ISSN 2185-159X

International Journal of

Environmental and Rural Development

Volume 3 Number 2

October 2012

International Society of Environmental and Rural Development

International Journal of Environmental and Rural Development

Official Journal of the International Society of Environmental and Rural Development

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.

The aims of IJERD are to publish the latest research development and achievements, to strengthen education systems, to promote cooperation in environmental and rural development and to contribute to the progress in sustainable development. The editorial board of this journal covers a variety of scientific disciplines.

Thematic Areas:

The following areas are envisioned in IJERD.

Education for Sustainable Rural Development:

Environmental Education, Food and Agricultural Education, Participatory Approach, Capacity Building, Community Empowerment, Agricultural Extension, etc.

Rural Development:

Marketing, Partnership, Value Added Product, Community Development, Access to Technology, Cultural Preservation, etc.

Environmental Management:

Bio-Diversity, Soil Degradation and Land Conservation, Water Quality Conservation, Deforestation and Sustainable Forest Management, Environmental Management, etc.

Agricultural Systems:

Organic Farming, Conservation Tillage, Mechanization, Irrigation and Drainage, Nutrient and Pest Management, Cattle Breeding, Agro-Forestry, Indigenous Technology, etc.

Infrastructural Systems:

Water Resource Development, Land Reclamation, Road Construction, etc.

Contents

Special Contribution on EFA and ESD

Research Article

Special Contribution on EFA and ESD *Review article*

Beyond ESD-EFA Dialogue

YOKO MOCHIZUKI*
United Nations Educational, Scientific and Cultural Organization, Paris, France
Email: y.mochizuki@unesco.org

Received 30 June 2012 Accepted 1 October 2012 (*: Corresponding Author)

Abstract The importance of the role of education in achieving sustainable development is underscored by the UN Decade of Education for Sustainable Development (DESD). As the final year of the DESD approaching in 2014 and the Millennium Development Goals (MDGs) and Education for All (EFA) goals approaching their target date in 2015, this article provides an overview of the emerging context in which Education for Sustainable Development (ESD) and EFA are played out, based primarily on the review of the recent UN publications. Building upon the outcomes of the Rio+20 conference and on-going re-thinking of development trajectories, the article calls for going beyond the traditional ESD-EFA dialogue and reshaping education as a critical lever for realizing more resilient, equitable and sustainable societies. The understanding that people are essential agents for redirecting development paths should profoundly change the ways in which education policy-makers craft and implement education policy.

Keywords Education for Sustainable Development, ESD, Education for All, EFA, climate change, Rio+20

INTRODUCTION

The United Nations (UN) Decade of Education for Sustainable Development (DESD), spanning 2005-2014, marked its midpoint in 2009. As a global education initiative coordinated by the United Nations Educational, Scientific and Cultural Organization (UNESCO), the DESD has been closely aligned, at least conceptually, to the forerunning global education and development initiatives, notably the Millennium Development Goals (MDGs) and the Education for All (EFA) movement (see, for example, UNESCO, 2004, 2005, 2006, 2008, 2009). Whereas the conceptual alignment of 'education for sustainability' with 'development goals' is at times negatively interpreted (by some environmental educators) as diluting the project of transformative learning for the transition to sustainability, promoting dialogue between Education for Sustainable Development (ESD) and EFA has been emphasized by UNESCO as its official strategy to mobilize support for the DESD. Such searching for common ground between EFA and ESD has led UNESCO to the obvious position that they are both about improving the quality of education. This special section of *International Journal of Environmental and Rural Development* is an attempt to advance ESD-EFA synergies by taking a closer look at the present situation and future prospects of cooperation between ESD and EFA stakeholders and activities. This article, as an introduction to the section, provides an overview of the emerging context in which EFA and ESD are played out.

SHAPING THE NEW GLOBAL EDUCATION AND DEVELOPMENT AGENDA

A renewed focus on learning

The 1990 adoption of the EFA goals at the World Conference on EFA (Jomtien, Thailand) demonstrated an international commitment to meeting basic learning needs for all. This commitment was affirmed in the 2000 Dakar Framework for Action's Goal 6, which focuses on "improving every aspect of the quality of education, and ensuring their excellence so that recognized and measurable learning outcomes are achieved by all, especially in literacy, numeracy and essential life skills"

(UNESCO, 2000, p.8). As we approach the target year of the EFA goals and MDGs in 2015, there is growing concern that millions of children and youth do not have the basic knowledge and skills necessary to succeed in school and life.

Since the official establishment of MDGs in 2000, most developing countries have sought to achieve the education MDGs (MDGs 2 and 3) and EFA goals as part of their national development policies, education policy formulation and planning, budget allocations and strategic interventions, with support from international and bilateral agencies which in turn aim at achieving these goals as part of their development assistance strategies. At the same time, high political profile of the MDGs (agreed by Heads of States) has overshadowed the EFA goals (agreed by sector Ministers). Education MDGs are restricted to primary level education (MDG 2) and gender equality (MDG 3). While EFA has always been not only about guaranteeing access but also about achieving quality learning for all since its inception in 1990, the strong focus on education MDGs has distorted progress with EFA, masking a variety of disparities and neglecting critical factors beyond access and completion of primary education.

The education MDGs underline enrolment rates, completion rates and gender parity index as key indicators of educational development, which has significantly contributed to making advocacy messages easy to understand and directing countries' efforts towards getting more children into school and reducing disparities between groups. These indicators are, however, inadequate for assessing benefits gained from investing in education. It is not access, completion or parity *per se* that matters; it is learning achievement that correlates with development both at individual and collective levels. The World Bank's education strategy now has a new emphasis on learning achievement over enrolment: "ultimately what matters for growth is not the years that student spend in school, but what they learn" (World Bank, 2011, p. 12). In order to "shift the conversation in education from a heavy focus on access to access plus learning" and "ensure that learning for all is a central component of the global development agenda", UNESCO and the Center for Universal Education at the Brookings Institution convened a "Learning Metrics Task Force" to identify common competencies (learning outcomes) at early childhood, primary and post-primary education levels (Global Compact for Learning, 2012).

Furthermore, to make a final push to meet the MDGs and prepare for the post-2015 agenda, the UN Secretary-General launched the global education initiative "Education First" in September 2012. The five-year initiative has three pillars: (1) put every child in school; (2) improve the quality of education; and (3) foster global citizenship. The second and third pillars demonstrate a renewed focus on learning, providing ample room for ESD implementation as an integral element of quality learning. Notably, the initiative identifies "understanding local environments, designing greener technologies, changing consumption and production patterns and coping better with the impacts of economic and natural shocks" as skills essential to ensuring environmental sustainability, which is added to the list of critical roles of education in development (UN Secretary-General, 2012, p.11). The Education First initiative provides a platform to enhance the ESD-EFA synergies by recognizing the role of education in promoting environmental awareness, knowledge and skills in addition to its classic roles in enhancing gender equality, economic opportunities and health.

ESD and Rio+20

The United Nations Conference on Sustainable Development in 2012, also referred to as Rio+20, provided UN agencies an opportunity to articulate the role of education in contributing to sustainable development. As one of the two main themes of the conference, "green economy" has emerged as a pathway towards sustainable development. As inputs into Rio+20, many UN documents were published with explicit references to the role of education in making a transition to greener economies. For one, UNESCO (2011) published a report entitled *From Green Economies to Green Societies: UNESCO's Commitment to Sustainable Development*, highlighting ESD and greening Technical and Vocational Education and Training (TVET) as important educational contributions to sustainable development.

A number of other UN reports also noted the significance of ESD. The UN Environment Management Group (2011) called for ESD to ingrain "requisite attitudes, knowledge and values needed for responsible eco-citizenship" (p.103). The UNDP Human Development Report 2011, titled *Sustainability and Equity: A Better Future for All*, demonstrated that progress in human development cannot continue without paying adequate attention to sustainability and equity. In its brief reference to the DESD, the Report singled out "tempering excessive consumption" and "encouraging sustainable consumption" as a major goal of ESD (UNDP 2011, p.27, Box 2.3). While the UNDP's interpretation of ESD was considerably narrower than UNESCO's definition, this is nevertheless one indication that ESD is being mainstreamed into the development agenda.

The International Labour Organization's (ILO/Cedefop, 2011) report *Skills for Green Jobs: A Global View* made a conclusion that strongly supports integration of ESD at all levels of education, although it did not use the term ESD: "Coherent multi-level skills development responses are seen as the most effective approach to greening economies, as they address both consumption and production patterns. They influence consumption by raising environmental awareness through general schooling or mass media; and they help production move to more environmentally conscious practices through training programmes, vocational, technical and higher education and training, and lifelong learning at enterprise level" (p. xxiii).

Furthermore, the final report of the United Nations Secretary-General's High-Level Panel on Global Sustainability (2012), titled *Resilient People, Resilient Planet: A Future Worth Choosing*, highlighted "[advancing] education for sustainable development, including secondary and vocational education, and building of skills to help ensure that all of society can contribute to solutions that address today's challenges and capitalize on opportunities" as one of the six priority areas for action needed to empower people to make sustainable choices (p.6).

The Rio+20 Conference marked a significant milestone in the advancement of ESD. In the Rio+20 outcome document *The Future We Want*, nations have agreed to "promote education for sustainable development and to integrate sustainable development more actively into education beyond the United Nations Decade of Education for Sustainable Development". Another relevant outcome of Rio+20 is the agreement by Member States to launch a process to develop a set of Sustainable Development Goals (SDGs), which is to converge wit the post-2015 development agenda.

Preparing for the Post-2015 Development Agenda

With the MDGs and the EFA goals approaching their target date in 2015, the UN Secretary-General established the UN System Task Team to support UN system-wide preparations for the post-2015 UN Development agenda. The UN System Task Team on the Post-2015 UN Development Agenda (2012), in its first report entitled *Realizing the Future We want for All*, clearly signals the integration of the concept of sustainability into the mainstream development discourse: "[the] continuous striving for improvements in material welfare is threatening to surpass the limits of the natural resource base unless there is a radical shift towards more sustainable patterns of consumption and production and resource use" (p. i). The Task Team further asserts: "Business as usual … cannot be an option and transformative change is needed" (p. i). Time is ripe to reconceptualise the role of education in making such transformative change happen.

ESD AS STRATEGIC INTERVENTIONS

From Rio to Rio+20

The year 2012 marked the twentieth anniversary of the 1992 Rio Earth Summit, which produced Agenda 21 as a major outcome. Chapter 36 of Agenda 21—which relates to the promotion of education, public awareness and training for sustainable development—consolidated the international discussions on the role of education in achieving sustainable development, and it is generally viewed as marking the birth of ESD in the international community. As Task Manager of Chapter 36 of Agenda 21 and lead agency of the DESD, UNESCO has promoted ESD, but its efforts have

focused largely on advocacy until recently. The 1992 Rio Summit also gave rise to the three Rio Conventions: the UN Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD) and the UN Convention to Combat Desertification (UNCCD). The Rio conventions include Articles which relate to education and oblige the State Parties to the conventions to develop and implement education and training programmes in these areas.

Partly because the main emphasis 20 years ago was to address long neglected and then emerging environmental concerns, environmental health and ecological balance have been emphasized in policy and practice on sustainable development. In the case of UNFCCC, "the extreme focus within the climate field on the science of emissions and impacts on the environment, compounded by the late entry of social scientists and social organizations into climate change work, as well as the late attention to adaptation as a priority in policy and practice" have delayed the integration of social dimensions into the climate change discourse—including the ways in which mitigation and adaptation measures are designed and assessed (UN Systems Task Team on Social Dimension of Climate Change, 2011, p. 8). Today the UN System Task Team on Social Dimension of Climate Change (2011) aims at integrating "social dimensions"—dimensions that reflect "the social, economic and behavioural aspects of the human conditions" including education—into the climate change architecture (p. 3).

Despite the recognition of ESD as a moral imperative and an important dimension of quality education, ESD has often been perceived as all-encompassing lofty ideals which have little relevance to strategic education interventions in developing countries. Such perception will quickly change as sustainability is mainstreamed into the development discourse. The UN System Task Team on the Post-2015 UN Development Agenda (2012) identifies human rights, equality and sustainability as the three fundamental principles upon which a vision for the future should rest. Twenty years since the 1992 Rio Summit, the international development community has come to accept the limits of the current model of progress and the need for major transformations in patterns of consumption and production and social organization. Today both the development discourse and the climate change discourse are being rearticulated to realize a better world for all, creating many entry points for ESD as concrete and strategic interventions in developing countries.

Climate change education as a tangible entry point to ESD

In 2009, UNESCO developed its strategy for the second half of the DESD, highlighting climate change, disaster risk reduction and biodiversity as priority themes. Consequently, UNESCO established the Climate Change Education for Sustainable Development (CCESD) Programme in 2010. This new development was at times misinterpreted as narrowing down ESD to thematic approaches to sustainable development and compromising its holistic approach. Such misinterpretation is based on the assumption that CCESD will be mainly about the greenhouse gas concentrations in the atmosphere and how to reduce emissions.

In recent years, the concept and practice of "Climate Change Education" have gained importance and been broadened to go beyond a traditional focus on climate science. ESD is increasingly understood as a holistic framework to advance Climate Change Education (Anderson, 2010; UNESCO/UNEP, 2011, p.56). Child-focused organizations like Plan International and UNICEF also recognize a holistic approach to education (formal and non-formal) —to increase the learner's understanding of key sustainable development issues and readiness to take action for shaping a resilient and sustainable society—as an integral aspect of reducing children's vulnerability to climate change and safeguarding their rights. UNICEF (2011) identifies "promoting environmental education and life skills" as one of the eight recommendations to enhance people's capacity to adapt to climate change, and calls for adapting TVET and non-formal education to "the requirements of low carbon economies" (p. 21, 6.6). Polack (2010) points out that the analysis of children's rights to education should reflect "the need for a more holistic approach to education focused around sustainable development" (p.34). These calls for an integrated approach to promoting climate change ducation—for mitigation and adaptation—and ensuring children's rights give a strong support to ESD implementation in developing countries.

Climate change is far from a solely environmental matter in terms of its root causes and actual and anticipated impacts, which makes it a strategic entry point to implementing ESD activities in a holistic manner. First, climate change has far-reaching repercussions for where people can settle, grow food, keep built infrastructure and count on functioning ecosystems. Climate change therefore touches upon myriad aspects of sustainable development, ranging from human displacement to food security and sustainable livelihoods, concretizing what it means to address environmental, economic and social dimensions of sustainable development in an integrated manner. Moreover, climate change does not affect everybody equally, not only because its effects on temperature, rain fall, sea level and natural hazards vary across regions, but also because the capacity of individuals and societies to respond and protect themselves also varies tremendously. Overall, developing countries bear many of the costs of climate change. For example, Small Island Developing States (SIDS) are highly exposed to natural disasters and vulnerable to sea level rise. There is broad consensus on the central importance of education in enhancing resilience of vulnerable groups and communities and their coping capacities. In regions vulnerable to extreme weather events—such as droughts, storms and floods—that can be induced or exacerbated by climate change, there are emerging positive synergies in efforts to promote Climate Change Education as an adaptation strategy and efforts to integrate disaster risk reduction (DRR) in education.

Second, while focusing on climate change impacts on human life allows ESD interventions to target the most vulnerable populations or "victims" of the adverse effects of climate change, addressing the root causes of climate change and designing mitigation and adaptation measures require ESD programmes to highlight human-beings as both the "drivers" of climate change and the "essential agents for redirecting development trajectories" (UN System Task Team on Social Dimensions of Climate Change, 2011, p. 5). Climate Change Education thus can address the needs of the most vulnerable populations (who are also the targets of MDG and EFA interventions), encourage rethinking of the current model of progress, and empower people to become change agents. Climate Change Education in the context of ESD is especially compelling at this critical juncture when the international community is deliberating the next set of development goals and many nations are committing themselves to more robust strategies for mitigation and adaptation.

CONCLUSION

Sustainable development has always been about addressing the development and environmental agendas in an integrated manner, but it has too often been associated exclusively with the environmental agenda. This explains why ESD has often been equated with environmental education. With Rio+20 and the on-going rethinking of the development goals towards 2015, the development community and environmental community are making mutual approach towards sustainable development in the genuine sense of the word. As the global development agenda will be renegotiated in the coming years, we should go beyond the traditional ESD-EFA dialogue (which assumes the dichotomy between ESD and EFA) and start articulating education as a critical lever for realizing more resilient, equitable and sustainable societies. The understanding that people are essential agents for redirecting development trajectories should profoundly change the ways in which education policy-makers craft and implement education policy.

DISCLAIMER AND ACKNOWLEDGEMENTS

The author is responsible for the choice and the presentation of the facts contained in this article and for the opinions expressed therein, which are not necessarily those of UNESCO and do not commit the Organization. The author is grateful to Professor Yuto Kitamura of Sophia University, who was formerly working on EFA coordination at UNESCO Paris, and Mr Mikko Cantell of Plan Finland, who was formerly with the ESD unit at UNESCO Bangkok, for contributing their articles to this section and providing their thoughtful reflections on the topic.

REFERENCES

Anderson, A. 2010. Combating climate change through quality education. The Brookings Institution, Washington D.C.

Global Compact for Learning. 2011. Learning metrics task force: Rationale. Available at: http://www.globalcompactonlearning.org/learning-metrics-rationale/.

ILO/Cedefop. 2011. Skills for Green Jobs: A Global View. ILO, Geneva.

Polack, E. 2010. Child rights and climate change adaptation: voices from Kenya and Cambodia (Research report by Children in a Changing Climate). Institute of Development Studies (IDS) & Plan International.

UNESCO. 2000. Dakar framework for action - Education for all: Meeting our collective commitments. UNESCO, Paris.

UNESCO. 2004. Draft DESD International implementation scheme. UNESCO, Paris.

UNESCO. 2005. DESD International Implementation Scheme. UNESCO, Paris.

UNESCO. 2006. Promotion of a global partnership for the UN Decade of Education for Sustainable Development (2005-2014): The international implementation scheme for the Decade in brief. UNESCO, Paris.

UNESCO. 2008. EFA-ESD dialogue: Educating for a sustainable world (authored by Ros Wade and Jenneth Parker). UNESCO, Paris.

UNESCO. 2009. Education for sustainable development and Millennium Development Goals (Policy Dialogue 2). UNESO, Paris.

UNESCO. 2011. From green economies to green societies: UNESCO's commitment to sustainable development. UNESCO, Paris.

UNESCO/UNEP. 2011. Climate change starter's guidebook. UNESCO & UNEP, Paris.

UNDP. 2011. Human development report 2011 sustainability and equity: A better future for all, UNDP, New York.

UNICEF. 2011. Children's vulnerability to climate change and disaster impacts in East Asia and the Pacific. UNICEF East Asia and Pacific Regional Office, Bangkok.

UN Environment Management Group. 2011. Working towards a balanced and inclusive green economy: A United Nations system-wide perspective. United Nations, Geneva.

UN Secretary-General. 2012. Education first: An initiative of the United Nation's secretary-general. United Nations, New York.

UN Secretary-General's High-level panel on global sustainability. 2012. Resilient people, resilient planet: A future worth choosing. United Nations, New York.

UN Task Team on the Post-2015 UN development agenda. 2012. Realizing the future we want for all: Report to the Secretary General. United Nations, New York.

UN Task Team on Social dimension on climate change. 2011. The social dimensions of climate change: Discussion draft. http://www.who.int/globalchange/mediacentre/events/2011/social-dimensions-of-climate-change.pdf.

World Bank. 2011. Learning for all: Investing in People's knowledge and skills to promote development. World Bank Group Education Strategy 2020, World Bank, Washington D.C.

Special Contribution to EFA and ESD *Review article*

The Mutually Complementary Relationship between EFA and ESD in Cambodia

YUTO KITAMURA*
Sophia University, Tokyo, Japan
Email: yuto.kitamura@gmail.com

Received 20 June 2012 Accepted 20 August 2012 (*: Corresponding Author)

Abstract This paper examines the significance of the concepts of EFA and ESD occurring in attempts at education reform and education improvement in developing countries, and discusses the issues found therein. Within this discussion, this paper analyzes why it is important to implement ESD on multiple occasions along with the promotion of EFA, with particular focus on the importance of the role of education in achieving a democratic society. This paper will also consider the state of "citizenship education," which is thought to hold a major key to the promotion of ESD. Based on the above conceptual examination, this paper then provides an overview of how ESD is being promoted in Cambodia today in historical, social, and cultural contexts as part of the implementation of EFA, from three perspectives: (1) acquisition and improvement of life skills; (2) enhancing environmental education; and (3) promotion of peace education and human rights education. It is worth noting here that although the educational activities conducted in Cambodia are not necessarily known as ESD, they certainly embody its principles and characteristics. Although EFA focuses on the diverse states of education in and out of school, its chief concern lies in enhancing the quantity and quality of school education. Moreover, fundamentally, it is public organizations, such as governments under international agreements, who take on most of the responsibility of promoting EFA, expanding basic education together with various other stakeholders. In contrast to this so-called top-down feature of EFA, ESD is a more bottom-up operation, based on autonomic educational activities by proactive citizens; the areas it covers include a wide range of issues, such as daily life, social forms, and the natural environment. As a conclusion, the paper emphasizes that the positioning of EFA and ESD as essential lifelong learning is important to achieve a sustainable society.

Keywords life-skills, environmental education, peace education, human rights education, Education for Sustainable Development (ESD), Education for All (EFA)

INTRODUCTION

Cambodia was in a state of social disorder, particularly from the 1970s to 1990s, due to ongoing civil wars and genocide by the Pol Pot regime. However, the political situation and social environment gradually began to stabilize in the late 1990s; presently, Cambodia is achieving steady economic growth. Under these circumstances, Cambodia has actively promoted national education reforms to improve the education situation (especially basic education), particularly since the year 2000, based on the goals of the international initiative "Education for All (EFA)" to expand basic education. The results of these reforms are gradually becoming apparent; however, many issues have also come to light, such as the issue of education quality. Under such circumstances, promoting "Education for Sustainable Development (ESD)" is not only essential to achieve EFA but also it is expected to be relevant for improving the whole education situation in Cambodia. In many developing countries such as Cambodia, EFA and ESD cannot be treated separately. It is important to examine how a mutually complementary relationship is being built (or attempting to be built) between the two initiatives.[1]

First, this paper considers the significance of the concepts of EFA and ESD in the context of education reform and education improvement in developing countries, and discusses the issues

found therein. Within this discussion, this paper examines why it is important to implement ESD on multiple occasions along with the promotion of EFA, with particular focus on the importance of the role of education in achieving a democratic society. This paper will also consider the state of "citizenship education," which is thought to hold a major key to the promotion of ESD.

Following the examination of the concepts of EFA and ESD, this paper then provides an overview of how ESD is being promoted in Cambodia today in historical, social, and cultural contexts as part of the implementation of EFA, from three perspectives: (1) acquisition/ improvement of life skills; (2) enhancing environmental education; and (3) promotion of peace education and human rights education. It is worth noting here that although the educational activities conducted in Cambodia are not necessarily known as ESD as such, they certainly embody its principles and characteristics.

LINKAGES BETWEEN "EFA" AND "ESD"

It is widely known that the international goals to promote basic education based on the concept of EFA were established in 1990. However, there has been a trend in many countries since the 1990s of governments attempting to reduce costs for public services; the expansion of basic education means difficult decisions for governments as it requires policies and measures accompanied by increased government spending to increase capital and to secure teachers' jobs.

One notable issue in the promotion of EFA is the emphasis on achieving macro-level objectives; no specific initiatives are suggested for tackling issues such as rectifying regional disparity within a country or improving learning outcomes in schools. One reason for this is a policy-level connection between the strong demand from the aid providers for international targets to be reached by 2015 and the government's motivation to maintain power and stability. This has led to situations where despite substantial funds being invested into basic education, ordinary people are not guaranteed the opportunity to participate in the policy dialog process and education is often turning into a governmental means for populism.

On the other hand, under global capitalism-in which funds, goods, labor, and technology move freely-economy and culture become internationalized, and with phenomena such as an increase in migration, there is a greater necessity for multicultural education. As a consequence, many countries are promoting "citizenship education" to develop democracy and cultivate community ethics. Furthermore, with the transfer of the state's redistributive function to the market accompanying the rise of neoliberalism, the power of state has become more relative. The relationship between the state and individual citizens has altered; "independent/autonomous citizens" are expected to survive in a competitive society at their own risk. Moreover, many developing nations in which the social and political systems are still fragile often have multicultural, multiracial, and multilingual settings, making national unity through education and the cultivation of a national identity essential. This indicates that, in reality, education reforms based on neoliberal ideology are often being promoted in a mutually complementary relationship with a nationalist trend of thought.

Thus, as many countries search for an education system that meets the needs and aspirations of both the individual and the state, which may seem contradictory at first, it is necessary to ask who ought to take charge of new education reforms. The answer to that question is "citizens," first and foremost; the government and international organizations—the public actors—ought to keep playing a supporting role to the independent and autonomous reforms of "citizens." To further deliberate on this question, it is necessary to look at ESD, an attempt at "bottom-up reforms" aimed at independent/autonomous education reforms at the local level, such as reforms by individuals and communities. This is because ESD can potentially provide an opposing or complementary discussion to the "top-down reforms" seen in the EFA promotion process.

The concept of ESD that covers diverse areas initially came out of a concern for the "quality of education." Behind this is the fact that despite EFA advocating a concept of basic education to cover a wide range of areas, in reality, there was little awareness of education's initial role in raising "citizens" who are able to build sustainable society, while many countries became more interested in the quality of academic learning achievements in formal education. By contrast, ESD,

which raises "citizens" as members of a democratic society and the community and is supported by those "citizens," is a conceptual mechanism to broaden the scope of the "quality of education."

This can be seen in the fact that the Education Sector in UNESCO headquarters established a Section for Education for Sustainable Development within the Division for the Promotion of Quality around the year 2002—the period in which the concept of ESD was being proposed—with UNESCO having placed the role that ESD plays in planning for improving the quality of education to be important.[2] Although there is not really any general international consensus on how to position ESD as an educational practice, the author considers that the significance of promoting ESD will be made clear by returning it to its original purpose of improving the quality of education.

Although the ESD concept focuses on covering a wide range of issues, its characteristic is that it places each individual person as a starting point, irrespective of the issue. The existing discussions on developing countries tend to emphasize the quantitative aspects of the expansion of education; there has been little interest in the qualitative aspects of what is being taught. Furthermore, where the quality of education has been considered, there has been little interest in subjects that deal with the development of individuals as engaged and responsible citizens—namely, citizenship, ethics, and values—compared to the excessive interest in the level of achievement in academic subjects. Furthermore, the public actors in ESD—the governments and international organizations—are expected to support the independent and autonomous "bottom-up reforms" by "citizens"; this is the way education policies should be formulated and implemented in developing countries in the post-neoliberal era.

Conceptually, ESD can be independent and autonomous educational activities at the local level of schools and communities. In practice, however, pressures from administration play a major role in shaping ESD and people on the ground may easily follow the direction set by the government. Promotion of ESD by governments and international organizations like UNESCO and the United Nations University (UNU), therefore, has the possibility of contradicting the original idea of ESD. It is critically important to synergize citizen-led ESD and government-led EFA.

ESD IMPLEMENTATION IN CAMBODIA

This paper has discussed the conceptual framework of EFA and ESD; on the basis of this discussion, it now examines how these two concepts are implemented in Cambodian education.

Acquisition and improvement of life skills

The basic strategy of the Cambodian education sector is a five-year plan known as the *Education Strategic Plan (ESP)*. Four of these five-year plans have been put in place since 2000: (1) 2001-2005; (2) 2004-2008; (3) 2006-2010; (4) 2009-2013. The education sector has created a five-year program called the *Education Sector Support Program (ESSP)* as an implementation program for the ESP (the five-year period is the same as the ESP). Furthermore, the education sector has also set in place the *EFA National Action Plan 2003-2015* to deal with basic education. The highest priority in each of these policy documents is implementing "fair access to high quality education" at the basic education stage.

However, despite the provision of these education policies, there is probably still room left for improvement in terms of the quality of education, such as textbooks, teaching materials, curriculum, teaching methods, teacher training, and school facilities (Hirosato & Kitamura, 2009). In promoting ESD, formal education (especially primary and lower secondary education), the most basic educational foundation within a society, is more desirable than anything; however, in Cambodia, there are major issues with the quality of basic level school education. Most of all, it is essential to improve the quality of teachers who play a central role in school education. From that perspective, the National Institute of Education (NIE), the main teacher training institution in Cambodia, aims to provide training that incorporates ESD while teaching, especially in the secondary teacher training program, and to improve the quality of education of the regular curriculum while also promoting ESD (UNESCO, 2010).

While Cambodia needs education to support sustainable development, it first needs to raise the quality of basic education. Studies on the quality of education have often tended to focus only on the level of achievement in academic subjects (so-called scholastic improvement). As previously mentioned, however, education has a major role to play in fostering engaged and responsible citizens and critical thinkers who can shape a better future. It is essential to promote broad-perspective initiatives such as ESD.

Accordingly, initiatives to promote ESD are being undertaken, particularly in various areas that cannot be covered by basic school education alone. The most typical initiative is education with the aim of acquiring and improving "life skills." The *Policy for Curriculum Development 2005-2009*, adopted in 2004, aimed to introduce a new subject known as "Local Life Skill Program (LLSP)" from grades 1 to 10 to raise citizens capable of contributing to building a healthy and productive society. This policy defines life skills as the "intellectual, personal, interpersonal, and vocational skills that enable informed decision-making, effective communication, and coping and self-management skills that contribute to a healthy and productive life" (MoEYS, 2004, p.8). The introduction of these new life skills programs shows that there is an emphasis on educating public-minded citizens and developing useful skills for life in society.

The acquisition and improvement of life skills in school education is particularly conducted through vocational training, health education, HIV/AIDS education, and human rights education. However, school education, which focuses on passing on information and skills in academic subjects, cannot adequately pass on life skills, that is, knowledge and skills covering a wide range of areas. Furthermore, life skills are necessary for everybody, regardless of age or gender. Since school education only targets a certain age bracket, it is not possible to promote the acquisition of life skills to many people in Cambodian society. Consequently, non-formal education is very important.

In order to promote non-formal education, a number of villages have established Community Learning Centers (CLCs) or similar educational organizations. These CLCs provide non-formal education, making use of existing facilities wherever possible, such as temples, village offices, homes of village heads, etc., and building new facilities wherever necessary. In 1994, UNESCO and the National Federation of UNESCO Associations in Japan provided assistance to the Cambodian government to establish the first CLCs in the provinces of Siam Reap, Battambang, and Kandal. Support then began to come in from other aid agencies and NGOs. Presently, villages in several provinces have established CLCs (or similar educational organizations) and implemented literacy training, vocational training for income generation and family education for childcare, playing a major role in fostering people's life skills. An important feature of CLCs is that although they receive assistance from the government, they are basically managed and operated by villagers. This type of community-based style of management is essential to embody the concept of ESD. The aforementioned *EFA National Action Plan* identifies the importance of CLCs in implementing non-formal education.

Supplementing environmental education

Although the term ESD is not generally used in the Cambodian education sector, the field of environmental education is one area where education activity is actively promoted based on the concept of ESD.

In 2009, Cambodia's Ministry of Environment set out its five-year plan, *the Five-Year Strategic Plan on Environmental Education for 2009-2013*, asserting the importance of "Environmental education for sustainable development" (EESD) at the beginning of the policy document (Department of Environmental Education and Communication, 2009). This *Strategic Plan* stipulates the *Strategic Goal and Action Plan on EESD for 2009-2013* from an ESD perspective, in particular.

If we examine these initiatives, we see that they are plans to further enrich basic environmental education and do not necessarily focus on ESD. Nevertheless, providing "training on environmental issues and ESD" under the human resource development initiative aims at fostering people with a deep understanding of ESD to become involved in environmental education. Moreover, at-

tempting to raise people's awareness by spreading information on environmental issues will require the use of a wide range of media, from printed media, such as books and magazines, to electronic media, such as the Internet. The use of printed media is very significant in Cambodia, where provincial towns and villages still have limited access to electronic media, despite the fact that in recent years an increasing number of people own mobile phones and that internet cafes and the like are becoming more commonplace.

Furthermore, the Ministry of Education, Youth and Sports, the Ministry of Tourism, and the Ministry of Culture and Fine Arts are working together on a master plan for building a learning program on environmental protection and biodiversity in the Tonle Sap Basin.[3] This learning program is known as a "learning laboratory"; it aims to provide opportunities to learn about sustainable development while coming into close contact with the actual natural environment. The program can, for example, deepen people's understanding of how a body of scientific, experiential, and indigenous knowledge about protecting the biosphere can be used to implement sustainable development. Moreover, the program can also have people think about policies to make improvements in the environment (such as biodiversity conservation), human life and livelihood (such as reducing poverty) or economic benefits (such as increased income through developing the tourism industry). Other countries outside Cambodia, such as Vietnam, are also building these "learning laboratories," supported by UNESCO (Nguyen et al., 2010).

Peace education and human rights education

Cambodia entered a state of war in the late 1960s affected by chaotic situations of the Vietnam War; a coup was staged in 1970, followed by a civil war. In the 1970s, Cambodia came under the Pol Pot regime of the Khmer Rouge and their radical Maoist ideology. The political instability continued into the 1980s with interference by Vietnam and the Soviet Union; the Cambodian society remained at the height of chaos until the late 1990s. However, after the signing of the 1991 Paris Peace Agreement, the social situation did begin to gradually stabilize despite various issues, and Cambodia began to show a significant economic growth in the 2000s.

Given this history, more than anything, the people in Cambodia want to maintain a peaceful society that they have taken such great pains to bring about. In order not to repeat the tragedies of violence and atrocities in the past, it is important to address peace and human rights through education. This paper will now outline how Cambodia is implementing peace education and human rights education, which constitute the main fields of ESD.

While peace education exists in Cambodia, in reality, there has been a limited number of classes on peace education in schools until recently. For example, it was not until recently that history classes began to adequately address the issue of what the Pol Pot regime did in the 1970s. Behind this was the thinking that children would be able to envisage a bright future for Cambodia if they were not taught the negative aspects of history, as well as the viewpoint that it was unnecessary to teach children things that would only fuel conflict between people as many people who supported the Khmer Rouge are still alive and living in society. However, in 2003, the Cambodian government and the United Nations agreed to the establishment of a special tribunal to administer justice for the genocide of the Pol Pot regime. Investigations began in 2006 and the trials are still being conducted at the present time. Because of these developments, Cambodia has begun to acknowledge the importance of teaching children the accurate facts of this negative part of history and has begun to publish revised history textbooks and supplementary teaching material *The History of Democratic Cambodia*. Initiatives toward peace education in schools are gradually starting to increase.

Public organizations and associations as well as NGOs have also been actively involved in implementing peace education in Cambodia, at times with overseas support. One example of this is the implementation of peace education through the Tuol Sleng Museum, a concentration camp during the Pol Pot regime. The Japan International Cooperation Agency (JICA) established the "Okinawa-Cambodia Peace Museum Collaboration" Grassroots Technical Cooperation Project to support this. In this project, the Okinawa Prefectural Peace Memorial Museum, the implementing or-

ganization, taught the curators and staff of Tuol Sleng Museum about the "peace museum" concept and the know-how necessary to operate it, such as data collection and preservation methods, and peace education activities. The two museums continue to have dialog to further enhance their respective peace education activities.[4]

Furthermore, the aforementioned NIE teacher training program provides training on World Heritage Education as part of its ESD training. This training also encourages the consideration of peace issues through world heritage.

Cambodia is also undertaking human rights education in the form of government-led programs as well as educational activities outside the school classroom. In particular, various projects have been developed by schools, public organizations, and NGOs since 2005 to promote human rights education based on the "United Nations World Programme for Human Rights Education" adopted by the UN Commission on Human Rights in 2004.[5]

These projects include human rights workshops and the publication of a Khmer language version of the "Human Rights Education Lesson Plans for Southeast Asian Schools," which teaches about human rights issues and situations with a particular focus on human rights in the Southeast Asian region. The Cambodia Office of the United Nations Centre for Human Rights and the Cambodian Buddhist Society, a human rights NGO, also created the "Human Rights and Buddhism Training Curriculum for Buddhist Monks and Civil Servants" and are engaging in other initiatives using Cambodia's traditional cultural resource of Buddhism to promote human rights education.[6]

CONCLUSION

This paper has outlined Cambodian initiatives to promote ESD, based on its relation to EFA. As mentioned at the beginning of this paper, a consideration of Cambodian education cannot separate EFA and ESD, but should constantly be aware of the mutually complementary relationship between them. Furthermore, the positioning of EFA and ESD as essential lifelong learning is important to achieve a sustainable society.

In particular, although EFA focuses on the diverse states of education in and out of school, its chief concern lies in enhancing the quantity and quality of school education. Moreover, fundamentally, it is public organizations, such as governments under international agreements, who take on most of the responsibility of promoting EFA, expanding basic education together with various other stakeholders. In contrast to this so-called top-down feature of EFA, ESD is a more bottom-up operation, based on autonomic educational activities by proactive citizens; the areas it covers include a wide range of issues, such as daily life, social forms, and the natural environment.

Accordingly, this paper has provided an introduction on ESD in Cambodian education while being always conscious of its relation to EFA (for instance, its placement within school education). It is extremely important to bring ESD into schools from the perspective that it is vital to improve the quality of education not only to raise the level of achievement in academic subjects but also to pass on important knowledge and skills necessary for acquiring and advancing life skills. Furthermore, school education and non-formal education can be organically connected by being based on the concept of ESD. As outlined in this paper, various initiatives for this have been set in place, with active measures being taken. However, we cannot deny that many initiatives are still insufficient, both quantitatively and qualitatively.

To improve this situation, as previously mentioned, ESD initiatives should fundamentally be promoted by citizens. At the same time, this cannot be done without active participation by public organizations such as the government. The United Nations Decade of Education for Sustainable Development will end in 2014, but long term initiatives to promote ESD should continue.

