizer application, that could be adopted by farmers for improving rice yield and soil fertility management in sandy soil under rainfed lowland rice ecosystems and
4. To develop extension packages or technical implementing procedures (TIP) for extension workers and farmers to use in rice production of rainfed lowland rice ecosystems in Cambodia.

## MATERIALS AND METHODS

Three research studies were conducted: (i) agro-ecosystem analysis and rice agro-ecosystems assessment in Champei commune, Bati district of Takeo province; (ii) study of interaction of NPK fertilizers and compost on rice yield and cost effectiveness for production in sandy soil in rainfed lowland rice agro-ecosystems in Cambodia and (iii) adaptive research on farmer fields (on-farm trials) on rice yield and cost effectiveness of production on sandy soil in rainfed lowland rice agro-ecosystems in Cambodia.

### Agro-ecosystem and rice eco-systems analysis in Champei commune

Agro-ecosystems analysis (AEA) is a participatory analysis tool used by multi-disciplinary teams in participation with farmers to identify the problems, constraints and impacts on rice production systems and to identify options and measures to overcome these. The assessment used the agro-ecosystems analysis (AEA) tools and methods including secondary data collection (e.g. commune profile), soil sampling and analysis, meteorology data (rainfall and temperatures), rapid rural appraisal (RRA-time line/trend lines, transect walks, seasonal calendars, venn diagrams and problem trees or causes and effect analysis). Check list questionnaires of fertilizer use, soil fertility management, and farming systems were also used with farmer cooperators.

### Interaction of NPK fertilizers and compost on rice yield and cost effective rice production

Fertilizer recommendations for the Prateah Lang Soil type in rainfed lowland rice ecosystems in Champei commune are $N_{50}P_{25}K_{30}$, which means 50 kg N, 25 kg P and 30 kg K, with 5 to 10 tones of compost. The improved aromatic rice variety of Phkar Rumduol was selected for the experiments during the wet seasons of 2007 and 2008. Nine different treatment combinations of NPK and compost rates were tested: $N_0P_0K_0$ (T1), 5 t of compost (T2), 10 t of compost (T3), $N_{25}P_{13}K_{15}$ (T4), $N_{25}P_{13}K_{15}$ + 5 t of compost (T5), $N_{25}P_{13}K_{15}$ + 10 t of compost (T6), $N_{50}P_{25}K_{30}$ (T7), $N_{50}P_{25}K_{30}$ + 5 t of compost (T8) and $N_{50}P_{25}K_{30}$ + 10 t of compost (T9).

### On-farm adaptive research (on-farm trials) on rice yield and cost effectiveness of production

These experiments were conducted in nine selected farmer fields on sandy loam soils (Prateah Lang soil type) with four selected combinations of NPK and compost: $N_{50}P_{25}K_{30}$, 10 tones of compost, $N_{50}P_{25}K_{30}$ + 10 t of compost and $N_{25}P_{13}K_{15}$ + 10 t of compost. Phkar Rumduol rice variety was also selected for these experiments during the wet seasons of 2007 and 2008.

## RESULTS AND DISCUSSION

### Agro-ecosystem and rice ecosystem analysis in Champei Commune

**Agriculture and soil condition:** Based on agro-ecosystem analysis (AEA), rice-based farming is a major occupation in Champei commune and most families also raise cattle and pigs as well as poultry (chicken and ducks). The AEA identified Prateah Lang soil type (red yellow podzol) with 642 ha as the major soil type in the rainfed lowland rice eco-systems in Champei Commune. This was followed by the Bakan soil types (Grey Hydromorphs or Luvisols) covering 585 ha. Kbal Po (Alluvial soil or gleysol) was also found to be a major soil type covering 354 ha in recession rice and irrigated dry season rice areas. The Prateah Lang soil is of low fertility and needs to be improved for better yield and profits. NPK is the major fertilizer used with combinations of Urea, DAP and NPK (16-16-20) at a rate of about 1-2 bags or 50 to 100 kg/ha for wet season rice. Rice yields are in the range of 1.5 to 2.5 tonnes per hectare.

**Table 1 Soil properties in main rice soils in Champeir commune, Bati district, Takeo**

| Soil property | Prateah Lang soil (Red yellow podzol) | Bakan soil (Grey Hydromorph) | Kbal Po soil (Alluvial soil) |
|---|---|---|---|
| Organic matter (OM) % | 0.67 | 1.12 | 1.8 |
| C % | 0.29 | 0.68 | 0.91 |
| N % | 0.04 | 0.043 | 0.10 |
| P (ppm) | 21 | 37 | 46 |
| K meq/100g soil | 0.03 | 0.07 | 0.19 |
| pH | 4.5-5.1 | 5.7 | 5.9 |

*Source: Soil result analysis, September 2007, Soil Lab analysis, General Directorate of Agriculture.*

Results of AEA also indicated that the sandy soil in Champei commune is generally low in organic matter content (0.64%), low pH (4.5-5.1), low CEC and low N, P, K, S, and Mg. Some locations have Fe, S and Mn toxicity and poor drainage. Low productivity and low yield of rice in rainfed lowland rice is primarily due to poor soil fertility. Production is often reduced by drought and flood. Production is also limited by poor crop management practices including poor land preparation, poor on-farm water management, poor fertilizer management, poor weed management, use of unpure seed and poor post-harvest practices. Pests, especially an outbreak of brown plant hoppers (BPH), appeared in the 2007 wet season.

### Climatic conditions

**Rainfall:** During the past ten years the average rainfall in Champei commune was 1,249 mm and during 2000 and 2001 the rainfall was higher than previous years. The Commune received 1,555 mm in 2000 and 1,597 mm in 2001. In 2007, rainfall commenced in March and annual total amount was 1,213 mm. However in 2008, rainfall was only 1,040 mm which was lower than the ten year average. Rainfall variability is a constraint for rice production in the rainfed lowland (Fig. 1).
**Temperature:** The average temperature during the past ten years has not changed much. The peak of the hot season is during April and May (30 $^oC$). From June to December the average temperature declines from 29 $^oC$ to 26 $^oC$. Maximum temperatures are high during April-May with 35-36 $^oC$ and declines to 31-33 $^oC$ from June to December. Minimum temperature is less variable (20 $^oC$ to 26 $^oC$). These temperatures provide good conditions for rice plant growth, especially in the rainfed lowland rice ecosystem (Fig. 2).

These results clearly indicated that the factors and parameters impacting on rice productivity and yield were poor soil fertility (sandy soil) and poor soil fertility management. The study also identified options for improving fertility management on sandy loam soils in rainfed lowland rice ecosystems and identified best practices and cost-effective soil fertility management for improving rice production and quality. Adoption of these practices would contribute to improved household food security and income generation for rural poor farmers.

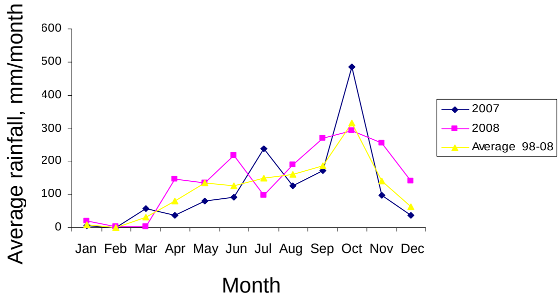



**Fig. 1 Average rainfall during 1998-2008 in Bati district**

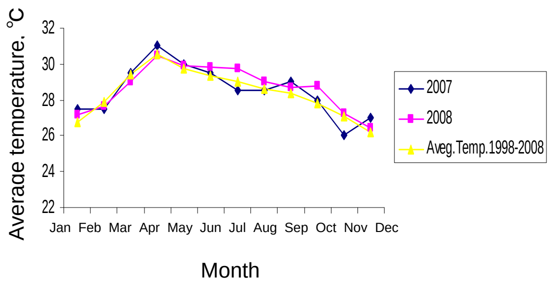
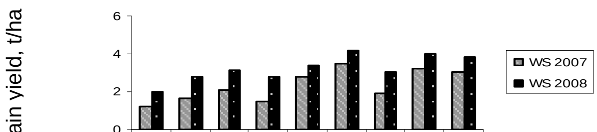



**Fig. 2 Monthly average temperature during 1998-2008 in Bati district**

**Interaction of NPK fertilizers and compost on rice yield and cost effective rice production**

The results of fertilizer experiments during the wet season 2007 and 2008 indicated that on sandy soil, the optimum rate of fertilizer application for increasing rice yield is $N_{25}P_{13}K_{15}$ (Urea 44 kg, DAP 25 kg and KCl 25kg) plus 5 to 10 tonnes of compost per hectare. The fertilizer treatments differed significantly for their effect on rice yield (P<0.01). $N_{25}P_{13}K_{15}$ plus 10 tones of compost on sandy soils (Prateah Lang Soil) gave a rice yield of 3.50 t/ha in the 2007 wet season and 4.17t/ha in the 2008wet season. $N_{25}P_{13}K_{15}$ plus 5 t of compost gave a yield of 2.81 t/ha in the 2007 wet season and 3.42/ha in the 2008 wet season (Fig. 3).




| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 |
|---|---|---|---|---|---|---|---|---|---|
| WS 2007 | 1.18 | 1.66 | 2.07 | 1.51 | 2.82 | 3.48 | 1.92 | 3.18 | 3.03 |
| WS 2008 | 2.02 | 2.78 | 3.09 | 2.74 | 3.42 | 4.17 | 3.01 | 4.04 | 3.8 |

**Fig .3 Grain yield for NPK and Compost trials in wet season 2007 and 2008**

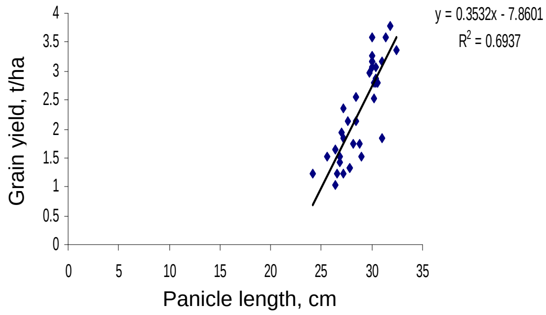



**Fig. 4 The correlation between panicle length and yield of experiment 2007**

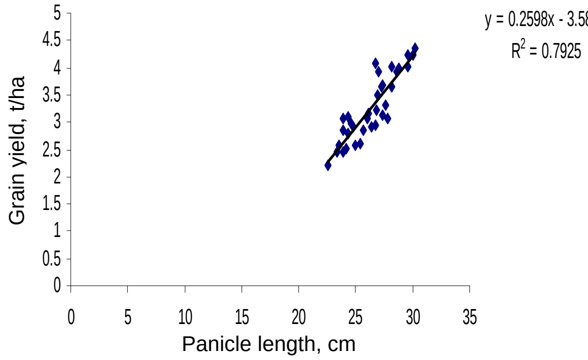



**Fig. 5 The correlation between panicle length and yield of experiment 2008.**

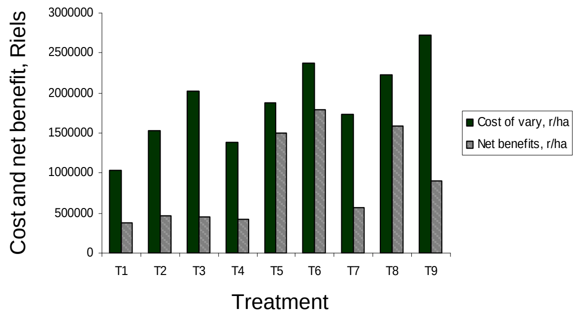



**Fig. 6 Net benefit of experiment in wet season 2007**

The result of experiment in wet season 2007 and 2008, the correlation between yield component and yield are also indicated that the increasing of yield components is correlation between yield in difference treatment of NPK and compost (Figs. 4 and 5).

The gross margin of both wet season experiments in 2007 and 2008 indicated that $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost gave net profits from US$ 436 to US$ 640 per hectare, respectively. The treatment of $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of Compost gave net profits from 1.49-2.22 Million KHRiels per hectare in 2007 and 2008 (Figs. 6 and 7).

The purpose of these experiments was to identify economic and environmentally sound practices that could be adopted by farmers with sandy soil in rainfed lowland rice agro-ecosystems. From the results, we concluded that the two best options for improving soil fertility management and rice yield were: (a) farmers with few cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of compost per hectare, (b) farmers with more cattle and compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost per hectare.

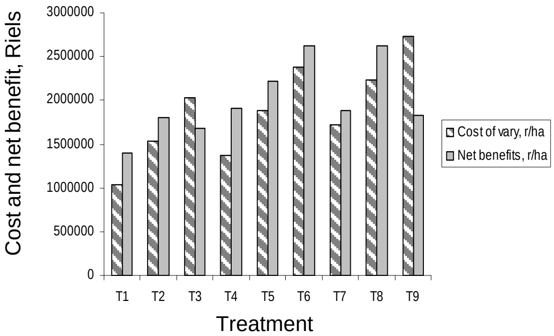



**Fig. 7 Net benefit of experiment in wet season 2008**

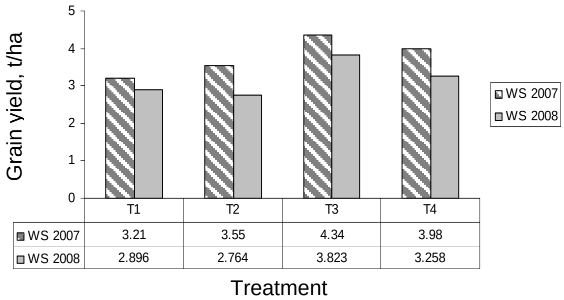



**Fig. 8 Grain yield for On-farm adaptive trials of NPK and Compost in wet season 2007 and 2008**

**On-farm adaptive research (on-farm trials) on rice yield and cost effectiveness of production**

The results of on-farm adaptive trials with NPK fertilizers and compost during the wet seasons of 2007 and 2008 showed that the optimal rate of fertilizer application for better rice yield and profit was $N_{25}P_{13}K_{15}$ (Urea 44 kg, DAP 25 kg and KCl 25 kg) plus 10 t of compost per hectare (Fig. 8).

The recommended rate ($N_{50}P_{15}K_{30}$) and 10 t of compost per hectare gave low rice yield and benefit. In fact, half the recommendation rate ($N_{25}P_{13}K_{15}$) plus 10 t of compost on sandy soil gave a higher rice yield (Phkar Rumduol variety) of 4.34 t/ha and net profit per hectare at US$ 690 in 2007 and 3.82 t/ha and net profit at US$538 in 2008 (Figs. 9 and 10). $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost gave a net profit per hectare at US$ 692 in 2007 and US$ 540 in 2008, respectively.

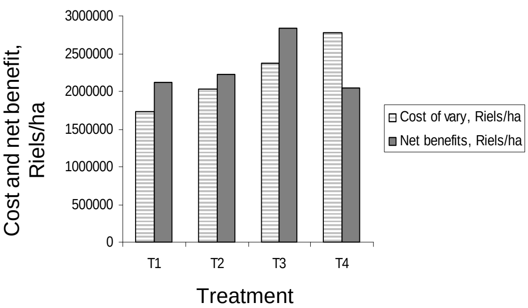



**Fig. 9 Net benefit of on-farm experiment in wet season 2007**

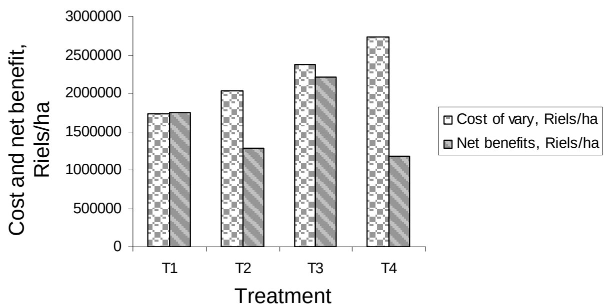



**Fig. 10 Net benefit of on-farm experiment in wet season 2008**

## CONCLUSION

The results showed that use of chemical fertilizer (NPK) alone on sandy soil did not improve soil and crop productivity. Chemical fertilizer alone has potential negative impacts on soil structure and texture, micro-organisms in the soil and mineral toxicity to underground water. However use of organic fertilizer alone on sandy soil also has low effects on soil fertility and crop yield. These effects have become clear after only several years of continuous applications of organic fertilizers (compost). Two options for best farming practice in rainfed lowland rice are: (1) farmers with few cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 tonnes of compost per hectare (2) farmers with available cattle and compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of compost per hectare. The results of these experiments were also used to develop best practice extension packages or technical implementing procedures (TIPs). These are used by researchers, extension workers and farmers for improving soil fertility management and conservation, and rice production in the sandy soils of rainfed lowland rice ecosystems in Cambodia. The collection of organic manure also results in cleaner households, farms and villages and therefore improved hygiene and sanitation.

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*Research article*

# Soil Fertility Management in Rainfed Lowland Rice Eco-systems

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**Abstract** Rice (*Oryza Sativa* L.) is a staple food of the Cambodian population and accounts for 68-70 percent of daily calorie intake. Rainfed lowland rice ecosystems are often hampered by drought, submergence and soil problems (Acid Sulphate) that are associated with low productivity and with a high incidence of poverty. A study was conducted to identify the best practices in soil fertility management and conservation on sandy soil for improving rice yield and cost effectiveness of rainfed lowland rice production systems in order to contribute to the improvement of food security and income generation of rural farmers. Three experiments were conducted in rainfed lowland rice agro-ecosystems in Champei commune, Bati district of Takeo province from the middle of 2006 to the middle of 2009: (i) assessment of agro-ecosystem analysis and rice agro-ecosystems, (ii) study on interaction and cost-effectiveness of NPK fertilizers and compost on rice yield in sandy soil in rainfed lowland production systems and (iii) on-farm adaptive research on interaction of NPK fertilizers and compost in sandy soil of rainfed lowland rice ecosystems. The results clearly indicated that the factors and parameters impacting on rice productivity and yield are poor soil fertility (sandy loam soil) and poor soil fertility management. Two options of best practices were identified for improving soil fertility management and rice yield. Firstly, for farmers raising a limited number of cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea at 44 kg, DAP 25 kg and KCl 25 kg plus 5 tones of compost per hectare. Secondly, for farmers raising more cattle and producing large amounts of compost fertilizer recommendations are the same with 10 tones of compost per hectare.

**Keywords** soil fertility, sandy soil, rainfed lowland, rice productivity, Cambodia

## INTRODUCTION

Rice, *Oryza sativa* L., is a staple food for the Cambodian population and accounts for 68-70 percent of daily calorie intake. The rice Agro-Ecosystem in Cambodia is categorized according to geographical location, ranging from mountainous to deepwater areas including upland, rainfed lowland, floating rice and dry season rice (Men Sarom, 2007). Rainfed lowland rice ecosystems are often hampered by drought, submergence and soil problems (Acid Sulphate) that are associated with low productivity and with a high incidence of poverty. These ecosystems have many factors and constraints to rice production such as poor soil quality, flood and drought, water problems, pest and diseases and crop management practices of farmers.

Recently increasing fuel and fertilizer prices have also raised concerns for farmers, especially for rice farming, to maintain the delicate balance between sufficient profitability for farmers and sufficient rice supply at affordable prices for the urban and non-farming rural poor. As fertilizer prices increase, research and extension workers often advise farmers to reduce fertilizer use to save money. However, crop yield is directly related to the amount of nutrient taken up by the crop. Use of less of fertilizer means lower crop yield and less profit for farmers. Important questions are: how much fertilizer is needed to maximize profit and how could we improve rice production under these conditions?

To address these constraints, we conducted the research study: "Strategy for Soil Fertility Management in Rainfed Lowland Rice Eco-system in Cambodia". This research aimed to identify the best practices in soil fertility management and conservation on sandy soil for improving rice yield and cost effectiveness of rainfed lowland rice production systems in order to contribute to improved food security and income generation for rural farmers. Objectives of the research were:

1. To identify the problems and constraints in rice production systems and to identify options to address these in rainfed lowland rice eco-system in Cambodia
2. To develop best practices for effective application of NPK fertilizers and compost on rice yield and cost-effectiveness in sandy soil under rainfed lowland production systems in Cambodia
3. To identify the best practices of appropriate fertilizer application, that could be adopted by farmers for improving rice yield and soil fertility management in sandy soil under rainfed lowland rice ecosystems and
4. To develop extension packages or technical implementing procedures (TIP) for extension workers and farmers to use in rice production of rainfed lowland rice ecosystems in Cambodia.

## MATERIALS AND METHODS

Three research studies were conducted: (i) agro-ecosystem analysis and rice agro-ecosystems assessment in Champei commune, Bati district of Takeo province; (ii) study of interaction of NPK fertilizers and compost on rice yield and cost effectiveness for production in sandy soil in rainfed lowland rice agro-ecosystems in Cambodia and (iii) adaptive research on farmer fields (on-farm trials) on rice yield and cost effectiveness of production on sandy soil in rainfed lowland rice agro-ecosystems in Cambodia.

### Agro-ecosystem and rice eco-systems analysis in Champei commune

Agro-ecosystems analysis (AEA) is a participatory analysis tool used by multi-disciplinary teams in participation with farmers to identify the problems, constraints and impacts on rice production systems and to identify options and measures to overcome these. The assessment used the agro-ecosystems analysis (AEA) tools and methods including secondary data collection (e.g. commune profile), soil sampling and analysis, meteorology data (rainfall and temperatures), rapid rural appraisal (RRA-time line/trend lines, transect walks, seasonal calendars, venn diagrams and problem trees or causes and effect analysis). Check list questionnaires of fertilizer use, soil fertility management, and farming systems were also used with farmer cooperators.

### Interaction of NPK fertilizers and compost on rice yield and cost effective rice production

Fertilizer recommendations for the Prateah Lang Soil type in rainfed lowland rice ecosystems in Champei commune are $N_{50}P_{25}K_{30}$, which means 50 kg N, 25 kg P and 30 kg K, with 5 to 10 tones of compost. The improved aromatic rice variety of Phkar Rumduol was selected for the experiments during the wet seasons of 2007 and 2008. Nine different treatment combinations of NPK and compost rates were tested: $N_0P_0K_0$ (T1), 5 t of compost (T2), 10 t of compost (T3), $N_{25}P_{13}K_{15}$ (T4), $N_{25}P_{13}K_{15}$ + 5 t of compost (T5), $N_{25}P_{13}K_{15}$ + 10 t of compost (T6), $N_{50}P_{25}K_{30}$ (T7), $N_{50}P_{25}K_{30}$ + 5 t of compost (T8) and $N_{50}P_{25}K_{30}$ + 10 t of compost (T9).

### On-farm adaptive research (on-farm trials) on rice yield and cost effectiveness of production

These experiments were conducted in nine selected farmer fields on sandy loam soils (Prateah Lang soil type) with four selected combinations of NPK and compost: $N_{50}P_{25}K_{30}$, 10 tones of compost, $N_{50}P_{25}K_{30}$ + 10 t of compost and $N_{25}P_{13}K_{15}$ + 10 t of compost. Phkar Rumduol rice variety was also selected for these experiments during the wet seasons of 2007 and 2008.

## RESULTS AND DISCUSSION

### Agro-ecosystem and rice ecosystem analysis in Champei Commune

**Agriculture and soil condition:** Based on agro-ecosystem analysis (AEA), rice-based farming is a major occupation in Champei commune and most families also raise cattle and pigs as well as poultry (chicken and ducks). The AEA identified Prateah Lang soil type (red yellow podzol) with 642 ha as the major soil type in the rainfed lowland rice eco-systems in Champei Commune. This was followed by the Bakan soil types (Grey Hydromorphs or Luvisols) covering 585 ha. Kbal Po (Alluvial soil or gleysol) was also found to be a major soil type covering 354 ha in recession rice and irrigated dry season rice areas. The Prateah Lang soil is of low fertility and needs to be improved for better yield and profits. NPK is the major fertilizer used with combinations of Urea, DAP and NPK (16-16-20) at a rate of about 1-2 bags or 50 to 100 kg/ha for wet season rice. Rice yields are in the range of 1.5 to 2.5 tonnes per hectare.

**Table 1 Soil properties in main rice soils in Champeir commune, Bati district, Takeo**

| Soil property | Prateah Lang soil (Red yellow podzol) | Bakan soil (Grey Hydromorph) | Kbal Po soil (Alluvial soil) |
|---|---|---|---|
| Organic matter (OM) % | 0.67 | 1.12 | 1.8 |
| C % | 0.29 | 0.68 | 0.91 |
| N % | 0.04 | 0.043 | 0.10 |
| P (ppm) | 21 | 37 | 46 |
| K meq/100g soil | 0.03 | 0.07 | 0.19 |
| pH | 4.5-5.1 | 5.7 | 5.9 |

*Source: Soil result analysis, September 2007, Soil Lab analysis, General Directorate of Agriculture.*

Results of AEA also indicated that the sandy soil in Champei commune is generally low in organic matter content (0.64%), low pH (4.5-5.1), low CEC and low N, P, K, S, and Mg. Some locations have Fe, S and Mn toxicity and poor drainage. Low productivity and low yield of rice in rainfed lowland rice is primarily due to poor soil fertility. Production is often reduced by drought and flood. Production is also limited by poor crop management practices including poor land preparation, poor on-farm water management, poor fertilizer management, poor weed management, use of unpure seed and poor post-harvest practices. Pests, especially an outbreak of brown plant hoppers (BPH), appeared in the 2007 wet season.

### Climatic conditions

**Rainfall:** During the past ten years the average rainfall in Champei commune was 1,249 mm and during 2000 and 2001 the rainfall was higher than previous years. The Commune received 1,555 mm in 2000 and 1,597 mm in 2001. In 2007, rainfall commenced in March and annual total amount was 1,213 mm. However in 2008, rainfall was only 1,040 mm which was lower than the ten year average. Rainfall variability is a constraint for rice production in the rainfed lowland (Fig. 1).

**Temperature:** The average temperature during the past ten years has not changed much. The peak of the hot season is during April and May (30 $^oC$). From June to December the average temperature declines from 29 $^oC$ to 26 $^oC$. Maximum temperatures are high during April-May with 35-36 $^oC$ and declines to 31-33 $^oC$ from June to December. Minimum temperature is less variable (20 $^oC$ to 26 $^oC$). These temperatures provide good conditions for rice plant growth, especially in the rainfed lowland rice ecosystem (Fig. 2).

These results clearly indicated that the factors and parameters impacting on rice productivity and yield were poor soil fertility (sandy soil) and poor soil fertility management. The study also identified options for improving fertility management on sandy loam soils in rainfed lowland rice ecosystems and identified best practices and cost-effective soil fertility management for improving rice production and quality. Adoption of these practices would contribute to improved household food security and income generation for rural poor farmers.

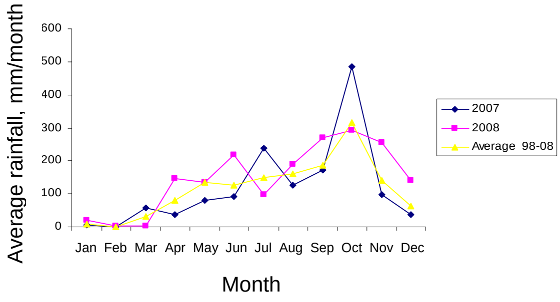


**Fig. 1 Average rainfall during 1998-2008 in Bati district**

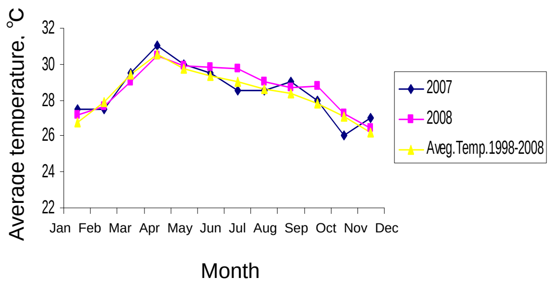


**Fig. 2 Monthly average temperature during 1998-2008 in Bati district**

## Interaction of NPK fertilizers and compost on rice yield and cost effective rice production

The results of fertilizer experiments during the wet season 2007 and 2008 indicated that on sandy soil, the optimum rate of fertilizer application for increasing rice yield is $N_{25}P_{13}K_{15}$ (Urea 44 kg, DAP 25 kg and KCl 25kg) plus 5 to 10 tonnes of compost per hectare. The fertilizer treatments differed significantly for their effect on rice yield (P<0.01). $N_{25}P_{13}K_{15}$ plus 10 tones of compost on sandy soils (Prateah Lang Soil) gave a rice yield of 3.50 t/ha in the 2007 wet season and 4.17t/ha in the 2008wet season. $N_{25}P_{13}K_{15}$ plus 5 t of compost gave a yield of 2.81 t/ha in the 2007 wet season and 3.42/ha in the 2008 wet season (Fig. 3).

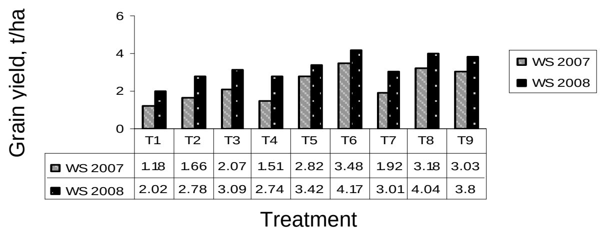


**Fig .3 Grain yield for NPK and Compost trials in wet season 2007 and 2008**

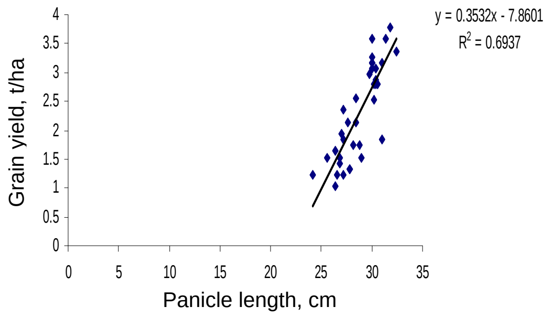


**Fig. 4 The correlation between panicle length and yield of experiment 2007**

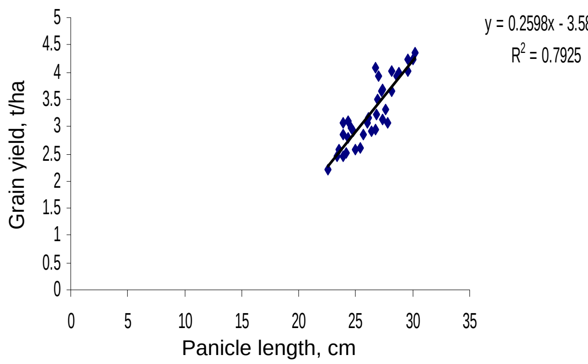


**Fig. 5 The correlation between panicle length and yield of experiment 2008.**

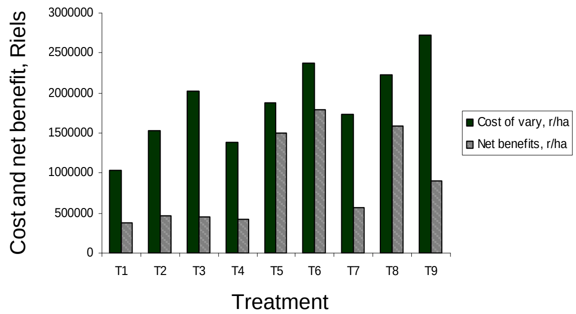


**Fig. 6 Net benefit of experiment in wet season 2007**

The result of experiment in wet season 2007 and 2008, the correlation between yield component and yield are also indicated that the increasing of yield components is correlation between yield in difference treatment of NPK and compost (Figs. 4 and 5).

The gross margin of both wet season experiments in 2007 and 2008 indicated that $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost gave net profits from US$ 436 to US$ 640 per hectare, respectively. The treatment of $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of Compost gave net profits from 1.49-2.22 Million KHRiels per hectare in 2007 and 2008 (Figs. 6 and 7).

The purpose of these experiments was to identify economic and environmentally sound practices that could be adopted by farmers with sandy soil in rainfed lowland rice agro-ecosystems. From the results, we concluded that the two best options for improving soil fertility management and rice yield were: (a) farmers with few cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of compost per hectare, (b) farmers with more cattle and compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost per hectare.

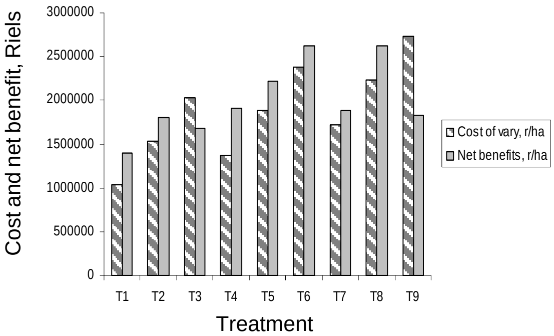


**Fig. 7 Net benefit of experiment in wet season 2008**

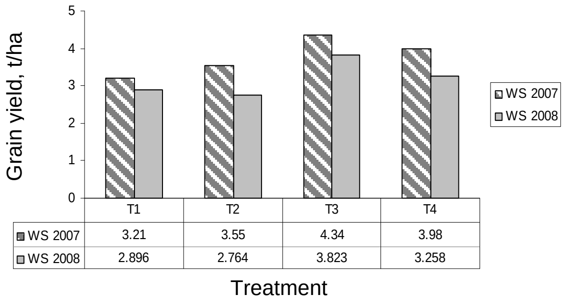


**Fig. 8 Grain yield for On-farm adaptive trials of NPK and Compost in wet season 2007 and 2008**

**On-farm adaptive research (on-farm trials) on rice yield and cost effectiveness of production**

The results of on-farm adaptive trials with NPK fertilizers and compost during the wet seasons of 2007 and 2008 showed that the optimal rate of fertilizer application for better rice yield and profit was $N_{25}P_{13}K_{15}$ (Urea 44 kg, DAP 25 kg and KCl 25 kg) plus 10 t of compost per hectare (Fig. 8).

The recommended rate ($N_{50}P_{15}K_{30}$) and 10 t of compost per hectare gave low rice yield and benefit. In fact, half the recommendation rate ($N_{25}P_{13}K_{15}$) plus 10 t of compost on sandy soil gave a higher rice yield (Phkar Rumduol variety) of 4.34 t/ha and net profit per hectare at US$ 690 in 2007 and 3.82 t/ha and net profit at US$538 in 2008 (Figs. 9 and 10). $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 10 t of compost gave a net profit per hectare at US$ 692 in 2007 and US$ 540 in 2008, respectively.

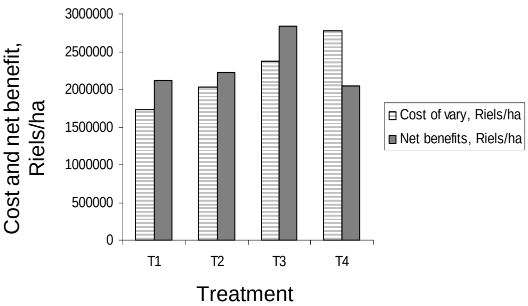


**Fig. 9 Net benefit of on-farm experiment in wet season 2007**

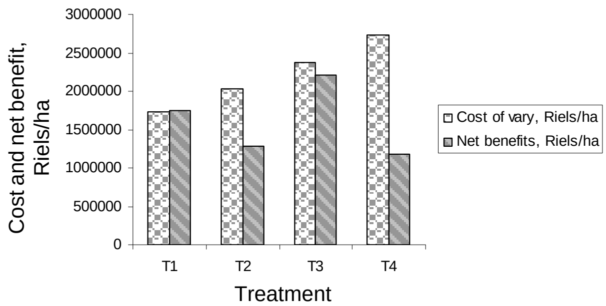


**Fig. 10 Net benefit of on-farm experiment in wet season 2008**

## CONCLUSION

The results showed that use of chemical fertilizer (NPK) alone on sandy soil did not improve soil and crop productivity. Chemical fertilizer alone has potential negative impacts on soil structure and texture, micro-organisms in the soil and mineral toxicity to underground water. However use of organic fertilizer alone on sandy soil also has low effects on soil fertility and crop yield. These effects have become clear after only several years of continuous applications of organic fertilizers (compost). Two options for best farming practice in rainfed lowland rice are: (1) farmers with few cattle (1-2 cattle) and limited access to compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 tonnes of compost per hectare (2) farmers with available cattle and compost fertilizers should use $N_{25}P_{13}K_{15}$ or Urea 44 kg, DAP 25 kg and KCl 25 kg plus 5 t of compost per hectare. The results of these experiments were also used to develop best practice extension packages or technical implementing procedures (TIPs). These are used by researchers, extension workers and farmers for improving soil fertility management and conservation, and rice production in the sandy soils of rainfed lowland rice ecosystems in Cambodia. The collection of organic manure also results in cleaner households, farms and villages and therefore improved hygiene and sanitation.

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*Research article*

# Organic Rice Farming Systems in Cambodia: Potential and Constraints of Smallholder Systems in Takeo

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**Abstract** The development of organic farming is limited in Cambodia because of low literacy rates for farmers in rural areas. In this study, organic rice farming systems were demonstrated to the farmers in Takeo province, Cambodia. As the result of the application, the farmers improved their income through increasing yields, premium prices and reduced expenditure on chemical fertilizers after implementing organic farming techniques. Moreover, all of the farmers adopting organic farming system improved their conditions of health, food quality and the ties of family and community. Nevertheless, these benefits were not completely distributed to all individuals and communities. Very poor and isolated farmers were generally unable to access the benefits. In conclusion, the three main factors for empowering Cambodian farmers to initiate the organic farming system are considered as follows: the individual's endowment of resources, the strength of the farmer groups and the policies and facilitation of the supporting organizations.

**Keywords** organic rice, farming system, potential, constraints, smallholder systems

## INTRODUCTION

Rice-based farming systems in Cambodia incorporate rain-fed lowland rice and dry season rice, and are often integrated with livestock, aquaculture, vegetable gardens and other activities (Mak, 2001). As the adverse environmental and social consequences of high input agriculture have been discussed, attension has been focused on sustainable systems of agricultural production. For approaching towards the sustainability, some points should be clarified, such as what the sustainability actually is and how to achieve it. One of the technological innovations, which resulted in strong farming institutional changes in recent year in Cambodia, is approaching to organic rice farming. Organic farming has become a significant element in policies promoting food safety and environmental quality of global food production considering that it rules out the use of mineral fertilizers and other chemicals such as pesticides and herbicides (Zanoli and Gambelli, 1999). Intensive agriculture has increased crop yields but also posed severe environmental problems (Knudsen et al., 2006). Sustainable agriculture would ideally produce good crop yields with minimal impact on ecological factors such as soil fertility (Knudsen et al., 2006).

The motivation of farmers to convert to organic farming ranges from pure production system considerations to conditions in the market (Christensen and Frandsen, 2001). By focusing on the production system, there is a need to get a better understanding of the importance of the factors that determine the conversion rate and the economics of organic farming (Sorensen et al., 2005). The required increased knowledge on these factors includes the type of farm (production practice), the labour situation and the economic constraints (Sorensen et al., 2005). However, Elizabeth et al. (2007) stated another important factor associated with the deliberation of farmers to convert to organic farming practice is the motivation.

The goal of this research was to analyse the potential and constraints of smallholder system in Tramkok district as our case study. The results of this thesis will be served as guidelines to set up appropriate strategies for the future development of organic farming in other areas in Cambodia. The objectives of the study were to (1) interview organic rice farmers in Tramkok district, Takeo province for evaluating their production technologyies and marketing and (2) identify major obstacles and opportunities for organic farming.

## METHODOLOGY

The results presented in this paper are based on qualitative and quantitative methods of primary data collection and inquiry. In order to study the differences between two rice farming systems, a total of 60 farmers were interviewed: 30 organic farmers and 30 conventional farmers.

Qualitative methods such as semi-structured interviews, identification of key-informants and field visits were used to complete the picture. The interviews aimed at finding out the rationale and the motivation of organic rice producers in this area as well as the constraints, the opportunities and the strategies as perceived by the farmers. The knowledge gained in the interviews was used in a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis to formulate options for the future.

## RESULTS

**Farm management in organic farming systems:** Organic rice farming integrated with livestock or irrigation systems plays the most important for rice farmers especially during dry season. Due to lack of irrigation, farmers in this area grew rice only during wet season and rainfall is the main water resource for rice production as well as human consumption. Rice organic farming system mainly is related to the small livestock production (cattle, pigs, chickens and ducks). Incorporated the dungs from livestocks with the other resources to produce organic manures, is the most important elements for organic farmers in their organic rice production.

Organic farmers in this area usually apply straw, rice grain and the rest of food from houses to feed the various cattle, as chicken, pig, and then make the manure with dungs from those animals. Farmers start to collect manure, kitchen waste etc and keep it in the organic store beside their homes. After 4 or 5 months, through the action of micro-organisms on those wastes become organic manures which are available to use during the raining season. Moreover, during dry seasons, some farmers cultivate the seasonal crops which do not need much water. Also, they use residues of the crops as green manures after harvesting by incorporated or plowed into the soil to add organic matter and nutrients for rice crop in the next season (i.e. ground bean etc).

**Evaluating amounts of labour**: Normally, the amounts of labour for rice production between men and women were not allocated equally. Referred to the information from the field survey, men are usually involved in task such as ploughing, fertilizing and transporting. Women undertake sowing, transplanting, weeding, while both are involved in harvesting and post harvesting. Concerning the labour, most of people who live in the study site hire labours during transplanting and harvesting period. People who live in the village or nearby the village and do not cultivate rice can sell their labour in for these activities. Table 1 shows the evaluation of amount of labour in organic and conventional rice faming. Organic farming needed much more labour intensively for weed control (19.2 md vs. 3.8 md) and nutrient management (8.5 md vs. 1.2 md) than in conventional farming. The rest of labor was nearly the same. Because of this, organic farmers need to spend at least 22 md (14%) more than conventional farmer per hectare rice filed.

**Table 1 Evaluating labour utilization per hectare**

| Items | Organic farm | Conventional farm |
|---|---|---|
| | man-day (md) | |
| Land preparation | 10.6 | 8.8 |
| Transplanting | 14 | 15.8 |
| Nutrient management | 8.5 | 1.2 |
| Manual weeding | 19.2 | 3.8 |
| Harvesting | 35 | 35.5 |
| Total | 87.3 | 65.1 |

**Trends of organic farmers:** Based on the field survey, all organic rice was cultivated by System of Rice Intensification (SRI). In the beginning, most farmers living in the two villages of the site did not believe and joint the association to produce or cultivate organic rice, so the number of households and the size of lands were small and limited in scale for the organic rice cultivation. Even some farmers decided to grow organic rice to meet the market demand; they did not cultivate organic rice fully in their fields.
**Trends of non-organic farmers:** Many farmers kept some fields for traditional farming system which depends on agricultural chemicals. According to the information collected in the interview with local farmers, the shortage of the information on organic farming system made farmers difficult to accept organic farming system fully and became major constraints to convert their farming system.
**Potentials and constraints of organic rice faming system in Tramkok:** The relative potentials and constraints of smallholder system for organic farming system were analyzed on the basis of the SWOT analysis. The data obtained from the survey were classified into 4 categories: Strengths, Weaknesses, Opportunities and Threats.

**Strengths**

- Incorporated the new method of organic farming system in the rice farm, farmers could get higher rice yield than the previous farming method (traditional or conventional method).
- Even farmers are poor but they could consume the premium quality of the free-chemical products and made them healthier than before.
- Instead of chemical fertilizers purchased only from the import markets, farmers could produce their organic fertilizer (i.e. compost) by using the resource available in the farms especially the manures from their small livestock such as cattle, pig, chicken etc.
- Increased the rice production in the organic farms, farmer has possibility for greater food security and selling surplus locally with the premium prices which provide more income for their families. Moreover, the profit net from rice production increases as the cost of input has been reduced by less or no cost for the organic fertilizers used.
- Stop chemical fertilizers and replaced it by organic fertilizers, the soil quality has been improved and better for the environment.

**Weaknesses**

- Organic farming always involves substantial additional labour input, especially weed control and nutrient management.
- Organic farming is priority for small farm size which mostly located nearly the village or home. Lack access for transportation for huge amount of compost or cow manure and taking care after the transplantation through weeding is also a barrier for farmers.
- Conflict location between the organic and conventional farms may introduce the high risk of insects for organic farms and the flow of chemical fertilizers from conventional farms into organic farms during the raining. However, farmers tried to induce the organic farming system to their neighbours but some of them did not care because they consider rice production as their second source of income.
- Since the illiteracy rate is high at farmers, the adoption of new technology is slowly developed according to their limit knowledge. Moreover, the availability of information on organic farming to farmers is still very limited. The main sources of information for organic farmers include the publication (books and magazines) and the communication among farmers.
- With the large scale of rice farm (>2 ha), farms could not afford to purchase the external labour (hiring labour especially for weeding etc) and the huge amount of organic fertilizers.

**Opportunities**

- Organic rice farming is the first priority for farmers to manage it (including the amount of organic fertilizer, the labour used for taking care and weeding after the transplanting) especially for smallholders system since the majority of the farms in this area hold land less than 0.80 ha.
- Organic farming can create new on farm income for farmers and generating opportunities.
- Opportunities for greater social contacts and aids through international/local NGOs and Ministry of Agriculture Forestry and Fisheries (MAFF).
- High market opportunities of products since the organic products have been considered as premium quality.
- With growing public concern for food quality and safety, animal welfare and nature resources; Organic farming become more accepted by government, farmers and consumers worldwide. This trend and market demand directly influence the rapid grow of organic farming in Cambodia.

**Threats**

- The organic farming movement is still very new to Cambodia. That is a reason why organic markets and consumers are very limited. Also, people may concern the price of products as the majority of Cambodia people live under poverty line up to now.
- Lack of irrigation system, farmers can produce rice only in wet season and also they depend on the natural situation (drought).
- There is no international certificate of organic rice. And organic farmers have to sell their products to consumers by NGOs markets.
- Nowadays, the organic producer groups are under the project support of each NGO, “Will organic farmers sustain by themselves in future after the projects finish?”

## DISCUSSION AND SUGGESTIONS

**How to improve weakness of organic farming:** The major constrains of organic farmers in the study area are; impact on labour utilization, conventional farm always located near organic farm, high impact of the epidemics (virus and bacteria) by uncontrolled quality of manures.
**Improvement of the labour requirement:** The labour requirement has been increased mainly during the growing stage of rice production through weed control (19.2 md vs. 3.8 md) and nutrient management (8.5 md vs. 1.2 md).
**Improvement of the labour input on weed control:** Farmers could choose the indirect method to prevent the development of weed and the improving of nutrient management such as; (1) Crop rotation is one of the weed management practices in the cultivation. Each rice culture is associated with a characteristics weed problem, influenced cultural practices used (i.e. three-year rotation of rice / soybeans / grain crop.) (2) Choosing appropriate rice varieties which are although completive again weeds. (3) Water management will play an important role in rice cultivation. Since ancient times, water has been used to manage weeds in rice fields. Many non-aquatic weeds do not survive in submerged environment, Moreover, grassy weeds can be largely eliminated by continuous flooding. (4) Biological weed control is the utilization of natural enemies for the reduction of weed population. Natural enemies of weeds include insect, nematodes, fish and other animals. Example: ducks eat new-borne weeds in the growth stage of rice. The ducks walk 3-4 km/day on the field, making the water turbid in which weed seed or seedlings cannot grow up.
**Improvement of the labour input on nutrient management:** Two weeks after the transplantation, farmers in this area start to provide more organic manures or livestock manure directly (cattle dung, pig manure, chicken manure) until the flowering stage. They believed that the rice productivity increases with providing fertilizers in this period. Referred to Reich (2000), the best times to apply organic fertilizers are early spring and fall or even a few months before planting, because that allows time for soil microbes to digest the organic matter and transform nutrients into forms plants can use (Reich, 2000). Therefore, farmers could apply all the compost

fertilizers in the first land preparation in order to save their labour input on the nutrient management during the growing period of rice crop.

**Controlling manure and limit of manure:** Up to now, uncontrolled the quality of manure and over dosage of manure applied to rice field. It was not yet considerded as main problems for farmers. In addition, (1) it is better that farmers use the resources which are available in their villages in order to prevent their health and other domestic animals from the epidemic of virus or bacteria. (2) If farmers have to bring the manures from other farms outside their villages, farmers have to be sure those manures is from the sanitary farm. (3) Moreover, farmers have to consider well how to apply manure in the rice field in order to reduce water pollution of surface and groundwater by nitrate, phosphate and other heavy metals such as copper, zinc etc. in the manures.

**How to cope with threats in organic farming:** External factors of organic farming include market, consumer, and role of government which plays an important part in developing and establishing organic farming in this region.

**Development of organic market:** Recently, it seems that organic rice farming system have been growing very fast especially for small holder farming in Cambodia, but in fact organic rice farming is still very limited as compared to the total land rice in this country (0.02 percent of total land rice). Moreover, organic farmers are also facing the similar drawback as the conventional farmers, generally improving the business environment and investment climate at the local as well as national level, are likewise essential. The latter would also stimulate investment in the agro-industry sector, which traditionally is the major link between farmers and markets and the driving force for agricultural growth.

**Improvement of the irrigation system in the rural area:** Beside this, poor governance of Cambodia government is a major concern to late development of the agriculture sector in Cambodia. Evidently, 85 percent of Cambodia people relies agricultural business for their income. However, agriculture sector appeared slower progress compared to other sectors such as industry and service following 4.4%, 17% and 11% of GDP growth in 2006, respectively (EIC, 2008). In addition, 36 percent of total Cambodia population (including 40 percent of people live in rural area) have been living under the poverty line as recorded in 2007 (World Bank, 2008).

In order to develop the agriculture sector in Cambodia particularly organic rice farming system and other cropping system, the government should (1) build more canals or dams which supply water for irrigation in the dry season and avoid the flooding in the raining season. Water is used not only for agriculture but also it use for drinking, cooking and bathing. Also, (2) attention should be paid to construct more roads and bridges in the rural area. Mostly farm gate prices are squeezed by the high transportation costs through the drawback in transportation services.

**How to develop and sustain organic farming in the future:** All the organic rice farming is under the support project of local and international NGOs. Sustainability of this farming method is still a main concern to smallholders system because many farmers still unaware of their ability to pay on certifying their organic products in the future despite the fact whether organic markets grow or stop in near future. Fortunately, Royal Government of Cambodia has recently become interested in organic farming with the market expansion for promoting sustainable agriculture.

Furthermore, to develop organic farming in this area as other area in Cambodia; (1) general awareness needs to be raised for easy access to organic seeds and technical training. (2) Awareness of organic farming could be enhanced through appropriate research and extension programs as well as education, training and promotion activities. (3) Public-private sector partnerships are also urgently needed if the rapid growth of organic farming in the country is expected, along with continuing international assistance in the form of technical and financial aid for strategic initiatives, networking and collaboration with stakeholders in organic and fair trade movements, and to stimulate market access. (4) International organic certificate is necessary for organic farmers to export their product to the other countries.

## CONCLUSION

This paper dealt with the discussion on organic farming, which was demonstrated to the farmers in

Tramkok district of Takeo province, Cambodia. As the results applied organic rice farming systems in Tramkok district, the farmers improved their income through increasing yields, premium prices and reduced expenditure on chemical fertilizers after implementing organic farming techniques. Moreover, all of the farmers adopting organic farming system improved their conditions of health, food quality and the ties of family and community. Nevertheless, these benefits were not completely distributed to all individuals and communities. Very poor and isolated farmers were generally unable to access the benefits.

It was considered that there may be three main factors for empowering Cambodian farmers to initiate organic farming system, the individual's endowment of resources, the strength of the farmer groups and the policies and facilitation of the supporting organizations.

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*Research article*

# Indigenous Agricultural Knowledge - A Sample of Practice in Northeast Thailand

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**Abstract** The Northeast is the largest region of Thailand with approximately one third of both the total land area and population of the country. However, the region has the lowest per capita income. This is due to the region's agricultural systems being dominated by rainfed farming, poor soil quality and fluctuation in market demand and price for the agricultural produce. In general, more than 50% of farm income is earned from the crop sector rather than livestock. In a risky business, farmers have learned to understand their environment which includes physical, biological and socio-economic and site-specific factors. In response to the environment, farmers have adapted their practices and this has been given the name "indigenous agricultural knowledge" to improve crop yield and household income. This paper illustrates the overview of indigenous agricultural knowledge in Northeast Thailand which includes land preparation, pre-germinated seeds, thinning buds, detaching flowers, decreasing leaf area, suppressing weeds, alleviation of insect damage, improving soil quality, post-harvest techniques and multiple cropping. Indigenous agricultural knowledge has not been systematically recorded in written form and therefore is not readily accessible to agricultural researchers. Indigenous agricultural knowledge is an immensely valuable resource that provides farmer-to-farmer training or local technology transfer.

**Keywords** indigenous agricultural knowledge, farmer training, Northeast Thailand

## INTRODUCTION

Amongst the four regions of Thailand, Northeast Thailand has the most land devoted to agriculture (Office of Agricultural Economics, 2008). The region is considered an integral component in agricultural production with rice being grown on 65% of the arable land. Other major crops include sugarcane, cassava, rubber and peanut. Indigenous knowledge is local knowledge unique to a given culture or society. Indigenous knowledge is an immensely valuable resource that provides small holders and resource-poor farmers with insights on how they have interacted with their changing environment for survival (Chamber et al., 1989; Reijntjes et al., 1992; Bouguera et al., 2003; Cools et al., 2003). It is not possible in such a brief paper to give a full inventory of the indigenous agricultural knowledge in Northeast Thailand. However, a sample of practices will serve to highlight the good sense shown by farmers.

## OBJECTIVE

The objective of this paper is to give some examples of indigenous knowledge and practices in Northeast Thailand to illustrate that farmers have a holistic understanding of the specific environment and how they adapt with limited resources for survival.

## INDIGENIUS AGRICULTURAL PRACTICES

### Land preparation

Increasing cropping intensity by planting on the residual moisture left in fields following the rice harvest presents a challenge in which farmers demonstrate considerable imagination. Soil preparation for rice involves puddling to reduce water loss and the leaching of nutrients through percolation. To plant a second crop like peanut, this surface, which becomes hard as it dries, must be broken to aerate the seed zone and allow oxygen to penetrate the water free macro pores. This is critical to germination but must be done at exactly the right time. If the soils are too wet and top dry it is not possible to obtain a good tilth. Land preparation is again dictated by measuring soil moisture. Once the monsoon has passed it is important to start preparation as soon as possible. To encourage soil drying to optimum levels, field tests were carried out by the scientist under the conditions indicating that the soil moisture is close to field capacity. Farmers cut the rice straw as close as possible to the ground, and then put it on the bunds of the paddy fields, to allow sunlight to dry out the soil surface. The ground is ploughed and harrowed three to four times. After each ploughing the land is harrowed several times. Therefore, time devoted for land preparation could be shortened, thus allowing adequate soil moisture for peanut without irrigation throughout the growing season. Good land preparation also provides water-free macro pores with advantages to conserve soil moisture in deeper soil layers by cutting capillary rise to the soil surface.

### Pregerminated seed

Peanut grown after rice harvest in the post-monsoon period requires rapid seed germination and seedling growth in order to reach maturity before the plants are subjected to water stress and reduced yield.

To receive rapid seed germination, farmers soak peanut seeds in water for 1-2 days before seeding. Some farmers soak the seeds for 24 hours and subsequently place them in a wet sack for another day before seeding. This results in a quick and uniform peanut germination. Pre-soaking of peanut seeds before seeding is very useful for promoting seed germination especially when seeds are sown in slightly dry soil (Chippendale, 1934). Pre-germinating seeds before planting minimizes the lag period between sowing and seedling establishment. Moreover, pre-soaked seeds will not be easily exposed to pests, especially rats and ants. The early emerged seedlings also have a competitive advantage over associated weeds.

### Re-nutrition of planting material

Mature stems of cassava after harvest is used as planting material. Normally, farmers do not plant cassava soon after harvest due to unfavorable weather conditions. Mature stems are, therefore, kept in the shade for 1-2 months prior to planting. During this period, axillary buds initiate at the upper nodes. Most of the food reserves will be used during this period. To solve this problem, farmers dip stem cuttings (15-25 cm long) into an aqueous solution containing 13-5-5 ($N$-$P_2O_5$-$K_2O$) fertilizer, some farmers use liquid fertilizer diluted in water before planting. Dipping stem cuttings into nutrient solutions will restore nutritional status in stem tissues. This results in an increasing rate and percentage of shoot emergence, early rooting and fast shoot growing. CIAT (1981) reported that the nutrient status of stem cuttings influences their development. Cuttings of stems taken from plants grown on fertilized plots give an early shoot growth and higher yields when these cuttings are planted in an infertile soil.

### Eliminating buds

Cassava is one of the most important cash crops for the farmers in Northeast Thailand. Due to decreasing of land holdings, increasing tuber yield per unit of land area is an important way increase farm income. To increase tuber yield, farmers eliminate bud from stem cuttings used as planting material. Normally, stem cuttings used for planting are around 15-25 cm long. Nowadays, farmers use stem cuttings around 50 cm long and eliminate buds before planting. The longer stem cutting as planting material means that there are more buds and consequently increased number of tubers in the soil. However, deep plowing, animal manure and chemical fertilizer application are required to obtain a high tuber yield. Deep plowing improves soil aeration and facilitates the growth of tubers in the deeper soil layer. Adequate amounts of nutrients need to be applied to the soil in order to increasing root (tuber) weight per plant.

**Detaching flowers**

In crop plants, the fully expanded mature leaf is a major “source” of food (photosynthates) for the plant. The organs which store or use photosynthates are known as a “sinks”. In yambean plants, tubers, flowers and fruit are important sinks. Therefore, flowers and developing fruits have a significant effect of the distribution of assimilates in the plant. The supply of photosynthates is finite and competition between sinks will eventually occur. Therefore, detaching flowers to prevent fruit development leads to greater allocation of assimilates to tubers. When yambeans begin to flower, the farmers use a long bamboo stick striking the top of plant to detach the flowers for improving tuber yield.

**Decreasing leaf area**

Cassava grown on soils containing high levels of organic matter or nitrogen, in general, produce excessive leaves but low tuber yield. To solve this problem, farmers cut the tops off young shoots at 2-3 months before harvesting to improve tuber yield. Cock (1985) reported that heavy applications of fertilizers, particularly nitrogen, can stimulate top growth. Although total plant weight increases, the yield of tubers may decrease. Top cutting is a manipulation of the source-sink relationship. If cassava has a leaf area index (leaf area/unit of land area) over the optimum value, mutual shading will occur. Photosynthates will be allocated to lower shade leaves where the respiration rate exceeds the photosynthetic rate. As a result, there will be less allocation of photosynthates to tubers. Farmers also practice top cutting young shoots of rice at the vegetative growth stage to improve grain yield similarly to cutting the tops of young cassava shoots.

**Suppressing weeds**

Dry direct-seeding or broadcasting rice utilizes rain from the first peak of the region’s bimodal rainfall pattern for crop establishment. This allows the early planting of rice at a time when rainfall is often insufficient for transplanting, thus guaranteeing a crop and also reducing the yield losses often associated with late transplanting of the photo-sensitive rice varieties used in rainfed areas in the Northeast. To maintain a satisfactory yield, however, an effective weed control method is required in dry direct-seeded or broadcasting rice. In general, farmers practice weed control by cutting rice and weeds using a hand lawn mower at the vegetative growth stage. Rice stubble and weeds are cut around 5-10 cm above the ground surface. The rice regrows faster than the weeds and cutting results in better competition with associated weeds.

Polthanee (2006) conducted an experiment to study the effects of cutting rice and weeds on subsequent weed growth and grain yield of dry-direct-seeded broadcast rice. Rice and weed cutting at 30, 45 and 60 days after seeding reduced weed dry weight as compared with that from the uncut-unweeded treatment. Grain yields following cutting after 30 or 45 days were significantly higher than from the uncut-unweeded treatments (Table 2).

**Table 1 Weed dry weight ($g/m^2$) after regrowth at flowering growth stage as affected by cutting dates at 30, 45 and 50 days after seeding (DAS)**

| Treatment | Weed species | | | | Total |
|---|---|---|---|---|---|
| | Grass [1] | Grass [2] | Broadleaf [3] | Sedge [4] | |
| Uncut-unweeded | 66.2$^a$ | 89.1$^a$ | 3.9 | 4.7 | 163.9$^a$ |
| Cut 30 DAS | 19.9$^b$ | 47.9$^b$ | 2.3 | 3.4 | 73.5$^b$ |
| Cut 45 DAS | 49.9$^b$ | 21.2$^c$ | 3.1 | 3.6 | 76.8$^b$ |
| Cut 60 DAS | 49.7$^a$ | 14.7$^c$ | 3.5 | 1.7 | 69.6$^b$ |
| F-test | ** | ** | NS | NS | * |
| C.V.(%) | 18.1 | 27.2 | 24.7 | 21.4 | 31.4 |

[1]*Ischaemum rugosum,* [2]*Panicum repens,* [3]*Ludwigia sp.,* [4]*Fimbristylis miliacea*

**Table 2 Yield and components of rice as affected by cutting dates at 30, 45 and 60 days after seeding (DAS)**

| Treatments | Grain yield (kg/ha) | Panicles (no./$m^2$) | Filled grain (no./panicle) | 1,000 grain weight (g) |
|---|---|---|---|---|
| Uncut-unweeded | 1,814$^b$ | 163.5$^b$ | 64.7$^b$ | 25.4 |
| Cut 30 DAS | 2,159$^a$ | 241.0$^a$ | 80.9$^a$ | 27.4 |
| Cut 45 DAS | 2,138$^a$ | 233.8$^a$ | 74.1$^{ab}$ | 26.5 |
| Cut 60 DAS | 2,075$^{ab}$ | 223.3$^a$ | 66.4$^b$ | 26.1 |
| F-test | * | * | * | NS |
| C.V.(%) | 19.1 | 16.3 | 11.6 | 7.5 |

** = Significant at 5% by DMRT, NS = Not significant*

## Improving soil quality

Rice in Northeast Thailand is normally planted on undulating land which includes upper paddy and lower paddy, on sandy loam or sandy clay loam soil of low fertility. To solve this problem, farmers collect the fallen leaves from the forest area near the village and/or village settlement area. The leaves are incorporated into the soil during land preparation to improve soil fertility. Sae-lec at al. (1992) reported that tree leaves provide several important nutrients such as N, P, K, Ca and Mg but the concentration varies between tree species. Some farmers apply rice husks and incoporate them into the soil in order to improve rice yield when grown on saline soil.

Most sugarcane in Northeast Thailand is grown on coarse textured soil with sandy and sandy loam textures and having low fertility. To maintain soil fertility and maintain the sugarcane yield at a satisfactory level, farmers grow peanut as crop rotation after harvesting sugarcane (over a cycle of two years). The peanut crop is incorporated into the soil after removing the pods from the plant before planting sugarcane. Hemwong (2008) reported that peanut residues returned about 146 kgNha-1 to the soil and increased sugarcane tillering and yield.

Integrated farming is a system which combines the activities of agriculture, animal husbandry, crop production, fisheries, forestry and other sciences related to agriculture in one area of land. Some farmers manage the nutrient cycle to maintain soil fertility using crop residues and weed residues available on the farm to produce compost fertilizer for application to the soil.

## Alleviation of insect damage

Subterranean ants are normally a major pest causing damage to peanut pods and consequently reduce peanut yield. To solve this problem, farmers use mature coconut fruit after removal of husk and place it in the soil in the area where peanuts are grown. Subterranean ants usually enter the coconut fruit to feed on the coconut meat through the coconut's eye. The ants become trapped in the fruit and are brought out of the field and destroyed by burning. Keerati-Kasikorn and Singha (1985) reported that the strong smell of coconut meat in a coconut fruit as a bait is more attractive to ants than peanut pods.

### Post harvest technology

Harvesting of sesame cannot be delayed until all the seed capsules reach the fully ripened stage. This is because the capsules mature unevenly and some seeds in fully ripened capsules may be lost through shedding. To solve this problem, farmers estimate the optimum time to harvest the crop from experience. When a crop is mature enough for harvesting, they observe that most of the leaves of the sesame plant have turned yellow. At this point they open the third or fourth seed capsule from the top. If the seeds inside the capsules are brown, they decide that it is time to harvest the crop. The plants are cut with a sickle or pulled from the soil by hand and stacked into a small heap. Each heap is covered with rice straw or dry coconut leaves for 7-10 days. Then, they tie the sesame plants together to make bundles. Three bundles are tied together to form a tripod-like structure. The plants in the tripod-structure are left and dried in the field under the sun until the capsule tips open. The farmers then turn the bundles upside down and let the seeds fall on to plastic sheets. They found that the technique allows them to harvest all mature seed capsules and to obtain a maximum yield from the crop.

### Multiple cropping

A form of intercropping is practiced by the farmers. Maize and cucumber are planted together in January after rice harvest under irrigated conditions. The maize is planted in rows by hand. Cucumber seed is then seeded into the soil near the maize seeds. The two crops have quite a different growth habit and maturation period. The maize matures first. The two crops grown together use solar radiation, water and nutrients more efficiency during the dry season.

Other forms of relay intercropping are practiced. Peanut or mungbean are planted with maize under rainfed conditions. The peanut or mungbean seed is planted with zero-tillage between rows of mature maize. If the maize is harvested early then the more profitable peanut which requires more moisture and a longer growing period will be planted. If the harvest is likely to be delayed farmers grow the quick maturing mungbean.

Other legumes are also grown with maize, maize and rice bean planted together in the one hole. The corn matures first and provides stalks for the rice bean to climb. The bean provides nitrogen to the maize through symbiotic fixation, provides a ground cover which protects against erosion and leaves a residue of nitrogen for the next crop.

## CONCLUSION

A case study of indigenous agricultural knowledge practiced in Northeast Thailand has shown that farmers have an intimate understanding of their biophysical and socio-cultural environments, and have the capability to develop new technologies by trial and error, in order to improve production systems with limited resources.

To achieve better outcomes in agricultural development for small holder farmers, researchers need to take full advantage of any opportunity to receive information and learn from local knolwedge. A full exchange of information will enhance both the knowledge of scientists and their ability to design suitable ways of improving the lot of small holder farmers.

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Research article

# Influences of Land and Water Use on the Water Quality of Canals through Agricultural Areas

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**Abstract** Shinotsu Canal passes through an agricultural area that contains a high pollutant load from catchments. This pollutant load influences the Ishikari River water quality, which consequently affects downstream aquatic biota. This study was conducted to evaluate the influences of agricultural land and water use activities on Shinotsu Canal water quality. The Shinotsu Canal is 25 km long and contains a 10,864 hectare catchment area, which is divided into 10 sub-catchment areas. The proportions of major land uses such as paddy fields, uplands, and forests were categorized by the supervised classification method using satellite data for each sub-catchment area. Water samples were collected manually from 11 points (P1~P11) upstream to downstream from May 2006 to April 2009. The suspended sediment (SS) concentration was analyzed by suction filtration; nitrate nitrogen ($NO_3$-N) was measured by ion-chromatography; and total nitrogen (TN), total phosphorus (TP) were measured by UV-spectrophotometry. The SS, TN, and TP concentrations were highest during the puddling period (PP), whereas the highest $NO_3$-N concentration occurred during the snow melting period (SMP). There was a positive significant relationship between accumulated paddy field area (APA) and SS ($r = 0.94$) and between the accumulated upland area (AUA) and SS ($r = 0.96$) at <0.001significance level during the PP. The TP concentration was also significant during the SS. TN was highly correlated with APA ($r = 0.94$, $P < 0.001$) and AUA ($r = 0.98$, $P < 0.001$) during the SMP. The SS, TN, and TP concentrations were higher downstream (P11) than upstream (P1) at all periods except for TN during the normal irrigation period. We conclude that land and water use for agriculture, seasonal meteorological characteristics, and fertilizer management affect Shinotsu Canal water quality.

**Keywords** land and water use, water quality, agricultural area, Hokkaido

## INTRODUCTION

Shinotsu Canal in the Shinotsu district is 25 km long with both inlet and outlet on the Ishikari River, Hokkaido, Japan. The canal basin is covered by paddy fields, upland fields, and forests. Agriculture is the main land use activity in this district. It is well known that agricultural non-point source pollution from watersheds is a major cause of water quality degradation. Intensive agriculture emits significant amounts of nutrients, particularly nitrogen, phosphorus, and sediment (Monaghan and Smith, 2004). The water quality of streams, rivers, and lakes is highly related to land use in the catchments, which can affect the quantity and quality of runoff during and after precipitation. Tong and Chen (2002) examined the hydrologic effects of land use in Ohio and discovered a significant relationship between land use and stream water quality, especially with respect to nitrogen and phosphorus contamination. Tachibana et al. (2001) reported that non-point pollution greatly influences the water quality of the Ishikari River. Reuse water may contain higher levels of pollutants from surface runoff, i.e., sediments, pesticides, and nutrients, than natural streams. Water reuse is one of the most important factors for water quality degradation downstream of the Shinotsu Canal. Polluted water also affects the downstream agricultural watersheds and aquatic biota of the Shinotsu Canal. However, some natural and agro-environmental problems associated with water use and quality, land use, and management of the Shinotsu Canal still remain to be solved. The objective of this study was to evaluate the influences of agricultural land and water use activities on the water quality of the Shinotsu Canal.

## MATERIALS AND METHODS

The investigation was conducted on the Shinotsu Canal in the Shinotsu district of the southern part of the Ishikari River basin in the west-central part of Hokkaido, northern Japan (Fig. 1). Its agricultural catchment area (CA) is 10,864 ha, and the main crops are rice, wheat, maize, onion, vegetables, etc.

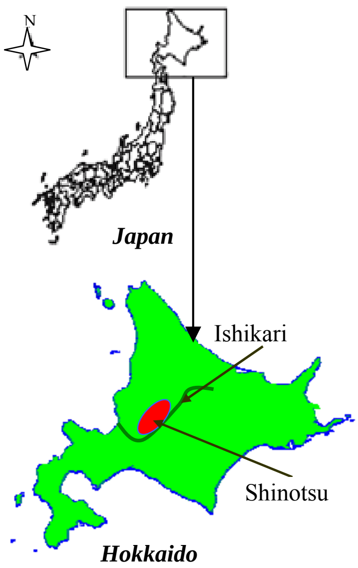



**Fig. 1 Location map of study**

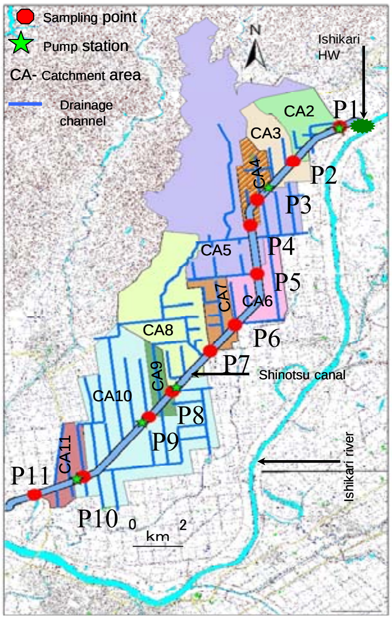



**Fig. 2 Investigated area of Shinotsu**

The annual average precipitation is 1024 mm and most of it falls as rain from June to September. The annual snowfall is 9500 mm and occurs from mid November to April. Maximum snowfall occurs in January. The annual temperature ranges from a minimum of −7.4°C in January to a maximum of 23°C in August. The study area is within the temperate zone, so there are four seasons. However, we divided the study year into five periods: puddling (PP; May), normal irrigation (NIP; June~August), post irrigation (PIP; September~mid November), snow covered (SCP; mid November~mid March), and snow melting (SMP; mid March~April). Water samples were collected manually from May 2006 to April 2009 from upstream to downstream at 11 points along the Shinotsu Canal. Sampling points are indicated by P1~P11 in Fig. 2. Samples were collected 10 times during the PP, 11 times during the NIP, 11 times during the PIP, 9 times during the SCP, and 8 times during the SMP. In the laboratory, a portion of each sample was filtered through pre-rinsed 0.2-µm filter paper, and the nitrate nitrogen ($NO_3$-N) concentration was determined using ion chromatography.

Water samples were analyzed according to the Japanese Industrial Standard (JIS). SS was determined gravimetrically by suction filtration, and total nitrogen (TN) and total phosphorus (TP) were determined by UV spectrophotometry. The investigated area was determined using ArcGIS 9.2 modeling software. The total catchment area was divided into 10 sub-catchment areas, represented as CA2~CA11 (Fig. 2). The catchment area for the P2~P11 sampling points was also represented by CA2~CA11. The catchment and sub-catchment areas were delineated on 1:25,000 scale digital topographic maps, and land use was categorized by the supervised classification method (Satellite Pourl Observation deta Terra (SPOT) of June 4, 2006, and Advance Land Observing Satellite (ALOS) data of July 28 and Aug 9, 2006). Simple linear regression was applied to evaluate the relationships of the paddy and upland fields with SS, TN, and TP for each period.

## RESULTS AND DISCUSSION

There was a significant difference in nutrient concentrations among the sampling points. The SS concentration showed its highest average value of 81 mg/L during the PP at P10 and the lowest value of 1 mg/L during the SCP at P1 (Fig. 3). During this period, maximum water is irrigated and there is excess used water runoff through the drains into the canal, which carries a high SS load.

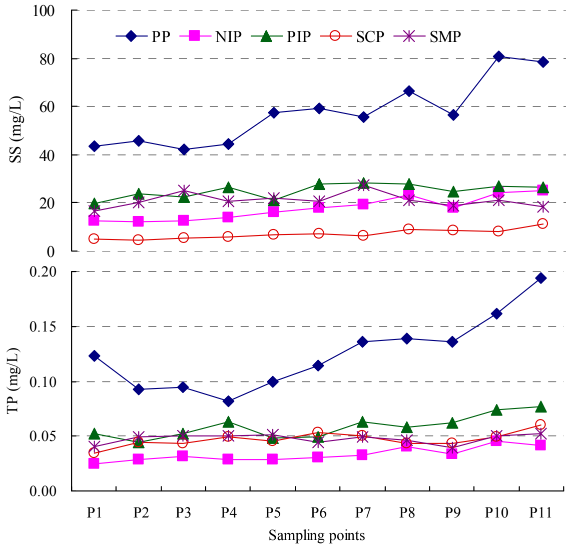



**Fig. 3 Periodic variations in SS and TP**

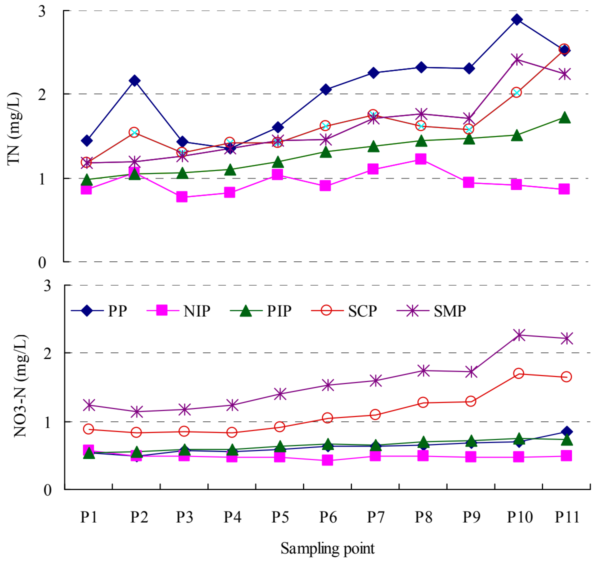
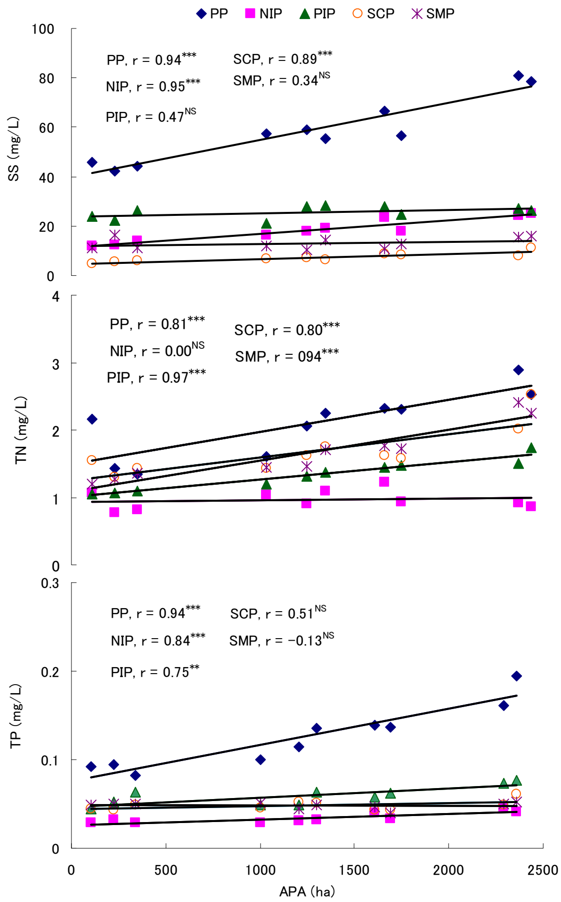



**Fig. 4 Periodic variations in TN and $NO_3$-N**

Russell et al. (2001) found that farm fields in agricultural watersheds are the major sediment sources and determined the rate of soil loss from fields in response to various agricultural practices. The lowest SS value occurred during the SCP, because the land surface is covered by snow, and there are no land use activities. We found an increasing trend in the SS concentration in the order of SCP < NIP < SMP < PIP < PP. The TN and TP concentrations are higher during the PP (Fig. 3, 4), because chemical fertilizers are applied during transplanting, resulting in an increase in dissolved nutrient concentrations in the drain water and discharge of the nutrients via surface drainage water into the Canal. It has been reported that the nitrogen and phosphorous concentrations in drainage water increase during the PP, transplanting, and when fertilizer is applied (Takeda et al., 1991; Feng et al., 2004). Hiroaki et al. (2009) also suggested that TN and TP are high during the puddling and transplanting periods in Shimane Prefecture, Japan. During the NIP, the average TN and TP concentrations were lower than those during others periods, which might have been due to the retention time of water in the paddy fields during the growing season for plants with high nutrient uptake. Tomas et al. (2003) and Braskerud (2002) reported that the retention of water in paddy fields during the growing season induces purification mechanisms, such as denitrification, plant uptake, or sedimentation, similar to those present in natural and artificial wetlands. The average SS, TN, and TP concentrations during the PIP, SCP, and SMP were relatively higher than those during the NIP. Because no agricultural activities are conducted in this area during the PIP, SCP, and SMP, it is believed that residual soil nutrients are leached by rain and snowmelt water, which subsequently flow into the Canal. The $NO_3$-N concentration at P10 during the SMP was 2.26 mg/L (Fig. 4). During this period, snow melt continuously percolates into the soil, and nitrogen fertilizer decomposes to $NH_4$+ through nitrification, which oxidizes to $NO_3$- under aerobic conditions. Nitrate is water soluble and is lost through leaching in melting water and increased drainage discharge though the Shinotsu Canal, which had high $NO_3$-N concentrations during the SMP. A significantly higher $NO_3$-N concentration is found in agricultural streams and rivers during high flow conditions (Castillo et al., 2000). A recent study indicated that the large loading of nutrients into rivers occurs during the early stage of the snowmelt period in Hokkaido (Hayakawa et al., 2003).



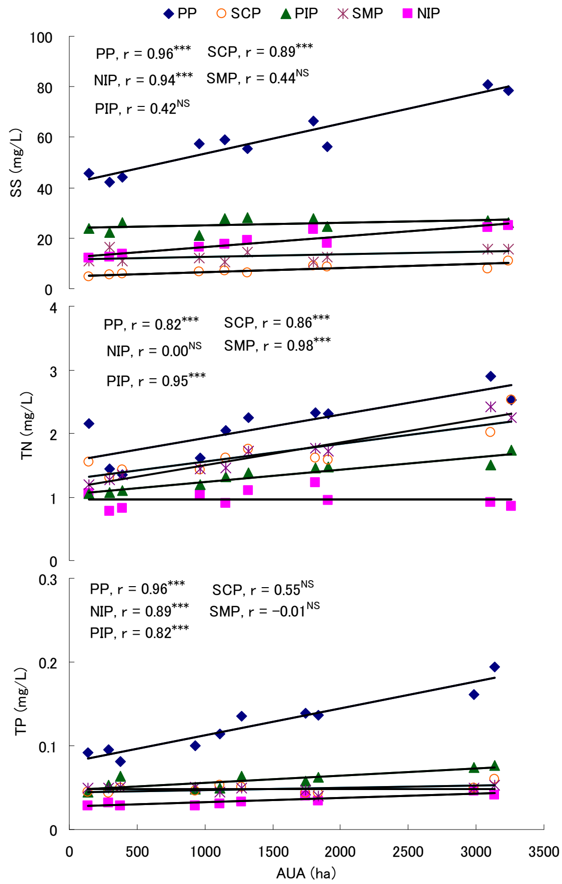




**Fig. 5 Relationship between APA and nutrients Fig. 6 Relationship between AUA and nutrients**

There was a relationship between water quality parameters (SS, TN, and TP) and the accumulated paddy field area (APA) and accumulated upland area (AUA) during the PP, NIP, PIP, SCP, and SMP. APA is calculated as in Eq. (1)

$$APA\ i = \sum_{2}^{i} PAi = PA2 + PA3 + \cdots + PAi, \quad (1)$$

where (i = 2~11). AUA is calculated in the same manner. Linear regression results showed a highly significant correlation between APA and SS during the PP ($r = 0.94$), NIP ($r = 0.95$), and SCP ($r = 0.89$) ($P < 0.001$; Fig. 5), as well as between AUA and SS during the PP ($r = 0.96$), NIP ($r = 0.94$), and SCP ($r = 0.89$) ($P < 0.001$; Fig. 6) due to intensive agricultural activities during the PP and NIP. There were no such relationships during the PIP and SMP, because agricultural activities were absent. Hamill and McBride (2003) reported that lowland stream sediments were highly associated with intensive agricultural land use in Southland, a New Zealand province. TP showed a similar trend of correlations with both APA and AUA as SS did, but not during the SCP. It has been reported that the concentration of phosphorus is more transport limited because phosphorus adsorbs on sediments and is therefore lost through runoff and erosion (Heathwaite et al., 2000).

The TN concentration showed a strong and significant relationship with AUA during the SMP (r = 0.98) and PIP (r = 0.95) (P <0.001; Fig. 6). Similarly, APA and TN during the SMP (r = 0.94) and PIP (r = 0.97) were significantly correlated (P < 0.001; Fig. 5). There was also a highly significant correlation between TN and AUA during the PP (r = 0.81) and SCP (r = 0.80) and between TN and APA during the PP (r = 0.82) and SCP (r = 0.86) (P < 0.001). However, there was no relationship during the NIP for either APA or AUA. There was a stronger relationship with TN during the SMP than during other periods because melting water percolates into the soil and the surplus nitrogen is discharged with melted water. Osborne and Wiley (1988) examined an east Illinois watershed and found that median nitrate concentrations are correlated with agricultural practices during the high-flow spring period and are correlated with urban land use during the low-flow summer and autumn. Turner et al. (2001) reported that nitrogen concentrations in streams, rivers, and lakes are highly related to landscape characteristics and land use.

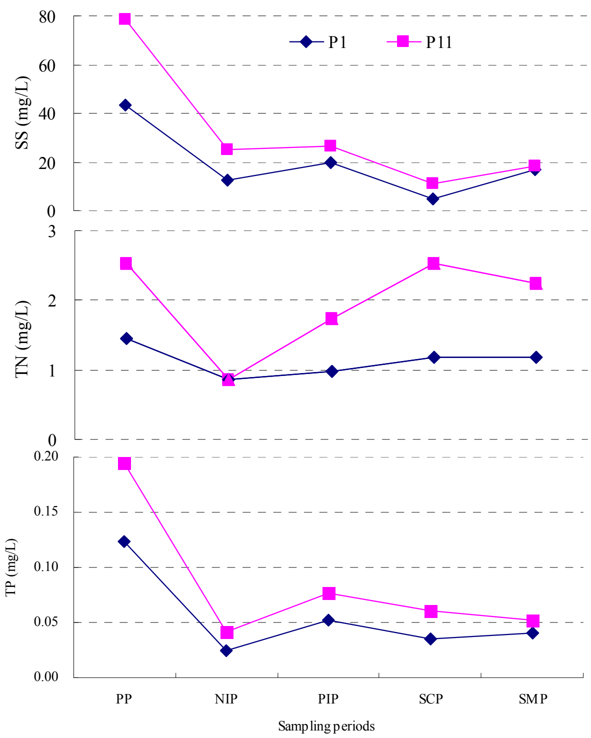



**Fig. 7 Comparisons of P1 and P11 streams nutrients in each period**

The inlet (P1) of the Shinotsu Canal is at the Ishikari River, which flows downward, and the outlet is at the lower reach (P11) of the Ishikari River. Therefore, P1 is the upstream point and P11 is the downstream point. Thus, P1 represents the Ishikari River water quality and P11 represents the Shinotsu Canal water quality. The SS and nutrient concentrations, except TN, were higher downstream than upstream during every period (Fig. 7). The TN concentration had its lowest value during the NIP, because during that period, paddy plants are in the growing stage and higher amounts of nutrients are discharged than during other periods (Fig. 7). Especially during the PP, the SS and nutrient concentrations were higher downstream than upstream due to puddling activities in the paddy field and the frequent re-use of drainage water as irrigation water at the lower-stream agricultural area of the Shinotsu Canal. Water reuse and land use activities affect water flow from upstream to downstream, so SS and nutrient concentrations increase downstream and degrade water quality of the Shinotsu Canal and the lower reaches of the Ishikari River.

## CONCLUSION

This study has shown that there are periodic stream nutrient fluctuations in the Shinotsu Canal. The SS, TN, and TP concentrations were highest during the PP and lowest during the SCP, except for TN during the NIP. $NO_3$-N concentration was highest during the SMP and lowest during the NIP. APA and AUA were significantly correlated with stream SS during the PP, NIP, and SCP, whereas no relationship existed during the PIP and SMP. The TN concentration was highly associated with APA and AUA during the entire study period, except during the NIP. The concentration of TP had no relationship with APA and AUA during the SCP and SMP, but a strong relationship was found during the PP, NIP, and PIP. It was also found that nutrient concentrations were higher at P11 than at P1 during every period, except for TN during the NIP. Though P11 showed higher values of concentrations during almost every period, there must be an impact of land use and water management on the agricultural area of the Shinotsu Canal. Therefore, it can be concluded that land and water use for agriculture, the seasonal characteristics of meteorology, and fertilizer management reduced the water quality of Shinotsu Canal and ultimately of the Ishikari River.

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*Research article*

# Assessing Clients' Satisfaction of Microfinance Institutions in Cambodia - A Case Study of AMK

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**Abstract** Microfinance is widely advocated as a powerful tool to reduce poverty and improve social inclusion. It can assist the poor by reducing their vulnerability and avoiding economic shock. While scale and outreach have been critical indicators of microfinance performance, there has not been much investment in measuring whether clients are satisfied with the microfinance products and services they have been accessing. This article presents findings of a study by Angkor Mikroheranhvatho Kampuchea (AMK) which is measuring client satisfaction with microfinance product and services. While the overall aim is to access whether clients are satisfied or dissatisfied with microfinance products and services, the study also explores the loan use (in comparison with other competitors). Is microfinance widely accepted by the clients? Do microfinance products provide good coverage at affordable interest rates? Do the delivery mechanisms effectively meet the clients need? These are among the key findings addressed in this study. The study was designed to be qualitative by in-depth interview and gathering information from March to May 2009 covering totally 648 new AMK clients in 18 provinces. The findings provide the clients' perception of microfinance product and services; in generally clients are satisfied with AMK; more than 85 percent of the clients at least gave one reason for satisfaction feedback. Approximately, 8 percent to 17 percent had at least one negative comment on microfinance product and services. Low interest, providing loan as needed and giving loan at doorstep are crucial aspects of microfinance AMKs' competitive advantage. The study also reported that the great majority of clients have used at least part of their loans for productive purpose, mostly in farm-related activities (agriculture and livestock). Notably the study gives strong signals for improving product development and service; more than that trying to retain as many clients as possible.

**Keywords** assessment, clients' satisfaction, microfinance, AMK, Cambodia

## INTRODUCTION

Client retention is important and less costly than finding new clients; therefore microfinance institutions (MFIs) have to take care of their clients and understand their needs. Client satisfaction survey is an efficient tool to assess the feedback of clients toward products and services. In this context, AMK conducts client satisfaction surveys on an annual basis in order to provide the Management team with valuable information for business decision making, in particular regarding the improvement of the products and services range. Besides retrieving positive and negative feedbacks from clients, the survey also provides key information on the loan uses (in comparison with other competitors) and the percentage of AMK clients having multiple loans simultaneously.

## METHODOLOGY

The client sample selection was done in two different steps: first, the villages were randomly selected proportionate to the size of the new client population in all of AMK operation areas and second, in each village 12 clients were randomly selected for the study and extra six clients as replacement sample. The study extracts information collected from March to May 2009 in 18 provinces and 54 villages.

## RESULT AND DISCUSSION

As many as 504 new village bank (VB) clients and 144 new individual clients were interviewed. Among the 648 clients, 86 clients had paid their loans back at the time of the interview (61 VB and 25 ID clients); therefore only 562 clients (443 VB and 119 ID clients) provide feedback on AMK's product and service.

Note that 443 active VB AMK clients have 459 active loans with AMK (6 households reported two loans and 2 households reported three loans at the time of the interview) while 119 ID clients have 121 active loans with AMK because 2 households reported two active loans.

### How many client households are making multiple (simultaneous) loans?

In addition to their loans from AMK, households borrow from a range of other sources, both informal (moneylenders or relatives) and formal (Bank, MFIs or NGOs).  Table1 below provides the detailed figures of the aggregate - 30 percent of VB AMK clients and 37 percent of ID clients who are also borrowing from other additional sources.

**Table 1 Estimation of AMK client's multiple loans**

| | Total client | VB client | ID client |
|---|---|---|---|
| A. Inactive | 86 | 61 | 25 |
| a. Client with Active Loans from AMK (only) | 387 | 312 | 75 |
| b. Client with Active AMK loans+ other loan(s) | 175 | 131 | 44 |
| B. Client households with Active AMK loans (a+b) | 562 | 443 | 119 |
| Total Client sample (A+B) | 648 | 504 | 144 |
| Multiple Loan (b/B) | 31% | 30% | 37% |

Of the 443 households with current outstanding VB loans with AMK, a total of 312 households only had outstanding loans with AMK while 131 also reported additional loans from either formal or informal sources. Of these 131 households, 115 households (88%) had two outstanding loans while 16 households (12%) had three outstanding loans.

Of the 119 active ID AMK clients, 44 clients have simultaneous loans from either formal or informal sources. AMK does not provide loan to client having loan with other sources, however it is noteworthy that the fact that a household has multiple loans does not necessarily mean that there was a breach in policy regulations since the household may have borrowed from another source after borrowing from AMK.

### What do they use their loan for?

Based on the proposal made by the client, each loan is given for a specific use. The clients normally use the loan according to their needs and convenience. Each household was allowed to identify multiple responses since many households use the loan for more than one purpose. Table 2 provides the summary of the findings for AMK VB and ID clients respectively in terms of both total loan uses as well as the percentage of households who invest their loan for different purposes.

There was marginal different figure in using loan between VB and ID clients for productive purpose (77% Vs 80%) and consumption (44% Vs 40%); only 16% of VB clients used their loan to build assets while ID clients used up to 28%.

In general 56% of total loan uses were used for productive purposes, 13% for asset building and 31% to consumption purposes. 78% of total clients reported using at least part of their loans for productive purposes, 19% in asset building and 43% for consumption purposes.

**Table 2 Loan use of clients**

| Loan Use | Total # | | % active clients (562) | | | % Total loans use (783) | | |
|---|---|---|---|---|---|---|---|---|
| | VB | ID | VB (443) | ID (119) | Total | VB (607) | ID (176) | Total |
| **Productive purposes** | **342** | **95** | **77** | **80** | **78** | **56** | **54** | **56** |
| Agriculture | 120 | 33 | 27 | 28 | 27 | 20 | 19 | 20 |
| Animals | 84 | 31 | 19 | 26 | 20 | 14 | 18 | 15 |
| Fishing/common property resources | 33 | 4 | 7 | 3 | 7 | 5 | 2 | 5 |
| Manufacture | 30 | 5 | 7 | 4 | 6 | 5 | 3 | 4 |
| Petty Trade | 24 | 6 | 5 | 5 | 5 | 4 | 3 | 4 |
| Services | 51 | 15 | 12 | 13 | 12 | 8 | 9 | 8 |
| **Asset buildings** | **72** | **33** | **16** | **28** | **19** | **12** | **19** | **13** |
| **Consumption Purpose** | **193** | **48** | **44** | **40** | **43** | **32** | **27** | **31** |
| Debt | 17 | 6 | 4 | 5 | 4 | 3 | 3 | 3 |
| Give Loan | 17 | 9 | 4 | 8 | 5 | 3 | 5 | 3 |
| Food | 68 | 12 | 15 | 10 | 14 | 11 | 7 | 10 |
| Health | 54 | 9 | 12 | 8 | 11 | 9 | 5 | 8 |
| Celebrations | 9 | 4 | 2 | 3 | 2 | 1 | 2 | 2 |
| Emergency needs | 19 | 5 | 4 | 4 | 4 | 3 | 3 | 3 |
| Other | 9 | 3 | 2 | 3 | 2 | 1 | 2 | 2 |

Finally, approximately 16 percent of the AMK active clients (93 cases) reported having difficulty in repaying AMK loan, mostly because of enterprise problems (no profit in business activity, animals have died or having problem with sales) (73%) and to a lesser extent for sickness in the family (23%).

**Are AMK clients satisfied with AMK products and services?**

This issue is the crucial part of the article as the objective here is to assess whether clients are satisfied with AMK products and services or not. Each client was allowed to name a maximum of three reasons for satisfaction and dissatisfaction with AMK. Fig. 1 shows that clients are generally satisfied with AMK: (a) more than 86% of the active VB clients and 94% of active ID clients expressed at least one reason for satisfaction with AMK and (b) only 8% of the 459 active VB clients and 17% of the 121 active ID clients had any negative feedback.

Also, the total numbers of positive and negative comments further confirm the general positive attitude of clients towards AMK: households with positive feedback usually have more than one positive comment while households with negative comments usually have only one comment. Not a single client cited three negative comments towards AMK. Finally, the total positive feedbacks considerably outnumbered total negative feedbacks (748 vs. 37 for VB clients and 209 vs. 21 for ID client households).

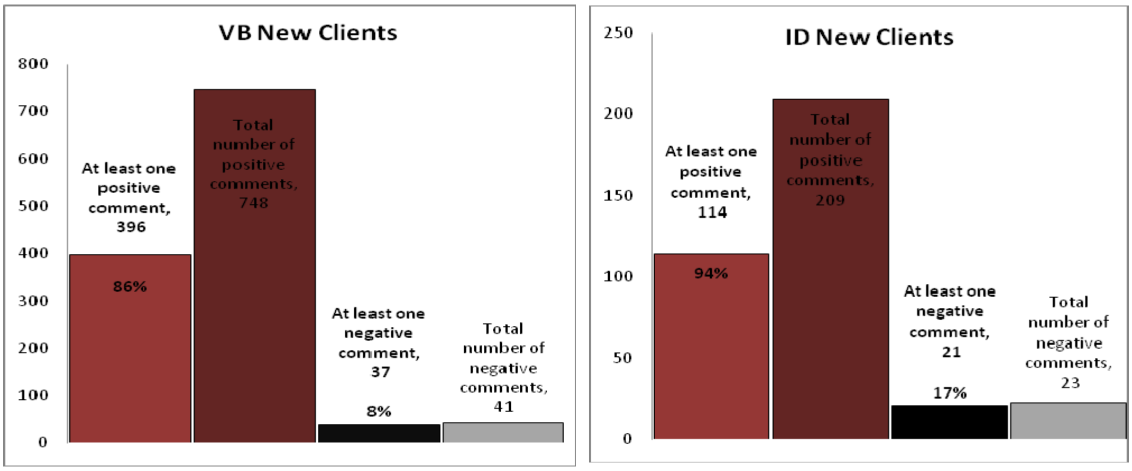


**Fig. 1 General Feedback of VB and ID clients**

Table 3 shows that, generally, AMK's clients reported being satisfied with AMK. The main two sources of client satisfaction are the fact that AMK provided loan when needed or it was easy and fast to get loan (200 comments for VB clients and 69 comments for ID clients) and that AMK's interest rate were moderate or lower (220 comments for VB clients and 38 comments for ID clients). In addition, other positive comments included financing at the doorstep; satisfaction with AMK staff; AMK products (installment [45 comments] and emergency loan [17 comments] and End of Term [3 comments]); satisfied with AMK policies and regulations and because of AMK helps the poor.

**Table 3 Satisfactory feedback (ordered by importance)**

| Description | VB | | ID | | Total | |
|---|---|---|---|---|---|---|
| | # | % | # | % | # | % |
| Provided loan when needed/Fast disbursement/easy to get loan | 200 | 45 | 69 | 58 | 269 | 48 |
| Interest (moderate or lower) | 220 | 50 | 38 | 32 | 258 | 46 |
| Finance at doorstep | 153 | 35 | 47 | 39 | 200 | 36 |
| Like staff behavior | 63 | 14 | 21 | 18 | 84 | 15 |
| AMK product [Installment=45 , Emergency loan=17, EoT=3) | 45 | 10 | 20 | 17 | 65 | 12 |
| Good regulation/policy | 33 | 7 | 4 | 3 | 37 | 7 |
| Help the poor/kind | 24 | 5 | 2 | 2 | 26 | 5 |
| Other [loan size (10) , group(4), no pressure(3), loyalty(1)] | 10 | 2 | 8 | 7 | 18 | 3 |
| Total | 748 | | 209 | | 957 | |

Although only 11% of clients had any negative feedback, there were 64 negative comments, as shown in Table 4. The main sources of dissatisfaction were the small loan size (10 comments for VB clients and 4 comments for ID clients) and slow disbursement (9 comments for VB clients and 5 comments for ID clients) followed by high interest (only 1 comment for VB client while 5 comments for ID clients) and strict policy (4 comments for VB client, 2 comments for ID clients).

Other negative comments cited included problems with AMK staff, or difficulty in getting a loan. A few clients were not familiar with repayment schedule and calculating interest or principle payment, moreover the survey also found that they did not like installment method, required collateral and charged upfront fee (1 comment each). For totally new clients, it is noteworthy that the great majority of clients were satisfied with AMK's interest rate with 258 positive comments versus 6 negative comments.

**Table 4 Dissatisfactory feedback (ordered by importance)**

| Description | VB | | ID | | Total | |
|---|---|---|---|---|---|---|
| | # | % | # | % | # | % |
| Small loan size | 10 | 2.3 | 4 | 3.4 | 14 | 2.4 |
| Slow disbursement | 9 | 2.0 | 5 | 4.2 | 14 | 2.4 |
| High interest | 1 | 0.2 | 5 | 4.2 | 6 | 1.0 |
| Strict policy | 4 | 0.9 | 2 | 1.7 | 6 | 1.0 |
| Dislike AMK staff | 5 | 1.1 | 0 | 0.0 | 5 | 0.9 |
| Difficult to get loan/ask many questions | 3 | 0.7 | 2 | 1.7 | 5 | 0.9 |
| Irregular/strict repayment schedule | 4 | 0.9 | 0 | 0.0 | 4 | 0.7 |
| Not familiar with loan calculation(interest/principle) | 3 | 0.7 | 1 | 0.8 | 4 | 0.7 |
| Hard to find group/group member require/need guarantee | 2 | 0.5 | 1 | 0.8 | 3 | 0.5 |
| Other [dislike installment, collateral , penalty /fee] | 0 | 0.0 | 3 | 2.5 | 3 | 0.5 |
| Total | 41 | 9.3 | 23 | 19.3 | 64 | 11.4 |

**Comparison of Client's Satisfaction on AMK's Product/Service and Competitors**

Table 5 below shows the positive and negative feedback comparing between active loans with AMK and active loans with other providers (this last one from both client and non-client households).

**Table 5 Main positive and negative feedback on AMK and other competitors (%)**

| Positive Feedback | AMK | | Other | | Negative Feedback | AMK | | Other | |
|---|---|---|---|---|---|---|---|---|---|
| | VB | ID | VB | ID | | VB | ID | VB | ID |
| Provided loan when needed | 44 | 57 | 41 | 37 | Slow disbursement | 2.0 | 4.1 | - | - |
| Interest | 48 | 31 | 17 | 13 | Small loan size | 2.2 | 3.3 | 0.4 | - |
| Finance at doorstep | 33 | 39 | 5 | - | High interest | 0.2 | 4.1 | 9.0 | 11.8 |
| Like lender behavior | 14 | 17 | 4 | 3 | Strict policy | 0.9 | 1.7 | 0.9 | - |
| Loan product | 10 | 17 | 2 | 3 | Difficult to get loan | 0.7 | 1.7 | - | 1.5 |
| Good regulation/policy | 7 | 3 | 4 | 1 | Dislike lender | 1.1 | - | 0.9 | 4.4 |
| Help the poor/kind | 5 | 2 | 7 | 9 | Far from village | - | - | 0.9 | 1.5 |
| Loan size | 1 | 5 | 4 | 6 | | | | | |
| No interest | - | - | 17 | 13 | | | | | |

AMK has a competitive advantage in three main fronts:
VB new client households:

- Providing loans when needed or easy to get loan (44% for AMK loans vs. 41% to other sources).
- Lower interest rate than competitors (48% of positive feedback in AMK loans vs. 17% of positive feedback from other additional loans sources, only 0.2% negative feedback for AMK loans vs. 9% negative feedback in loans from other loan sources). However about 17% of clients in VB who get loans from other sources were satisfied with no interest charging.

- Providing loans at their doorstep: positive feedback 33% from AMK loan sources and 5% from other sources and plus 1% of negative feedback for other loans because providers were far from village.

### ID new client households

Providing loans when needed or easy to get loan (57% for positive feedback to AMK loans vs. 37% to other sources, but 1.7% of ID clients for AMK loan vs. 1.5% for another loan sources claimed that was difficult to get loans). Lower interest rate than competitors (31% of positive feedback in AMK loans vs. 13% of positive feedback from other additional loans sources; 4% negative feedback for AMK loans vs. 11% negative feedback in loans from other loan sources).

## CONCLUSIONS

The main highlights of this article are the following: As many as 31 percent of new AMK clients in 2009 have multiple loans simultaneously with other sources of credit, similar to the results found in 2008 (33%) but higher than results in 2007 (28%) and 2006 (13%). The great majority of VB new and ID AMK clients reported using at least part of their loans for productive purposes, mostly in farm-related activities (agriculture and animal-raising). A little less than half of VB clients (44%) and ID clients (40%) allotted part or all of their loans for consumption purposes (mainly food and medical expenses).

AMK clients are generally satisfied with AMK. About 86 percent of VB clients and 94 percent of ID clients expressed at least one reason for satisfaction with AMK. The primary sources for satisfaction are: the fact that AMK provides loans when needed or that it is easy to get loans, the interest rates are fair and AMK provides loan at their doorstep. Only 8% of group clients and 17% of ID clients had (at least) one negative feedback about AMK, mainly related to the small loan size or slow disbursement or the high interest rate. Small loan size was most complained among both VB and ID client households.

Finally, the study evaluated the strengths and weaknesses of current products and services and client demand for new product/service offerings. Low interest, providing loan when needed and finance at doorstep appeared as AMK's competitive advantages by VB clients. For ID client households, providing loan when needed, providing loan at their doorstep and low interest are also a crucial aspect of AMK's competitive advantage to enlarge and retain clients.

## ACKNOWLEDGEMENTS

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*Research article*

# Present Status of Agriculture and Possibility for Increased Export of Food and Agricultural Products in Cambodia

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**Abstract** This paper aims to discuss the possibility of increased export of food and agricultural products on the basis of collected data sources and interviewing for the policy makers and to build up the good relationship through Japanese investor to promote agricultural export in Cambodia. Government announced the exportable agricultural products with high potentials such as rice, maize, soybean, mung bean, sesame, peats, cassava, cashew nuts, pepper, rubber, fish products and cattle/buffalos. As far as government announcement is concerned, the direction for export expansion should be put already traded items in terms of amount bases. Even in already traded items, they should be developed with higher added value.

**Keywords** agricultural production, agricultural marketing, agricultural policy, export, foreign direct investment, public private partnership (PPP)

## INTRODUCTION

Cambodia is an agriculture-based country with food self sufficiency centering on rice as staple food. Accordingly, her emphasis should be to put the stable fulfillment of domestic supply copied with the increased food demand on agricultural policy. In reality, however, a part of food and agricultural products is substantially dependent on the import; nevertheless it is possible to produce them domestically.

Towards the direction on agricultural policy, an import substitution by means of the increased and diversified local production should be implemented in accordance with the shift of demand for food and agricultural products while the increased export of food and agricultural products with advantageous competitiveness should be promoted, taking a careful look for international market.

Therefore, better understanding of the agriculture sector with possible accuracy will be necessary for clarifying the faced problem. Based on such understanding, an adequate strategy and political approach in solving the problem should be established, taking bilateral governmental cooperation and foreign private investment in Cambodia and Japan into consideration.

This paper aims to discuss the possibility of increased export of food and agricultural products on the basis of collected data sources and interviewing for the policy makers and to build up the good relationship through Japanese investor in order to promote agricultural export in Cambodia.

## PRESENT STATUS AND PROBLEMS

### Agriculture at the macro level

According to the statistics shown in the Ministry of Agriculture, Forestry and Fisheries of Cambodia (MAFF in Cambodia, 2009, GDP share of agricultural sector for total GDP has fallen down substantially from 44.8% in 1998 to 34.4% in 2008 (29.7% in 2007). On the one hand, gross value added in agriculture has increased by 52.2% during 1996 to 2008 at the nominal growth rate.

In the composition rate of gross value added shown by industry of agricultural sector in 2008, crops was 52.7%, 25.0% in fisheries, 15.5% in livestock & poultry, 6.8% in forestry & logging. In the composition rate by annual crops in 2006, rice was 54%, 8% in vegetables, 5% in maize, 5% in cassava, 3% in soybean and by industrial crops rubber was 5%, 3% in cigarettes, 8% in other cash crops (JAICAF, 2009). In addition, 80% of total population is living in rural area, and most of population engaging in farming.

**Trend of rice production**

Agriculture is still the predominant sector in economic activity, and rice is especially and overwhelmingly positioned at the center of crops. Table 1 shows the trend of planted area, yield and production of rice for the period of 9 years from 2000 to 2008.