I sincerely hope that the aforementioned active ESD initiatives will continue to grow and further enhance the future of education in Cambodia and that this, in turn, will contribute to the expansion of EFA. From my heart, I hope that raising "citizens" who can give much thought to democracy and public morals will create a sustainable Cambodian society.

NOTES

1) *See Wade & Parker (2008) for general discussion on the relationship between ESD and EFA.*
2) *Afterwards, there was repeated reorganization within UNESCO and the position of ESD as aiming to improve the quality of education became ambiguous.*
3) *See the Ministry of Tourism website for the Master Plan for Sustainable Tourism Development in Peri-Tonle Sap Lake and Establishment of a Learning Laboratory for Sustainability (http://www.mot.gov.kh/ministry-activity.php?id=15 [accessed 2-25-2012]).*
4) *For further details on these projects, see the JICA website (http://www.jica.go.jp/topics/2009/20091026_01.html [accessed 2-25-2012]).*
5) *For details on the United Nations World Programme for Human Rights Education, see the website of the Office of the United Nations High Commissioner for Human Rights. (http://www2.ohchr.org/english/issues/education/training/programme.htm [accessed 2-25-2012]).*
6) *See Kimura (2000; 2007; 2008) for the present status of human rights education in Cambodia.*

REFERENCES

Department of Environmental Education and Communication. 2009. 5 year strategic plan on environmental education for 2009-2013. Ministry of Environment, Phnom Penh.

Hirosato, Y. and Kitamura, Y. (eds.) 2009. The political economy of educational reforms and capacity development in Southeast Asia: Cases of Cambodia, Laos and Vietnam. Springer, Dordrecht.

Kimura, M. 2000. An attempt to indigenize human rights education in Cambodia. The Bulletin of the Graduate School of Law, Ryukoku University, 2, 1-15.

Kimura, M. 2007. Human rights education during UNTAC's tenure in Cambodia: An analysis on the human rights teaching curriculum used in formal education. Quarterly Bulletin of Third World Studies, 47(3), 52-81.

Kimura, M. 2008. A study of human rights education rooted in Cambodian Buddhism: An approach from the sociology of law and forensic anthropology. The Journal of Human Rights, 8, 123-136.

MoEYS. 2004. Policy for curriculum development 2005-2009. Ministry of Education, Youth and Sports, Phnom Penh.

Nguyen, N.C., Bosch, O.J.H. and Maani, B.K. 2010. Creating 'learning laboratories for sustainable development' for UNESCO Biosphere Reserves. A paper presented at the 28th International Conference of the System Dynamics Society, July 25-29, 2010, Seoul, Korea. www.systemdynamics.org/conferences/2010/proceed/ [accessed 3-25- 2011].

UNESCO. 2010. UNESCO National education support strategy: Cambodia 2010-2013. UNESCO, Phnom Penh.

Wade, R. and Parker, J. 2008. EFA-ESD dialogue: Educating for a sustainable world (Education for Sustainable Development Policy Dialogue No.1). UNESCO, Paris.

Special Contribution on EFA and ESD *Review article*

ESD in the Asia-Pacific

MIKKO CANTELL*
Plan Finland, Helsinki, Finland
Email: mikko.cantell@plan-international.org

Received 20 June 2012 Accepted 20 August 2012 (*: Corresponding Author)

Abstract The article is an attempt to describe the challenges and opportunities in integrating ESD into mainstream policy-making in the Asia-Pacific. The role of education in development is variably understood. It is widely recognized as a *sui generis* guarantor of personal and collective development. Educating for sustainable development has much untapped potential both in driving development in general and improving the contribution of education as a sector within development. ESD in the Asia-Pacific has diverse forms of expression. Effective, frank and constructive intellectual exchanges could lead to significant progress in ESD. Reorienting "quality" in education should assume priority position in education and will ideally, for the sake of its relevance, appeal and continued development, include several dimensions of sustainable development.

Keywords Education for Sustainable Development (ESD), quality education, Asia-Pacific

INTRODUCTION

The Asia-Pacific region is geographically vast and both culturally and ecologically speaking extremely rich in diversity. It is also home to the majority of the world's population, witnessing an unforeseen period of positive change both economically and politically. Unfortunately, it also hosts a wealth of serious global challenges. More than two-thirds of people lacking basic sanitation, underweight children and the extreme poor live in the region (UNDP, 2012). These lives in the margins of human existence are also the most at risk and worst prepared for the perils of disasters, be they "natural", man-made, or economic in character. Threats to life in the region are not theoretical - the Asia-Pacific is, for example, considered the world's most vulnerable region when it comes to natural disasters (UNISDR, 2011).

All of the above calls for serious changes in how we are managing our lives and maintaining human dignity of our fellow human beings. Correspondingly, integrating the principles of sustainable development in education has been agreed to be one of the answers in meeting these challenges. While the vision of the UN Decade of Education for Sustainable Development (DESD 2005-2014) is "a world where everyone has the opportunity to benefit from education and learn the values, behaviour and lifestyles required for a sustainable future and for positive societal transformation", the stated goal of the Decade is to "integrate the principles, values, and practices of sustainable development into all aspects of education and learning" (UNESCO, 2005, p. 6). This is quite naturally impossible to achieve in one decade and requires significantly more resources and political commitment than has since been awarded to programmes and projects implementing the UN decade.

Countries in the Asia-Pacific have had varied approaches to ESD and some have been far more ambitious than others. It is to be noted, however, that approaches which have not been labeled ESD explicitly may have had and continue to have excellent results in advancing sustainable development. Two such processes come to mind easily: the philosophy of "sufficiency economy" in Thailand and the Gross National Happiness process in Bhutan.

Excellent and diverse approaches to integrating sustainability in education can be found in most countries, for example in Australia, Brunei, Cambodia, China, Indonesia, Lao PDR, Malaysia, Nepal, Republic of Korea, Thailand and Vietnam.[1] In the field of ESD, Japan must be mentioned as being incomparable in supporting other countries' efforts and having a major role in the creation of the Decade itself, and by boasting a large number of ESD initiatives at all levels of education.

EDUCATION AS DRIVER OF DEVELOPMENT

Education's role in human development is widely recognized as being central. It is argued that sustainable development calls for more education. This is somewhat contradictory given that on average, where economic progress and education systems are at their most mature, ecological footprints are often also the largest (see, for example, Cantell and Elias, 2011). ESD therefore advocates for changes in the status quo, to instill a broader understanding of the causalities surrounding our lives. Such understanding can seem a trivial skill to provide to poor communities struggling with day-to day subsistence. In reality it means providing them with the requisite skills to develop beyond survival and holding authorities accountable for progress in this area. In this vein, ESD is often seen as a systematic approach to integrate sustainability into education systems, processes and practices (Richmond, 2008). The United Nations Decade of Education for Sustainable Development (DESD, 2005-2014) comprises four major thrusts, around which ESD is globally expected to revolve: improving access to quality basic education; reorienting existing education programmes; developing public understanding and awareness; and providing training (UNESCO, 2005, p.7).

But similar to sustainable development, ESD, too, is not universal one in its colour and shape. For the Asia-Pacific region, UNESCO has in consultation with its member states formulated the following operational definition for ESD, which aims to "facilitate the degree to which an education system is prepared for, and is responsive to, existing and emerging challenges (e.g. disasters)" (UNESCO, 2011, p.2). This definition all but spells out the salience and centrality of change and the importance of education's ability to prepare citizens for it, without prescribing it in a preemptive fashion.

SUSTAINABILITY CHALLENGES IN THE ASIA-PACIFIC

As a region, the Asia-Pacific is far from a socially cohesive one, as are its constituent countries. In the face of newly acquired economic power and growing consumption, vast differences in living standards exist and emerge within countries. A recent report put the dilemma in blunt terms: "[i]n 17 countries, 10 per cent or more of the population subsists on inadequate diets. Other people aspire to the high-consumption lifestyles of the global consumer class" (UNDP, 2012, p.5).

For individual countries the details of development challenges, and consequently answers to them, differ markedly. In Cambodia, where a third of the population lives in conditions of extreme poverty (Hayden and Martin, 2011, p.31), the priority may be obvious. Further, Cambodian political history with its utter devastation of organized, intellectual society and education, directly lead to current challenges, including largest sizes of classes in Southeast Asia (ibid., p.44) and societal inequities spilling over to and bequeathed by education with potentially "catastrophic consequences" (ibid., p.43).

ESD CHALLENGES IN THE ASIA-PACIFIC

Sustainable development is like most good things. It is easy to agree on in principle and impossible to implement to perfection. Among other metaphors, it has been said to resemble a journey, to underscore its not being a preset destination. It is also more often than not described by what it is not, by highlighting the problems it intends to prevent and solve. The magnitude of the world's problems carries with it much weight and brings about processes intended to alleviate them. However, with lacking or no reliable monitoring mechanisms in place to read progress by, an illusion of perfect has often become the enemy of the good, also in the area of ESD.[2]

And yet, the inescapable reality in a typical political decision-making situation remains. One will always want highest attainable quality to the greatest number possible at the lowest cost. And yet, in education, most systems are so structured that quantity in access greatly reduces quality while exponentially increasing cost. It is most often this mindset that the minister of education has when allocating funds to initiatives.

ESD may not always play very well in this paradigm and system of thinking. For it is saying, among many other and potentially contested thematic emphases, that the current educational priorities might be wrong. Numeracy and literacy will never go out of fashion, but traditional teaching and learning techniques, corporal punishment and studying irrelevant information to the test may not bring about the kind of development one desires. It is such important and profound (if slow) changes that, coupled with locally defined relevant content, ESD queries tend to lead to. The implications would not be few if fully taken into account - these will typically include reform in teacher education, curricular content, sector planning and school management, but the resources to instigate change with have generally been rather ludicrous in comparison with the needs.

Lack of financial resources to work at country level and increasing demand from its member states led UNESCO to an idiosyncratic conclusion in the Asia-Pacific. Having conducted a series of subregional workshops with member state representatives and experts, UNESCO produced regionally a guide ("the Astrolabe") on ESD coordination and implementation at the national level (UNESCO, 2011). This guide was intended to move the process of sustainability integration in education one level higher and ensure a close connection with the overarching national policies and strategies. A process of identifying the most salient sustainable development priorities and translating them into implementable action at community and classroom was put forth in the guide.

Therefore, in theory, the countries themselves were going to select priority areas of action and implement much of the expert work previously expected of UNESCO. As this would have made coordination highly demanding, in reality there was a further attempt within UNESCO to operationalize the concept into a manageable number of priority areas, which would make sense for most member states. These areas were general support to implementing the UN Decade of ESD (2005-2014) and member states' own work through the Astrolabe guide publication; climate change education and disaster risk reduction; supporting and developing efforts to (quantifiably) measure the impact of ESD and its contribution to the quality of education; and tracking trends in ESD (e.g. education and sustainable business models, ESD's role in promoting health and cognitive development).

Strengthening networks and partnerships and extracting evidence of functioning ESD models is as much a necessity in the Asia-Pacific as elsewhere. While UNESCO is doing this at the global level, regional collections have a tendency to carry more weight among peers. Research in ESD-related pedagogy, skills and monitoring is in need of support, which can oftentimes be simply a mixture of moral support and increased visibility. Evidence of what works and needs to be further promoted and/or researched will be a priority in any successful ESD programme, which will then use this newly established evidence base in focused policy advocacy for maximum performance in the fields of teaching and learning, school management, and education policy and planning.

The last component in particular was an attempt to return to the education sector's internal discussions on quality. For as we know, cognitive development has long since been identified the major explicit objective of all education systems (UNESCO, 2004, p.17), but it is also a wonderful indicator as regards several sustainability issues - health, social progress, wealth distribution, geographical cohesion - and whether or not the education delivered is relevant in reality.

What is perhaps in highest demand and what will likely yield the largest dividends in the region, however, is the work on ESD indicators. It is an effort that may be as likely to fail as it is to succeed, but it will drive progress forward, and is vitally important for ESD. Country representatives look for guidance in this regard for practical reasons. Having indicators would help concretise an otherwise diffuse programme and, most of all, helps set political targets. It calls for the collaboration, data and expertise of statisticians at ministries of education, which in turn will help make the case for ESD in the political arena. Suggested measurements have included existing rates between school employing ESD programmes and those that do not as well as, between rural and urban schools (UNESCO, 2011).

THE POTENTIAL OF ESD TO SUPPORT EFA

EFA has been vastly successful in getting as high a percentage of the population as possible to be a part of education. Clear, measurable targets have helped fast track processes and funnel funding where it has been needed in many cases. Criticism has ensued also for EFA being allegedly in reality excessively number-oriented and grappling with intelligent ways of measuring quality. The process may also not be able to effectively to inform decision makers if and when education is not in the best interest of the child. Teacher absenteeism and poor quality in particular violate the student's right to quality education. Violence in schools and tutoring fees are other critically important factors which can go unseen despite their gravity.

ESD for its part is concerned exactly with what type of education would best serve societal, environmental and economic interests of both the individual and her community. Importantly, as a senior UNESCO staff remarked, it is "not simply an addition to existing education systems, processes and practices, an optional extra that countries may or may not incorporate into their plans and programmes. Instead, ESD properly understood requires a fundamental reorientation of the purposes and tasks of education" (Richmond, 2008, p.3). He goes on to say how deep the implications go: "in due course, no aspect of educational provision will be left unaffected. [ESD] is an approach that embraces an holistic vision of education and one that takes in the key building blocks of a comprehensive and integrated framework: educational planning, policy development, teacher education (initial and in-service), curriculum renewal, textbooks and other learning materials, assessment and examinations, as well as a recognition of all modalities of provision" (Richmond, 2008, p.3).

In the realm of development, everything ultimately relates to everything. It would be foolhardy to not concentrate scarce resources of the education sector for the benefit of human development. In development at large, such synergies are forming and evidence is emerging. As an example, UNISDR (2011) quotes experiences from several countries how a more integrated approach to disaster risk management and climate change adaptation contributes to sustainable poverty reduction and other development outcomes.

Every challenge presents with it an opportunity. Advice given at an inconvenient moment, when the lead organization of the UN Decade is trying to make ends meet and keep key processes in motion with what is at its disposal may be inappropriate, but from the margins of a specialized UN agency with arguably the best and most noble mandate in human development, this would appear the moment to consider the future direction of education and the most central dividend it is capable of producing, sustainable human development. At the time of this writing UNESCO is facing what some call a temporary cashflow crisis following the United States freezing its dues making up for over a fifth of the organization's regular budget. The depth and temporal length of the crisis remain to be seen and much energy is being used to debate the negative consequences. It has been noted elsewhere that fundamental reforms of the education sector often only take place in times of drastic changes. Perhaps this financially taxing time could provide the necessary impetus towards finding more practical synergies between existing programmes? EFA as the flagship programme of the Education sector is coming to a close (or at least an interim one) in 2015. Having been highly successful in several of its stated objectives and measurable goals, it has all the potential in the world to mature further from a race between numbers to more quality and developmental impact, reflecting its shifting role from education only to an overall development agenda priority item.

Again, this means reorienting how we measure quality. If and when education has a central role to play in human development, its indicators should logically include those reflecting community and societal development. If a school of migrant children in a middle income country[3] can by focusing on sustainability transform itself from being unattractive to the children's families and ridden with seasonal disappearances and high incidences of pushouts, to a school whose students surpass the average grades in the national language examinations - the children's second or third language in every single case - in a matter of years, what can systemic changes yield? The changes

were controlled yet subtle and had to do with the community's needs and the children's joy and ability to learn.

CONCLUSION

This paper has given an overview of the processes involved in ESD implementation in the Asia-Pacific and some recommendations to the way forward. UNDP's (2012, p.6) recent human development report for the Asia-Pacific reads: "Countries thus have to strike a balance between cutting back on the over-exploitation of their resources and simultaneously increasing consumption of energy services, better food, water and sanitation services that would enable poor communities to become more resilient. The region must also look ahead. Human development involves expanding choices for all, including the generations to come." Such massive expansion of choice in the region will call for the best available education to each individual.

Integrating sustainability in education is a complex undertaking, and one which requires the attention of both the political elites and technical experts, but it is attainable if shades of grey are considered progress, and if debates concerning ESD remain constructive and productive at the same time.

To some extent, sustainable development is universal and timeless as its best practices and principles often date back to the ways of peoples which today are referred to as indigenous. Take the principle of the seventh generation practiced in some indigenous cultures. Certainly a cornerstone of planning for sustainable development, this precautionary principle calls for deliberation which takes into consideration the impacts of any decision on the seventh generation to come. An Asia-Pacific idiosyncrasy appears to a European observer to be the pursuit for equilibrium, another central tenet of sustainability thinking. As with all displays of human reasoning, these two examples are crude generalizations of thousands of local, national and transnational approaches and ways of thinking. An area in need of further attention and study for its high relevance remains then the multifaceted relationship between sustainability understood and implemented in local communities and cultures on the one hand, and international commitments and goals on the other.

NOTES

1) *See, for example, for Australia and Lao PDR UNESCO, 2011a, p.5; Brunei Darussalam <http://stepcentrebruneiblogspot.com>; China <www.unesco.org/new/en/rio-20/single-view/news/education_for_sustainability_governments_get_the_message/>; Indonesia UNESCO, 2009, p.12; Nepal <www.accu.or.jp/esd/projects/ip/ip01_nepal.shtml>; Malaysia <http://unesdoc.unesco.org/images/0019/001929/192914e.pdf>; Republic of Korea <www.unesco.or.kr/eng/front/resource_center/data_center_01_view.asp?articleid=82&cate=>; Thailand <www.accu.or.jp/esd/forum_esd_2010/program/program08_02/index.html> and Vietnam <www.unesco.org/new/en/hanoi/education/education-for-sustainable-development/>.*
2) *UNESCO concluded a Japanese Funds-In-Trust supported ESD Monitoring and Evaluation project in the Asia-Pacific some years ago. The project employed structural and often binary indicators such as a strategy being in place which do not measure ESD outcomes intended here. A new project has been launched in 2011 with UNESCO, UNU and IGES.*
3) *Reference is made to Bansungkon school in Chiang Rai province in Thailand.*

REFERENCES

Cantell, M. and Elias D. 2011. For bulls and bears alike: Education as investment in sustainable development. C Brock and L. Pe Symaco (Eds.) Education in Southeast Asia. Symposium Books, Oxford, 323-340.

Hayden, M. and Martin, R. 2011. The education system in Cambodia: Making progress under difficult circumstances. C Brock and L. Pe Symaco (Eds.) Education in Southeast Asia. Symposium Books, Oxford, 31-51.

Richmond, M. 2008. The role of UNESCO in the decade of education for sustainable development. Speech delivered at the International Forum on ESD Dialogue 2008 in Tokyo, Japan.

UNDP. 2012. One planet to share: Sustaining human progress in a changing climate. Routledge for UNDP, New Delhi.
UNESCO. 2005. DESD International Implementation Scheme. UNESCO, Paris.
UNESCO. 2009. ESD currents: Changing perspectives from the Asia-Pacific. UNESCO Asia and Pacific Regional Bureau for Education, Bangkok.
UNESCO. 2011a. Astrolabe: A guide to education for sustainable development coordination in the Asia-Pacific. UNESCO Asia and Pacific Regional Bureau for Education, Bangkok.
UNESCO. 2011b. Meeting report on monitoring and evaluation on processes and learning, 15-17 February, 2011. UNESCO Asia and Pacific Regional Bureau for Education, Bangkok.
UNISDR. 2011. At the crossroads: Climate change adaptation and disaster risk reduction in Asia and the Pacific. UNISDR Asia and Pacific secretariat, Bangkok.

Special Contribution on EFA and ESD *Research article*

Environmental Education through Eri-culture for Reducing Amounts of Chemical Pesticide Applied in Greater Phnom Penh of Cambodia

KUMIKO KAWABE*
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan
Email: sunshinekumiko@gmail.com

MACHITO MIHARA
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan

KEISHIRO ITAGAKI
Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Tokyo, Japan

Received 30 August 2012 Accepted 20 September 2012 (*: Corresponding Author)

Abstract Cambodia is located in Southeastern Asia with more than 70% of population is living in rural areas and engaged in agriculture and related sectors. Agriculture is the most important sector for the country, and the government focuses on increasing productivity and trying to meet the international market demand. However, farmers are usually less educated and there are difficulties and obstacles for local farmers to increase knowledge for better ways of agriculture and creating better quality of life. Most of farmers apply agricultural chemicals with low knowledge to increase crop yields that causes various illnesses of local farmers and environmental problems. Statistical data showed that literacy rate of Cambodia from 2005 to 2010 was only 74% for over age of 15 years old. The rate in rural area was much worse than the city. Education for All (EFA) aims to provide quality basic education for "every citizen in every society." Although education is one of the fundamental factors for the country to be developed, daily life security such as basic and stable income is more significant for local people. However, ensuring stable income needs basic education such as literacy and basic numerical ability. This paper deals with environmental education through eri-culture, raising eri silkworms, for reducing amounts of chemical pesticide taking into account the perspective of Education for All (EFA) and Education for Sustainable Development (ESD). Following the first survey in March 2011 for evaluating the potential of local farmers to reduce chemical pesticide through eri-culture, the results showed that expected percentage of chemical pesticide to be reduced for eri silk-raising farmers was remarkably higher than the other farmers. However, research interests have been focused on how much amounts of chemical pesticide local farmers succeeded to reduce compared to the conventional use. So, this study dealt with the evaluation of the amounts of chemical pesticide reduced through eri-culture in Kampong Cham province, Cambodia. The results showed that 35% of eri silk-raising farmers reduced the amounts of chemical pesticide to 80 to 100%, 45 % of eri silk-raising farmers reduced to 60 to 80% while only 5% of eri silk-raising farmers reduced to 20-40% and other 50% reduced to 0-20%. Consequently, eri silk-raising farmers succeeded to reduce the amounts of chemical pesticide use through eri-culture, and eri-culture has educational function to increase the environmental awareness to local farmers, especially, in terms of reducing chemical pesticide use.

Keywords eri-culture, sustainable rural development, ESD, environmental awareness

INTRODUCTION

Cambodia is located in Southeastern Asia, bordering the Gulf of Thailand, between Thailand, Vietnam and Laos. Population is 14,952,665 (July 2012 est.), and population growth rate is in 2012 up to 1.687%. More than 70% of population is living in rural areas and engaged in agriculture and related sectors (CIA Factbook). Agriculture is the most important sector for the country, and the government focuses on increasing productivity and trying to meet the international market demand. However, farmers are usually less educated and there are difficulties and obstacles for local farmers to increase knowledge and technique for better ways of agriculture that hinder creating better quality of life for local farmers.

Most of farmers apply agricultural chemicals to increase crop yields, however at the same time they face to the risks to be affected by agricultural chemicals that leads them to various illnesses, such as cancer or skin disease. Most of agricultural chemicals are imported from neighboring countries and are sold with label in foreign languages. Prohibited agricultural chemicals such as Methyl parathion and Methamidophos are still on sale in the local market and farmers purchase those chemicals without knowing it is categorized as prohibited ones or not knowing the appropriate usage, just simply because they are illiterate or have low level of literacy, so they listen and believe what sellers say.

Statistical data show that literacy rate of Cambodia from 2005 to 2010 is only 74% for over age of 15 years old. Literacy rate of male is 83%, while that of female is 66% (UNESCO Institute for Statistic database, 2012). Literacy rate of female is lower than that of male, and also the rate in rural area is much worse than the city, Phnom Penh and it is also lower than the average literacy rate of other developing countries.

Education for All (EFA) is an international initiative and started in 1990 under the coalition cooperation of UNESCO, the World Bank, national government, development agencies and etc., to provide quality basic education for all children, youth and adults, “every citizen in every society.” EFA sets up six goals to be met by 2015. So, Governments, development agencies, civil societies and the private sectors are working together to reach the EFA goals that include to ensure the learning needs of all young people and adults should be provided through equitable access to appropriate learning and life-skills programs (Dakar Framework for Action, UNESCO, 2000). EFA expects literacy rate goes up to 78% in total, 85% for male, 72% for female by 2015.

However, promoting EFA or ESD to local farmers in Cambodia, some kind of incentive related to poverty reduction and sustainable development are the keys to spread the concepts of EFA and ESD. Although education is one of the fundamental factors for the country to be developed, daily life security such as basic and stable income is more significant for local people. On the other hand, ensuring stable income needs basic education such as literacy and basic numerical ability. In short, promoting EFA and ESD are inseparably related to poverty reduction and income generation, and it is important that above aspects should be promoted together that will raise the level of “Sustainable Development”.

Eri-culture, raising eri silkworms, has introduced to local famers in Kampong Cham province in October 2010 and has been promoted since as a part of regional challenges of Regional Centres of Expertise (RCE) to promote as environment education (Kawabe, 2010). After 6 months passed since eri-culture introduced to local farmers in Kampong Cham province, questionnaire survey was conducted to evaluate the effects of eri-culture on promoting environmental awareness. The results showed local farmers who raise eri silkworms wanted to reduce 92.5% of chemical pesticide compared to the conventional use, while local farmers who just participated in the workshop or who have never participated in the workshops showed only 72.3% or 66.9% of chemical pesticide to be reduced (Kawabe et al., 2012). The expected percentage of chemical pesticide to be reduced for local farmers who raise eri silkworms was significantly higher than that for local farmers who just participated in the workshop or who have never participated in the workshops. So, it was considered that eri-culture has educational function for local farmers especially, regarding the reduction of chemical pesticide application.

OBJECTIVE

Accordingly, this paper deals with environmental education through eri-culture for reducing amounts of chemical pesticide, taking into account the perspective of Education for All (EFA) and Education for Sustainable Development (ESD). First survey was conducted 6 months passed after eri-culture has introduced to the local farmers in Kampong Cham province for the first time in October 2010 to evaluate the potential of local farmers to reduce chemical pesticide through eri-culture. However, research interests have been focused on how much amounts of chemical pesticide local farmers succeeded to reduce compared to before starting eri-culture. So, this study aims to evaluate quantitatively the amounts of chemical pesticide reduced through eri-culture in Kampong Cham province, Cambodia.

METHODOLOGY

Eri-culture

Eri-culture, raising eri silkworm (*Samia cynthia ricini*) is conducted not only for rural development but also for women's capacity building and income generation in some developing countries, such as Thailand, Vietnam, Philippines, south China, and Ethiopia where the areas can grow the host plants of eri silkworms, castor (*Ricinus communis*) and cassava (*Manihot esculenta*). Eri silkworm is categorized as wild silkworm although it is completely domesticated as same as silkworm of the mulberry tree (*Bombyx mori*). While *Bombyx mori* hatches once or twice per year according to the types, eri silkworm hatches approximately 6 times a year. In October 2010, eri-culture has introduced to local farmers in Kampong Cham province, Cambodia. Since then, workshops and demonstrations on promoting eri-culture have been conducted in the villages.

Photo. 1 Eri silkworms

Photo. 2 Cocoons of eri silkworms

Photo. 3 Extension activity for promoting eri-culture in Kampong Cham, Cambodia

The first survey was conducted in March 2011 to evaluate the effects of eri-culture on promoting environmental awareness of local farmers in Kampong Cham province. The results showed that eri silk-raising farmers wanted to reduce 92.5% of chemical pesticide compared to the conventional use. While local farmers who just participated or who have never participated in the workshops showed only 72.3% or 66.9% of chemical pesticide to be reduced. Environmental awareness of eri silk-raising farmers on chemical pesticide to be reduced was significantly higher than that of other farmers who just participated in the workshop or who have never participated in the workshops (Kawabe et al., 2012). Sequel questionnaire survey was conducted in October 2011, 12 months passed after eri-culture has introduced to local farmers, as attention has been paid how much in fact the eri silk-raising farmers did reduced the amounts of chemical pesticide applied compared to conventional use.

Research sites

The research sites are namely Wat Chas village and Roung Kor village in Baray commune, Prey Chhor district in Kampong Cham province where located approximately 100 km northeast from the capital of Cambodia, Phnom Penh (Fig. 1). Due to the suitable location for distributing agricultural products to Phnom Penh, most of farmers apply agricultural chemicals for farming practice to increase the productivity.

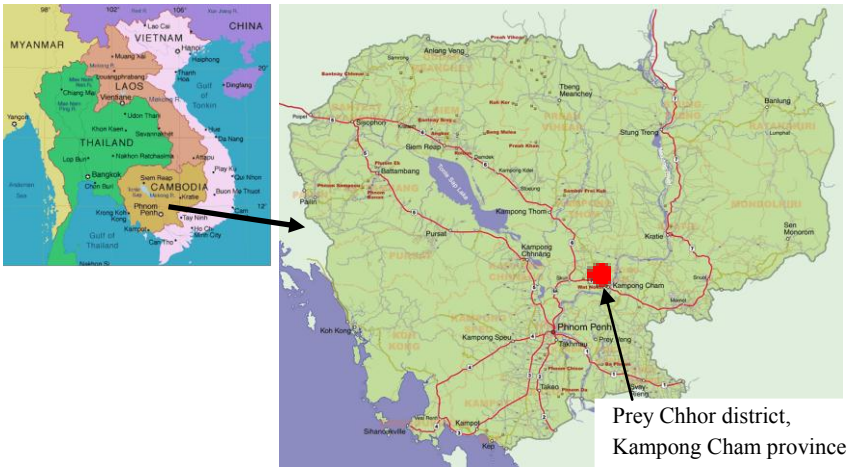


Fig. 1 Location of Wat Chas and Roung Kor villages in Baray commune, Prey Chhor district in Kampong Cham province

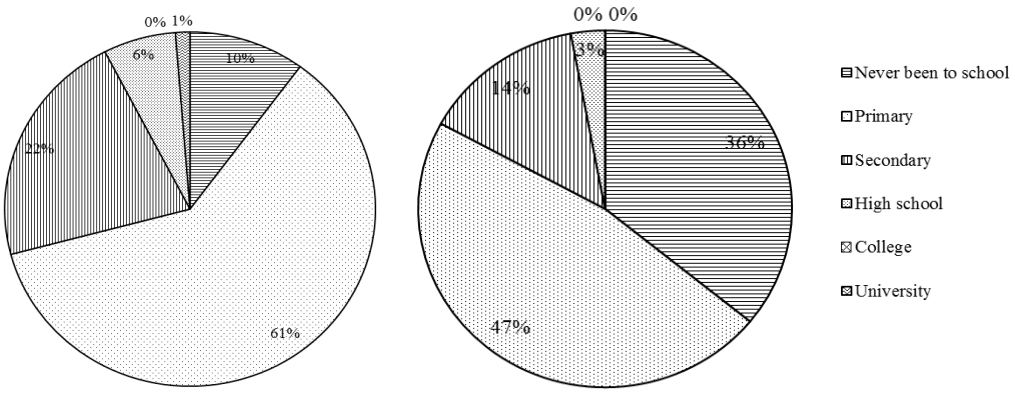


Fig. 2 Education level of famers at Wat Chas (Left) and Roung Kor (Right) villages, Kampong Cham province

Source: ERECON Questionnaire Survey in 2009 and 2010

According to the surveys conducted in 2009 and 2010 by the Institute of Environment Rehabilitation and Conservation (ERECON), level of education of farmers at Wat Chas and Roung Kor villages were observed. The results shows 10% of farmers have never been to school, and 61% completed only primary school and 22% completed secondary school, while only 6% completed high school in Wat Chas village (Fig. 2). In Roung Kor village, less percentage of farmers completed secondary or high school as shown in Fig. 2.

Education for adults is usually not paid enough attention, also not enough provided. Local farmers tend to think education is costly and they are too old to go back to school for study. However, they face difficulties due to being illiterate or less educated that cause poor access to the knowledge of agriculture and adoption of new techniques. Being illiterate, the information and technology are not easy for local farmers to access. Thus, any kind of non-formal education could take an important role for local farmers to reach appropriate and reliable information and knowledge that promote sustainable development.

In the research sites, all men and women aged 18 and over were eligible to receive land equally by the Cambodian government when Pol Pot regime was over. Thus, the average farmland is quite small and approximately 0.45 ha per household today. Rice in paddy filed and some amounts of vegetables in upland fields are cultivated. Due to the limited size of farmland and one-crop system for most of farmers, agro-production is limited and poverty level is higher than other province of Cambodia (Kawabe, 2011).

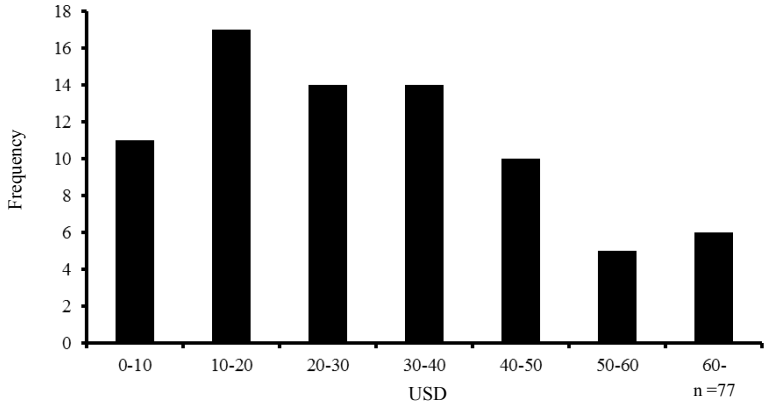


Fig. 3 Monthly income from agriculture at Wat Chas village, Kampong Cham province

Source: ERECON Questionnaire survey at Wat Chas village, 2009

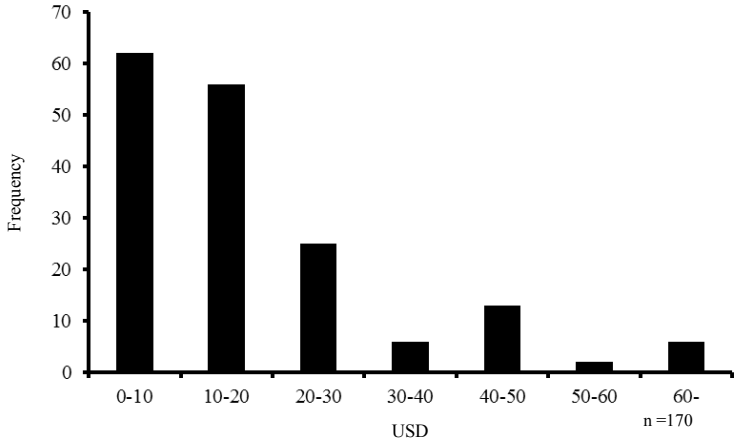


Fig. 4 Monthly income from agriculture at Roung Kor village, Kampong Cham province

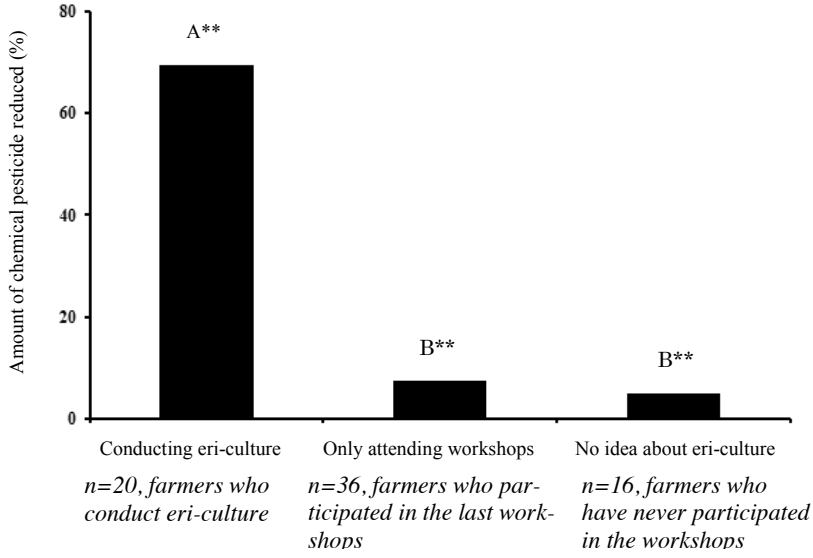
Source: ERECON Questionnaire survey at Roung Kor village, 2010

According to basic survey, monthly income from agriculture at Wat Chas village is shown in Fig. 3. Income from agriculture, main income for living remains relatively low, and the income range of 0 to 40 US dollar dominates 70% of the farmers in Wat Chas village, while the income range of 0 to 30 US dollar dominates 83% in Roung Kor village (Fig. 4). However, increasing and maintaining in yields, most of farmers purchase agricultural chemicals with small income and apply into farmlands that cause not only weighing down the household budget, but also causing health problems of farmers, degradation of soil and water.

Solving the above mentioned problems, eri-culture has introduced to local farmers in Kampong Cham province as part of regional challenges of Regional Centres of Expertise (RCE) to promote ESD through the food, agriculture and environment education.

RESULTS AND DISCUSSION

In the first survey in March 2011 to evaluate the effects of eri-culture on promoting environmental awareness of local farmers, the results showed that eri silk-raising farmers wanted to reduce 92.5% of chemical pesticide compared to the conventional way.



Different letter indicates the significant difference at 99%(**)

Fig. 5 Difference in actual percentage of chemical pesticide reduced between eri silk-raising farmers and others

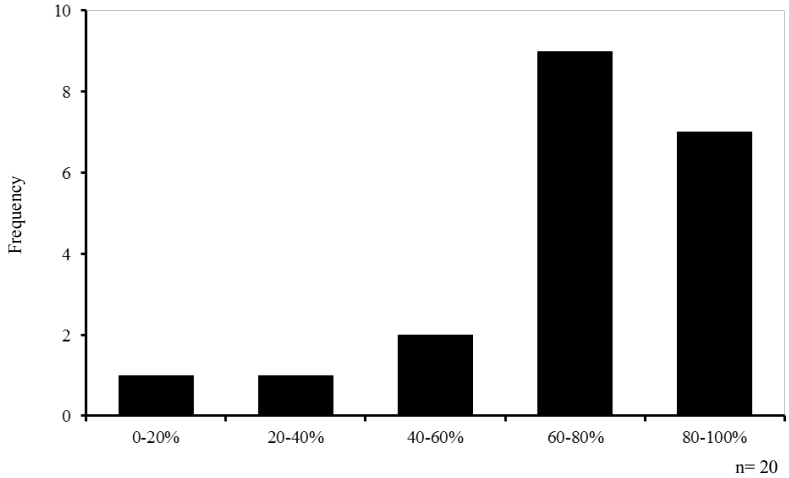


Fig. 6 Percentage of chemical pesticides reduced for eri silk-raising farmers

While local farmers who just participated or who have never participated in the workshops showed only 72.3% or 66.9% of chemical pesticide to be reduced (Kawabe, 2010). Expected percentage of chemical pesticide to be reduced for eri silk-raising farmers was remarkably higher than the other farmers. So, an attention has been paid to reveal that how much in fact the eri silk-raising farmers reduced the amounts of chemical pesticide application compared to the conventional use. Questionnaire survey was conducted in October 2011, one year after eri-culture had introduced to the local farmer in October 2010.