**Table 1 Trend of rice production, planted areas and average yield in Cambodia, 2000-2008**

| Year | Production (1000Mt) | Planted area (1000ha) | Average yield (Mt/ha) |
|---|---|---|---|
| 2000 | 4026.1 | 2318.5 | 2.12 |
| 2001 | 4099.0 | 2240.9 | 2.07 |
| 2002 | 3822.5 | 2137.1 | 1.92 |
| 2003 | 4711.0 | 2314.2 | 2.10 |
| 2004 | 4170.3 | 2374.2 | 1.98 |
| 2005 | 5986.2 | 2443.5 | 2.48 |
| 2006 | 6264.1 | 2541.4 | 2.49 |
| 2007 | 6727.1 | 2585.9 | 2.62 |
| 2008 | 7175.5 | 2615.7 | 2.75 |

*Source: Bunthan NGO (2009) "Appropriate compost application as sustainable farming practices in Cambodia" (Doctorate Thesis not published). Original data was cited from Ministry of Agriculture, Forestry, and Fisheries (MAFF) (2008) "Report on agriculture in 2007 and direction of 2008-2009" (Khmer version)*

As shown in Table 1, rice production increased from 4.03 million tons in 2000 to 7.18 million tons in 2008. Planted area increased from 2.32 million hectares to 2.62 million hectares while production per hectare increased from 2.1 tons to 2.7 tons. Accordingly, an increase of rice production for this period was contributed by the growth of yield more than planted area. Nevertheless, average rice production per hectare is far from 5.0 tons in Vietnam and 3.0 tons in Thailand in 2007 (FAOSTAT). Since rice planting takes place during both rainy and dry seasons, rice production in the rainy season is the mainstream with a share of 80% (Bunthan, 2009). Average rice production per hectare is higher in the dry season with 3.93 tons than in the rainy season with 2.49 tons in 2006 (JAICAF, 2009).

Even though rice production has substantially increased from 2000 to 2008, it was not necessarily uptrend consistently. In particular, rice production in 2002 and 2004 decreased greatly compared to the previous year due to the occurrence of serious flood during the rainy season (JAICAF, 2009). Generally speaking, rice production is significantly dependent on weather condition. Since attaining rice self-sufficiency in 1996, the surplus of rice has sustainably been exported. MAFF of Cambodia mentioned that a part of fragrant rice with high quality enabled to export at the higher price in the international rice market.

**Trend of other crops' production**

Table 2 shows the production trend of the other main crops consisting of maize, cassava, sugarcane and soybean from 2000 to 2007. As shown in Table 2, production of each crop has been uptrend for this period, showing heavy fluctuation year by year. Such fluctuation of each crop production was caused by the serious problems as mentioned below.

**Table 2 Trend of main crop production (excluded rice) in Cambodia (unit: 1000Mt)**

| Year | Maize | Cassava | Sugarcane | Soybean |
|---|---|---|---|---|
| 2000 | 157 | 148 | 164 | 28 |
| 2001 | 186 | 142 | 169 | 25 |
| 2002 | 149 | 122 | 209 | 38 |
| 2003 | 315 | 331 | 173 | 63 |
| 2004 | 257 | 362 | 130 | 110 |
| 2005 | 248 | 536 | 118 | 179 |
| 2006 | 377 | 218 | 142 | 98 |
| 2007 | 380 | 200 | 170 | 117 |

*Source: FAOSTAT*

### Problems on agricultural production

MAFF of Cambodia revealed the constraints on agricultural production as follows (JAICAF, 2009).

- Inadequate rural infrastructures: roads, irrigation systems, rural markets, etc.
- Limited technological changes at community level as well as farmers and producers, agricultural research and extension are still inadequate.
- Limited access to credits and micro-finances in the rural areas.
- Limited investment capacity or interest in investing in agriculture.
- Variable climatic condition and water resources.
- Limited access to agriculture inputs: fertilizers (chemical organic), pesticides, machineries, improved seeds, etc.
- Weak agri-business and agro-enterprises.
- Export constraints due to technical barriers (Quality standard, quality control, quality certifications).

### Present status and problems in agricultural marketing

Agricultural marketing system in Cambodia is complicated and diversified. The present status of agricultural marketing will be clarified from the result of interviewing concerned persons. In depth interviewing survey was conducted for local trader handling mainly some kinds of vegetable in Phnom Penh. The trader is establishing the system in selling vegetable to restaurant and supermarket and at the same time provides the farmer with agricultural inputs like seed and financial support. The trader instructs vegetable growing technology for the farmer and finally purchases vegetable from the farmer on a contract basis. As a result of interviewing the trader, some serious problems were clarified as follows. (1) Hard to collect vegetable due to insufficient farmer's group; (2) Selling vegetable to other traders or buyers without contract basis; (3) Difficult for the farmer to learn the growing technology because the farmer does not come to the training class over in-service training; (4) Depressed local price due to inflow of Vietnamese vegetable at the lower price. According to the information from the trader, in case of assuming the existence of local market demand it is difficult to collect the quality-controlled vegetable through the formal route and carry stable supply to the local wholesale market; and consequently the shortened supply of vegetable is set off by Vietnamese vegetable.

Basic marketing channel of vegetable is described as follows: Harvesting vegetable at farm → Collecting vegetable in the production area → Transporting vegetable from the production area → Transacting at the wholesale market → Transacting at the retailed market → Consumer purchasing. Since there are other specific channels like the contract farming system between trader and farmer mentioned above, the marketing system is multi-dimensional and not transparent. In addition, since vegetable is not clearly classified by kind, size, shape, maturity, freshness and appearance based on any regulation and criteria, a process in pricing is unclear. Furthermore, it is unclear which part of the vegetable is used for consumer and for food processing industry as well as how vegetable is transacted and what pricing mechanism is working.

Under such incompleteness of the marketing system, it is impossible to say that a transaction of vegetable is carried out properly between farmer and consumer or trader and food processing industry. Based on the lack of storage facility, hardness of collecting the market information and inaccurate data due to the incompleteness of marketing system, a market price of vegetable is inclined to fluctuate significantly. A speculation is easily occurring with price fluctuation. The incompleteness of the marketing system is applicable to other agricultural products as well. It will be against the sound development of agriculture and food processing industry.

Some trader interviewed mentioned equal word that transportation cost was extremely high. The higher transportation cost is attributed to high petrol price, no good road condition and vehicles. The higher transportation cost is brought about by the higher marketing cost, which is becoming to be one of the important hazards in transporting agricultural products smoothly.

**Possibility for increased export of food and agricultural products**

Cambodia is exporting various food and agricultural products. Table 3 shows the trend of exported principal agricultural products from 2000 to 2007. Though natural rubber and cigarettes are mainstream of exported agricultural produce, they are materials for industrial use, not for edible food. Edible food for export is maize, soybean and rice though export trend is largely fluctuating within a year.

**Table 3 Trend of export value of main agricultural products in Cambodia (unit: 1000Mt)**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| Natural rubber | 6258 | 18447 | 28258 | 33402 | 36933 | 8304 | 18142 | 25877 |
| Cigarettes | 1838 | 2216 | 650 | 885 | 1143 | 11017 | 25241 | 22650 |
| Maize | - | - | - | - | 3713 | 1600 | 2461 | 6177 |
| Soybean | - | - | - | 62 | 3442 | 6486 | 4405 | 6104 |
| Palm oil | - | - | - | 437 | 797 | 1113 | 1754 | 1635 |
| Rice | 94 | 2386 | 1691 | 639 | 1889 | 744 | 2440 | 1357 |

*Note: 1. Order of commodity is based on 2007; 2. Cigarettes excluded tobacco. Rice in 2000 consists of rice milled, rice broken, rice husked and rice paddy*
*Source: FAOSTAT*

Apart from these export items, in 2007 other exports were as follows - salted cattle (FAOSTAT, same data in below, 850,000US$), cassava starch (619,000US$, cashew nuts (with shell and shelled) (598,000US$), garlic (516,000US$), chillies and peppers, dry (297,000US$), sesame seed (148,000US$), spices (143,000US$), dried Beans (106,000US$), pastry (94,000US$). However, in reality it should be noted that active transaction in nearby borders with Thailand and Vietnam may be conducted illegally though it is never shown on statistics.

Government announced the exportable agricultural products with high potentials such as rice, maize, soybean, mung bean, sesame, peanuts, cassava, cashew nuts, pepper, rubber, fish products and cattle/buffalos. Even in already traded items, they should be developed with higher added value. For instance, the export of fragrant rice should be greatly increased (10,000 ton was exported to United States, Hong Kong and EU at this moment). Organic vegetable and fruits have high potentials as exportable items. In Cambodia any technology and know-how for food processing is significantly constrained. The Ministry of Agriculture, Forestry and Fisheries in Cambodia is expecting with great pleasure that foreign investors are able to work jointly with local manufacturers. The Ministry of Commerce indicated that development of higher value added cassava with help of foreign investors would be promising direction for export promotion in the future.

## CONCLUSION AND RECOMMENDATION

An effective strategy in developing agriculture can be described in three ways. (1) To strengthen domestic food supply chain in response to the demand change of food and agricultural products; (2) To combine effectively among the different industries such as the sector linkage between agriculture and tourism; (3) To enhance international competitiveness of food and agricultural products with higher export potentials. These three different kinds of agricultural development strategy are called “Demand pulled approach”. Among these strategies, export oriented strategy is likely to have most effectiveness on accelerating the process of agricultural development by transferring the dynamism for agricultural development from external origin to the domestic agriculture and food manufacturing industry. When Cambodia increases export with high value added products to the developed countries, higher barriers like inspection, certification and quality control for exportable product should be overcome in addition to stably providing it at the relatively lower price. If this seems to be hard, it will be impossible to increase export;. Cambodia should have full knowledge of what, how many, at what price and with how quality can meet export standard to the destination. Cambodia should predict change on the external conditions along global trade liberalization. In this case, exportable products are requested to make a selection with criteria in creating out job opportunity and incrementing income multiplied by the additional supply increase. As for the criteria in making selection of exportable products, products should be selected along the lower cost, using local resources with rich-endowment. Producer and food manufacturer are needed to learn and apply the sophisticated technology to increment exportable products at the lower price. Trader and exporter are requested to handle and transport the products efficiently. Among each actor playing role along food supply chain, precious information and human resources should be networked functionally. Each actor has to make an effort for capacity building of human resources and at the same time fulfillment and arrangement of physical infrastructure and marketing system as well as law and institution building should be implemented to promote export of food and agricultural products.

This, however, will be not easy to conduct only with own effort. Japan will be able to help by means of actively participating in the export promoting project for food and agricultural products concerning the selection of exportable products, fulfillment of physical infrastructure, technology transfer, financial support, capacity and institution building along the scheme of public and private partnership in both countries. The increased export for food and agricultural products in Cambodia will not only contribute to agricultural development, but also to ensure food security in Japan with stable supply of the imported food and agricultural products.

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*Research article*

# Rice Soil Fertility Classification and Constraints in the Mekong Delta

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**Abstract** In the Mekong Delta, Vietnam, areas of intensive rice production have been rapidly enlarged. Soil fertility degradation in this system can be one of the most important factors contributing to the yield decline. Information on soil fertility and recommendations on improving soil constraints will provide basic data for proper soil management, land evaluation and land use planning. A Fertility Capability Classification (FCC) system incorporates characteristics of soil morphology, soil physics, and soil chemistry. Data from 300 soil profiles in rice fields and 28 field experiments on fertilizers efficiency were collected, showing that there were 25 rice soil fertility types, in which types **CC** (clay in top and subsoil) and **CCs** (clay in top and subsoil and saline effected) occupied in large extent. The major soil constraints for rice cultivation can be listed as follows: low organic carbon content (**o**); high P fixation and high Fe toxicity potential (**i**); potential salinity (**s**$^-$); low available P (**p**); high acidity and Al toxicity (**a**); the separation of actual acid sulfate soils (**c**, **c**$^-$) and potential acid sulfate soils (**f**, **f**$^-$).

**Keywords** FCC, soil fertility, constraints, modifier

## INTRODUCTION

In the Mekong Delta, rice cultivation is usually irrigated and highly productive, featuring multiple rice crops. They also face serious problems, including the unsustainable exploitation of water and soils, inefficient use of chemical inputs, and emerging or worsening disease and pest problems. The intense and increased pressure on land leads to its degradation and pollution, which may result in a partial or complete loss of its productive capacity.

According to Sanchez (2001), differences in soil taxonomy are important to establish the broad picture, but what does it mean in agronomic and ecological terms? The problem with soil taxonomy is that it quantifies only permanent soil parameters, most of which are located in the subsoil. To overcome this limitation, a Fertility Capability soil Classification system (FCC) was developed more than 25 years ago to interpret soil taxonomy and soil tests in a quantitative manner that is relevant to growing plants (Buol et al., 1975; Sanchez et al., 1982). It is now widely used and is included in the worldwide FAO soils database (FAO, 1995). Most of class limits are borrowed from Soil taxonomy (Soil Survey Staff, 1994) or the FAO/Unessco soil classification system (FAO, 1974). Emphasis is placed on features that are easily detectable in the field, such as texture, color, depth of horizons, presence or absence of mottles, etc. Soil analytical laboratory data are only used to support the classification if available. The strength of this system is its ease of use, which allows the soil to be classified at several locations simply and quickly. To facilitate the easy transfer of information about soil properties and constraints, the system consists of a series of individual letters to describe the soil. These properties signify fertility limitations with different interpretations, and represented by small letters.

Based on the integrated system for soil fertility evaluation, it was used for soil fertility classification and recommendation for rice soil of the Mekong Delta, where rice cultivation dominantly applies, which can assist the land use planner or agricultural extension officers in identify the constraints, and recommend for proper use.

## METHODOLOGY

The Fertility Capability Classification (FCC) from Sanchez et al (2003), with some modifications from Vo Quang Minh (2007) was used as reference system. Approximately about 300 top and subsoil samples in rice fields were collected within the Mekong Delta from 1996 to 2007 (Fig. 1) for soil chemical and physical analysis (soil texture, pH, ECe, $Al^{3+}$, $Fe^{3+}$, $K^{+}$, $Na^{+}$; $Ca^{2+}$, $Mg^{2+}$, CEC, organic matter, P available) and soil profile description based on the guideline of FAO (1974), which was recommended by the system, and data of 28 field experiments on fertilizers efficiency for rice cultivation. Fourteen (14) modifiers that indicate the soil fertility status and effect to rice growth in the Mekong Delta were determined: **a**, $\mathbf{a}^-$ (Al toxicity, low pH), **c**, $\mathbf{c}^-$ (actual acid sulfate soils), **e** (high leaching potential), **k** (low Nutrient Capital Reserves), **f**, $\mathbf{f}^-$ (potential acid sulfate soil), $\mathbf{g}^+$ (constant saturation), **i** (high phosphorus fixation), $\mathbf{n}^-$ (potential Sodic), **s**, $\mathbf{s}^-$ (saline), **o** (low organic matter status), and **p** (low inherent P content), which efftect to rice root. In which, modifiers **p**, **o**, **c**, $\mathbf{c}^-$, **f**, $\mathbf{f}^-$ were added by Vo Quang Minh (2007), and superscripts **+** or **-** indicate a greater or lesser expression of the modifier. The soil fertility was named as soil texture of each soil layer (**C**, **L, S**) plus modifiers.


**Fig. 1 The Mekong delta in Vietnam**

## RESULTS AND DISCUSSION

### Soil fertility classification for rice cultivation in the Mekong Delta

The term "FCC" is used to indicate adaptation of the Fertility Capability Classification, as developed by Sanchez and Buol (1982), and Sanchez et al (2003), and modified by Vo Quang Minh (2007) to the soil and rice growing conditions present in the Mekong delta, which deal with soil morphology, physic, and chemistry characteristics. We set out below the meaning of each soil fertility type, including 25 soil fertility types, which was converted from soil map at 1/250.000 scale, identified by its corresponding letter and the corresponding limits (Table 1).

**Table 1 Summary of soil fertility capability classification (FCC) for rice cultivation in the Mekong Delta (Based on a system from Sanchez et al, (2003), Vo Quang Minh (2007) and the conversion of rice soil map - WRB 1998 at scale 1/250,000)**

| FCC | Soil fertility capability interpretation | ha | % |
|---|---|---|---|
| **CC** | texture is clay (**C**) within 50 cm from the soil surface | 328,382 | 18.6 |
| **CCs** | texture is clay (**C**) within 50 cm from the soil surface, severe salinity in subsoil (**s**) | 327,099 | 18.4 |
| **LC** | texture is loamy (**L**) between 0 and 20 cm, and a clay (**C**) between 20 and 50 cm | 160,013 | 9.0 |
| **CCc$^-$** | texture is clay (**C**) within 50 cm from the soil surface, Moderately actual acid sulfate soils (**c**$^-$) | 128,952 | 7.2 |
| **CCi$^+$** | texture is clay (**C**) within 50 cm from the soil surface, iron toxicity if prolonged, soil submerged (**i**$^+$) | 117,015 | 6.6 |
| **CCai$^+$** | texture is clay (**C**) within 50 cm from the soil surface, soil is very acid (**a**), iron toxicity, if prolonged soil submerged (**i**$^+$) | 109,560 | 6.1 |
| **CCv** | texture is clay (**C**) within 50cm from the soil surface, cracking clays(v) | 102,027 | 5.7 |
| **LLacp** | texture is loamy (**L**) within 50 cm from the soil surface, soil is very acid (**a**), strongly actual acid sulfate soil (**c**), low inherent P content(**p**) | 100,863 | 5.6 |
| **LL** | texture is loamy (**L**) within 50 cm from the soil surface | 61,990 | 3.4 |
| **LLai** | texture is loamy (**L**) within 50 cm from the soil surface, soil is very acid (**a**), high phosphorus fixation (**i**) | 54,003 | 3.0 |
| **CCacps$^-$** | texture is clay (**C**) within 50 cm from the soil surface, soil is very acid (**a**), strongly actual acid sulfate soil, low inherent P content (**p**), slightly salinity in subsoil (**s**$^-$) | 44,739 | 2.5 |
| **CCf$^-$** | texture is clay (**C**) within 50 cm from the soil surface, moderately potential acid sulfate soils (**f**$^-$) | 35,773 | 2.0 |
| **LLs$^-$** | texture is loamy (**L**) within 50 cm from the soil surface, potential salinity (**s**$^-$) | 30,175 | 1.7 |
| **LLc$^-$** | texture is loamy (**L**) within 50 cm from the soil surface, Moderately actual acid sulfate soils (**c**$^-$) | 28,494 | 1.6 |
| **CCc$^-$s$^-$** | texture is clay (**C**) within 50 cm from the soil surface, Moderately actual acid sulfate soils (**c**$^-$), potential salinity (**s**$^-$) | 25,287 | 1.4 |
| **LLfs$^-$** | texture is loamy (**L**) within 50 cm from the soil surface, shallow potential acid sulfate soils (**f**), slightly salinity in subsoil (**s**$^-$) | 25,210 | 1.4 |
| **LLf$^-$** | texture is loamy (**L**) within 50 cm from the soil surface, moderately potential acid sulfate soils (**f**$^-$) | 21,749 | 1.2 |
| **LLc$^-$s$^-$** | texture is loamy (**L**) within 50 cm from the soil surface, Moderately actual acid sulfate soils (**c**$^-$), slightly salinity in subsoil (**s**$^-$) | 16,180 | 0.9 |
| **LLi** | texture is loamy (**L**) within 50 cm from the soil surface, high phosphorus fixation (**i**) | 15,941 | 0.9 |
| **CCacp** | texture is clay (**C**) within 50 cm from the soil surface, soil is very acid (**a**), strongly actual acid sulfate soil (**c**), low inherent P content (**p**) | 14,001 | 0.7 |
| **LLf$^-$s$^-$** | texture is loamy (**L**) within 50 cm from the soil surface, moderately potential acid sulfate soils (**f**$^-$), slightly salinity in subsoil (**s**$^-$) | 11,472 | 0.6 |
| **LLi$^+$** | texture is loamy (**L**) within 50 cm from the soil surface, iron toxicity if prolonged soil submerged (**i**$^+$) | 5,051 | 0.2 |
| **CCf$^-$s$^-$** | texture is clay (**C**) within 50 cm from the soil surface, moderately potential acid sulfate soils (**f**$^-$), slightly salinity in subsoil (**s**$^-$) | 3,760 | 0.2 |
| **LLf** | texture is loamy (**L**) within 50 cm from the soil surface, shallow potential acid sulfate soils (**f**$^-$) | 3,506 | 0.2 |
| **LLacps$^-$** | texture is loamy (**L**) within 50 cm from the soil surface, soil is very acid (**a**), strongly actual acid sulfate soil (**c**), low inherent P content (**p**), slightly salinity in subsoil (**s**$^-$) | 15 | 0.001 |
| | | 1,771,267 | 100 |

**The constraints for crops cultivation**

The attribute used in the system is the lower-case letters of the constraints that have been identified for that soil indicated in the soil fertility type. Based on the field observations, soil analysis of chemical, physical, rice field behavious, and from several field experiments results, the major soil constraints for rice cultivation in the Mekong Delta can be identified and grouped as below.

**Constraints related to soil mineralogy**

**High leaching potential (e)**: Soils with a low cation exchange capacity (CEC) have topsoils with a low organic matter content, a low clay content, clay minerals with low CEC, or all these properties. These soils have a low inherent fertility and also a low capacity to retain nutrients added as fertilizer. More exacting N management needed; identifies degraded paddy soils and low organic matter; if potential $H_2S$ toxicity can occur if $(NH_4)_2SO_4$ is used as N source; in coarse texture soils often Mn deficient; application of large organic material keeps pH low even after flooding.
**High phosphorus fixation (i)**: This constraint is caused primarily by a high content of free ferric oxides ($Fe_2O_3$) in the clay fraction, which fix phosphate ions in unavailable forms. It is a feature also found in strongly acidic soils, and hence commonly associated with the **a**, or **a$^-$** constraint, aluminium toxicity. High P fixation by Fe; P deficiency likely; Fe toxicity potential; soils difficult to puddle and will regenerate original structure rapidly.
**Low Nutrient Capital Reserves (k)**: Low inherent fertility because of low inherent reserves of wethearable minerals; potential K deficiency depending on base contents of irrigation water.
**Low organic matter status (o)**: N deficient; response to N fertilization very likely; low ECEC on sandy soils; N fertilizer should be applied in frequent, small doses.
**Low inherent P content (p)**: Plant available P deficient; response to small additions of P fertilization very likely.

**Constraints related to soil reaction**

**Al toxicity, low pH (a, a$^-$)**: These are soils in which the exchange complex is dominated by alumina. The problem is commonly described as one of strongly acidic soils, can be caused by strong leaching from high rainfall, and mainly from oxidation of sulfidic material, which often associated with **c**, **c$^-$** modifiers. Aluminium toxicity will occur in aerobic layers.
**Actual acid sulfate soils (c, c$^-$)**: Al and Fe toxicity, low pH, and P deficiency, which originated from oxidation of sulfidic material.
**Potential acid sulfate soil (f, f$^-$)**: Potential acid-sulfate soils, causing Fe and S toxicity when anaerobic and Al toxicity when aerobic; depth at which **f** modifier occurs determines feasibility of rice production; Zn deficiency common; prevent seepage from this areas.
**Constant saturation (g$^+$):** Prolonged submergence causes Zn deficiency. N loss increased if soil is intermittently flooded and drained.
**Saline (s, s$^-$)**: Defines saline soils; drainage needed, consider conductivity of irrigation water.
**Potential Sodic (n$^-$)**: This soil has a slightly high content of sodium but is low in calcium and magnesium salts causing soil dispersion, puddling, poor infiltration and poor aeration, and if sodium is high in the plow layer, increased probability of surface crust formation. Defines sodic soils; reclaiming with drainage and gypsum applications may be needed; Zn deficiency common.

**Strategies for better utilization of soil and soil fertility conservation**

The management requirements are given per interpreted soil property or group of properties. A complete listing of all possible combinations is not given because only a limited number of combinations of soil properties will be found in any area under consideration. At large scale, however, interpretation of the soil properties in relation to farming systems, local expertise or rice varieties could be a valuable extension tool.

**Table 2 Extent of modifiers and soil fertility constraints in rice soils of the Mekong Delta (Based on the conversion of rice soil map-WRB at 1/250.000 scale)**

| Modifiers | Soil fertility constraints | Area (ha) |
|---|---|---|
| **p** | low available P | 327,099.4 |
| **s** | Strongly salinity of subsoils | 327,099.4 |
| **a** | Acid soil, iron, aluminium toxicity | 323,183.1 |
| **$i^+$** | High phosphorus fixation and high Fe toxic potential | 231,628.0 |
| **$c^-$** | Depth actual acid sufate in subsoil | 198,914.3 |
| **c** | shallow actual acid sufate soils | 159,619.2 |
| **$s^-$** | slightly salinity in subsoils | 156,840.9 |
| **v** | Cracking clays soils when working the soil, we meet obstacle because soil usually flood out, rice root can be broken when soil is dry | 102,027.1 |
| **$f^-$** | Potential acid sulfate in subsoil | 72,757.0 |
| **i** | High phosphorus fixation | 69,944.7 |
| **f** | Shallow potential acid sulfate soils | 28,716.8 |

*Each soil unit can have more than 1 indicator*

The management requirements are based on Smith (1989), Sanchez et al (1982, 2003), Vo Quang Minh (2007), field observations, and several experiments in the Mekong Delta on soil management, reclamation, fertility adaptation, rice varieties, etc. A description of soil fertility or management constraint identified is given below.

**Al toxicity, low pH (a, $a^-$)**: Soluble and exchangeable acidity should be removed as much as possible by leaching before applying amendments. Leaching with fresh water is efficient in removing free $H_2S0_4$, and efflorescences of soluble Fe and Al salts from the soil. Due to directly effected by low pH, and high Al contents (Vo Thi Guong, 1997), on very low soil pH and very high Al, the amount of lime should be changing from 6 to 10 ton/ha (Vo Tong Xuan et al, 1982).

**Actual acid sulfate soils (c, $c^-$)**: Iron and aluminium or manganese toxicities and phosphorus deficiency are common. Physical properties are very poor. Jarosite mottles occur at 10 to 50cm depth (**c**) or more than 50cm (**$c^-$**). This soil should not be drained. Draining results in a dramatic decrease in pH. High liming rates (greater than 10t/ha every 3 to 4 years) or long term leaching would then be required for crop production (Van Breeman and Pons, 1978). The most profitable practice is shallow drainage to grow one crop of a medium-term rice (Vo-Tong Xuan et al., 1982).

**High leaching potential (e)**: These soils suffer from a combination of low organic matter content and a coase texture, resulting in an extremely low cation exchange capacity. Soil management interventions to remedy these constraints are bound to be expensive and often unprofitable as they imply a change in the clay-humus complex through considerable organic matter and/or high activity clay inputs.

**Potential acid sulfate soil (f, $f^-$)**: When **f** soils are exposed to air and are low in calcium carbonate, $FeS_2$ is oxidized to ferric sulfate and free sulfuric acid, producing pH values on the order of 2 or 3. Drained acid sulfate soils are extremely infertile. Flooded rice is often grown, since under constantly reduced conditions, the pH is sufficiently high to eliminate aluminium toxicity.

**High phosphorus fixation (i)**: High P-fixing soils can be identified as those with clayey topsoils having red or yellowish colours indicative of high contents of iron oxides, usually accompanied by a strong granular structure. These soils require high levels of phosphate fertilizers or special P management practices.

**Low Nutrient Capital Reserves (k)**: Potassium fertilizers must be added. Usually the K fertilizer rates are low on newly cleared land but they increase with time. Generally these soils have also limited capacity to retain nutrients and the potassium, calcium and magnesium added can be easily lost (Vo Thi Guong, 1997; Nguyen My Hoa, 2003).

**Prolong submergence ($g^+$):** Prolonged submergence causes Zn deficiency, especially on all year round cultivation soil remittently flooded and drained. $H_2S$ toxicity symptom can occurred if soil high in organic matter (Ponnamperuma, 1977)

**Potential Sodic ($n^-$)**: Reclamation requires the replacement of $Na^+$ on the exchange complex by $Ca^{2+}$ and leaching of $Na^+$ out of the root zone. Soil permeability and internal drainage must also be improved so the displaced sodium ions can be leached out of the root zone. Common mineral amendments used are: gypsum, phosphogypsum, calcite and other acid-forming salts like iron and aluminium sulfates, limesulphur and pyrites.
**Low organic matter status (o)**: N deficient; response to N fertilization very likely; low ECEC on sandy soils; N fertilizer should be applied in frequent, small doses. Increasing the levels of organic matter in these soils would improve nutrient supply, increase CEC, increase water holding capacity (P. W. Moody et al, 2008).
**Low inherent P content (p)**: P management should be considered as a long-term investment in soil fertility, and it is more effective to prevent P deficiency than to treat P deficiency symptoms. P requires a long-term management strategy because P is not easily lost or added to the root zone by biological and chemical processes that affect N supply.
**Saline (s, $s^-$)**: Na, Ca, Mg, Cl, and $SO_4$ are the major ions involved. Presence of soluble salts requires drainage and special management for salt-sensitive rice varieties. Total reclamation of saline soils is often impractical because of the lack of high quality water for irrigation and leaching. Wetland rice production may be an economical alternative.

## CONCLUSION

A Fertility Capability Classification (FCC) system, based on the work of Sanchez et al (2003), Vo Quang Minh (2007) was used for rice soil fertility in the Mekong Delta relies mostly on the topsoil properties that indicate the soil fertility capability and affect rice production and some properties at subsoil which related to topsoil properties. There were 25 rice soil fertility types, in which clay soil texture in both layers and without modifiers (**CC**) and the same as soil with saline (**s**) modifier (**CCs**) occupied largest extent. The major soil constraints for intensive rice cultivation in the Mekong Delta including High P fixation and potential Fe toxicity (**$i^+$**), Potential salinity (**$s^-$**), Low available P (**p**), acid and Al toxicity (**a**), respectively. However, constraints of actual acid sulfate (**c**, **$c^-$**), potential acid sulfate (**f**, **$f^-$**), and low organic carbon status (**o**), are major constraints for intensive rice cultivation in the Mekong Delta. The major strategies for better utilization of soil could be the reclamation of acid sulfate and saline soils by leaching acid and soil toxicity, and improving soil nutrient status such as N, P, K fertilizers and organic matter application.

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Research article

# Zinc Deficiency in Agricultural Systems and Its Implication to Human Health

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**Abstract** There are more than 3 billion world population are directly or indirectly affected with low zinc (Zn) supply to their food causing up to severe health problems, which is also linked to Zn deficiency in most agricultural soils world-wide. Agricultural technologies contribute to improving nutritionally rich food systems, which plays key role in public health. We therefore review in this paper on the importance of agricultural systems and its role in human health under Zn deficient situation. Several studies have been done to understand the Zn dynamics on crop and plants. There have been much more efforts given to see agronomic, physiological and molecular aspects of Zn in plants and soils. It is however, equally important to look at the human consumption perspective for healthy population. Therefore, this review discusses the role of Zn on soil and crop in view of human nutrition. Agricultural strategies could help to combat such problems in many ways such as breeding Zn efficient genotypes, application of different Zn fertilizers, using high Zn content seed for crop production; and seed priming. The content of Zn in grains and fruits can in some cases be increased through soil or foliar applications of Zn fertilizers. Level of Zn in plant foods could be achieved either by increasing the concentration of compounds which promote their uptake like ascorbic acid, or by decreasing the concentration of compounds which inhibit their absorption of Zn like phytic acid or phenolic compounds. Low cost and easy approaches such as seed priming are also effective measures to load higher Zn in edible parts. Plant breeding and genetic engineering techniques have the greatest potential to increase Zn content in grains, roots and tubers to combat the Zn deficiency world-wide.

**Keywords** zinc deficiency, agricultural systems, human nutrition

## BACKGROUND

Agricultural technologies can be directed towards improving nutritionally-rich food systems, which play an important role in public health. Food systems in many developing countries are now failing to provide adequate quantities of essential nutrients in the people's diet (Graham and Welch, 1996; Welch and Graham, 2005). Cropping systems promoted by the green revolution have increased the food production but also resulted in reduced food-crop diversity and decreased availability of micronutrients (Welch, 2002; Stein et al., 2007). Micronutrient malnutrition is causing increased rates of chronic diseases (cancer, heart diseases, stroke, diabetes and osteoporosis) in many developing nations; more than 3 billion people are directly affected by the micronutrient deficiencies (Cakmak et al., 1999; Welch, 2002; WHO, 2002; Welch and Graham, 2004).

Unbalanced use of mineral fertilizers and a decrease in the use of organic manure are the main causes of the nutrient deficiency in the regions where the cropping intensity is high (Prasad, 1984; Welch, 1993, 2005). Moreover, agricultural intensification requires an increased nutrient flow towards and greater uptake of nutrients by crops. Until now, micronutrient deficiency has mostly been addressed as a soil and, to a smaller extent, plant problem. Currently, it is being addressed as a human nutrition problem as well. Increasingly, soils and food systems are affected by micronutrients disorders, leading to reduced crop production and malnutrition and diseases in humans and plants (Welch et al., 1982; Welch and Graham, 2004). Conventionally, agriculture is taken as a food-production discipline and was considered a source of human nutrition; hence, in recent years many efforts (Rengel and Graham, 1995a, b; Cakmak et al., 1999; Frossard et al., 2000; Welch and Graham, 2005; Stein et al., 2007) have been made to improve the quality of food for the growing world population, particularly in the developing nations.

Among the micronutrients, zinc (Zn) is the most important for activity of various enzymes and proper growth and development of plants, animals and humans (Alloway, 2004; Welch and Graham, 2004; Singh et al., 2005). Naturally, plant species differ in capacity to grow at low level of soil Zn and to accumulate Zn in the grains. Among different cereal crops, wheat is considered less tolerant to Zn deficiency stress (exhibits significant yield losses due to Zn deficiency) compared to more tolerant species such as peas, carrots and rye (Hacisalihoglu and Kochian, 2003). Several studies (Cakmak et al., 1996; Moussavi-Nik et al., 1997; Erenoglu et al., 1999; Rengel, 1999; Hacisalihoglu et al., 2001; Gonzalez et al., 2007) have investigated different aspects of Zn uptake mechanism. This paper aims at evaluating role of agriculture on Zn nutrition for human being and elucidates the strategies potentially help combating Zn deficiency problems in soil-plant-human continuum.

## ZINC IN SOILS

Zinc deficiency in soils and plants is a global micronutrient deficiency problem reported in many countries (Sillanpaa, 1982; Graham and Welch, 2000; Alloway, 2004; Singh et al., 2005). Low availability of Zn in calcareous soils is one of the most widely distributed abiotic stresses in world agriculture, particularly in Turkey, Australia, China and India (Cakmak et al., 1999; Kenbaev and Sade, 2002; Brennan and Bolland, 2006). Zinc deficiency is particularly widespread in cereals growing on calcareous soils (Graham, 1991; Graham et al., 1992; Cakmak et al., 1997; Genc et al., 2006). Zn deficiency is the most important micronutrient deficiency in wheat (Cakmak et al.. 1998; Kabata-Pendias. 2001; Alvarez and Gonzalez. 2006; Bagci et al.. 2007), resulting not only in low production but in the poor nutritional quality of food (Graham and Welch, 1996). In southern Australia more than 18 million hectares of agricultural land are Zn-deficient (Brennan and Bolland, 2006). Similarly, in India alone more than 85 % of the cereal growing area is affected by low Zn. So, availability of Zn appears to be one of the most limiting factors for quality crop production worldwide. Zinc deficiency is common on neutral and calcareous soils, intensively cropped soils, paddy soils and poorly drained soils, sodic and saline soils, peat soils, soils with high available phosphorus and silicon, sandy soils, highly weathered acid and coarse-textured soils (Cakmak et al., 1998; Singh et al., 2005). Factors such as topsoil drying, subsoil constraints, disease interactions and high cost of fertilizer also contribute to zinc deficiency (Sillanpaa, 1982).

## ZINC IN PLANTS

Zn is involved in many cellular processes, including activation of enzymes, protein synthesis and membrane stability, but the knowledge of Zn transport in plants is inadequate (Longnecker and Robson, 1993; Marchner, 1995; Grusak et al., 1999; Rengel, 1999; Alloway, 2004). Plants have a natural ability to extract ions from soil and to distribute them between the roots and the shoot. Within a certain concentration range, some heavy metals are essential for the growth of higher plants (Breckle, 1991). In this context, long-distance root-to-shoot transport in the transpiration stream via the xylem as well as the transfer from the xylem to the phloem and the retranslocation via the phloem must be considered as important processes for the redistribution of an element within a plant (Marschner, 1995). Several studies have demonstrated that Zn is easily transported in the phloem of wheat (Pearson and Rengel, 1995; Herren and Feller, 1996; Haslett et al., 2001) and that its redistribution may depend on the plant age and on the Zn content of the source organs (Pearson and Rengel, 1995; Herren and Feller, 1996). Longnecker and Robson (1993) reported that the first pool of Zn in plant is seed and this Zn is mobilized to growing seedling. Moussavi-Nik at al. (1997) also reported that the Zn has a stimulatory effect on crop germination and establishment as well as the final yield, especially in Zn-deficient soils. Wheat seedlings grown from seed with high Zn content produced more tillers and had better growth than seedlings grown from seed with low Zn content (Rengel and Graham, 1995a,b). Seed loading of Zn is affected by plant species and availability of Zn to the parent plant (Longnecker and Robson, 1993). Different species load different amount of Zn into their seeds even when grown in the same environment (Takker et al., 1988; Longnecker and Robson, 1993; Mozafer, 1993; see review by Rengel et al., 1999).

## ZINC IN HUMAN NUTRITION AND HEALTH

It is estimated that about one billion people in the world do not eat sufficient food to meet their energy requirements and are consequently undernourished (Stein et al., 2007). Many more people suffer from 'hidden hunger': 150 million are vitamin-A-deficient, almost 2 billion are iodine-deficient, between 4 and 5 billion are iron (Fe) deficient (Hotz and Brown, 2004; Stein et al., 2007) and about 3 billion are Zn-deficient (WHO, 2002; Hotz and Brown, 2004; Stein et al., 2007). Zinc acts as a stabiliser of the structures of membranes and cellular components; in human body, most Zn is in the bone and skeletal muscles (Frossard et al., 2000). In addition to its role in enzyme function (Rivera et al., 1998), Zn also plays a major role in gene expression (Sandstrom, 1997). Zn deficiency in humans reduces growth, sexual maturity and the immune defense system (Frossard et al., 2000; Cunnigham-Rundles et al., 2005). Few studies (Ninh et al., 1996; Ruz, 1997; Rivera et al., 1998) reported that increased growth in Zn-supplemented infants and preschool children have lowered the incidence of diarrhoea and respiratory infections. Meat and seafood are good sources of Zn, and most of the Zn in the developed countries' diet is provided by animal products (Sanstead, 1995). However, in many parts of the developing world, most Zn is provided by cereals and legume seeds. These plant foods are high in phytic acid, which is a potent inhibitor of Zn absorption in the human digestive system (Frossard et al., 2000). Among population children and women are mostly affected with Zn deficiency (White and Broadley, 2005, Stein et al., 2007).

Given the context of growing world population pressure with limited food supply capacity of arable lands and cropping systems, the holistic sustainable improvements in the entire food systems are required to solve the massive problems of malnutrition and increasing chronic diseases in developed and especially developing countries (Welch, 2005). The question is how agriculture can contribute to sustainable solutions to these malnutrition problems. In that context, it is important to understand the dynamics of Zn accumulation in grains and other edible parts, which has an implication for human nutrition.

## DISCUSSIONS AND CONCLUSION

Primary source of nutrients supply to human being is from crop and livestock products hence. Agricultural systems have great impact on human health and productivity. Among micronutrients, Zn is most limiting element for crop and animal productivity. Zinc deficiency is prevalent mostly in developing nations, causing the up to severe limitations on physical and intellectual capacity of the people as well as adversely affect their health and well-being (Frossard et al., 2000).

Conventionally, public health has been responsible to address the micronutrient malnutrition, rather than agriculture, despite the same underlying cause: an inadequate intake of balanced diet (Stein et al., 2007). Zinc deficiency has received little public attention, and no systematic interventions are currently in place to control this micronutrient deficiency (IM 2005 as cited in Stein et al., 2007). In recent years, efforts have been initiated in agricultural research and development to increase micronutrients density in edible parts (Cakmak, 2008).

Among different strategies to combat Zn deficiency in soils, application of Zn fertilizers to soil such as ZnSO4 increases the yield of crops Zn-deficient soils (Yilmaz et al., 1997). It also significantly contributes in increased Zn concentration in cereal grains (Graham et al., 1993, Rengel et al., 1999). Similarly, foliar application of Zn fertilizers significantly increased the Zn concentration in seeds (Yilmaz et al., 1997). Harris et al. (2007) found that priming seeds in Zn-containing solutions is a practical way to increase seed Zn prior to sowing and to contribute to better seedling growth. Similarly, priming maize seeds in 1% w/v ZnSO4 solution for 16 h significantly increased seed Zn concentration, and the seedlings derived from these seeds showed greater biomass and significantly greater grain yield (Harris et al., 2007 as cited in Cakmak, 2008). Soil types, growth stage, and genotypes also play key role in efficient use of Zn fertilizers, therefore those factors to be taken into account while applying fertilizers.

Plant breeding techniques to introduce high Zn traits into high yielding crops another promising approach to load the higher Zn content into edible parts of the crops. Efforts to increase the micronutrients density into edible parts have been initiated to develop crop genotypes (Cakmak, 2008). Similarly, genetic engineering and molecular genetics have great role in agricultural research to identify key regulatory steps in the acquisition of Zn by plants. Identifying and transferring of the corresponding genes to agriculturally important crops might allow to increase their nutrient uptake capacity. However, it is important to take into account of diverse soil types and environments, which have impact on plant growth and development.

Bioavailability of minerals for man is critical because mineral absorption by man from plant foods is often low. This appears to be mainly due to the presence of phenolic compounds or phytic acid (Fairweather-Tait and Hurrell, 1996 in stein et al., 2007), which is very strong chelator for Zn and other minerals. Therefore, it is equally important to identifying bioavailability of Zn in plant products by understanding the presence of other inhibitors like phenolic compound and phytates in edible parts or presence of ascorbic acids (which help in absorption of Zn for human being). However, with the increased concentration of Zn would help to increase in absorption proportionately assuming low absorption in the low-Zn plant and high in the high-Zn plant.

## CONCLUSION

Agriculture is the mainstay in supplying main sources of nutrition to human being, particularly in developing nations. Large number of population are affected with low Zn supply in their food are living in developing nations, among the most Zn deficient population are children and women. Low cost and easy approaches such as seed priming, soil and foliar application of Zn fertilizers, are effective measures to load higher Zn in edible parts. Similarly with less immediate application but potential approaches are breeding and genetic engineering techniques have the greatest potential to increase Zn content and reducing phytate and phenolic compounds in edible parts to combat the Zn deficiency world-wide.

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*Research article*

# Diversity of the Actinomycetes Community Colonising Rice Straw Residues in Cultured Soil Undergoing Various Crop Rotation Systems in the Mekong Delta of Vietnam

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**Abstract** Actinomycetes are involved in important environmental processes such as the decomposition of organic matter. In this study, we examined the impact of crop rotation on the actinomycetes community colonizing rice straw residues in soil over 3 field seasons by means of Denaturing Gradient Gel Electrophoresis (DGGE) fingerprinting analysis of actinomycetes 16S rRNA gene fragments amplified from field-incubated rice straw residues and analysis of actinomycetes 16S rRNA gene clone libraries from selected samples. The studied yearly crop rotation systems were rice-rice-rice (CRS1), rice-rice-baby corn (CRS2), rice-rice-mungbean (CRS3) and baby corn-rice-mungbean (CRS4), applied on different experimental plots of the same field location. Litter bags containing rice stems were inserted into the soil and recollected at different time points for comparison of the structure of the actinomycetes community colonizing the rice straw. The actinomycetes community was significantly different in composition in the baby corn-rice-mungbean rotation system (CRS4) compared to those in the 3 other systems during the growth of the first crop and second crop. In contrast, during the cultivation of the third crop, actinomycetes communities were significantly different in the rice-rice-rice (CRS1) system compared to those in the 3 other systems. The analysis of the 16S rRNA gene libraries constructed from selected samples of rotation systems CRS1 and CRS4 during growth of the first two crops confirmed the DGGE results. The diversity of actinomycetes tended to be highest in the CRS4 system and lowest in the CRS1 system.

**Keywords** Actinomycetes community, diversity, crop rotation, Mekong delta

## INTRODUCTION

Actinomycetes, phylogenetically defined as a number of taxa within the high-GC subdivision of the gram-positive phylum (Embley et al., 1994), represent a group of relatively abundant and metabolically diverse bacteria in soils (Labeda and Shearer, 1990; McCarthy and Williams, 1992; Holmalahti et al., 1994). They are involved in important processes in a wide range of habitats (Williams et al., 1984), such as the decomposition of organic materials in soil, including lignin and other recalcitrant polymers, and in the degradation of agricultural and urban wastes (Crawford, 1988; McCarthy, 1987).

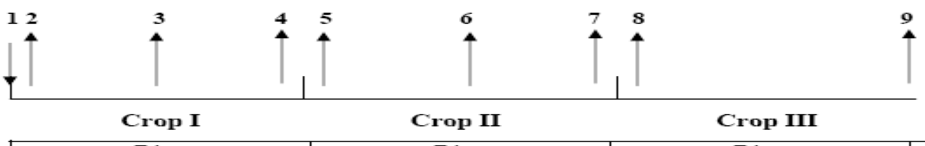
The composition of a soil microbial community can be affected by various factors such as soil characteristics, environmental conditions, plant growth and crop management strategies (Curl and Truelove, 1986). Numerous studies have compared microbial communities among different ecosystems such as agricultural soils versus soils from forest or grassland systems (Ovreas and Torsvik, 1998; Waldrop et al., 2000; Yao et al., 2000), among soils undergoing different long-term cropping and management regimes (Zelles et al., 1992, 1995; Bossio et al., 1998; Drijber et al., 2000), and among soils cultivated by different plant species (Grayston et al., 1998; Siciliano et al., 1998; Ibekwe and Kennedy, 1999; Miethling et al., 2000; Marschner et al., 2001). However, there are few studies documenting the effects of crop rotation systems on specific soil microbial communities (Lupwayi et al., 1998). Especially, the effect of crop rotation on soil actinomycetes has been poorly studied despite the important role of this group of micro-organisms in degradation of organic matter and nutrient cycling.

Rice is the most important crop in the Mekong Delta of Vietnam. The total area cultivated with rice in that region occupies nearly 4 million hectares per year. The introduction of high yielding rice varieties and intensive rice cultivation has resulted into numerous constraints, such as high plant disease pressure, the extensive use of fertilizers and pesticides and soil degradation. In order to reduce chemical inputs, to improve profitability, and to increase sustainability, new cropping systems and management practices for rice production in the Mekong Delta are being assessed. In this context, we have initiated different field experiments in which we assessed the effect of crop rotation on rice productivity and soil health. As a part of this study, we examined whether the type of crop rotation affected microbial communities playing a role in soil functioning. In this paper, we assessed the effect of crop rotation system on the actinomycetes community colonizing and degrading rice straw residues in soil which had been historically cultivated for continuous rice production for more than 10 years.

## METHODOLOGY

### Set-up of field experiment and sampling approach

The experimental field used in this study is located in Cay Lay district, Tien Giang province, Vietnam. The field was designed as a complete randomized block of experimental plots undergoing 4 different crop rotation systems (CRS) with 3 replicate plots per system since the year 2001. Each plot covered an experimental area of 90 $m^2$ (6 by 15m). The 4 applied rotation systems were (1) CRS1: rice (Crop I) - rice (Crop II) - rice (Crop III), (2) CRS2: rice (Crop I) - rice (Crop II) - baby corn (Crop III), (3) CRS3: rice (Crop I) - rice (Crop II) - mungbean (Crop III) and (4) CRS4: baby corn (Crop I) - rice (Crop II) - mungbean (Crop III).




| Crop I | Crop II | Crop III | |
|---|---|---|---|
| Rice | Rice | Rice | CRS1 |
| Rice | Rice | Baby corn | CRS2 |
| Rice | Rice | Mungbean | CRS3 |
| Baby corn | Rice | Mungbean | CRS4 |

**Fig. 1 Time schedule showing the recovery of litter bags from the Cay Lay field experiment**

*Arrow indicated with 1 refers to litter bags inserted before the start of the experiment. Arrows indicated with 2, 5 & 8 refer to sampling of litter bags after 14 days of cultivation of crops I, II and III, respectively. Arrows indicated with 3 & 6 refer to sampling of litter bags after 50 days of cultivation of crops I and II, respectively. Arrows indicated with 4, 7 & 9 refer to sampling of litter bags at harvest of crops I, II and III, respectively. The cropping calendars of three cropping patterns were as follow: crop I (between 20/6/2006 and 1/10/2006), crop II (between 1/11/2006 and 10/2/2007) and crop III (between 30/2/2007 and 10/6/2007).*

Litter bags (nylon material with a pore size of 200 ηm) were filled with 5 g of dried rice straw residues and buried, prior to seeding of the first crop, into the soil at a depth of around 10 cm on 20 June 2006.Before inserting, the bags with rice straw were sterilized at 121$^{o}$C for 20 minutes. The litter bags were periodically recovered from the soil for 16S rRNA gene based DGGE analysis of the actinomycetes community colonizing rice straw according to the time schedule shown in Fig 1. At each time point, 3 litter bags were recovered from each plot.

### DNA extraction and DGGE analysis

DNA was extracted from the rice straw as described by Boon et al. (2000). 30µl of the extract was cleaned from humic acids by adding 2mg acid-washed PVPP (Sigma-Aldrich Chemie GmbH, Steinheim, Germany) and 30µl TE-buffer. The mix was vortexed and centrifuged at 11,000 rpm during 5 min. The supernatant was recovered and subjected to PCR amplification of the target 16S rRNA gene. To amplify actinomycetes specific 16S rRNA gene fragments, a nested PCR approach was used in which in the first PCR the actinomycete specific forward primer F243 (Heuer et al., 1997) was used together with the bacterial reverse primer R1378 (Heuer et al., 1997). The product of this PCR was used as template in a second PCR with primers F984GC (Nubel et al., 1996) and R1378. PCR reactions were performed in a Mastercycler apparatus (Eppendorf; Hamburg, Germany), according to van Dillewijn et al. (2002). DGGE of amplified actinomycetes 16S rRNA gene fragments was performed on an Ingeny phor U-2 system (Leiden, The Netherlands). 30 µl portions of the PCR product were loaded onto an 8% (w/v) polyacrylamide gel with a denaturing gradient ranging from 35% denaturant to 65% denaturant in Tris–acetate–EDTA (TAE) buffer. Electrophoresis was performed for 15 h at 60°C and 120 V. The gels were stained for 30 min with 1xSYBR Gold (Molecular Probes, Leiden, and The Netherlands) and photographed on a UV transilluminator with a GeneLink camera system (SYNGENE, Cambridge, UK). Gelcompar II version 3.5 (Applied Math's, Sint-Martens-Latern, Belgium) was used for UPGMA cluster analysis of DGGE fingerprints. Dendrograms were constructed by using the Pearson correlation index for each pair of lanes within a gel and cluster analysis by the unweighted pair group method using arithmetic averages.

### Cloning and sequencing of 16S rRNA gene fragments

PCR products were cloned into pCR®2.1-TOPO®, using the TOPO TA Cloning kit (Invitrogen, Merelbeke, Belgium) as described by the manufacturer. To check transformants for the incorporation of the actinomycetes 16S rRNA gene, a nested PCR was performed consisting of a first PCR with M13f and M13r primers as described by Invitrogen followed by a second PCR with bacterial primers GC-984F and 1378R. DGGE fingerprints from fragments amplified from the clones were compared with the actinomycetes 16S rRNA gene DGGE fingerprints obtained from environmental DNA and appropriate clones were chosen for sequence analysis. The PCR products obtained from the clones were purified with the PCR purification kit (Promega) as described by Promega and subjected to DNA sequencing reactions performed with the QuickStart DNA sequencing kit (Beckman) and analysed on an automatic sequencer (CEQTM8000, Beckman Coulter, Fullerton, CA, USA). Resulting partial 16S rRNA gene sequences (about 400 bp) were analyzed by BLASTN search (Altschul et al., 1997).

## RESULTS AND DISCUSSION

### DGGE analysis of actinomycetes community colonizing rice straw incubated under various crop rotation systems

Fig. 2 shows the actinomycetes 16S rRNA gene DGGE profiles obtained from rice straw residues incubated under the different crop rotation systems at 14 days of cultivation, at 50 days of cultivation and at harvest of crop I, crop II and crop III while Fig. 3 shows the corresponding

UPGMA cluster analysis. The DGGE profiles revealed that the composition of the actinomycetes community in colonizing rice straw residues was strongly affected by crop rotation. The clearest difference was observed between plots undergoing system CRS4 on the one hand and the 3 other systems on the other hand during growth of crop I and II, and between CRS1 plots on the one hand and the other 3 systems during growth of crop III.

During growth of crop I, at 14 days of cultivation, at 50 days of cultivation and at harvest, the profiles of the replicates of systems CRS1, CRS2 and CRS3 clustered as a separate group from the profiles of replicates of system CRS4 in the UPGMA clustering analysis (Fig. 3A). Profiles from replicate plots of systems CRS1, CRS2 and CRS3 were highly similar with a similar level among the 3 systems of 48.2, 42 and 76% for samples taken at 14 days of cultivation, at 50 days of cultivation and at harvest, respectively. In contrast, profiles from system CRS4 were 36.5%, 31 and 72.8% similar to profiles originating from the other 3 rotation systems at 14 days, at 50 days of cultivation and at harvest, respectively.

During growth of crop II, which was rice in all systems, at 14 days of cultivation and at 50 days of cultivation, profiles for systems CRS1, CRS2 and CRS3 were still more similar to each other than to profiles obtained for system CRS4, i.e., the profiles of CRS1, CRS2 and CRS3 were about 70.4 % and 71.5% similar to the profiles of CRS4 at 14 days and 50 days of cultivation, respectively, while the values of similarity were 87 and 87.5% among the profiles of CRS1, CRS2 and CRS3 at day 14 and day 50, respectively. However, at harvest of crop II, the profiles clustered into two main groups (Fig. 3B). One group consisted of the profiles of CRS1 and CRS2 and the other group of profiles of CRS3 and CRS4. The similarity between the group containing CRS1 and CRS2 and the group containing CRS3 and CRS4 was 59.5% while the similarity of profiles within the two groups was 69% and 66.9%, respectively.

During cultivation of crop III, at day 14 of crop cultivation and at harvest, the actinomycetes community profiles clustered into two main groups, i.e., a first group consisting of profiles from systems CRS2, CRS3 and CRS4 and a second group consisting of profiles derived from system CRS1 (Fig. 3C). Profiles from CRS1 were 42.1% and 34.5% similar to profiles originating from the other rotation systems at day 14 and at harvest, respectively. The similarity among the CRS2, CRS3 and CRS4 profiles was 50.9% at day 14 day and 45.0% at harvest.

**Analysis of 16S rRNA gene clone libraries**

16S rRNA gene clone libraries were constructed from two representative samples of the CRS1 and CRS4 system, i.e., a sample taken at 50 days of cultivation of crop I and a sample taken at 50 days of cultivation of crop II. For each library 15 to 20 clones were analyzed by DNA sequence analysis. Figure 4 shows the phylogenetic distribution of the 16S rRNA gene sequences within each library.

In the sample taken at 50 days of cultivation of crop I in system CRS1, most of the 16S rRNA sequences matched with 16S rRNA gene sequences of actinomycetes especially with the family Nocardioidaceae (22.3%) and uncultured actinomycetes (33.3%).Unexpectedly, other clones carried sequences which were not related to 16S rRNA gene sequences of actinomycetes but rather to sequences associated with the phyla verrucomicrobia and fimircutes (44.4%). In contrast, in the corresponding samples taken from the CRS4 rotation system, almost all sequences were associated with the actinomycetes (84.75%) while only a minority was non-actinomycetes sequences such as sequences associated with the phylum verrucomicrobia (15.3%). Interestingly, the actinomycetes present in the CRS4 system were apparently more diverse than those in the CRS1 system, showing the presence of four different families of actinomycetes, i.e., Microbacteriaceae, Promicromonosporaceae, Nocardioidaceae, and Mycobacteriaceaee. The family Microbacteriaceae constituted the most abundant family (53.8%).

Diversity in the actinomycetes community was also found at day 50 of cultivation of crop II. Moreover, although in both systems, rice was the cultivated crop, the samples from the two systems apparently contained two different actinomycetes communities. The community in the CRS4 system was more diverse and included members of five actinomycetes different families, i.e., Streptomycetaceae, Catenulisporaceae, Nocardioidaceae, Mycobacteriaceae and Promicromonosporaceae while the CRS1 sample contained members of two families, i.e., Microbacteriaceae and Mycobacteriaceae. The family Streptomycetaceae was dominant (43.2%) in the CRS4 system while in the CRS1 system, the Microbacteriaceae family was dominant (46.7%). In both systems, the actinomycetes were still the most highly represented sequences (53.3% in CRS1 and 88.3% in CRS4) but also non- actinomycetes 16S rRNA gene sequences were found (46.7% in CRS1 and 14.2% in CRS4), which were associated with the groups of proteobacteria, verricomicrobia and firmicutes. Xuan et al (2007) found that the family Microbacteriaceae was present in rice straw decomposing in soil of two experimental sites in the Mekong Delta while Hesham et al (2006) showed Streptomyces as the dominant actinomycetes genus in rice straw decomposition although also members of the genera Nocardiopsis, Micromonospora and Nocardioides were present.

Three main conclusions can be taken from our study. First, the actinomycetes community seems to be dynamic in function of time, both during the growth of a particular crop and of different crops. This can be explained by changes in substrate (i.e., the rice straw) composition during decomposition (Lynch and Harper, 1985; Aulakh et al., 1991).

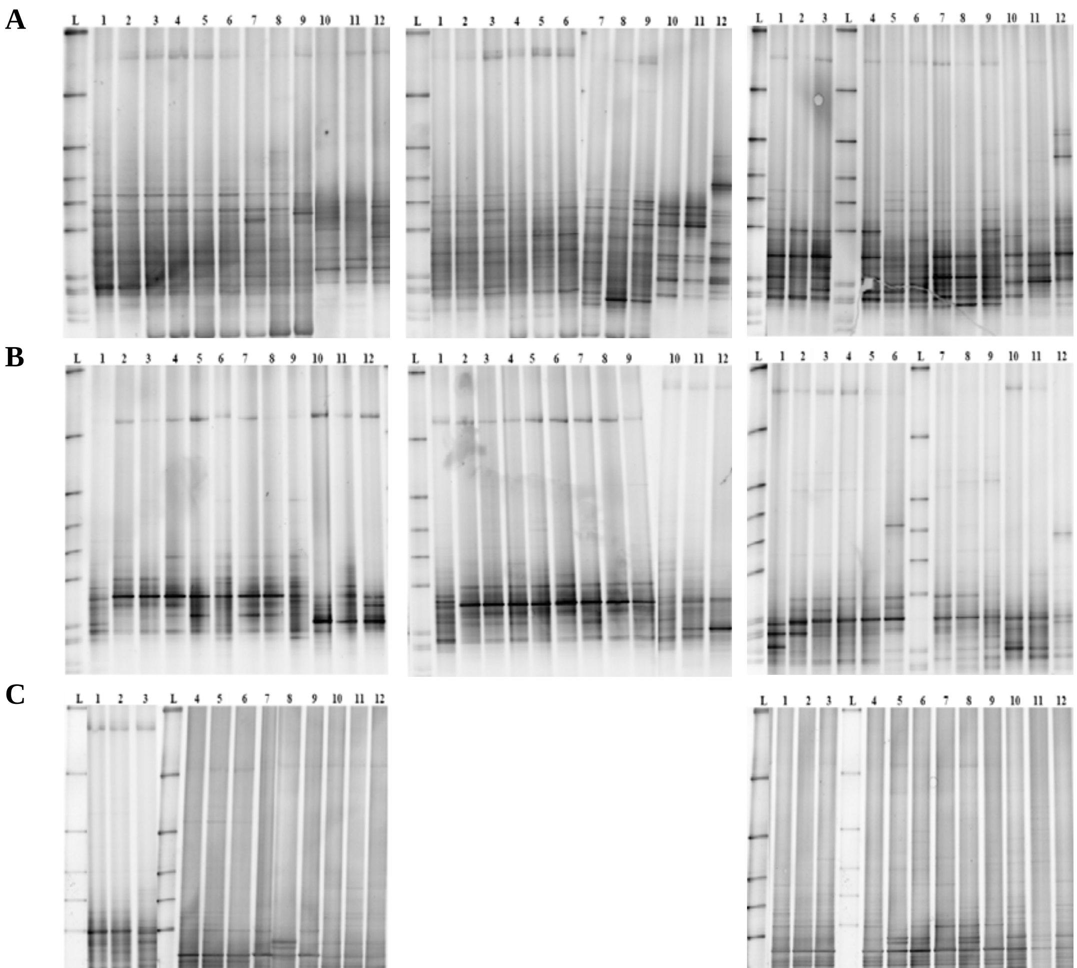



**Fig. 2 16S rRNA gene DGGE fingerprints of the actinomycetes community colonizing rice straw residues in 3 replicate plots undergoing the studied crop rotation systems at 14 days (left), 50 days (middle) and harvest (right) of crops I (A), II (B) and III (C)**

*Lanes 1-3: replicate plots undergoing system CRS1; lanes 4-6: replicate plots undergoing system CRS2; lanes 7-9: replicate plots undergoing system CRS3; lanes 10-12: replicate plots undergoing system CRS4. Lane L: reference bacterial 16S rRNA gene ladder.*

Alternatively, the different environmental conditions implemented when different crops are cultivated can be a reason. Different crop species might produce different types of root exudates which supply nutrients to the microbial community (Miethling et al., 2000; Smalla et al., 2001; Marschner et al., 2001).

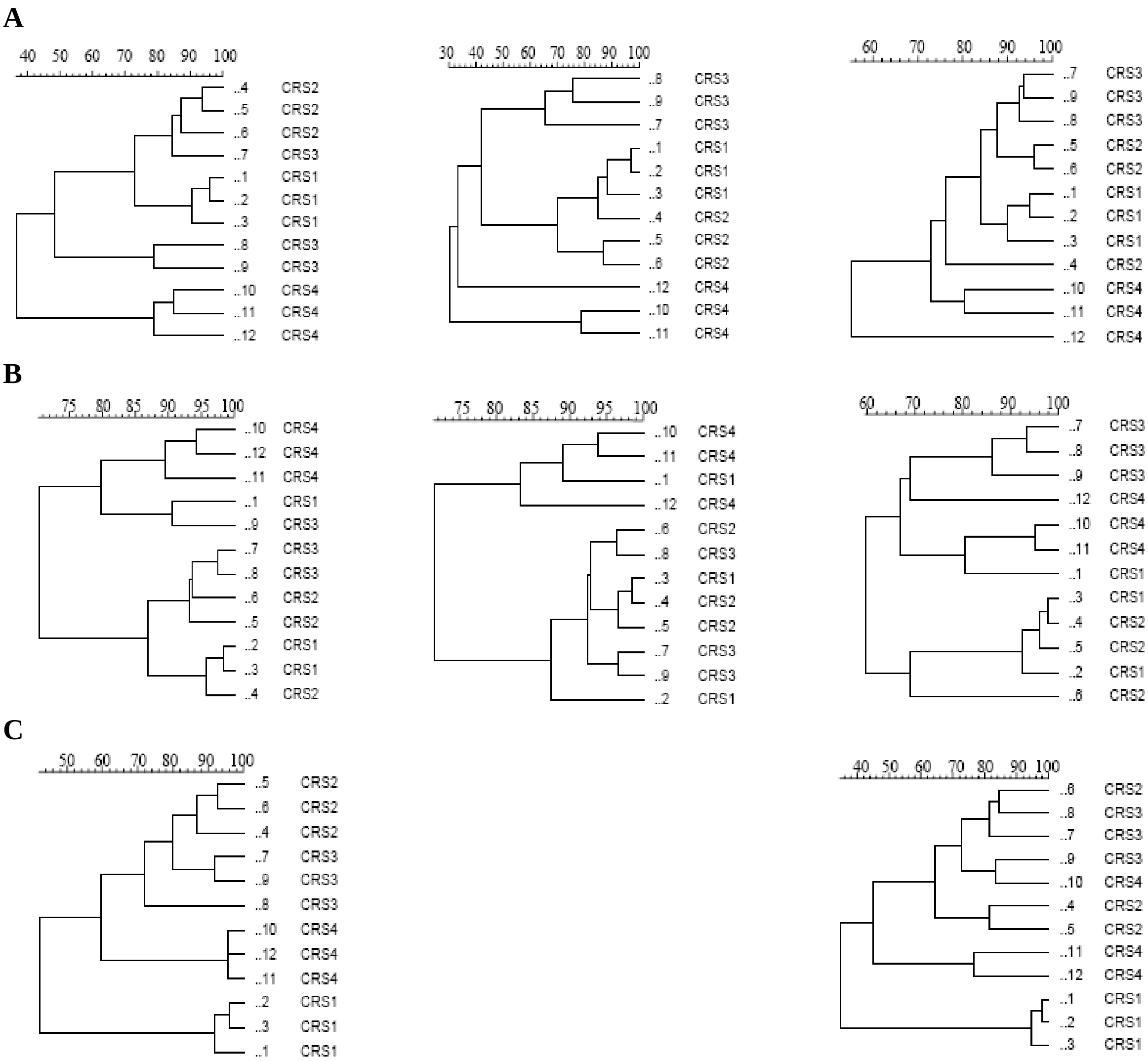



**Fig. 3 UPGMA clustering of actinomycetes 16S rRNA gene DGGE profiles recovered from rice straw residues in replicate plots undergoing the different crop rotation systems during cultivation of crops I (A), II (B) and III (C) at 14 days of incubation (left), 50 days of incubation (middle) and harvest (right), respectively**

*Indicated numbers correspond with lane numbers used in Fig. 3.*

Second, the main factor which drives actinomycetes community composition in the different crop rotation systems seems to be whether the soils were saturated and unsaturated with water, i.e., whether aerobic and anaerobic conditions were implemented. Indeed, during growth of crop I, profiles from systems CRS1, CRS2 and CRS3 clustered in one group different from profiles of systems CRS4. Crop I was rice for systems CRS1, CRS2 and CRS3 cultivated under saturated soil conditions while it was an upland crop for system CRS4 cultivated under unsaturated soil conditions.

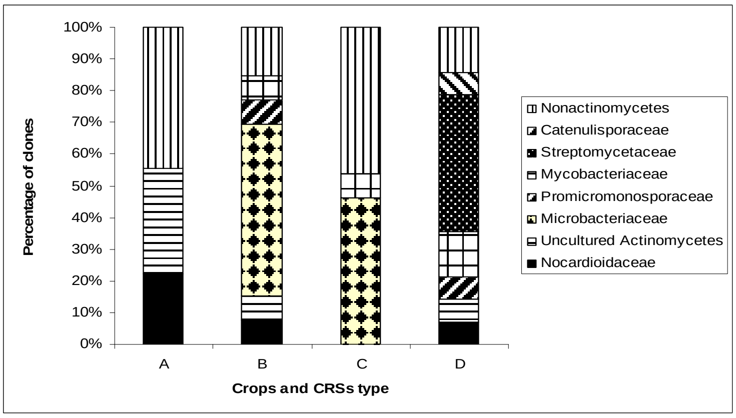



**Fig. 4 Fractions of recovered 16S rRNA gene sequences divided among different relevant bacterial families**

*The codes A and B indicate 16S rRNA gene libraries recovered from samples taken at 50 days of cultivation of crop I in rotation system CRS1 and CRS4, respectively. Codes C and D indicate 16S rRNA gene libraries recovered from samples taken at 50 days of cultivation of crop II in rotation systems CRS1 and CRS4, respectively.*

Previously, Reichardt et al. (2001) showed a negative correlation between the biomass of fungi, as primary microbial decomposers of crop residues, in soil and the soil-water content. Moreover, micro-site differences of aerobic or anaerobic conditions such as those influenced by the rhizosphere and residue decomposition were previously shown to affect the makeup of a soil microbial community (Lynch and Harper, 1985; Aulakh et al., 1991). However, no data exist on the effect of soil moisture content on Actinomycetes community structure.

As a third conclusion, differently structured actinomycetes communities were also observed between systems CRS4 on the one hand and systems CRS1, CRS2 and CRS3 on the other hand, during growth of crop II which was rice cultivated in water saturated soil in all systems. This was especially the case at day 14 of sampling while at day 50 and especially at harvest, major differences in community profiles disappeared. The differences in actinomycetes community profiles between systems CR4 and CRS1 during growth of crop II was also shown by the 16S rRNA gene library analysis. This might indicate that the type of rotation system affects the actinomycetes community profile despite similar cultivation conditions. It is well-accepted that crop rotations have an important effect on soil microbiology. Several studies indicated that crop rotation tend to result in a higher microbial diversity and/or biomass (Zelles et al., 1992, 1995; Drijber et al., 2000; Larkin , 2003; Collins et al., 1992; Kirchner et al., 1993; Olsson and Gerhardson, 1992). However, studies on the effect of crop rotation directed to the actinomycetes are rare. Martyniuk and Wagner (1978) found a higher number of actinomycetes in a rotation system including maize, oats, wheat and red clover than in continuous systems of maize or wheat. Similarly, Kirchner et al. (1993) found that the number of actinomycetes is significantly higher in soil undergoing maize-crimson clover rotation than in soil undergoing continuous maize cultivation. On the other hand, Collins et al. (1992) reported that actinomycetes biomass was significantly higher under monoculture wheat than under wheat-fallow rotation. On the other hand, it is possible that DNA of actinomycetes communities colonizing the rice straw during cultivation of crop I and which died off when anaerobic conditions where implemented, did remain under those conditions and resulted into amplification.

## CONCLUSIONS

Overall, our results show that the actinomycetes communities were affected by the crop rotation systems, but that the implemented environmental conditions rather than the rotation system as such affected the community composition. Further studies will identify more specific changes associated with particular rotations and relate these changes to potential effects on disease management, crop health, and crop productivity.

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*Research article*

# Seasonal Direct-Use Value of Cheung Ek Peri-Urban Lake, Phnom Penh, Cambodia

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**Abstract** Cheung Ek Lake receives 80% of Phnom Penh's urban wastewater. Since most of the lakes around Phnom Penh are being reclaimed for urban development, surveys were undertaken to analyze the direct-use economic value of Cheung Ek lake in the dry season, which could serve for policy-makers' future considerations. The direct-use value was assessed by summing total income of all activities performed on the lake. Income was calculated using a bottom-up approach based on a stratified sampling and on in-depth interviews of 192 households using structured questionnaires for each household's activity. The primary activities are water spinach, water mimosa, and rice cultivation, fishing, and duck raising. Over a six-month period, farmer receive an average profit of 4,168 USD/ha from water mimosa cultivation, 1,553 USD/ha from water spinach cultivation, 512 USD from fishing, 506 USD/ha from dry season rice cultivation, and 157 USD/100 ducks from duck raising. After multiplication by the total area of plants (from remote sensing), and number of household and duck numbers (by direct investigation), the direct-use value was estimated at more than 1 million USD, of which water spinach production contributes 65%, fishing 20%, water mimosa production 13%, duck raising 1%, and dry season rice production 0.7%. The study suggests that almost a thousand of direct-beneficiaries can generate part of their income from agriculture or fishery-related activities performed on the lake. Moreover, the research targeted only one part of direct-use value of the lake and thus largely underestimated the overall value of the lake. Indirect-value components are community health (which can be greatly improved through water purification), and indirect-use value of the lake (e.g. tourism), both of which have major economic implications and which must be taken into account in further research.

**Keywords** direct-use value, Cheung Ek Lake, water spinach, Phnom Penh

## INTRODUCTION

Wastewater use in agriculture and aquaculture has a long history in China (Zhiwen, 1999), Cambodia and Vietnam, to culture fish and aquatic plants in peri-urban wetlands (Kuong et al., 2005; Leschen et al., 2005; Lan et al., 2007). Phnom Penh, with a surface area of 375 km², is surrounded by wetland, of which 80% comprises natural lakes and low-plain agriculture. Every day, about 55,600 $m^3$ of urban household wastewater and nearly 1 million $m^3$ of storm water are discharged into these wetlands (Muong, 2004). This wastewater is used in numerous plots located within and around the wetlands in peri-urban Phnom Penh, and provides important sources of edible aquatic vegetables and fish farming to supply the food demand of the city and other areas of Cambodia (Khuong et al., 2005). Cheung Ek Lake, a seasonally inundated lake located about 5 km to the south of Phnom Penh, is a large water body that receives 80% of the wastewater from Phnom Penh's urban population and from factories (garment and various other factories). Rainfall run-off also discharges into the lake (Seyha and Tuan Anh, 2004). Cheung Ek Lake is an important area for growing aquatic plants and fish production, and harvesting is undertaken throughout the year. The activities on the area of Cheung Ek Lake represent not just the most important source of the income of many households, but also the employment and income earning opportunities for many seasonally hired labourers engaged in setting up, maintaining and harvesting the plants (Balmisse and Sylvain, 2003), as well as low-cost wastewater treatment. In 2009, 429 hectares of water spinach, 32.1 hectares of water mimosa, and (during the dry season) 13.5 hectares of dry-season rice were cultivated within the Cheung Ek Lake boundary (Teang, 2009).

The purpose of this research is to understand the economic value of Cheng Ek Lake by identifying the primary human activities performed on the lake and assessing the direct use value of the lake from those activities that could assist policy-makers' future considerations.

## METHODOLOGY

An inundated lake, Cheung Ek Lake, was the research site of this study. The sampling was primarily stratified by activity, as the human activity performed on the lake is very diverse. It was then stratified by village in order to obtain more reliable results, as farmers involved in each activity live in 15 different villages around the lake. 192 households from a total of 900 households working directly on the lake were randomly selected for in-depth interview using a structured questionnaire. The study was conducted from December 2008 to May 2009, which was a period of dry season. Direct observation and interviews with key informants were first used to better understand the diversified activities and the landscape of the area, followed by direct household interviews to obtain information on the household's income-generating activities performed on the lake. The direct-use value of the lake was assessed by summing up the total profit of all activities performed on the lake. The profit of each activity was calculated by the total income minus by the total expense. This excluded the labour costs of 2–3 producers per household in each activity; these producers were not paid salary, being all family workers.

## RESULTS AND DISCUSSION

On Cheung Ek Lake, five main socio-economic activities are undertaken by the farmers who have migrated from other provinces throughout Cambodia. These five major activities are: water spinach cultivation (350 households), water mimosa cultivation (110 households), dry season rice cultivation (19 households), fishing (402 households) and duck raising (19 households). In 2009, a total of 900 households were working directly on the lake during the dry season.

Many of the respondents are not born in the districts, communities or villages where they currently reside; they are mostly migrants from other provinces throughout the country. They came from Kampong Chhnang, Kampong Thom, Kandal, Prey Veng, Svay Reang and Takeo provinces. As shown in Fig. 1, most of the water spinach and water mimosa cultivators and less than half of fishermen and dry season rice cultivator are migrants while all the duck raisers were born in this region. The study indicated that the migration from the provinces for water mimosa cultivation in Cheung Ek Lake started within the last five years, while for water spinach cultivation it started more than 20 years previously and has been increasing with time. The results from this research indicate similar reasons for the migration process to those found by Rigg and Salamanca (2006a). It is suggested that the major reasons that respondents gave for moving to peri-urban aquatic plants production region are: to find work, to follow or join their families, to move into a new economic zone, to pursue a work-related initiative, as well as due to war or marriage. Thus, it can be assumed that the movement of people to peri-urban regions are propelled primarily by work or livelihood concerns. The migration rate has been steadily increasing over time, which leads to greater demand of land for agricultural activities, thus pushing the renting cost to increase significantly.

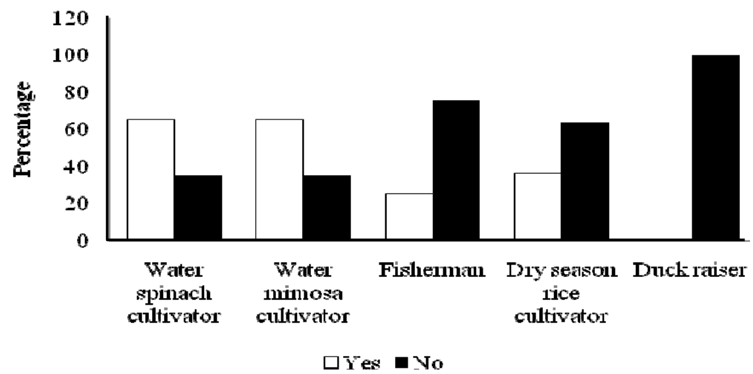


**Fig. 1 Migration of farmers to Cheung Ek Lake**

As most of the farmers working on the lake were migrants from other provinces throughout the country, they needed to rent the land on average 300-400 USD per hectare for their activities: as shown in Table 1, almost of the water spinach and water mimosa cultivators were renters, as were more than half of dry season rice cultivator and duck raisers. Some of the producers on the lake own the land for cultivation. In a very few cases, farmers were asked to look after the land by the landlord and were able to work on the land without paying rent. According to Rigg and Salamanca (2006b), the ownership of the land among surveyed households in Aquatic Food Plants Production Systems in both Bangkok and Ho Chi Minh City is high, but this is not the case for either Phnom Penh or Hanoi. Kuong et al. (2006) stated that, in Phnom Penh, about 10% of the households from two villages, Kbal Tumnub and Thnout Chrum, owned the land for water spinach cultivation. The present research has found similar results: most of the water mimosa and water spinach cultivators and the duck raisers in Cheung Ek Lake need to rent the water surface area from the landlord for their cultivation (95%, 92% and 63% respectively). In addition, only 53% among 19 households of dry season rice cultivators need to rent the land for dry season rice practice on the lake.

**Table 1 Land ownership by activity**

| Activity | Rent (%) | Owned (%) | Other (%) |
|---|---|---|---|
| Water spinach cultivation | 92.4 | 7.6 | 0.0 |
| Water mimosa cultivation | 95.0 | 5.0 | 0.0 |
| Dry season rice | 53.0 | 21.0 | 26.0 |
| Duck raising | 63.2 | 21.0 | 15.8 |

Generally, villagers can only own water surface area they inherited from their forebears. Few migrants own the water area they use for cultivation. Most farmers find difficulty in facing the high cost of water-surface area rental and the expense of chemicals. Thus, they need to borrow money in any way they can for their initial inputs. The cultivators usually borrow money from the middlemen and they pay the interest in the form of selling the product back at slightly lower than the market price, or they borrow from their neighbours at a high rate of interest (about 10%) and can sell their products at the market price. There are a limited number of farmers who borrow money from micro-credit banks or organizations, as most do not want to follow the institution’s restrictions. It is very rare for the fishermen, rice cultivators, and duck raisers to borrow the money from their production as their initial input is not as high as water spinach and water mimosa production. Most of the farmers working on both aquatic plants cultivation and fish culture in the four main cities in Southeast Asia mentioned the need to take a loan for their initial costs of production, except in Ho Chi Minh City where most of the farmers could not take the credit from any sources of loan as they did not meet the loan terms set by the government. According to Yoonpundh et al. (2006), fewer aquatic plant cultivators took out loans for their cultivation (water spinach cultivator 27% and water mimosa cultivator 10%). Nevertheless, the results from Kuong et al. (2006) found that many water spinach producers in Kbal Tumnob and Thnout Chrum villages in the Phnom Penh peri-urban region took out credit (60% and 40% respectively). The results from this research, as shown in Fig. 2, are similar to the previous results of Kuong et al. (2006), as 63% of the total households from 8 villages working on water spinach cultivation and 59% of water mimosa cultivators took loans from various sources for the initial input of production.

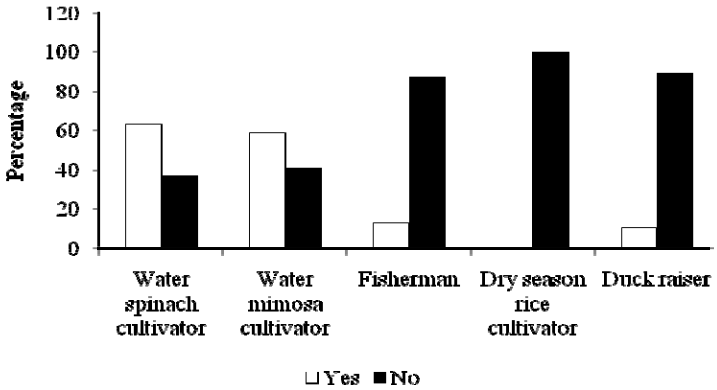


**Fig. 2 Credit for inputs of production**

The producer can either sell the product to the middlemen or sell it directly at the markets. The product is transported by middleman or producer to the wholesalers in the main markets in Phnom Penh. At these markets, the wholesalers sell the product to retailers from other markets in Phnom Penh and also to other traders from the provinces, such as Koh Kong, Sihanuk ville, and Kampong Cham. Finally, the product is sold to consumers for their daily household diet. The results from this study are similar to those of (Yoonpundh et al., 2006; Huy and Hung, 2006; Phuong et al., 2006; Kuong et al., 2006) regarding market processing. It seems that the marketing process for aquatic food production is quite similar throughout Southeast Asia. The transaction cost from producer to consumer is an average 900 riels per bunch for water spinach and 1,600 riels per kilogram for water mimosa. The prices of both water spinach and water mimosa are higher in the dry season than in the wet season. Fishermen sell their product to the local markets in the nearest accessible market whereas the main markets for the middlemen’s supply are not identified yet. Duck eggs are sold by farmers to the middlemen, and then they are supplied to the local market and also transported to the main markets in Phnom Penh. The product from rice production is usually used for household consumption, although in some cases it is sold to neighbours in the villages.

The findings show that the household income varies with activity: water spinach cultivators obtained an average income of 1,431 USD, water mimosa cultivators 1,795 USD, fishermen 512 USD, dry season rice cultivators 359 USD, and duck raisers 537 USD per household per dry season. Yoonpundh et al. (2006) stated in the report of the Production in Aquatic Peri-Urban Systems in Southeast Asia (PAPUSSA) that the water spinach farmers in Bangkok received higher income (3,943 USD/HH/year) compared to water mimosa farmers (120 USD/ HH/year). This happened as the water mimosa was destroyed by contaminated water in the canal during the time of survey. These are similar results to those of Huy and Hung (2006). The results of the survey on per-urban aquatic food production in Phnom Penh showed that income levels of households involved in water spinach production in the Cheung Ek lake area were mostly found to be within 200-500 USD/HH/year. Less than one third of these households ranked their annual income from water spinach production in the range of 500-1000 USD and only a few earned within 1000-5000 USD (Kuong et al., 2006). The average price received by the producer per bunch of water spinach was only 134 riels. The present research shows that water spinach cultivators in Cheung Ek Lake now receive improved benefits than in the previous 3 years, with an average profit of 1,431 per six months. The profit of water spinach cultivators may be increased as the average price per bunch of water spinach has increased to 550 riels, and most of the cultivators have increased the water surface area for water spinach production. The difference of the results of current research and the results of Kuong et al. (2006) may happen because of the sampling methods. Koung et al. (2006) randomly selected the respondents from the two main villages involved in water spinach cultivation whilst in the present research, the respondents were selected from all the 15 villages where the farmers are involved in water spinach cultivation and the sampling is first stratified by activity performed on the lake and then by village.

The direct use value of Cheung Ek Lake is the sum of the total cash net income from each direct human activity during the period of the dry season. Table 2 shows that households received a total profit of 1,020,236 USD over the six months of the dry season: a substantial total. Within this, water spinach production gave the main contribution (65%), 666,237 USD with a total cultivation area of 429 ha whilst dry season rice production is the smallest contribution among the five (0.67%) with a total profit of 6,912 USD with a total area of 13.5 hectares.

**Table 2 Direct use value of Cheung Ek Lake during the dry season**

| Activity | Average profit (USD) | Total area/household/head | Total profit (USD) |
|---|---|---|---|
| Water spinach | 1,553 /ha | 429 ha | 666,237 |
| Water mimosa | 4,168 /ha | 32.1 ha | 133,793 |
| Fishing | 512 /HH | 402 HHs | 203,412 |
| Dry season rice | 506 /ha | 13.5 ha | 6,912 |
| Duck raising | 157 /100 heads | 6,293 heads | 9,882 |
| Total | | | 1,020,236 |

## CONCLUSION

Cheung Ek Lake is a vital economic resource on the urban margin of Phnom Penh, providing at least more than a million USD per dry season to about a thousand direct beneficiaries. The agricultural activities provide a vital fresh food source for markets and help to assure food security in Phnom Penh as well as being distributed to other provinces throughout the country. This regional economy also involves growers, wholesalers, distributors and local customers, and provides a valuable trade network in essential commodities such as foodstuffs and animal fodder. Among the five types of farmers, water mimosa cultivators receive the highest household income (1,795 USD) whereas dry season rice cultivators obtain the lowest (359 USD). Within the substantial profit from the direct value of the lake, water spinach production gives the main contribution (65%) whilst dry season rice production is gives the least contribution among the five (0.67%). Given the significant value of the lake to the local people found in this research, policy-makers should make careful considerations before implementing future development plans on this lake region as it may affect seriously on many households' livelihoods and the food security in Phnom Penh.

The direct use value here is just a part of the overall economic value of the lake and it focuses only that from the direct beneficiaries of the human activities on the lake. The value from the indirect beneficiaries such as harvester, middlemen, wholesalers, and retailers should be explored and considered as a part of the direct use value of the lake, as well as the indirect impact of health and future tourism. This body of water also functions as a means of water purification, which is regarded as another component to the direct use value. Water purification and the indirect use value of the lake which are great importance for future economic potential must be taken into account to assess the overall economic value of the lake. Although agricultural activities provide a vital economic link to food markets, there is growing concern for the health implications of this practice. Waste, including heavy metals, organic pollutants, dissolved nutrients, and biologically active agents are entering the lake throughout the year, with dilution as the only mitigating factor. This wastewater constitutes a dangerous situation for the socio-economic importance of Cheung Ek Lake, as negative effects on human health and economic viability of agricultural practices begin to appear. The implications are two-fold: (i) for the individual - the high cost medical bills and (ii) for the community - mitigating problems of poor health and disease epidemics, compounded by a workforce containing significant numbers of people too unwell to contribute to the economy. A simple wastewater treatment plant to reduce pathogens and contaminants entering the lake could overcome many of these problems. If coupled with policies on waste for industries, agriculture and urban communities will see a positive impact on the socio-economic health and wealth of this region. In addition, there is the indirect use of the lake region that could arise in the future from tourism if the lake is relatively unpolluted.

## ACKNOWLEDGEMENTS

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*Research article*

# Contribution of Kampong Preak Fish Sanctuary (Tonle Sap Lake, Cambodia) to Livelihoods in Two Adjacent Floating Villages

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**Abstract** This study focused on the contribution of natural resources (fish, wildlife, vegetation, flooded forest, etc) to the livelihoods of communities living in two floating villages located near Kampong Preak fish sanctuary, Krakor district, Pursat Province. The approach was based on a combination of Rapid Rural Assessment (RRA) and economic assessment methods. Data was collected from 60 households. Stratified random sampling was used to interview rich, medium and poor households. Quantitative information was complemented by interviews of key informants and of village chiefs. Analysis focused on i) quantitative data, and ii) perceptions of interviewees about the contribution of natural resources and of the fish sanctuary to their livelihoods. This study showed that the fish catch is an important element of income. The living standards of villagers varied, depending on fish production and aquatic plant collection. Labor, aquaculture, pig farming and wildlife catching were the other sources of income in the two floating villages. During six months of fishing season, rich households can catch up to 8020 kg of fish worth USD 1938 while medium households can catch 1,950 kg of fish (USD 778) and poor households can catch 1,426 kg of fish worth in average USD 422. The fish sanctuary contributed to household consumption and income generation in all households. Fish, snake, water bird, turtle, edible wild plant and fire wood are most important for daily subsistence of poor households. Overall people in rich households derive more benefits from natural resources because they have more capital to invest on fishing equipment and to bribe law enforcers.

**Keywords:** Conservation, fisheries, rural development, environmental management

## INTRODUCTION

Cambodia has the most productive inland fisheries in the world. With an estimated production ranging between 290,000 and 430,000 tonnes per year (Van Zalinge et al., 2000), the fish yield is one of the highest in the world and contributes between 8 and 12 % of country's GDP (Kurien et al., 2004-2005). More than a million Cambodian rely upon fisheries for their livelihoods and the majority of Cambodian population lives within the central floodplain of Tonle Sap Great Lake and

Mekong River (ADB, 2003). At least 1.2 million people live the Tonle Sap Lake and exploit its resources. They depend on fish, flooded forest and wildlife as primary or secondary sources of income, employment, food and firewood (ADB, 2003, Chanthy, 2006). According to Balzer et al. (2002), in the Tonle Sap Great Lake, many wildlife species including birds, snakes, turtles, bee but also plants are used by the local people. Usually, the rural people catch wildlife for household consumption as well as for sale and income generation.

The Tonle Sap Great Lake is also a site of global ecological and conservation significance and was classified as a UNESCO international biosphere reserve (Royal Decree, 2001).Within this area, fish sanctuaries (i.e. zones where fishing is completely banned) were already recommended by Chevey and Le Poulain in 1940. In fact, two fish sanctuaries in Pursat Province (namely Kampong Preak and Reang Til) existed before 1950s (Deap, 1992). Two more fish sanctuaries (Kampong Pluk in Siem Reap province and Phat Sandai or Pi Stoun in Kampong Thom province) were established during the 1960s (Sovan,1992). Then four more fish sanctuaries were established later on (Chroy Sdey and Dey Roneat in Pursat province, Ba Lot fish in Kampong Thom province, and Park Konteal in Battambang province; Chheng, 2008); thus to date there are eight sanctuaries located around the permanent lake; they are characterized by different levels of law enforcement and of biological efficiency (Chheng, 2008).

The purposes of the current research is to i) identify the different social groups using natural resources in Kampong Preak fish sanctuary, ii) determine how these social groups use natural resources as a livelihood strategy, and iii) assess the contribution of natural resources to income generation in each social group.

## RESEARCH METHODOLOGY

The research was conducted between December 2008 and May 2009. A Rapid Rural Appraisal (RRA) approach was used. RRA is a “Systematic, semi structured activity conduced on site, with the aim of acquiring new information and hypotheses about rural life and rural resources” (Coolison, 1981). This method is a way to identify rural priorities in a short time frame, focusing on aspects related to planned intervention or change.

The two villages selected for study were Anlong Raing and Kampong Preak villages, located outside the Kampong Preak fish sanctuary. The two floating villages were chosen because the local livelihoods are based on the natural resources, especially flooded forest, fish and wildlife in the Kampong Preak fish sanctuary. There has not been any organization to protect and conserve it in the past, and at the present there CI to provide funds to protect and conserve endangered animal and fish species as well as flooded forest within the fish sanctuary.

The differences between social groups, their wealth and the corresponding households in each village were determined during a preliminary stratification phase by a wealth ranking exercise and discussion with the village leaders. 60 households of different social group from a total of 148 households collecting directly resources around the fish sanctuary were randomly selected for in-depth interview using a structured questionnaire. The profit of each natural resource from fish sanctuary was calculated by the total income minus by the total expense which was not included the labor cost. The expenditure of employment was covered by the owner.

## RESULTS

### Contribution of natural resources to the livelihood of different social groups

An analysis of the household interviews gathered in the two floating villages near Kampong Preak fish sanctuary indicates how much natural resources around fish sanctuary are used by different social groups. Table 1 shows that fishing, snake catching, fire wood collection and water bird catching all play an important role in the livelihoods of all social groups. There is a substantial difference between social groups only about turtle catching. Rich and medium household catch turtles by using horizontal cylinder traps and enclosure nets, whereas poor households can not use them because these gears are expensive and a boat is needed to use them far from their home. There are some differences between social groups involved in the use of edible wild plants because rich and medium household use them also for pig farming, whereas poor households don't raise pigs.

**Table 1 Contribution of natural resources to livelihood of different social groups**

| Sources | Rich households | | Medium households | | Poor households | |
|---|---|---|---|---|---|---|
| | Frequency | (%) | Frequency | (%) | Frequency | (%) |
| Fishing | 11 | 100 | 26 | 100 | 23 | 100 |
| Snake catching | 10 | 91 | 26 | 100 | 23 | 100 |
| Fire wood collection | 10 | 91 | 25 | 95 | 22 | 95 |
| Edible wild plants collection | 10 | 91 | 26 | 100 | 23 | 100 |
| Water bird catching | 6 | 55 | 14 | 58 | 11 | 55 |
| Turtle catching | 4 | 36 | 6 | 23 | 1 | 4 |

**Kinds of fish caught by the different social groups**

An analysis focussing on fish catch, fish groups and social groups is detailed in Table 2. Among the three fish groups, white fishes consist of long distance migrants (Tonle Sap - Mekong mainstream), black fishes of local residents (floodplain fishes), and grey fishes consist of short distance migrants (Tonle Sap - local tributaries).

**Table 2 Fish caught by different social groups in the villages studied during 6 months**

| Fish guide | Rich households | | Medium households | | Poor households | | Average total catch |
|---|---|---|---|---|---|---|---|
| | fish catch (kg) | (%) | fish catch (kg) | (%) | fish catch (kg) | (%) | fish catch (kg) |
| White fish | 4,758 | 59 | 960 | 49 | 716 | 50 | 6,434 |
| Gray fish | 1,806 | 23 | 552 | 28 | 358 | 25 | 2,716 |
| Black fish | 1,456 | 18 | 438 | 23 | 352 | 25 | 2,246 |
| Total | 8,020 | 100 | 1,950 | 100 | 1,426 | 100 | 11,396 |

This table shows that there are substantial differences between social groups in terms of fish catch. In the six months of fishing season between December and May, rich households can catch more than 8,000 kg of fish (including 59% of white fish, 23% of gray fish and 18% of black fish) because they use bigger and illegal fishing gears such as enclosure nets (more than 500 m of nets) and giant lift nets (18m x 18m x 9m); whereas medium household can catch 1950 kg of fish (49% of white fish, 28% of gray fish and 23% of black fish) and poor households can catch only 1,426 kg of fish (50% of white fish, 25% of gray fish and 25% of black fish species) because they don't use large fishing gears and fishing equipment like rich households.

**Fishing gear used by different social groups**

According to Deap et al. (2003), more than 102 fishing gears have been identified in Cambodia. However, the main fishing gears used by social group in the villages studied are not that many; they consist mainly of gillnets, brush parks or fyke nets (Table 3).

**Table 3 Frequency and percentage of different social groups using a given fishing gear**

| Fishing gears | Rich households | | Medium households | | Poor households | |
|---|---|---|---|---|---|---|
| | Frequency | (%) | Frequency | (%) | Frequency | (%) |
| Gill nets (25-35 mm) | 10 | 91 | 25 | 95 | 23 | 100 |
| Brush parks | 8 | 73 | 25 | 96 | 14 | 61 |
| Gill nets (65-120 mm) | 9 | 82 | 18 | 69 | 15 | 65 |
| Hook | 6 | 55 | 14 | 54 | 10 | 44 |
| Fyke nets made | 3 | 27 | 11 | 42 | 3 | 13 |
| Enclosure nets | 6 | 55 | 2 | 8 | - | - |
| Giant lift nets | 5 | 45 | - | - | - | - |
| Horizontal cylinder traps | 3 | 27 | 4 | 14 | 1 | 4 |
| Hook long line | 1 | 9 | 2 | 8 | 4 | 17 |
| Cast nets | - | - | - | - | 2 | 9 |

Gill nets (25-35 mm or 65-120 mm mesh size) are the most common gear and are used by all social groups because of their low cost compared to other fishing gears. Less fishermen use long line with hooks because this gear catch less fish and requires much time for seeking bait. Brush parks are used by all social groups because they are efficient and cheap (although illegal); they are used between March and May. People from rich households also use enclosure nets (more than 500 m of nets) and giant lift nets (18m x 18m x 9m) because these fishing gears are very efficient although they are very expensive and require paying bribes since they are illegal. With enclosure seine nets fishermen harvest around a patch of water hyacinths previously gathered and under which fish sought refuge. Those gears catch a mixture of small fish species and are used between October and February. There are no differences between social groups in the use of hooks and horizontal cylinder traps. Fyke nets, although illegal, are used when water rises, especially in May - July, and target fish migrating from the river into the flooded forest. Horizontal cylinder traps is a gear targeting only snakehead fish between July and April. This gear can catch from 3 to 15 kg of fish per day, depending on the season; in dry season they catch more than in wet season and then fishermen check and collect fish every two days. Cast nets are only used by 9% of respondents, all of them from poor households; because this gear is cheap but catches less fish than other gears (and small fishes of low value only).

## Economic activities of the different social groups

An analysis of household interviews in the villages studied indicates how much social groups earned from the use of natural resources during the 6 months of the study (Table 4). In fact natural resources contribute more or less to income generation depending on the social group. The expense of some kind of resources was zero as it was already included in fishing expense.

Fishing is the main source of income; this activity contributes more than 60% of income in rich and medium households and 82% in poor households. Over six months of fishing season, rich households can earn around USD 2000 in average from fishing, while medium households make around USD 800 and poor households USD 400. Aquaculture and pig farming are the second sources of income for rich and medium household. Aquaculture contributes 22% of income in rich households (USD 630), 19% in medium households (USD 244), and pig farming (on floating platforms) contributes 7% of income to rich and medium households. Snake catching contributes 7% of income to medium and poor households. Turtles catching, fire wood collection and bird catching made the smallest, often negligible, economic contribution. Thus respondents from rich and medium household get income from fishing activities, aquaculture and pig farming, but did not have any other sources of income; conversely, medium and poor households rely largely on income from young workers who migrate to urban areas.

**Table 4 Contribution of each activity to livelihoods of different social groups**

| **Sources** | Rich household | | Medium household | | Poor household | |
|---|---|---|---|---|---|---|
| | Average (USD) | | Average (USD) | | Average (USD) | |
| | Income | Expense | Income | Expense | Income | Expense |
| Fishing | 1,938 | 813 | 779 | 255 | 422 | 113 |
| Aquaculture | 630 | 283 | 244 | 150 | 0 | 0 |
| Snake catch | 23 | 4 | 84 | 13 | 39 | 5 |
| Employment | 8 | 0 | 68 | 0 | 45 | 0 |
| Pig farming | 195 | 166 | 92 | 81 | 0 | 0 |
| Fire wood | 0 | 0 | 11 | 1.5 | 7 | 0.5 |
| Turtle catch | 9 | 0 | 0.5 | 0 | 2 | 0.5 |
| Bird catch | 3 | 0.25 | 0 | 0 | 0 | 0 |
| **Total** | **2,806** | **1,266.25** | **1,278** | **470.5** | **515** | **118.5** |
| **Profit (USD/6 months)** | **1,540** | | **807.5** | | **396.5** | |

*Source: Field survey 2009, 1 USD was equivalent to 4,150 Riel during 6 months.*

Overall these results show that rich households benefit much more, economically speaking, from natural resources than other social groups, and that people do not emigrate towards urban areas if they can get enough income from local harvesting activities.

## DISCUSSION AND CONCLUSIONS

This study shows that natural resources from Kampong Prak sanctuary play a critical role in the lives of people living around that protected area. Fishing activities are the major source of differences between social groups (both household consumption and income generation). Aquaculture and pig farming are secondary sources of income for rich and medium households. Firewood collection and catching snakes, water birds and turtles are sources of subsistence for poor households. The people living in the villages studied preferred to collect edible wild plants during the flooded season and to catch water birds in the dry season. They preferred to catch turtles, from the end of rainy season until the dry season. These results confirm those of Chanthy (2006) and Rahut et al. (2007) who also showed that fishing is an important source of income in floating villages. Thouk and Sina (1997) also found that very poor households, although they spent more time fishing than rich households, had a lower catch per unit effort. In better-off households, the higher importance of fishing is explained by the fact that men fish more, use bigger fishing gears and travel further to exploit better fishing grounds. Labor and fish cage culture are another source of income for rural livelihoods. Flooded forests play a role in supporting aquatic life and rural livelihoods as a source of fuel wood, handicraft materials, wild vegetable, wildlife and traditional medicines (ADB, 2002). Snakes represent an important income source and food sources for some of poorest people in Cambodia (Roudy 2002, Brooks et al. 2007). Snake catching is more popular than other wildlife catching, because villagers can process the snakes locally and sell processed snakes at a high price (12,000 Riel per kilogram).

From our study it can be concluded that natural resources from the fish sanctuary contribute very substantially to the livelihood and income of people living in floating villages around Kampong Prak. The use of natural resources is different between social groups, and that the living standards are proportional to the level of fish catch. Fishing is thus the main source of income for livelihoods in floating villages, but it requires a higher investment than the collection of other natural resources. For that reason, rich households collect more natural resources, in particular more fish, than medium and poor household. Wildlife and plants also make a substantial contribution to the livelihood and diet of villagers, in particular since they are easy and cheaper to collect.

## ACKNOWLEDGMENTS

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*Research article*

# Assessing Poverty Outreach of Microfinance Institutions in Cambodia - A Case Study of AMK

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**Abstract** The microfinance industry works to balance social and financial benefit, which is viewed as an effective way of helping the poor. The industry, however, faces the challenge to measure the social bottom line, especially the depth of poverty outreach which refers to serving the poorest clients. This paper aims to investigate poverty outreach and analyze the depth of outreach for AMK. It assesses the depth of outreach through two main measures: the Wellbeing Score and Daily Food Expenditure per capita. The analysis is based on both secondary data and primary data from a survey in 2009 with 810 samples [648 clients (504 group clients and 144 individual clients) and 162 non-clients] randomly selected in 18 provinces in Cambodia. The results of AMK's depth of poverty outreach for group clients based on the Wellbeing Score indicate that AMK reaches more poor and medium level households than in the control group of non-clients, but less better-off clients. For individual clients AMK reaches a larger share of medium households, less poor households and a slightly smaller share of the better-off households than what is found in the general population. The results based on the number of clients spending on food below Food Poverty Line (FPL) confirm that AMK clients are poor with 56% of group clients and 58% of individual clients below FPL. Therefore, we conclude that AMK achieves the social bottom line in term of poverty outreach.

**Keywords:** Assessment, poverty outreach, microfinance, AMK, Cambodia

## INTRODUCTION

Microfinance is a crucial tool to help the poor access financial services. For poor households, having sources of reliable, convenient and reasonably-priced financial tools would improve their situation (Collins et al., 2009). Therefore, the Royal Government of Cambodia and its development partners are increasingly paying attention to the connections between poverty and microfinance.

In Cambodia, microfinance institutions (MFIs) started in the early 1990s with support from the international community. In recent past years the industry has made significant progress and has witnessed high growth from 2006 to 2008. During this period the number of clients has more than doubled and the loan portfolio almost tripled. Meanwhile the number of licensed MFIs has increased remarkably.

The obsession with growth of the industry has led to a situation where there is a concern that MFIs are turning to commercial principles of operation and neglecting the poor. In conjunction with the financial and economic crisis there is increasing concern about mission drift of MFIs - sliding away from the original idea of helping the poor. Therefore it is crucial to measure the poverty outreach and the depth of the outreach. Poverty outreach refers to how many poor people microfinance is reaching, and depth of outreach (or depth of poverty outreach) refers to the poverty level of clients served. The purpose of this article is to determine the level of poverty outreach and then analyze AMK client data to assess the performance of AMK in terms of the depth of outreach.

Fig. 1 provides information about the trend in the microfinance industry from 2003 to 2009. It reveals that the microfinance situation in Cambodia was determined by rapid growth. This resulted in a tremendous increase of loan portfolio from $ 59 million in 2003 to $ 492 million in 2009. Over the same period, the number of loans borrowed increased from 351,055 to 1,102,246. (refer to a Figure in the text before presenting it)

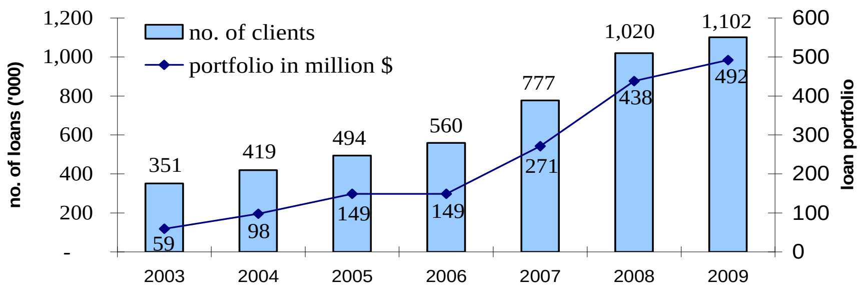


**Fig. 1 Evolution of loan portfolio and no. of clients**

## METHODOLOGY

This research assesses AMK's depth of outreach through two main measures: Wellbeing Score and Daily Food Expenditure per capita. The Wellbeing Score, a relative measure, is the main tool as it is a multidimensional measure of poverty and provides a good picture of the wellbeing situation for client households. Client households are then classified into wellbeing groups according to their particular Wellbeing Scores and information is presented for these groups. To provide an absolute measure of poverty, AMK also compares the Daily Food Expenditure per capita with the Food Poverty Line (FPL) in rural areas. The AMK Wellbeing Score is based on Principal Component Analysis and was defined in 2006 (reference?). The 22 indicators that comprise the Wellbeing Score cover three poverty dimensions: expenditures, assets (physical, human and social), and vulnerability and food security. The specific indicators selected are the following:

**PHYSICAL ASSETS**
- Total land area owned by household (HH)
- Floor, wall and roof materials for the house/dwelling
- HH owns a television, a motorcycle and assets of modest, mid or high value

**EXPENDITURES**
- Expenses in clothing and footwear pc
- Total HH expense in food
- HH outflows include: inputs for income activities, buying HH materials and durable assets
- Main HH expenditures include food

**HUMAN ASSETS**
- Number of adults (income earners)
- Health: strategies to pay for healthcare
- Education: literacy of head of household

**SOCIAL CAPITAL**
- Number of good friends / neighbors in community

**VULNERABILITY & FOOD SECURITY**
- Food Security
- Household diet in the last year
- Self-reported level of difficulty in affording large expenses - Ordinal
- Incidence of reducing nutritious quality of foods
- Main income activities: casual labor or temporary migration (domestic or international)
- Savings and reinvestment behavior
- Coping strategies: less food consumption, less non-food expenses, selling personal property

The AMK-PCA model was based on the IFRI/CGAP Poverty Assessment Tool but was adapted to the rural Cambodian context and applied to food security as the main poverty benchmark. The AMK-PCA model achieved relatively good results. Note that the Kaiser-Meyer-Olkin (KMO) index was 0.818 when applied to non-clients and 0.848 to the total 450 HH. In general, index scores > 0.60 are acceptable, > 0.70 are good, > 0.80 are commendable, and > 0.90 are exceptional.