The results showed that eri silk-raising farmers succeeded to reduce the amounts of chemical pesticide 69.5% compared to the conventional use, while famers who only participated in the eri-culture workshops or who never participated in the eri-culture workshops reduced only 7.5% or 5% (Fig. 5). Observing the detail amounts of chemical pesticide reduced by the eri silk-raising farmers, 35% of eri silk-raising farmers reduced the amounts of chemical pesticide to 80 to 100%, 45 % of them reduced to 60 to 80%, while only 5 % of them reduced to 20-40% and other 5% of them reduced to 0-20% (Fig. 6).

Consequently, eri silk-raising farmers succeeded to reduce the amounts of chemical pesticide use through eri-culture, and eri-culture has educational function to increase the environmental awareness to local farmers, especially, in terms of reducing chemical pesticide use. Moreover, eri-culture has strong impact on local farmers who raise eri silkworms to move forward to sustainable rural development.

CONCLUSIONS

Expected percentage of chemical pesticide to be reduced for eri silk-raising farmers was remarkably higher than the other farmers. So, an attention has been paid to reveal that how much in fact the eri silk-raising farmers reduced the amounts of chemical pesticide application. Questionnaire survey was conducted in October 2011, one year passed after eri-culture had introduced to the local farmer in October 2010. The results showed that eri silk-raising farmers succeeded to reduce the amounts of chemical pesticide 69.5%, while famers who only participated in the workshop or who never participated in the workshops reduced only 7.5% or 5%. Observing the detail amounts of chemical pesticide reduced by the eri silk-raising farmers, 35% of them reduced the amounts of chemical pesticide to 80 to 100%, 45 % of eri silk-raising farmers reduced to 60 to 80% while only 5% of eri silk-raising farmers reduced to 20-40% and other 50% of them reduced to 0-20%. Consequently, eri silk-raising farmers succeeded to reduce the amounts of chemical pesticide use compared to conventional use through eri-culture, and eri-culture has educational function to increase the environmental awareness to local farmers, especially, in terms of reducing chemical pesticide use although most of farmers have less education in childhood. Moreover, eri-culture has strong impact on local farmers who raise eri silkworms to move forward to sustainable rural development, especially supplementary income is great motivation for local farmers to learn and obtain knowledge and skills more and more. Education is the key for development, but it is not necessarily a panacea for everything, and it should be discussed along with the ideas of income generation for adult education.

ACKNOWLEDGEMENTS

Institute of Environment Rehabilitation and Conservation, ERECON, has been supported the promotion of eri-culture in Kampong Cham province, Cambodia. Also, Ms. Nittaya Mahachaiwong, Knowledge and Technology Center for Northern Textile (Fai Gaem Mai), Science and Technology research Institute, Chiang Mai University and Dr. Bunthan NGO, Royal University of Agriculture have been advising technical and social aspects on eri-culture. Authors would like to express special thanks to them.

REFERENCE

Central Intelligence Agency, https://www.cia.gov/library/publications/the-world-factbook/geos/cb.html.

ERECON. 2009, 2010. Questionnaire Survey at Baray commune, Prey Chhor district, Kampong Cham province, Cambodia on November 2009 and 2010.

Kawabe, K. 2010. Eri-culture for sustainable rural development. ERECON Annual Report, Institute of Environment Rehabilitation and Conservation, 2009-2010, 4.

Kawabe, K., Tal, M. and Mihara, M. 2011. Effects of eri-culture on promoting environmental awareness in Greater Phnom Penh of Cambodia. International Journal of Environmental and Rural Development, IJERD 3(1), 22-29.

Mihara, M. 2005. The effect of natural weed buffer on soil and nitrogen losses in Japan. Catena, 65, 265-271.

Mihara, M. and Fujimoto, A. 2009. Sustainable farming practices for environmental conservation. Institute of Environment Rehabilitation and Conservation, Japan.

United Nations Education, Scientific and Culture Organization, http://www.unesco.org/new/en/education /themes/leading-the-international-agenda/education-for-all/.

United Nations World Food Programme, http://foodsecurityatlas.org/khm/country/provincial-Profile/Kampong-Cham.

Special Contribution on EFA and ESD *Research article*

Climate Change Impacts on Agriculture and Vulnerability as Expected Poverty of Kampong Speu Province, Cambodia

NYDA CHHINH*
Royal University of Phnom Penh, Phnom Penh, Cambodia
Email: chhinh.nyda@rupp.edu.kh

BUNNAK POCH
Western University, Phnom Penh, Cambodia

Received 30 August 2012 Accepted 22 September 2012 (*: Corresponding Author)

Abstract As a developing country that is heavily dependent on agriculture, Cambodia has been severely affected by natural hazards. Since the 1990s, there has been an increase in the frequency and severity of flooding and drought induced or exacerbated by climate change. Literature has demonstrated that Cambodia is very vulnerable to the adverse impacts of climate change. Vulnerability, as posited by the Intergovernmental Panel on Climate Change (IPCC), is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity. This paper measures the vulnerability as expected poverty (VEP), introduced by Shubham Chaudhuri, in a province in Cambodia, Kampong Speu (KPS), using household survey data. The results show that among all of the exposures to natural hazards in Cambodia, drought poses the highest risk for rain-fed agriculture dependent households. The VEP shows that more than 60% of households in the KPS province are vulnerable to climate change with an income threshold of US $1 per day. Some policy recommendations resulting from this study include building irrigation systems to mitigate the impacts of droughts, ensuring secondary income generation opportunities for poor households so that households do not depend exclusively on agriculture, and increasing the education level of villagers.

Keywords Cambodia, climate change, vulnerability, adaptation, education

INTRODUCTION

The main sectors that drive Cambodia's economic growth are Agriculture (including Fisheries and Forestry), Industry and Service. Each sector's share of GDP is 28%, 28.6% and 38.3%, respectively (NIS, 2008). The Strategic National Development Plan (SNDP) places the agricultural sector as the central focus of Cambodian development for the next decade, and it is believed that agriculture sector will be a major contributing factor to inclusive growth (CDRI, 2012). The agricultural sector currently employs 59% of Cambodia's total labor force (NIS, 2008).

The industry that generates the most money in Cambodia is Textile, Wearing Apparel and Footwear (CDRI, 2007). However, the garments produced in Cambodia are created from raw materials supplied from outside of Cambodia, including fabrics. The Royal Government of Cambodia (RGC) believes that once the agricultural sector is developed, Cambodia can produce the raw materials (the agro-industrials) to supply to industry, particularly cotton and rubber. Therefore, the growth of agriculture will contribute to the growth of the industrial sector.

Paddy rice is the central livelihood of rural people. More than 50% of Cambodian workers are employed in the agriculture sector, the majority of whom work in the cultivation and harvesting of paddy rice. Cambodia's 2008 general census (NIS, 2008) showed that more than 80% of Cambodians live in rural area and are engaged in subsistence farming. Approximately 47% of them own less than one hectare of land and have an average of five household members; more than one-fourth of

all households in Cambodia are headed by females (NIS, 2009). The majority of paddy fields are rain fed; therefore, the planting index of rice in Cambodia is around 1.2 per year (MoE, 2005). Cambodia's rice yield is low at around two tons per hectare compared to approximately three tons per hectare in Vietnam and Thailand (Yu and Fan, 2011).

Agricultural activities in Cambodia are not sophisticated and require only low levels of skills and training. Farmers have an average of seven years of education (NIS, 2009). With this level of education, it is hard for agricultural experts to share knowledge and skills about how to use high-tech equipment to improve agricultural practices. Since many farmers are still using traditional methods and tools to cultivate their land, Cambodian farmers are highly sensitive to environmental changes, especially drought.

Frequently, Cambodia experiences floods, drought, windstorms, insect outbreaks, underground water salinisation and seawater intrusion (MoE, 2005). Since the country is heavily dependent on the agriculture sector, these natural hazards have severe effects on the livelihoods of the 80% of Cambodians who live in rural areas (MoE, 2005, NCDM, 2008, Geres-Cambodia, 2009, MoE and UNDP Cambodia, 2011). On a national scale, flood and drought caused crises in three consecutive years from 2000 to 2002. Flooding in 2000 was considered the most severe in four decades and was followed by flooding of a similar intensity in 2001, while in 2002 both flood and drought hit the country (Chan and Sarthi, 2002).

Due to the negative effects of natural calamities caused by climate change on the agricultural industry, achievement of the Millennium Development Goals in Cambodia may be hindered, especially the elimination of poverty and hunger. The United Nations World Food Program (WFP, 2003) identified provinces along the Mekong River as areas prone to flooding and flash flooding, and found that more than 80% of famers are living in drought-prone areas in Cambodia. This is of great concern as the irrigation scheme is very limited in Cambodia. Assessments from government institutions show that flooding did similar damage to drought (Fig. 1) (MoE, 2006). The Economy and Environment Program for Southeast Asia's (EEPSEA) Framework to Assess Climate Change Vulnerability demonstrated that Cambodia is highly vulnerable to climate change; not because of exposure but because of its low adaptive capacity (Yusuf and Francisco, 2010).

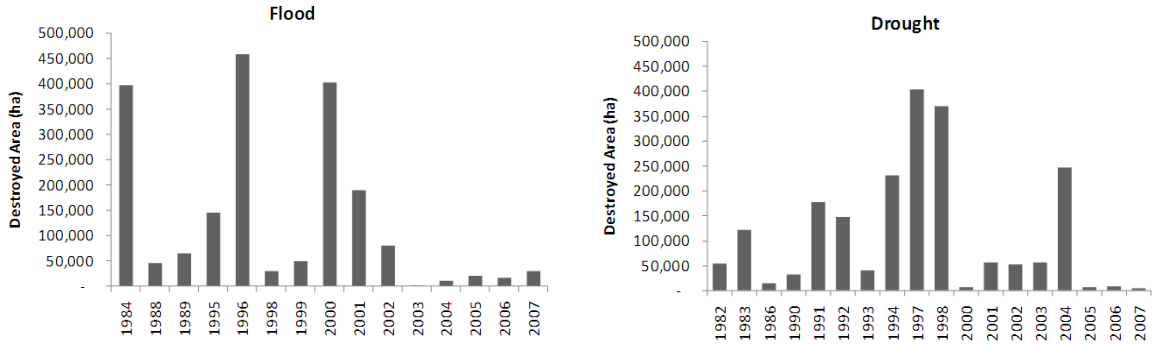


Fig. 1 Flood and drought damages on rice fields in Cambodia 1982-2007
Source: Am, 2010

Shocks, including natural disasters, are regarded as the driving force that pushes vulnerable people into extreme poverty, especially those who have few assets or savings (World Bank, 2006). A case study by the Analyzing Development Issues (ADI) Team found that the severe floods and drought in Cambodia that occurred in 2000/01 and 2004/05 contributed to crop failure and that people exploited common pool resources (Ang et al., 2007). Droughts have impact when they occur during the three stages of rice production activities: planting (June-July), growing (August-September) and harvesting (October-November) period. At a national level, the National Adaptation Programme of Action (NAPA) has been developed to mitigate the impact of climate change, which includes a proposal for an irrigation scheme and a flood prevention dike (MoE, 2006). NAPA states that the Agriculture and Water resource sectors are the highest priority in both short- and long-term strategies.

This paper investigates the impacts of climate change on farmers in the Kampong Speu (KPS) province, specifically the dynamic impacts on households. It argues that the natural hazards faced by households in this province are the major factors in preventing people from escaping poverty and that integrated policy intervention is necessary to address climate change impacts.

METHODOLOGY

Vulnerability framework

Vulnerability is defined differently in different disciplines. In this study, we adopt the Intergovernmental Panel on Climate Change's (IPCC) definition: "The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (McCarthy et al., 2001, p. 995).

Exposure to environmental hazards, especially flood and drought, has been well studied in many countries where agriculture is dominant. Methods employed to understand the nature of these climate-induced disasters vary from author to author. Liverman's (1990) study on vulnerability of farmers to drought in Mexico, for example, suggests that using diverse quantitative data makes it possible to identify the places and people who are prone to drought. National Committee for Disaster Management (NCDM) (2003) identified where drought and flooding occurred through examining the affected areas, rice dependency and food security based on rice production in Cambodia.

Vulnerability is conceptualized by many scholars (Adger, 2006, Eriksen and O'Brien, 2007, Smit et al., 1996, Smith et al., 2000, Smit and Wandel, 2006). It can be best understood as an interaction between exposure, sensitivity and adaptive capacity. At any point in time, the greater the exposure (of people, agricultural systems and businesses), the higher the vulnerability. Vulnerability, however, is reduced when the sensitivity of the system(s) is lower. Sensitivity decreases or increases over time due to the adaptation measures taken following the disaster(s). If exposure and sensitivity remain constant from household to household, adaptive capacity of individual households will be highly associated with their vulnerabilities.

This study adopts the approach to measuring household economic vulnerability posited and elaborated in Chaudhuri's (2003) study of household vulnerability. Household vulnerability as expected poverty is defined as the probability that households will move into poverty given certain environmental shocks, current poverty status and household characteristics of respondents. While poverty reflects the current state of deprivation, vulnerability reflects what a household's future prospects are (Elbers and Jan, 2003). Thus, a household's consumption or income can be regressed on household characteristics and shocks in order to obtain the estimated coefficients to be used for further prediction of the household's future poverty. In this regard, households with high predicted poverty are considered vulnerable. Unlike Chaudhuri (2003), who analysed households' monthly per capita consumption expenditure, this study analyses households' monthly income to measure the household vulnerability index due to the lack of expenditure data.

Technically, the household vulnerability index is derived from the difference between the expected log per capita income and the minimum log per capita income threshold, with households having per capita incomes lower than the minimum per capita income defined as vulnerable (poor). The expected log per capita income is estimated using the three-step feasible generalised least squares (FGLS) method.

The predictors of log per capita income used in the analysis include: droughts in the past 12 years (dummy); windstorms in the past 12 years (dummy); floods in the past 12 years (dummy); household size; level of education; possession of motored vehicle (dummy); access to credit (dummy); presence of disabled persons in the households (dummy); and the dependency of livelihood on agriculture (dummy).

Survey design

The total land area of the KPS province is approximately 653,396 hectares divided into eight districts and 87 communes. The household survey samples were selected from six communes in six districts within two geographical areas: highland areas (two districts) and the lowland area (four districts). Three natural disasters were considered: flash flooding, drought, and windstorms. Areas were defined using Geographical Information Systems, which can be used to produce a Digital Elevation Model. Administrative boundaries were used to define provinces, districts and communes. Natural disaster occurrence was based on information given from key informant interviews from the Sub-national and local authorizes. A total of 600 questionnaires were collected from households.

RESULTS

Profile of the respondents

Among the six communes we selected, five communes were classified as rural and two communes were located in highland. The majorities of the respondents were female and constituted 60% to 77% of each commune (Table 1). Also, an overwhelming number of respondents reported that they did not rely exclusively on agricultural work. In the rural highland commune of Tasal, the highest number of respondents (13%) identified agriculture as the only source of income. On average, all respondents completed secondary education, and urban dwellers (Chbar Mon commune) have higher education than their rural counterparts. The lowest school attendance was reported in the highland communities of Tasal and Morhasaing.

Table 1 Sex and occupation of respondents

Commune	Topography	Number of Respondents	Sex of respondents		Occupation of respondents	
			Female	Male	Agriculture only	Agriculture and others
Chbar Mon	Urban/Lowland	100	65	35	9	91
Kork	Rural/Lowland	100	69	31	7	93
Morhasaing	Rural/Highland	100	73	27	6	94
Peang Lvea	Rural/Lowland	100	61	39	7	93
Rolang Chork	Rural/Lowland	100	65	35	7	93
Tasal	Rural/Highland	100	77	23	13	87
Total number		600	410	190	49	551
Total percentage		100%	68.3%	31.7%	8.2%	91.8%

Source: Survey 2011

Household Characteristics

There were on average five people within a household within the surveyed areas. This is well above the national average household size (4.7) in 2008 (NIS, 2008). Rolang Chork has the smallest average household size (4.99 people per household on average) and the highest level of education among its population (9.6 years of schooling on average). The Kork and Chbar Mon communes had larger household sizes than the other selected communes (5.64 and 5.59 people per household on average, respectively).

About 60% of respondents reported that their households have at least one motorcycle. There was a large variation in the proportion of households possessing motorcycles between communes, with the Chbar Mon (73%), Peang Lvea (74%) and Rolang Chork (68%) communes having a higher percentage of motorcycle-possessing households than the Tasal (44%), Kork (50%) and Morhasaing (53%) communes. The survey also revealed that 11.7% of respondents live in house-

holds with at least one person with disability. Peang Lvea commune has the highest proportion of households containing a person with a disability (21%), followed by Rolang Chork (13%), Kork (12%), Tasal (11%), Morhasaing (7%) and Chbar Mon (6%).

Natural hazards and exposure index

The three natural hazards that impact on people's livelihoods in Cambodia including flood, windstorms and drought are investigated in this paper. It is important to note that the indicators of these events are measured as dummy, indicating whether the respondents have experienced drought, flood and windstorm over the last 12 years (1999-2010).

As indicated in Table 2, an overwhelming majority of respondents have reported experiencing drought ranging in the last 12 years. In the rural communities of Morhasaing, Peang Lvea and Tasal, 100 % of the respondents reported experiencing drought. In contrast, the percentages of respondents who have experienced floods or windstorms in those 12 years are significantly lower than those who have experience drought.

Although respondents reported a slight decline in the number of droughts over the 12-year period, they had experienced a number of particularly devastating droughts in 1999, 2000, 2003 and 2004. Villagers from the Pongrek village (Peang Lvea commune, Odung district) stated that the 2010 drought was also a very severe drought which badly affected rice yields.

Table 2 Households experiencing floods, windstorms or drought in the last 12 years (1999-2010)

Commune	Urban/ rural	Total number of respondents	% of households		
			Floods	Windstorms	Drought
Chbar Mon	Urban	100	12	5	83
Kork	Rural	100	2	6	99
Morhasaing	Rural	100	9	13	100
Peang Lvea	Rural	100	2	5	100
Rolang Chork	Rural	100	31	12	90
Tasal	Rural	100	4	1	100
Total number		600	60	42	572
Total (%)		100%	10%	7%	95%

Source: Survey 2011

Vulnerability analysis based on expected poverty

Table 3 presents the results of the FGLS analysis. Among the environmental impacts, only drought was found to have had a significant negative impact on log per capita income ($b= -0.379$, $p<0.001$). This indicates that households who have experienced drought over the last three years are predicted to have log per capita income 0.379 less than those who have not experienced drought (controlling for other household and individual characteristics in the model). Windstorms and flooding did not have significant impacts on log per capita income.

The windstorms and flash floods that occurred in the period between 2005 and 2010 did not have a significant impact on log per capita income. This may be due to the long period of time over which the occurrences of windstorm and flash flooding were measured in this study. With the exception of drought, the respondents' experience of windstorm and flash floods in the last five years has not changed considerably. It may be difficult to detect environmental impacts that have frequently occur over long periods of time due to people having developed adaptive strategies to mitigate their impacts. Few respondents experienced flash flooding or windstorms in the years prior to completing the survey.

Household size, the possession of motor vehicle and a livelihood dependency on agriculture are significantly and inversely associated with log per capita income. Specifically, the larger the household size, the lower the expected log per capita income (the coefficient is -0.182, p<0.001). In addition, the possession of a motor vehicle is positively related to expected per capita income (the coefficient is 0.312, p<0.001); while households who depend on agricultural work alone tend to have lower per capita income than those households who have an additional secondary occupation (the coefficient is -0.899, p<0.001). In addition, the education attainment of respondents has a positive effect on log per capita income, although the effect is small (the coefficient is 0.044, p < 0.001). Access to credit and the presence of person living with disability in the household does not significantly affect log per capita income.

Table 3 Results of least squares regression analysis of log monthly household per capita income

	Initial model			FGLS model		
	Coefficient	**Standard error**	**P>t**	**Coefficient**	**Standard error**	**P>t**
Drought in past 3 years	-0.143	0.067	0.035	-0.379	0.071	0.000
Windstorm in past 12 years	-0.264	0.133	0.047	-0.199	0.132	0.133
Flashfloods in past 12 years	-0.076	0.113	0.503	-0.137	0.116	0.238
Household size	-0.197	0.017	0.000	-0.182	0.017	0.000
Education	0.047	0.010	0.000	0.044	0.010	0.000
Having motorcycle	0.265	0.071	0.000	0.312	0.072	0.000
Access to credit	-0.091	0.068	0.183	-0.061	0.068	0.375
Presence of person with disability	-0.033	0.105	0.753	-0.026	0.106	0.808
Agriculture plus secondary occupation	-1.103	0.123	0.000	-0.899	0.118	0.000
Constant	3.700	0.138	0.000	3.714	0.139	0.000
Model summary						
Adjusted R-squared	0.339			0.341		
F (9,590)	33.64			33.97		
N	600			600		

Source: Survey 2011

Household vulnerability

The expected log per capita income obtained from the above FGLS analysis was used to create vulnerability index at a US $1.00 daily threshold (Cambodia poverty line) and at a US $1.25 daily threshold. Households are considered vulnerable (or poor in the future) if they score higher than 0.50 on the vulnerability index. Table 4 presents the results of the vulnerability analysis disaggregated by commune.

Given different household characteristics, the overall mean vulnerability is 0.65 using the US$ 1.00 threshold with some small variation in the mean vulnerability across all six communes (Table 4). The vulnerability incidence is found to be high in highland and low in urban communities. The analysis suggested that contributing factors to vulnerability incidence among households are livelihood (highly depending on agriculture) and low education. In our sample, we found that vulnerability incidence is 70 %. This figure is high compared to the rate generated from general vulnerability assessment in a provincial poverty report (NCDD, 2009).

Table 4 Vulnerability index and incidence per commune at US $1.00 daily threshold

Commune	Mean vulnera-bility	Standard deviation of vulnerability	Vulnerability incidence (%)	Rank
Chbar Mon	0.63	0.18	73.00	5
Kork	0.68	0.16	82.00	3
Morhasaing	0.64	0.17	76.00	4
Peang Lvea	0.66	0.16	83.00	2
Rolang Chork	0.61	0.17	73.00	5
Tasal	0.70	0.17	85.00	1
Total	0.65	0.17	78.67	

When the threshold is increased to US $1.25 the mean vulnerability increases to 0.72 and the incidence of vulnerability increases to 90.67% (an increase of 39.5%). This means that with a cut-off point of US $1.25, more than 90% of these respondents will become poor in the future. The highest percentage of vulnerable households is in Kork (with 98 %), followed by Peang Lvea with 93%, Kork with 92%, Rolang Chork with 89%, Morhasaing with 87% and Chbar Mon with 85%.

Based on the model, it is apparent that poor communes, like Tasal and Kork, as indicated by low percentage of motor vehicle possession, high percentage of villagers depending solely on agriculture and a high percentage of households with a person with a disability, are likely to be vulnerable now and in the future.

Vulnerability and per capita income

Each graph below is divided into four sections representing the vulnerability cut-off point and poverty cut-off point at a US $1.00 threshold in Fig. 2 and at a US $1.25 threshold in Fig. 3. Dots in the graphs represent the interviewed households. Those households in the upper left quadrant are both currently poor and vulnerable, that is, they are likely to continue to be poor in the future. Those in the lower left quadrant are households that are currently poor but are not vulnerable. Those in the upper right quadrant are households that are currently not poor but vulnerable, meaning that they are likely to be poor in the future. Households that are in the lower right quadrant are neither currently poor nor vulnerable, meaning that they are less likely to be poor in the future.

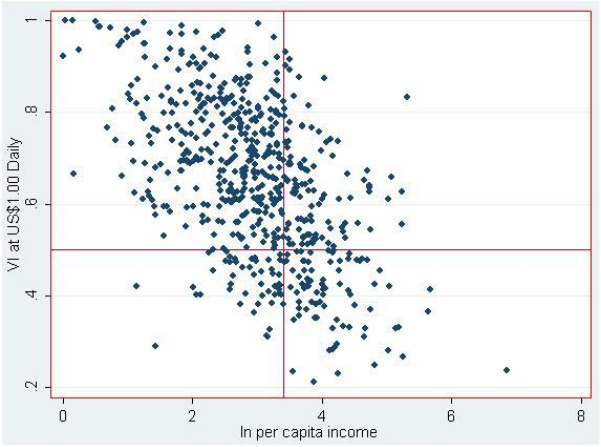


Fig. 2 Vulnerability vs log per capita income at US $1.00 threshold

Comparing Fig. 2 and Fig. 3, it is evident that increasing the threshold of per capita income from US $1.00 to US $1.25 decreases the number of households that are not currently vulnerable and increases the number of households that are vulnerable. This means increasing the per capita

income threshold results in moving more households into future poverty, regardless of their current poverty status. However, the increase in the future incidence of poverty due to an increase in the threshold is more severe among those who are currently poor than among their counterparts who are not currently poor in all communes, with a higher increase in the number of poor and vulnerable in poor communes like Tasal, Rolang Chork and Kork.

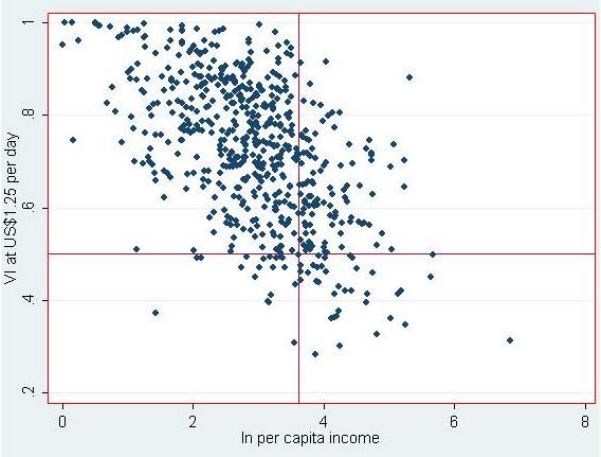


Fig. 3 Vulnerability versus log per capita income at US $1.25 threshold

DISCUSSION

Natural hazards have had multiple impacts on communities in the KPS province. Windstorms had the smallest impact on people, while flashfloods occurred infrequently but caused medium degrees of damage while drought was the most severe and pronounced hazard.

The drought in 2003 decreased rice yields, this means that villagers had inadequate food. Some villagers began eating vines as a substitute for rice. As a result of the impacts of disasters, in every study site commune people migrated to find employment opportunities elsewhere. Among the respondents from the six communes, the percentage of temporary migration is about 30% in Tasal and Kork, about 10% in Morhasaing and Chbar Mon, 20% Rolang Chork, with Peang Lvea having the highest rate of migration at 60%. Many anecdotes were shared in the focus group discussions about children dropping out of school and women bearing health and livelihood burdens due to the impacts of disasters.

Discussions in Kork commune stated that poor families were the most vulnerable to drought in community, especially those with children who consume unclean water, therefore getting sick and incurring an additional cost for their families. During periods of drought some households had the ability to rent pumping machines so they could pump water from nearby sources in order to supply their rice fields with the water necessary for rice production. Others that were short on capital would have to take loans from microcredit institutions and local lenders. For some this resulted in high levels of debt which could not be paid back and hence assets and property were confiscated.

The survey here found that farmers usually undercultivated land and produced low yields (as low as 500 kilograms per hectare during the drought spell). Believing that agricultural adaptation options could increase yield and income as well as food security, farmers have considered many strategies to mitigate drought impacts and increase rice production including changes in crop calendar and crop variety and the increased use of chemical fertilizer. The most urgent adaptation measure in KPS is to provide water for rice fields, especially when there is a prolonged drought during the middle of a wet season. The experts in agriculture of the province highlighted that providing training on modern agricultural methods and small-scale water management are also a priority.

While the model used in this study captures only household characteristics and natural hazards and escaping from disasters are beyond households' capacity and should rest on other stakeholders

such as government agencies, non-governmental organizations (NGOs) and private sectors. Currently, there are a number of stakeholders working to assist farmers such Department of Agriculture but it may not effective in terms of the increasing threats from climate change.

CONCLUSION

Changing climate and climate variability may prevent Cambodia from reaching its development goals, particularly those related to reducing poverty. As indicated by the Ministry of the Environment (MoE), flash flooding and drought are responsible for the reduction in rice production in Cambodia (MoE, 2001, MoE, 2005). At the provincial level, Yusuf and Francisco (2010) indicated that the KPS province is the third most vulnerable province to climate change in the country.

The study aims to identify the impact of environmental shocks (flash floods, windstorms and drought) and household characteristics on per capital income and to create vulnerability indexes to predict future poverty incidence in the communities of the KPS province. Drought is found to be the most common environmental hazard experienced by people in these communities. The study found that, among the three indicators of environmental shocks, only drought resulted in a decrease in the per capita income of households between 2008 and 2010. Drought can be more devastating than either windstorms or flash flood, as it can easily destroy an entire season of crop.

Two of the household characteristics that negatively affected household per capita income are a household size and agricultural dependency. This suggests that households that have many children and do not have other sources of income are likely to be poor and continue to be poor (vulnerable) in the future. In contrast, the education of respondents and households' possession of motor vehicles are positively related to per capita income.

Some policy recommendations resulting from this study include building irrigation systems to mitigate the impacts of droughts, ensuring secondary income generation opportunities for poor households so that they do not depend exclusively on agriculture, and increasing the education level of villagers.

In conclusion, drought is the most severe natural hazard in KPS and farmers reported that they regularly experience a late onset of rainfall. There is a widespread problem of water scarcity and most farmers do not have access to irrigation systems or other technology that can supply water, such as water pumps. Based on the VEP, the study shows that many people are unable to cope with environmental shocks, especially drought. As a result, farmers are not able to fully cultivate their paddy fields and therefore experience reduced crop yields. It is imperative to increase the adaption capacity of farmers who have livelihoods that are highly sensitive to natural hazards. Diversifying livelihoods is also recommended, but it is beyond the scope of this paper. While enhancing adaptive capacity is very critical, there is currently limited intervention from the local government and sub-national government. Whereas NGOs are working to enhance the livelihoods of communities through community risk management, there has only been limited cases of direct resource and knowledge transfers. Farmers have limited access to credit at their locality when they need it most to save their livestock and paddy fields during natural hazards.

ACKNOWLEDGEMENTS

This work was carried out with the aid of a grant from the International Development Research Centre, Ottawa, Canada and Economy and Environmental Program for Southeast Asia. Also, there were contributions from the Hue College of Economics, SEARCA, the University of the Philippines Los Banos and the Provincial Department including Provincial Hall, the Department of Water Resource and Meteorology and the Department of Agriculture in the Kampong Speu province. Rural communities are highly appreciated for their time answering our questions. Authors are grateful to Dr. Yoko Mochizuki for her comments on the paper.

REFERENCES

Adger, W.N. 2006. Vulnerability. Global Environmental Change, 16, 268-281.

Am, P. 2010. Impact of climate change on rice production of Cambodia, MAFF, Phnom Penh.

Ang, S., Oeur, I. and McAndrew, J. 2007. Understanding social captal in response to floods and droughts. http://www.ccc-cambodia.org.

CDRI. 2007. Annual Development Review 2006-07, Cambodia Development Resource Institute (CDRI), Phnom Penh.

CDRI. 2012. Cambodia's Priorities for Inclusive growth, Regional Integration and ASEAN Leadership, Phnom Penh,

Chan, S. and Sarthi, A. 2002. Facing the Challenges of Rural Livelihoods, CDRI, Phnom Penh.

Chaudhuri, S. 2003. Assessing vulnerability to poverty: concepts, empirical methods and illustrative example http://info.worldbank.org/etools/docs/library/97185/Keny_0304/Ke_0304/vulnerability-assessment.pdf.

Elbers, C. and Jan, W.G. 2003. Staying Poor: Chronic Poverty and Development Policy, University of Manchester, UK.

Eriksen, S.H. and O'Brien, K. 2007. Vulnerability, poverty and the need for sustainable adaptation measures. Climate Policy, 7, 337-352.

Geres-Cambodia. 2009. Public perceptions of climate change in Cambodia. Phnom Penh Franke, Sandra. 2005., Canada.

McCarthy, J., Canziani, O., Leary, N., Dokken, D. and White, K. 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability, Cambridge University Press, Cambridge.

MoE. 2001. Vulnerability and Adaptation Assessment to Climate Change in Cambodia, Ministry of Environment, Phnom Penh.

MoE. 2005. Vulnerability and adaptation to climate hazards and to climate change: A survey of rural Cambodia households, Ministry of Environment, Phnom Penh.

MoE. 2006. National Adaptation Programme of Action to Climate Change, Ministry of Environment, Phnom Penh.

MoE and UNDP Cambodia. 2011. Cambodia Human Development report 2011. Building Resilience: the Future of Rural Livelihoods in the Face of Climate Change.

NCDD. 2009. Kampong Speu Data Book 2009, NCDD, Phnom Penh.

NCDM. 2003. Mapping vulnerability to natural disasters in Cambodia. Phnom Penh, National committee for disaster management (NCDM), Phnom Penh.

NCDM. 2008. Strategic National Action Plan, National Committee for Disaster Management, Phnom Penh.

NIS. 2008. Statistical Year Book of Cambodia 2008, Ministry of Planning, Phnom Penh.

NIS. 2009. Cambodia Socio-economic Survey 2009, Ministry of Planning, Phnom Penh.

Smit, B., McNabb, D. and Smithers, J. 1996. Agricultural adaptation to climatic variation. Climatic Change, 33, 7-29.

Smit, B. and Wandel, J. 2006. Adaptation, adaptive capacity and vulnerability. Global Environmental Change, 16, 282-292.

Smith, B., Burton, I., Klein, R.J.T. and Wandel, J. 2000. An Anatomy of Adaptation to Climate Change and Variability. Climatic Change, 45, 223-251.

WFP. 2003. Mapping vulnerability to national disasters in Cambodia, Phnom Penh.

World Bank. 2006. Managing risk and vulnerability in Cambodia: An assessment and strategy for social protection, Washington DC.

Yu, B. and Fan, S. 2011. Rice production response in Cambodia. Agricultural Economics, 42, 437-450.

Yusuf, A.A. and Francisco, H.A. 2010. Mapping climate change vulnerability in Southeast Asia, Singapore.

Special Contribution on EFA and ESD *Research article*

Integration of Local Knowledge into Teaching-Learning Activities of Agricultural Subjects in Primary Education

CHAICHARN WONGSAMUN*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: chaichrn@kku.ac.th

NIWAT MARTWANNA
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

PRAPATSORN TAECHAPRASERTWITAYA
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

SUMONCHART CHAROENKORNBURI
Faculty of Education, Khon Kaen University, Khon Kaen, Thailand

Received 19 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract It is stated in the National Education Act of Thailand that there shall be the application of local knowledge in teaching-learning process of academic subjects in various educational levels. In order to assess a suitable procedure on how to integrate local knowledge into teaching-learning activities of agricultural subjects in primary education, this research was conducted by collecting data from teachers, students, administrators and community leaders in Khon Kaen Province, Thailand, through survey, case studies, training and seminars. It was summarized that there should be four stages in integrating local knowledge into the educational process of agricultural subjects. These included: 1) raising awareness on the importance of local knowledge and building cooperation among relevant persons, such as educational administrators, community leaders, local intellectuals, students and parents; 2) preparing a lesson plan with suitable contents, materials and resources; 3) conducting teaching-learning and evaluation activities; and 4) disseminating the outputs from teaching-learning activities to the public. Agriculture teachers had a prominent role in all four stages and their duties on studying, selecting, integrating and disseminating local knowledge were defined.

Keywords local knowledge, agricultural subject, primary education

INTRODUCTION

There are a number of definitions for local knowledge or indigenous knowledge. Department of Education (1997) defined local knowledge as the accumulated knowledge of local people and has been handed down to new generations. It is the core knowledge that people use for making a living, solving problems and adapting to sustain their community existence. Buasonth (1990) noted that local knowledge is the paradigm of the self to the world and the environment. This paradigm derived from the foundation of religious teaching and customary principles which had been inherited and practiced with continuous improvement to the changing social context of each period of time. Somkanae (1992) described that local knowledge is the mass of knowledge and experiences of the people who had been using them to make a happy living. The accumulation of knowledge was inherited through the development process and consistent with the passage of time.

The importance of local knowledge has been recognized by international development agencies. The World Bank (2005) stated that indigenous knowledge (IK) or local knowledge can be a

powerful tool in a learning environment to teach students. However, educational curricula in many countries do not support students' learning based on local knowledge existing in their community. It is needed to adapt learning environments to help students learn and appreciate various aspects of their local knowledge. Educators should identify appropriate pedagogical techniques to combine local knowledge into academic programs. When IK is integrated into the learning environments, students can better connect to the material taught, and it can become a major knowledge source for sustainable development of local communities. International Institute of Rural Reconstruction (1996) described that local knowledge is embedded in a dynamic system in which livelihood activities, spirituality, kinship, traditions and other aspects in a particular community are tied together and influence one another. Local technologies and know-how have an advantage over introduced ones in that they rely on locally available skills and materials and are thus often more cost-effective than the technologies from outside.

Wasie (1987) stated that the community should be the center of learning process to students. Local schools and communities should have cooperation in providing education for young people. Local intellectual persons should be invited to take part in curricular development and teaching different courses in the school. Students should be assigned to study local knowledge in the community and the teachers should do the survey of existing local bodies of knowledge and apply them into the teaching-learning activities of relevant subjects.

According to the Primary Education Curriculum, issued in 2001, local schools are required to teach agricultural subjects to students in every class level. In the National Education Act, issued in 1999, there is a list of articles that set up guidelines stating that there shall be the application of local knowledge in teaching-learning process of academic subjects in various educational levels, including agricultural subjects in primary education.

However, it was reported that a high number of teachers who were responsible for this subject area did not finish their education in agriculture and lacked of appropriate approaches and methods for integrating local knowledge and technology into the teaching-learning process (Wongsamun et al., 1987, Imwiriyawat et al., 1989, and Thalangsri, 1994). Therefore, the research was conducted in Khon Kaen province during 2004-2006 to assess a suitable procedure on how to integrate local knowledge into teaching-learning activities of agricultural subjects in primary schools.

METHODOLOGY

The activities of this research were divided into four sub-projects, including 1) Study of the process, problems and needs in conducting teaching-learning activities in agricultural subjects at the primary education level (grade 4-6) of teachers in Khon Kaen province; 2) Study on the opinions of related parties towards the integration of local knowledge into teaching-learning process of agricultural subjects in primary education; 3) Development of a model and methods for integrating local knowledge in the teaching-learning process of agricultural subjects in primary education; and 4) Summary of lessons learned and dissemination of a suitable model and methods for integrating local knowledge in the teaching-learning process of agricultural subjects applied in primary education. In the first sub-project, research data were collected from 216 teachers, who were selected with multi-stage random sampling, by mailed questionnaires. The collected data were statistically analyzed for frequency, percentage, arithmetic mean, standard deviation, maximum, minimum, t-test and F-test.

In the second sub-project, 10 primary schools were selected and a case study for each school was conducted to assess the opinions of the school administrators, teachers and students towards the integration of local knowledge into the teaching-learning process of agricultural subjects. A one-day workshop was also conducted for 65 participants, including teachers, school administrators, educational supervisors and local agricultural extension workers, to share, exchange and discuss their ideas and experiences on applying local knowledge into primary education.

In the third sub-project, 25 teachers from five districts of Khon Kaen province were selected to participate in a two-day training program on the preparation of a lesson plan of agricultural subjects with the integration of local knowledge into educational process. After the participating teachers

had used those lesson plans at their schools in the following term, they were invited to participate in the second training program for sharing their experiences and improving their lesson plans. At the same time, a model on how to integrate local knowledge into educational process was discussed and drafted taking into account the findings, comments and suggestions from previous activities of the project.

In the fourth sub-project, three local workshops were conducted in three districts for teachers, school administrators, parents, community leaders and students to summarize lessons learned and express their opinions and give suggestions towards the drafted model on integrating local knowledge into the educational process of agricultural subjects. About 40 participants were involved in each of the workshop.

RESULTS AND DISCUSSION

Results and discussion can be divided into four main parts in accordance with the sub-projects of the research. The details of each part are the following.

Teaching-learning process and problems, and training needs of teachers

Backgrounds of agriculture teachers: Results revealed that the average age of the teachers was 45 years old, 69.4 % of them were male, only 23.6% finished academic major in agriculture and 96.3% taught other subjects beside agriculture.

Agricultural teaching-learning activities at the school: The first three most popular agricultural activities at schools were vegetable growing (79.6%), fish culture (61.1%) and ornamental plant growing (59.7%). Most of the teachers, 89.4%, integrated agricultural subject into other subjects of school curriculum with an average of 2.5 periods of instruction per week. Subject matters in agriculture that were commonly taught by the teachers included vegetable growing (87.5%), agricultural tools and usage (86.1%), work safety (83.3%), ornamental plant growing (66.2%), conservation of energy and environment (64.4 %) and integrated farming (61.6%). Learning processes used at the "high" level were learning by actual practice and learning from experiences. Teaching techniques highly used by the teachers were integrated approach, group work and demonstration. For evaluation, the methods used were individual and group performances, work outputs and reports, and assessment of practical work. Important problems faced by the teachers included lack of instructional media (61.6%) and lack of parents' cooperation (46.3%).

Training needs of agriculture teachers: Training topics in agriculture highly needed by the teachers were crop production, conservation of energy and environment, plant protection, fish culture and animal raising. For teaching preparation, the training topics highly needed by the teachers included preparation of course syllabus, preparation of lesson plans, preparation of budget, place, materials and equipment for instruction, learners' preparation and getting cooperation from local intellectuals and related organizations. For instructional media, the training topics highly needed by the teachers were preparation of instructional manual, photography for instructional media preparation, preparation of specimen, model and video media, classroom research and preparation of agricultural tools. For conducting students' activities, the teachers highly needed training in the following topics: learning from actual practice, learning from documentary inquiry, learning from experienced persons and learning from students' group work. For evaluation aspects, the following training topics were highly needed by teachers: evaluation from individual and group performances, evaluation from work outputs and reports, assessing and evaluating practical work, assessing and evaluating students' skills, and evaluating students' portfolio. For supporting aspects, the teachers expressed highly needs for training on the following topics: getting support from school principal, requesting for technical publications and materials from related organizations and getting cooperation from students' parents and community leaders.

Comparisons of training needs of teachers: Comparisons of training needs of teachers found that those with different sexes, age groups, numbers of years in teaching agricultural subjects, majors of

graduation, areas for agricultural activities at school and locations of school in rain-fed or irrigated areas had statistically different levels of needs on certain training topics.

Strengths and weaknesses of instruction in agricultural subjects

It was found in the case studies which were carried out at 10 schools in five districts of Khon Kaen province that most primary schools allocated two periods per week of instructional time for agricultural subjects for students in grades 4-5 was (1 period = 50 minutes) and three periods for students in grade 6. The teaching-learning activities included classroom instruction and field practices. From the opinions of respondents, the strengths of the instruction in agricultural subjects in primary schools included: (1) good coordination with relevant agencies, (2) having areas in the school for agricultural practices of students, (3) good cooperation from local intellectuals to help in teaching agriculture in school, and (4) provision of out-of-school activities to learn agriculture in real-life situations. On the other hand, they expressed that the weaknesses of the instruction in agricultural subjects included (1) lack of instructional media and agricultural tools for field practices, (2) lack of water resources for agricultural activities during the dry season, (3) teachers lack of experiences in agricultural work and did not finish their education in agriculture, (4) parents lack of understanding on the importance of teaching agriculture in school, (5) limited school areas for agricultural practices, and (6) teachers have limited knowledge on local situation, culture and wisdom. To be able to integrate local knowledge into educational process of agricultural subjects, it was suggested that there should be a cooperative effort among school administrators, teachers, students, local community leaders and related organizations. The suggested procedures for the integration included (1) setting clear policies and guidelines by the high-level education offices, (2) studying and collecting local knowledge in the community, (3) preparing lesson plans with contents and activities related to relevant local knowledge, (4) conducting teaching-learning activities, (5) supervising teaching activities, and (6) evaluating students' achievement and teaching performance.

Training, lesson plan preparation and development of teaching model

During the two-day training, all 25 participating teachers exchanged their teaching experiences and received additional information on local knowledge, how to study this type of knowledge and how to include it in teaching-learning process. Each teacher was asked to prepare a lesson plan to be taught at his or her school in the following academic term. The plan contained the standard components of lesson plan, consisting of teaching topic, important concept, learning objectives, subject matter, teaching-learning process, media and learning resources, evaluation of learning achievement, suggestions for additional learning activities, and assignment worksheets. At the same time, the teachers had to identify and include local knowledge to be included into their lessons plans. As a result, by the end of the training, all teachers had their own lesson plans for teaching at their schools. Then, they came back for the second training to share their experiences and improve their lesson plans for future use. At the same time, they were involved in a discussion on suitable models and methods for integrating local knowledge in the teaching-learning process of agricultural subjects in primary education which consisted of various procedures and activities of related persons as described in the conclusion below.

Summary of lessons learned by related parties

As a result, three local workshops were conducted after all main stake holders, including teachers, school administrators, parents, community leaders and students had gone through relevant activities on integrating local knowledge into educational process in agricultural subjects at their local schools. It was agreed that the integration could be done, and was useful for students. Each party should have certain responsibilities to do in order to have a successful model of instruction. Under a good cooperation of related persons and organizations, existing problems or limitations could be

solved and students' learning accomplishment and appreciation on local knowledge could be strengthened.

CONCLUSION

From the research findings, it was concluded that a suitable model for integrating local knowledge into the educational process of agricultural subjects consisted of four stages, and the teachers had prominent tasks in implementing this model. The details and teachers' tasks of those stages are the following:

Stage 1: Raising awareness on the importance of local knowledge and building cooperation among relevant persons including educational administrators, community leaders, local intellectuals, students and parents. Teachers' tasks include organizing meetings for related persons, disseminating information on successful cases in using local knowledge, publicizing students' work outputs, and organizing field trips for related individuals.

Stage 2: Preparing lesson plan with suitable contents, materials and resources. The teachers' tasks include studying structure of curriculum, education policies of administrators and local environment, studying and collecting local agricultural knowledge, preparing integrated lesson plans, and preparing teaching media, learning resources and assignment worksheets

Stage 3: Conducting teaching-learning and evaluation activities. The teachers' tasks include studying and reviewing the lesson plans, preparing instructional media, classroom and places for field practices, delivering the contents of subject matters and conducting learning activities with students' centered approach, coordinating with local intellectuals as needed, following up the progress of students' work, preparing evaluation tools and measures, and implementing them as planned, and recording successes and problems of teaching-learning activities with suggestions for future improvement.

Stage 4: Disseminating outputs from teaching-learning activities to the public. The teachers' tasks include identifying means and opportunities to present to students' outputs in the school and community, providing suggestions in media preparation and delivery for students, evaluating students' accomplishments, collecting and reviewing data on the successes and problems of the course, and writing reminding statements for the future improvement of contents and teaching delivery.

REFERENCES

Buasonth, R. 1990. The role of primary schools and the transfer of local knowledge. Journal National Education, 24(4), 68-74.

Department of Education. 1997. Summary of research findings entitled local knowledge and curriculum development. Ministry of Education. Bangkok: Kurusapa Ladprao.

Imwiriyawat, S., Taechaprasertwitaya, P. and Wongsamun, C. 1989. Training needs of agriculture teachers in primary schools in Northeastern Region, Thailand. Research Report. Faculty of Agriculture, Khon Kaen University, Thailand.

International Institute of Rural Reconstruction. 1996. Recording and using indigenous knowledge: A manual. IIRR: Silang, Cavite, The Philippines.

Somkanae, A. 1992. Conditions and problems on integrating local wisdom in curricular development for primary schools in Ubon Ratchathani.province, Master's degree thesis in Education. Graduate School. Chulalongkorn University, Thailand.

Thalangsri, S. 1994. Management of agricultural education in grades 5-6 of teachers in primary schools under the Office of Education, Kalasin province. Master Degree of Education in Primary Education. Graduate School. Khon Kaen University, Thailand.

Wasie, P. 1987. Thai local wisdom for development. Community Development. 1, 5.

Wongsamun, C., Bunthamcharoen, C., Imwiriyawat, S. and Taechaprasertwitaya, P. 1987. Training needs of agriculture teachers in primary schools in Khon Kaen province. Research Report. Faculty of Agriculture, Khon Kaen University, Thailand.

World Bank. 2005. Education: Building on indigenous knowledge. IK Notes No. 87, December 2005. http://www.worldbank.org/afr/ik/iknt87.htm.

Research article

Evaluation of On-Farm Pond Water Budget in Khon Kaen Province, Thailand

KEWAREE PHOLKERN*
Groundwater Research Center, Faculty of Technology, Khon Kaen University, Kohn Kaen, Thailand
Email: rekawee@hotmail.com

VICHAI SRIBOONLUE
Groundwater Research Center, Faculty of Technology, Khon Kaen University, Kohn Kaen, Thailand

Received 19 December 2011 Accepted 7 February 2012 (*: Corresponding Author)

Abstract An on-farm pond is an essential technique for water resources management in northeast Thailand. It can be used for many purposes e.g. farm water supply, supplementary irrigation, livestock, aquaculture, and flood mitigation. The purpose of this research is to evaluate the suitability of two calculation methods for on-farm pond water budget. Two on-farm ponds in Ban Wangwa were selected to be the study sites and the water balance of the ponds including water inflow and water outflow components were calculated. Water inflow was determined by two methods, namely watershed routing and synthetic unit hydrograph. The results show that the synthetic unit hydrograph method gives the better agreement to the observed data than the watershed routing method in both of peak discharge and runoff volume. The main causes of water losses are evaporation, water usage, and seepage. Evaporation from the ponds was determined by two methods, namely the Penman method using Priestley-Taylor evaporation equation and the Evaporation pan method. Subsequently coefficient of the Priestley-Taylor evaporation (α) and coefficient of the evaporation pans (K_p) are 1.66 and 0.88, respectively. The evaporation by pan evaporation is fast, simple and easier than Priestley-Taylor evaporation.

Keywords on-farm pond, water budget, inflow, evaporation

INTRODUCTION

An on-farm pond is an appropriate technology for water harvesting in northeast Thailand. The undulating landscapes, which dominate the northeast topography, enhance the efficiency and usability of on-farm ponds, by providing catchment areas and reasonable head for water conveyance. It can be used for many purposes e.g. farm water supply, supplementary irrigation, live stock water consumption, aquaculture, and even flood mitigation (Suresh, 2002; Ngigi et al., 2005; Yoo and Boyd, 1994; and Kumar, 1992).

The climate of the northeast is monsoon, where wet season is from May to October and dry season is the rest of the year. Therefore more than 80% of annual rainfall is in the wet season, on-farm pond harvests water during 6 months of the wet season and supplies water for the next dry 6 months. The study of the nature of the on-farm pond inflow and outflow is important for the on-farm pond design, construction, and management. To utilize an on-farm pond to its highest potential and in an environmentally sound way, its study of water balance must be performed. This study presents a suitable method for calculating the pond water inflow and water loss of the on-farm ponds.

STUDY AREA

The study areas located at two on-farm ponds in Ban Wangwa, 25 km south of Khon Kaen, were chosen as study sites. The two ponds are closed together, and one is considered to be the north pond while the other is considered the south pond. The north pond has the dimensions of 20×30×4 m. Its elevation of the bottom is 194.44 m above the mean sea level. The south pond has the size of 17×33×4 m and the elevation of the bottom is 194.95 m amsl. Fig. 1 shows the satellite image of the ponds and their environment which consists of upland crops, fallows, and eucalyptus woodlands.

The surrounding topography of the two ponds was surveyed using a level and a hand-held GPS. The topographic contours and the watershed areas of the two ponds are shown in Fig. 2. The catchment of the north pond is like a butterfly in shape which should produce a sharp peak with a short time base. The catchment of the south pond is an elongated shape that should produce a mild peak with a long time base. The outlet from the watershed or the inlet into the pond for each of the cases is quite special. For the north pond, the inlet is at the northeast corner of the pond and close to the road, therefore we installed a rectangular weir for inflow measurement. For the south pond, the outflow from the watershed passes through a ditch which leads across a road to the pond, a complicated inflow arrangement. The length and slope of the main channel for the north pond are 167 m and 0.0096 respectively, and for the south pond are 480 m and 0.0165 respectively. The areas of the watershed of the north and the south pond are 10643 m^2 and 12618 m^2 respectively. Piezometers were installed to observe groundwater levels, two for the north pond at P_2 and P_4 in Fig. 2 and one for the south pond at P_5. Automatic water level recorders were installed on north and south ponds at P_3 and P_6 respectively. An automatic weather station was set up near the north pond. It recorded rainfall, air and dew point temperatures, relative humidity, wind speed and direction, and net radiation.

METHODOLOGY

Water balance equation or continuity equation can be used to describe the flow of water in and out of pond. Using all components that might possibly be significant, solve the continuity equation for groundwater seepage (Chow, et al., 1988) as equation (1).

$$P + R_i + G_i - E - R_o - G_o - U = \frac{\Delta S}{\Delta t} \quad (1)$$

where P is precipitation, R_i and R_o are Runoff in and out respectively, G_i and G_o are Groundwater seepage additional to the pond and removal respectively, U is water use and $\Delta S/\Delta t$ is change in storage.

Water balance in the on-farm pond was divided into two main sections. First section is the evaluation of accuracy of the water harvesting or water inflow of the on-farm ponds. The second section was conducted to calculate the factors affecting water loss or outflow of the on-farm ponds.

(1) On-farm ponds water harvesting

The water which flows into the pond consists of rainfall in to the pond, runoff and groundwater inflow. The main component of water inflow is runoff. Two simple lump models were used in this study, namely the watershed routing technique and the synthetic unit hydrograph method.

The watershed routing technique

Based on the assumption that the outflow from the watershed varies nonlinearly with the storage in the watershed, van den Akker and Boomgaard (1996) suggested the following model.

$$q_2 = \frac{k - 0.5\Delta t}{k + 0.5\Delta t} q_1 + \frac{\Delta t}{k + 0.5\Delta t} i \quad (2)$$

where q_1 and q_2 are discharges as depth per unit time at time steps 1 and 2 respectively, i is intensity of excess rainfall, k is parameter and Δt is time interval.

The watershed routing model can be used to predict the flow rate from the present flow rate and intensity of rainfall data. The unit flow rate, q, can convert to total flow rate, Q, by multiplying with the watershed area.

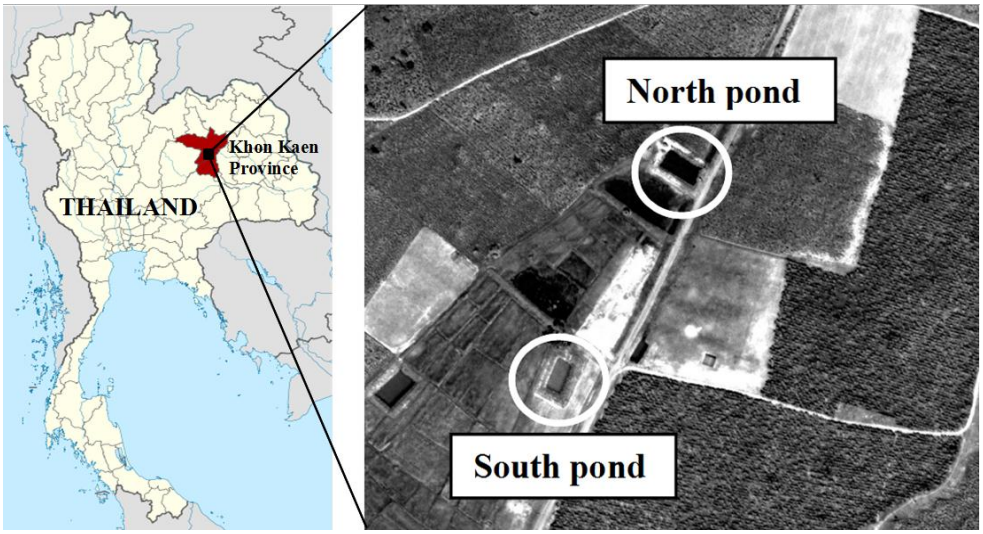


Fig. 1 Location of the two experimental ponds satellite image

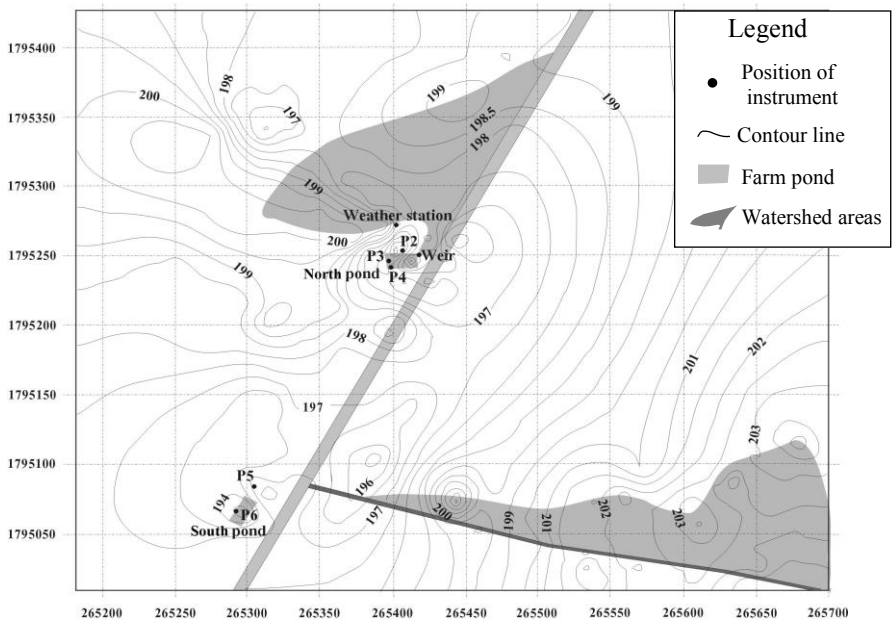


Fig. 2 Location watershed areas and its environment

The synthetic unit hydrograph

The unit hydrograph is a direct runoff hydrograph resulting from a unit rainfall (1 cm depth) of the specific rainfall duration (Shaw, 1994). The unit hydrograph is normally derived from records of rainfall and runoff data. When dealing with small watersheds, coupled rainfall and runoff data are hardly available, we therefore resort to the synthetic unit hydrograph. The unit hydrograph that is synthesized from topographic and climatic features is called a synthetic unit hydrograph (Shaw, 1994).

The shape of a unit hydrograph may be assumed as the gamma function distribution (Aron and White, 1982). Akan and Houghtalen (2003) suggest an equation for coordinate of unit hydrograph as equation (3).

$$u = \frac{C_p A}{t_p}[(t/t_p)\exp(1-(t/t_p))]^{n-1} \quad (3)$$

where C_p = proportional constant, t_p = time to peak discharge, A = watershed area, t = time, u = unit discharge at time t and n is a constant which related to C_p as equation (4).

$$n = 1.0685 + 0.1175C_p + 0.782C_p^{\,2} \quad (4)$$

We selected 3 prominent storm events, two storms in the year 2006 on 30 Aug, and 17 Sept, and one storms in the year 2007 on 12 Sept for this study. The runoff data were interpreted from the incremental volume of the pond storage with the time interval of recording. Table 1 shows the data of rainfall and runoff for the north and the south pond.

Table 1 The data of rainfall and runoff into the north and the south pond

Time (min)	30 Aug 2006			17 Sep 2006			12 Sep 2007		
	Rainfall (mm)	Runoff (m^3/s) north pond	Runoff (m^3/s) south pond	Rainfall (mm)	Runoff (m^3/s) north pond	Runoff (m^3/s) south pond	Rainfall (mm)	Runoff (m^3/s) north pond	Runoff (m^3/s) south pond
0	0	0	0	0	0	0	0	0	0
10	0.20	0.005	0	0	0	0.031	0	0	0
20	3.80	0.004	0.006	2.60	0.012	0.008	8.2	0.004	0.007
30	10.60	0.056	0.023	4.00	0.044	0.017	2.2	0	0.002
40	4.60	0.060	0.044	7.20	0.034	0.011	3	0.016	0.005
50	3.00	0.049	0.061	4.80	0.029	0.019	7.2	0.047	0.028
60	0.60	0.024	0.077	4.40	0.023	0.011	7	0.016	0.033
70	0.80	0.002	0.022	1.60	0.026	0.036	1	0.026	0.018
80	0.60	0.008	0.022	2.00	0.025	0.014	0	0.022	0.024
90	0.60	0	0.013	0.60	0.006	0.014	0	0.019	0.029
100	0.60	0.004	0.008	0.20	0.005	0	0	0.013	0.015
110	1.20	0.009	0.022	0	0.001	0.008	0	0.010	0.009
120	1.60	0.013	0.004	0.20	0.001	0.006	0	0.008	0.004
130	0.60	0.002	0	0	0	0	0.2	0.007	0.003
140	0	0.008	0.008	0	0	0	0	0.007	0

(2) Water loss or outflow

The outflow of water or water loss from a pond, consists of evaporation, water use and groundwater seepage. The query found that both on-farm ponds are not water used for any activity. Groundwater seepage can be determined from the water balance equation or continuity equation. This study presents a method to determine water loss from evaporation, that water loss is the factor of most important (Vichai, 2008).

In the design and management of the reservoir, evaporative water loss is the factor of most important (Vichai, 2008). The most popular method for determining the amount of evaporation, Penman equation (1948) was employed. Penman equation combines the energy balance with the mass transfer method and derives an equation to compute the evaporation from open water. Penman equation is quite difficult to be calculated and requires a lot of information. Then pond evaporation data was estimated by Penman equation by using variables of other evaporation equation that was more simple, as follows.

Priestley and Taylor evaporation equation

In 1972, Priestley and Taylor have revised the penman equation to be calculated easier as the Priestley and Taylor evaporation equation (5).

$$E_{pond} = \alpha \frac{\Delta}{\Delta + \gamma} E_r \quad (5)$$

where E_{pond} = pond evaporation, Δ = gradient of the saturated vapor pressure curve at air temperature, E_r = evaporation rate, γ = psychrometric constant.

α is unknown parameter value. There will be slight variations in location of the study area. Determining evaporation by Priestley and Taylor evaporation equation is much easier than Penman equation.

Evaporation pan

The general methodology for evaporation calculation is the evaporation pan (E_p). There are various types of evaporation pan. Adjustment factors or pan coefficients (K_p) have been determined to convert the data recorded in evaporation pans so that they correspond to evaporation from large open water surface. Equation of the evaporation pan (Chow, et al., 1988) is as equation (6).

$$E_{pond} = K_p E_{pan} \quad (6)$$

The evaporation from the pond was computed by using data from an automatic weather station, which was set up on the study area in dry season of year 2006 and 2007 (November 2006 to April 2007). Evaporation pan (E_{pan}) data of study area from Thai Meteorological Department was used.

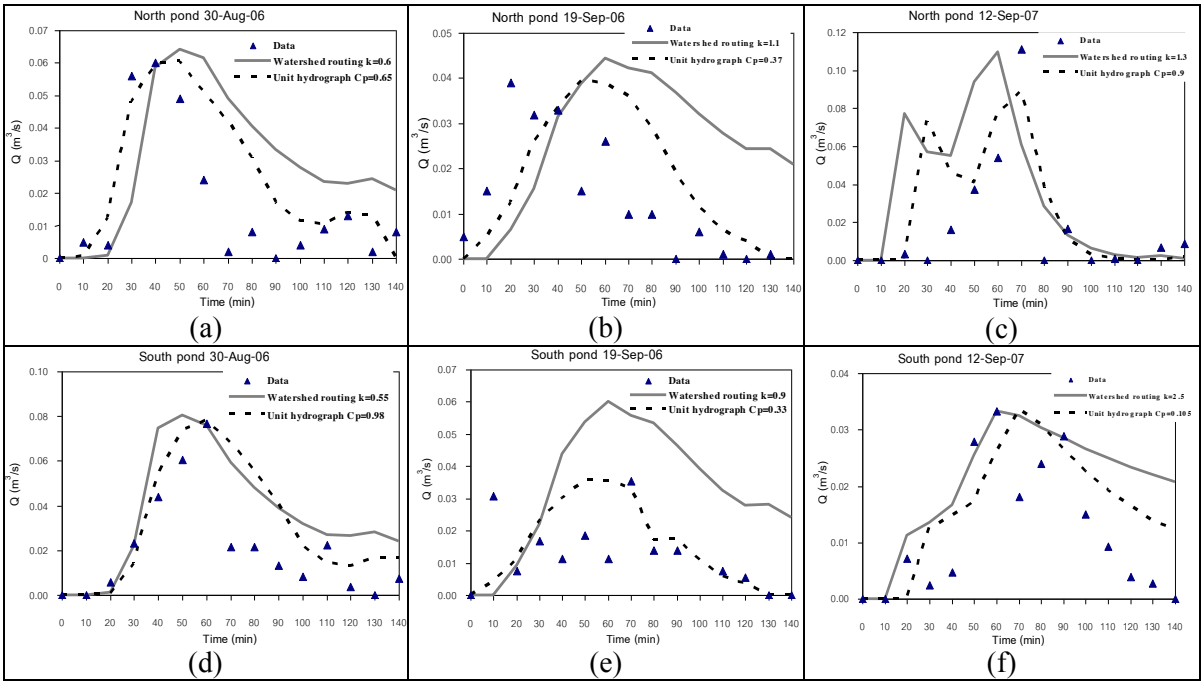


Fig. 3 Comparison of the predicted runoffs to the observed data, (a), (b), and (c) for the north pond and (d), (e), and (f) for the south pond

RESULT AND DISCUSSION

Three sets of rainfall-runoff data on 30 Aug and 19 Sept, 2006 and 12 Sept, 2007 were used. The observed hydrographs were plotted and compared with the two predicted methods in Fig. 2. It is clear from Fig. 3 that the synthetic unit hydrograph method has better agreement with the observed hydrograph than the watershed routing technique. For peak discharge, the synthetic unit hydro-

graph method gives lower values that are closer to the observed data than the routing technique, although not by much. However, for the volume of flow, the watershed routing technique predicted much larger volumes than the observed data or the unit hydrograph method.

The k values vary in the ranges 0.6-1.3 and 0.55-2.5 for the north and the south pond respectively. The coefficient C_p values of the synthetic unit hydrograph are in the ranges 0.37-0.90 and 0.10-0.98 for the north and the south pond respectively. The variations in both k and C_p demonstrate the nonlinearity of the flow system. The average values of k of both ponds are rather varied, but C_p of both ponds are fairly close. It is suggested that the runoff calculation from rainfall for an on-farm pond water harvesting in northeast Thailand should be done by using the synthetic unit hydrograph. The suitable C_p value can be obtained by fitting the model to several observed data then averaging the values.

Evaporation of on-farm ponds, in November-February are in the ranges 4.48-4.77 mm/day, those in March and April are 5.26 mm/day and 6.03 mm/day respectively as shown in Table 1. The research results help to find the coefficients for the simpler method namely Priestley-Taylor evaporation equation and the Evaporation pans method. The average coefficient α values of Priestley-Taylor evaporation equation in Ban Wangwa are in the ranges 1.37-1.86 (average 1.67). The pan coefficient K_p values of evaporation pans are in the ranges 0.80-0.91 (average 0.87) for Ban Wangwa.

Table 2 Evaporation of water in the on-farm pond and the most suitable values of α and K_p

Month	The data of evaporation (mm/d)	α (Priestley and Taylor evaporation equation)	K_p (Evaporation pan)
November 2006	4.40	1.37	0.89
December 2007	4.34	1.82	0.90
January 2007	4.47	1.86	0.91
February 2007	4.80	1.80	0.85
March 2007	5.31	1.50	0.80
April 2007	6.04	1.40	0.85
Average	**4.89**	**1.67**	**0.87**

CONCLUSION AND RECOMMENDATION

The synthetic unit hydrograph method gives better predictions than the watershed routing technique for both the peak discharge and the runoff volume. The k-values of the routing technique vary in the range 0.55-2.5 (avg 1.16). The C_p-values of the unit hydrograph method vary in the range 0.10-0.98 (avg 0.56). The variations in k and C_p demonstrate the nonlinearity of the flow systems.

Evaporation of on-farm ponds, in November-February are in the range 4.48-4.77 mm/day, those in March and April are 5.26 mm/day and 6.03 mm/day respectively. The results help to find the coefficients for the simpler method namely Priestley-Taylor evaporation equation and the Evaporation pans method. The average coefficient α value of Priestley-Taylor evaporation equation is 1.66. The pan coefficient K_p value of Evaporation pans is 0.88. However, the evaporation by pan evaporation is fast, simple and easier. Because the data used are less and easier to find.

ACKNOWLEDGEMENTS

This research is funded by Japan International Research Center for Agricultural Sciences (JIRCAS) and Groundwater Research Center (GWRC), Khon Kaen University, Thailand. The authors thank Mr. Suwanchai Nadee and Mr. Phayom Saraphirom for their useful suggestions.

REFERENCES

Aron, G. and White, E. 1982. Fitting a gamma distribution over a synthetic unit hydrograph. Water Resources Bulletin, 18(1).

Chow, V.T., Maidment, D.R. and Mays, L.W. 1988. Applied Hydrology. McGraw-Hill.

Penman, H.L. 1948. Natural evaporation from open water, bare soil, and grass, Proc.R.Soc.London A, Vol. 193, 120-146.

Shaw, E.M. 1994. Hydrology in practice. 3rd ed., Chapman and Hall.

Sriboonlue, V. 2008. Hydrology. Faculty of Engineering, Khon Kaen University, Thailand.

Suresh, R. 2002. Soil and Water Conservation Engineering. 2nd ed., Standard Publishers.

Van den Akker, C. and Boomgaard, M.E. 1996. Hydrologie. Technische Universiteit Delft, Netherland.

Research article

Science and Conservation of Aquatic Animals in Thailand

PATCHARA NITHIROJPAKDEE*
Faculty of Science, Burapha University, Chonburi, Thailand
Email: patjj_22@yahoo.com

RUNGTHIP PLONGSESTHEE
Faculty of Science, Burapha University, Chonburi, Thailand

FREDERICK WILLIAM HENRY BEAMISH
Faculty of Science, Burapha University, Chonburi, Thailand

PUNNATUT KANGRANG
Faculty of Science, Burapha University, Chonburi, Thailand

Received 19 December 2011 Accepted 7 February 2012 (*: Corresponding Author)

Abstract Conservation policy, plans and implementation require the integration and management of a multitude of disciplines including the natural, physical and social sciences, law, economics and government policy. This study describes several major steps to implement a conservation plan for degraded rivers in Thailand and provides new approaches to assist in repairing degraded freshwater fish communities. Conservation of aquatic animals requires an understanding of their environmental requirements, preferences and species associations to accompany existing tactics to improve physical and chemical conditions of rivers. At present this ecological information is dreadfully inadequate in Thailand. Some freshwater environments in Thailand are currently experiencing an alarming decline in biodiversity. As a result, scientists and managers should undertake immediate management techniques to protect what remains of these aquatic systems. First step in conservation is to recognize a need and this is not likely to be easy. Effective conservation projects are likely to be lead by a committee representing a wide range of expertise including ecology, policy, law, economics and sociology along with appropriate government representatives. Second step is to determine objectives and an implementation strategy. Each river is dynamic and unique. Conservation may be approached and applied in different ways depending on human and financial resources, timeframe, information and severity of resource depletion, including recovery, rehabilitation, restoration and replacement. A third step might include restructuring the biotic community in a degraded river once the physical damage or source of contamination has been contained and the chemical and physical conditions repaired. Conservation planning is an activity in which social, economic and political imperatives may modify, sometimes drastically, scientific prescriptions. This interaction need not be all one way.

Keywords bioenvironmental associations, ecosystem dynamics, conservation, species richness, aquatic animals, Southeast Asia

INTRODUCTION

Ecosystems are complex and temporally dynamic and need to be understood to implement conservation plans and actions. Conservation plans for degraded aquatic systems should at the outset clearly define temporal objectives recognizing available finances as well as physical, chemical and biological resources information. Success is likely to be enhanced by incorporating human values and needs within the ecosystem model. The specific applicability of these broad principles is context-specific because all ecological systems are unique as a function of their location, physical and chemical environment and current level and type of human use.

The outcomes of conservation efforts commonly depend on how and by whom problems are framed. Conservation biology focused mostly on regional issues in the early years; however, recognition of the impact of human activities on global climate and potential consequences has contributed a new level of urgency and understanding. While conservation biology is part of a multifaceted and interdisciplinary social-ecological system, social factors are likely to be the more forceful and manipulable. This means solutions to conservation problems require integrated and holistic management taking into consideration relevant aspects of sociology, local and regional politics, law and economics.

Mainland Southeast Asia has undergone rapid social and economic changes in recent decades and with these has been a precipitous rise in the degradation of natural resources. In Thailand, forest cover, coastal mangroves, coral reefs and many aquatic and terrestrial animals have declined in distribution and numbers, in some cases dramatically (Aksornkoae, 1996; Nabhitabhata and Chan ard, 2005; Sanguansombat, 2005; Ahmed et al., 2007). Certainly, Thailand has cause for the conservation concern that is recognized within several governmental departments, including the Royal Forest Department, Fisheries Department, Ministry of Natural Resources and Environment as well as a number of small nongovernmental groups scattered throughout the country. A multitude of threats to species and habitats as a consequence of human activities can lead to widespread environmental losses (New, 1998). Conservation is one response to environmental losses associated with anthropogenic activities. Science is required to help in the planning and implementation of conservation actions. Perhaps of no less importance is knowledge and cooperation from local people in concert with guidance and assistance from the appropriate governmental and non governmental leaders. This study describes several major steps to implement a conservation plan for degraded rivers and provides a new approach to assist in repairing degraded freshwater fish communities.

METHODOLOGY

First step in conservation is to recognize a need and this is not likely to be easy. Effective conservation projects are likely to be lead by a committee representing a wide range of expertise including ecology, policy, law, economics and sociology along with appropriate government representatives. Almost certainly there will be contrasting views of objectives and solutions within any such committee.

There is no international or even national standard that can be applied to determine a conservation need. Perception of the level of degradation varies among those making the assessment, their background and agenda. Recognition of a biological need for conservation of aquatic ecosystems or habitats can be difficult. Historically, water quality monitoring has relied on chemical testing which provides no information on water quality resulting from non-chemical activities. Physical alterations such as habitat destruction, flow and discharge are undetected by chemical monitoring. Water quality might better be evaluated from the occurrence and abundance of aquatic organisms that inhabit rivers. These organisms provide a direct association with water quality as they continuously integrate the direct and interactive effects of all environmental variables and stresses, making them holistic indicators of water quality. A comprehensive bioassessment model is important for all geographic regions and one should be developed specifically for Thailand waters in recognition of Thai species distributions and habitat characteristics.