The analysis for this article is based on data collected from both AMK new clients and non-clients from 54 villages in 18 provinces over the period from March to May 2009. Eight hundred and ten samples (648 clients and 162 non-clients) were interviewed. Among the 648 clients, 504 were group or Village Bank (VB) clients and 144 Individual (ID) clients. In order to assess how AMK is reaching the poor, clients referred to in this study were those who joined AMK within a year prior to the field survey.

The client sample selection was conducted in two steps: first, 54 villages with at least 18 new clients were randomly selected; and second, 12 clients per village were randomly selected plus 6 clients as potential replacements. One reason of choosing 12 clients is efficiency which is based on past experience of AMK research team. For relative poverty study, 3 non-clients per village were selected for interviews. This means that the ratio between client and non-client samples is 4:1. The non-client samples had to be non-client households who were next to the selected client households. Therefore, the total number of interviewed clients and non clients was 810.

## RESULTS AND DISCUSSION

Currently, there are one million clients with 492 million US$ loan outstanding covered by 20 licensed MFIs, one commercial bank (ACLEDA small loan) and one licensed NGO, accordingly to Cambodia Microfinance Association (CMA). Table 1 shows that the top three institutions which include AMK account for 60% of the market share in term of client outreach.

Table 2 shows that more than half of AMK loans were used for productive purposes either for farm or non-farm activities. Meanwhile AMK clients also used loans for different purposes: 10% for food, 8% for health, 14% for buying assets (vehicles, land and gold), and 9% for other consumption.

**Table 1 Market share by MFIs**

| MFIs | No. of clients | Share (%) |
|---|---|---|
| AMRET | 224,708 | 20 |
| ACLEDA | 223,687 | 20 |
| AMK | 217,818 | 20 |
| VFC | 98,777 | 9 |
| TPC | 91,170 | 8 |
| PRASAC | 87,945 | 8 |
| Others | 158,141 | 14 |

*Values were calculated on the basis of the data from CMA*

**Table 2 Loan uses by AMK clients**

| Loan uses by AMK clients | | Share (%) |
|---|---|---|
| Productive purposes | Farm | 40 |
| | Non-farm | 19 |
| Savings | Assets | 11 |
| | Land and gold | 3 |
| Consumption | Food | 10 |
| | Health | 8 |
| | Others | 9 |

*Source: AMK field research, 2009*

According to Gulli (1998), there is a positive correlation between reaching many poor people and financial sustainability. Therefore AMK, as a social MFI, has worked hard to include the poor from both rural and urban locations. So far, its performance in reaching large number of poor has been higher than the national average of the industry. Also AMK has achieved financial sustainability since 2004.

### Assessment by Wellbeing Score

The average Wellbeing Score for VB clients was -0.020 and for non-clients was 0.080 (Fig. 2). This indicates that clients were poorer than non-clients (the t-test for equality of means is not significant while the independent t-test is: N=630, F=0.04, p-value=0.315). Regarding ID client status, Fig. 2 shows that the average wellbeing score for AMK ID clients was 0.076 and the average wellbeing score for non-clients was -0.019, indicating that ID clients are wealthier than non-clients (the t-test for equality of means is not significant while the independent t-test is: N=180, F=3.15, p-value=0.609). It is important to realize that VB non-client scores and ID non-client scores are different groups because they are from different locations.

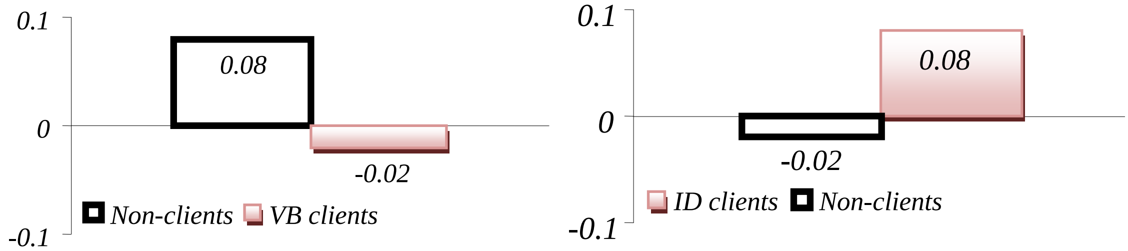


**Fig. 2 Average household wellbeing score**

Fig. 3 shows the cumulative frequency for non-clients and VB clients; there is a small difference in poverty levels between the two groups only in the upper 40% and lower 40% of households on the cumulative frequency. Fig. 3 also shows the cumulative frequency for non-clients and clients, showing a margin of difference in poverty levels between the two groups situated in the lower 50% part of the cumulative frequency.

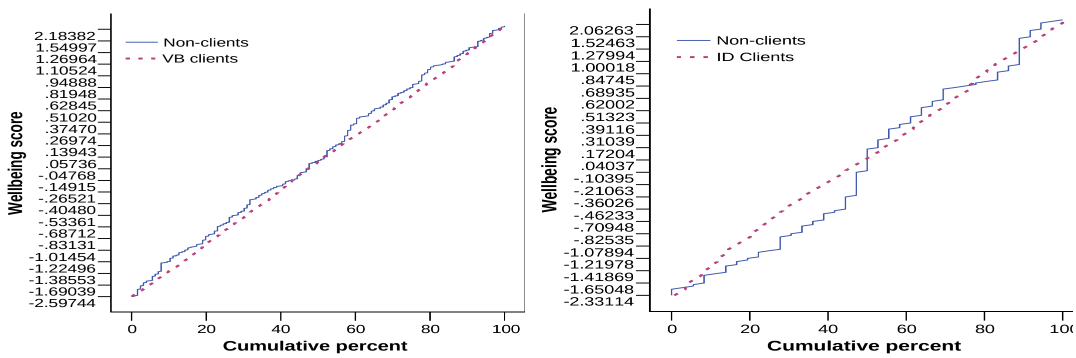


**Fig. 3 Accumulative Frequencies for Non-Clients and Clients**

## Assessment by tercile analysis

The Wellbeing Score is a relative poverty score and measures whether a household is worse off or better off compared to other households in the general population. Each household sampled has been assigned a Wellbeing Score: the lower the score, the poorer the household relative to all other households with higher scores. The following steps were followed to develop the tercile results.

First the 126 non-client households from VB villages were sorted in ascending order according to their Wellbeing Scores. Second these 126 samples were divided into terciles based on Wellbeing Scores: the bottom third of the non-client households are grouped into the “poor” group, followed by the “middle” and the “better-off” group. Since there are 126 non-clients, each group contains 42. The cutoff scores for each tercile define the limits of each poverty group and they were -0.3428 and 0.5309. Third, the 504 client households were then categorized into the same three groups based on their scores using the cutoff scores defined above for the AMK-PCA case (i.e. -0.3428 and 0.5309).

If the pattern of poverty among client households matches exactly that of non-client households, the client households will divide equally among the three wellbeing groupings in the same way as non-client households, with 33 percent falling into each group. Any deviation from this equal proportion would signal a difference between the client and non-client populations. The results shown in Fig. 4 are that VB clients are slightly over-represented within the poorer tercile, remain the same in the medium and are under-represented in the higher tercile. Therefore AMK is reaching a larger share of the poor households, an equal share of medium classified households and a slightly smaller share of the better-off households than in the general population.

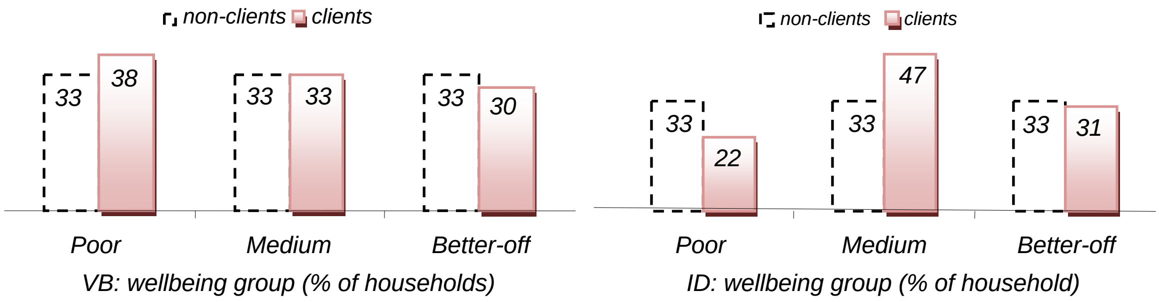


**Fig. 4 Tercile analysis by wellbeing group**

For the ID case, the same steps were followed. First the 36 non-client households were sorted in ascending order according to their Wellbeing Scores. Second this 36 household sample was divided into terciles based on Wellbeing Scores: the bottom third of the non-client households are grouped into the “poorer” group, followed by the “middle”-ranked group, and finally, the “better-off” group. Since there are 36 non-clients, each group contained 12 households. The cutoff scores for each tercile define the limits of each poverty group and they were -0.755 and 0.568. Third, the 144 client households were then categorized into the same three groups based on their scores using the cutoff scores defined above for the AMK-PCA case (i.e. -0.755 and 0.568).

The results indicate that ID clients are under-represented within the poorer tercile, highly over-represented in the medium and are slightly underrepresented in the higher tercile (Fig. 4). Therefore, AMK is reaching a larger share of the medium households, less poor households and a slightly smaller share of the better-off households than found in the general population.

**Assessment by absolute poverty benchmark**

The Wellbeing Score calibrates relative poverty but does not provide information on the absolute level of poverty, i.e. it measures the extent to which a household is worse off or better off compared to other households, but does not assess the actual level of deprivation of the poorer category of households or the level of affluence of the better-off households. To provide an estimate of absolute levels of poverty, AMK compared the Daily Food Expenditure per capita with FPL in rural areas. AMK Daily Food Expenditure figures include not only the cash expenses in food items but also quantify consumption from the household’s own production (including rice and other crops, vegetables or animals) and from other food items gathered, collected or fished.

The overall Cambodian Poverty Line for rural areas was set at Riel (R) 1,753 per person per day and the FPL for rural areas at R 1,389 per person per day in 2004. The Cambodian FPL allows a person to consume a food basket that provides at least 2,100 calories of energy per day. Therefore, a person who consumes less than this FPL is not receiving the minimum amount of calories necessary to maintain their health. Since there are no rural inflation figures in Cambodia, in order to update the 2004 FPL to the prices at the time of the fieldwork, AMK uses a proxy: the rural FPL is updated with the Phnom Penh Consumer Price Index (CPI) for food and beverages. Details of the proxy update are shown in Table 3.

**Table 3 Proxy update of poverty line (1 US dollar = 4,118 Riel)**

| | Total Poverty Line 2004 | Food Poverty Line (FPL) 2004 | AMK Proxy FPL 2009 | |
|---|---|---|---|---|
| | | | Riel / day | US$ / day |
| Phnom Penh | 2,351 | 1,782 | 2,855 | 0.69 |
| Other Urban | 1,952 | 1,568 | 2,512 | 0.61 |
| Rural | 1,753 | 1,389 | 2,225 | 0.54 |

Several years ago almost all AMK clients were below the conventional definitions of the poverty line (Chetan, 2007). This study indicates that the number of clients below the poverty line has decreased but average food expenditure remains lower among ID clients than VB clients. Fig. 5 shows the Daily Food Expense per capita for both VB and ID AMK clients and compares it with the updated rural FPL (AMK proxy for May 2009). This confirms that most clients are consuming less than the minimum calorie intake per day and thus can be classified as poor, which partially confirms AMK's commitment to provide services to the poor.

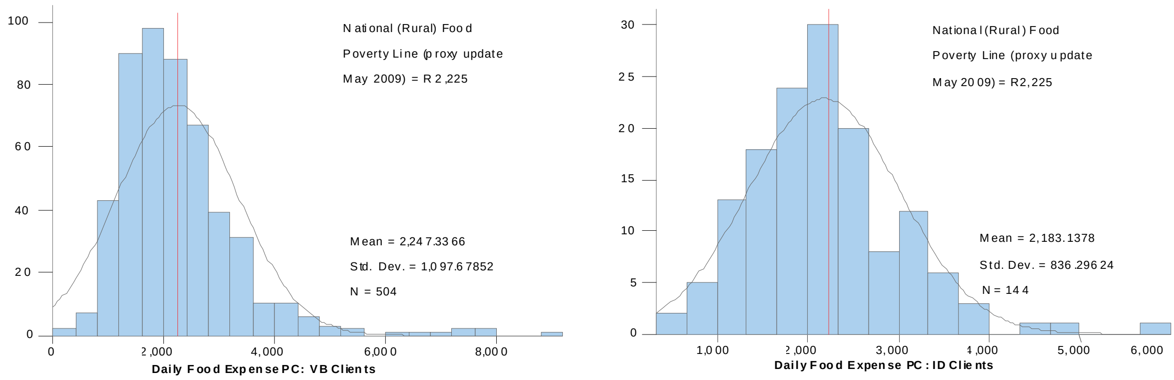


**Fig. 5 Daily food expenditure per capita**

As a national benchmark the overall Cambodian poverty headcount is estimated at 30.1%, but with wide variations: it was 35% in rural areas, 22% in other urban areas and only 1% in Phnom Penh as of 2007. As for national food poverty, 22% of the population in the rural, 11% in the urban and 1% in Phnom Penh are considered to consume less than FPL. Note that the percentage of non-client households who consumed less than this benchmark was lower (49%) but the significant test cannot confirm that the differences are statistically significant (Chi Square (N = 180) = 0.051, p = 0.821). Also note that the reasons for these large discrepancies in the poverty figures have not been completely assessed and that this issue is yet to be resolved.

However, new AMK clients below FPL were 71% in 2006, 75% in 2007 and 63% in 2008 (AMK, 2008). In 2009, food poverty analysis has shown that 56% of VB client households consumed less than FPL of R 2,225 (Table 4). Clients falling into the Poor tercile group had the highest percentage of household below FPL at 68%, followed by the medium and the better-off at 54% and 44%, respectively.

The study also indicates that 58% of ID client households consumed less than FPL of R 2,225. Meanwhile, the percentage of non-client households who consumed less than this benchmark was slightly lower at 56%. Poor group has the highest percentage of household below FPL at 78%, followed by the medium at 60% and the better-off at 39%.

**Table 4 Clients below the Cambodian FPL**

| Description | | Non-clients | Clients | | | |
|---|---|---|---|---|---|---|
| | | | Overall | Poor | Medium | Better-off |
| VB Clients | No. of HH below the FPL | 62 | 283 | 128 | 90 | 65 |
| | % of HH below the FPL | 49 | 56 | 68 | 54 | 44 |
| ID Clients | No. of HH below the FPL | 20 | 83 | 25 | 41 | 17 |
| | % of HH below the FPL | 56 | 58 | 78 | 60 | 39 |

## CONCLUSION

The results of the two measures of depth of poverty outreach (the AMK Wellbeing Score and the rates of absolute poverty compared with Cambodian FPL for rural areas) allow the conclusion that based on the Wellbeing Score AMK is reaching less better-off clients than what is found in the control group of non-clients, but more medium and poor level households. The results of AMK's depth of poverty outreach for VB clients in 2009 based on the number of clients who fell below the Cambodian Food Poverty Line, confirm that indeed AMK clients are poor with 56% of clients below the line.

The results of AMK's depth of poverty outreach for ID clients in 2009 based on the Wellbeing score indicate that these clients are on average relatively better-off than VB clients. However, this is somewhat skewed upward due to a high proportion of very well off ID clients. With a Wellbeing Score assessment only among the ID samples, AMK is reaching more medium clients than what is found in the control group of non-clients but less in better-off and poor-level households. The results of AMK's depth of poverty outreach for ID clients in 2009 is based on the number of clients spending less on food than the Cambodian Food Poverty Line, and this confirms that indeed AMK clients are poor with 58% of clients falling below the Cambodian Food Poverty Line.

## ACKNOWLEDGEMENTS

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Gulli, H. (1998) Microfinance and poverty, Questioning conventional wisdom. Microenterprise Unit, Sustainable Development Department, Inter-American Development Bank, USA.

Research article

# Cattle Feeding and Management Practices of Small-holder Farmers in Kampong Cham Province, Cambodia

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**Abstract** Almost all cattle in Cambodia are produced by small-holder farmers. The cattle are raised in an extensive way for draught power and wealth accumulation purposes. Feed availability is a major challenge for farmers associated with poor management which limits cattle productivity. This study reports a survey which was conducted to describe the cattle feeding and management practices of small-scale farmers in Cambodia. Sixty farmers raising cattle in Kang Meas and Tbong Khmum districts in Kampong Cham Province were randomly selected for an interview in 2008. On average the interviewed farmers raised 4-5 cattle per household. Most of them had cows aged older than 3 years which were mainly kept for breeding. More than 80% of cattle in Kang Meas were crossbred, but about 40% of cattle in Tbong Khmum were local breed. Very few farmers practiced weaning and none timed the date for their cows to calve. However, most of them selected a bull in their village for mating to cows. No artificial insemination was practiced in the village. The majority of farmers vaccinated their cattle to prevent the Hemorrhagic Septicemia (HS) while very few de-wormed their cattle. Cattle feed was mainly based on grazing in dry and rainy seasons. During the flooding season farmers in both districts relied on cut-and-carry native grasses and crop residues. Lastly, 60-70% of farmers sold cattle while only 10-20% bought cattle during the last year. In conclusion, cattle management by small-holder farmers was assessed as very low in terms of management and feeding. Farmers still raise their cattle in the traditional way with low health care intervention. Better housing of cattle with proper health care and improved feeding systems are recommended to farmers as ways to improve cattle production.

**Keywords:** Cattle feeding, management, small-holder farmers, production, Cambodia

## INTRODUCTION

In Cambodia, livestock accounts for 20.9% of agricultural GDP and contributes 7.6% to overall GDP (FAO, 2005). Most livestock, including cattle, poultry and pigs are produced by small-holder farmers. According to Ballard and Thun (2007) small-scale farms produce nearly 85% of total livestock and meat in the country. Moreover, small-scale producers own 75% of the pig population, 85% of poultry and nearly all cattle and buffalo. As most Cambodian people are engaged in crop production, cattle are mainly used for draught power in the household.

Cattle are raised in an extensive way in small-holder production systems in Cambodia and there are several breeds of cattle. Native yellow cattle are the most common breed while other major breeds are Haryana and Brahman (Harding et al., 2007). There is not proper genetic improvement program as the natural breeding is widely practiced by farmers. Then the feeding systems for cattle are characterized by the use of a wide diversity of feed resource. These are based largely on the use of crop residues, forages and other resources. Rice straw and other crop residues including grasses, weeds and shrubs are the dominant feedstuffs.

Harding et al (2007) reported that there are two basic systems of cattle production in Cambodia, but each has the same constraint. In lowland areas, the land is dominated by rice which creates significant constraints for feeding cattle. There is more land available in upland areas; however, most of this land is unavailable for cattle production because the government has conceded it to private companies. There is a relationship between the labor constraint faced by small-holders and the availability of grazing land. The severity of feed shortage varies between regions, but poor nutrition is a common problem. Poor nutrition also contributes to a higher incidence of cattle diseases and parasites. The major diseases that affect cattle and buffalo in Cambodia are HS, Foot and Mouth Disease (FMD) and blackleg (MAFF, 2006). Other major health problems experienced are parasites, with liver fluke being the major internal parasite (Soun et al., 2006) and ticks and flies the major external parasites. Animal health is recognized to be the source of production losses such as low weight gain, draught performance, fertility and lactation (Copeman and Copland, 2008).

Kampong Cham province accounts for 13% of cattle population of the country and has great potential for cattle development with small-holder farmers. In 2003, the use of forage fodder banks was introduced by CIAT through the Livelihood and Livestock Systems Project in this province. To improve cattle production of small-holder farmers in Cambodia, the project “Improved Feeding Systems for More Efficient Beef Cattle Production in Cambodia”, which is funded by the Australian Center for International Agriculture Research (ACIAR), is being carried out from 2008 to 2011. The research reported in this paper is a baseline study of the above project with the aim of describing the cattle feeding and management practices of small-holder farmers in Kampong Cham Province.

## METHODOLOGY

Two districts in Kampong Cham, Kang Meas and Tbong Khmum, were selected for this study as they are the target area of the project. Geographically, these districts are different with Kang Meas being a lowland area along the Mekong River receiving flooding every year while Tbong Khmum is a high land area. Thmey Kor village located in Roka Koy commune in Kang Meas district was chosen as research site 1 and Chroy Ko village located in Chiro Pi commune in Tbong Khmum district as research site 2. The stratified random sampling method was used for the sample selection for an interview. First, a list of all households of each survey site was assembled with the help of the chief of village, showing which households raised cattle and which households have planted forages. Sixty farmers raising cattle (30 from each research site) were randomly selected for the interview using a semi-structured questionnaire. The questionnaire was designed to understand cattle herd size and structure, husbandry practices, feed management and cattle buying and selling practices. All data from the survey, both qualitative and quantitative data, were stored in Windows Excel and analyzed using SPSS version 13.0.

## RESULTS AND DISCUSSION

### General characteristics of cattle production in studied areas

Large scale cattle production was not typical in the studied areas. Farmers kept a small number of cattle as they did not have enough capital to invest more in cattle production. About 60% of farmers in both districts raised their own cattle, but 40% also raised cattle for other rich farmers by sharing the returns. Cattle production contributed about the same proportion to household income (about 20%) in both studied sites, even though the income from crop production was different.

Most farmers in the study areas kept their cattle under the house during the night, with or without mosquito nets. The cattle were not kept under the house during the day; they may be tied under a tree or kept in the surrounding field, although this provides no shade to cattle. Cattle are grazed in the field when there are no crops. Farmers also spent a lot of time cutting and carrying native grasses or crop residues to feed their cattle. They rated the lack of feed and disease as the most challenging factors in cattle production. The cows had low productivity because the inter-calving was too long while growing cattle had low growth rate.

**Cattle herd size structure**

The percentage of the households raising different types of cattle and average number of cattle per household are shown in Table 1. Farmers in both studied sites raised on average 4-5 cattle per household. Most households (more than 80%) had cows older than 3 years, but the average number of cows was higher (P=0.042) in Tbong Khmum (2.33) than in Kang Meas (1.57). However, bulls were more important for farmers in Kang Meas (43%) than in Tbong Khmum (3%). The number of bulls per household was significantly higher (P=0.000) in Kang Meas (0.97) than in Tbong Khmum (0.07). Furthermore, around a half of farmers in both sites raised young bulls and heifers in their farm, with more heifers than bulls. Only one third of farmers in both sites had male or female calves in their household.

**Table 1 Percentage of farmers raising different type of cattle and average number per household**

| | Kang Meas | | Tbong Khmum | | P-value |
|---|---|---|---|---|---|
| Types of cattle | Percent | Mean | Percent | Mean | |
| Bulls >3 years | 43 | 0.97 | 3 | 0.07 | 0.000 |
| Young Bulls 0.5-3 years | 37 | 0.43 | 50 | 0.8 | 0.125 |
| Male Calves 0-0.5 years | 13 | 0.17 | 37 | 0.47 | 0.062 |
| Cows >3 years | 80 | 1.57 | 87 | 2.33 | 0.042 |
| Heifer 0.5-3 years | 43 | 0.7 | 57 | 1.27 | 0.178 |
| Female Calves 0-0.5 years | 20 | 0.23 | 33 | 0.38 | 0.297 |
| Total | - | 4.3 | - | 5.3 | 0.230 |

**Breeds of cattle and production purpose**

Fig. 1 shows that most farmers in Kang Meas (82%) had crossbred cattle in their farm while very few raised local or Haryana cattle. However, local cattle were the most common for farmers in Tbong Khmum (45%) followed by crossbred and Haryana. No farmers in the studied area had Brahman cattle.

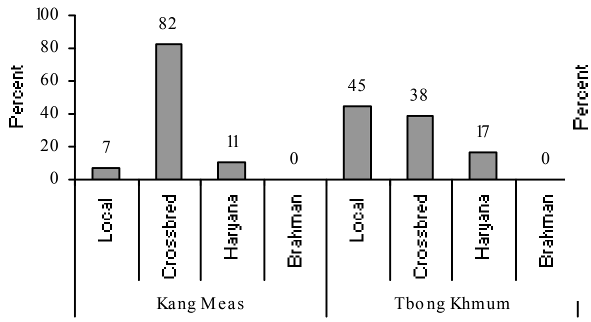



**Fig. 2 Percentage of farmers keeping different cattle breeds**

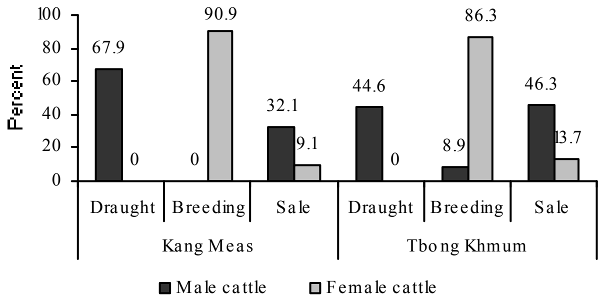



**Fig. 1 Percentage of purpose of cattle production by sex of cattle**

The purpose of cattle production by sex of cattle is illustrated in Fig. 2. The result shows that the majority of female cattle in both studied sites were raised for breeding purpose (up to 90%) while very few were sold. Breeding cows refers to the cow that produce calves for keeping in the farm or selling when farmers needed money. On the other hand, male cattle were primarily used as draft power by farmers. More cattle in Kang Meas (68%) were draught animals than in Tbong Khmum (44.6%). Apart from draught purposes, male cattle were also kept for sale (32.1% in Kang Meas and 46.3% in Tbong Khmum). Finally, only 8.9% of male cattle in Tbong Khmum were breeding cattle.

**Cattle husbandry practices**

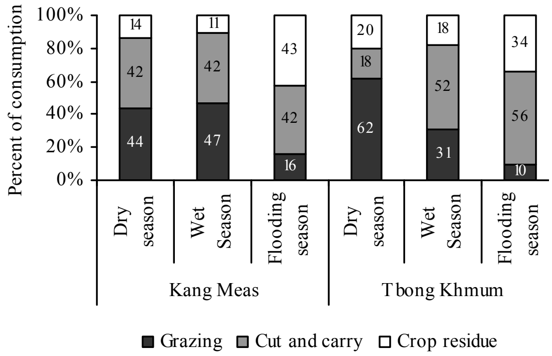
The cattle husbandry practices of farmers are summarized in Table 2. There were only 17% of farmers in Kang Meas who separated (weaned) a calf from its mother. Farmers allowed the calf to suckle the cow until it stopped spontaneously (up to 12 months). Very few farmers timed the date for their cow to calve as only 10% considered this important. Castrating male cattle was more common. More than half the farmers in Kang Meas castrated bulls while one third did so in Tbong Khmum. Most farmers (more than 80%) chose and paid for a bull for mating their cows. Artificial insemination was not used as this technology had not been introduced in the study areas. The bulls chosen for mating were mostly sourced within the village as it was easy for farmers to manage cow mating. Around 80% of farmers led their cows to a bull in the village when they observed the peak of the heat period. Besides breeding, more than 80% in both sites vaccinated the cattle and only 20% did not. The disease which was the most preventive was HS. The rate of farmers vaccinating for FMD in Kang Meas was twice that in Tbong Khmum, 46% and 21% respectively. Black leg was a minor preventive disease for which only 4% in both sites undertook vaccination. No farmers had thought about Anthrax vaccination. Lastly, the rate of farmers de-worming their cattle was low - only 23.3% of the farmers in Kang Meas and 63% in Tbong Khmum.

**Table 2 Cattle husbandry practice of farmers in the survey sites**

| Information | Kang Meas (%) | Tbong Khmum (%) |
|---|---|---|
| Weaning calves | 17 | 0 |
| Castrating male cattle | 53 | 37 |
| Timing of calving | 7 | 3 |
| Paying a bull for mating cows | 87 | 93 |
| Source of bulls for mating cows | | |
| Own bull | 0 | 0 |
| Within village | 84 | 79 |
| Within district | 8 | 0 |
| Outside district | 8 | 21 |
| Using artificial insemination | 0 | 0 |
| Vaccinating their cattle | 80 | 80 |
| Kinds of vaccination | | |
| HS | 87.5 | 100 |
| FMD | 46 | 21 |
| Black leg | 4 | 4 |
| Anthrax | 0 | 0 |
| De-worming their cattle | 23 | 63 |

**Feeding management**

The cattle feeds were mainly natural grasses and rice straw. The grasses were provided by grazing and cut-and-carrying and the rice straw was used during scarcity of natural grasses. Farmers also used some other crop residues such as maize stems and sweet potato stems as additional feeds for their cattle. As shown in Fig. 3 the main source of cattle feed consumption in dry season was grazing on the field (45% in Kang Meas and 62% in Tbong Khmum).



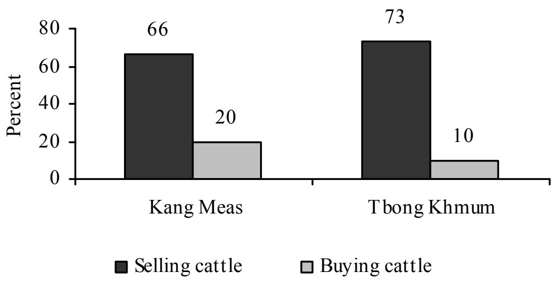




**Fig. 3 Feed consumption by different season**

**Fig. 4 Percentage of farmers buying and selling cattle during the last one year**

There was more dependence on 'cut and carry' of native grasses in Kang Meas (42% compared to 18% in Tbong Khmum). In the early wet season, cattle feed was grazing (47%) and 'cut and carry' (42%) in Kang Meas. By contrast in Tbong Khmum 'cut and carry' was more important (52%) because more land was available for collecting native grasses. Farmers in both sites depended on 'cut and carry' and crop residues for cattle feed in the flooding season. More than 80% of feed was sourced from these two kinds of feeds. The farmers in Kang Meas utilized rice straw, maize stem and sweet potato stem for their cattle while the farmers in Tbong Khmum also used other crop residues such as bean stem, peanut stem and rice bran. Lastly, there was more native grass cut for cattle in Chroy Ko (56%).

**Cattle buying and selling**

The percentage of cattle sold and bought by the farmers in the studied areas during the last 12 months is shown in Fig. 4. Sixty to seventy percent of farmers sold their cattle while only 10-20% of them bought 1 or 2 cattle during the last year. Cattle selling and buying occurred most commonly between farmers with female cattle. Female cattle were bought for cow-calf production. However, sometimes small traders or market sellers came to the village to buy cattle. These traders mostly bought male cattle for slaughter and sale in the local market or for transport to other provinces and neighboring countries. The money from selling cattle was not used to buy more cattle, but farmers used the funds for different purpose.

## DISCUSSION

In small-holder cattle production systems, cows were most important for farmers because they were used for breeding to produce calves. However, bulls were used for draught purposes, especially in the areas along the Mekong River (Kang Meas). In the last 10 years, it was reported that cattle were mainly kept as draught animals rather than for meat production as they were concentrated in the rice growing areas (Maclean, 1998). Cattle were also raised for selling indicating that farmers were responding to market demands. Cattle along the Mekong River were almost all crossbred, however, more local breed cattle were found in the upland area (Tbong Khmum). Harding et al (2007) found that cattle were concentrated along the Mekong because more forage was available.

Cattle husbandry intervention of farmers was low in terms of health and disease control. Windsor (2008) reported that farmers had little knowledge of husbandry and did not have funds to improve husbandry. The breeding program was absent in small-holder cattle production systems. Breeding was done by selecting a bull within the village to mate cows. Inbreeding could be a problem if no records were kept of breeding and management. Vaccinations in the studied sites were only available for some diseases such as HS and FMD. Some farmers did not have access to vaccines and some were not concerned. Since cattle were generally grazed in the fields for farmers were not able to provide best cattle management practices. Management of cattle in pens is a better way to control the condition and health of cattle and to provide necessary treatments. Vaccination to prevent some common diseases must be provided to cattle to minimize the economic losses.

Cattle feeds were mainly natural grasses and rice straw. The grasses were provided by grazing and cut-and-carrying, which required high labor input. Windsor (2008) reported that more than 4 hours were required for those activities. Because of feed scarcity, especially during the flooding and dry seasons, farmers fed rice straw to their cattle which had very low nutritive quality. There are some options for farmers to improve the feeding system of their cattle. First, supplementing traditional feed resources with planted forages is a simple solution (Stür and Horne, 2001). Forages are grasses and legumes that can be used for feeding animals and for better management of the environment (Stür and Horne, 1999). Planting forage can help farmers to solve problems such as general feed shortages, dry season feed shortages, and freeing up labor for feeding animals. Second, to increase the quality of crop residues such as rice straw, farmers can provide small amounts of protein and mineral supplementation such as sugar, salt, urea, oil cakes, fish meals and rice by-product. Another option to improve the quality of available feed resources, such as maize stems, sweet potato stems and sugar cane stems, is to make them into silage for cattle feed. Even though these options require extra inputs, farmers can choose the best option for them based on to their resources.

Small-holder farmers do not think about the time of calving and weaning. According to Petit et al. (1992), cows should be managed to calve before the grass growing season and calves weaned at the end of the season. During this season, cows eat more than the requirement for maintenance and lactation and use the extra nutrient to recover their body weight and fat reserves. Then the cycle of oestrus and ovulation is stimulated.

Lack of feed is a serious problem for cattle productivity which limits the ability to expand cattle numbers (Harding et al., 2007). Farmers had less opportunity to participate in cattle markets. Selling and buying of small-holder cattle mostly occurred between farmers. Others such as local traders, market sellers and slaughterhouses sometimes come to the village to purchase cattle. Ramsay and Maclean (1998) found that cattle were less frequently brought to town to sell directly to slaughterhouses or to consumers.

There are two options for small-holder farmers to improve the cattle production in order to increase their income. The first option is to fatten cattle for 2-4 months before sale to increase the meat yield and enable farmers to receive a higher sale price. Fattening refers to keeping cattle in pens and feeding them good quality forages and water. It is easy for farmers to check the condition and health of animals in the pens and provide treatments including de-worming and vaccinations (Stür and Varney, 2007). The second option is to improve cow-calf production which is the most important production cycle in small-holder system. More efficient cow-calf production means that cows can produce as many calves as possible by reducing the inter-calving period. Underfeeding during lactation may reduce the milk yield of the cow and the growth rate of its calf (Hodgson et al., 1980), especially when the cows are already thin at calving. So good quality feeds must be provided to cows during lactation. Weaning of calves at age of 40-70 days will help cows to return to oestrus and conceive during the breeding season (Laster et al., 1973). However, the weaning time is depended upon the condition of calf and the good quality and adequate feed should be provided to the weaned calf.

## CONCLUSION

The cattle production of small-holder farmers was assessed as very low in terms of management and feeding. Farmers raised their cattle in the traditional way with low health care intervention. Moreover, there was no breeding program to manage the genetic improvement in small-holder cattle production systems. Cattle feeds were mainly based on natural grasses and rice straw. Providing locally available feeds was a major challenge for farmers which required high labor input, especially during the dry and flooding seasons. Lack of feed was a critical factor limiting the ability of farmers to expand cattle numbers. As a result, farmers had less opportunity to participate in cattle markets. Better housing of cattle with proper health care and improved feeding system is recommended to improve cattle production. Planting forages including grasses and legumes is a simple solution for farmers to respond to the lack of feed. Keeping cattle in pens for fattening before sale and improving cow-calf production can help improve management of cattle in order to increase income and expand the number of cattle to respond more to market demand

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Research article

# Incentives of Local Farmers toward Organic Fertilizer Application in Nan Province of Thailand

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**Abstract** In recent year, many of agricultural and environmental problems occur due to high amounts of agricultural chemical or pesticide applied. The most important step for reducing soil degradation or water pollution is to mitigate nutrient losses from agriculture fields where used to work as non-point sources. For decreasing the amounts of agricultural chemicals, organic fertilizer has been proposed as it may contribute to reduce the expense of agricultural chemicals and to be safe for human health and natural environment. However, it is important to make farmers understand the background of the application of organic fertilizers, such as its benefit or technology, through the demonstration or the training. The studies were conducted to evaluate granular compost application comparing with chemical fertilizer or conventional compost application from viewpoints of reducing soil and nutrient losses under natural rainfall, and of plant growth for 2 cycles of cultivation in agricultural field. The experimental results showed that in the natural rainfall having 14 to 38 mm/hr, the losses of soil, total nitrogen and organic matter from the plot applied granular compost were significantly lower than that from the plot applied chemical fertilizer or conventional compost. Additionally, the results of the 1st cultivation showed that plant length and live weight of the ridge broadcasted granular compost after planting were higher as same as the ridge applied chemical fertilizer. However for the 2nd crop, plant length and live weight of the ridges applied granular compost before or after planting were the highest among all ridges. It means granular compost application is the effective way for decreasing the amounts of soil and nutrient losses from agricultural fields, and for making plants grow efficiently.

**Keywords** organic fertilizer, granular compost, soil loss, nutrient loss, plant growth

## INTRODUCTION

Since 50 years ago, there has been a major change in agricultural sector from small scale farming to larger monoculture for commercials or agro-businesses. Farm productivities have increased dramatically with lager amounts of chemical fertilizers and pesticides applied (Novotny, 1999).

Agriculture fields are recognized as a non-point source of nutrient components, which causes pollution in the water system (Sharpley et al., 1994). Especially, eutrophication occurs when the nutrients in sediments, animal wastes, plant nutrients, crop residues or chemical fertilizer are discharged into the water system by surface runoff or percolation (White and Howe, 2004). Boers (1996) reported that agriculture caused 60% of total nitrogen losses and 40-50% of total phosphorus to the further down water system which were mainly caused by the large amounts of fertilizers used.

Especially, soil erosion is one of the dominate processes discharging nutrients associated with soil particles or organic matters (Correll et al., 1999). Mihara (2001) reported that around 40% of annual nitrogen loads from the vegetable fields were lost by one day typhoon event. Surface runoff with severe soil erosion was the main factor to enhance nitrogen loss from agricultural fields.

So, a strategy to reduce agricultural nutrient losses especially nitrogen and phosphate needs to be implemented where water systems have been identified as at risk or polluted. The most important step in the control of soil degradation or water pollution is mitigating nutrient losses from agriculture fields or non-point sources (Johnes, 1996; Cherry et al., 2008).

The objective of this research is to evaluate granular compost application comparing with chemical fertilizer or conventional compost from a viewpoint of reducing soil and nutrient losses in the field under natural rainfall and plant growth for 2 cycles of cultivation.

## RESEARCH METHODS

### Soil and nutrient losses under natural rainfall

In the experiment of soil and nutrient losses under natural rainfall, 4 plots (Fig. 1) of 0.8 m wide x 2.5 m long were set up in the agricultural fields of Nan, Thailand. As shown in Table 1, fertilizers of chemical, conventional compost and granular compost were broadcasted in each plot at the same rate of 10.0 g N/m$^2$. Then, surface runoff occurred by natural rainfall was sampled and the concentration of soil, total nitrogen and organic matters was analyzed. In addition, surface discharge was measured at a certain interval.

**Table 1 Soil and fertilizers applied for field experiment at Nan**

| | Total nitrogen (g/kg) | Organic matter (g/kg) | Soil type |
|---|---|---|---|
| Field experimental soil | 0.05 | 61.3 | Light clay |
| Chemical fertilizer | 80 | - | - |
| Conventional compost | 10.7 | 320.9 | - |
| Granular compost | 8.83 | 302.1 | - |

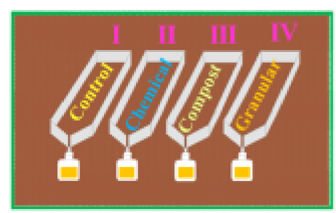



**Fig. 1 Field experimental plots**

### Plant growth for 2 cycles of cultivation

Plant growth for 2 cycles of cultivation was conducted in the agricultural fields of Nan, Thailand for observing the efficiency of plant growth by fertilizers applied. Six ridges (Fig. 2) of 1.0 m wide x 2.0 m long were prepared in the fields and fertilizers of chemical, conventional compost or granular compost was broadcasted in each ridge at the same rate of 10 g N/m$^2$.

For the 1st cultivation, morning glory (*Ipomoea aquatica*) was planted by seeding at the same amount of seeds in each ridge on 5 July, 2007. After 25 days growing, morning glory was harvested and measured the live length and weight on 30 July, 2007. Then after 4 days of harvested morning glory, the 2nd cultivation of kwang tung (*Brassica juncea* var.) was cultivated at the same soil of six ridges from 3 to 31 August 2007 for 28 days without any fertilizers added. Then plant length and live weight were measured. Plant growth for 2 cycles of cultivation was conducted under natural condition with giving same amounts of irrigation at 5-7 mm/day to every ridge.

- **Ridge 1: no added any fertilizer**
- **Ridge 2: applied chemical fertilizer after planting**
- **Ridge 3: applied compost before planting**
- **Ridge 4: applied compost after planting**
- **Ridge 5: applied granular compost before planting**
- **Ridge 6: applied granular compost after planting**

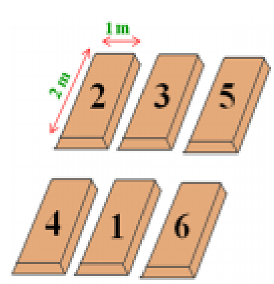



**Fig. 2 Six ridges for plant growth experiment**

## RESULTS AND DISCUSSION

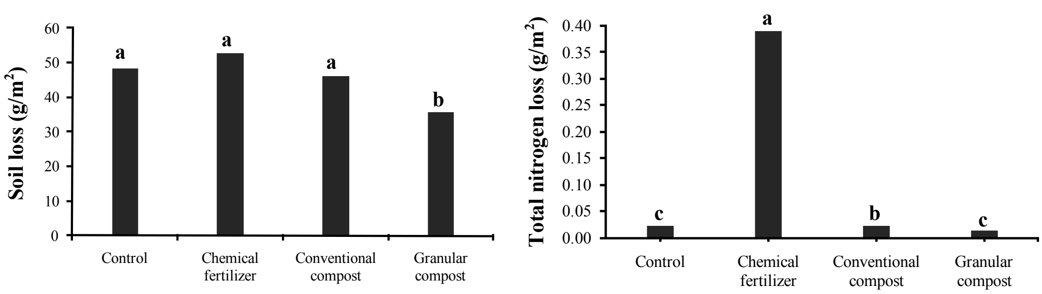
### Changes in soil and nutrient losses under natural rainfall

In order to evaluate granular compost application comparing with chemical fertilizer or conventional compost from a viewpoint of reducing soil and nutrient losses under natural rainfall, the experiment was conducted in Nan, Thailand on 24 July 2007.

The water samples of surface runoff from every plot were collected during the time of 5:00 – 7:00 a.m. This rainfall was started from 4:00 a.m. and finished around 8:00 a.m., and had rainfall intensities in the range from 14 to 38 mm/hr.

The losses of soil, total nitrogen and organic matters with surface runoff were measured and compared among the plots without fertilizer (control), with chemical fertilizer, conventional compost and granular compost.

As shown in Fig. 3, soil loss from the plot applied granular compost was significantly lower than that from other plots of control, chemical fertilizer and conventional compost at 95% confidence level based on one-way ANOVA analysis. Additionally, there was no significant different in soil losses among the plots of control, chemical fertilizer and conventional compost. It means that conventional compost was not effective for decreasing soil loss under this natural rainfall.

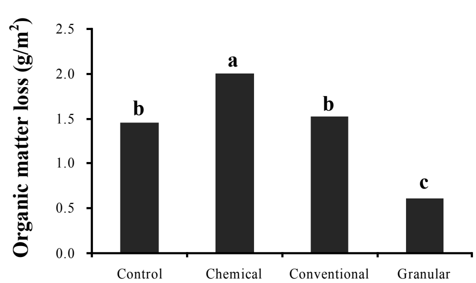



*The data followed by different letters differs significantly at 95% confidence interval based on one-way ANOVA.*

**Fig. 3 Soil and total nitrogen losses with surface runoff under the natural rainfall**

In case of total nitrogen losses, the results showed that total nitrogen loss from the plot applied chemical fertilizer was significantly higher than that from other plots at 95% confidence level. Additionally, total nitrogen losses from the plot applied granular compost and the plot of control were significantly lower than the plot applied conventional compost at 95% confidence level. So, it showed that total nitrogen in granular compost was not washed off easily by rainfall or surface runoff under the rainfall intensities from 14 to 38 mm/hr.

The results of organic matter losses (Fig. 4) with surface runoff showed the same tendency as soil loss. The loss of organic matters from the plot applied granular compost was significantly lower than that from the plot applied chemical fertilizer or conventional compost at 95% confidence level.



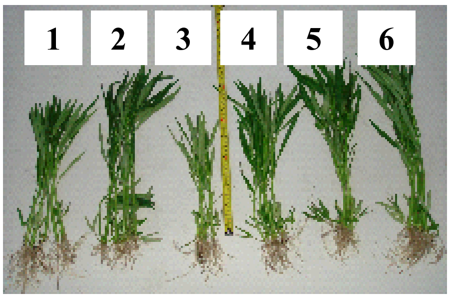

*The data followed by different letters differs significantly at 95% confidence interval based on one-way ANOVA.*

**Fig. 4 Organic matters losses with surface runoff under the natural rainfall**

**Changes in plant growth for 2 cycles of cultivation**

The experiment of plant growth for 2 cycles of cultivation was conducted in the agricultural fields of Nan, Thailand for observing the efficiency of fertilizers applied for plant growth. Duration of cultivating the 1st cultivation of morning glory (*Ipomoea aquatica)* was from 5 to 30 July 2007. Then the 2nd cultivation of kwang tung (*Brassica juncea* var.) was cultivated at the same soil without any fertilizers added at six ridges from 3 to 31 August 2007.

Fig. 5 shows the 1st cultivation of morning glory *(Ipomoea aquatica*) and Fig. 6 the 2nd cultivation of kwang tung (*Brassica juncea* var.). The efficiency of fertilizers for plant growth was evaluated by the measurement of plant length and weight.




- Ridge 1: no fertilizer added
- Ridge 2: broadcasted chemical fertilizer after planting
- Ridge 3: mixed compost with soil before planting
- Ridge 4: broadcasted compost after planting
- Ridge 5: mixed granular compost with soil before planting
- Ridge 6: broadcasted granular compost after planting

**Fig. 5 First crop cultivation in Nan**


- Ridge 1: no fertilizer added
- Ridge 2: no fertilizer added after the 1st crop cultivation
- Ridge 3: no fertilizer added after the 1st crop cultivation
- Ridge 4: no fertilizer added after the 1st crop cultivation
- Ridge 5: no fertilizer added after the 1st crop cultivation
- Ridge 6: no fertilizer added after the 1st crop cultivation

**Fig. 6 Second crop cultivation in Nan**

The results of plant length for 2 cycles of cultivation were shown in Fig. 7. The 1st cultivation showed that plant length of the ridges broadcasted conventional compost and granular compost after planting was higher than 47 cm, it was similar to the plant length of the ridge applied chemical fertilizer. Plant length of the 1st cultivation from the ridges mixed conventional compost or granular compost with soil before planting tended to be short; it may be affected from releasing rate of nutrients from fertilizers.

There were 2 ways of fertilizations in plant growth experiment, one was applying fertilizers and mixing with soil before planting and the other broadcasting fertilizers after planting. It was considered the nutrient releasing from fertilizers broadcasted after planting was higher than that mixed with soil before planting. So, plant growth in the ridges broadcasted fertilizers may be advanced more than that in the ridges mixed fertilizers with soil.

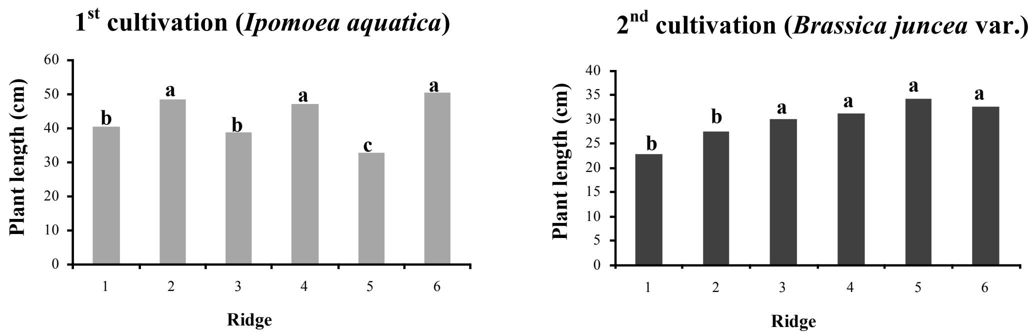
However for the 2nd cultivation, plant length of the ridges applied conventional compost before and after planting or applied granular compost before and after planting was significantly higher than that of the ridge applied chemical fertilizer at 95% confidence level.

Additionally, the 1st cultivation showed that plant weight (Fig. 8) of the ridges broadcasted granular compost after planting was 16 g heavier, and there was no significant different with plant weight of the ridge broadcasted chemical fertilizer at 95% confidence level. However, in the 2nd cultivation, plant weight of the ridge applied chemical fertilizer was the lowest among all ridges. Conversely, plant weight of the ridges applied granular compost before and after planting was significantly higher than that of all other ridges at 95% confidence level.

**Discussion from soil and nutrient losses and plant growth**

Granular compost application was compared with chemical fertilizer or conventional compost application from a viewpoint of reducing soil and nutrient losses under natural rainfall in the selected agricultural field of Nan province, Thailand. The rainfall intensities of field experiment were from 14 to 38 mm/hr at 30 minutes interval. But during the natural rainfall, there were high intensities beyond 50 mm/hr for several minutes. So, other areas having different rainfall intensities, the results of soil and nutrient losses may be difference.

Additionally, plant growths for 2 cycles of cultivation were conducted in the field of Nan province, Thailand. The types of vegetables applied in this research were popular and suitable for evaluating the fertilization effects within a few months. The results showed that conventional compost or granular compost broadcasted after planting was effective not only for the 1st cultivation but also for the 2nd cultivation. It was considered that the way of fertilization affects to the processes of decomposing and releasing nutrients. Generally, there may be 2 types of decomposing processes. One is the physical process advanced by slaking, shearing force of flowing water or impact of raindrop, and the other is the biological process by microorganism which is mainly inorganic process including nitrification.

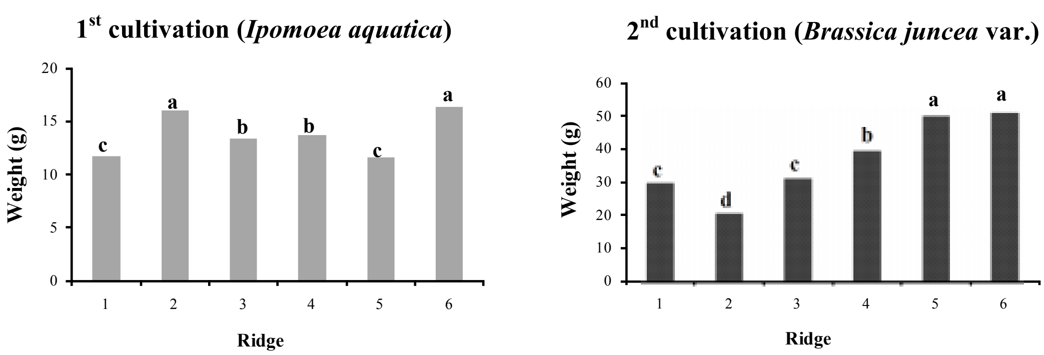



*The data followed by different letters differs significantly at 95% confidence interval based on one-way ANOVA.*

- Ridge 1: no fertilizer added
- Ridge 2: broadcasted chemical fertilizer after planting
- Ridge 3: mixed compost with soil before planting
- Ridge 4: broadcasted compost after planting
- Ridge 5: mixed granular compost with soil before planting
- Ridge 6: broadcasted granular compost after planting

- Ridge 1: no fertilizer added
- Ridge 2: no fertilizer added after the 1st crop cultivation
- Ridge 3: no fertilizer added after the 1st crop cultivation
- Ridge 4: no fertilizer added after the 1st crop cultivation
- Ridge 5: no fertilizer added after the 1st crop cultivation
- Ridge 6: no fertilizer added after the 1st crop cultivation

**Fig. 7 Plant length for 2 cycles of cultivation**




*The data followed by different letters differs significantly at 95% confidence interval based on one-way ANOVA.*

- Ridge 1: no fertilizer added
- Ridge 2: broadcasted chemical fertilizer after planting
- Ridge 3: mixed compost with soil before planting
- Ridge 4: broadcasted compost after planting
- Ridge 5: mixed granular compost with soil before planting
- Ridge 6: broadcasted granular compost after planting

- Ridge 1: no fertilizer added
- Ridge 2: no fertilizer added after the 1st crop cultivation
- Ridge 3: no fertilizer added after the 1st crop cultivation
- Ridge 4: no fertilizer added after the 1st crop cultivation
- Ridge 5: no fertilizer added after the 1st crop cultivation
- Ridge 6: no fertilizer added after the 1st crop cultivation

**Fig. 8 Plant weight for 2 cycles of cultivation**

## CONCLUSION

This research dealt with the evaluation of granular compost application comparing with chemical fertilizer or conventional compost application from viewpoints of reducing soil and nutrient losses under natural rainfall and of plant growth for 2 cycles of cultivation.

The results showed that in the natural rainfall having 14 to 38 mm/hr, the losses of soil, total nitrogen and organic matter from the plot applied granular compost were lower comparing with that from the plot applied chemical fertilizer or conventional compost. Additionally, the 1st cultivation from 5 to 30 July 2007 showed that plant length and live weight of the ridge broadcasted granular compost after planting were same as that of chemical fertilizer. However for the 2nd cultivation from 3 to 31 August 2007, plant length and live weight of the ridges applied granular compost before or after planting were the highest among all ridges. It means chemical fertilizer application was effective for plant growth in a short time, less than around 30 days, but it did not sustain more than the period.

According to the experimental results, it was concluded that chemical fertilizer or granular compost broadcasted after planting were the most effective for getting higher yields in the crop cultivation within 30 days. In case the duration of crop cultivation would be more than 30 days; granular compost applied either before or after planting was the most effective.

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Research article

# Market Channel and Trade of Fermented Small-Sized Fish Paste in Cambodia

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**Abstract** Fermented small-sized fish paste is considered to be one of the main food sources for Cambodians, especially for the poor. However, most small-sized fish are used as direct feed for aquaculture or dried for animal feed. This study was conducted in order to identify market channel and trade of fermented small-sized fish paste. Phnom Penh city, Kendal, Kampong Chhnang, Battambang, and Siem Reap Provinces were selected as the study areas. The study revealed that there were three main sources of product which should be considered when analyzing total volume of annual production. The total production of the fermented fish paste in 2007-2008 was around 6,659 tons, of which 50.18% was domestically consumed and 49.82% exported to Thailand and Vietnam. Marketing and trading differed according to trading sites, stakeholder characteristics, and fish species containing in the fermented fish paste.

**Keywords:** Market channel, trade, small-sized fish, fermented small-sized fish paste, Cambodia

## INTRODUCTION

Fish has played an important role in ensuring food security in Cambodia. Fermented fish paste (or Prahoc in Khmer), a processed fish product, is a concentrated form of fermented fish which is typically made from small freshwater fish in which the fermentation has digested the fish to the point where the form of the fish is no longer clearly visible (Hortle, 2007). Fermented fish paste is desirable and is kept in houses all year round. It contributes to food availability, especially in the period when fresh fish is in short supply. There are two kinds of fermented fish paste - boneless and bony fish paste - which are bought and used by different classes of people. Some boneless fish paste is processed from small-sized fish species, but it is sold at a higher price compared to that of bony fish paste. Normally bony fish paste, also processed from small-sized fish, is consumed by the poor who have limited income.

Nearly all small-sized fish - around 92% - are used as direct feed for cage and pond aquaculture (So et al., 2005). These competing uses are a challenge to human consumption, especially to the poor. Based on the rapid decrease of small-sized fish numbers in the river, the Royal Government of Cambodia placed a ban on snakehead fish farming. As a result more fish is available and an opportunity exists for the poor, and for small-sized fish paste stakeholders, to access more fish for their living and businesses. In addition around 50% of small-sized fish is processed into small-sized dried fish and salted fish or converted into small-sized fish paste or fish sauce (Asian Development Bank (ADB), 2006).

Information about fermented small-sized fish paste market and trade in Cambodia has not previously been investigated and understood. This study was conducted to identify the market channel and trade of fermented small-sized fish paste in Cambodia.

## METHODOLOGY

Phnom Penh City and Kandal Province, in the Mekong-Bassac River zone, and Kampong Chhnang, Battambang and Siem Reap Provinces, in the Great Lake and Tonle Sap River zone, were selected as study areas. Samples for interviews were categorized into six groups, processors, middlemen, exporters, wholesalers, retailers, and end consumers, based on their characteristics in the trade and markets. The total sample size in the study was 150. Two kinds of data, primary and secondary, were required for the study. Primary data comprised information from interviews. Structural interviews using six different design questionnaires were conducted with survey respondents who were purposively selected. Key informants, such as officers at Fisheries Administration Cantonment and local authorities in each city/province, were also semi-structurally interviewed, and observations conducted. Secondary data were taken from technical papers, books, journals, and other publications. The collected primary data were installed and analyzed in SPSS version 12.

## RESULTS AND DISCUSSION

There are three main actors in the fermented fish paste market channel:

Processors: Among the five study areas Kampong Chhnang has the largest amount of fermented small-sized fish paste processing. Fermented small-sized fish paste production rose from 1124 tons in 2000-2001 to 1,448 tons in 2007-2008, but declines occurred in the years 2002-2003 and 2005-2007 because of shortages and an increasing price of small-sized fish.

Exporting Companies: There were three exporting companies - Trey Meas and Marchhar Steoung Sangkae, located in Battambang Province and Marchhar Meas Angkor, based in Siem Reap Province. The total amount of salted small-sized fish bought, processed, and traded by these three exporting companies in 2001-2002 was 800 tons and rose to 4,139 tons in 2007-2008.

Wholesalers and Retailers: It was estimated that the total amount of fermented small-sized fish paste which went through wholesalers and retailers, and did not go through processors or exporters, was 1,071 tons in 2007-2008.

Thus, the total amount of the fermented fish paste produced in 2007-2008 was about 6,659 tons. Of this 3,341 tons (50.18%) was domestically consumed, 3,268 tons (49.07%) was exported to Thailand, and 50 tons (0.75%) was exported to Vietnam.

In 2000, the total amount of fermented fish paste produced by family-scale processors was between 17,500 and 25,000 tons. Commercial-scale processors produced 12,681 tons (Touch, 2001), of which 7,187 tons (56.68%) were domestically consumed and 5,494 tons (43.32%) were exported (Department of Fisheries, 2001). However, (Nao et al., 2001) state that the actual amount of fish paste exported was much higher.

About 58.82% of salted small-sized fish which was bought by middlemen came from fishermen; 92.75% bought by exporters came from middlemen; 73.50% bought by wholesalers was from middlemen; 43.13% bought by retailers was from processors. When sold, 63.83% was sold from processors to middlemen; 65.14% from middlemen to exporters; 88.74% from exporters to middlemen; 33.97% from wholesalers to provincial wholesalers/retailers. The fermented fish paste was mostly not classified when traded in markets.

This study also showed that the average price of fresh fish was 1,497 Riel/kg in 2007-2008 (processors) and of (final) fermented small-sized fish paste was 3,141 Riel/kg in 2000-2001, 3,594 Riel/kg in 2001-2002, 3,783 Riel/kg in 2002-2003, 4,014 Riel/kg in 2003-2004, 4,541 Riel/kg in

2004-2005, 5,026 Riel/kg in 2005-2006, 5,707 Riel/kg in 2006-2007, and 6,789 Riel/kg in 2007-2008, compared to the study of Touch in 2001 which showed that the price of bony fish paste per kilogram in 2000 was about 1,500 Riel and 5,000 Riel for boneless fish paste. Note that the exchange rate used is 4,000 Riel to 1 US Dollar.

Market channels of fermented small-sized fish paste differed in the five study areas. In Phnom Penh, the total amount of fermented small-sized fish paste which was marketed and distributed to other provinces was about 421 tons (6.34% of total amount of fermented small-sized fish paste (6,659 tons) being annually traded in Cambodia). In Fig. 1, processors in Phnom Penh played an important role to supply (final or finished) fermented small-sized fish paste to stakeholders in markets; they sold the product to provincial middlemen and markets, and to Phnom Penh middlemen and markets. Moreover, processors in Kandal Province also sold their (final) fermented small-sized fish paste to some markets and to middlemen in Phnom Penh. And middlemen in Phnom Penh also bought fermented small-sized fish paste in semi-final form (or called salted small-sized fish) from processors in Kampong Chhnang Province and from exporting companies in Battambang Province. After being processed and stocked in cement reservoirs or earthenware pots this fermented fish paste was sold to either Phnom Penh and provincial markets or consumers.

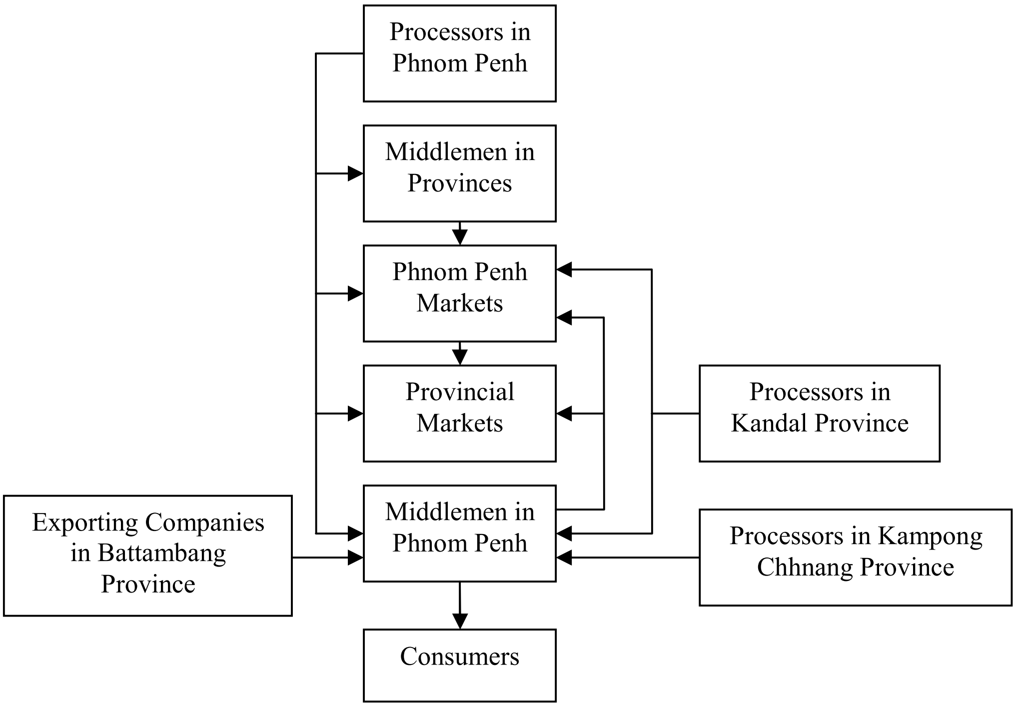


**Fig. 1 Market channel of fermented small-sized fish paste in Phnom Penh City**

In Kandal Province, the total amount of fermented small-sized fish paste which was either marketed within the province or distributed to other provinces was 445 tons (6.70% of the total amount being traded in Cambodia every year). As shown in Fig. 2, processors supplied fermented small-sized fish paste to middlemen in the province and to other provinces, to Phnom Penh and provincial markets, to middlemen in Phnom Penh, and to consumers. Middlemen both inside and outside the province sold the product to Phnom Penh market which it was then distributed from Phnom Penh markets to some markets in other provinces. Furthermore, middlemen in Kandal and other provinces, and those in Phnom Penh sold their products to markets in Kandal Province and to other provinces as well.

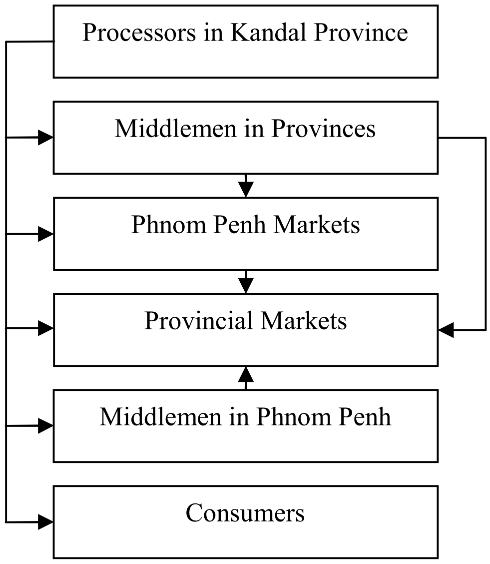


**Fig. 2 Market channel of fermented small-sized fish paste in Kandal Province**

The total amount of fermented small-sized fish paste which was being either marketed in Battambang or distributed to other provinces and to Thailand was 3,730 tons (56% of the total amount being traded annually in Cambodia). In Fig. 3, second processors in Battambang bought salted small-sized fish from first middlemen living near the Tonle Sap river. After being processed (through adding more salt or making into final products), the fermented fish paste was sold to wholesalers/retailers in markets, to middlemen both inside and outside the province and to Phnom Penh middlemen. Moreover, first processors in Battambang sold salted small-sized fish directly to some markets in Battambang and in other provinces. First middlemen in Battambang also supplied the salted fish to sellers in markets of Battambang and other provinces and exporting companies in Battambang. These companies bought salted small-sized fish from first middlemen in Kampong Chhnang. After being salted and stocked, it was sold out to second processors in Battambang, to provincial markets, to provincial middlemen, to Phnom Penh middlemen, and to Thai markets.

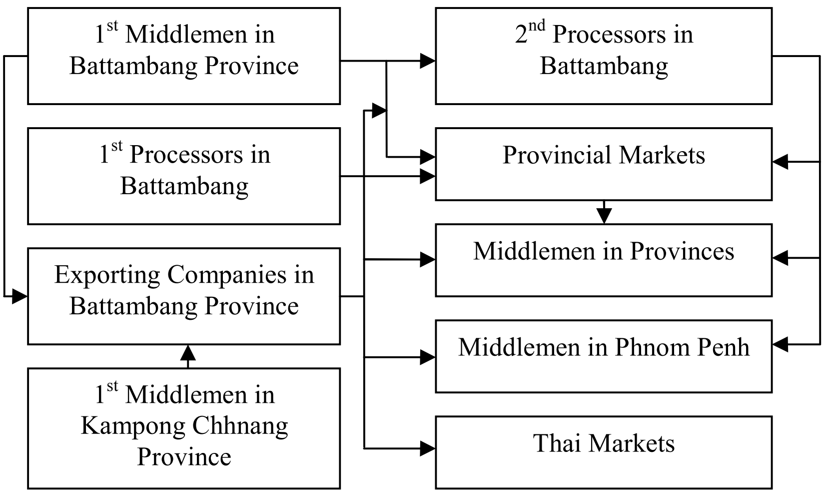


**Fig. 3 Market channel of fermented small-sized fish paste in Battambang Province**

The total amount of fermented small-sized fish paste which was being marketed in Kampong Chhnang and distributed to other provinces was 960 tons (14.43% of the total amount being traded in Cambodia). In Kampong Chhnang the product which was sold by processors was salted small-sized fish, called fermented small-sized fish paste by local people in the province. As shown in Fig. 4, the salted fish was sold from processors to Phnom Penh markets, to provincial markets, to second middlemen in the provinces, to middemen in Phnom Penh, and to other middlemen from other provinces. Some of the salted fish was taken to Vietnam by Vietnamese processors when the processing season was finished. Moreover, some of the salted fish was also exported to Thai markets by the processors. Additionally, first middlemen from other provinces also sold salted small-sized fish to second middlemen in the province and to some wholesalers and retailers either in the province or in other provinces. After being stocked (or sometimes not), the fermented fish paste was distributed to provincial markets, to middlemen in other provinces as well as in Phnom Penh city.

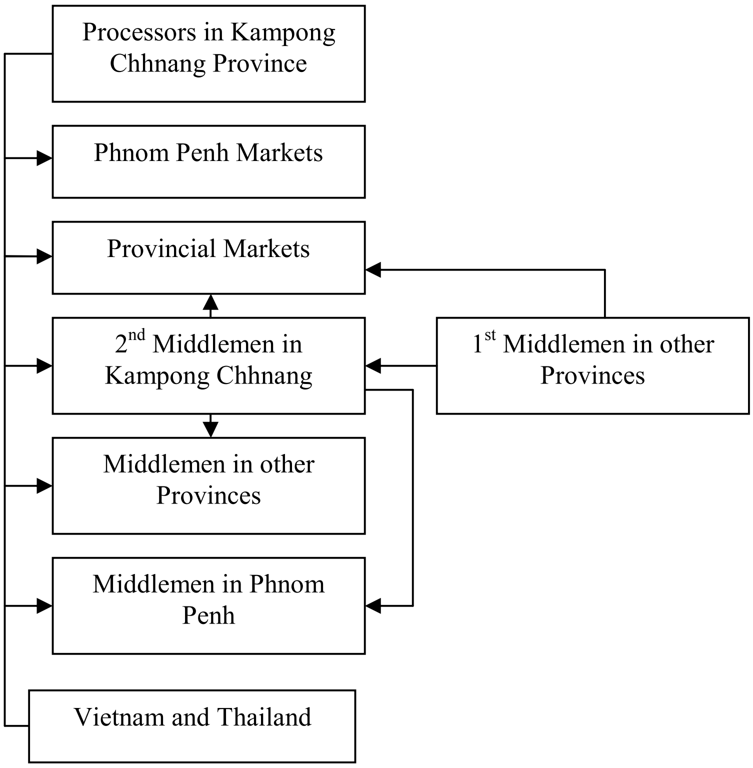


**Fig. 4 Market channel of fermented small-sized fish paste in Kampong Chhnang Province**

The total amount of fermented small-sized fish paste which was being marketed in Siem Reap, distributed to other Provinces and to Thailand was 1,100 tons (16.53% of the total amount being traded in Cambodia). Unlike the other four Provinces in Siem Reap both bony and boneless small-sized fish paste were marketed. Fig. 5 shows that processors sold fermented fish paste as finished products to markets and middlemen in the province, and to markets in Phnom Penh. Middlemen in the province also sold the fermented fish paste to markets in the province. In addition first middlemen in Pursat and Battambang Provinces brought salted fish from fishermen and sold to exporting companies in Siem Reap. After being salted and stocked (or sometimes not), the salted fish was exported to Thai markets. Furthermore, an exporting company in Siem Reap and first middlemen and first processors in Battambang sold salted fish and final fermented fish paste (mostly from exporting company) to wholesalers and retailers in some markets in Siem Reap Province. This would later be processed into finished products before sale to consumers.

Generally the market channels for fermented fish paste are affected by seasons, which determine the availability of fish for fermented small-sized fish paste processing. Seasonal factors influence the presence of the product in markets from month to month and business outcomes.

Overall, fermented small-sized fish paste is locally marketed and traded in both finished and unfinished form depending on the business purposes of stakeholders. The product was ultimately sold to domestic consumers as finished products or exported to neighboring countries as unfinished product which could later be processed into finished products to meet export market needs.

The market channel of fermented small-sized fish paste in the five study areas differed in terms of condition (finished or unfinished) and type (bony or boneless) of fermented small-sized fish paste being marketed, and means of transport (car, cart or boat).

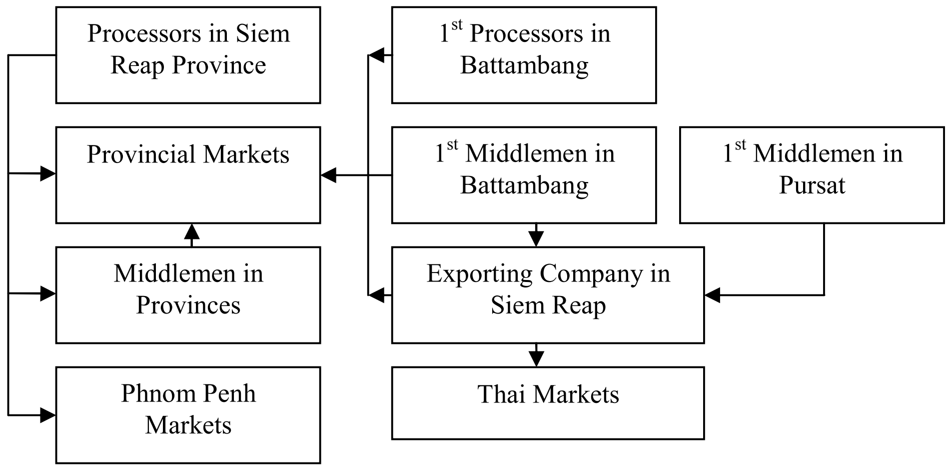


**Fig. 5 Market channel of fermented small-sized fish paste in Siem Reap Province**

## CONCLUSION

Fermented small-sized fish paste was traded differently according to trading sites, stakeholder characteristics, and fish species. Moreover the fermented fish paste market and trade was complicated because not only was finished fermented small-sized fish paste marketed and traded but also salted small-sized fish. Although there seemed to be complications in the market channel and trade, the fermented fish paste was sufficiently processed for domestic needs and nearly half of the total production was exported to neighboring countries. Most of the product which was exported to neighboring countries was in semi-final form which could reduce some of the added value. Hence, more value adding could be obtained if the product could be processed locally into finished products to meet the demands of consumers in other countries.

## ACKNOWLEDGEMENT

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*Research article*

# Comparison of Microbial Diversity of Paddy Soils in Sustainable Organic Farming

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**Abstract** Agricultural management significantly influences soil microbiological properties, such as microbial biomass carbon, microbial biomass nitrogen and respiration rate. Besides soil parameters, microbial diversity is useful for monitoring changes in soil quality to evaluate sustainable agriculture. This study aims to develop and use microbial diversity in rice soil as an indicator of soil quality for sustainable organic rice farming. An experiment was carried out using the existing rice fields (Kao Dawk_Mali 105 variety) in Surin Rice Research Center, Thailand. Four plots of rice received different management practices for over 11 years, including (1) conventional farming (CF) with a normal rate of chemical fertilizer applied, (2,3) two plots of organics: one with green manure (GM) and the other with rice straw (RS) and (4) a control plot (CT) without external sources of plant nutrients. Soil microbial communities were determined by cultural and molecular methods such as total plate counts, community level physiological profiling (CLPP) with BIOLOG$^{TM}$ Ecoplate, and PCR-amplified (16S rDNA) and analysed by denaturing gradient gel electrophoresis (DGGE). Two-way ANOVA of results revealed that total plate counts were significantly ($P<0.05$) affected by the four different management practices. However, the GM plot ($2.3x10^6$ CFU $g^{-1}$ of dry soil) and CF plot ($1.8x10^6$ CFU $g^{-1}$ of dry soil) were not significantly different ($P>0.05$). Likewise soil management practices influenced the microbial diversity, both in functional and genetic diversity in the rice plots studied. Further a narrow range of Shannon-Weaver diversity index ($H_f'$) was obtained with values between 2.77 for CT and 3.01 for GM. Statistical analysis (ANOVA) performed using substrate richness (S) from potential substrate utilization patterns as the input data, showed that the GM treatment increased the microbial diversity.

**Keywords:** Microbial diversity, organic farming, paddy soil, CLPP, PCR-DGGE

## INTRODUCTION

Rice production is commonly associated with conventional farming practices including the use of chemical fertilizers and pesticides. Therefore, conventional farming practices, if not managed properly, can have adverse environmental consequences (Schionning et al., 2004). To ensure human survival it is necessary to maximize rice production while minimizing negative effects on the environment (e.g. soil quality and microbial diversity). Alternative farming systems such as organic farming are required. Organic farming avoids or minimizes the use of synthetic fertilizers, pesticides and antibiotics. It has a positive effect on the build up of soil organic matter (SOM), mainly because of high organic matter inputs to the soil (green manure or rice straw), which is beneficial for soil microbial biomass and activity. Soil micro-organisms such as bacteria, fungi, protozoa, and nematode, play an important role in maintaining soil quality in agricultural management systems. Sustaining soil fertility is governed largely by the decomposition activity of the microorganisms. Agricultural management practices have been reported to influence soil microbial community structures (Sun et al., 2004). Microbial communities in soil mediate key processes that control ecosystem carbon (C) and nitrogen (N) cycling as well as other beneficial plant nutrients. The essence of sustainable agriculture is the maintenance of viable, diverse populations and functioning microbial communities in the soil. Microbial diversity relates to environmental impact and soil functioning, both of which seem inadequate for use as indicators (Anderson, 2003). Therefore, analyses of soil microbial diversity and community structures are essential when monitoring environmental influences on soil quality. Bacteria occurring in the soil are excellent indicators of soil health because they are involved in many soil processes and they respond quickly to changes in the soil ecosystem (Winding, 2004). Bacterial diversity is critical to ecosystem functioning because of the diversity of processes for which bacteria are responsible, including decomposition and nutrient cycling (Kennedy, 1999).

Recently a number of different methods and approaches have been used to investigate the microbial community. Previously investigation of microbial populations was determined by total plate count, which underestimates the actual soil microbial population. This is because less than 0.1% of agricultural soil micro-organisms are culturable. The BIOLOG$^{TM}$ EcoPlate assay is sensitive to changes in the short term from management practices. To investigate microbial diversity in the soil more data are required for PCR-amplified (16S rDNA) and analysed by DGGE to study genetic diversity of bacterial in the paddy soil. To accomplish this, a careful and thorough investigation of factors affecting bacterial diversity is required. A full appreciation of the genetic diversity of soil bacteria has not yet been accomplished compared to functional diversity. The aim of this paper is to investigate microbial diversity to serve as a biological indicator which can be further developed for use in an organic rice field.

## METHODOLOGY

### Study area, experimental design and soil sampling procedures

The study area was used to grow rice under organic and conventional farming at the Surin Rice Research Center, located in Korat Plateau, Muang District, Surin Province, Thailand (latitude 14$^{o}$ 55'N and longitude 103$^{o}$ 25'E). The studied soil belongs to the Roi Et series, which is widely distributed and used for rice production in northeastern Thailand. This soil has properties of an infertile acid loam and sandy loam to a depth of 10 cm, which is the active rhizosphere for rice plants and good microbiological activity. The experimental design consisted of four plots, each with an area of 0.16 ha. All four plots included (1) CF, using a chemical fertilizer (16-16-8, N-$P_2O_5$-$K_2O$), (2, 3) two organic treatments; one received Sesbania rostrata as GM, and the other treatment/plot with RS, and (4) control plot (CT), which has no external source of plant nutrients. Rice (Oriza sativa, KDML 105 variety) was grown on all plots under rainfed lowland conditions. Representative top soil samples were taken from the plots which have been cultivated with rice for eleven years. After sampling, all samples were kept at 4$^{o}$C for total plate count and BIOLOG$^{TM}$ EcoPlate analysis, and -20$^{o}$C for PCR-DGGE analysis. Each individual treatment was sampled three times in 2007; before growing rice in May, when maximum tillering occurred, and immediately after rice harvest. A topsoil layer (0-10 cm) was collected using a soil core device with diameter of 2.5 cm. Based on random sampling, six points were chosen from each plot and when the sampling was completed, topsoil from the six points was thoroughly mixed into one sample.

**Total plate count analysis**

The effect of agricultural management practice on the total number of culturable bacteria was determined by the plate count technique (pour plate) of colony-forming units (CFU). Five grams of fresh soil were prepared in 45 ml sterile ¼ Ringer solution (Merk, Germany), and homogenized in a centrifuge tube (50 ml) using vortex for 3 min. at maximum speed. Then the samples were centrifuged for 5 min at 129 x g (or 1,074 rpm) (Calbrix et al., 2007) and the supernatant liquids were serially diluted (10-fold steps) with sterile ¼ Ringer solution and 0.1 ml aliquots of each dilution were pipetted into a sterile Petri plate in triplicate, then melted tryptic soy agar (TSA) was poured in and mixed with the sample. All plates were incubated at $37^{o}C$ for 48 hr.

**Community levels physiological profile (CLPP) analysis**

CLPP was undertaken using the Biolog$^{TM}$ Ecoplate and each plate containing 96 microtiter wells was divided into three replicated sets. Thirty-two wells in each of the sets contained different substrates and a blank control well contained water. Soil extracts were prepared with 5 g of fresh soil in 45 ml sterile ¼ Ringer solution (Merk, Germany), and homogenized in a centrifuge tube (50 ml) using vortex for 3 min. at maximum speed. Then the samples were centrifuged for 5 min. at 129 x g (or 1,074 rpm) (Calbrix et al., 2007) and the supernatant liquid was diluted ($10^{-3}$ dilution) with sterile ¼ Ringer solution and inoculated onto BIOLOG$^{TM}$ EcoPlate system (Biolog Inc., CA, USA). The aliquots of 130 µl from a $10^{-3}$ dilution were inoculated into the microplates. The plates were incubated at $37^{o}C$ in dark. Color development in each well was examined optical density (OD) at 405 nm every 12 h for 7 d (Zak et al., 1994) using a microplate reader (DNM-9602G, Beijing Prolong New Technology Co., Ltd).

**Polymerase chain reaction-denature gradient gel electrophoresis (PCR-DGGE) analysis**

For the analysis, variations of diversity of microbial genes in paddy soil were studied using directly extracting total DNA, and amplifying 16S rDNA by PCR-DGGE. Community DNA was directly isolated from the paddy soil samples without duplicate using the FastDNA® SPIN Kit for Soil and the FastPrep® Instrument as described by the manufactures (MP Biomedicals, Solon, Ohio, USA). Extracted DNA was then purified by Sephadex G-50 Mini Column® according to the manufacture (Geneaid, Taiwan) to remove humic acid and fulvic acid contamination. Total bacterial communities were analysed with specific primer sets; 357f-GC and 518r (Kurisu et al., 2002; Muzer et al., 1993). Extracted DNA was amplified by PCR amplification using these specific primer sets (357f-GC and 518r) for 35 cycles in a 24 µl reaction volume. PCRs were performed using a thermal cycler (BioRad Laboratories, lnc). PCR mixtures were amplified as follow: preincubated at 94°C for 9 min, 35 cycles of denaturing (30 sec at 94°C), annealing (30 sec at 53°C), and extension (30 sec at 72°C) and a final elongation was at 72°C for 10 min (Kurisu et al., 2002). Analysis of PCR products by DGGE was performed according to Muzer et al. (1993) with modifications using a DCode$^{TM}$ Universal Mutation Detection System (Bio-Rad Laboratories, USA). A 20 µl volume of amplified products was loaded onto 8% (wt/vol) polyacrylamide gel in 1x TAE buffer reservoir (7 L). The 8% (wt/vol) polyacrylamide gel (bisacrylaminde gel stock solution, 37.55:1 (Bio-Rad Laboratories, lnc) were prepare with denaturing gradients of urea and formamide ranging from 20 to 70%. The electrophoresis was run at 60°C, first for 300 min at a constant voltage of 130 V. After electrophoresis, the gel was incubated for 20 min in 15 mL of Milli-Q water containing two drops of ethidium bromide and photographed with a Polaroid camera. The gels were analyed using Quantity One software (Bio-Rad Laboratories lnc, USA).

### Data analysis and statistical analysis

Plate count data were normalized by log transformation and significant differences between group means were determined by analysis of variance (ANOVA) and calculation of the minimum significant difference by the Least-Significant Different (LSD) test at P = 0.05. The net optical diversity (OD) at 405 nm for each substrate well for BIOLOG$^{TM}$ EcoPlate was calculated by subtracting the control well OD from the substrate well OD. If this subtraction gave a negative number, 0 was used in the subsequent analyses. Microbial activity in each microplate was expressed as average well-color development (AWCD). The AWCD was determined by the following equation; AWCD = $\sum OD_i/31$, where $OD_i$ is the optical density value from each of the 31 wells by water blank substraction (Garland and Mills, 1991). The absorbance values at 72 h were used to calculate diversity indices. Shannon-Weaver index ($H_f'$) was calculated as follows; $H_f' = -\sum p_i (\ln p_i)$, where $p_i$ is the ratio of the activity on each substrate ($OD_i$) to the sum of activities on all substrates ($\sum OD_i$). Substrate richness ($S_f$) is the number of different substrates that were used by the bacterial community, i.e. equivalent to species richness in the soil, and was calculated by counting all positive OD reading (Zak et al., 1994). The AWCD, $S_f$, and $H_f'$ were analyzed by ANOVA and comparisons of means by the LSD test at P = 0.05. The genetic diversity indices were calculated from DGGE profiles. Scanned gels analyzed the intensity of individual bands (peak height of bands) in all lanes with Quantity One software package. Genetic diversity was evaluated by calculating Shannon-Weaver index ($H_g'$) as follows; $H_g' = -\sum (n_i/N)\ln(n_i/N)$, where $n_i$ is the intensity of band i as judged by its peak height, i is the number of bands in DGGE gel profile and N is the sum of all peak heights in a given DGGE profile.

## RESULTS AND DISCUSSION

### Total plate count

Lower numbers of culturable heterotrophic bacteria (CFU) were isolated from the CT because this plot had low SOM (5.85±3.32 g $kg^{-1}$) and also low in biological activity such as basal respiration (3.80±1.95 mg $CO_2$-C $kg^{-1}$ $d^{-1}$), potentially mineralizable nitrogen (8.71±3.55 mg $NH_4$-N $kg^{-1}$, microbial biomass carbon and nitrogen (0.331±0.355 g $kg^{-1}$ and 0.186±0.158 g $kg^{-1}$) (Thuithaisong et al., 2010). Two-way ANOVA of the results revealed that total plate counts were significantly (P<0.05) affected by the four different management practices. However, a GM plot ($2.29x10^6$ CFU $g^{-1}$ of dry soil) and CF plot ($1.80x10^6$ CFU $g^{-1}$ of dry soil) were not significantly different (P>0.05) (Table 1). This implied that without plant nutrients provide to the soil, growth of culturable bacteria was restricted. Both GM and CF at the rate applied are equally effective in supporting a better growth and perhaps survival of the cultivable bacteria, because they both contain an array of organic compounds such as carbohydrates, fatty acids and peptide that are substrates for growth of culturable bacteria.

### Community level physiological profiles

The overall color development in the BIOLOG$^{TM}$ Ecoplates was calculated as the mean of all 31 wells. The temporal changes obtained from AWCD were different between soil samples, with the CT plot being the lowest, suggesting a lower level of microbial community in this plot. The number of carbon sources that gave positive reactions for each soil treatments again highlighted the lower values for CT compared to the other plots (Table 1). The GM plot had a high AWCD value and a high number of carbon sources. All indices of bacterial diversity (functional diversity) in GM plot increased the microbial diversity, especially the Shannon-Weaver index ($H_f'$) and substrate richness ($S_f$) as indicated by their highest values at 3.01 and 14.78 respectively.

### Polymerase chain reaction-denaturing gradient gel electrophoresis

Bacterial community structure determined by DGGE banding patterns are showed in Fig.1. Numerous distinct DGGE bands, resulting from differences between the 16S rDNA gene sequences of different bacterial species, were obvious. Each band represents at least one unique ribotype, as reflected by the relative band intensity on a DGGE gel. The higher the intensity, the more dominant is the bacterial ribotype corresponding to that band. The DGGE patterns from the paddy soils of different agricultural management practices (CT, RS, GM and CF) had distinctly different features of bacterial community, suggesting that different soil environmental conditions influence bacterial community structure. Based on the DGGE image, the expression level of 16S rDNA gene sequences was strongly expressed in samples collected in May but they were weak in October and December. SOM, which is beneficial for soil microbial growth, was highest in the samples collected in May (those soils were under aerobic condition). Therefore the intensity of DGGE bands in May was expressed strongly due to the aerobic bacteria. In contrast bacterial populations from rice soils of the four plots decreased in all the samples collected in October. Because such samples were obtained under anaerobic condition the intensity of DGGE bands has lowest. The degradation of SOM by aerobic bacteria was strongly inhibited because oxygen levels were reduced by flooding. However, the intensity of DGGE bands in soil samples collected in December was higher than in October because the soils were again under aerobic conditions. The Shannon-Weaver Index ($H_g'$) was quite similar between RS and GM plots and their $H_g'$ was higher than from CF and CT soil treatments.

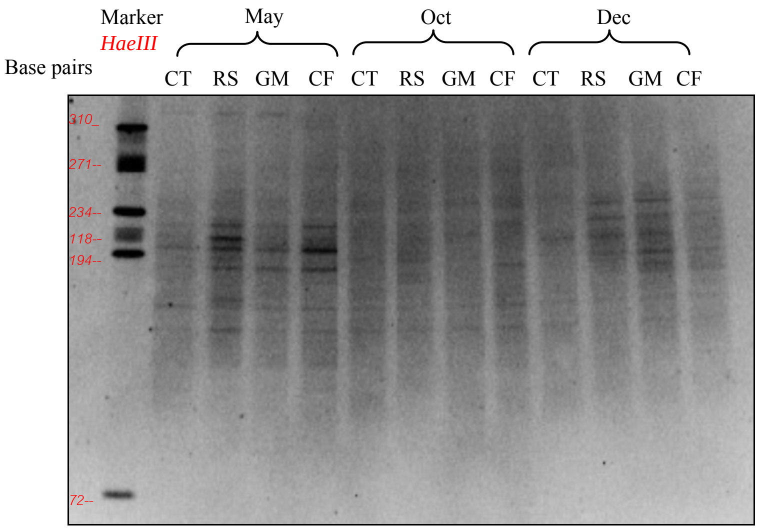


**Fig. 1 DGGE images of PCR-amplified products from different agricultural practices (CT, RS, GM and CF) during different sampling time (May, October, and December)**

**Table 1 Effect of different farming management practices on soil microbial communities**

| Plot | Total plate count (CFU $g^{-1}$ of dry soil) | AWCD | No. of C sources utilized | Functional diversity | | Genetically diversity | |
|---|---|---|---|---|---|---|---|
| | | | | ($H_f'$) | ($S_f$) | ($H_g'$) | ($S_g$) |
| CT | 8.42±5.49x$10^{4}$ $^{a*}$ | 0.19±0.10 $^{a}$ | 6.0±3.87 $^{a}$ | 2.77±0.15 $^{a}$ | 5.3±2.96 $^{a}$ | 1.62±0.32 $^{a}$ | 6.0±2.00 $^{a}$ |
| RS | 3.23±4.04x$10^{5}$ $^{b}$ | 0.28±0.16 $^{b}$ | 9.7±5.95 $^{b}$ | 2.83±0.15 $^{a}$ | 9.0±1.73 $^{b}$ | 2.08±0.23 $^{a}$ | 9.0±3.00 $^{a}$ |
| GM | 2.29±1.61x$10^{6}$ $^{c}$ | 0.46±0.30 $^{c}$ | 13.9±7.93 $^{c}$ | 3.01±0.82 $^{b}$ | 14.8±4.12 $^{c}$ | 1.96±0.43 $^{a}$ | 8.3±3.05 $^{a}$ |
| CF | 1.80±1.33x$10^{6}$ $^{c}$ | 0.30±0.17 $^{d}$ | 8.8±4.57 $^{b}$ | 2.86±0.12 $^{a}$ | 10.0±3.04 $^{b}$ | 1.89±0.38 $^{a}$ | 8.3±2.52 $^{a}$ |

** Values are expressed as means and standard deviations followed the different regular letters (a, b, c) in row are significantly different ($P<0.05$) by Least Significant Different (LSD). AWCD=average well color development, $H_f'$ =Shannon-Weaver diversity index of functional diversity, $H_g'$ =Shannon-Weaver diversity index of genetic diversity $S_f$ =substrate richness, and $S_g$=species richness.*

This indicates that the influence of management practice on soil microbial communities did occur. Based on the finding organic farming (RS, GM) seemed to have an edge over the conventional management (CF). However, the statistical analysis (ANOVA) performed for the Shannon-Weaver index ($H_g$') and species richness ($S_g$) from DGGE profiles data showed no significant differences between the four plots (CT, RS, GM and CF) (Table 1).

## CONCLUSION

Based upon the results obtained from this study soil management practices have influenced microbial diversity, both in functional and genetic diversity, in the rice plots studied. Further a narrow range of Shannon-Weaver diversity index ($H_f$') was obtained with the values between 2.77 for CT to 3.01 for GM. In the statistical analysis performed using substrate richness ($S_f$) from potential substrate utilization patterns data, the GM treatment increased microbial diversity. Even within the constraints of organic farming practices, it is possible for farmers to adopt and continue this application to improve soil bio-physiochemical properties, provided that the rate and source of organic materials used is site specific.

## ACKNOWLEGEMENT

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*Research article*

# Effect of Land Use Change on Land Quality and Water Resources in Phatthalung Watershed, Thailand

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**Abstract** A watershed scale study was conducted to assess the effect of land use change on land and water quality using selected indicators in the Phatthalung watershed, Thailand. The changes in water quality in the study area were assessed by computing a Water Quality Index (WQI) using some important water quality parameters, including pH, suspended solids and plant nutrients. Water quantity was also assessed through estimating soil moisture storage. Land quality was assessed by developing a Land Quality Index (LQI) based on indices of soil resource, land degradation status and water resource. The quality of land from two different areas, i.e. where land use has changed, and where no change has occurred, was assessed using the selected indicators. The computed WQI decreased during the study period. The highest WQI was 97.5 in 1997 and 2003 and the lowest was 80.0 in 2005 and 2006. Suspended solids (SS) was the major factor influencing WQI. Water quantity, in terms of soil moisture storage, showed positive results as the number of months of water surplus increased from one month per year in 1976 to 4 months in 2006. This was due to the decline in paddy field area. For LQI the indices of soil resource and land degradation status were higher, and water resource lower, in areas where land use did not change compared to those where land use did change.

**Keywords:** Land use change, land quality, water quality, Phatthalung Watershed

## INTRODUCTION

Recently the pressure on land and water resources has increased due to the expansion of population and economic development. The major pressure on land is attempts to increase agricultural production from land, as intensification of agricultural activities increases food production for an increasing population. However this causes impacts on the agricultural inputs, such as soil and water resources.

Land use change has positive and negative effects on land and water, the key resources for agricultural production. Land use and land use change generally reflect changes in agricultural activities, and give rise to issues in land and water quality (Dalal and Mayer, 1986; Bushchbacher et al., 1988; Fu et al., 1990). Excessive and careless use of fertilizers and pesticides can have negative effects on land and water resources through impacts on groundwater and runoff and associated ecological damage (George et al., 2002). Eventually such changes can be dangerous for human health. Moreover runoff of excess nutrients, especially phosphorus, leads to eutrophication with taste and odour impacts on public water supplies and excess algae growth leading to deoxygenation of water and fish kills (FAO, 1996). Using heavy machines also plays an important role in the deterioration of land and water resources due to soil compaction, decreased soil porosity, increased soil erosion and loss of top soil nutrients and organic matter. Therefore recognition of the current situation with regard to land use and its consequences can be useful for planning future land uses to protect land and water resources.

Phatthalung watershed, a major agricultural area of southern Thailand has experienced land use change, particularly the replacement of paddy areas by rubber plantations. These changes of land use are driven by of internal and external factors, economic return being one of the major drivers. Therefore, an assessment of quality of land and water is needed to understand the current situation, and to provide an early warning and guide for future land resource management and development. The establishment of land and water quality indicators can measure changes in the land resource due to external disturbances; especially land use for agricultural activities.

## METHODOLOGY

### Water quality assessment

The water quality of Phatthalung watershed over the period 1994 to 2006 was determined on the basis of the WQI proposed by Rodriguez de Bascaron (Pesce and Wunderlin, 2000; Sanchez et al., 2007; Wu et al., 2008) as follows:

$$WQI_{sub} = k \frac{\sum_i C_i P_i}{\sum_i P_i} \tag{1}$$

where, $WQI_{sub}$ is the water quality index of surface water of Phatthalung watershed, k is a subjective constant with a maximum value of 1 for good quality water and 0.25 for highly polluted water (in this study the k value was not considered and hence assigned as 1), $C_i$ is the value assigned to each parameter after normalization (Table 1), and $P_i$ is the relative weight assigned to each parameter. This weight was assigned as 1 in all cases in this study to account only for variation due to measured parameters. The WQI used in this study included four parameters as follows:

$$WQI = \frac{C_{pH} + C_{SS} + C_P + C_N}{4} \tag{2}$$

where, $C_{pH}$, $C_{ss}$, $C_P$ and $C_N$ are the values of pH, suspended solids (SS), and Phosphate and Nitrate values after normalization, respectively.

**Table 1 Values of normalization factor ($C_i$) for selected parameters of water quality**

| Parameter | Normalization factor ($C_i$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
| pH | 7 | 7-8 | 7-8.5 | 7-9 | 6.5-7 | 6-9.5 | 5-10 | 4-11 | 3-12 | 2-13 | 1-14 |
| SS | <20 | <40 | <60 | <80 | <100 | <120 | <160 | <240 | <320 | <400 | >400 |
| Nitrate | <0.5 | <2.0 | <4.0 | <6.0 | <8.0 | <10 | <15 | <20 | <50 | ≤100 | >100 |
| Phosphorus | <0.16 | <1.6 | <3.2 | <6.4 | <9.6 | <16 | <32 | <64 | <96 | <160 | >160 |

*All values, except pH, in mg/l (Pesce and Wunderlin, 2000; Sanchez et al., 2007)*

### Water quantity assessment

In this study, soil moisture storage was used as the indicator for water quantity assessment. Soil moisture can be affected by various types of agricultural activities and changes in land use. Soil moisture storage and its change were assessed in this study by using Eq. (3):

$$\Delta SM = P - ETc - q \tag{3}$$

where, $\Delta SM$ is the change in soil moisture (cm), $P$ is rainfall (cm), $ETc$ is crop evapotranspiration (cm), and $q$ is runoff depth (cm).

**Land quality assessment**

The quality of land resource was assessed through the LQI. In this study the LQI was developed to address changes in land quality due to land use change. LQI consisted of major components of the land resource included soil properties, water resource, and land degradation status. The set of indicators used is presented in Table 2.

Because of the different scale and unit of selected land quality indicators, it was necessary to standardize the values in order to compare between land quality indicators for land use changes compared to the no change area. Therefore the linear scaling method was used to normalize the different scale values.

**Table 2 Land quality indicators**

| Indicator suite | Component attributes | Measurement and method |
|---|---|---|
| Soil | | |
| Physical property | Water holding capacity | Laboratory analysis |
| | Soil texture (sand and clay content) | Laboratory analysis |
| Nutrient status | Cation exchange capacity (CEC) | Laboratory analysis |
| Water resource | Water sufficiency | Effective rainfall |
| Land degradation status | Erosion status | Erosion model |

**RESULTS AND DISSUSSION**

Land use in Phatthalung watershed has been undergoing change, significantly so since 1976. The major change has been the rise in rubber plantations, continuously increasing due to rapidly increase in rubber prices in the local and global market during the period 1990 to 2006, The forest area decreased continuously and significantly and the rubber plantation area rapidly increased (+37.3%), resulting in a decreasing of paddy field (-36.1%) and forest area (-12.4%). Fig. 1 shows the areas where land use change occurred.

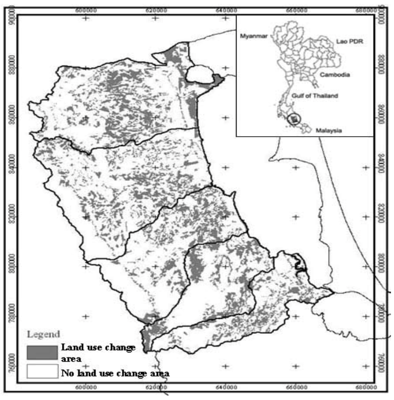


**Fig. 1 Land use change area during 1990-2006**

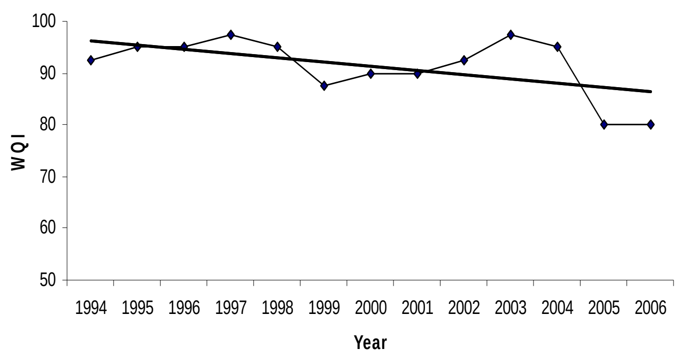


**Fig. 2 Computed WQI during 1994-2006**

**Water quality analysis**

Based on the parameters presented in the above section, the computed WQI varied ranging from 80 to 97.5 in the study area (Fig. 2). The WQI declined in the period 1998 to 2003 and slightly increased in 2003 due to lower amounts of suspended solid being loaded into water bodies. The index decreased again from 2004 to 2006. The highest water quality was in 1997 and 2003 (WQI = 97.5), and the lowest WQI (WQI = 80) was in the most recent years (2005 and 2006). The computed WQI for all periods indicated that water quality is of "good" and "excellent" condition, as described by Jonnalagadda and Mhere (2001). However, the WQI trend indicates declining water quality during the study period, implying that the quality of water is degrading based on the parameters used in this study.

**Water quantity analysis**

The quantity of water can mean different things in different contexts. From an agricultural point of view soil moisture is very important and was used in this study to refer to water quantity. Soil moisture is important for agriculture as it is an input to plant production. It can be lost through many channels including runoff, deep percolation, evaporation and transpiration. Land use is a major factor capable of controlling the level of moisture loss through its influence on surface runoff.

The soil moisture change of Phatthalung watershed during the study period was computed using the concept of soil moisture balance. The number of months in which surplus water implied high soil moisture increased during the study period. Surplus water was found only in November in 1976 (Fig. 3) and 1990 (Fig. 4) but it had increased to four months (January, October, November and December) in 2006 (Fig. 5).

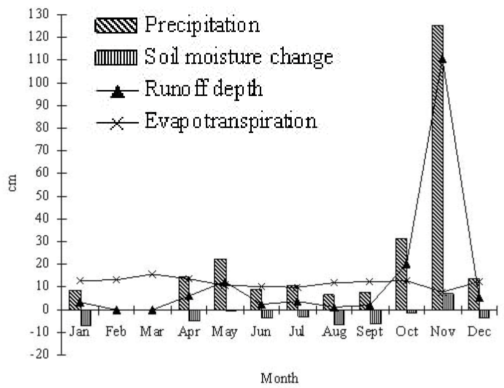


**Fig. 3 Soil moisture of Phatthalung watershed in 1976**

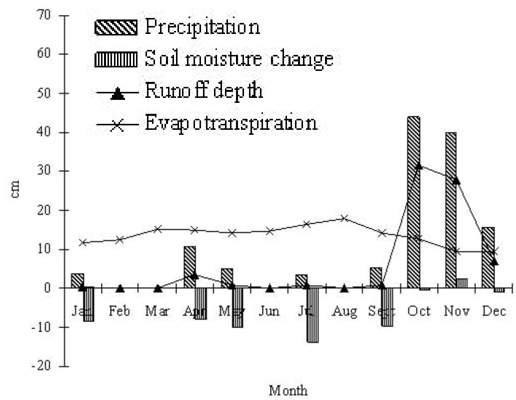


**Fig. 4 Soil moisture of Phatthalung watershed in 1990**

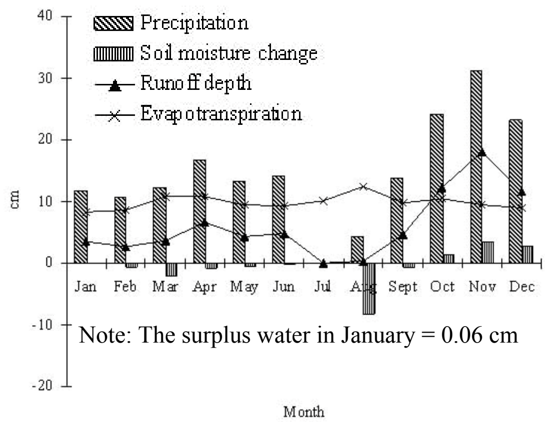


**Fig. 5 Soil moisture of Phatthalung watershed in 2006**

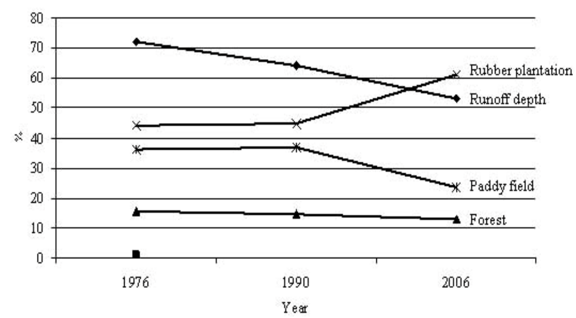


**Fig. 6 The relationship of land use types and the surface runoff**

The moisture of soil in 2006 increased because of the reduction in runoff. Fig. 6 shows the relationship between land use and annual runoff depth of the three main land uses. Note that the increasing area of rubber plantation and decreasing area of paddy field resulted in the reduction in runoff depth. Hence, the decline in paddy field area and the increase in area of rubber plantation can cause positive effects on soil moisture storage

## Land quality analysis

Land quality of the study area was assessed through three selected indicator sets, which included soil, water resource and the status of land degradation. Four indicators were used to assess the quality of soil resource; those were sand and clay content, CEC and water holding capacity (WHC). Water sufficiency and soil erosion rate were the selected indicators used to assess water resources and land degradation status, respectively. Table 3 presents the detailed computed score for each indicator under each land use scenario. The overall LQI, an aggregated index value for the whole study area, was 0.452 for the land use change area and 0.629 for no use change area. However, there was no statistically significant difference between the groups.

The no change land use areas have higher LQIs than the land use change areas. the overall soil resource index of the two areas was significantly different, but the water resource and land degradation indices were not significantly different. For the soil resource index, the score for the no change area (0.785) was significantly higher ($p<0.05$) than for the area of land use change (0.708).

For individual indicators the area of no land use change has higher scores in most of the indicators, except for clay content. This was because the soil sample points that represented the land use change were mostly located in the areas that had been paddy field in the past, and which usually contain higher clay content.

This is to note here that the computed land quality scores of no change area were higher than the area where land use change occurred in terms of the selected indicators.