Second step is to determine objectives and an implementation strategy. Each river is dynamic and unique. There are many causes of degradation: physical, chemical and biological, so conservation needs and solutions can be expected to be complex and uneven in cost. For example, conservation of a situation in one river may require relatively simple physical changes to improve bank stability, reduce erosion and turbidity, possibly leading to increased habitat diversity and enhanced plant and animal diversity and abundances. In another river, chemical contamination may have replaced many indigenous plant and animal species with invasive organisms. The source of chemical contaminants may be outside the jurisdiction of those wishing to implement the conservation project further complicating the process.

Objectives should consider time, cost and completeness of conservation area. Important to conservation projects is a clear understanding of the ultimate target. If for example, a community decided their once beautiful river had become polluted and needed to be changed, one important question would have to be "changed to what and how quickly"? Aquatic conservationists recognize there can be degrees of change to an ecosystem or its components. Perhaps the simplest change is called 'recovery' which simply means to stop the source of whatever is negatively affecting the condition of their river and let it regain its former condition through natural processes. This has the advantage of low cost but is slow and species that may no longer inhabit the river may not be available or unable to repopulate the river. Another target might be 'rehabilitation'. This is understood to include changing parts rather than the entire degraded river. Advantages include relatively low cost and being able to evaluate partial rather than a complete conservation effort. A third category is 'restoration' which is to return an ecology or river to the way it was before being changed by human activity. A special category is called 'replacement' which is to improve a degraded river by adding components that were not present in the original river. This might include different species or improved habitat such as enlarged riffles, pools or spawning areas. Closely related to this is understanding the chemical, physical and biological conditions prior to its degraded conditions and in the absence of this information how it can be hindcasted. We must remember that in rivers, in the absence of anthropogenic influences, a harmonious association between the chemical and physical characteristics and the resident biota has evolved over long periods of time. It is unreasonable to expect biotic associations with abiotic factors to suddenly change in accord with human resources and timeframes. Indeed, experience has found aquatic biota to be constrained within specific physical and chemical ranges, although the number of species for which this information is known is alarmingly small. Thus, if we wish to conserve, restore or rehabilitate river biota it is incumbent on the conservationists to understand the environmental needs of the targeted biota. Without doing so is almost certain to lead to failure. Obviously then conservationists must know what species are present at the outset of a conservation plan and the reason for managing fish species.

A third step might include restructuring the biotic community in a degraded river once the physical damage or source of contamination has been contained and the chemical and physical conditions repaired. This is likely to require information on all of the species that used to live there. Guidelines to estimate total number of species within taxonomic groups are now available. If a river has only recently become degraded then it is likely some local residents can be helpful in recalling at least some of the former taxa and their relative abundances. This is most likely for taxa considered to be useful to local residents such as fish and plants of medicinal or food value. In rivers degraded for decades custodial memories may have been lost or at least faded, however, under these conditions science can help. Recently, the relationship between fish species number and river length has been examined for several regions in Thailand. Number of fish species in relation to river size was determined by electrofishing sites selected by a randomized stratified procedure based on river order. Number of potential sites within each order was based on cumulative length relative to total. With adequate sampling equipment and experience most rivers can be sampled by two people within a few days. Total number of species was estimated by the non parametric Jackknife method (Krebs, 1989; Smith and Jones, 2005).

Companion information needs that are useful to conservation programs include environmental conditions necessary to sustain target species. In this regard it would seem enormously beneficial to the conservation of rivers in Thailand to have a national compendium of baseline information for all taxa of plants and animals and effective and efficient technologies available for the implementation of approved conservation practices. Of course this would be complicated by a large and diverse array of abiotic and biotic interactions. Until such information becomes available recent scientific investigations have provided some useful guidelines. Practical studies of associations between fish species, their abundances and significant physical and chemical environmental conditions have been undertaken for rivers in several regions of Thailand (Beamish et al., 2006; Beamish and Sa-ardrit, 2007). These studies have been conducted in rivers throughout Thailand and include measurements of a large number of physicochemical factors at each of an even larger number of sites together with quantitative sampling of resident fish species and their abundances. This infor-

mation was then analyzed using canonical correspondence analysis (CCA) to identify significant habitat variables and fish species associations, described in an ordination diagram in which species are represented by coded numbers and, significant physicochemical variables, by vectors.

RESULTS AND DISCUSSION

Number of fish species estimated by our laboratory for the relatively pristine nine rivers sampled in central, southern and western Thailand increased in relation to their length (Fig. 1). However, the increase in species diversity was less than predicted from a direct relation with length. Furthermore, there is a suggestion of regional differences in species diversity with western rivers appearing to sustain more species per unit of length than in other regions.

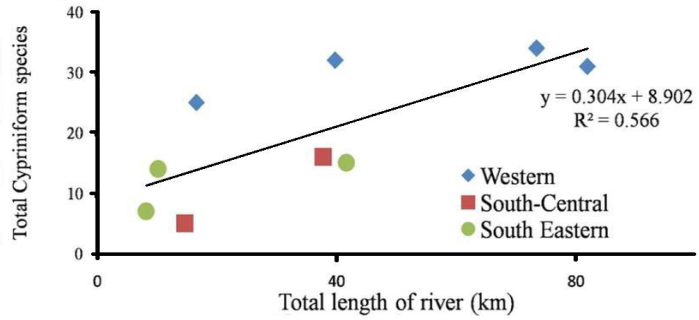
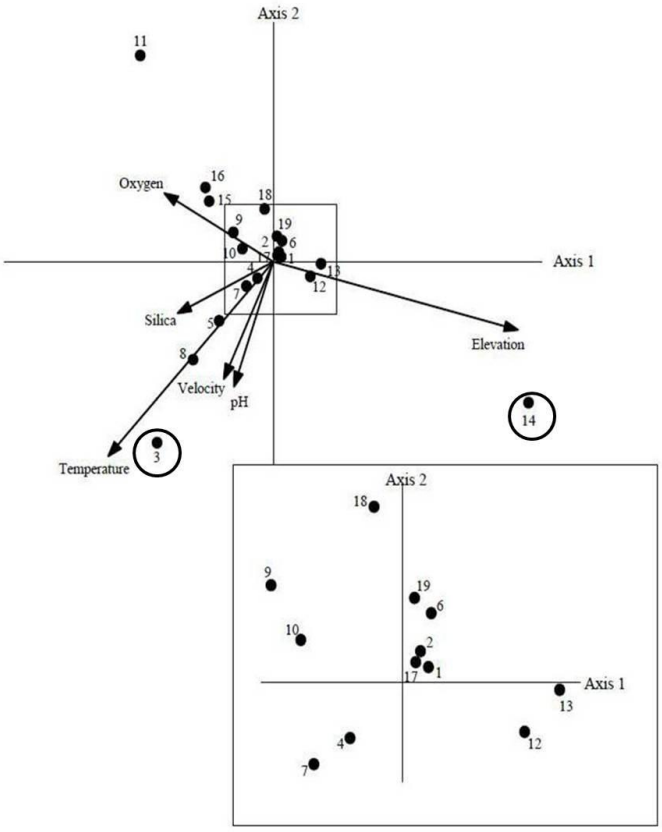


Fig. 1 Relationship between total number of cypriniform species and river length in Western, South-Central and South Eastern river systems

This is important preliminary information for the conservation of fishes in degraded rivers that emphasizes a need to estimate baseline species numbers for more rivers from throughout Thailand. Wherever information on species numbers prior to habitat degradation is not available from records or local residents, regressions such as that in Fig. 1 can provide a simple method for hindcasting potential target numbers.

Associations between fish species and statistically important chemical and physical environmental variables have been described in our laboratory for several regions of Thailand. One example of the extent to which balitorid species vary in their association with environmental conditions was demonstrated in several rivers in Thailand (Plongsesthee, 2011; Fig. 2). The distribution and abundance of balitorid species in these rivers was significantly related to several factors with elevation and temperature being of primary importance followed by dissolved oxygen, silica, pH and water velocity. The extent of influence by each environmental factor varies among fish species. For example, distribution and abundance of *Schistura balteata* (#14 in Fig. 2) *is* positively associated with elevation and negatively, dissolved oxygen while the occurrence and abundance of *Balitora kwangsiensis* (#3 in Fig. 2) is associated positively and primarily with temperature and secondarily with pH and water velocity. Other species were variously associated with the other significant environmental factors highlighting the importance of identifying and understanding the environmental conditions most suitable for each species. Information on species associations and the important environmental variables provide essential baseline data especially in the absence of pre-degradation information and should be of great benefit to conservation efforts of degraded rivers in Thailand.

Conservation of aquatic animals requires an understanding of environmental requirements and species associations to accompany existing tactics to improve physical and chemical conditions of rivers. Some environmental factors have long been known or accepted to be beneficial for fish or habitat conservation and can be implemented with simple technology, relative ease and low cost, such as current deflectors and embankment protection with boulders, gabions or tree plantings. Deflectors can be designed for a variety of purposes (Gore, 1985) including deepening and narrowing channels, scouring pools, altering water velocity and chemistry, and removing silt from spawning gravels and critical areas for benthic invertebrate production.



Name		ID
Acanthocobitis	*botia*	1
Acanthocobitis	*zonalternans*	2
Balitora	*kwangsiensis*	3
Homaloptera	*bilineata*	4
Homaloptera	*confuzona*	5
Homaloptera	*sexmaculata*	6
Homaloptera	*smithi*	7
Nemacheilus	*binotatus*	8
Nemacheilus	*masyae*	9
Nemacheilus	*pallidus*	10
Nemacheilus	*platiceps*	11
Schistura	*sp.*	12
Schistura	*aurantiaca*	13
Schistura	*balteata*	14
Schistura	*kohchangensis*	15
Schistura	*crocotula*	16
Schistura	cf *sexcauda*	17
Schistura	cf *mahnerti*	18
Tuboroschistura	*baenzigeri*	19

Fig. 2 Distribution of Balitoridae species from lightly exploited rivers in Thailand with respect to significant habitat variables identified by canonical correspondence analysis on axes 1 and 2, for each, the vector length and direction (Plongsesthee, 2011)

Generally dams are to be avoided in conservation strategies. The key ingredient to all habitat-improvement technologies is an understanding of aquatic ecology in concert with the conservation objectives and resources along with the development of practical tools that can be used to determine environmental requirements of aquatic animals and species associations in undisturbed and environmentally threatened rivers. This is of critical importance for conservation in Thailand now and in the future.

CONCLUSION

Conservative principles need to be developed, approved, implemented and managed to perpetuate aquatic resources for the benefit of all humankind. An understanding of the needs of flora and fauna must be acquired because without this information conservation efforts may prove unproductive. At present this ecological information is dreadfully inadequate in Thailand. Some freshwater environments in Thailand are currently experiencing an alarming decline in biodiversity. As a result, scientists and managers should undertake immediate management techniques to protect what remains of these aquatic systems. Conservation planning is an activity in which social, economic and political imperatives may modify, sometimes drastically, scientific prescriptions. This interaction need not be all one way.

ACKNOWLEDGEMENTS

We are grateful to the RGJ-Ph.D. Program (Grant No. PHD/ 2. S.BU/ 49) and to BRT and ETM programs for financial support. We gratefully acknowledge the permit to collect fish provided by the Thailand Department of Fisheries.

REFERENCES

Ahmed, M., Boonchuwongse, P., Dechboon, W. and Squires, D. 2007. Overfishing in the Gulf of Thailand: Policy challenges and bioeconomic analysis. Environment and Development, 12, 145-172.

Aksornkoae, S. 1996. Scientific mangrove management in Thailand. Tropical Forestry in the 21st Century. Mangrove Ecosystems, 10, 118-126.

Beamish, F.W.H. and Sa-ardrit, P. 2007. Abundances and habitat sensitivities of some fishes in Thailand. Tropical Freshwater Biology, 16(1), 57-73.

Beamish, F.W.H., Sa-ardrit, P. and Tongnunui, S. 2006. Habitat characteristics of the Cyprinidae in small rivers in central Thailand. Environmental Biology of Fishes, 76, 237-253.

Gore, J.A. 1985. The restoration of rivers and streams: Theories and experience. Butterworth Publishers, Stoneham. 280.

Krebs, C.J. 1989. Ecological methodology. First Edition. Harper Collins Inc., New York.

Nabhitabhata, J. and Chanard, T. 2005. Thailand red data: Mammals, reptiles and amphibians. Office of Natural Resources and Environmental Policy and Planning, Bangkok, Thailand.

New, T.R. 1998. Invertebrate surveys for conservation. Oxford University Press, UK.

Plongsesthee, R. 2011. Environmental associations of Balitorid fishes with special emphasis on the genus Schistura in Central Thailand. MSc dissertation, Environmental Science, Faculty of Science, Burapha University.

Sanguansombat, W. 2005. Thailand red data: Birds. Office of Natural Resources and Environmental Policy and Planning, Bangkok, Thailand.

Smith, K.L. and Jones, M.L. 2005. Watershed-level sampling effort requirements for determining riverine fish species composition. Canadian Journal of Fisheries and Aquatic Science, 62, 1580-1588.

Research article

Effect of Culture Media on Fertilization Rate in Bovine and Caprine Embryos Production

SARUTTIWONG BOONKONG
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

CHAINARONG NAVANUKRAW*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Agricultural Biotechnology Research Center for Sustainable Economy (ABRCSE), Khon Kaen, University, Khon Kaen, Thailand
Email: chanav@kku.ac.th

JIRATTI THAMMASIRI
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

WINAI JAIKAN
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

SUTHIPONG URIYAPONGSON
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

Received 19 December 2011 Accepted 7 February 2012 (*: Corresponding Author)

Abstract The objective of this experiment was to determine the effect of culture media (Tyrode Albumin Lactate Pyruvate-In Vitro Fertilization-Synthetic Oviduct Fluid; TALP-IVF-SOF and SAGE media™) on fertilization rate in bovine and caprine embryos production. Thai crossbred bovine ovaries (n=40) were collected at a local abattoir located in Khon Kaen municipality. Caprine ovaries (n=22) were collected by the surgery method at the Department of Animal Science, Faculty of Agriculture, Khon Kaen University. In order to compare the culture media, oocytes were recovered and randomly cultured in TALP-IVF-SOF and SAGE media™ during in vitro oocytes maturation and fertilization as described by the standard protocols for in vitro maturation, in vitro fertilization and in vitro culture, respectively. Oocytes, obtained from ovaries with corpus luteum (CL) and without CL, were recovered and determined as recovery rate prior in vitro culture. The results revealed that the recovery rates of bovine and caprine oocytes were not significantly different between ovaries with CL (58.5 and 27.6%) without CL (43.5 and 29.4%) respectively; bovine oocytes had significantly more layers of cumulus than caprine oocytes. IVF and IVC, developed from two cells to blastocyst stage, derived from SAGE media™ were better than that of TALP-IVF-SOF.

Keywords culture media, in vitro fertilization, embryo, beef, goat

INTRODUCTION

In vitro production techniques of bovine and caprine embryos become widely used to genetic improvement. The improvement of bovine and caprine embryo culture systems is highly desirable in term of the production of preimplantation stage embryos for biotechnological studies and for the embryo transfer. A standard medium for in vitro maturation is tissue culture (Lonergan et al., 1994). TALP-IVF-SOF is the medium commonly use for embryo fertilization and embryo culture in vitro. SAGE Media™ is also available as a commercial product. This culture media has been modified by addition of amino acids. The effect that the culture media may have on the developing embryos between different media is unknown.

Thus, the objective of this study was to determine the effect of culture media on the fertilization rate in bovine and caprine embryos production.

MATERIAL AND METHODS

The experimental procedures were approved by the Animal Ethic committee of Khon Kaen University (Reference No. 0514.1.12.2/88). Bovine ovaries were collected at a local abattoir located in Khon Kaen municipality and caprine ovaries were collected by surgery method at the Department of Animal Science, Faculty of Agriculture, Khon Kaen University. In order to compare the culture media, oocytes were recovered and randomly cultured in two media: TALP-IVF-SOF (Table 1) and SAGE media™ (CooperSurgical Inc., Trumbull, CT) as shown in Table 2.

Oocyte collection in bovine and caprine: Bovine oocyte collections were recovered from slaughtered bovines at Khon Kaen municipality and transfered in 0.9% saline to the laboratory within 1h (Yang et al., 1990). Follicles were aspirated with an 18 gauge needle using vacuum suction.

Caprine oocyte collections were recovered from live goats by surgery method at the Department of Animal Science, Faculty of Agriculture, Khon Kaen University and transferred in 0.9% saline to the laboratory within 1 h (Yang et al., 1990). Follicles were aspirated with a 21 gauge needle using vacuum suction.

Table 1 Chemical composition of culture media (TALP-IVF-SOF)

Composition	TALP-IVF	SOF-IVC
NaCl (mM)	114.00	-
KCl (mM)	3.20	-
NaH_2PO_4 (mM)	0.40	-
$CaCl_26H_2O$ (mM)	2.00	-
HEPES (mM)	0.50	-
Glucose (mM)	5.00	-
PVA (mg/mL)	1.00	-
Lactate (sodium salt) (mM)	13.00	-
Pyruvate (mM)	10.40	-
Penicillamine (mM)	3.35	-
Gentamicin (µg/mL)	50.00	-
Sodium pyruvate (g)	-	0.33
$NaHCO_3$ (g)	-	1.00
Glutamine (g)	-	1.50
Glucose (g)	-	10.00
Serum (mg/ml)	-	0.10
EDTA (g)	-	0.10
Streptomycin (g)	-	0.10

Table 2 Chemical composition of culture media SAGE Media™ Product

Catalog Number SAGE Media™Product	ART-1020/1021 Fertilization (HTF)	ART-1026/1027 Cleavage	ART-1029 Blastocyst
Basic Media Components	X	X	X
Non-Essential Amino Acids	X	X	X
Essential Amino Acids			X
Vitamins			X
Magnesium Sulfate Heptahydrate Magnesium Chloride	X	X	X
Potassium Phosphate, Monobasic Anhydrous	X		X
Calcium Lactate (L+)	X	X	X
Taurine	X	X	X
Citric Acid	X	X	
EDTA	X	X	

In vitro maturation (IVM): Oocytes were placed in maturation medium (TCM-199) under mineral oil (Rose et al., 1992). Maturation proceeded for 22-24 h at 38.5 ºC in an environment of 5% CO_2 in air.
In vitro fertilization (IVF): Frozen semen was thawed at 37 ºC for 30 second and washed by centrifuging at 700 g for 5 minutes to remove any remaining semen extender (Gandhi et al. 2000). Before transfer to fertilization drops, oocytes were transferred into drop of fertilization medium under mineral oil. Oocytes were coincubated with spermatozoa for 22-24 h at 38.5 ºC in an environment of 5% CO_2 in air.
In vitro culture (IVC): At 24 h post-insemination, the presumptive embryos were washed in culture medium and embryos were placed into culture medium under mineral oil at 38.5 ºC in an environment of 5% CO_2 in air. Cleavage rate was recorded at 24, 48, 72, 96 and 120 h post-insemination.
Statistical analysis: Data were analyzed using Chi-square test (Steel et al., 1997). Statistical analysis was performed in all tests at a 95% confidence interval.

RESULTS

Studies on the influence of ovaries with CL (ovaries within the development of CL) and without CL showed that ovaries with CL and without CL were not significantly different (P>0.05) (Table 3).

Table 3 Recovery rate of oocyte obtained from bovine ovaries

Ovary	Number		% Recovery of oocyte
	Follicle	Oocyte	
with CL	123	72	58.54 (72/123)
without CL	147	64	43.54 (64/147)

Table 4 The recovery rate of oocyte obtained from caprine ovaries

Ovary	Number		% Recovery of oocyte
	Follicle	Oocyte	
with CL	94	26	27.66 (26/94)
without CL	17	5	29.41 (5/17)

Studies on the influence of ovaries with CL (ovaries within the development of CL) and without CL showed that ovaries with CL and without CL were not significantly different (P>0.05) (Table 4).

Morphology of bovine oocytes and caprine oocytes

Study of the morphology of bovine and caprine cumulus cells have shown that bovine oocytes had significantly more layers of cumulus than caprine oocytes and can effect fertilization of oocytes.

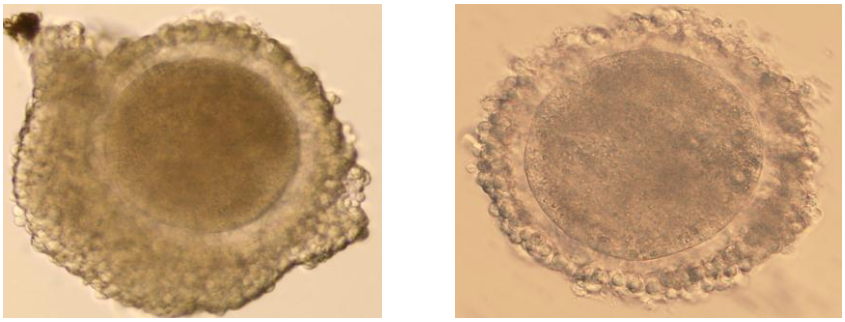


Fig. 1 Morphology of bovine oocytes (left) and caprine oocytes (right)

Effect of culture media on in vitro fertillization in bovine embryo production

The results revealed that IVF and IVC, developed from two cells to the blastocyst stage of SAGE media™, were better than that of TALP-IVF-SOF as determined by the embryo image analysis**.**

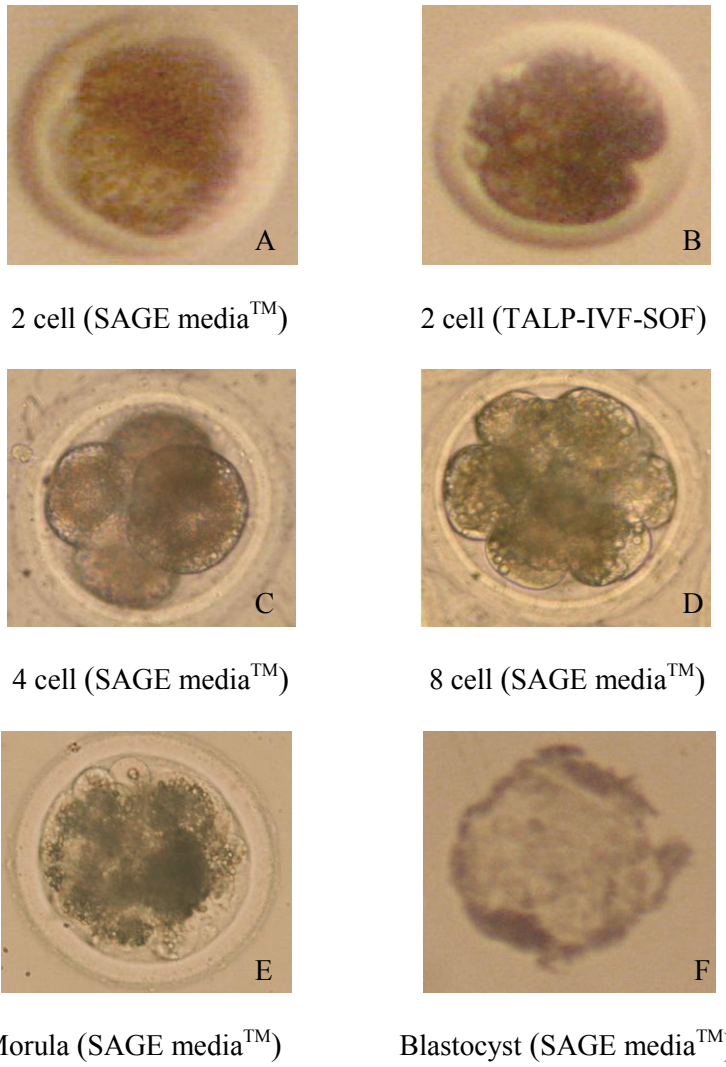


Fig. 2 (A-F) Morphology of bovine embryo during early development

CONCLUSION

The present study suggested that the number of cumulus cells is important for supporting embryo development and culture media can increase the cleavage.

ACKNOWLEDGEMENTS

The authors would like to express the most appreciation to the Thailand Research Fund Master, Research Grants: TRF-MAG Window II (MRG-WII535S012), and Research Group of Beef and Buffalo production, Department of Animal Science, Faculty of Agriculture, Khon Kaen University.

REFERENCES

Gandhi, A.P., Lane, M.L., Gardner, D.K. and Krisher, R.L. 2000. A single medium supports development of bovine embryos throughout maturation fertilization and culture. Human Reproduction, 15, 395-401.

Gordon. I. 1994. Laboratory production of cattle embryos. CAB International, Oxon, UK, 640.

Lonergan, P., Carolan, C. and Mermillod, P. 1994. Development of bovine embros in vitro following oocyte maturation under defined conditions. Reproduction Nutrition Development, 34, 329-339.

Nagano, M., Katagiri, S. and Takahashi, Y. 2006. Relationship between bovine oocyte morphology and in vitro development potential. Zygote, 14, 53-61.

Rose, T.A. and Bavister, B.D. 1992. Effect of oocyte maturation medium on in vitro development of in vitro fertilized bovine embryos. Molecular Reproduction Development, 31(1), 72-7.

Steel, R., Torrie, J. and Dickey, D. 1997. Principles and procedures of statistics: A biometrical approach. WCB/McGraw-Hill, a Division of the McGraw-Hill Companies, 666.

Yang, N.S., Lu, K.H. and Gordon, I. 1990. In vitro fertilization (IVF) and culture (IVC) bovine oocytes from stored ovaries. Theriogenology, 33(1), 352-362.

Research article

Constraints on Small Scale Cattle Production in Kandal Province, Cambodia

SEREY MOB*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: serey.mob@gmail.com

YUTHY VAY
Royal University of Agriculture, Phnom Penh, Cambodia

PISETH LONG
Royal University of Agriculture, Phnom Penh, Cambodia

MIRANDA PEN
New England University, Armidale, Australia

MOM SENG
Royal University of Agriculture, Phnom Penh, Cambodia

Received16 December 2011 Accepted 7 February 2012 (*: Corresponding Author)

Abstract This study was conducted in Kandal Steng and Saang District, Kandal Province, Cambodia, to determine the constraints on small scale cattle production in this area. Sixty small holding cattle keepers were interviewed using semi-structure questionnaires. Faeces samples from 80 cattle were selected and subjected to intestinal parasite investigation at the Royal University of Agriculture Laboratory. Cattle are kept for draught power and reproduction purposes. Crossbreed animal types were dominant in these areas. The average herd size is 2.5, ranging from 2 to 3 heads. Eighty five of respondents practiced vaccination and 26% de-worming. However, the Foot and Mouth Disease (FMD) and Haemorrhage Septicaemia disease usually occurred as it was mentioned by farmers. Five types of parasites (Fasciola, Paramphystomum, Gastro-intestinal strong (GIS), Eimeria and Toxocara) had been detected; majority of GIS (68%) was found in feaces. The farmers expressed that the major constraints to cattle production are disease outbreak (95%), lack of feed (35%) and that price of cattle is low (26%). In order to improve livestock production at small scale level, animal health services for vaccination and treatment should be strengthened and animal bio-security management should be applied. Technical support should be in place, in order to encourage farmers to provide proper feeding management, sufficient amount and quality of food so that growth rate, reproductive performance and disease resistance of animals can be improved.

Keywords cattle, management, feeding, parasite

INTRODUCTION

In Cambodia, large ruminants play an important role in the agricultural sector of rural areas, providing draught power, organic fertilizer, and cash accumulation (Pen et al., 2009). Livestock are raised through traditional management methods, such as rice straw and other seasonal crop residues usually used for the main feed (Maclean, 1998; Pen et al., 2009; and Sath et al., 2008). During the dry period, major grazing activities take place (Sath et al., 2008) exposing animals to disease and internal parasites (Keyyu et al., 2005), especially the calves which are more vulnerable.

Recently, the number of cattle in the province had significantly decreased due to; the incidence of infectious diseases, an increased use of land for cropping and an increase in the use of machiner-

ies for land preparation and transportation reducing the need for draught power. In addition, labor demands for feeding the animals are relatively high, consequently, some farmers decided to reduce the herd size (Pen et al., 2009). In order to identify the situation of cattle production and intestinal parasite investigation among farmers with small holdings, this study was conducted in Kandal Steng and Saang District, Kandal Province.

MATERIALS AND METHODS

Study site

The survey and internal parasites investigation were conducted as a baseline study for the project "Establishment of *Leucaena leucocephala* and *Gliricidia sepium* as forage supplementation for cattle of small scale farmers in Kandal Province" carried out between Royal University of Agriculture (RUA) and Cambodia Agriculture Research Fund (CARF). The study started from March 18 to April 18, 2010 in Kandalsteng and Saang districts, where small producers handle cattle for crop farming systems. These areas lay on a flat land in Kandal province, 12 km and 25 km from Phnom Penh city, respectively. 60 households were selected for individual interview on animal production aspects and 80 cattle were chosen for intestinal parasite study.

Sampling procedure for baseline study

Randomized sample of correspondents among small scale cattle keepers were selected. Twenty producers in each commune, Koktrop and Ampovprey (Kandal Steng district) and Krangyov (Saang district) were chosen. Equal number of adoption forage and non-adoption forage farmers was selected. Krangyov is the busiest farming area among all selected sites, where farmers cultivated rice almost 3 times per year.

Data collection for parasites study

Faeces samples for intestinal parasites identification were collected from the animals owned by the same recipients in Kandalsteng district (Koktrop and Ampovprey village). The samples were harvested from rectum with new unused gloves for each animal and stored at 4 ^{0}C in a refrigerator and analyzed within 3 days. Faecal samples were examined for the presence of parasite eggs, namely: Fasciola, Paramphystomum, Gastro-intestinal strong (GIS), Eimeria (Coccidiosis) and Toxocara.

RESULTS

Herd size and breed

In the study sites, rice was the staple crop for securing villagers' livelihood, whereas livestock was the second sources of food, draught power and income generation. Compared to other species (pigs and poultry), cattle were present in highest number in those areas (Fig. 1). The average number of animals per household was approximately 2.5 head, which is similar to the finding of Maclean (1998). The herd size varied according to the farming aspect, in Krangyov, 35 percent of correspondents raised 4 animals whereas only 10 and 20% in Apovprey and Koktrop (Table 1).

The crossbred animal was the dominant breed type found in these study sites (Fig. 2). The characteristics of this breed were similar, as described by Sath et al., 2008. Villagers selected bulls (Haryana) in their area for natural mating with local types. According to the farmers, crossbreed cattle show significant difference in body condition and usually fit with labor work. Moreover, the traders usually put their high interest and demand on crossbreed cattle. Majority of livestock were purchased by neighboring villagers (Fig. 3). Approximately 36% of live animals were sold for draught power rather than for breeding or slaughter. The male animals were temporary kept and

tended to be replaced when the holders were able to gain more profit. Traditionally, farmers in these areas sold their draught animal after rice harvesting (January to February). Later, they were looking for new animals in the early rainy season (April to May). The holders confirmed that during the dry season, frequently, animals lack feed and it was uneconomic to keep unused-animals.

Table 1 Average of households (Head/hs) keeping in Kandal province

Herd size (head)	Households (%)			
	Koktrop	Ampovprey	Krangyov	Means
1	15	25	15	18.3
2	45	20	5	23.3
3	20	25	25	23.3
4	20	10	35	21.7
5	0	20	10	10.0
5<	0	0	10	3.3

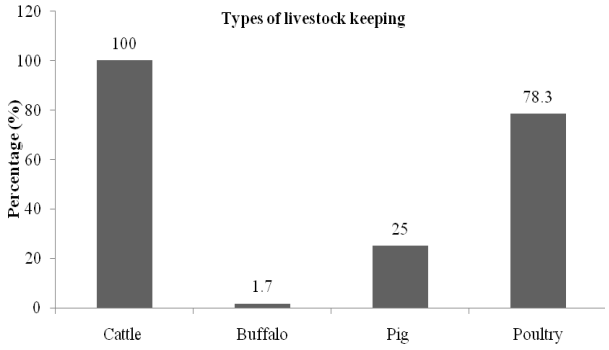


Fig. 1 Types of livestock kept

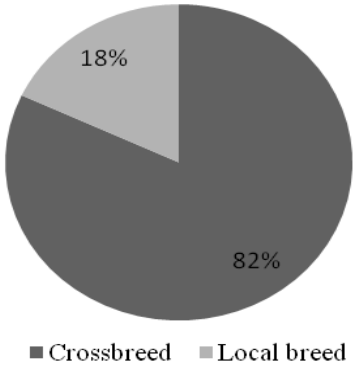


Fig. 2 Breed preference

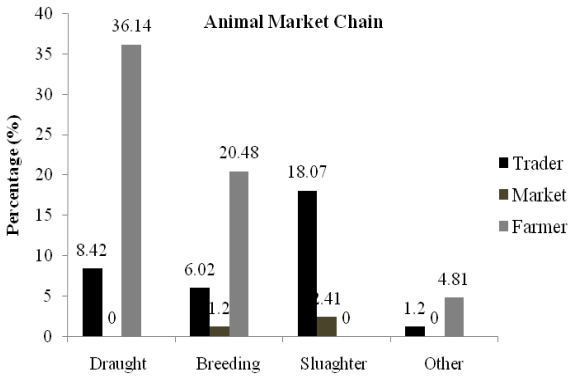


Fig. 3 Animals Market Chains defining the major constraint of animals production

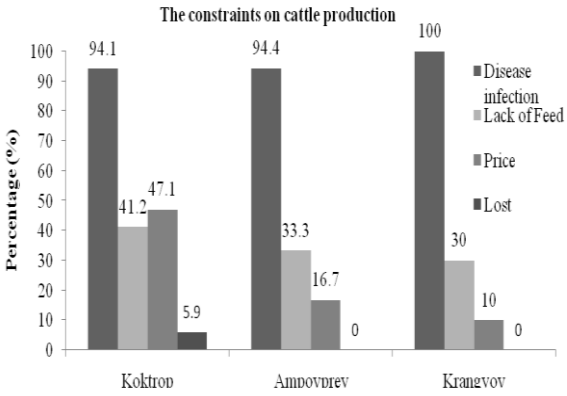


Fig. 4 Constraints on cattle production

Disease was identified in the survey as the major problem (95%) which limits the production whereas feed supply (35%) and market price (26%) were considered to be less important (Fig. 4). Most farmers reported that Foot and Mouth disease and hemorrhages septicemia were regularly occurring even though eighty five percent of them attempted to use vaccinations (Fig.5).

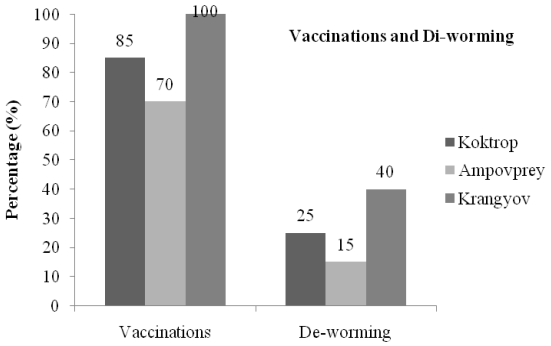


Fig. 5 Vaccinations and deworming

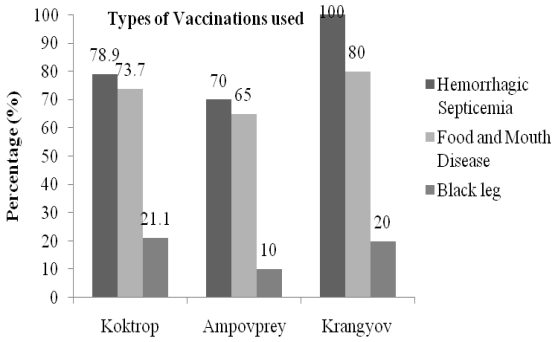


Fig. 6 Types of vaccinations used

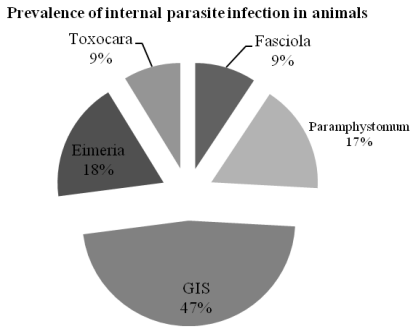


Fig. 7 Prevalence of internal parasite infection on animals

The transmission of infectious diseases increased when the diet failed to meet the energy and nutrient requirements of the animal (Ben et al., 2006; Daovy et al., 2008). Thus the host is more susceptible to infection when fed a low quality feed. As can be seen in this study, majority of producers were using rice straw low quality based-diet annually, particularly in Krangyov (Figs. 8 and 9). Similarly to Sath et al. (2008), when the rice fields were vacant, grazing activities in the selected sites highly increased in dry period, especially in Koktrop and Ampovprey. Collected native grasses were almost twice in raining season for all selected villages. In Krongyov, paddy rice fields were cultivated almost three times per year; hence native grass can be harvested on the edge of rice field boundaries. Interestingly, some families in that area allocated their land close to their residential land for Para-grass planting. This forage was not only used for feeding their animals, but also for selling to the other neighboring cattle holders. A bunch of cut grass accounted 1000 Riels.

Although deworming treatment for preventing five types of parasites (Fasciola, Paramphystomum, Gastro-intestinal strong (GIS), Eimeria and Toxocara) had been conducted (Fig. 5); the majority of worm eggs found were in GIS of 68% (Fig. 7). High presence of GIS can be found in border cattle production in many areas and countries (Keyyu et al., 2005; Swai et al., 2006). Cut and carrying or eventually grazing of natural pastures may increase the opportunity of transmission of internal parasites (Keyyu et al., 2005; Maichomo et al., 2004). However, most of the animals examined during the present survey had low to moderate strongly eggs and Coccidia oocyst counts, meaning that the infections were usually sub-clinical.