**Table 3 Land quality assessment**

| Land quality indicators | Land use change | No change | Significance |
|---|---|---|---|
| Soil resource | | | |
| Physical property | | | |
| %Sand | 0.705 | 0.804 | 0.051 |
| %Clay | 0.965 | 0.827 | 0.025* |
| Water holding capacity | 0.468 | 0.689 | 0.277 |
| Nutrient status | | | |
| CEC | 0.675 | 0.819 | 0.361 |
| Overall soil resource index | 0.708 | 0.785 | 0.045* |
| Water resource | | | |
| Water sufficiency | 0.327 | 0.337 | 0.065 |
| Land degradation status | | | |
| Soil loss | 0.643 | 0.878 | 0.086 |
| Overall LQI | 0.452 | 0.629 | 0.377 |

## CONCLUSION

Land and water resources of the Phatthalung watershed are influenced by various factors, and land use is the influencing factor investigated in this study. The computed WQI indicated that the overall water quality of Phatthalung watershed has declined during the observed period (1994 to 2006). Suspended solid has been increasing over the years. Overall the water quantity status of Phatthalung watershed has increased during the study period because about half of paddy field area was replaced by rubber plantation, with positive impacts on the water quantity in terms of increased water storage. The reason is that paddy field areas have the capability to generate higher surface runoff compared to rubber plantation and forest areas, which can reduce the amount of the moisture in soil.

The computed LQI of the no change in land use areas tended to have better land quality in terms of the selected factors, however the changes were not significantly different between two areas. In the individual indicator level, no land use change areas had relatively better scores for most of the land quality indicators compared to the area where land use changed, except for water sufficiency and clay content. The rubber plantation area has higher water sufficiency as it can utilize higher amounts of rainfall with lower water loss through surface runoff. In other words, rubber plantation areas which have not undergone land use change may exhibit higher LQIs in terms of water sufficiency. Similarly, the long term rice cultivation areas can have higher clay content compared to the areas where soil disturbance occurred due to land use change.

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*Research article*

# Effective Heat Dissipation in Hot-humid Climates: the Hypothesis Formulated by the Results in Swamp Buffaloes

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**Abstract** Most countries of Southeast Asia belong to hot-humid climates with high humidity and small diurnal changes in air temperature throughout the year. These conditions are harsh for large livestock ruminants because the conditions prevent evaporative heat loss (panting and sweating). Swamp buffaloes are distributed widely throughout this climatic zone as a large livestock ruminant, and traditionally provide power to plough farm fields. Buffaloes are also valuable for small farmers as these animals show a good digestibility to low quality roughage. For animal production in hot-humid climates, crossbred cattle have been exploited as an efficient tool for blending the adaptability of tropical cattle accompanying with high sweating rate. But effective heat dissipation is still a major problem in this area. Buffaloes easily sustain heat stress under solar radiation as compared to tropical cattle, but they quickly recover after moving into shade or spraying with water. Therefore these adapted animals must have an effective physiological system for heat dissipation under hot-humid conditions. Several comparative experiments have been conducted comparing thermo-regulatory responses between swamp buffaloes and cattle. Hormone and blood parameters were also compared between the two species in terms of blood volume and distribution in the body. The results show active heat transport through blood flow and water turnover in buffaloes as compared to temperate or tropical cattle. In hot-humid climates, there is usually high water availability with a large amount of precipitation. Therefore the effective heat dissipation in buffaloes may be developed through water utilization rather than evaporative heat loss. The observed physiological system suggests that the adapted heat dissipation is combined with behavioral heat dissipations such as wallowing.

**Keywords:** Swamp buffaloes, heat dissipation, hot-humid climates, Southeast Asia

## INTRODUCTION

For large livestock animals living in hot climates it is very important, though difficult, to dissipate excessive internal heat through sweating and panting. There are some instances in which animals living in severe environments have shown distinctive thermo-regulatory responses. Schmidt-Nielsen et al. (1957) reported that the rectal temperature of camels fluctuates within a large range, allowing these animals to avoid heat stress without body-water loss through sweating and panting. Although the low humidity in hot-dry climates lends itself to evaporative heat loss, it is very difficult to find water in this climate. Thus the adaptation to dissipate heat without body-water loss is achieved using the large diurnal change in air temperature. Among hot climates the difficulty of heat dissipation varies between hot-dry and hot-humid climates. In hot-humid climates high humidity is generally paired with a small diurnal change in air temperature and thus evaporative heat loss is not as effective for body-heat dissipation. However, there is usually an abundance of water in hot-humid climates which may be effectively used for body-heat dissipation.

Swamp buffaloes are found in hot-humid climates and are an important livestock ruminant for East and Southeast Asia. Despite being endemic to this habitat, rectal and skin temperatures in buffaloes increase rapidly under solar radiation and the rate of sweating is lower than in cattle. Respiratory evaporation is ineffective because panting in buffaloes induces an increase in blood pH and causes respiratory alkalosis. In contrast, panting does not cause blood pH changes in cattle (Koga et al., 1991a). Regardless of the inefficacy of evaporative heat loss, the rectal temperature in buffaloes decreases rapidly when they are moved into the shade or sprayed with water following heat stress. A large fluctuation in rectal temperature was observed in buffaloes exposed to artificial controlled temperature that fluctuated diurnally between 25 and 35˚C (Fig. 1; Koga et al., 1999b). Under natural conditions, the rectal temperature in buffaloes was correlated with seasonal changes in environmental temperatures, but the same was not true for Friesian cattle in temperate zones (Koga et al., 1991b) or tropical cattle in tropical zones (Koga et al., 2004). Furthermore, under natural conditions, haematocrit (Ht) in buffaloes was correlated with seasonal changes in environmental temperatures, but the same was not true for Friesian cattle in temperate zones (Fig. 2; Koga et al., 1991b). A correlation was detected between rectal temperature and Ht in buffaloes, but not in cattle (Koga et al., 1991b; 2004). These results suggest that thermo-regulation in buffaloes is more reliant upon heat transport through blood flow than in cattle.

Water turnover is generally higher in temperate cattle than in tropical cattle (Siebert and Macfarlane, 1969), because the retention of body water is very important for dissipating heat through blood circulation in hot conditions. Although buffaloes are endemic to the tropics, the water turnover in these animals is higher than in temperate cattle (Siebert and Macfarlane, 1969). Moreover, Chaiyabutr et al. (1987) reported that water turnover increases when buffaloes are exposed to hot conditions, which contradicts the findings in cattle. This increase in water turnover is accompanied by high water requirements and body water content, especially in hot conditions (Siebert and Macfarlane, 1969). In previous experiments water intake in buffaloes increased markedly with increased air temperature, and it was significantly higher than in Friesian cattle at 35˚C (Koga et al., 1999a). The volume of urine and the water content of the faeces were also higher in buffaloes than in Friesian cattle under normal conditions (Koga et al., 2002). These results suggest that water excretion contributes to heat dissipation in the thermo-regulatory system of buffaloes.

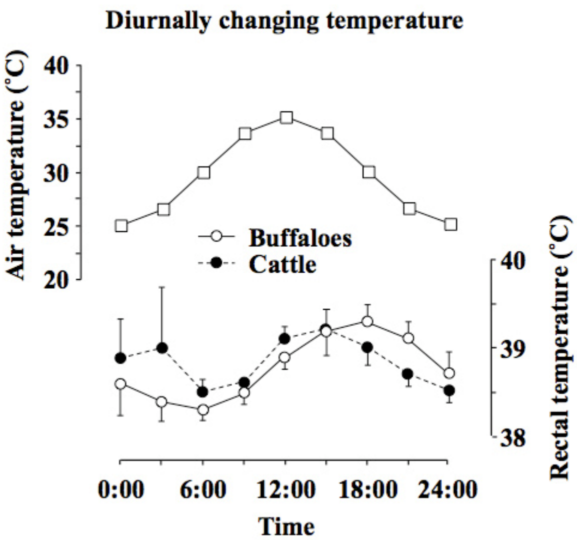


**Fig.1 Change of rectal temperature with diurnally changing temperature**

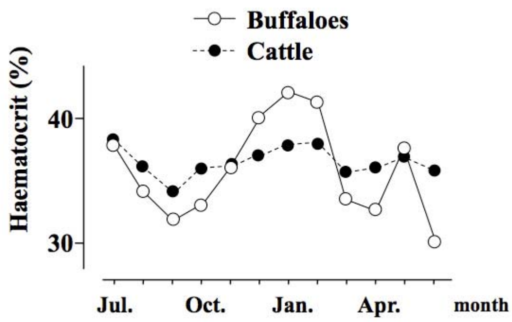


**Fig.2 Monthly mean values of haematocrit during the course of one year**

On the basis of these reports the physiological system in buffaloes suggests that the adaptive thermo-regulatory functions use internal and external water in hot-humid climates. Because of plentiful rainfall in these climates an abundant supply of water is available. Therefore, in this short review two distinctive physiological systems in buffaloes are discussed with the results obtained from several experiments.

## RESULTS AND DISCUSSION

### Marked increase in blood volume and blood flow to the skin surface

In animals the redistribution of cardiac output generally arises from the necessity to dissipate heat under hot conditions, which is facilitated by sending more blood to the surface of the body. Excessive heat is left in the subcutaneous tissues and skin temperature increases (Hales, 1973). Consequently the internal heat gradient between the rectal and skin temperature is narrowed and the external heat gradient between the skin and the surrounding air is widened, thus promoting body-heat dissipation from the skin surface. On the basis of published reports, we compared the changes in blood and plasma volume, rectal and skin temperature, and blood flow to the skin surface before and after heat exposure in both buffaloes and temperate cattle. From the results of several experiments the blood volume, especially plasma volume, increased more in buffaloes than in cattle after heat exposure. The increase in skin temperature and blood flow to the skin surface was also larger in buffaloes than in cattle after heat exposure (Koga et al., 1999a). In addition, the difference of rectal and skin temperature (R-S difference) was calculated, and a relationship between R-S difference and blood volume (as indicated by Ht) was compared in both species (Koga et al., 1998). The R-S difference was significantly smaller in buffaloes than in cattle. And Ht in buffaloes decreased significantly as the surrounding temperature increased, while the Ht in cattle was almost stable during the same period (Fig. 3; Koga et al., 1998). Conversely, as the surrounding temperature decreased the R-S difference and the Ht in buffaloes increased, and the any significant difference between the animals vanished after that point (Koga et al., 1998).

### Distinctive arginine vasopressin response to a decrease of blood volume in buffaloes

MacFarlane et al. (1967) reported that body-water regulation, which involves the renin-angiotensin axis and arginine vasopressin (AVP), is influenced by the availability of water in the native habitat of animal species. Based on this work, the correlation between plasma AVP concentrations and Ht (as an index of plasma volume) were investigated between swamp buffaloes and Friesian cattle after 3 days of water deprivation (Fig. 4; Koga et al., 2002). An increase in AVP concentration and Ht was finally larger in buffaloes (3267% in AVP and 30.5% in Ht) than in cattle (886% in AVP and 19.0% in Ht) on day 3. But the initial response in AVP was distinctive in buffaloes. From day 0-1, the AVP/Ht ratio, (as an index of AVP sensitivity) was lower in buffaloes (2.51) than in cattle (3.40), although the increase in Ht was larger in buffaloes (16.0%) than in cattle (4.8%) during the same period. From Days 1-2 and 2-3, the AVP/Ht ratio was higher in buffaloes than in cattle (the values are shown in Fig. 2), although there was a similar increase in Ht in both species (7.1% and 5.1% in buffaloes, and 9.2% and 3.9% in cattle, respectively).

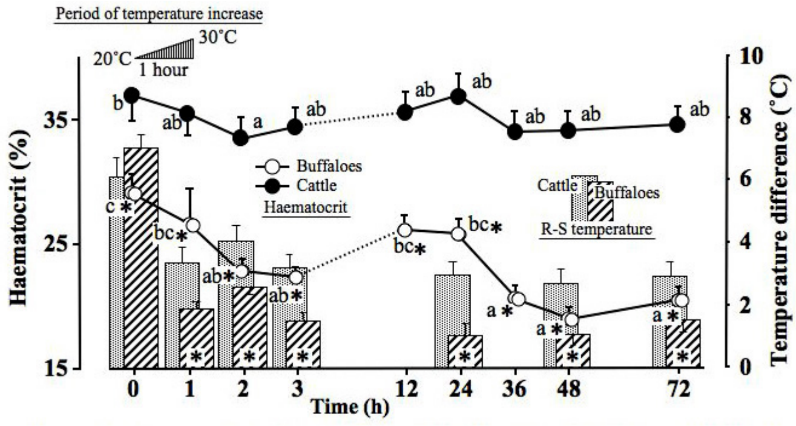


**Fig.3 Change in rectal-skin (R-S) temperature and haematocrit following a temperature increase from 20 ˚C to 30 ˚C during one hour**

** Significant difference from cattle (p<0.05)*
*a, b, c: Values having same letters in the same line are not significantly different (p<0.05) (Modified from Kogo et al., 1998)*

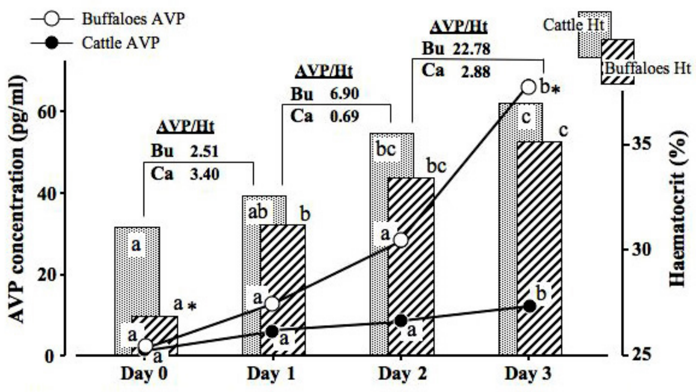


**Fig.4 Change in AVP and haematocrit over 3 days following water deprivation**

** Significant difference from cattle (p<0.05)*

## CONCLUSION

This research has shown that heat transport through blood flow is more active in buffaloes than in cattle, and that the initial AVP sensitivity is lower in buffaloes than in cattle, as indicated by a decrease in plasma volume. The increase in blood volume in buffaloes maintains an elevated skin temperature under hot conditions, thus facilitating the dissipation of heat from the surface of skin when buffaloes wallow in the mud or move into the shade. The initial decreased AVP sensitivity observed in buffaloes permits a decrease in body water through urine excretion, within certain limits, and appears to be a typical response for animals living in habitats with high water availability. Our findings in swamp buffaloes contradict the findings in temperate and tropical cattle in that buffaloes, unlike cattle, use body-water for heat dissipation. In hot-humid climates there is generally an abundance of water as well as high humidity and a narrow diurnal range in air temperature. Therefore, the physiological responses observed in buffaloes demonstrate that the heat dissipation system via body-water circulation is more adaptive than evaporative heat loss in these climates. For animal production systems in hot-humid climate areas, this animal species may be expected a good potential with the adapted heat dissipation system as well as good digestibility of low quality roughage (Homma, 1994).

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Research article

# Social Land Policy for Sustainable Rural Development in Cambodia

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**Abstract** On 1st of July 2009, Cambodian Prime Minister Hun Sen signed the "Declaration of the Royal Government on Land Policy". According to this document emphasis should be given to State reform, land law, and environmental law with their impacts on the use of non-renewable resources (land, water, and soil). The implementation of the Cambodian social land policy should start with the need to ensure access to land and to sustain rural development and environment for a modern, prosperous Cambodia. The legal framework for sustainable rural development and land policy includes the Constitution from 1993, and the Land Law from 2001, and Sub-Decrees. Land policy can be interpreted as a central element of property policy. Property is protected under the Constitution and the Land Law from 2001. State public property must be interpreted as the property of all Cambodian people, or as social land policy, that serves the purposes of humans living in the country as a public interest, particularly in rural areas. With a land use planning system the Cambodian planning authorities are able to guide and to restrict the use of land property to foster sustainable rural development. Social land policy needs a broader basis in Cambodia than at present State public property with the guarantee for private use, e.g. through land leasing and concessions, is absolutely sufficient, efficient and effective. Social land policy is an interdisciplinary approach of good governance, land and constitutional law, land economy, spatial planning, and gender issues. This policy can also be a state-driven concept for rural areas in other (developing) countries. It must be legally classified as a public interest so that the eternal ground rent, as the economic gain of the land use, is appropriated and then distributed to all Cambodians in equal shares.

**Keywords:** Social land policy, sustainable rural development, land law, Cambodia

## INTRODUCTION

On 1st of July 2009, Cambodian Prime Minister Hun Sen signed the "Declaration of the Royal Government on Land Policy". According to this document emphasis should be given to State reform, land law, and environmental law with their impacts on the use of non-renewable resources (land, water, and soil). Moreover the Royal Government of Cambodia (RGC) "attaches priority to granting land ownership rights to poor households and vulnerable groups for housing, farming and small businesses" and wants to "ensure land use efficiency". In 2009 Cambodia still experienced a high rural poverty rate, high land concentration and "anarchy in illegal land possession, illegal claim of state land and protected areas as privately owned and unlawful logging" (RGC, 2008). A national goal has been established in order to solve these problems, especially rural poverty (World Bank, 2007). This goal aims to alleviate poverty by ensuring food security, equitable economic and social development, fair distribution of land and national resources, secure housing rights and environmental protection.

Development under the "new rural paradigm" depends on government activities at all levels and including local stakeholders (OECD, 2006). Hence rural development is a cornerstone of social land policy and good land governance. The "rule of law" can be interpreted as a central element of land policy and environmental governance issues for water, forests and land (Deininger, 2003).

Land Law, Planning Law, Property Law and the Constitution are crucial for the appropriate use of natural resources in Cambodia. The Land Law of Cambodia from 2001 was expected to be implemented to ensure an equitable and efficient system of land management. This includes provisions for fair land distribution, land tenure security, eradication of illegal settlements and encroachment, eradicating land grabbing, and the control of ownership concentration for speculative purposes. At present it is not clear if the Land Law or the planning instruments, let alone other policy documents and regulations, will be able to fulfill all of these expectations. This article outlines the necessities for implementing a social land policy for rural development, a spatial planning system, and socio-ecologic and environmentally-sound land policy in Cambodia. This process has started from "point zero" because of the lack of the State's awareness of urban and rural land inventories.

## METHODOLOGY: SOCIAL LAND POLICY AND THE "RULE OF LAW"

Social land policy in Cambodia should try to answer the following core questions (Graefen and Baldi, 2009): what kind of arable land and how much of that should be allocated (land reform)? Which land uses are envisaged? Are the beneficiaries of the State's interventions in land markets landless households or also land-poor people? Approximately 80 % of Cambodian territory consists of State property (World Bank, 2008). The management of public land is of crucial importance for rural development, but implementation faces numerous problems. These include the often confusing difference between State public land (Art. 17 Land Law) and State private land (Art. 14 and Art. 15 Land Law), unclear boundaries in urban and rural areas, a weak rule of law, and the unfinished recovery of administrative documents for titling, mapping, properties, and taxation (for land value and land property).

The methodology of this paper follows the "rule of law": the State is always the main actor in the land sector and has to guarantee State public property which cannot be transformed into private property. State land management needs to be broadened in Cambodia within its Constitution, the Land Law, and Sub-Decrees. One of the main purposes of public-oriented and constitutionally-justified land management is that it ensures private land access for all Cambodian people (Suárez et al., 2009). Private land use under the conditions of tenure security is more efficient than State land use, but that does not *per se* require the designation of private property. State public property with a guarantee for private land use is absolutely sufficient, efficient, effective, and sustainable. State public or State private land cannot be owned by private people, except with a legal document such as a Sub-Decree or registration procedure.

## RESULTS AND DISCUSSION

### Common property and cooperatives for rural development

Land use models with the concept of common property resources (CPR) or community-based natural resource management (CBNRM) with regulations, participation and decentralization strategies for avoiding a land-free-for-all-mentality are underdeveloped in Cambodia (CBNRM, 2009; Markussen, 2008). Land management and socio-ecological land policy (RGC, 2009b) also need a sound land use planning system which is completely missing (Thiel, 2009), apart from some pilot planning at regional and communal level. An innovative land use alternative might include agricultural associations and service/producer cooperatives or group rights under control of women's groups on common property resources (land, forest, water) (Ostrom, 1990). These are additional instruments which can secure gender-equal land rights. Cooperatives need to be based on key principles such as strictly voluntary membership and exit options, autonomy and independence from government activities, self-organization, and governance, including autonomous decisions about objectives, strategies, and management (Kirk, 2004).

Cooperatives may be suitable for landless and land-poor female-headed households for residential, rural and agricultural community empowerment. They encourage self-help groups, house construction and business communities, income generation for women and agriculture food processing. Agricultural extension services can be a basis for food security and poverty reduction in Cambodia since 80 % of the population lives in rural areas (World Bank, 2007). Moreover, cooperatives and associations can provide access to micro-credit institutions and build up credit/loan/mortgage communities including value chain business approaches.

**Spatial planning for rural development**

Although the Cambodian Constitution states that “the State shall protect the environment and the balance of natural resources and establish a precise plan for the management of land” (Art. 59 Constitutional Law) a coherent, hierarchic spatial planning/land use system for urban and rural areas is still under-developed. Ideally rural development in Cambodia would be based on a comprehensive spatial planning system which would develop, organize, and protect the entire rural territory. Legal protection would be achieved with integrative and strategic territorial planning, and the harmonization of regionally - and locally - significant instruments and measures. These include Commune Land Use Planning (CLUP), Participatory Land Use Planning (PLUP) and Initial State Land Use Plan (I-SLUP), which are part of the land allocation process for social and economic rural development (LASED) project in three Cambodian provinces.

Sufficient compliance with the land use planning objectives would be achieved. Regionally significant plans and measures would be harmonized and conducted with comprehensive development concepts while satisfying the requirements of the current land use planning policy. Rural development and land management are cornerstones within Cambodian policy papers aiming at food security, poverty reduction, and agricultural extension, such as the Rectangular Strategy (RGC, 2008). Rural and infrastructural developments that ensure cultural preservation and community empowerment such as village renewal can be very costly and time-consuming to undertake. This depends on cooperation with land owners who have to pay for the supply of infrastructure systems. Hence, the Cambodian municipalities should be entitled to some limited value capture. To ensure the development of local public transportation and communication infrastructure (energy supply, public health services, sanitation and water supply) in the context of village renewal and rural development, land owners should be required to bear some of these infrastructure costs. Moreover development in rural areas depends on the poly-rationalities and properties of the involved land owners. These poly-rationalities can be divided into individualist bias (private property), egalitarian bias (common property) and hierarchist bias (rearranged land use rights) (Davy, 2009). Therefore rural development needs a property steering component to integrate these rationalities of land owners affected by rural development planning instruments and their modules. However, even the best plans are useless when they cannot be implemented. In some cases plans are blocked by private land owners who do not accept the planning determinations for their plots and the restrictions on their private property. Instead these private land owners hope to increase and appropriate the ground rent (or “rent seeking”).

This interlocking set of land use plans on a national, provincial, district and communal level is necessary to avoid urbanization, urban sprawl, hoarding of underused land, the destruction of fertile farm land and, with growing importance, to gain comprehensive, systematic and transparent information for the assessment (screening and monitoring) of large scale foreign direct investments (FDI) in agriculture, hydropower and mining. Land use plans should protect land that has been designated for a special purpose, such as the protection of a landscape for biodiversity and agricultural uses, or to prevent development of an open space or fertile land area for other uses (e. g. conversion of farmland which reduces food security).

**Public property for rural development**

Land use regulations must satisfy the public interest. The term “public interest” should be integrated into Art. 58 of Cambodian Constitutional Law to clarify that State public property is of essential public interest. Avoiding land speculation and combating illegal claims for State land must be a constitutionally-demanded public interest and hence a cornerstone of State land management. Social housing and any sustainable use of forests, fisheries, and other resources should also clearly be defined as public interests of the Cambodian State. The problem of (private) encroachment on State (public) land raises the question whether there is enough public, and political, awareness of the need for socially-balanced land distribution. Thus the State has a responsibility to provide "secure land rights for all" (UN-Habitat/GLTN, 2008) and social citizenship in Cambodia.

However, social land policy shows insufficient results in implementation, in spite of increasing capacities and political commitment from the Ministry of Land Management, Urban Planning and Construction (MLMUPC). At present, there is a demand for mapping in the context of tenure security for Cambodia's indigenous communities since land disputes and "land grabbing" by the rich and the powerful are rising in the face of an "elite capture of law" (Menzel, 2008). Practices of public administration, which are not foreseen by law, fill the gaps between traditional and modern concepts of law, and land disputes are decided in the interest of private individuals or wealthy urban investors (Adler et al., 2006).

Ground rent-seeking, speculation, a massive competition for land through Economic Land Concessions (ELC) and FDIs are causing deforestation, a decreased amount of land available, latent conflicts, anarchic encroachment, and both legal and illegal land transactions. These processes are faster and seem more rational to some members of indigenous communities than mapping, registering of collective title, and legislation processes for indigenous land rights. Individualist rationalities of the indigenous people in remote areas towards short-term profit, in particular for cash needed for health treatment, motorcycles, education and household consumption, from the land resource are stronger than the long-term management and maintaining of community ownership for scarce natural resources.

**Land leasing for rural development**

Leasehold tenure on land can reduce transaction costs for access to agricultural and residential land since it is the market mechanism that offers the greatest short-term potential for increasing the access of the poor to land (Bruce et al., 2006). Private land use (land rights and land tenure) does not have to be linked to private property. Private-property-oriented western nations have effectively created a situation in which private property rights have negative consequences for land use planning, land allocation, and land distribution because of the incremental economic value and rent of the land. Private property rights are, to some extent, obstacles for a sustainable land use planning policy and for a social land law. The "control of ownership concentration for speculative purpose" (one of the clear political aims of the National Strategic Development Plan (NSDP) from 2006-2010 (RGC, 2005)) would not be necessary if there were no exclusive private property rights for non-renewable natural resources such as land, soils and other assets.

Cambodia can achieve a land-use system similar to the land leasehold tenure regulations in many modern states. In addition, the Cambodian state could partly appropriate the economic ground rent through taxes such as income tax, unused land tax and other tax forms that have to be constitutional before implementation. In other words land use planning by the State would become neutral when private property ownership of land would be replaced by public land leasing. All citizens should have the same chance to access land and its products via leasehold rights and auctions of the private land use rights. But such an innovative land allocation and distribution system causes higher rents, land values and thus higher leasehold fees if an adjustment to ground rents is made. A revolving (local) land fund can solve this problem by pooling the ground rents paid and then redistributing these rents in equal shares to the people (Löhr, 2009). A leasehold tenure and distributed ground rents system can prevent tenure insecurity for indigenous rural land owners and for communes. Instead, the Land Administration Sub Sector Program (LA-SSP) in Cambodia focuses on systematic land registration rather than registering time-restricted land leasing rights to create private ownership and tenure security. Leasehold tenure can reduce transaction costs for access to agricultural land. Leasehold tenure regulations that already exist in the Cambodian Land Law 2001 (Art. 106-113; Rendall, 2003) are excellent land tenure alternatives to private property rights and absolutely equivalent to secure land tenure rights. The granted land use rights have to be paid for by users because of the economic potential. The lower the income per household, the lower the cost of the lease and the transaction costs for this household. In a sound public land management system land hoarding for speculative purposes and "rent seeking" would no longer exist. Moreover leasehold tenure can avoid the lack of tenure security for indigenous land rights and for rural communes. It can help register land to women who primarily tend to achieve secure land use rights for their families to undertake subsistence farming or smallholder businesses. However, major challenges remain in ensuring effective land ownership security for farmers and equality in land access for marginal groups like women, the young and the poor. This is valid for land policy not only in Cambodia but also for other developing countries.

## CONCLUSION

Based on the "Declaration of the Royal Government on Land Policy" from 2009, the Cambodian legislator has a unique opportunity to elucidate and improve social land policy throughout the whole territory, in particular for rural areas where 80 % of the population lives. Therefore, land policy should include:

- Different property forms and tenure securities for land beyond the private property rights solution for the use of non-renewable natural resources and any immovable property;
- Effective and efficient State land management with non-transferable public property;
- Leasehold tenure contracts, eventually combined with innovative land taxation models (redistribution of the ground rent for the benefit of the people as an "add up");
- Indigenous, customary and other informal land use rights, eventually combined with leasehold rights, in particular for agriculture land;
- Rural development and village renewal as essential elements of land use planning policy;
- Property steering function of the spatial/land use planning policy (property policy) and
- Reduced transaction costs for the access to arable land.

Social land policy, State land management and spatial/land use planning policy need framework arrangements guaranteed by the institutions responsible for land use development in Cambodia. The Council of Ministers, national ministries, the legislature, the Council for Land Policy, the institutions of the provinces, districts, municipalities and the civil sector must consider these planning and property issues for the Cambodian people. Different institutions for the management of the non-renewable resource land have to be built up in the future.

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*Research article*

# Management of Manure Taking into Account of *E.coli* Loss from Farmland

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**Abstract** Manure fermented insufficiently includes pathogen such as *E.coli* threatens the environment and human health. Thus, a proper management of the excrement is an important issue. In addition, *E.coli* can be easily transported by surface runoff or percolation from farmland where manure had been applied. So, the loss of *E.coli* from farmlands and its survival limit in manure are big concern from the viewpoints of environmental conservation. Model experiments were conducted under artificial rainfall simulator to investigate *E.coli* loss. Slope plots were filled with soil and then applied 3 types of manure; fresh cow dung, manures fermented for 14 days and 60 days. It was proven that *E.coli* losses occurred even from the manure which was fermented for 60 days. In addition, to acquire a proper treatment of manures, the experiments were conducted to investigate the survival limit of *E.coli* in the manure. It was observed that *E.coli* vanished at the temperature higher than 60 degrees Celsius. Furthermore, the reduction of water content was not enough to eliminate *E.coli*. So, it became clear that controlling temperature of manure is important for vanishing *E.coli* existing in manures.

**Keywords** *E.coli*, surface runoff, manure, temperature, water content

## INTRODUCTION

Large amounts of livestock excrements are being produced in Japan. The Ministry of Agriculture, Forestry and Fisheries of Japan estimated 9,000,000 tons of livestock excrements are being produced per year, and 60% of total livestock excrements are cow dung. At present, these large amounts of excrements are being utilized as manure for improving soil condition. However, large amounts of manure production lead to insufficient fermentation of cow dung. In developing countries, it is difficult to ferment cow dung sufficiently, because of the lack of tools or equipments. There were reports that insufficient fermented manure includes pathogens such as *E.coli*, a microorganism which is normally present in intestinal tract of animals (Chun-Ming Gong et al., 2005). This bacterium will easily propagate in the surrounding environment and can be a threat to sanitation once being discharged with the excrements (Saito et al., 2006). Also, *E.coli* can be easily transported by surface runoff along with soil sediments during heavy rainfall or by percolation into groundwater (Yagura et al., 2006). Thus, a proper treatment of cow dung before applying to farmlands became big concern. Therefore, research interests have been paid to the survival limits of *E.coli* in manure for preventing the loss of *E.coli* from farmlands. So, the objective of this study was to investigate the proper treatment of manure from the viewpoints of environmental conservation.

## EXPERIMENTAL METHODS

### Experiment on *E.coli* loss

Model experiments were conducted to investigate the *E.coli* loss from farmlands employing slope plots under artificial rainfall simulator as shown in Fig. 1. Cow dung was utilized as the material source of *E.coli* in this study, as it includes more *E.coli* than other animal excrements. The properties of each material are shown in Table 1. The cell numbers of *E.coli* in fresh cow dung, 14 days fermented manure and 60 days fermented manure were 4.1 x $10^7$, 1.6 x $10^5$ and 8.0 x $10^4$ cfu/g dry matters, respectively.

Three stainless slope model plots were prepared at 8 degrees as it is the maximum slope limit on handling agricultural machineries in sloping lands. Soil was compacted into the slope plots at 1.00 ± 0.06 g/$cm^3$ in dry density (Kawai et al., 2007) and then cow dung or 2 kinds of manure were applied. Fresh cow dung was spread at Plot 1, while Plot 2 and Plot 3 were spread with fermented manures for 14 days and 60 days, respectively. Both cow dung and fermented manures were broadcasted into each plot uniformly. In order to observe and compare the losses of *E.coli* and organic matter from 3 types of plot, artificial rainfall at 60mm/h intensity was simulated for 2 hours.

Discharge of surface runoff was measured at certain interval and sampled from each plots. The *E.coli* in each sample was cultured by the spread plate method on the XM-G agar at 37 degrees Celsius. After 20 hours, the number of blue spots showing *E.coli* colonies appeared on the agar was counted. On the other hand, organic matter was analyzed by means of the ignition loss method.

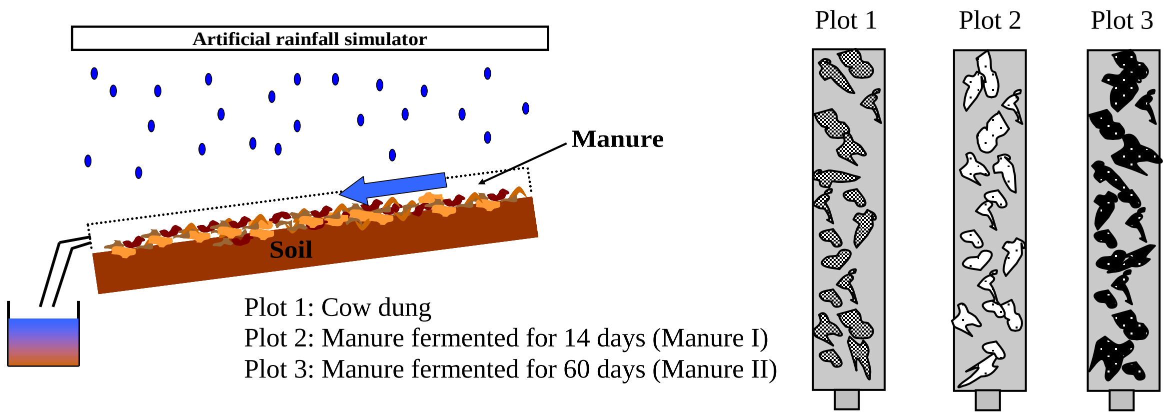



**Fig. 1 Slope model experiment**

**Table 1 Properties of materials**

| Sample | Sub-material | Fermentation term (day) | *E.coli* (cfu/g dry matter) | Water content (%) |
|---|---|---|---|---|
| Cow dung | Sawdust | 0 | 4.1 x $10^7$ | 82 |
| Manure I | Sawdust | 14 | 1.6 x $10^5$ | 73 |
| Manure II | Sawdust | 60 | 8.0 x $10^4$ | 72 |

### Experiment on survival limit

Another experiment was conducted to investigate the survival condition of *E.coli* in the manure. As shown in Tables 2 and 3, cow dung and manure fermented for 14 days were used in this experiment. The change in *E.coli* cell number was observed under different temperature or water content.

Cow dung or manure fermented for 14 days was enclosed with plastic wrap to avoid the reduction of water content and kept in the incubator under the different temperature at 30, 40, 50 and 60 degrees Celsius. Additionally, the changes in *E.coli* cell number with water content were observed. Cow dung or manure fermented for 14 days was kept in the greenhouse for enhancing evaporation, and then certain amounts of samples were collected occasionally for analyzing *E.coli* cell number as well as water content.

**Table 2 Properties of cow dung or manure used in experiment at different temperature**

| Sample | Sub-material | Fermentation term (day) | *E.coli* (cfu/g dry) | Water content (%) |
|---|---|---|---|---|
| Cow dung | Sawdust | 0 | $1.8 \times 10^7$ | 82 |
| Manure I | Sawdust | 14 | $1.4 \times 10^3$ | 72 |

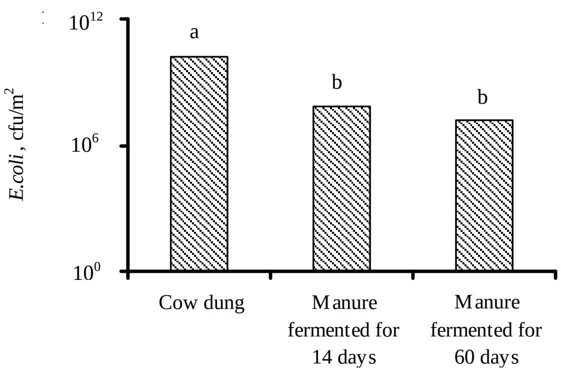
**Table 3 Properties of cow dung or manure used in experiment at different water content**

| Sample | Sub-material | Fermentation term (day) | *E.coli* (cfu/g dry) | Water content (%) |
|---|---|---|---|---|
| Cow dung | Sawdust | 0 | $1.4 \times 10^8$ | 79 |
| Manure I | Sawdust | 14 | $8.6 \times 10^5$ | 70 |

## RESULTS AND DISCUSSION

### *E.coli* loss from plots applied cow dung or manure

As shown in Fig. 2, *E.coli* loss from the plot applied fresh cow dung was the highest among all plots at 99% confidence interval. The loss of *E.coli* was observed not only from the plot applied fresh cow dung but also from the plot applied manure fermented for 14 days or 60 days. Figs. 3, 4 and 5 show the correlation between the amounts of *E.coli* and organic matter. It showed that *E.coli* loss increased with organic matter in sediments.




**There was a significant difference in total surface E.coli loss at 99% between a and b.*

**Fig. 2 *E.coli* loss by surface runoff during rainfall simulation for 2 hours**

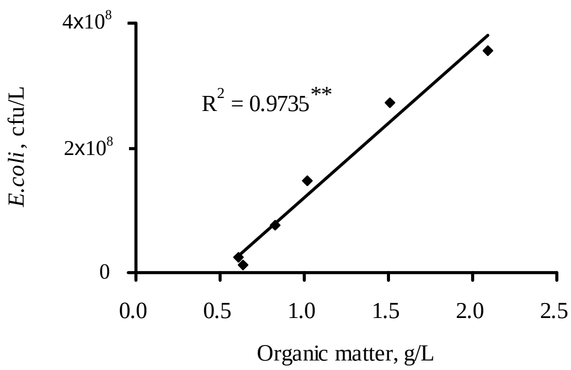



**Fig. 3 Relationship between *E.coli* and organic matter in plot applied cow dung**

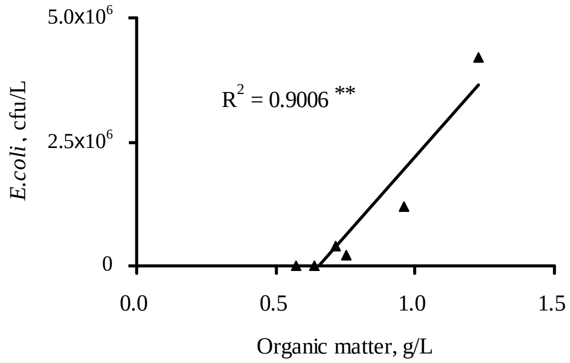



**Fig. 4 Relationship between *E.coli* and organic matter in plot applied manure fermented for 14 days**

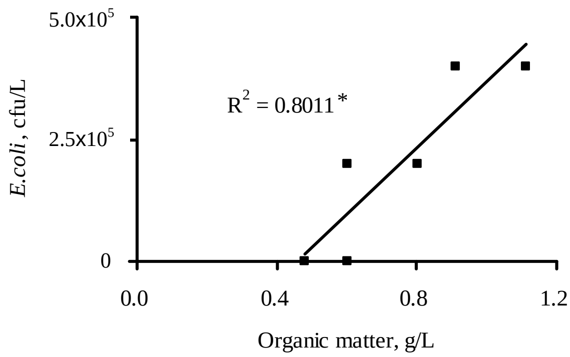



**Fig. 5 Relationship between *E.coli* and organic matter in plot applied manure fermented for 60 days**

## Change in *E.coli* cell number

Based on the results of the experiment employing the incubator, the changes in *E.coli* cell number at different temperature were summarized in Figs. 6 and 7. The cell number of *E.coli* started to decrease at 50 degrees Celsius in either cow dung or manure; however it did not vanish completely. It was observed that *E.coli* vanished completely at 60 degrees Celsius in either cow dung or manure. In opposition, there was no significant difference in *E.coli* cell number among various temperatures under 50 degrees Celsius in either cow dung or manure.

The results of the experiment on the changes in *E.coli* cell number with water content were summarized in Figs. 8 and 9. Water content decreased to 10% in either cow dung or manure for 9 days. There was a tendency for *E.coli* cell number in either cow dung or manure to decrease with the decrease in water content. Additionally, the fluctuation of *E.coli* cell number in cow dung was comparatively smaller than that in manure. Although *E.coli* cell number at 28 days passed was significantly smaller than that at initial stage at 99% confidence interval, the reduction of water content was not enough for vanishing *E.coli.*

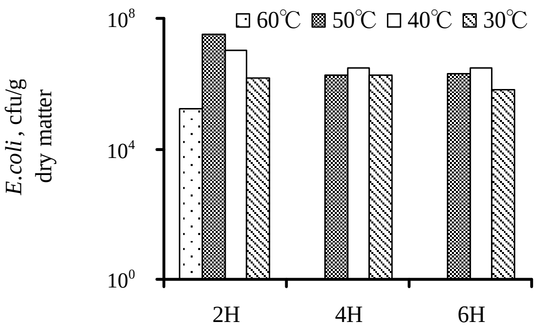



**Fig. 6 Changes in *E.coli* with temperature in cow dung**

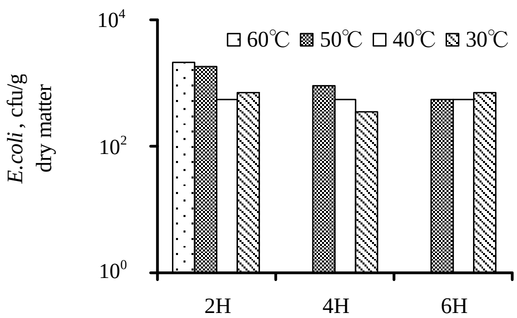
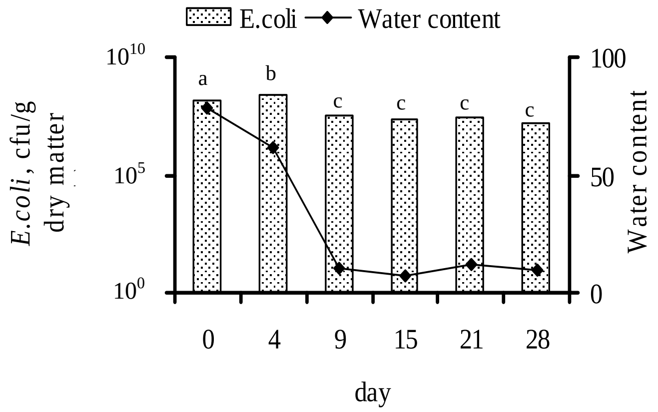
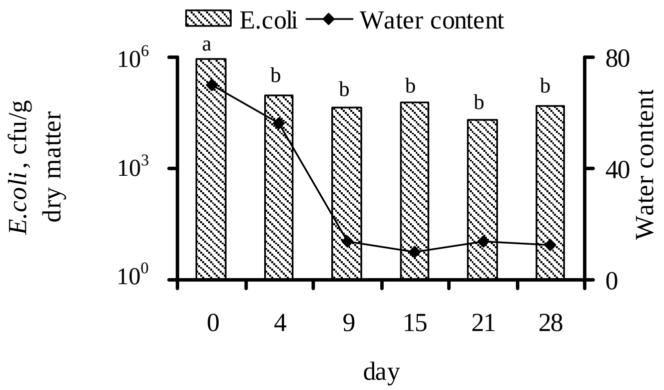



**Fig. 7 Changes in *E.coli* with temperature in manure fermented for 14 days**




*The data followed by different letters differs significantly at 99% confidence interval.*

**Fig. 8 *E.coli* cell number with reduction of water content in cow dung**




*The data followed by different letters differs significantly at 99% confidence interval.*

**Fig. 9 *E.coli* cell number with reduction of water content in manure fermented for 14 days**

## CONCLUSION

As the loss of *E.coli* from farmlands is big concern from the viewpoints of environmental conservation, this study dealt with 2 kinds of experiments, one is for observing *E.coli* loss using slope model plots under artificial rainfall simulator and the other is for observing survival limit of *E.coli* in the manure.

It was proven that the loss of *E.coli* was observed not only from the plot applied fresh cow dung but also from the plot applied manure fermented for 14 days or 60 days. Also, *E.coli* loss increased in proportion to the loss of organic matter in sediments. So, it was considered that attentions should be paid more to soil erosion process, as it accelerates *E.coli* loss from upland fields.

Also, it was concluded that *E.coli* vanished at the temperature higher than 60 degrees Celsius.The reduction of water content was not enough to eliminate *E.coli*. So, it became clear that controlling temperature of manure is important for vanishing *E.coli* existing in manures.

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*Research article*

# The 'Jorani Project': Incorporating Principles of Sustainable Rural Development into the Education System of Cambodia

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**Abstract** An illustrated children's book "Jorani and the Green Vegetable Bugs" has been published in Khmer language to teach children and teachers in rural areas about integrated pest management (IPM) in upland crops and the positive impacts on the environment and human health in Cambodia. The project involves introducing the Jorani Project to school directors and teachers; development of a teacher guide; implementation in schools; and celebration and public launch. Further books in the series are planned to teach the benefits of other sustainable land management practices. The project targets five primary schools in northwestern Cambodia in the district of Samlout in Battambang Province where the Maddox Jolie-Pitt Foundation (MJP), in collaboration with the Ministry of Education, Youth and Sport (MoEYS) is working to strengthen primary education for all school-aged boys and girls. The potential to achieve the stated agricultural extension and primary education objectives will be evaluated after completion of the pilot project. Social network analysis will be used to test the effectiveness of the proposed learning environment model. Depending on the findings, a Life Skills framework for rural primary schools will presented to the MoEYS for endorsement and roll-out to primary schools in other Districts and Provinces in Cambodia.

**Keywords** rural development, primary education, life skills, crop diversification, food security, nutrition

## BACKGROUND

Since 2003, the Australian Centre for International Agricultural Research (ACIAR) has funded two projects in upland areas of Cambodia to help reduce poverty and contribute to food security through the development of sustainable farming systems for upland crops such as maize, soybean, peanut, mungbean and sesame. The original ACIAR project involved discussion with farmers, validation of local knowledge, documentation of case studies and agronomic field experiments. The project was conducted in collaboration with the Cambodian Agricultural Research & Development Institute (CARDI) and with support from the Cambodian Department of Agricultural Extension in the Ministry of Agriculture, Fisheries and Forestry (MAFF).

The approach of the ACIAR project (Farquharson et al., 2010) has been to first investigate and demonstrate new technologies or improved practices in a farming systems context through a network of on-farm trials and demonstrations. These are combined with village workshops to identify the social and economic constraints to adoption of new technologies and changes in management practices. "Crop Profit Groups" of local farmers have been formed to assess the economic costs and benefits of new technologies and changed management practices. The project provides outside expertise in a co-learning environment with local farmers, government advisers and NGOs. Education and capacity-building for Cambodian collaborators has been an important part of the work.

Various extension publications have also been produced targeting agricultural extension professionals and tertiary agricultural educational institutions. These publications have a high potential for impact on the profitability of small-holder farms, leading to poverty reduction, and food security. Extension materials directed at farmers, however, are somewhat ineffective because of the low literacy levels in the rural areas of Cambodia. It was thought that production of educational material for rural primary school children and teachers could improve the flow of new agricultural information to farm families.

The idea for the Jorani Project arose when it became evident that government agencies did not have the physical infrastructure or human resources to implement extension messages such as environmentally friendly agriculture to the local communities in a sustainable way. MJP, working with teachers and school directors in the region since 2006 to reach the UN Millennium Development Goals (MDG 2) in primary education, identified the primary school classroom as a potential vehicle to not only deliver the messages, but also create child friendly life skill 'farming' activities for both the teacher and student.

To move the project forward, ACIAR agreed to publish an illustrated children's book created by a team of authors, including local Samlout teachers to raise awareness on sustainable green farming practices. The book, called "Jorani and the Green Vegetable Bugs" is to complement the second ACIAR project "Enhancing production and marketing of maize and soybean in north-western Cambodia" (ASEM/2006/130) which commenced in 2008 and runs to 2011. The aim of the ACIAR project is to improve the functioning of the production and marketing system for maize and soybean in north-western Cambodia as a key to increasing cash income, sustainable growth and poverty reduction for small-holder farmers. The project facilitates the sharing of knowledge and information at all stages of the value chain from farmer to end-user.

The Jorani Project will teach children in five target schools in Samlout about integrated pest management (IPM) in crops and the positive impact on human health and the environment. If the pilot is successful, further books in the series are planned to teach the environmental benefits of reduced cultivation and burning in crop production, and also the value of wildlife conservation and healthy eco-systems.

Jorani's success will also be linked to the Maddox Jolie-Pitt Foundation's environmental youth program. In 2008, the Ministry of Education, Youth and Sport (MoEYS) gave approval to MJP to create a youth program called 'Eco-Rangers', a club designed to help Samlout's children and their families explore and learn about their environment. The Jorani Project will be included in the 'Eco-Ranger Club' initiative. It will establish links between agriculture and other community activities such as those directed to improving human health and nutrition.

Teacher training in Cambodia may include a variety of agricultural topics such as chemical and organic fertilizers, insect pests, IPM, rice production, water usage, land preparation and chicken-raising. Most school directors, however, do not develop or implement the given Government agriculture curriculum, instead pushing it into the voluntary Life Skills program. Unfortunately, most teachers use the time allocated to Life Skills for clean-up day, presumably because of lack of teacher training and life skills resource materials for teachers.

The Jorani Project could easily be integrated into the Life Skills program if teachers are provided with resources, appropriate training and technical support from agricultural experts. This strategy has been achieved in other countries. For example, Hoppers (2007) noted that the need for life skills development as a core set of competencies is accepted in countries such as Brazil, Namibia, Burkina Faso, Uganda and Thailand. In Cambodia, however, little appears to have been done to include these types of activities in school curricula. Part of the problem appears to be that technical expertise for life skill subjects such as agriculture is provided by different government ministries and teachers might find it difficult to access appropriate information. This is the case in Cambodia where tertiary agricultural education is administered through the Ministry of Agriculture, Foresry and Fisheries. It is important to note that MoEYS officials advised MJP that previous attempts to introduce life skills programs had not been sustainable in Cambodia and that any project will need to have clear goals and be coordinated through MoEYS.

The Jorani Project is a case study to see if agricultural content can be incorporated into the life skills program. Benefits to primary education at student, teacher and system level will need to be demonstrated as well as improved uptake of agricultural technologies. Taylor and Mulhall (2001) carried out research on linking learning environments through agricultural experience to enhance the learning process in rural primary schools in Tanzania, Sri Lanka, India and Ethiopia. They examined the way in which teachers in rural primary schools link the formal school curriculum with the life experience of their pupils, particularly in relation to agriculture. They found that teaching aids and materials, particularly those which relate to the local context, were often in short supply or lacking altogether. Where they were available, teachers' guides and pupils' textbooks often used urban-based examples which were not familiar to children in rural areas.

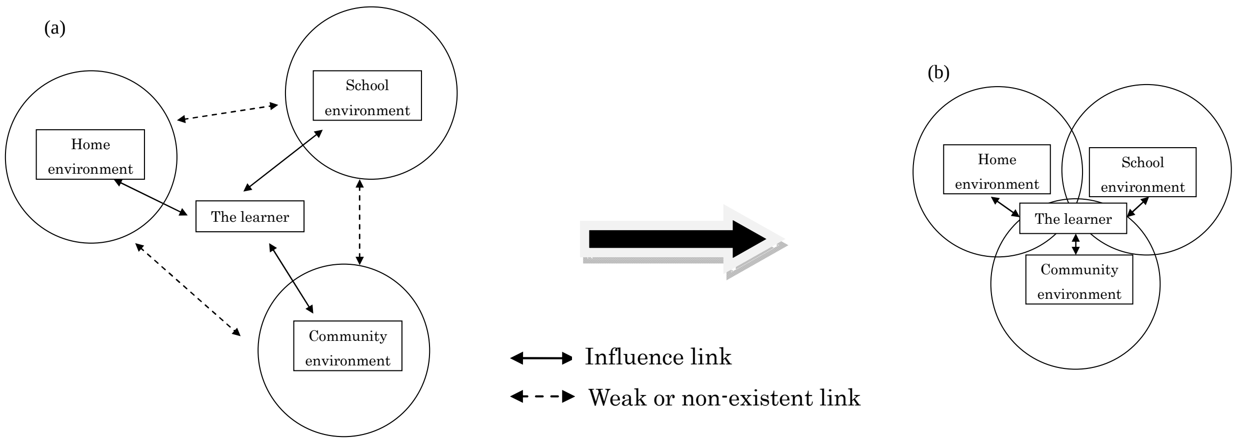


**Fig. 1 Strengthening the learning environment linkages between school, home and community (Taylor and Mulhall, 2001)**

Taylor and Mulhall identified three key learning environments for school-going children: the school, the home and the wider community. They observed that these three learning environments are often disconnected and the experiences gained in each are seldom drawn together and integrated in the learning process (Fig. 1a). According to Taylor & Mulhall, weak linkages between the three learning environments infers that the experiences gained by pupils in school are often perceived to be divorced from life outside school, not only by pupils but also by parents and teachers. Learning could become more effective if these linkages were strengthened and if the interfaces between learning environments were maximised (Fig. 1b). Developing life skills programs that are relevant to rural communities may achieve the outcomes suggested by Taylor & Mulhall.