Limitation of the herd size was not only due to widespread of disease but also due to the long calving interval (18.5 months) which resulted from lower quantity and quality of feed supply (Pen et al., 2009). In the study areas, calves were weaned approximately 10 months earlier than those in the report of Sath et al., (2008) (12 to 15 months), although this practice of reducing calving intervals was extended to small scale farmers. According to Baiden and Duncan (2008), 3 months weaning can be done in case farmers are fatting cattle for slaughter purpose, however, certain

amount of concentrated feed supplements (grass and legume) may be given in order to gain 330g/day in the 12 months indoors.

Table 2 Prevalence of faecal GIS, Eimeria and Toxocara egg counts in all type and age of animals

Parasites	Range of eggs	Number of examined animals	% of animals that excreted eggs
GIS	None	26	32.5
	50-200	34	42.5
	250-500	18	22.5
	>500	2	2.5
Eimeria	None	59	73.8
	50-200	11	13.7
	250-500	2	2.5
	>500	8	10
Toxocara	None	70	87.5
	50-200	10	12.5

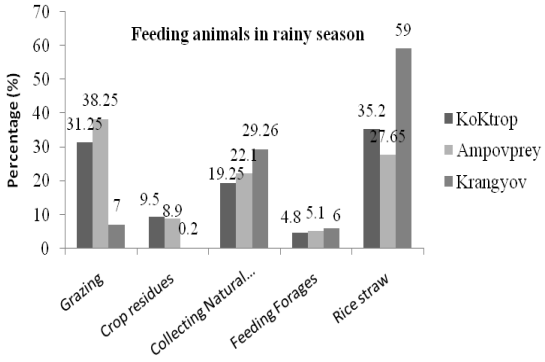


Fig. 8 Feeding animals in rainy season

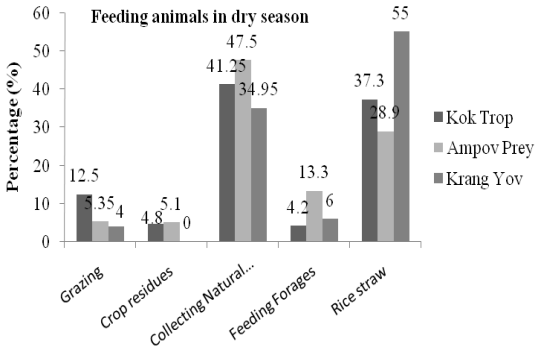


Fig. 9 Feeding animals in dry season

Table 3 Weaning and Castration practices

Calves	Kok trop	Ampov Prey	Krang Yov	Mean	STD
Weaning (Months)	9	12	8	9.7	2.1
Castration (Year)	1.15	1.78	0.45	1.13	0.7

CONCLUSION

Based on the study, followings were concluded;
- Cattle production is linked to farming activities, and the majority of household keep animals from 2-3 heads
- Crossbred are dominant and appropriate for the market demand
- Infectious diseases are influenced by production performance, there is not enough community veterinary service to have emergency support to the farmers
- Feeding is depending on grazing, collecting natural grasses and rice straw
- Improve feed quality, quantity and fattening cattle for slaughterhouse was not consistent, and
- Carrying out traditional weaning are prolonging calving interval.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial support from CARF and RUA Research Laboratory, because without their support, this research would not have been possible. Special thanks to the farmers who contributed with their valuable time and welcomed our study.

REFERENCES

Baiden, R.Y. and Duncan, L. 2008. Performance of indigenous beef cattle under two management systems at Pokuase, Ghana. 20(88). http://www.lrrd.org/lrrd20/6/baid20088.htm.

Ben Salem, M., Djemali, M., Kayouli, C. and Majdoub, A. 2006. A review of environmental and management factors affecting the reproductive performance of Holstein-Friesian dairy herds in Tunisia. Livestock Research for Rural Development, 18(53). http://www.lrrd.org/lrrd18/4/sale18053.htm.

Daovy, K., Preston, T.R. and Ledin, I. 2008. Survey on the utilization of local foliage species for goats in Xaythanee district, Vientiane City. Livestock Research for Rural Development,20. http://www.lrrd.org/lrrd20/supplement/daov1.htm.

Keyyu, J.D., Kassuku, A.A, Kyvsgaard, N.C. and Willingham, A.L. 2003. Gastrointestinal Nematodes in indigenous zebu cattle under pastoral and Nomadic management systems in the lower plain of the Southern highlands of Tanzania, Veterinary Research Communication, 27, 371-380. http://www.ncbi.nlm.nih.gov/pubmed/14509451.

Maclean, M. 1998. Livestock in Cambodian Rice Farming Systems. Phnom Penh: Cambodia-IRRI-Australia Project.

Maichomo, M.W., Kagira, J.M. and Walker, T. 2004. The point prevalence of gastro-intestinal parasites in calves, sheep and goats in Magadi division, south-western Kenya, Ondersterpoort Journal of Veterinary Research, 71, 257-261. http://www.lrrd.org/lrrd20/6/baid20088.htm.

Sath, K., Borin, K. and Preston, T.R. 2008. Survey on feed utilization for cattle production in Takeo province. Livestock Research for Rural Development, 20. http://www.lrrd.org/lrrd20/supplement/sath1.htm.

Swai, E.S., Mtui, P.F., Mbise, A.N., Kaaya, E., Sanka, P. and Loomu, P.M. 2006. Prevalence of gastro intestinal parasite infections in Maasai cattle in Ngorongoro District, Tanzania. Livestock Research for Rural Development. 18(107). http://www.lrrd.org/lrrd18/8/swai18107.htm.

Research article

A Study on Cassava Marketing in Chang Krang Commune, Chhet Burei District, Kratie Province

SOPHAT ATH*
Royal University of Agriculture, Phnom Penh, Cambodia
Email:ath.sophat@yahoo.com

KONGKEA CHHAY
Royal University of Agriculture, Phnom Penh, Cambodia

CHANTHA NUTH
Royal University of Agriculture, Phnom Penh, Cambodia

SOPHEARITH SOK
Royal University of Agriculture, Phnom Penh, Cambodia

Received 16 December 2011 Accepted 7 February 2012 (*: Corresponding Author)

Abstract Cassava, an agro-industry crop, has been cultivated for years by farmers; however, it was not popular in the past. Recently, the market demand for cassava root has radically increased; hence, the number of farmers and cultivated areas has boosted considerably. This study on Cassava Marketing was conducted to measure: 1) cassava household production, 2) cassava marketing, and 3) the important of cassava production in farmer household. 81 producers, 5 traders and 4 key informants in Chang Krang commune, ChhetBurei district, Kratie province were selected. Multiple tools in Participatory Rural Appraisal (PRA) method were employed. The result of the study shows that the majority (95%) of Chang Krang commune farmers depend on Cassava production. The cultivating method is operated in a traditional way and depends on rain fed-crop. The majority of households own more than one ha of cassava field. Mostly, cassava is converted into dry chip and sold between January and March; the average price was 850 riels/kg. Approximately ninety five percent of the yield is exported to Vietnam. The cassava marketing pattern in the selected area was appropriate as not only are they rich in middlemen, but also the location is close to the Vietnamese border. The cassava price is defined by Vietnamese buyers and the information regarding to market price was limited. Most farmers could get benefit both from cassava root and trunk. Cassava production contributed 87.68% to rural livelihood. The advantages of planting cassava included not only generating family income but also employing rural workers and reducing local and cross border migration. In conclusion, cassava production is very important for farmers in Chang Krang commune and the marketing situation is the main factor that effects production chain.

Keywords cassava household production, marketing, income household

INTRODUCTION

Agriculture is the most important sector in the Cambodian economy and plays an important role in improving economics, poverty alleviation, and building social sustainability. In 2009, agriculture contributed 33.5% to the Gross Domestic Production (GDP) and crops production was 52.9% of agriculture sector (Ministry of Agriculture, Forestry, and Fisheries"MAFF", 2009). Besides rice, which is the major food production in Cambodia, farmers, local and international traders, and industrials are attracted to cassava production. Recently, Chinese businessmen have been fascinated with cassava and plan to produce cassava in Cambodia- about 150,000 tons per year for export to

Republic of China (Phnom Penh Post Newspaper, 2011). As a result, cassava growing areas have risen remarkably. In 2008, the cassava growing area was only 108,122 hectares and, in 2010, it was increased to 200,821 hectares (MAFF, 2010).

Cassava is a kind of root crop that is convenient to grow, drought tolerant, insect and illness resistance, and has a high yield (FAO, 2007). In Cambodia, there are two main types of cassava: sweet cassava and bitter cassava. Sweet cassava is commonly grown for family consumption and bitter cassava is generally grown for animal feed or as a raw material for processing industries (Hung, J. et al., 2009). According to the Food and Agriculture Organization (FAO), the utilization of cassava will continue to increase in food processing and animal feed both locally and for export abroad.

Nowadays, the government of Cambodia has tried to attract local and international business-men to invest in the cassava market, especially, the Chinese. This is because cassava will become the root crop of the future (Cambodia Daily Newspaper, 2011).

In conclusion, cassava production will continue to be developed, especially its technical production and marketing. As technical production improves, it will extend to all farming areas. As for marketing will be promote both in local and international. As a result, farmer living standard will be better and prosperity from cassava production.

METHODOLOGY

Study site: The study was conducted in 3 villages (Chang Krang, Or Chhor, and ToulTrang village), Chang Krang commune, Chhet Borei district, Kratie province. In these areas, most people grow cassava and depend on it.

Sampling size and method: The study included 81 farmer households, 5 traders, and 4 key informants in this commune. The samplings of 81 farmer households were chosen in 3 villages; Chang Krang had 51 households, Or Chhor had 6 households, and Toul Trang had 24 households. Moreover, it was including 1 person from the Kratie Provincial Department of Agriculture, and 1 person from the Provincial Department of Commercial.

RESULT AND DISCUSSION

History of Cassava in Kratie Province

Cassava was brought to grow in Kratie Province in 2004 by Mr. Leang Seng, Deputy Director of Provincial Department of Agriculture. He cooperated with Ben Perk Province, Vietnam. Vietnam has provided the KM-94 variety of cassava for Cambodia two times: 2004 and 2005. Cassava was initially grown in Pi Thnou and Sre Char communes, Kratie Province.

Table 1 Initiative of growing cassava in Kraties Province

Year	Amount of Cassava (trunk)	Grow Area size (ha)	Yield Harvested of fresh root (t)
2004	400,000	300	-
2005	650,000	500	9.000

Cassava Household Production

Capital: Cassava production capital was from loan provider and farmers' own capital. Typically, farmer used their own capital for production account to 60.49% and borrowed from loan provider about 39.51%. The reason that farmers didn't prefer to use outside capital because the interest rate was high and farmers could not afford it. For farmer that accept loan, they commonly paid back in dry chip cassava. They were unable to pay back in interest rate. Farmer in study area could not use

credit from Rural Micro-Finance for the reason that they have no property or land title to pawn for the Micro-Finance.

Machinery for land preparation: For land preparation, farmers mostly use their own machinery (tractors) because their land could not be prepared by animal power. Farmer who does not own the machinery hired it from others. Farmer use tractor for land preparation around 80% of the time and prepared the land with animals, which accounted for 20%.

Size area: According to the results, Cassava area was larger than other kind of crops' area. In all three villages of Chang Krang Commune, the cassava area was larger than 50%. The cassava area in Chang Krang was 58.05%, Toul Trang was 53.76%, and Orchor was 65.86%. So, we can conclude that farmers paid more attention to cassava than other crops like corn, soy bean, sesame, and bean.

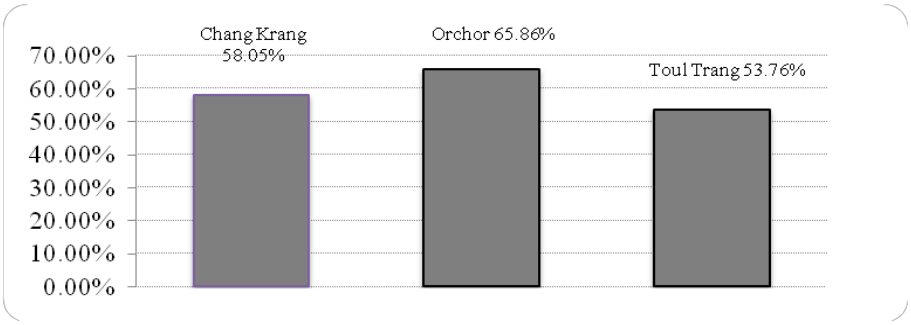


Fig. 1 Cassava area of each village

Growing Technique: Farmers in the study location had poor knowledge of growing technique. They applied traditional techniques, cultural way, and rain water. For maintaining the growing area, farmers did not use chemicals or fertilizer. They just cleared small forests or grasses several times.

With respect to cassava variety, farmers grow only KM-94 that has been imported from Vietnam. This variety provides high yield and is tolerant to drought and pests. This variety is suitable for processing in dry chip form. KM-94 is commonly called Migort or Mimaly by farmers, which in Thai is called KU-50.

Generally, the cassava season lasts for 8 months. Farmers start to grow cassava at any time between February and May. It depends on rain: if there was enough rain in February, farmer will start to grow in February. But, if there was less rain, farmer will wait until to April or May. The harvest time is from October to February. Farmer harvests the product by relying on the market. Frequently, if farmer grow in February or March, farmer will harvest in October or December. However, if they grow in May, they will harvest in January or February.

Cassava marketing

Cassava in the market: The majority (95%) of cassava production was exported to Vietnam through the Kratie and Kompong Cham Provincial Border. These two borders were extremely economically for exporting agricultural products to Vietnam. Local consumption of cassava production was around 5%. Vietnam is the most important market for traders.

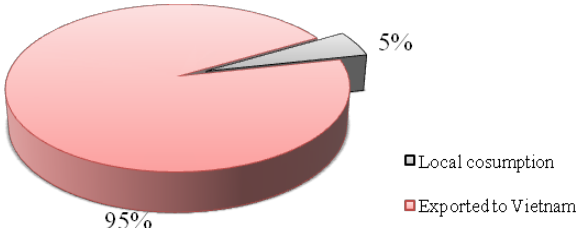


Fig. 2 The percentage of cassava exported to Vietnam

Traders export yield to Vietnam because the local demand is low and limited. The processing industries are only located in Phnom Penh capital city and Kompong Cham Province. On the other hand, exporting products to Vietnam is easier because it is convenient to transport and high demand. Moreover, farmers around industrial areas could afford the industry's raw materials. So, when it was surplus in the local market, the traders need to export to another area, especially, to Vietnam.

The main factors in the market: The main factors that play an important role in the cassava market are: the farmer, the collector, the small trader, the trader that transports cassava to Vietnam, the loan provider, and the Vietnamese trader that stands at the Vietnam border.

- Farmer: the producer
- Collector: someone who collects products from the farmer for the trader that transport to Vietnam and get the commission
- Small trader: someone who buys the products from the farmer in small amounts and sells it to traders that transport to Vietnam or the loan provider to get some profit. A small trader is the one who lives permanently in Chang Krang commune
- Trader that transports to Vietnam: the one who transports all cassava products to Vietnam and cooperates closely with Vietnamese traders
- Loan provider: the one who provides loan to farmers and allows farmers pay back in dry chip cassava. The loan provider also exports cassava to Vietnam directly
- Vietnamese traders: They are all Vietnamese, who stay at Vietnamese borders to get the products from Khmer traders

Marketing structure: The marketing structure starts from the farmer, who is the producer. The product flows from farmers to Vietnam border through collectors and small traders. Collectors transfer products to the trader that transported to Vietnam and small trader exchange products to trader that transported to Vietnam and also to loan provider. Traders and loan providers bring the products directly to the Vietnam border. Moreover, farmers sell their consignment directly to the trader and loan provider as well. After collecting enough cassava, traders and loan providers deliver the products to the Vietnamese traders via two different borders, Kratie and Kompong Cham provinces.

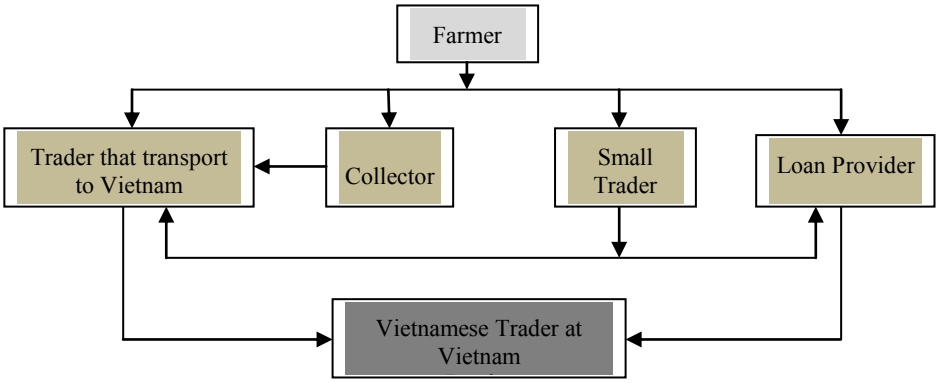


Fig. 3 Marketing structure

Marketing constraint: The biggest marketing constraint is price fluctuation. The price of cassava is seemingly unpredictable. Both traders and farmers were not satisfied with the price situation. In fact, this year the price was high and farmer enjoyed with it, but they were really not happy with the price instability. Farmer was unable to predict for the price next year and later on because they have experienced extremely low prices in the past.

The importance of cassava in farmers' households

Cassava is very important for family households in rural regions. Households mainly rely on cassava production. In families, both fresh leaves and fresh root cassava are commonly consumed for food. As for fresh root, farmers boil it for a snack. Cassava is not only for household

consumption, but also for gross income. Cassava provided farmer income that can support the family living situation. The benefit of cassava product is extremely important for all households in the surveyed region. Farmers can support child education, material and equipment, household repairs, food and other nutrients, and other expenditure for daily living.

Furthermore, cassava production offers employment to all members of the family. It reduces migrant labour and members of household can earn more profit from hiring labor in cassava production.

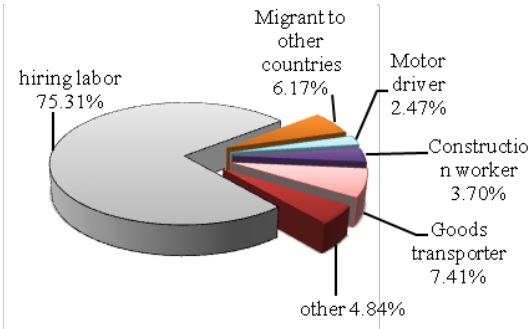


Fig. 4 The percentage of hiring labor and other activities

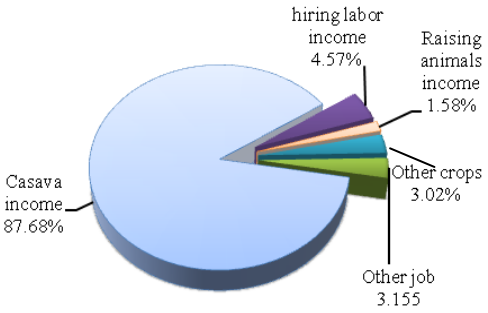


Fig. 5 The income source in the household

CONCLUSION

Cassava production is the main root crop for farmers in the surveyed region. People rely on it more than other kinds of crops. However, the growing techniques were still inefficient, simply using traditional methods and rain water. Most cassava produced is exported to the neighboring country of Vietnam and a small amount is left that is need in local industrials. Kratie and Kompong Cham were the most important borders for transport to Vietnam. The significant factors that play important roles in marketing were: the farmer, the collector, the small trader, the trader that transports to Vietnam, the loan provider, and the Vietnamese trader that stands at the Vietnam border. In addition, the core income in farming households was from cassava. Farmers can support their living standard by depending on this crop. Finally, farmers' income was maily from cassava production. So, in conclusion, growing technique and market were the main point that could improve farmers' living situation.

ACKNOWLEDGEMENTS

This research was supported by Centro International de Agricultura Tropical (CIAT) cooperated with Royal University of Agriculture (RUA). Sincerely, I would like to thank CIAT, RUA, lecturers, parents, and other partner who assisted in the research.

REFERENCES

Cambodia Daily Newspaper. 11 January 2011. Phorn Bopha and Paul Vrieze, Published 17 February 2011.

Centro International de Agricultura Tropical (CIAT). 2010. A new future for cassava in Asia: Its use as food, feed and fuel to benefit the poor. Proc. 8th Regional Workshop, help in Vietnam, Lao PDR. Oct 20-24, 2008.

FAO. 2007. Cassava development strategy for Mozambique. 2008-2012. Volume I, Sub-sector Strategoc Study on Cassava.

Huang Jie, Tain Yinong, Seng Srey, Kang Aun, Chiv Phiny and Suon Serey. 2009. Cassava production and Utilization in Cambodia.

MAFF. 2009. Annual report about agriculture 2008-2009, Cambodia.

MAFF. 2010. Annual report about agriculture 2009-2010, Cambodia.

Phnom Penh Post Newspaper. 11 January 2011, published 17 January 2011.

Research article

An Aassessment of the Natural Resources of Ang Trapeang Thmor and Its Impact on the Livelihoods of Pongro and Sambour Villages

THIRA PINN*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: thearapinn@yahoo.com

CHANKAKADA CHHOEUM
Royal University of Agriculture, Phnom Penh, Cambodia

NORITHYA SAMAN
Royal University of Agriculture, Phnom Penh, Cambodia

Received 15 December 2011 Accepted 7 February 2012 (*: Corresponding Author)

Abstract Ang Trapeang Thmor (ATT) is a protected area (PA) which history dates back to the late 1970s with the creation of a huge reservoir for rice irrigation during the Khmer Rouge reign. The designation of ATT as a crane sanctuary in 2000 led to changes in use and management of resources around the area. This study sets to identify the local livelihood strategies in Pongro and Sambour and to define the level of participation, acceptance and understanding of the need for conservation of the Protected Area. Some methods have been selected to collect necessary data such as informal interviews, participatory rural appraisal (PRA) such as a drawing exercise with school children on environmental education and children's perceptions, awareness on ATT, and nature. Furthermore, focus group discussions were conducted with two groups of villagers separately. The findings reveal that a very common practice of households at Pongro and Sambuor were wet season rice cultivation in ATT, livestock breeding, vegetable growing, collecting NTFP and fishing in ATT. The general perception of the villagers on ATT is negative probably because they passively participate in the management of it and due to the lack of understanding of the aim of the conservation project. There are conflicts between Pongro and Sambuor opposed to the villages south of the main gate of the reservoir over water levels on the reservoir. Water levels and recent increase in cassava prices have led to illegal encroachment into a state forest East of ATT. However the conservation of ATT and the surrounding natural resources still present opportunities in connection to tourism and community forestry that can be beneficial to the villagers of Pongro and Sambuor.

Keywords conservation, Ang Trapeang Thmor, conflicts, livelihoods, natural resources, community participation

INTRODUCTION

Banteay Meanchey province is situated on the Thai border in north-western Cambodia and its capital province is named Sisophon. This province is poor and there are still many unexploded mines in the fields and forests of the province. Ang Tropeang Thmor is located in Phnom Srok district, Banteay Meanchey province, about 80 km northwest of Siem Reap town. The protected area covers about 12,650 ha consisting of a large lake, lowlands and forest (WCS, 2007). It consists of a large reservoir of water contained by 11 km and 9 km long dykes to the south and east, respectively. The southern dyke has three water gates with ten decaying Chinese-made sluices. The reservoir covers less than 1,000 ha during the dry season but expands to cover most of the reserve during the late rainy season (August - October). The PA is a huge reservoir created by forced labor during the

Khmer Rouge regime, which harbors a unique wetland now. The reservoir harbors more than 200 species of other birds, of which 18 have been classified as globally threatened or globally near threatened. In February 2000, a Royal Decree was signed establishing a Sarus Crane Conservation Area. Soon after the decree was passed, a local conservation team was set up with the technical and financial support of the Wildlife Conservation Foundation (WCF) and International Crane Foundation (ICF).

METHODOLOGY

The objective of this study is to identify the local livelihood strategies in Pongro and Sambour villages and define the level of participation, acceptance and understanding of the need for conservation of the PA in Pongro and Sambour villages. The field study was conducted from 7th - 19th March 2009 (duration 12 days) in Ang Trapeang Thmor, Poey Char commune, Phnum Srok district, Banteay Meanchey province. We had done our study in Sambour and Pongro villages which are situated around PA. To achieve this objective, some methods have been designed such as semi structured interviews, transect walk, Participatory Rural Appraisal, questionnaire surveys, and GPS mapping to collect necessary data.

RESULTS

Local Livelihoods

The people living around ATT are strongly depended on natural resources. The state of the natural resources directly affects local people's livelihoods. In this part, the livelihood of the villagers is assessed; both concerning how they are affected by the fact that they live on the border of ATT and how the local livelihoods are affecting the environment in and around ATT. Fig. 1 shows the distribution of livelihood strategies among the households in Pongro and Sambuor. As it can be seen, most households apply wet season rice cultivation in ATT and livestock breeding. The most common livestock is hens and chickens, followed by cows, ducks and pigs. Only few households have water buffalos. Only three households had their livestock grazing in ATT, but of the 11 collecting NTFP in ATT most of them collects fodder for the livestock in ATT. Also 68% of the households are fishing in ATT making it a very common practice. Only three households cultivate cassava in the state forest to the east of the villages and two cultivate sweet potato and maize in the forest.

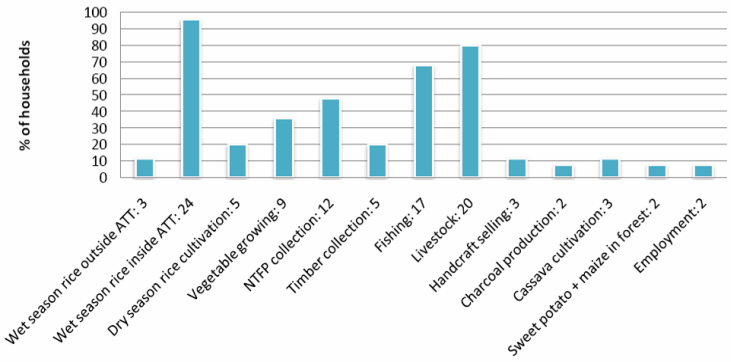


Fig. 1 Livelihood strategies that the households applied

Local participation in conservation

The level of participation and environmental understanding among the villagers has been assessed through questions about their awareness of the Wildlife Conservation Society's (WCS) presence in the area. The majority (86%) of the villagers from Sambuor and Pongro have heard about the WCS (refer to Fig. 2). In most cases information about the NGO has been provided by the authority

(54%), referring to the local village chief or commune chief. Nonetheless, 29% of the villagers have heard about the WCS from the organization itself and 14% heard about the NGO from their neighbors.

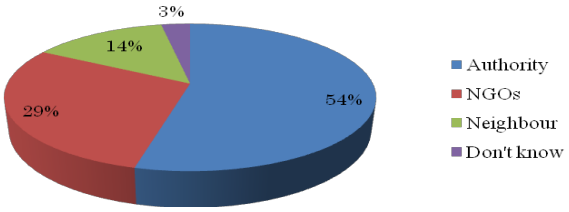


Fig. 2 The results of the questionnaire ***"Have you heard of WCS, and if so, from where?"***

There is a general confusion about whether WCS has actually been providing specific training courses on conservation and sustainable use of the area. It is equally not clear whether they have invited villagers for information meetings or if information and "training" has simply been a part of the village meetings among other important subjects. Therefore, when villagers mention the training courses and the meeting they have been participating in, this might very well refer to the same activity. 21% of the villagers say that they have been participating in a training course, while 46% (out of the 24 persons who had heard about the WCS) has been participating in any kind of activity in relation to ATT and WCS (which may include training courses). 31% of the villagers participated in the planning of ATT while 69% attend meetings about the PA. Regularly, from these results, it can be said that although the villagers participate in these activities at a passive level, over half of them take part in the meetings related to ATT. This means that over half of the villagers have an idea, based on these meetings, of what management activities have been implemented in ATT.

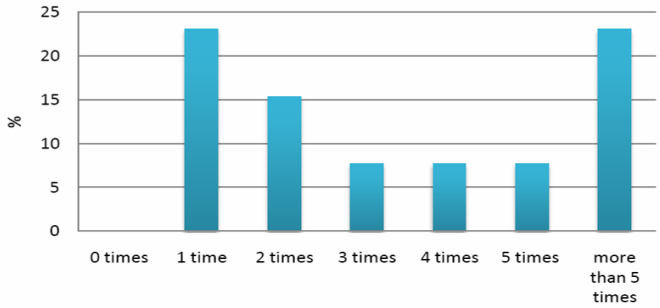


Fig. 3 Percentage of villagers who attended meetings

Some villagers did not participate in the previous meetings about conservation. When they were asked about the reason, the answers were; lack of time (45%) or lack of information (55%), further underlining the point that not everyone has an opportunity to participate.

Perceptions

The different perceptions in Table 1 both positive and negative were expressed by different villagers.

Table 1 Positive and negative perceptions expressed by villagers

Positive perceptions:	Negative perceptions:
- Likes ATT because of sustainability and ecology conservation - Likes the birds - Very good, because they can still do farming, fishing, etc., inside the PA	- Most villagers like it. However, if they can benefit from it, then it would be good. Overall, though, they have lost a lot of land. - No idea about the PA, but the water level is a problem. - The birds destroy the rice. - It is good for nature, good for wilderness. Not good for villagers though. Most villagers are unhappy. - Doesn't like the lake at all. - Eco tourism is good, but the problem of the flooded fields since 2003 decreased the rice yield.

Further livelihood opportunities

Despite the conflicts observed in the use, management and conservation of ATT and the surrounding areas, the natural resources still offer other opportunities for the local livelihoods. Apart from the traditional livelihood activities of wet season rice cultivation, fishing, collection of NTFPs and most recently cassava cultivation, there are a number of other opportunities related to tourism and community forestry.

Tourists are not new to the area. The study investigated the attractiveness of the area for tourists before and after it was declared a PA. 20% of the respondents think they saw tourists before the area was declared a PA. Meanwhile, 48% of the respondents think they saw tourists in the area only after it was declared a PA. Fig. 4 presents the various categories and their percentages.

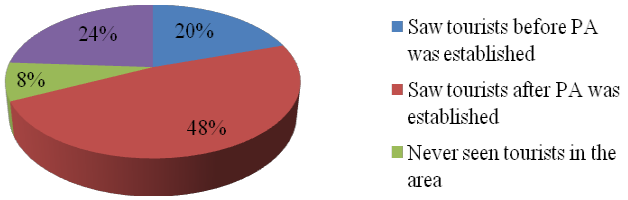


Fig. 4 Respondents' views on tourists in the area before and after PA was established

The general perception of tourism in the area is very good. 80% of the respondents think it is a good area for tourist though only 16% actually know how they can be benefited from tourism. Even though tourists visit the area, so far there is no benefit from tourism to Pongro and Sambuor as none of the respondents have ever sold any items or benefited from the largesse of the visiting tourists.

SWOT analysis

Table 2 presents a synthesis of the analyses of the result in the form of a SWOT

Table 2 SWOT analysis of ATT

STRENGTHS	WEAKNESS
- Biodiversity conservation	- Flooding of rice fields
- Reservoir for irrigation and water utilization	- Food insecurity
- Fishing	- Field difficulties
	- Passive participation by local communities
OPPORTUNITIES	**THREATS**
- Tourism	- Conflict in water management and utilization
- Community forestry	- Increased flood hazard
- Increase of biodiversity	- Illegal occupation of adjacent forest
- Training programmes from WCS	- Destruction of rice fields by birds
- Sustainable natural resource management	- Water levels threatens crane habitat

DISCUSSION

The management of ATT certainly affects the villagers in Sambuor and Pongro. This becomes clear when the villagers mention their flooded rice fields and the fact that they are forced to grow cassava in the forest. When asked questions on ATT, the villagers often refer to the floods in PA. The villagers still blame the conservation project and the WCS.

As mentioned above, several conflicts were found in the area. Due to that, the pressure on the natural resources in ATT was not as high as expected. A question like: “Have you seen any illegal activities in the protected area?” clearly indicates expectations about discovering illegal activities (hunting, logging and NFTP collection), performed by poor villagers, who were limited in their opportunities, and did not have any other choices. However, this was not the case, and fewer illegal activities than expected were reported, which did not make this issue that important.

Concerning the opportunities for the villagers to improve their livelihood and income possibilities, which were not considered initially, they were discovered during the fieldwork undergone. Tourism seems to be the most obvious opportunity although a lot of efforts still need to be put into the area, to attract international tourists. The international tourists though, have already started visiting the area. The guesthouse in Pongro may enhance the activity. The natural resources in ATT were initially expected to produce a positive effect, since this is the aim of the conservation project.

CONCLUSION

In 2000, the villagers of Pongro and Sambuor experienced changes in the size of their fields for rice cultivation because they both were within the designated PA. This led to the reduction at their rice yields and made effect on the livelihoods. However, the situation has been affected negatively with the flooding of the rice fields because of the closure of the main gate. The management of water resources of the reservoir is in the center of a conflict between Pongro and Sambuor. The land in ATT is officially owned by the state; however, the villagers cultivate the land without legal rights. The high water levels and the recent increase in cassava prices have led to the illegal encroachment on the forest to the east of ATT.

With respect to ATT and its management, the general perception of the villagers is negative. This is partly because WCS unilaterally manages ATT and only inform the villages of what has been decided as well as the fact they see ATT as the cause of their flooded rice fields. The level of participation by the villagers is limited to information meetings which is equal to *passive participation*. Even though they have a negative perception of ATT, they are generally aware of the importance of conservation. However, ATT and the surrounding resources have a potential to sustain the local livelihoods of Pongro and Sambuor. These potentials can be harnessed from tourism and community forestry.

REFERENCES

International Crane Fondation. 2009. Sarus crane, ICF. http://www.savingcranes.org/saruscrane.html.
WCS, Cambodia Program. 2007. Paoy Char Commune Natural resources management profile.

Research article

Mango Leather Development in Kiensvay District, Kandal Province by Adaptation of Traditional Techniques

CHAKRIYA NORNG*
Graduate School, Royal University of Agriculture, Phnom Penh, Cambodia
Email: chariya_norng@yahoo.co.nz

CHIM CHAY
Graduate School, Royal University of Agriculture, Phnom Penh, Cambodia

ENGNY TAN
Graduate School, Royal University of Agriculture, Phnom Penh, Cambodia

Received 15 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract Kiensvay district, Kandal province is a popular place for mango leather processed in Cambodia where plenty of mango trees are grown. However, due to lack of skill and technical knowledge of the people, the product has failed to make economic impact on their livelihoods due to poor product quality that does not meet market standards. Poor sanitation and lack of technical information are mainly responsible for this situation. This study was conducted among producers and farmers in the selected area with the objective to gain an understanding of the technical processing methods and to analyse the economic viability of this product. 55 people in these districts were interviewed with semi-open questionnaire: details of each family's technical method for mango leather processing were collected. The initial results were used to identify various techniques used by farmers in the processing method. Then, yes/no questionnaire was applied to 20 people in order to deeply understand the process. After this, the technical processes used by farmers were categorised. Experiments were carried out on farmers techniques and tested in controlled laboratory conditions of Graduate School of Royal University of Agriculture. The results of this research will provide an insight into the best processing technique that may be used for commercial development with the aim of improving the income and livelihoods of the inhabitants.

Keywords mango leather, processing, traditional technique

INTRODUCTION

Mango has become a naturalized and adapted fruit throughout the tropics and subtropics. Much of the spread and naturalization has occurred in conjunction with the spread of human populations, and as such, mango plays an important part in the diet and cuisine of many diverse cultures. There are over 1,000 named mango varieties throughout the world, which is a testament to their value to humankind. Mango is a common garden tree throughout the tropics. When ripe, this delicious dessert fruit is particularly high in vitamin A. The fruit is also an important source of sustenance for birds, bats, insects, and mammals (Bally, 2006). The fruit may be eaten green, processed into pickles, juice, pulps, jams, cream, wine, ice cream, dessert, children's food, and chutneys, and is frozen or dried (Swi-bea wu and Chen, 1993). Mango drying into edible mango slabs has long been a tradition of the people of this region. Mango is an essential commercial crop in the tropical countries (Donald and Robert, 2008).

The food industry contributes xx% of the GDP and provides employment for rural population, hence a source of income (Global Agri System, 2005). Most people enjoy eating ripe and green mangoes. However, high perishability of ripe mangoes, inadequate storage conditions and poor infrastructure for transportation to distant markets make profitable production to remain a challenge

to farmers, resulting into income loss. Mango is a seasonal crop; so, the fruits usually ripen at the same time, as a result market prices fall due to oversupply, making it hard to to be sold at a good price. Value-addition through food processing would be a good strategy to utilize rejected mango and other unmarketable fruits. It adds value to mango while keeping the cost of production down. It is also important for the products to be competitive in the world market. Fruit preservation will provide availability of mango flavour throughout the year, and is important to avoid wastage and increase income. Some of the simplest ways of preserving fruits include drying (mango leather), juicing, and making jam or chutneys (Agri Business Week, 2009).

The processed mango products would provide additional source of income, especially during peak season when there is a glut in supply and the price of mangoes is much cheaper. Although mango leather process has been an old tradition for Cambodian people, the techniques used for processing as well as the use of mango were limited. There is therefore a need to improve ripe mango processing techniques and improve sanitation during mango leather processing.This study was conducted to review existing methodologies and analyze the economic efficiency of mango leather production.

METHODOLOGY

This study was conducted in Kien Svay district (Fig. 1), one of the 11 districts of Kandal province. This is especially an agricultural district along the Mekong River and an important dam is located there.The study was done in two stages. The first stage focused on interviewing people in Sdaokan Lang village, Dey Ed commune, and Kompong Svay village, Kompong Svay commune, Kiensvay district, Kandal province. Sdaokan Lang village have 1,377 families and Kompong Svay village have 672 families who made mango leather. The second stage experiments (drying by solar dryer) were conducted at Royal University of Agriculture.

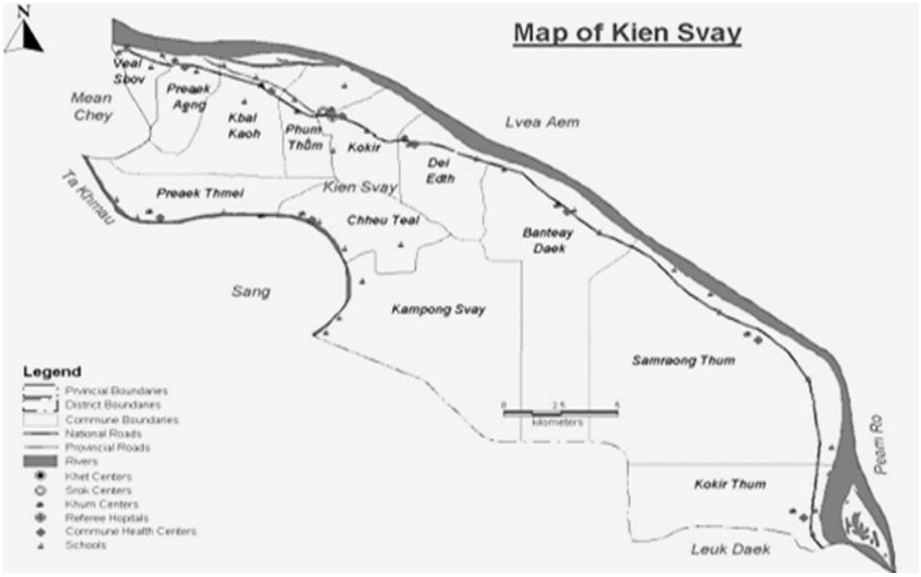


Fig. 1 Map of the study area in Kien Svay District

Yamane (1967 and 1973) equation was used for sample selection based on the calculation of the sample during field survey as shown below. Sample selection was chosen by purpose with the producers in the target areas.

$$Yamane(1967) n = \frac{N}{1 + N.e^2} = \frac{2077}{1 + 2077(0.05)^2} = 335 \quad (1)$$

$$Yamane(1973) n_i(Sdaokanlang) = \frac{nxN_i}{N} = \frac{335x190}{2077} = 31 \quad (2)$$

$$Yamane(1973) n_{ii}(KompongSvay) = \frac{nxN_{ii}}{N} = \frac{335x145}{2077} = 24 \quad (3)$$

This study involved interview of the focus group and direct observation. The focus group interviews adopted open-ended questions to obtain general information, as processing chain, hygienic practises during processing, and economic efficiency of producers. Specific questions were given to check for the answers and to observe the contexts related to each question.

The collected data was analysed using SPSS version 17.0 statistical software by using descriptive statistics to interpret the results. For economic efficiency, the data is analyzed by Microsoft Excel and then using the formula of Economic Efficiency = Total Revenue (TR) divided by Total Cost (TC).

RESULTS AND DISCUSSION

Mango processing technique was divided into three main procedures. The first procedure is preheating and stirring (involves selecting deteriorative mangoes, washing and peeling and chopping roughly into chunks/pieces or by the use of blending machine). The second procedure is heating and stirring (during which sugar and spices are added to the liquid solution and mix thoroughly). The third procedure is post heating and stirring. The mango mixture is evenly spread to approximately 1/4 -inch thickness on the trays as a thin sheet, and positioned on fruit roll liners on dryer trays and placed under the sun. Drying is done continuously for about 3-4 days depending on the temperature, and relative humidity. The trays are then removed from the sun when mixture is dry, with no sticky areas. Level of dryness is examined by touching gently in several places near centre of leather; where wetness indentation should be evident.

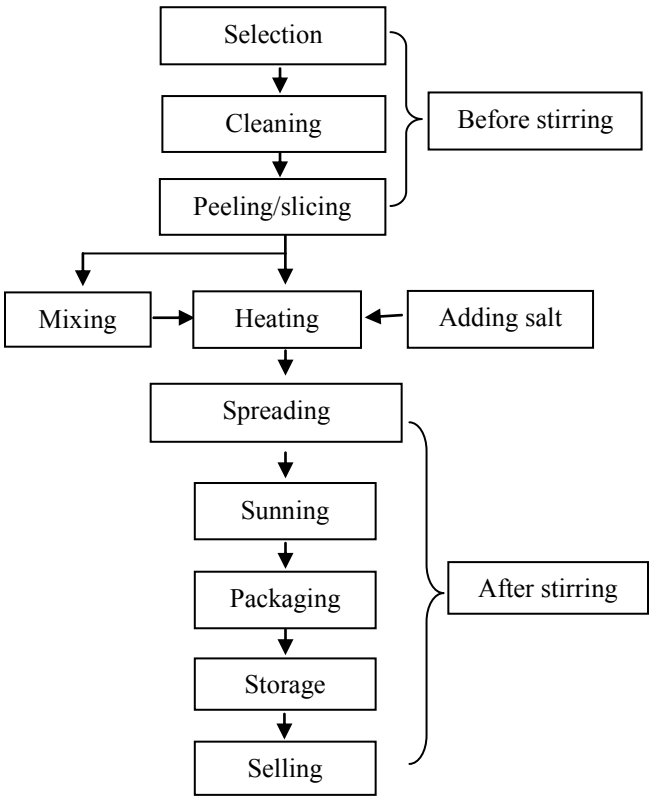
The leather is peeled from trays while still warm and left on the second tray on the dehydrator, while the first leather was peeled, the leather may be re-warmed slightly by exposing to the sun if they cool too much prior to peeling. The sheet is then cut into quarters, laid on a piece of clean plastic food storage wrap about 1 to 2 inches longer at each end of the plastic wrap and tightly closed.

The fruit rolls are stored in room temperature-quality plastic bags or airtight plastic container for short term storage, up to about 6 months. Leathers should be stored in a cool, dark and dry place. For longer storage up to 1 year, it should be placed in tightly wrapped rolls in a refrigerator. Drying time will be longer for the large leather than smaller ones. Drying time may also be longer depending on temperature during drying. For a large leather pieces, it is necessary to check the leather after 2 to 4 days.

The results of analysis also showed that all people washed the processing equipments and 76.4 percent of people washed hands during processing. The water used mostly was from wells (58.2%) which may be a source of contamination of microorganisms. In addition all people did not think about the sanitation while drying. Plastic is the packaging and storage container that people prefer to use than other containers (65.5% of people use plastic as storage container and 87.3% use it as packaging container).

Analysis on economic efficiency of mango leather processing

Mango leather processing provided an average economic efficiency of 1.29, which is equal to 128,100 Riel of profit on average during ripe mango season. Moreover, it helps to reduce the surplus mango product after selling or provides use for overripe mangoes. Table 2 below shows the 5 case studies on mango leather processing and demonstrates that fresh overripe mangoes could be processed into mango leather during peak season and could generate more income. Economic efficiency for this processing was started from 1.17 to 1.26 consistently. Saka et al., (2004) and Mithofer (2004) showed that harvesting fruit from the forest and the farm could reduce food shortage and improve local development and create more income by value-added products thus more products of greater economic value.



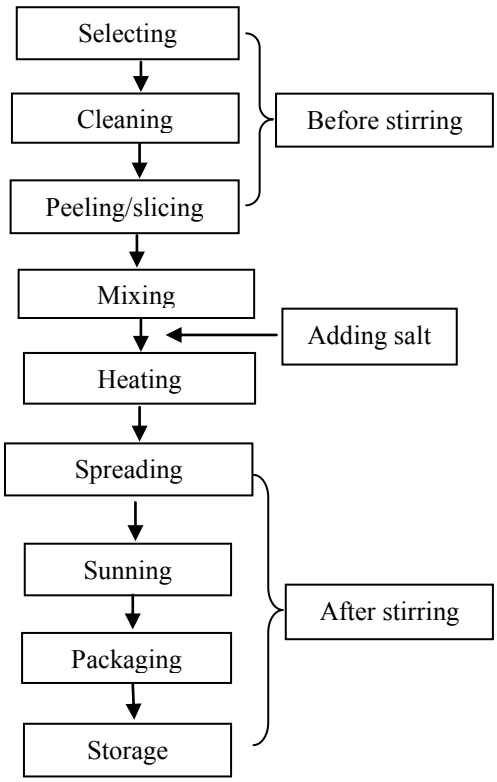


Fig. 2 Mango leather processing (producers) Fig. 3 Mango leather processing (experiment)

Table 1 Economic efficiency for 5 case studies with producers

Case Study	Total Revenue (Riel)	Total Cost (Riel)	Profit (Riel)	Economic Efficiency
1	209.000	169.342	39.658	1.23
2	264.000	217.400	46.600	1.21
3	216.000	184.267	31.733	1.17
4	336.000	288.100	47.900	1.17
5	352.000	277.417	74.583	1.26
	Average		128.100	1.19

Considerable factors for families that process mango leather

It was observed that factors that should be taken into consideration during processing are: (1) technical skill for producers such as ingredients used during processing, heating identification, stirring method, tasting method, thickness of the products, drying method or condition used, texture of the products, control condition for the products, testing for dryness, storage at room temperature/cool condition, dark, dry place, packaging material plastic, as bags, paper, jar or other suitable containers, uniformity of the product, and sanitation practice. (2) Suitable equipments or materials for drying. (3) Water quality used: well water has micro organisms and unsuitable components. (4) Market chain and management. (5) Share and acceptance of the experience with/from the experts.

Berdegue, J.A. et al., (2008) showed that small-scale farmers need to change their ways of working to be able to access restructured markets and, above all, to sustain participation over time, as these markets continue to evolve in ever more demanding ways. There seems to be three common elements to all successful case studies of smallholder farmer participation;

- Upgrading of technical skills, infrastructure and management capacities
- Specialization within multi-agent organizational arrangements
- Increased working and investment capital, usually requiring subsidized external support for prolonged periods of time

CONCLUSION AND RECOMMENDATIONS

Svay Koa Lmeat is a popular variety of mangos in Kien Svay district and it was a popular resource for being processed into mango leather. Processing of this product had 3 main stages: preparation, juice extraction and stirring, and straining and drying. During the preparation stage people used different techniques: some people used grinding machine and some people used knives for slicing followed by peeling. Generally, equipments used during processing were the simple ones and always cleaned before processing. Plastic was the preferred packaging and storage material used. 76.4 percent of the producers interviewed ensured that cleaning and sanitization was done before processing. 100 percent of producers did not care about the storage method during drying to protect infestation or contamination.

Processing provided more profit to the farmers, being on average 128.100 riel per ripening season. Although the economic efficiency on average was 1.19, the abundant fresh fruit could be utilized and provide more profit from processing on average 7000 riel per person. With these contexts, some recommendations have been made for improved profitability and quality

- Cleaning before process as a rule for producers-the equipments must be dried
- Increase product quantity by producers
- Filter well water before using for processing mango leather
- Producers must identify alternative suitable package for mango leather
- Survey on the equipments used during drying with respect to the conditions and socio-economics related to local livelihood
- Conduct more studies on the shelf life of the product
- Conduct studies on the preservation methods used to increase shelf life of the products
- Conduct quality assessment studies of the s with a focus on the micro organisms'
- Identify detail on the micro-organisms followed by the 5 parameters:
  (1) Fecal Coliform or Thermptolercent Coliform (2) *Campylobacter* spp (3) *Salmonella* spp (4) *Clostridium perfringer* (5) *Staphyloccocus aureas* for mango leather
- Extension services to train the producers on the best practices and hygiene requirements.

REFERENCES

Agri Business Week. 2009. Make mango rejects profitable through value-adding. (www.Agribusinessweek.com).

Bal, J.S. 1997. Mango. fruit growing, first edition. New Delhi, India, 155-182.

Bally, I.S.E. 2006. Species profiles for Pacific island agroforestry: Mangifera indica (mango). (www.traditionaltree.org).

Berdegue, J.A., Bienabe, E. and Peppelenbos, L. 2008. Keys to inclusion of small-scale producers in dynamic markets - Innovative practice in connecting small-scale producers with dynamic markets, Regoverning Markets Innovative Practice series, IIED, London.

Christian and Joffin, J.N. 1989. Food microbiology. Center Regional of Documentation of Bordeaux. Pasteur Institute of Cambodia, 40-46.

Global AgriSystem. 2005. Global AgriSystem Pvt. Ltd.

Mithofer, D. 2004. Economics of indigenous fruit tree crop in Zimbabwe. Ph.D thesis. Department of Economics and Business Administration, University of Hannover. Hannover, Germany.

Saka, J.D.K., Swai, R., Mkonda, A., Schombarg, A., Kwesiga, F. and Akinnifesi, F.K. 2004. Processing and utilization of indigenous fruits of the miombo in Southern Africa. World Agro-forestry Centre: Nairobi, Kenya, 343-352.

Swi-bea Wu, J. and Chen, H. 1993. Fruit juice processing technology: Mango juice. Agscience, Inc. Auburndale, Florida, 620.

Yamane, T. 1967. Statistic an introductory analysis, 2nd Edition, New York: Haper and Row, Institute of Food and Agricultural Science, University of Florida, USA.

Yamane, T. 1973. Statistics an introduction analysis, 3rd Edition, New York : Haper and Row, Institute of Food and Agricultural Science, University of Florida, USA.

Research article

Improvement of Khmer Traditional Rice Liquor (Sraa Sor) Productivity Using Different Fermentative Conditions

CHIM CHAY*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: chaychim@yahoo.com

CHAKRIYA NORNG
Royal University of Agriculture, Phnom Penh, Cambodia

DINA KOU
Royal University of Agriculture, Phnom Penh, Cambodia

HAMANO MITSURU
International Center for Agriculture Education, Nagoya University, Japan

Received 16 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract The objective of this research was to establish suitable conditions for rice liquor (*Sraa sor*) in order to improve its productivity in rural areas. Five treatments of fermented rice conditions were used: cool temperature, ambient temperature, ambient temperature with plastic bag-covered pot, high temperature and room temperature condition. Data of temperature, productivity, pure ethanol and ethanol percentage was collected. The data was analyzed using SPSS version 15 in general linear model univariate to identify the significant level. The results of analysis indicated that fermentation temperature had a strong significance at ($p<0.05$). Fermented rice changeable temperature was caused by ambient temperature. So the ambient temperature is very necessary for fermented rice conditions. Yeast activity is reduced by low temperature. At temperature between 30-38 ℃ in the fermented rice condition, the productivity, pure ethanol and ethanol percentage had strong significance ($p<0.05$). Lowest productivity was observed in cool temperature condition. In summary, rice fermentation in room temperature was found to be the best condition, while ambient temperature with plastic bag-cover pot was possible in rural area for development of rice liquor productivity. However, the level of added water during fermentation and period of fermentation should be examined.

Keywords Khmer traditional rice liquor (*Sraa sor*), fermentative condition, alcoholic percentage

INTRODUCTION

Rice liquor (sraa sor) is obtained through traditional fermentation of steamed/boiled rice by *me sraa* (yeast) in Cambodia. The fermentation of steamed/boiled rice into rice liquor is a complex biochemical process, during which yeasts utilize sugars and other constituents of steamed/boiled rice as substrates for their growth, converting them to ethanol, carbon dioxide, and other metabolic end products that contribute to the chemical composition and sensory quality of the rice liquor. Several factors affect yeast growth during alcoholic fermentation, including cooking rice condition, sanitation of pots, and temperature of fermentation. However, rice liquor fermentation condition is the single most important aspect for ethanol productivity. The rice fermentation condition varies depending on season, especially cold season causes low productivity but this condition can be controlled and improved.

METHODS

Location

This experiment was conducted in the bio-processing lab of the Graduate School, Royal University of Agriculture. The experiment was conducted in April 2011, which is the hottest month in Cambodia.

Experimental designs

Five treatments of rice fermentation temperature conditions were done in 3 replicates (Fig. 1). Completely randomized experimental design was used. The fermentation conditions are shown below: 1) Fermented rice in cool temperature (CT): cool temperature was achieved by adding ice to the water in a plastic box. 2) Fermented rice in ambient temperature (AT): ambient temperature was a place with free air flow with a roof but no walls 3) Fermented rice in ambient temperature with plastic bag-covered pot (ATPC): the condition was similar to second treatment condition, but a plastic bag was used to cover the pot. 4) Fermented rice in room temperature (RT): this was placed in the bio-processing lab. And 5) fermented rice in high temperature (HT): the HT was achieved in a small room by turning on lamps throughout the fermentation.

CT AT ATPC HT RT

Fig. 1 Rice fermentation temperature in different conditions

Table 1 Experiment material for conducting the treatments

Fermented condition	Rep.	Rice amount (kg)	Yeast amount (g)	Amount of added water (kg)	Femented period (hr)
CT AT ATPC HT RT	3	1	25 (me sra Phùòng Trang)	4.6	96

Rice liquor processing

Rice preparation: Rice was weighed and washed with water 2 to 3 times to remove the rice brain and husks.

- **Pan preparation:** Water was poured into the cooking pan and heated on the steaming plate (or table iron). The washed rice was placed on a cloth and put on the surface of steaming plate and spread to a uniform surface and then covered with a cloth
- **Steaming:** The rice was steamed for 30 minutes. The steaming rice was stirred using a bamboo stick, and sprinkled with water again and covered; the water was added to be boiled again. The same steps were repeated as above but the amount of water was reduced a little. After the water was boiled for the second time for 30 minutes, the fire gradually reduced and the steamed rice was taken out from a steaming pan.
- **Mixed rice with yeast:** The steamed rice was taken out from the pan and placed on a plastic mat. The steamed rice was spread thinly on the mat. Steamed rice was cooled at room temperature while the temperature was decreased between 35 to 38 ℃, suitable for mixing; yeast was sprayed on the surface of the steamed rice. After which the steamed rice was uniformly mixed with yeast. The steamed rice mixed with yeast was put in glass.

Fermented rice condition:

- **Fermentation without water:** Steamed rice mixed with yeast was put into a glass. The fermentation temperature and conditions were observed at six hours over a 48-hour.
- **Fermentation with water:** After 48-hour fermentation, water was added into the glass. Water was twice the amount of milled rice. The temperature was checked every six hours over 48 hours. The total time of rice liquor fermentation was 96-hour including fermented rice without and with water.
- **Distillation of rice liquor:** The liquid part of fermented rice was put at the bottom of distillation pan while solid fermented rice was put in the surface of the steaming table. The burned fermented rice was placed in the distillation pan until rice liquor was dropped. The rice liquor was dropped until one litter per kilogram of milled rice was obtained.

Data collection: Temperature of the fermented rice was taken every six hours using a thermometer. The results are shown in the Table 2 below.

Table 2 Temperature records of rice fermented and ambient conditions (in degrees C)

	First day				Second day				Third day				Fourth day				DD
Time (24hr)	06	12	18	24	06	12	18	24	06	12	18	24	06	12	18	23	06
Fermented Period (hr)	MT		10	16	22	28	34	40	46	52	58	64	70	76	82	88	94
	Temperature checking in fermented rice																

MT = Temperature of steamed rice mixed with yeast, DD = Distillation day

Ethanol percentage: Measure the degree of alcoholic percentage by hydrometer and look up the % alcohol on a table at 15 ℃.

Pure ethanol: Pure ethanol (kg) = ethanol volume (l) x ethanol percentage (%)/100

Productivity ethanol per kilogram of milled rice: Productivity (l/kg) = pure ethanol (l) / milled rice volume (kg).

Statistical Analysis

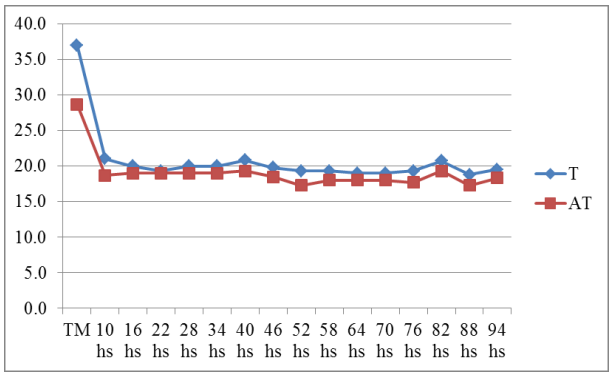
The data was analyzed using general linear model in the program SPSS version 15.0 for window XP. Multiple comparisons were conducted using Duncan at a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

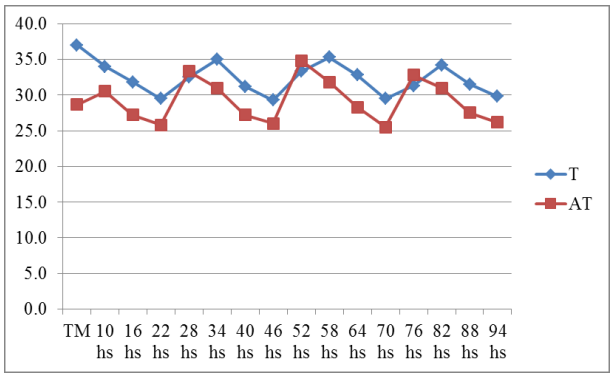
Fermented rice and ambient temperature

Fermented rice temperature had strong significance in different types of fermentation conditions ($P<0.05$). Fermented rice in cool temperature exhibited incomplete fermentation, as evidenced by continued yeast activity compared to the yeast activity observed in high temperature fermentation. Fermented rice in high temperature was more active than that in low temperature. Fermentable rice at low temperature was not completed because the period of fermentation was short, but it was complete at high temperature fermentation. The aroma of fermented rice at AT, ATPC and RT were good (sweet) but sour in CT and HT. Report by Fleet and Heard (1993) showed that temperature affects the rate of fermentation, with lower temperatures yielding slower fermenation rates and longer fermentation periods. At a low temperature, fermentation is exceedingly slow. But the low temperatures notably reduce the growth of acetic and lactic acid bacteria and they can facilitate the control of alcoholic fermentation (Ribereau-Gayon et al., 2002). On the other hand, fermented rice in high temperature condition was quite rapid with complete fermentation as compared to low temperature.

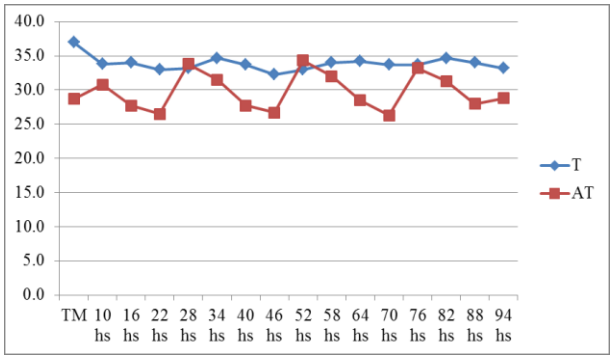
Fermented rice was variable depending on the ambient temperature (Fig. 2a). However, fermented rice in ambient temperature with plastic bag-covered pot was stable but ambient temperature varied according to the external temperature (Fig. 2b). The unstable temperature affected the yeast activities. Moreover, fermented rice in room temperature was stable even out and inside temperatures (35 to 38 degree Celcius). According to Fleet and Heard, (1993); Ribereau-Gayon et al., (2000) reported that temperature has an impact on yeast development and on fermentation kineties.



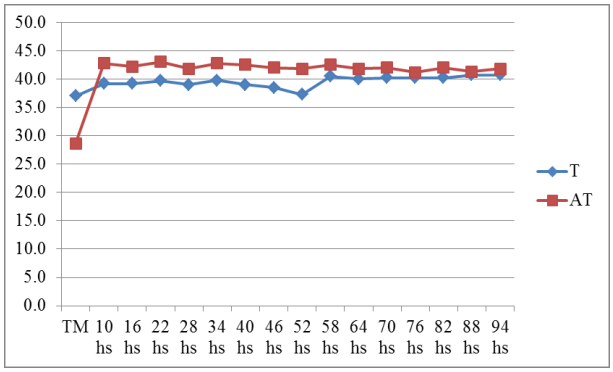
a) Fermented rice in cool temperature



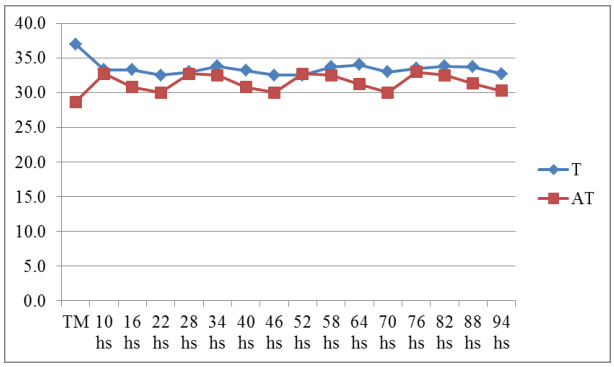
b) Fermented rice in ambient temperature



c) Fermented rice in ambient temperature with plastic bag-covered pots



d) Fermented rice in high temperature



e) Fermented rice in room temperature

Fig. 2 Fermented rice and temperature (in degree Celcius)

Based on these results, fermented rice in cool temperature was unsuitable as fermention temperature of rice liquor condition. Rice fermemntation in ambient temperature was impossible in cold season but suitable in hot season. On the other hand, fermented rice in ambient temperature with plastic bag-covered pot and room temperature were possible for fermented rice liquor in both cool and hot conditions or seasons. It was observed that fermented rice in ambient temperature with plastic bag-covered pot is a suitable way for producing rice liquor by rural farmers. It may be concluded that rice fermentation in room temperauture is the best way. The temperature between 30 to 38 degree Celcius of the rice fermentation condition was suitable for producing rice liquor in Cambodia within fermentation periods of 96 hours.

Table 3 Ethanol production per kilogram of milled rice

Fermented condition	Milled rice (kg)	Ethanol % (%)	Pure ethanol (L)	Liquor (L)	Productivity (L/kg)
CT	1	9.2[b]	0.09[b]	1	0.09[b]
AT	1	31.4[a]	0.31[a]	1	0.31[a]
ATPC	1	33.4[a]	0.33[a]	1	0.33[a]
HT	1	29.0[a]	0.29[a]	1	0.29[a]
RT	1	33.2[a]	0.33[a]	1	0.33[a]

CT = fermented rice in cool temperature, AT = fermented rice in ambient temperature, ATPC = Fermented rice in ambient temperature with plastic bag-covered pot, RT = fermented rice in room temperature and, HT = fermented rice in high temperature

Table 4 Temperature of fermented rice in different fermentation conditions (degree C)

Fermentation without water

	Mixed yeast		F 10 hrs		F 16 hrs		F 22 hrs		F 28 hrs		F 34 hrs		F 40 hrs		F 46 hrs	
	TM	AT	T	AT	T	AT	T	AT	T	AT	T	AT	T	AT	T	AT
CT	37.0	28.7	21.0[c]	18.7[c]	20.0[c]	19.0[d]	19.3d	19.0[d]	20.0[c]	19.0[c]	20.0[c]	19.0[c]	20.8[d]	19.3[d]	19.8[d]	18.5[d]
AT	37.0	28.7	34.0[b]	30.5[b]	31.8[b]	27.2[c]	29.5c	25.8[c]	32.5[b]	33.3[b]	35.0[b]	31.0[b]	31.2[c]	27.2[c]	29.3[c]	26.0[c]
ATPC	37.0	28.7	33.8[b]	30.8[b]	34.0[b]	27.7[c]	33.0b	26.5[c]	33.2[b]	33.8[b]	34.7[b]	31.5[b]	33.7[b]	27.7[c]	32.3[b]	26.7[c]
HT	37.0	28.7	39.2[a]	42.8[a]	39.2[a]	42.2[a]	39.7a	43.0[a]	39.0[a]	41.8[a]	39.8[a]	42.8[a]	39.0[a]	42.5[a]	38.5[a]	42.0[a]
RT	37.0	28.7	33.3[b]	32.7[b]	33.3[b]	30.8[b]	32.5b	30.0[b]	33.0[b]	32.7[b]	33.8[b]	32.5[b]	33.2[b]	30.8[b]	32.5[b]	30.0[b]
P <.05			**	**	**	**	**	**	**	**	**	**	**	**	**	**

Fermentation with water

	F 52 hrs		F 58 hrs		F 64 hrs		F 70 hrs		F 76 hrs		F 82 hrs		F 88 hrs		F 94 hrs	
	T	AT	T	AT	T	AT	T	AT	T	AT	T	AT	T	AT	T	AT
CT	19.3[c]	17.3[c]	19.3[c]	18.0[c]	19.0[c]	18.0[d]	19.0[d]	18.0[d]	19.3[d]	17.7[c]	20.7[c]	19.3[c]	18.8[d]	17.3[d]	19.5[d]	18.3[d]
AT	33.3[b]	34.8[b]	35.3[b]	31.8[b]	32.8[b]	28.3[c]	29.5[c]	25.5[c]	31.3[c]	32.8[b]	34.2[b]	31.0[b]	31.5[c]	27.5[c]	29.8[c]	26.2[c]
ATPC	33.0[b]	34.3[b]	34.0[b]	32.0[b]	34.2[b]	28.5[c]	33.7[b]	26.3[c]	33.7[b]	33.2[b]	34.7[b]	31.3[b]	34.0[b]	28.0[c]	33.2[b]	28.8[c]
HT	37.3[a]	41.8[a]	40.5[a]	42.5[a]	40.0[a]	41.8[a]	40.2[a]	42.0[a]	40.2[a]	41.2[a]	40.2[a]	42.0[a]	40.7[a]	41.3[a]	40.7[a]	41.8[a]
RT	32.5[b]	32.7[b]	33.7[b]	32.5[b]	34.0[b]	31.2[b]	33.0[b]	30.0[b]	33.5[b]	33.0[b]	33.8[b]	32.5[b]	33.7[b]	31.3[b]	32.7[b]	30.3[b]
P <.05	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

*TM = Temperature during mixed steamed rice with yeast, AT = Ambient temperature, T = Temperature in fermented rice, F = Fermentation period,Hr = Hour, * Significant, ** High significant*

The degree of ethanol percentage, pure ethanol and productivity were affected by fermentable temperature condition, as shown in Table 4. The degree of ethanol percentage, pure ethanol and productivity were strongly significant under different fermentation temperature conditions. Fermented rice condition in CT had the lowest productivity. Fermented rice condition in AT, RT, HT and ATPC showed similar production, but AT condition, suitable for hot season, losing its fermentative abilities in cool season. ATPC and RT produced stable liquor even in a cool or hot season. Fermented conditions were affected by the degree of ethanol percentage, pure ethanol and ethanol production. The alcohol yield is generally lower at elevated temperatures, which has been related to a drop in the ethanol yield and a reduction of substrate (Ribereau-Gayon et al., 1975; Llaurado, 2002; Torija et al., 2003).

Virender et al. (2000) showed that typical yield of alcohol from molasses is 0.225 l/kg when molasses contains 45% sugar, only 70-75% of the sugar get fermented to alcohol and the remaining sugars go into spent wash. On the other hand, in typical grain fermentation the alcohol yield is >0.36 l/kg of grain, containing 60% of starch which corresponds to 85% of conversion of sugar to

alcohol. An addition of sorghum can potentially give good yield of alcohol of about 0.38 to 0.39 litre of absolute alcohol per kilogram of grain provided and the process is optimized from 0.32 to 0.33 litre.

CONCLUSION

In summary, the fermention temperature affected the yeast activity, causing a decrease in the productivity of pure ethanol and ethanol percentages. The fermented rice in ambient temperature with plastic bag-covered pots and in room temperature were suitable temperatures for rice liquor production.

Temperatures between 30 to 38 ^{o}C were the best rice fermentation conditions. However, the amount of added water in fermented rice and period of fermented should be evaluated further.

REFERENCE

Fleet, G.H. and Heard, G.M. 1993. Yeast growth during fermentation. Wince Microbiology and Biotechnology, ed. G. H. Fleet Switzerland: Harwood Academic Publishers, 27-54.

Gina, J. 2004. Temperature at which beer is fermented. http://hypertextbook.com/facts/2004/GinaJohn.shtml.

Killian, E. and Ough, C.S. 1979. Fermentation ssters-formation and retention as affected by fermentation temperature. Am. J. Enol. Vitic. 30, 301-305.

Llaurado, J. M., Rozes, N., Bobet, R., Mas, A. and Constanti, M. 2002. Low temperature alcoholic fermentation in high sugar concentration Grape Must. J. Food Science, 67, 268-273.

Peterson, A. 1995. Production of fermentable extracts from cereals and fruits. Fermented Beverage Production (Lea, A.G.H, and Piggot, J.R., eds). London, UK, 1-31.

Ribereau-Gayon, J., Peynaud, E., Ribereau-Gayon, P. and Sudraud, P. 1975. Sciences Et Techniques Du Vin, Traité dÓenology IIParis: Dunod.

Ribereau-Gayon, P., Dubourdieu, D., Doneche, B. and Lonvaud, A. 2000. Handbook of Enology. The Microbiology of Wine and Vinifications Vol. I. West Sussex, England.

Robert, W. 2004. Mashing and fermentation. Heineken Brewing kettles, Amsterdam. http://running_on_alcohol.tripod.com/id20.html.

Sheorain V., Banka, R. and Chavan, M. 2000. Ethanol production from Sorghum. Technical and Institutional Options for Sorghum Grain Mold Management: Proceedings of an International Consultation, 228-239.

Torija, M.J., Rozes, N., Poblet, M., Guillamon, J.M. and Mas, A. 2003. Effects of fermentation temperature on the stain population of Saccharomyces Cerevisiae. Int. J. Food Microbiol, 80, 47-53.

Research article

New Biotechnologies for Sustaining Greener Agriculture

IVAN R. KENNEDY*
Faculty of Agriculture and Environment, University of Sydney, Australia
Email: ivan.kennedy@sydney.edu.au

NGUYEN THANH HIEN
Biofertilizer Action Center, Hanoi, Vietnam

PHAN THI CONG
Agriculture Green Future, Ho Chi Minh City, Vietnam

KHANOK-ON AMPRAYN
Faculty of Agriculture and Environment, University of Sydney, Australia

GANISAN KRISHNEN
Faculty of Agriculture and Environment, University of Sydney, Australia

MICHAEL ROSE
Faculty of Agriculture and Environment, University of Sydney, Australia

ANGUS CROSSAN
Faculty of Agriculture and Environment, University of Sydney, Australia

ZHANG YAN
Tianjin University of Science and Technology, Tianjin, People's Republic of China

WANG SHUO
Tianjin University of Science and Technology, Tianjin, People's Republic of China

Received 13 February 2012 Accepted 12 March 2012 (*: Corresponding Author)

Abstract Sustainable agriculture must face the challenge of sufficient productivity to feed and clothe up to 10 billion people this century. As a result, strictly organic methods, while environmentally welcome, can be no more than a partial solution because more land is needed than is available. However, recent development in a range of biotechnologies may provide safer environmental protection together with improving yields. For example, plant growth-promoting (PGP) microorganisms in Vietnam have been shown in field studies to offer reduced needs for seed, chemical fertilisers, pesticides, water and harvest yield losses. Interestingly, one PGP inoculant called BioGro was designed using validation of microbial strains from farmers' results; but these very same species are now being characterised in laboratories world-wide as PGP strains. Their laboratory analysis has shown similar traits as observed by farmers, such as extended root structure, nutrient mobilisation, biocontrol for pathogens and insecticidal activity. Despite less nutrient and pesticide needs and thus reduced environmental impacts, agrochemicals will still be needed for sufficient productivity. Research on tools for environmental risk management by farmers such as immunological ELISA analysis can also contribute here. Rapid 5-minute tests for monitoring both food and environment for pesticides can provide better stewardship of such chemicals, helping to ensure a 'greener future'.

Keywords nitrogen fixation, PGPR, safer pesticides, immunogold tests, risk management

INTRODUCTION

In this paper, two recent areas of biotechnology developments now being applied will be described. These are based on original research findings made in our group at the University of Sydney, in Vietnam and in China since around 2000 or earlier, leading to the application of these findings and their launching in a commercial format. More than 10 years has been required for this result, given the need for robust field research and extensive quality control of all outputs.

The two areas that will be described cover plant growth promoting microbes used to achieve nutrient efficient rice production and the development of rapid test kits for measuring pesticides used in crop production. Both of these outcomes are directed towards achieving more sustainable agriculture, by reducing environmental impacts and improving food safety.

MICROBIAL BIOFILMS AND PGPR RESOINSES ON RICE YIELDS

Microbial biofilms play an important role in agriculture and in food and fibre production. Whilst some microbial effects on crop plants are deleterious, it is increasingly recognised that biofilms may have strong beneficial effects in agriculture. Furthermore, realising these potential benefits is likely to play an increasing role in achieving sustainable solutions regarding improved crop yields and in human and environmental health. Such gains may be essential in the face of the increasing global population and climate change.

Plant growth promotion (PGP) for crops by microorganisms has been recognised for some time in biological nitrogen fixation (BNF) in legumes, shown in Germany in the late 19th century in the face of opposition by Justus Von Liebig. More subtle are the beneficial effects of the PGP microbes in cereals and other crops. These involve a complex of phytohormonal effects, nutrient mobilisation, BNF and biocontrol that benefit plant growth and overall yield (Kennedy et al. 2008). Essentially, it is possible to grow crops such as rice inoculated with microbes forming biofilms on the surfaces of their roots that allow significantly reduced input of chemical fertilisers, seed, pesticides and water, as well as reduced harvest losses.

In this paper we describe a successful biofertiliser, BioGro - now a commercial product in Vietnam invented by Professor Nguyen Than Hien; it consists of four microbial strains in peat (*Pseudomonas fluorescens*, *Bacillus* spp. and a soil yeast, *Candida tropicalis*) inoculated to the rhizosphere of rice seedlings (Nguyen et al., 2003; Phan et al., 2009, 2011). Remarkably, BioGro contained unidentified strains selected empirically on the basis of their effectiveness for rice farmers; later, these were identified in Australia to include species now recognised around the world in research laboratories as having a strong genetic basis for beneficial effects as inoculant biofertilisers (Kennedy et al., 2008).