Other studies in developing countries confirm these observations. Khupe et al. (2009) reported that education for most rural children has only a small, if any, relationship with students' lives outside the classroom. More than 30 years ago, Lindsey (1975) observed that school curricula were leaving rural children with a low capacity to function within their societies because they lacked the requisite skills. This appears to be true today. The challenge for rural education is not only that of achieving literacy, but also guaranteeing employment and self-employment of the 'economically active' population (Bouyer et al., 2005). Rural people make their own informal evaluations of local education, where they check school leavers' capacity to contribute towards community improvement. Formal education in many developing nations does not equip students with skills that could be useful in developing their communities. Acker & Gasperini (2003) emphasized that relevance of educational programs in rural areas is an important area for improvement especially with regard to relevance to local needs.

It should be noted that in some cases locally relevant life skills programs have met with hostility from parents who do did not see the point of having their children acquire practical knowledge which they felt they could provide themselves (Atchoarena and Gasperini, 2003). If parents send their children to school so that they can escape from rural life and find a job in the city they might not be happy with locally-relevant life skills programs (Bergmann, 1985). Therefore the Jorani Project will need to obtain feedback on attitudes and beliefs of all participants and stakeholders in the Samlout case study.

## THE “JORANI PROJECT”

The purpose of the Jorani Project was to conduct a pilot study in the district of Samlout to:

1. Determine if inclusion of agricultural subjects in the primary school life skills program leads to improved uptake of new technologies and more sustainable land management practices
2. Determine if life skills activities in rural primary that are relevant to rural communities can strengthen the linkages between the school, the home and the wider community.

The MJP education project team examined the curriculum for primary school grades 4, 5 and 6 to determine where the Jorani resource best fitted into the current curriculum. The education team then consulted with the agriculture team to produce activities and materials to enhance teachers' understanding of important content presented in the Jorani book. The education team worked with the Battambang Provincial Director of Primary Schools to develop a template for the Teacher Guide. The Director was also invited to be the advisor and possibly co-facilitator for teacher professional development. The project involved the Samlout district villages of Bueng Run, Kampong Touk, Kantout, Ou Chrab, Samlout and Sre Reach. The schools involved were: Kampong Touk, Ou Chrab, Sre Andoung II, Sre Andoung lower secondary and Sre Reach. The total number of children involved in the project was 638 (Table 1).

In phase 1 of the project a group of 20 teachers and school directors from Samlout district attended an introductory workshop on IPM run by the ACIAR project at Samlout in October 2009. The workshop was also attended by the Battambang Provincial Director of Primary Education. The workshop was in the same format as used for agricultural advisers and key farmers and consisted of a series of presentations, practical exercises and field activities. Resource materials included a workshop manual, an insect identification guide, notebooks and data recording sheets. The workshop covered: an overview of IPM; crop growth and development; insect management options; insect monitoring techniques; calculating economic thresholds; safe and proper use of pesticides; personal protective equipment (PPE); and types of insecticides available in local markets. The illustrated insect field guide provided a brief description of insect pests and the damage they cause as well as information on a range of beneficial insects and spiders that can be found in upland crops in north-western Cambodia.

**Table 1 Samlout District primary schools and numbers of children involved in the Jorani Project**

| | Grade 4 | | Grade 5 | | Grade 6 | | Sub Total | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F | |
| Ampob Leu | 10 | 17 | 0 | 0 | 0 | 0 | 10 | 17 | 27 |
| Kampong Touk | 9 | 4 | 15 | 2 | 0 | 0 | 24 | 6 | 30 |
| Ou Chrab | 33 | 31 | 36 | 30 | 37 | 26 | 106 | 87 | 193 |
| Sre Andoung II | 39 | 47 | 43 | 44 | 38 | 35 | 120 | 126 | 246 |
| Sre Reach | 36 | 27 | 20 | 21 | 15 | 23 | 71 | 71 | 142 |
| Total | 127 | 126 | 114 | 97 | 90 | 84 | 331 | 307 | 638 |

It is important to note that the education team consulted with MJP's agriculture team to produce activities and materials to enhance teachers' understanding of important content presented in the Jorani book. The education team also worked with the Battambang Provincial Director of Primary Schools to develop a template for the Teacher Guide. The Provincial Director was invited to be the advisor and possibly co-facilitator for teacher professional development.

Phase 2 of the project involved a three day workshop for all grade 4-6 teachers and school directors from the pilot schools as well as senior staff from the provincial and district offices of the MoEYS. The goal of this workshop, facilitated by the MJP education team and an expert teacher from Canada, was to demonstrate how a resource such as the Jorani book that is based on life skills important to students' families and community can be effectively used to develop literacy and scientific skills linked to curriculum expectations. During the workshop teachers learned and practiced 15 different methodologies such as jigsaw, book making, song creation, puppet plays, nature colour hunts, interviews and sports games. They created a journal record of each methodology and more importantly identified and discussed the skills students would be developing as they participated in these stimulating child-friendly activities. Discussions included how the same methodologies could be applied in different subjects within the curriculum. On the final afternoon teachers and staff developed plans for the next phase – development, timing and implementation of the IPM Life Skills program they would present using the Jorani book and the new methodologies they learned.

Phase 3 was designed to ensure teachers are well prepared and confident to provide the IPM Life Skills program. The design included one full-day training and two half-day workshops for teachers prior to their implementation of the IPM Life Skills program in their classrooms.

At the end of phases one and two teachers still had questions about IPM. Unlike classrooms in the developed world, students do not have access to the internet and teachers recognize they need to be the experts. The full-day training will be offered by an MAFF expert to provide sufficient content in the Khmer language for them to feel comfortable as IPM experts in the classroom. Resource materials will include an illustrated insect field identification guide and an IPM workshop manual.

The teachers will then participate in two half day workshops. The objectives of the first workshop are to: decide what content about plants, bugs, and pesticides should be covered in each school grade; develop their IPM Life Skills lesson plans incorporating some of the 15 methodologies they learned at the previous workshop. During the second half-day workshop, teachers will complete lesson plans for IPM Life Skills and produce teaching materials for the program. Teaching materials will be prepared and include school kits with specimens of insects occurring in local crops and as shown in the Jorani book, insect field guide book and the IPM workshop manual.

The project is to be implemented in the Samlout schools during January and February 2010. The teachers were advised to modify the program as necessary to adapt to the needs of the individual class. Suggestions for school class activities included:

- Working in groups to develop dramas based on the story and making costumes or masks to look like insect characters from the book (there should be a prior class discussion to identify the important agricultural information that should be built in to the plays);
- Simple hand puppets of the good and bad bugs could be made to create puppet shows to act out the roles of the good and bad bugs;
- Making up lyrics about the story and sing these to the tune of a popular song;
- Preparation of short speeches on integrated pest management (IPM) based on what was learned from the book;
- Creation of individual insect books or working collaboratively to make a large class book that could be placed in the school library.

Local farmers, agricultural experts and conservation officers will be invited to the school to talk to the students about their experience using IPM on their farms and the positive impact on the environment. Students will develop a series of interview questions ahead of time and one or two students will conduct the interview followed by a question and answer period where all students ask questions. Follow-up activities planned for the early wet season (May-June) include insect collections and school gardens.

The program will culminate in an open door Celebration Day including games, songs, puppet plays, displays of work books and artwork (Phase 4). During the event, each child will be presented with their own personal copy of "Jorani and the Green Vegetable Bugs" to take home. A total of 700 Khmer language Jorani books will be distributed.

## CONCLUSION

After completion of the pilot project, the ACIAR project team plans to carry out an evaluation to determine the potential to achieve both agricultural extension and primary education objectives. It is expected that the project messages will spread through expanding circles of sharing (like ripples) among small groups; the whole class; between classes; between schools; at home with parents; and with the wider community. Social network analysis as described by Borgatti et al. (2009) will be used to test the learning environment model proposed by Taylor and Mulhall. Depending on the findings, a proposed Life Skills program for rural primary schools will presented to the MoEYS for endorsement and roll-out to primary schools in other Districts and Provinces in Cambodia.

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Research article

# Building Capacity for Sustainable Rural Development: Lessons from Nepal

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**Abstract** Rural development has been a buzzword in recent years among international development professionals. Numerous programs and policies have been implemented worldwide to bring about positive development in rural areas. Consistent with such efforts, we have introduced a series of projects to promote sustainable livelihoods in the village of Hamsapur, Nepal, such as developing a system to supply clean drinking water, a storage system for potatoes, and a computer lab to improve education quality. The purpose of this paper is to illustrate the need for building human capacity to sustain benefits from development projects. Qualitative data derived from observation and key informant interviews were used to assess impacts. Findings indicate that these projects did not meet our expectations of improving livelihoods in a sustainable way. Some changes resulting from the projects did not last long, and others could not be continued after external support was withdrawn. The main reason for lack of long-term sustainability was the lack of local capacity, specifically, a lack of knowledge and skills by locals that are critical to planning and implementing development projects and associated activities. The beneficiaries were unable to maintain the projects locally.

**Keywords** capacity building, rural development, Nepal

## INTRODUCTION

Over four-fifths of the people of Nepal live in rural areas. Farming is their main occupation. They grow crops and tend livestock in a small land area. They understand the interdependence between nature and people. They practice subsistence agriculture that has sustained many generations. For generations, they followed a social system that governs their way of life. Rural development in this context could be synonymous with agricultural development.

International donor communities have widely recognized the need for rural development as a means to end hunger, poverty, inequality and unemployment in developing countries. National planners have adopted various plans and policies to promote rural development through a variety of programs, such as agricultural extension services for farmers, rural credit and cooperatives for farmers and entrepreneurs, construction of farm-to-market access roads, and irrigation schemes to increase crop yields. Development projects were implemented, but in many cases they were ineffective due to poor implementation and management (Government of Nepal, 2007). Of course, progress has been made to improve the livelihoods of many millions in rural areas. Policy reforms contributed to economic growth in the early 1990s. However, the initial momentum generated by the reforms began to wane by 1995 (Shakya, 2002). The rate of progress has not met the expectations of development professionals (Mishra, 2006; Panday, 1983). Moreover, some of the changes made by development projects were short-lived. Many project activities could not be continued by the local people after the donors pulled out. Local people did not have the financial and managerial capacity to maintain the development projects in their communities. To put it simply, although well intended, many development programs or projects have not been sustainable (Panday, 1983; Shakya, 2002; Nepal South Asia Center, 1998).

Sustainable development has been a buzzword in development literature. Global dialog on the concept and issues of sustainability began in the late 1970s (Orr, 2002). Scholars and practitioners continue to debate about what is to be sustained, and how we measure sustainability (Bell and Morse, 2000). Thompson (2007) argues that definition and conceptualization of sustainability have been philosophically open ended and continuously evolving tasks. Many tend to agree with the definition of sustainability advanced by the World Commission on Environment and Development in 1987: "meeting the needs of the present generation without compromising the ability of future generations to do the same." Similarly, there seems to be agreement on three primary dimensions of sustainability: social, economic and environmental. To some extent these dimensions overlap.

Michigan State University, in collaboration with a local school and a non-governmental organization, introduced a series of micro-projects to promote sustainable livelihoods in the village of Hamsapur, Nepal. These development programs included development of a system to supply clean drinking water, potato storage, and computer education at a public high school. This paper outlines the nature of these micro-projects, describes how they were implemented, and discusses the lessons learned for sustainable development.

## METHODS

This paper is based on a case study approach. A household survey was used to establish socio-economic benchmarks of the community. A survey instrument developed by the United Nations Development Program of Nepal was adopted. Trained interviewers conducted surveys of 838 households. Data were coded and entered into SPSS software. Descriptive statistics, including percentages, range, mean and standard deviations were used to analyze the data.

Observations and informal interviews with key informants were used to describe project implementation and impacts. The researcher visited the study area every year, taking digital photos, interviewing beneficiaries, observing changes over time, and listening to key informants about issues and impacts. Notes were reviewed, organized by project, and analyzed to draw conclusions. Findings are presented as case studies.

## RESULTS

Hamsapur is a typical hilly cluster of villages located in western Nepal near Pokhara. The population of the village is diverse, comprising Gurungs and Magars (major ethnic groups), Bishwokarma, Nepali/Magrati, Gharti/Bhujel, Bahuns and Chhetris. Education of the population is a critical factor for sustainable development. To respond to change, people must be able to read and write to understand messages for change. Table 1 show that in 2006, about one-fifth of the population of Hamsapur was illiterate. Although there seems to be an equal proportion of the population attending primary school and high school, higher caste people (e.g., Bahun, Newar and Chhetri) tend to pursue higher education more frequently than people from other castes or ethnic groups.

**Table 1 Educational level of school age population by caste/ethnicity (N= 4,302)**

| Caste/Ethnicity | N | Illiterate (%) | Literate/ Primary (%) | High School (%) | Higher Education (%) | Currently Studying (%) |
|---|---|---|---|---|---|---|
| Bahun | 2,194 | 17.1 | 27.7 | 28.1 | 21.2 | 5.9 |
| Chhetri | 114 | 16.7 | 43.9 | 25.4 | 10.5 | 3.5 |
| Pariyar | 64 | 17.2 | 29.7 | 18.8 | 4.7 | 29.7 |
| Gharti/Bhujel | 197 | 23.4 | 35.0 | 23.4 | 5.6 | 12.7 |
| Gurung | 566 | 15.0 | 38.5 | 31.6 | 7.4 | 7.4 |
| Magar | 137 | 24.8 | 34.3 | 32.1 | 7.3 | 1.5 |
| Bishwokarma | 656 | 33.8 | 43.6 | 8.7 | 2.6 | 11.3 |
| Nepali/Magrati | 135 | 31.1 | 33.3 | 16.3 | 4.4 | 14.8 |
| Newar | 241 | 20.3 | 25.3 | 26.1 | 17.4 | 10.8 |

Over 90 percent indicated that they are engaged in farming. Respondents were asked to indicate their total household incomes, derived from various sources. Crop yield and livestock production, salary and wages, including pension and remittances of all family members, were included in the household income computations. Table 2 shows the total household income for various caste and ethnic groups. It should be noted that some households did not report income.

**Table 2 Household' annual income by caste/ethnic group (N=802)**

| Caste/Ethnic Group | N | Mean Household Income (Nepali Rupees) | SD |
|---|---|---|---|
| Bahun | 415 | 131,309 | 219,932 |
| Chhetri | 23 | 113,842 | 114,172 |
| Pariyar | 10 | 142,280 | 153,169 |
| Gharti/Bhujel | 41 | 99,893 | 88,693 |
| Gurung | 102 | 177,993 | 336,149 |
| Magar | 18 | 199,642 | 266,290 |
| Bishwokarma | 123 | 69,684 | 97,300 |
| Nepali/Magrati | 28 | 98,136 | 61,444 |
| Newar | 42 | 90,876 | 48,928 |

*Exchange rate as of January 25, 2010: USD 1 = Nepali Rupees 74.4*

As shown in Table 2, Bishwokarma (traditional blacksmith caste) had the lowest household income. Magar households had the highest income, followed by Gurung. The Bahun and Chhetri households, although they belong to a high caste, had incomes lower than Magar, Gurung and Pariyar but higher than those of Bishwokarma, Nepali/Magrati, Newar and Gharti/Bhujel.

**Micro-development Projects:** We introduced a series of micro-development projects in Hamsapur. These projects included the construction of a drinking water system, bee keeping, raising of goats and pigs for income generation, promotion of coffee for cash income, potato storage, and development of a computer lab with Internet access to improve education. The following sections present three of these projects as case studies.

**Case I - Drinking Water System:** Drinking water is the major problem for Hamsapur residents during the dry season. The village is situated on the southern slope of an independent mountain and the mountain does not have a permanent spring to supply drinking water via gravity. Beginning in November, most water holes and springs at higher altitudes dry up as the monsoon ceases; the villagers are forced to go farther down the slopes to collect water from permanent springs/water holes. During December through May, women spend about three hours daily carrying pots of drinking water to meet family needs.

The shortage of drinking water has forced many households to migrate to the Terai region of Nepal or relocate their houses to the lower valleys. However, many villagers have neither the land in the valleys nor the resources to move their households. Needless to say, the poorest of the poor have no place to go for an improved quality of life.

In February 2000, the Mothers Group of Hamsapur approached the author of this paper to assist in finding appropriate help to address the drinking water situation in this village. During a village gathering, the local people agreed that a water user committee would be formed. The water user committee was tasked with setting policies for water distribution, mobilizing local people to volunteer for project implementation, and collecting monthly water user fees for managing the water supply.

The Rotary Club of Traverse City, Michigan sponsored this drinking water project. The Rotary Club of Pokhara, Nepal worked closely with the local Water User Group and an NGO, Indragufa Community Development Foundation, to implement the project. The author of this paper facilitated coordination of all partners for the project's implementation.

The major project activities included construction of a collection reservoir at Kurlungkhola; construction of a small pump house adjacent to the intake reservoir; and installation of a pump to lift water to the first reservoir (325 meters from the intake tank) and to the second reservoir (294 meters from the first reservoir). During the monsoon season, the electric pump may not need to be operational because water pipelines from a natural spring are connected to the second reservoir, using gravity to send the water to the reservoir. This system should provide a year-round water supply to almost 80 percent of water users in the village. To reach the remaining population, primarily in upper Syaklung, a third pump was installed at the second reservoir. Construction work started in May 2001 and was completed in February 2004. The supply of clean drinking water began in March 2004. A local person was trained to operate the system. Approximately 240 households benefited from the drinking water supply system.

One of the major problems for the system has been lack of a consistent supply of electrical power. Frequent lightning in the area and the fluctuation in electrical voltage blew the electrical fuse at the control panel. Every year, lightning damaged the motor or burned out the coiling inside the pump. The local people spent significant resources repairing the pump. Other problems included lack of timely payment or non-payment of water user fees by some households. In absence of an appropriate incentive for managing and maintaining the water system, the leadership of the local Water User Committee became dysfunctional. Despite the frequent interruptions in water supply and lack of leadership, the system was operational for five years. In 2009, the water pump at the base station was damaged badly and the water supply was not operational for the entire dry season. In January 2010, a new submersible pump replaced the old one, and the water supply has been restored. Challenges of maintenance, management and responsible fee payment are still to be addressed.

**Case II - Potato Storage:** Potato is a relatively new crop in the middle hills and valleys of Western Nepal. Farmers began planting potatoes in the 1970s. Many farmers of Hamsapur now grow potatoes. They harvest their potato crops in April and sell them at a low price, but they buy seed potatoes in October/November at very expensive prices. If farmers could store their potatoes for about six months, they could significantly increase their income from the sale of potatoes when demand is higher and supplies lower than at harvest time.

A group of farmers requested this researcher to demonstrate potato storage. The cost of constructing a community-based potato storage facility was funded by the Empower Nepal Foundation. Local farmers agreed to pay a small fee for the storage of their potatoes. It was proposed that the storage fee collected would be reinvested to build additional storage facilities for neighboring farmers during the second year and so on. Indragufa Community Development Foundation agreed to work with the local farmers' group to mobilize their resources and to build the demonstration potato storage facility.

The potato storage facility was constructed in 2001. The farmer who owned the storage facility indicated that he would begin storing the potato crop in 2002. He, however, was concerned if the right temperature and humidity could be maintained inside the storage facility. Once the storage facilty was complete, it stayed idle for a few years. No farmers used the potato storage facility. When asked why they did not use the storage facility, farmers said:

- "Needed cash, so I sold my potato crop immediately after the harvest. I did not need the storage."
- "I grow potato only for my family's use. I did not need the storage."
- "We don't know if the potato stays good for 5-6 months. What would happen if the crop got rotten? Who will pay for the loss?"

**Case III - Computer Lab to Improve Education Quality:** Ramkot Higher Secondary School is located about 35 kilometers southeast of Pokhara. It has over 400 students in grades 6 through 12. The school has 13 teachers and two support staff members. English, math, science, social studies, Nepali languages, and health studies are taught at the school. Twelve elementary schools and two middle schools in Hamsapur Village Development Committee feed students to Ramkot Higher Secondary School.

In March 2007, this researcher met with the Ramkot Higher Secondary School Management Committee to jointly develop a master plan for systemic educational quality improvement. The master plan included the use of technology in teaching and learning, construction of new classrooms and lab facilities, engagement of parents and volunteers in school improvement activities, and offering of technical training to enhance employment opportunities for graduates.

A computer lab having nine computers, access to wireless Internet, and a printer was established at Ramkot Higher Secondary School. The computer lab was intended primarily for use by the school teachers and students. Other professionals working in the area such as health technicians, agriculture extension workers, and Village Development Committee staff members could also access the computer lab on a “fee for use” basis.

The computer lab was originally set up in a small classroom at Ramkot Higher Secondary School. It was under direct supervision of the school administration. It was agreed that Ramkot Higher Secondary School would identify one or two teachers having basic knowledge of computer and/or showing strong interest in using computers. These teachers would be sent elsewhere for computer training. Upon their return, they would serve as instructors. They were expected to receive periodic upgrading courses as needed. The school would be expected to formulate policies and guidelines for the day-to-day operation of the computer lab. It was agreed that the computer lab would be open for students during school hours and open to community members and professionals during weekends and after-school hours. A small user-fee was proposed to sustain the operation of the computer lab.

It has been three years since the computer lab with Internet access became operational and the computers are kept covered to protect from dust. However, no teacher has been given full responsibility to manage the computer lab and/or offer classes to students and teachers. One teacher is assigned to look after all hardware and software on an ad-hoc basis. This teacher is asked to send e-mails for the school and uses word processing software to type examination questions and important school communications. The lab has never opened its door to students and not many teachers have made use of this facility. When asked why the lab is not made open to students and teachers, the head master and members of the School Management Committee said,

- “We had limited classroom space, so we had to move the computers to our office area. Now we have new classrooms and we hope to have one room dedicated to the computer lab. Soon, we will start offering computer training to students and interested teachers.”
- “Computer is not required in the curriculum, so there is no position for a computer teacher. As a result, we are unable to offer computer classes.”
- “The classes are scheduled from 10:00a.m. - 4:00p.m. There is not free time to schedule a computer class. It is possible that we could offer computer classes either before or after the regular school classes to interested students. We can offer computer classes if we have a hostel at our school.”

It should be noted that a few teachers and the school librarian have shown interest in learning how to use the computer. During a recent visit to the school, many students approached this researcher indicating that they are truly interested in learning the use of computer for word processing and Internet access.

## CONCLUSIONS

Hamsapur is a typical hill village of Nepal. Most households are subsistence farmers. Although school participation has improved in recent years, local people lack skills to manage technological aspects of rural development. For example, graduates from local high school have not skills in using electrical tools or plumbing equipments, and there is no easy access to receive training. Most development projects focus on technologies that require the use of electricity, operation of a machine or equipment. Thus, building local capacity is imperative.

We have found that human capacity is the fundamental factor in the sustaining benefits of rural development programs. Despite the fact that drinking water is a real need of the people of Hamsapur, local capacity to maintain the system was missing. The project did not include training of the local people as electricians and plumbers. They did not receive proper training on how to use the plumbing and electrical tools and equipments. Instead of building local capacity to prevent possible problems in the operation of the drinking water supply, the project depended on outside expertise for repairing the broken pumps. This increased the community’s dependency on the outside world and reducing local capacity for development.

The case of potato storage suggests that we, as development professionals, tend to move quickly to address problems without fully studying the nature and scope of a problem. It seems that long-term storage was not a real need of most of the farmers, who grow potatoes mainly for home consumption. Further, farmers having low levels of education are unable to comprehend the need to maintain stable room temperature and humidity for potato storage. Their perceived and real risk of losing the crop was greater than the potential long-term financial benefit of the storage. It would have been appropriate to demonstrate potato storage for a couple of years at no cost so the local farmers could learn from the experience, and adopt the practice after a few years if perceived as valuable to them. Again, building local capacity through a demonstration project would help the transfer of technology.

Use of computers has changed the way we do business globally. All businesses and industries of the modern world use computers for their operation. Teaching computers at high school has proven to be necessary for graduates to find employment. Many educational resources are now made available online. However, in the context of rural Nepal, most public schools have no infrastructure or resources to offer computer education to students. School teachers who never used computers have little appreciation of computer education. The school curriculum does not require use of computers. Accordingly, the government does not support computer teacher positions in public schools. In such a context, how can public schools begin offering computer literacy to their students? Questions abound. Who is responsible to develop computer literacy among high school students? What should be the role of the government? What should be the role of local schools and parents? Do development planners and policy makers realize that that students' ability to use computer is a corner stone for building local capacity for rural development in the 21st century?

In our work in Nepal, we emphasized community needs assessment, allocation of resources to address needs identified by the community, and insurance of participation by local people in project implementation. Nevertheless, our projects did not achieve their potential, particularly over the long term. We learned that participation in project planning and implementation is a necessary but not sufficient condition for sustainable development. Developing local capacity to manage the change over the long term is imperative, and should be addressed specifically during project planning. We suggest that development projects should develop the skills of the local people through training so they could operate and maintain machinery and equipments. More importantly, keeping the capacity in the village, either by incentivizing trained people to stay or by developing a system for training others to replace them, is essential for sustainable rural development.

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*Research article*

# Crop Profit Groups and Farmer Participation in Research: Some Experiences from Cambodian Upland Regions

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**Abstract** Reductions in poverty and improvements in food security are important issues for farmers and agricultural regions in Cambodia. In this paper we relate our approach and experience working in upland areas of Battambang Province to improve agricultural, environmental and social outcomes for farm families and villagers. Small farm sizes and observed low levels of agricultural productivity exacerbate poverty and food insecurity. We have approached this challenge by first investigating and demonstrating new agricultural methods (or technologies) in a farming systems context, through developing a network of farm trials and demonstrations. To this is added activity in contextual economic and social assessment of new versus old farming methods and management, with the objective of farmer adoption of improved methods and associated increases in farm family incomes. We have formed Crop Profit Groups of local farmers to assess the economic costs and benefits of changed management in the main cash crops of maize and soybean. We have also investigated marketing and value-chain issues since these affect upland farmers in important ways. Our approach has been to bring expertise to each situation and adopt a co-learning approach with local farmers, government officials and NGOs. Education and capacity-building of Cambodian collaborators has been an important part of the work. While our work is not yet finished we have found a genuine willingness by the Cambodian farmers to consider new 'ways of doing things' and be involved in assessing their own incentives to change. A variety of approaches are used in training and capacity building of the local researchers and officials. There seem to be substantial economic incentives to change some farming practices, but issues of farm input supply availability, markets and prices received for farm produce, transport costs and infrastructure appear to constrain improved farm and regional outcomes.

**Keywords** Cambodia, agriculture, environment, technology, poverty, food security,

## INTRODUCTION

Reductions in poverty and improvements in food security are primary objectives of project funding supported by the Australian Centre for International Agricultural Research (ACIAR), the Cambodian Agricultural Research and Development Institute (CARDI), and non-government organizations (NGOs) such as CARE-Cambodia (CARE) and the Maddox Jolie-Pitt Foundation (MJP). In this paper we draw on information and experiences from a number of ACIAR-funded projects in the upland regions of Cambodia. In recent years Cambodia has regained self-sufficiency in rice production and some research and development (R&D) priorities have moved to non-rice farming systems in upland regions. In the north-western Provinces of Battambang and Pailin the main non-rice field crops are maize and soybean, with mungbean, peanut, sesame and cassava also being important.

Our objectives in this work have been to investigate typical farms, farming systems, crop management and use of crop technologies to see whether improved management can be introduced and demonstrated so that, if adopted by farmers, our activities lead to improved farm-family incomes. The process followed has been one of assessing the existing situation, choosing and physically demonstrating new crop technologies and management, and then assessing the financial and social implications for change at the farm level. Throughout our focus has been on talking to farmers and farmer groups about how they do things at present, and asking what they might think of the opportunity to change - a co-learning approach. Our project work is not yet finished, so the outcomes of our R&D are not yet obvious - at least in terms of substantial uptake of new crop technologies by upland farmers.

As well, we have been keen to consider the environmental implications of our work and to neither impose external paradigms on these upland farmers nor to repeat mistakes that might have been made in other places and earlier times. This has involved a balancing of agricultural production, farm-family income and environmental objectives. In this paper we discuss issues that have been confronted in undertaking this balancing task.

Our recent work has focused on three districts, Pailin and Sala Krau in Pailin Province, and Samlaut in Battambang province, of north-west Cambodia. The target villages and clusters are shown in Fig. 1. Village clusters are Baysey, Bor Tangsu, Ou Ro El and Prey Santeah in Pailin district, and Beoung Run, Kampong Touk, Kantout and Sre Reach in Samlaut district.

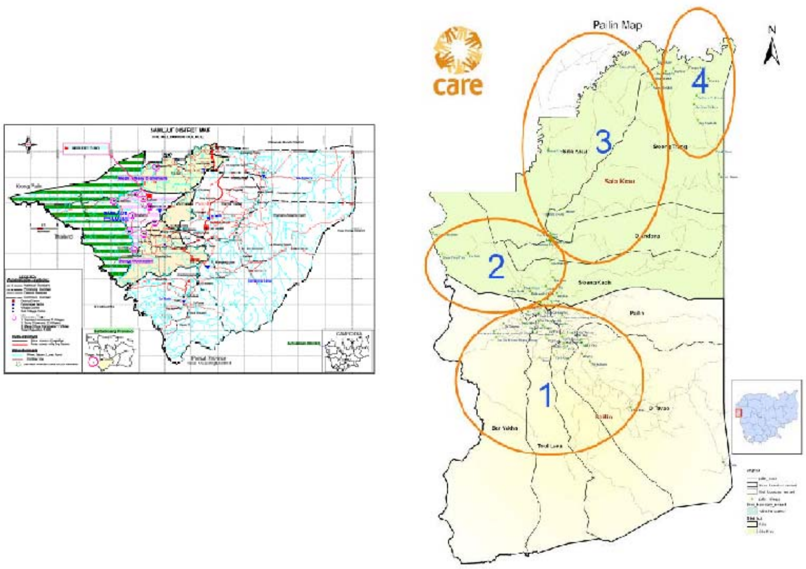


**Fig. 1 Target villages and clusters - Samlaut (left) and Pailin (right)**

## CONDITIONS

### Rural development, environmental outcomes and agricultural development ethics

Agricultural development activity in developing countries must face ethical questions such as 'what type of agricultural paradigm should be promoted in developing agricultural communities?' and 'how can the expressed needs of farm families, village communities and national governments be accounted for in agricultural development activities?' (Chrispeels and Mandoli 2003). There are alternative ways of improving farm family incomes, in terms of the agricultural technologies and management that can be promoted, and we can make choices based on the underlying moral and ethical belief systems of both the funding agency (and country) and the recipient communities (and country).

The traditional agricultural paradigm of production to feed the world at the lowest possible food price is being challenged by changes in societal thinking about the impacts of such changes on agricultural societies and the natural environment. The (western) utilitarian agricultural ethic of judging actions by their effects on fellow human beings (the greatest good for the greatest number of people) can be interpreted as emphasizing production without a full consideration of other (more nuanced) impacts. With a projected increase in world population an important need is for future agricultural production systems to be able to satisfy the associated increases in demand for food. But can that be accomplished without further detrimental effects on natural ecosystems and changes to a (perhaps idealized) view of how rural and urban societies should develop? The International Food Policy Research Institute (IFPRI) has a 2020 vision of a world:

- where every person has access to sufficient food to sustain a healthy and productive life;
- where malnutrition is absent;
- where food originates from efficient, effective, and low-cost food systems; and
- where food production is compatible with sustainable use of natural resources (IFPRI undated).

**How has our project matched against these sustainability and food security goals?:** The current project (Cambodian Crop Production and Marketing Project (CCPMP), see http://ccpmp.pbworks.com/) has four communities of practice - Production, Socio-Economics, Marketing and Value Chain. The teams associated with each community of practice conduct specific and coordinated activities to achieve the project goals. A Continuous Improvement and Innovation Approach to project management and evaluation was used (Madzivhandila et al. 2008). In this paper we focus on the Production and Socio-Economics team activities, but first we set the overall project context and report the perspectives of the project participants.

### Cambodian agricultural priorities and institutions

**National R&D priorities:** The Royal Cambodian Government's National Poverty Reduction Strategy (2003-2005) committed research centres and extension systems to focus on small-scale farmers and place emphasis on the use of improved tools and management practices for cropping systems. Priority was given to diversification and intensification of sustainable agricultural production with few external inputs as well as cost–effective management practices.

**Institutional priorities in Cambodia:** CARDI was established in 1999 by the Royal Government of Cambodia as a semi-autonomous institute. It has a vision of partnerships for livelihood improvement and economic growth in Cambodia, and a mission to contribute to the Royal Government of Cambodia Policies on poverty reduction and economic development (CARDI undated). CARE has worked for some time in Cambodia, initially (in the 1990s) with the United Nations to help refugees. Since then CARE has shifted its focus to long-term development programs, helping poor communities improve their standard of living (CARE undated). MJP is dedicated to eradicating extreme rural poverty, protecting natural resources and conserving wildlife; MJP promotes sustainable rural economies that directly contribute to the health and vitality of communities, wildlife and forests (MJP undated).

## Upland crop production in Cambodia

**Constraints to crop production:** Dillon and Hardaker's (1993) conceptualization of the constraints to production at the farm level has been adapted for this project as shown in Fig. 2. Biological and bio-physical constraints are addressed by the Production team, and other socio-economic constraints are addressed by the Socio-Economics, Marketing and Value Chain groups.

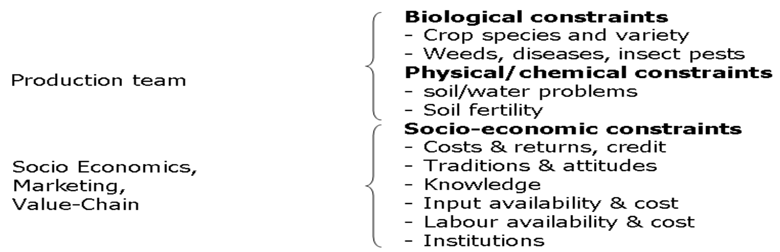


**Fig. 2 Project focus on constraints to crop production in Cambodia**

**New crop production technologies considered:** The new upland crop management technologies considered within CCPMP have been: (1) rhizobium inoculation of legume seeds, (2) the application of urea (Nitrogen (N)) fertilizer to maize, (3) changes in crop rotations and/or crop sequencing, (4) use of reduced or conservation tillage, (5) integrated pest management (IPM) for insects, and (6) weed control in crops. These have been trialed on farmer fields by project staff and subjected to farm management economic analysis.

## Project activities and methodologies

**Production team activities:** The CCPMP Production team activities have involved establishing trials of new crop technologies in farmer fields. These trials are supervised in establishment, maintenance and extension activities by the project team, especially the CARE and MJP officers. Careful experimental designs and plot planning and management have been conducted to facilitate farm walks and extension activities to demonstrate to farmer and village groups the possible physical changes that might accompany changes in crop management and technology use. The development of crop production information and publications for insect and weed identification has been an important part of the Production activities.

**Socio-Economic team activities:** Economic evaluation activities have been conducted on the basis that farm profits and economic incentives are important to these farmers in considering farm practice change (further discussion below). Pannell et al (2006) considered that adoption of rural innovations depends on a range of personal, social, cultural and economic goals. 'Adoption occurs when the landholder perceives that the innovation in question will enhance the achievement of these personal goals. Innovations are more likely to be to be adopted when they have a high 'relative advantage' (perceived superiority to the idea or technology that it supersedes) and when they are readily trialable (easy to test and learn about prior to adoption)' (Pannell et al., 2006). We have focused mainly on the economics of technology and management and less on social analysis in this project.

The Socio-Economic activities have consisted of several components. One economic activity has involved conducting economic analyses of new crop management and technology in the upland farm context. These activities have allowed us to estimate the likely economic appeal of our technologies to the target farmer groups and hence to rank and prioritize the technologies in terms of project focus. The economic assessments have considered the likely return on investment (ROI) to an upland farmer from undertaking the management change (adopting the technology) in the context of the cost of capital and size of the economic gain. A second component has involved training the Cambodian project officers in conducting simple economic comparisons, and then using a Crop Profit Framework in farmer workshops to consider new technologies. A third component involves conducting village workshops to assess economic and social issues for farmers in possible changes to their crop management and technology use. Each of these activities is discussed below.

Economic methodologies used have been relatively simple enterprise profit (gross margin) and partial budgeting approaches to compare existing and alternative management as set out by, among others, Malcolm et al. (2005). What do we mean by the ROI, or as it is sometimes called the marginal rate of return (CIMMYT, 1988)? For simplicity let's use an example of an upland farmer investing in a crop input like rhizobium - where the rhizobium must be purchased, applied to legume seed at sowing and a higher yield is expected to be achieved. We want to calculate the expected return and compare it with the extra cost. This extra cost is the amount of money invested by the farmer in the new crop technology.

From trial information we have an idea of how the yield might change and so we undertake an economic analysis for a typical upland farm to show the likely benefits before any farmer decision is made about using the technology. The analysis is conducted to provide information to the farmer about the decision to invest in rhizobium. The expected net benefit is the value of extra returns (extra yield multiplied by the price expected to be received by the farmer) less the extra cost (the cost of the rhizobium). There may also be other extra costs (e.g. harvest of a larger crop) which need to be included. The total extra cost is the amount invested which we assume is borrowed by the farmer.

The marginal rate of return (CIMMYT, 1988, p.32) is the marginal (or extra) net benefit divided by the marginal (or extra) cost, expressed as a percentage. As an example if $1 is borrowed and invested in a new crop input so that the expected net benefit is, say, $0.50 then the ROI is 50%. The size of this ROI can be compared to the cost of capital or set according to some minimum or target rate that accounts for such attitudes as the risk attitudes of indigenous farmers (Scott and Freeman, 2007). While it is not possible to provide an exact minimum or target figure, CIMMYT (1988) suggested a possible target rate of (a) twice the cost of capital, or (b) higher rates such as 50 to 100% (especially for farms in developing countries). In Cambodia the cost of capital to farmers is often 3% per month or more, so that a minimum ROI for new crop technologies or management change could be 100% per annum or more.

The Crop Profit Group framework was adapted from an ACIAR project in South Africa aimed at improving beef production for small farmers (see Madzivhandila et al., 2008). This framework is shown in Fig. 3, where the potential changes in enterprise economic return at the farm level can be identified in terms of partial productivity measures on the costs or returns side of the enterprise profit equation.

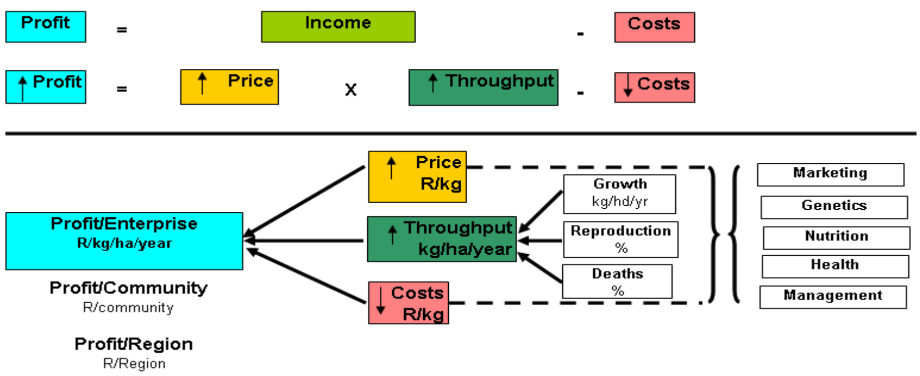


**Fig. 3 Crop Profit Group framework**

The village workshop approach conducted using Participatory Rural Appraisal methods (e.g. see de Zeeuw and Wilbers, 2004) relied on accompanying farmer groups at field walks conducted by the Production team and then taking those groups into workshops to conduct conversations about technologies and rural change. Similar activities have been reported by Sophal and Acharya (2002) and Sedara et al (2002).

## RESULTS

A picture of upland cropping systems and farm families in Cambodia was developed through surveys (Farquharson et al. 2006a). Average farm sizes of the surveyed farms in Battambang, Kampong Cham and Takeo Provinces were small (2-8 ha), capital (mechanical) equipment included draft animals, ox carts and mouldboard ploughs as well as tractors and disc ploughs in some areas. Levels of farmer education were relatively low and farm-family incomes were small. The cost of borrowing money for crop inputs in rural Cambodia can be 3-5% per month or more, depending on the source of funds. Problem areas for crops included low yields, lack of knowledge (especially about insects), concerns about profitability, land/soil constraints, labour/equipment issues and agronomic and climate risk (including drought). There were significant numbers of female farmers.

Other background information has been provided from MJP (2008), where a comprehensive survey was conducted to identify the poorest and most vulnerable households in Samlaut. Four categories were identified: poorest (extremely poor) with incomes generally less than US$1/day, poor with an income generally less than $2/day, middle with an income of $5-7/day, and high with an income of $8-10/day. Villages were ranked according to these categories and allocated into clusters for attention (Fig. 1).

Three reports were available from CARE - Samaiyar and Sopheap (2007a and b) and Kiereini (2007). Samaiyar and Sopheap (2007a, b) specifically targeted 28 villages in three clusters. Contributing factors to food insecurity were that 14% of rural households were landless in 2004, another 19% possessed less than 1ha of land, and that the variable climate and the frequency of natural calamities also contributed to food insecurity.

Outputs from CCPMP are in a number of different formats. Martin and Chanthy (2007) have published a crop weed identification manual in a hard-copy format suitable for farmer/field use.

For the Socio-Economic activities an important early question related to the farmers' basic farm management orientation. In contrast to rice production in Cambodia, which has traditionally been of a subsistence nature, the upland production of maize and soybean is primarily for sale to domestic and export buyers for human and animal consumption. Hence it is mainly commercially oriented and so farm profits and farm management economics were assumed to be important drivers for decisions and processes within the project.

Training in economic evaluation methodologies (gross margin, partial budgeting and ROI analyses) has been conducted via workshops and written notes (Scott 2008). This economic framework was the basis of the Crop Profit Group framework used in the village workshops.

Economic evaluations of crop production technologies were conducted and reported in Farquharson et al. (2006b, 2008) and Scott and Freeman (2007). These evaluations were for prospective technologies that were not yet available to farmers. The analysis of Scott and Freeman (2007) in the Samlaut district involved comparing improved with farmer practice based on crop yields from field demonstrations and expressing the economic result as a ROI figure (as explained above). Their main result was indicative return of 743% for rhizobium inoculation of peanut seed. Farquharson et al. (2006b) used data from on-farm trials to assess the likely advantages for upland farmers of changing crop technology and management. Their main result (expressed in terms of ROI) was that rhizobium inoculation could return up to 600% for soybean. These are very high numbers based on a substantial yield improvement from rhizobium trials and an expected low cost for the technology. This technology was not available to upland farmers at the time of these analyses.

This indication of high potential return for rhizobium inoculation was mirrored in the village workshops where upland farmers indicated a strong preference for trying this technology. In 2010 inoculum will be introduced and distributed for farmers to try themselves. Other recent trial data for the application of N fertilizer (urea) to maize showed only modest yield improvement and it seems that the upland soils retain a substantial level of the soil fertility that was present when they were (relatively recently) cleared for farming. Hence the project activities will not proceed with a strong recommendation for farmers to apply N fertilizer to maize. From observation in the field, adequate fallow and in-crop weed control would do more to improve maize yields.

Another technology considered within the project was of changes in crop rotations or crop sequencing. Such changes (from a monoculture) in other places have shown substantial improvement in crop performance due to insect, weed and disease threats being reduced with the use of varied crop sequences. In the Cambodian uplands the wet season allows two crops to be grown, and generally there is a different crop grown in the early to the main wet season. Given that the crops include legumes plus grains there appears to be an adequate amount of crop variation and there did not seem to be a need to further investigate the gains from changing crop sequences.

The fourth technology considered was reduced or conservation tillage to minimize soil erosion. Crop establishment methods in the upland areas are mixed, with some traditional methods such as mouldboard ploughing by oxen and planting by hand and stick, while other farmers own or hire tractors with disc ploughs and planters to establish crops. The development of a small-scale planter for farmer use has been investigated but the capital costs to construct and market such planters are considered prohibitive. No further action has been taken on this technology.

The fifth technology is IPM, especially with respect to insect control. Our project has strongly emphasized the use of IPM for insects by running workshops on insect identification and discussion of appropriate ‘soft’ chemical sprays, and also through training of a PhD student in Australia. An insect identification manual is being developed. Another approach to IPM has been the ‘Jorani project’ to develop educational material (including a children’s book) for the primary school Life Skills curriculum (Martin et al., 2010). The Jorani project provides technical training and resource materials to teachers including an IPM workshop manual and an illustrated insect identification guide. It is being introduced to years 4-5 in five primary schools on a trial basis in Samlaut district.

From our observations of farmer crops in the upland regions weed control is a major constraint to crop yields and profits. A number of issues are relevant here. In the past much crop weeding (by hand) has been performed by (often landless) laborers from nearby villages. More recently upland farmers have been using chemicals for weed control, but these chemicals are imported mainly from Thailand and the labels and instructions are written in Thai, which the farmers cannot read. We have discussed this with farmers in our workshops and they report that they do not understand how to appropriately apply these chemicals and we have observed inappropriate handling procedures injurious to human health.

We have observed that the price of labour has increased substantially in these districts – in 2005 farmers were paying 5000 Riel/day for labour to plant, weed and harvest crops but by 2009 this had risen to 10,000 R/d in Pailin and 12,000 R/d in Samlaut. Such a change in the price of an important farm input could be expected (by simple economic logic) to force cash-oriented farmers to adjust the use of crop inputs.

An analysis using a simple model with a limited amount of data developed the relationship shown in Fig. 4. The natural exponential function applied to data of labour price (P) over time (T), was analysed as shown in Eq. (1).

$$P = ae^{bT} \tag{1}$$

The advantage of this model is that the b-coefficient can be interpreted as an average annual growth rate in the dependent variable. The estimated b-coefficient of 0.185 (t statistic 5.36) indicates that the growth rate in the price of labour has been around 18% per annum.

In a recent (2009) visit to the project districts we asked questions of farmers at the field days and in the village workshops about weed control practices in their crops. In particular we asked them about the cost of weeding by hand (the traditional practice) and the costs of using herbicides. The results were that the cash costs of hand weeding were generally double, or more, the cost of using chemical sprays to control weeds. However, the farmers confirmed that weed control in crops is essential for successful crop production, and that if they did not control weeds the resultant yields would be either zero or completely uneconomic. Hence the project will focus more on chemical weed control using appropriate (soft) chemicals and application rates, and also on operational health and safety issues for farmers in applying chemicals.

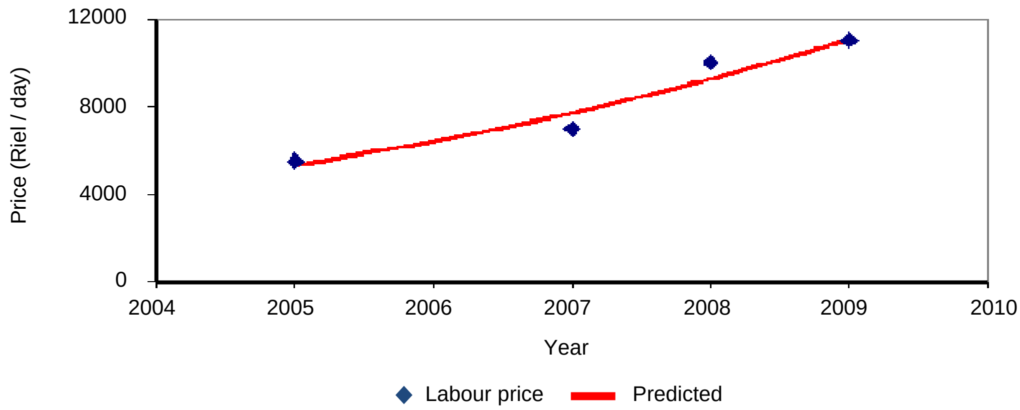


**Fig. 4 Actual and predicted price of labour, Battambang Province**

## DISCUSSION

Our Cambodian project experiences have touched on a number of issues relating to agricultural development as it relates to poverty alleviation, improvements in food security and agricultural development ethics. The farm and village systems that we have worked in are characterized by small-scale farmers with low financial reserves, low levels of education and low levels of agricultural productivity. Their institutions do not provide reliable input supplies or competitive markets for their outputs, and their cost of credit is very high. Hence many of them are vulnerable to climatic and market price risk.

Their farm objectives are stated to be commercial; hence we have used an economic framework to initially evaluate new crop technologies. We have conducted discussions with farmers using a Crop Profit Group approach to focus on potential benefits and costs of changing farming practices. This production economic focus has been set alongside discussions of social issues for change. We have not considered any fundamental changes to the type of agriculture practiced (e.g. changing to tree from field crops) in these districts although such changes are interesting to consider.

Chrispeels and Mandoli (2003) discussed the traditional agricultural production paradigm which has been criticized for not considering effects on the natural environment or social structures within communities. The expressed primary concern (by the Royal Cambodian Government, the NGOs and the Australian funding body) for poor farmers in Cambodia has been to reduce poverty and improve food security, and this has been taken as the primary objective in our project work. We have interpreted the best means of addressing these goals as through improvements in agricultural productivity and profitability so that farm family incomes are raised. But while doing this we have been aware of the need to consider environmental and social implications.

There is a (sometimes muted) debate in Cambodia about ‘sustainable’ farm practices, particularly in relation to the use of agro-chemicals for pest control, and fertilizer and hybrid seeds for crop production. We are now observing a change in the use of farm labour because of the opportunity cost of labour has risen. These are ongoing challenges that we need to address in our project.

Our main conclusion regarding agricultural technologies, based on farm trials and contextual economic analysis of farm trial data, is that rhizobium inoculation of legume seed prior to sowing seems to offer a major opportunity for improving crop productivity and profitability.

For crop production it is also apparent that insects, weeds and diseases need to be controlled; otherwise agricultural production is simply not feasible. We have focused on IPM as a desirable insect control approach and strongly emphasized provision of better information and training to farmers (and their children), and the education of scientific and extension R&D staff.

For weed control the price of labour has risen – whether because of improved income-earning opportunities off the farm or a shortage in labour supply is unknown. Because weed control is essential for successful crop production, and because the farmers are profit oriented, the only option is to use a cheaper means of weed control. An appropriate response from projects such as ours appears to be to improve the information available to, and skills of, farmers in using appropriate (softer) chemicals to achieve cost-effective crop production. However, it is not known whether such a practice is ‘sustainable’.

Capacity building for Cambodian personnel by the project has involved Australian PhD study for one Cambodian researcher in IPM; training of local research and extension officers in field identification of insects for IPM, the production and distribution of a weed identification manual, and training workshops for economic and statistical analysis; and discussions with farmer groups about the crop profit framework including returns, costs and profits.

New research ideas and priorities have been developed in the course of the project, using a continuous improvement and innovation approach to (1) review, (2) plan, (3) act, and (4) evaluate project activities. This allowed revision of thinking about project focus, from which new activities and information were developed. This information was transmitted to farmers through project activities which included the local agricultural extension network. Other ways of taking new ideas to upland communities included preparation of education material for primary school curricula (Martin et al. 2010) and further investigation of placing technical material in university courses.

## CONCLUSION

As individual project members we have come to this work with our own ideas on agricultural development ethics and agricultural development paradigms. The institutional setting of agricultural development entities in Cambodia (the Government, government institutions and NGOs) have set out their priorities in the stated visions and mission statements as specified here. Our work has been within the spirit of those institutional objectives and consistent with an agricultural development ethic that is aimed at making immediate improvements in the welfare of Cambodian upland farm families while minimizing detrimental effects on the natural environment and local communities.

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# International Society of Environmental and Rural Development

**Philosophy of ISERD:**

Recently, in developing countries, subsistence agriculture is being converted to export-oriented mono-culture, and the amounts of agricultural chemicals applied to the farmland are increasing every year. The applied chemicals in farmland cause serious environmental problems downstream such as eutrophication, unusual growth of aquatic plants, decrease in dissolved oxygen and accumulation of bottom mud in water resources. Also, there seem to be many cases in which people apply agricultural chemicals without understanding its impact to health and food safety. Therefore, it is necessary to promote and enhance understanding of sustainable rural development among local stakeholders including farmers.

Sustainable rural development aims to meet human needs while preserving the natural environment. As it should cover not only social and economic development but also natural environment conservation, no single organization can achieve sufficiently the aspirations of sustainable rural development. Collaboration among international, governmental and non-governmental organizations, together with the academe and scientific sector, is indispensable.

The knowledge and intelligence accumulated in universities and research institutions are also expected to make the programs facilitated by the international, governmental and non-governmental organizations more adequately implemented and meaningful to societal development. However, these cases especially those implemented locally have been scattered without having been summarized well or recorded in annals academic or scientific societies.

So, the International Society of Environmental and Rural Development founded in 2010, aims to discuss and develop suitable and effective processes or strategies on sustainable rural development focusing on agricultural and environmental aspects in developing countries. The ultimate goals of the society are to contribute to sustainable rural development through social and economic development in harmony with the natural environment, and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

**Purposes of ISERD:**

The primary purposes of ISERD are to contribute to sustainable rural development through social and economic development in harmony with the natural environment and to support the potential or capacity building of local institutions and stakeholders in the rural area with academic background.

In order to enhance the realization of the primary purposes of ISERD, the secondary purposes are;

- to facilitate interaction among international, governmental, non-governmental organizations and local communities,
- to hold conferences or symposia on environmental and rural development,
- to publish the International Journal of Environmental and Rural Development, and
- to encourage and develop local awareness concerning sustainable rural development.

**Membership:**

There shall be two categories of membership.
(a) Individual
(b) Organizational
An application for membership of ISERD shall be submitted to the secretariat of ISERD, Association of Environmental and Rural Development (Thailand) by writing or by other appropriate means.

**Council of ISERD:**

The affairs of ISERD shall be governed and managed by the ISERD Council. The councilors are as follows.

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