As was the case about a century ago with legumes and the rhizobia that form N_2-fixing nodules on their roots, obtaining an effective outcome from applying these biofilm-forming organisms to crops in the field is challenging. It is important that inoculants of high quality in terms of particular microbial strains in sufficient numbers (ca. 10^7 -10^8 cells per g of inert carrier). Furthermore, convincing farmers of the beneficial effects and the scale of economic benefits possible, limiting their risk, is also important. An efficient supply chain that includes quality control and delivery of economic and environmental benefits from biofertilisers to farmers is also essential.

A strategy for simultaneously achieving environment-friendly and economic benefits developed in a World Bank Development Marketplace project *Sustaining nitrogen-efficient rice production* (DM2008), was developed. Recent unpublished research indicates the role of cyclic lipopeptides and phenazines produced by *Pseudomonas* sp. CMR12a in root colonization, biofilm formation and biological control of soil borne plant pathogens, regulation of insect plant-beneficial pseudomonad and insecticidal activity of plant-associated pseudomonads: how they became insect pathogens, aiding plant salt tolerance by tissue specific regulation of sodium uptake, thus conferring plant growth promotion with yield increases from less fertiliser (Nguyen et al., 2003; Phan et al., 2009, 2011) in the application of such microbes to crops as biofertilisers like BioGro still needs to be determined.

However, the results of a participatory action process with the application of BioGro at village level in the Mekong Delta has led to significant increase in the profitability of rice farming (Fig. 1). Fig. 1 shows plots of yield ratio to profit ratio that farmers using BioGro replacing about 40% of urea application can obtain as greater yields and profits as a result of better tillering, lower N-fertiliser inputs, reduced pesticide inputs, improved water use efficiency and reduced harvest losses as machine harvesting could occur more promptly. The tendency to be in the top sector with ratios greater than 1.0 increased with experience, most of the values falling below 1.0 occurring in the summer-autumn crop of 2009 during the third crop before the annual flood in September when soil condition was acid sulphate and nutrients were low and soil toxicity greatest. Crops on the same plots twelve months later nearly all had ratios exceeding 1.0.

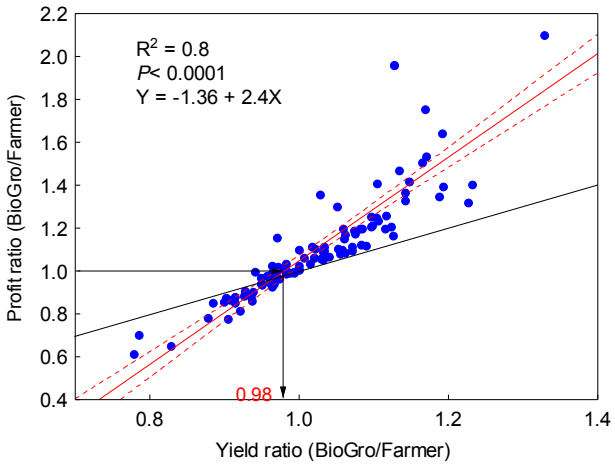


Fig. 1 Yield and profit ratios over four crops comparing farmers using 100 kg of BioGro reducing urea inputs to about 60% compared to normal farmer practice (100 kg urea-N per ha) on individual plots less than 1 ha are shown. T

An imperative here for success of this biotechnology shown in Fig. 1 with BioGro is ensuring the quality control of these inoculants; the correct strain species in the correct numbers must be present in commercial inoculant products. Using techniques similar to those employed to produce immunogold tests for herbicides described in more detail below, we have also generated similar immogold tests for beneficial PGPR microbes such as *Pseudomonas fluorescens*, one of the key components of BioGro (see Fig. 1).

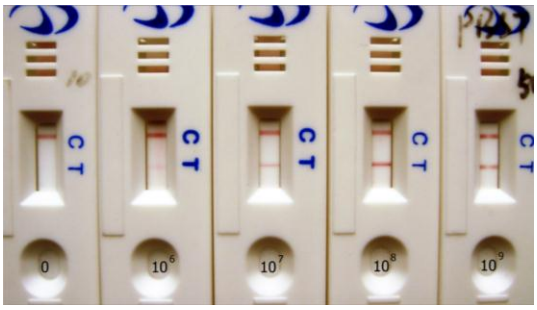


Fig. 2 Rapid immunogold quicktests for 1N (*Pseudomonas fluorescens*), a component of BioGro used in rice production

The test lines (T) show increasing concentrations of 1N (cfu's per mL). These devices are being applied to testing commercial peat cultures as part of their quality control, ensuring that specific strain cell numbers exceed 10^6-10^7 viable cells per g.

QUICK IMMUNOTESTS FOR HERBICIDES

In our research, three polyclonal antibodies against herbicides used in cotton growing, diuron, fluometuron and prometryn for the preparation of rapid lateral flow immunogold tests have recenly been developed. We will provide some details of the preparation of two of these rapid tests, for diuron and prometryn.

1. Diuron

A rapid immunotest for diuron was developed using published techniques. Haptens were synthesised as indicated. The hapten was attached to the protein carriers of keyhole limpet hemocyanin (KLH), bovine serum albumin (BSA), ovalbumin(OVA) and horseradish peroxidase (HRP) using the active ester method. The conjugates of hapten 4C-KLH, hapten 6C-KLH, hapten 4C-BSA and hapten 6C-BSA were all used as immunogens.

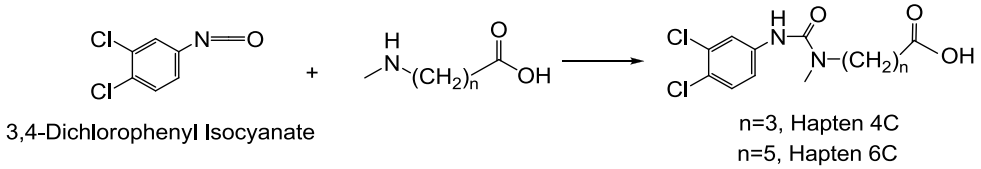


Fig. 3 Preparation of haptens for antibodies reactive with diuron

Sensitivity of the test could be controlled by varying the length of the coupling group used for conjugation to protein for injection into rabbits

A pair of male rabbits was immunized with each immunogen. Test results showed that rabbits immunized with the conjugate of hapten 4C-KLH produced the best specific antibody. To test the suitability of the antibodies, competitive indirect ELISA microtiter plates were coated with 100 µL per well of hapten 4C-OVA (0.1 µg mL^{-1} in 50 mM carbonate buffer, pH 9.6) overnight at 4 ^{o}C. The following day, the plates were washed with PBST and blocked with 200 µL per well of 0.5% milk powder diluted in PBS. 50µL per well of diuron and 50 µL per well of rabbit anti-diuron pAb (1 µg mL^{-1}, diluted in PBS) were added. Plates were shaken gently for one minute before incubated for 1 h at 37 ^{o}C. Then the plates were washed again with PBST, and 100 µL per well of 10000-fold diluted secondary antibody were added and incubated at 37 ^{o}C for 30min. After another washing step, 150 µL per well of substrate were added and incubated for 15 min. The enzyme reaction was stopped with 1.5 M H_2SO_4 and the plates were read at 450 nm (reference 650 nm). Having shown the suitability of the IgG, immnogold strip tests were prepared. Full details of their manufacture will be published elsewhere.

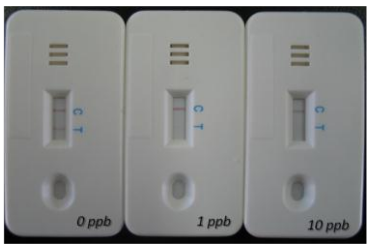
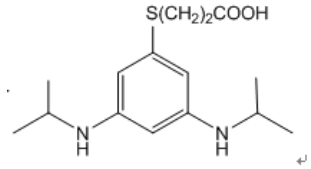


Fig. 4 Diuron Quick Test

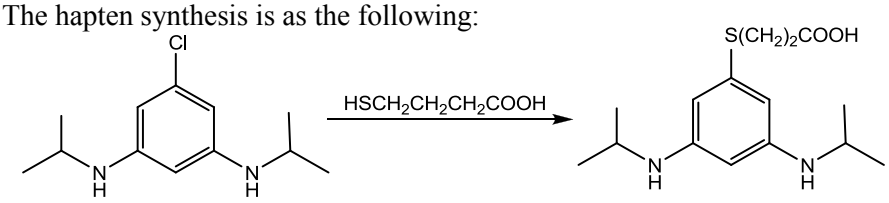
As test water samples contain diuron as a contaminant, the test line (T) disappears, The control line, containing non-specific antibody (C) indicates the antibody test is effective

2. Prometryn

The following is the chemical structure of the hapten for prometryn:



The hapten synthesis is as the following:



The hapten was attached to the protein carriers bovine serum albumin (BSA), using the N-hydroxysuccinimide active ester reaction Hapten-BSA was used as immunogen. The titre of the serum produced was 160,000, which was purified by protein A-sepharose-4B.

The optimization of a direct competitive ELISA for prometryn is ongoing, under the preliminary condition of ELISA, IC50 is 0.4 ppb.

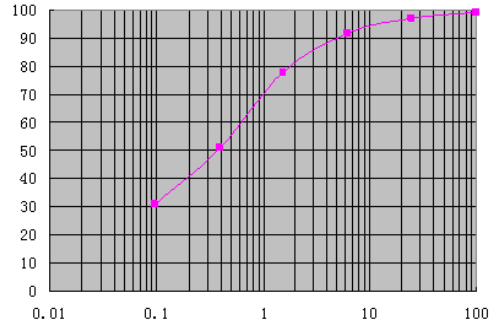


Fig. 5 The standard curve of direct competitive ELISA for prometryn

Immunogold tests for pesticides based on these ELISA results are currently in preparation

CONCLUSION

Farmers need many new tools to assist them to achieve sustainable agricultural practices. In this paper, we have described two areas where biotechnology has allowed advances that both help achieve higher crop yields for rice and also allow farmers to manage environmental risk regarding their application of agrochemicals. We plan to generate a large range of such rapid tests, including some for screening food products for aflatoxin produced by *Aspergillus flavus*. The availability of such rapid tests at a reasonable cost will provide tools supporting best management practices.

Organic production of crops is a worthwhile aim when consumers of farm products can afford to pay the higher costs. Organic production requires at least 50% more land than conventional agriculture so that only a small proportion of organic products can be expected without clearing more forests. With global climate change, this is unacceptable. But feeding the world sustainably will require most food to be grown using all farming tools available, leaving choices of the best production systems to farmers. Government agencies must support farmers to make the best choice and to undertake stewardship. Banning chemical products and farming practices such as land clearing is counterproductive. Far better for farmers to volunteer protection of the environment, using modern biotechnology such as that described in this article.

REFERENCES

Cong, P.T., Dung, T.D., Hien, T.M., Hien, N.T., Choudhury, Abu T.M.A., Kecskés, M.L. and Kennedy, I.R. 2009. Inoculant plant growth-promoting microorganisms enhance utilisation of urea-N and grain yield of paddy rice in southern Vietnam. European Journal of Soil Biology, 45, 52-61.

Hien, N.T., Deaker, R., Kennedy, I.R. and Roughley, R.J. 2003. The positive yield response of field-grown rice to inoculation with a multi-strain biofertiliser in the Hanoi area, Vietnam. Symbiosis 35, 231-245.

Kennedy, I.R., Choudhury, A.T.M.A., Kecskes, M.L. and Rose, M.T. (eds.) 2008. Efficient nutrient use in rice production in Vietnam achieved using inoculant biofertilisers. Proceedings of a project (SMCN/2002/073) workshop held in Hanoi Vietnam, 12-13 October 2007, ACIAR Proceedings, No. 130 137. Canberra ACT. www.aciar.gov.au.

Research article

Nitrogen and Phosphorus Released from Coconut Husk during Retting Treatment

JULIAN E. TORILLO JR.
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan
Email: juliantorillo@yahoo.com

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: m-mihara@nodai.ac.jp

Received 14 January 2012 Accepted 12 March 2012 (*: Corresponding Author)

Abstract Upland fields in Bohol of the Philippines are mostly located on areas with high slopes resulting in soil erosion. Although coconut husk has been applied as buffer strips for eliminating soil erosion, attention has been paid to the loss of nitrogen and phosphorus components not only discharged from synthetic fertilizer applied in upland fields but also those released from coconut husk. The leached nutrients associated with surface runoff and percolation water may cause pollution downstream. Thus, efficient utilization of the nutrient components from coconut husk is necessary from a view point of conservation agriculture in Bohol, Philippines. This study sought to find out the amounts of nitrogen and phosphorus in coconut husk, to quantify the amounts of nitrogen and phosphorus released from coconut husk during the pretreatment by retting process and to observe the optimum period of releasing nutrients from coconut husk. Retting of coconut husk were carried out for 140 days and small amounts of ret liquor was sampled at certain days of interval for nitrogen and phosphorus analyses. Based on the experimental results, it was observed that releasing nutrients from coconut husk rapidly increased from the starting day up to ten days of retting. Even after ten days, nutrient components released from coconut husk tended to increase gradually. It was also proven that about 87% of its phosphorus and 10% of its total nitrogen was released from the coconut husk. Therefore, it was concluded that coconut husk has a high tendency to release nutrients during the retting process, particularly for phosphorus component that can be a source for bio-fertilizer.

Keywords coconut husk, retting, nitrogen, phosphorus, bio-fertilizer

INTRODUCTION

Upland fields with protruding stones and rocks on ground surfaces as well as abandoned farmlands are dominant particularly in the southwestern part in the island of Bohol (Torillo and Mihara, 2011). Moreover, these lands are mostly located on slopes of areas with 8-18% and even some portions with more than 18% slope, particularly for subsistence agriculture (OIDC, 2006). Together with high squalls, uplands in the island are susceptible to soil erosion causing rapid degradation of land with the decrease of crop quality and yields.

To replenish the nutrients required by crops and to increase crop yields, local farmers choose to apply synthetic fertilizers. However, high prices of synthetic fertilizers lead to scarcity of these resources, particularly on phosphorus. Cordell et al. (2009) reported that phosphorus is mainly obtained from mined rock phosphate and its reserves could be exhausted in the next 50-100 years (Steen, 1998; Smil, 2000b) thus an effective approach to the management of phosphorus cycle is necessary. On the other hand, coconut husks that were installed as buffer strips for soil erosion control tended to release nitrogen and phosphorus. This tendency was observed during the slope modeling under artificial rainfall simulator (Torillo and Mihara, 2011). Those nutrients released from the coconut husk may leach through percolation and surface runoff resulting water pollution in downstream. Therefore, treating of coconut husk before its installation as buffer strips through

retting has been recommended. However, improper management on the treatment process may cause pollution to surface waters as well. Bijoy (1997) reported that coconut husk retting activity has caused large scale organic pollution with the mass destruction of flora and fauna, foul smelling stagnant waters in Kerala, India. Also, Ambika and Gopalakrishna (1990) added that pectin, pectosan, fat, tannin and also toxic polyphenols are liberated into ambient water by the activity of bacteria and fungi in the coconut husk retting area in backwaters at Cochin, India.

Thus, making use of the nutrient component in coconut husk for liquid bio-fertilizer has been desired. The objectives of this study were 1) to find out the amounts of nitrogen and phosphorus in coconut husk at different portions and layers, 2) to quantify the released amounts of nitrogen and phosphorus from the coconut husk during the retting treatment, and 3) to determine the optimum period for retting of coconut husk.

MEHODOLOGY

To find out the total amounts of nitrogen and phosphorus in the coconut husk, a preliminary analysis was carried out. The following procedure was also aimed to find out which portions and layers of the coconut husk have lower concentration of total nitrogen (T-N) and total phosphorus (T-P) that could be applicable as buffer strips for soil erosion control in order to mitigate the releasing of nutrients from coconut husk. As shown in Fig. 1, coconut husk were cut into three portions as bottom, middle and top then were sliced into three layers as inner, middle and outer then the bark layer. Pith and fiber were segregated, and were crushed into powder. Crushed pith and fiber were then analyzed for T-N and T-P components.

a) Cross-section of coconut husk *b) Segregated fiber, pith and bark* *c) Pulverizing of fiber, pith and bark*

Fig. 1 Preparation process for preliminary analysis of total nitrogen (T-N) and total phosphorus (T-P) in coconut husk

a) Minor pounding by hammer *b) Retting into cylinders with distilled water*

Fig. 2 Procedure of pretreating coconut husks

The coconut husks utilized as buffer strips for soil erosion control had released nutrient components, so it was proposed to carry out the pretreatment of the coconut husks by retting before installing into the site. To quantify the amount of T-N and T-P released from the coconut husk

during the retting treatment, the analysis of those nutrients in the ret liquor was carried out. Retting of coconut husk was performed using the following procedures; firstly, coconut husks were moderately pounded by hammer (Fig. 2) to produce porous material similar to that being installed into the site as buffer strips. Pounded coconut husks of 119.22 g in dry mass were then immersed into the 4,600 ml of distilled water.

Secondly, sampling of water soaked with coconut husk or so called ret liquor was done at certain days of intervals within 140 days. Thirdly, ret liquor samples were analyzed for T-N and T-P after the decomposition with sodium hydroxide (NaOH) and potassium peroxodisulfate ($K_2S_2O_8$) then the concentrations of T-N and T-P were measured by spectrometric methods (Mihara and Ueno, 2000).

RESULTS AND DISCUSSION

Amount of nitrogen and phosphorus in coconut husk

Coconut husks were portioned, layered and then pith, fiber and bark were segregated for analyzing the amount of total nitrogen (T-N) and total phosphorus (T-P). Based on the experimental results, it was found out that every portion of the coconut husk has different concentrations of T-N and T-P (Figs. 3 and 4).

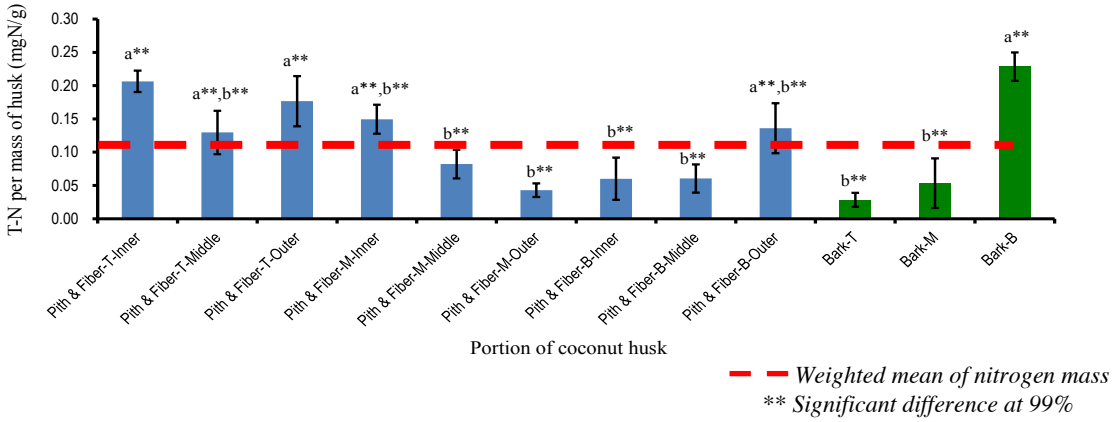


Fig. 3 Amount of total nitrogen (T-N) per dry mass of pith, fiber and bark at top (T), middle (M) and bottom (B) portions of coconut husk

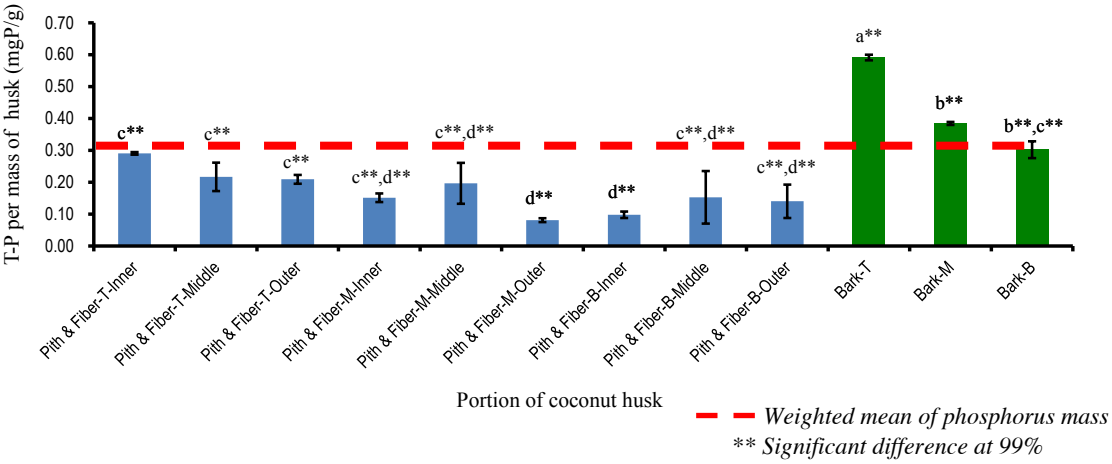


Fig. 4 Amount of total phosphorus (T-P) per dry mass of pith and fiber, and bark at top (T), middle (M) and bottom (B) portions of coconut husk

Most of the top portions showed significantly higher in the amounts of T-N and T-P than that of the middle and bottom portions. Top portion of the coconut husk is highly concentrated with T-N and T-P, it may be because of the pedicel and embryo (Fig. 1a) that are located in the top portion of the husk and nut. As Rancic et al. (2010) reported that water and nutrients which fruit growth depends on is transported from the stem into the fruit through the pedicel by xylem and phloem. The embryo which germinates at microphyle (Chan and Elevitch, 2006) develops a haustorium that provides a conduit for the supply of nutrients from kernel into the germinating embryo (Foale, 2003). These conditions might be the factors that most nutrients are accumulating at the top portion of the coconut husk.

As shown in Fig. 3, the weighted mean of T-N in the coconut husk was 0.1138 mgN/g and a significant difference at 99% was observed among portions. For the amounts of T-P, a weighted mean at 0.3037 mgP/g and also a significant difference at 99% were observed among the portions of coconut husk (Fig. 4).

Optimum retting period of coconut husk

Coconut husks were retted within 140 days and then the ret liquor samples were collected at certain days of interval for nitrogen and phosphorus analyses. It was observed that a remarkable increase in total nitrogen (T-N) and total phosphorus (T-P) components in coconut husk ret liquor from the starting day of retting up to a certain period of time then tended to increase gradually further.

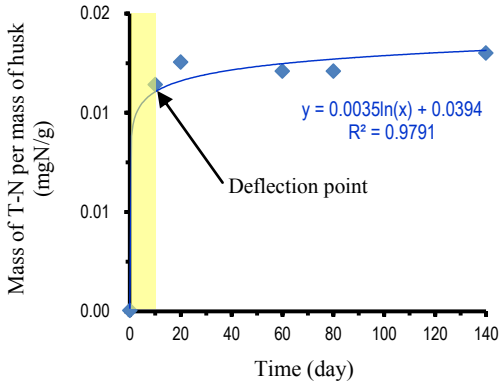


Fig. 5 Amount of T-N released from coconut husk into ret liquor

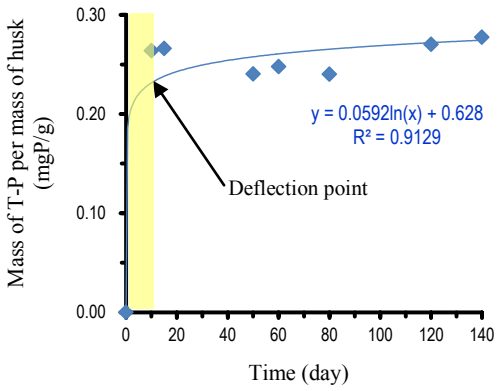


Fig. 6 Amount of T-P released from coconut husk into ret liquor

Based on the logarithmic curve as shown in Figs. 5 and 6, the deflection point lies approximately on the tenth day of retting. This trend indicates that up to the tenth day from the starting day of retting, T-N and T-P rapidly released from coconut husk. After then, the trend changed to release gradually of those nutrients. The results suggested that ten days of retting is an adequate period of pretreating the coconut husk when its nutrient components are mostly released.

Amounts of nitrogen and phosphorus released from coconut husk during the retting treatment

Coconut husks were retted in distilled water and ret liquor samples were collected at certain days of interval for total nitrogen (T-N) and total phosphorus (T-P) analyses. It was suggested that ten days retting of coconut husk is an adequate period of pretreating the material. As shown in Fig. 5, the amount of T-N released into the ret liquor was 0.0114 mgN/g during the tenth day. Based on the weighted mean of T-N in coconut husk as shown in Fig. 3 was 0.1138 mgN/g therefore it was proven that 10.01% of T-N was released from the coconut husk during the retting treatment.

Fig. 6 shows the amount of T-P in the ret liquor where 0.2639 mgP/g was released into the ret liquor during the tenth day of retting which is 86.89% in the weighted mean of 0.3037 mgP/g that is being shown in Fig. 4. Although, it was clearly observed that T-N and T-P were released from

the coconut husk during the retting treatment, a confidence interval was not observed. It was also indicated that the amounts of T-P released from the coconut husk during the retting period was significantly higher than that of T-N.

CONCLUSION

For sustainable use of resources, utilizing the nutrient components from the coconut husk which is locally available and a renewable resource in the region has good value. So, this study dealt with the optimum retting period of coconut husk to release its nitrogen and phosphorus components. The quantification of the amounts of nitrogen and phosphorus released from coconut husk into the ret liquor during the retting treatment were also sought to be found out of this study. However, as a fundamental basis on the quantification of nitrogen and phosphorus released into the ret liquor, finding out the amounts of T-N and T-P in the coconut husk is necessary. Thus, analyses on the amounts of T-N and T-P in the coconut husk were also carried out.

It was found out that the weighted mean of T-N and T-P in coconut husks were 0.1138 mgN/g and 0.3037 mgP/g, respectively. The experimental results also indicated that rapid release of nutrient from coconut husk during the tenth day of retting. During the tenth day period, 0.0114 mgN/g accounted for about 10% of 0.1138 mgN/g in coconut husk was released into the ret liquor. Meanwhile, phosphorus component was 0.2639 mgP/g accounted for about 87% of 0.3037 mgP/g in coconut husk has been released from the retted coconut husk into the ret liquor.

Therefore, it was concluded that ten days is enough period of treating the coconut husk by retting treatment. At this period, about 87% of T-P component from the coconut husk while about 10% of T-N were released during the retting treatment. Thus, rich amount of nutrient component particularly on phosphorus could be extracted from the coconut husk by retting method within ten days which could be the suitable source for bio-fertilizer.

ACKNOWLEDGEMENT

We would like to acknowledge the support of President Dr. Elpidio T. Magante of Bohol Island State University for his meaningful guidance and advice.

REFERENCES

Ambika, D.M. and Gopalakrishna, P.N. 1990. Effect of pollution due to coconut husk retting on the south-west coast of India. Indian Journal of Fisheries, 37(2), 145-149.

Bijoy, N.S. 1997. Retting of coconut husk: A unique case of water pollution on the southwest coast of India. International Journal of Environmental Studies, 52, 335-355.

Chan, E. and Elevitch, C.R. 2006. Cocos nucifera (coconut). Species Profiles for Pacific Island Agroforestry, 2-1, 1-27.

Cordell, D., Drangert, J.O. and White, S. 2009. The story of phosphorus: Global food security and food for thought. Global Environmental Change, Elsevier, 19, 292-305.

Foale, M. 2003. The coconut odyssey: the bounteous possibilities of the tree of life. Australian Centre for International Agricultural Research, 44-46.

Mihara, M. and Ueno, T. 2000. Nitrogen and phosphorus transfer in soil erosion processes, IAHS Publication, No. 263, 109-115.

Orient Integrated Development Consultants Inc. 2006. Bohol Agriculture Master Plan, CY2006-2026.

Rancic, D., Pekic, S. and Pecinar, I. 2005. Anatomy of tomato fruit and fruit pedicel during fruit development. Microscopy: Science, Technology, Applications and Education, 851-861.

Smil, V. 2000b. Phosphorus in the environment: Natural plows and human interferences. Annual Review of Energy and the Environment, 25, 53-88.

Steen, I. 1998. Phosphorus availability in the 21st Century: Management of a non-renewable resource. Phosphorus and potassium, 217, 25-31.

Torillo, J.Jr. and Mihara, M. 2011. Soil erosion control by coconut husk buffer strip in Bohol island of Philippines. International Journal for Environmental and Rural Development, 2(1), 25-30.

Research article

Pollination of *Apis mellifera* and *Trigona biroi* on the Productivity of Solanaceous Crops

JOSE T. TRAVERO*
Bohol Island State University, Bohol, Philippines
Email: jose_travero@yahoo.com

IAN L. NUEZ
Bohol Island State University, Bohol, Philippines

WELLIE S. SAGLIBA
Bohol Island State University, Bohol, Philippines

Received 16 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract This study was conducted to determine the effects of bee pollinators (*A. mellifera and T. biroi*) on the productivity of solanaceous crops. Two observation sites were selected for conducting this study. One was intended for the *A. mellifera* and other site for *T. biroi*. A randomized complete block design (RCBD) was laid out with four blocks and three replicates. Solanaceous crops used in the study were eggplant, tomato and sweet pepper. Of the three solanaceous crops, analysis of variance showed that *A. mellifera* had a highly significant effect at 1% level of significance on the percent pollinated flowers of eggplant. However, both bee pollinators had shown the same significant effects on sweet pepper and tomato. Furthermore, this study revealed that both *A. mellifera and T. biroi* are very efficient pollinators of eggplant crop. Eggplant is the best solanaceous crop with highest pollination efficiency to *A. mellifera* and *T. biroi*.

Keywords bee-pollinated, pollinators, solanaceous, stingless bees

INTRODUCTION

Pollinators strongly influence ecological relationship, ecosystem conservation and stability, genetic variation in the plant community, floral diversity, specialization and evolution. In farmed areas, bees are needed for the pollination of many cultivated crops for fruit and seed set and for maintaining biodiversity in 'islands' of non-cultivated areas. The main role of bees in the different ecosystems is their pollination work.

Being tropical, stingless bees are active all the year round although they are less active in cooler weather. The *Trigona* species is one of the known species of honeybees that are endemically living in the Philippines. This kind of bees is lacking of sting; in fact, they are harmless to humans but they defend by biting if their nest is disturbed. They are noted as good pollinators, the behavior of the most efficient pollinators carry plenty of pollens, visit several flowers of the same species in succession and move frequently from flower to flower and plant to plant. Foraging of these bee workers are mainly for pollen-gathering due to a very short tongue needed for gathering nectar.

On the other hand, honeybee or *Apis mellifera* originated in Europe and is widely popular among beekeepers for honey production is now widely used in commercial pollination. Beekeepers may quote a figure, courtesy of the USDA, that honeybees pollinate 80% of the U.S. crops that require pollination. According to researches, bee pollination increased crop production by 30% (Baconawa, 2002). This was the reason why the researchers came up with this idea to study about bee pollination among the solanaceous crops chosen for this research. Through natural pollination of the stingless bees, it would determine if it could contribute to productivity and increase yield quality and quantity. Hence, this study was conceptualized and conducted through actual and practical field observations.

OBJECTIVES

The primary aim of the study was to determine the pollination efficiency of both Honeybees (*Apis mellifera*) and Stingless bees (*Trigona biroi*.) to three solanaceous crops, namely; (a) Eggplant (*Solanum melongina*), (b) Tomato (*Lycopersicon esculentum*), and (c) Sweet pepper (*Capsicum anuum*). Specifically it sought to determine the percentage of fruit set between bee pollinated and non-bee pollinated.

METHODOLOGY

Research design and the research environment: The study on stingless bees was conducted at the upland area of the Oikos Peace Garden in Zamora, Bilar Bohol. The type of soil was sandy loam. The solanaceous plants were exposed to sunlight during the whole day. While the honeybees are at the Eco-farm, BISU-Bilar, Zamora, Bilar, Bohol, it is a flat open area with sufficient sunlight, alkaline soil and good drainage.

Randomized Complete Block Design (RCBD) was laid out at the experimental areas. The experimental lot had an area of 263.44 sq.m. There were four blocks representing the replication that had three plots per block measuring 3.2 m x 3.6 m per plot. One meter distance between blocks and plots served as an alleyway and at the same time the borders in the whole area. The planting distance was 60 cm. between hills and rows, allowing distance of 80 cm. in between the bee-pollinated and non-bee pollinated plants to provide a space for the construction of covers.

Research materials: The materials used in the study were the following: plow, meterstick, bamboo slats, wood, nails, honeybee colony, stingless bee colony, fine nets, solanaceous crops (eggplant, tomato, sweet pepper), bolo, seedling trays, vermicast, hammer, and weighing scale.

The plants opened for bee pollination were labeled Bp or Bee-pollinated, while the plants that were not pollinated by bees were labeled NBp or Non bee-pollinated. The code used for eggplant was 1(one), 2 (two) for tomato and 3 (three) for sweet pepper.

Construction of net covers: The construction of net cover was done by block one month after transplanting and after the second fertilizer application. The first ten plants from the right side of a plot were the Non-bee pollinated constructed with net covers. The net cover was 1.6 m in height.

Introduction of honeybees and stingless bees: The introduction of honeybees and stingless bees was done before transplanting to provide enough time for them to adjust the condition of the area. The hives were installed at a distance of 50 m. from the experimental area. Six hives were used in the study.

Data collection and analysis: Data collection started from the flowering stage up to the fruiting stage. Counting the flowers per hill for three times with an interval of one week was done to gather the total number of flowers per treatment. The same process was done during the fruiting and the harvesting stages.

The gathered data were tabulated and analyzed through the assistance of the Statistician. Analysis of Variance (ANOVA) was used for the statistical treatment of data.

Fig. 1 One of the two experimental areas (left) and colonies of stingless bees

RESULTS AND DISCUSSION

Table 1 shows the average percent pollination of stingless bee. It shows that Eggplant had the highest percent of pollination of 54.80 while Tomato had the lowest percent of pollination of 32.87.

Table 1 Average percent pollination of stingless bee

Crops	Block				Treatment total	Treatment mean
	I	II	III	IV		
Eggplant	36.36	56.25	72.72	53.85	219.18	54.80[a]
Sweet pepper	27.10	37.54	36.16	37.60	138.40	34.60[b]
Tomato	34.13	30.59	32.32	34.45	131.49	32.87[b]
Grand Total					489.07	
Grand Mean						40.76

Means within treatment mean column followed by a common letter are not significantly different at 0.05 level of probability using Least Significant Difference (LSD) test

Table 2 Analysis of variance on the average percent pollination of stingless bee

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Computed F	Tabular F	
					5%	1%
Block	3	328.359	109.453			
Treatment	2	1188.56	594.279	8.46*	5.14	10.92
Expt'l Error	6	421.718	70.2864			
Total	11	1938.63				

*cv = 20.6%, * = Significant at 5% level*

Table 2 presents the analysis of variance on the average percent pollination of stingless bee. It shows that there is significant ($P<0.05$) difference among treatments since the computed F value of 8.46 is higher than the Tabular F value at 5% level (5.14) but lower than 1% level (10.92) of significant. On the other hand, Eggplant is the best solanaceous crops with highest pollination efficiency of stingless bee (*Trigona biroi*) compared to sweet pepper and tomato (Table 1). This implies that stingless bees are more efficient on eggplant crops compared to sweet pepper and tomato.

Table 3 shows the average percent pollination of honey bee. It shows that eggplant had the highest percent of pollination of 86.45 while sweet pepper had the lowest percent of pollination of 25.68.

Table 3 Average percent pollination of honey bee

Crops	Block				Treatment total	Treatment mean
	I	II	III	IV		
Eggplant	100.00	55.69	90.11	100.00	345.80	86.45[a]
Sweet pepper	22.77	13.61	40.33	26.01	102.72	25.68[b]
Tomato	18.88	23.22	48.12	20.18	110.40	27.60[b]
Grand Total					558.92	
Grand Mean						46.58

Means within treatment mean column followed by a common letter are not significantly different at 0.05 level of probability using Least Significant Difference (LSD) test

Table 4 presents the analysis of variance on the average percent pollination of honey bee. It shows that there is significant ($P<0.01$) difference among treatments since the computed F value of 28.46 is higher than the Tabular F value at 5% level (5.14) but lower than 1% level (10.92) of significant.

Furthermore, eggplant is the best solanaceous crops with highest pollination efficiency of honey bee (*Apis millefera*) compared to sweet pepper and tomato (Table 3). This implies that Honeybees are more efficient on eggplant compared to sweet pepper and tomato.

Table 4 Analysis of variance on the average percent pollination of honey bee

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Computed F	Tabular F	
					5%	1%
Block	3	1260.66	420.219			
Treatment	2	9546.67	4773.33	28.46**	5.14	10.92
Expt'l Error	6	1006.36	167.726			
Total	11	11813.70				

*cv = 27.8%, ** = highly significant at 1% level*

CONCLUSION

Based on the findings of the study, the researchers concluded that both honeybees (*A*. *millefera*) and stingless bees (*Trigona biroi*) are efficient in pollinating solanaceous crops. *A millefera*, however is more efficient than *T*. *biroi* particularly on eggplants. This can be attributed to the bigger size of the flower of eggplant compared to the size of the flower of other solanaceous crops under study. Other factor could be the size of *A*. *millefera* which is obviously bigger comparatively with *T*. *biroi*.

REFERENCES

Amano, K., Nemoto, T. and Heard, T. 2000. What are stingless bees, and why and how to use them as crop pollinators? A review of JARQ 34(3), 183-90.

Baconawa, Antonio Jr. 2000. The economics of bee pollination in the Philippines.

Bispo dos Santos, Roselino, S.A.A.C., Hrncir, M. and Bego, L.R. 2009. Pollination tomatoes by the stingless bee *Melipona quadrifasciata* and the honey bee *Apis mellifera* (Hymenoptera, Apidae), 8(2), 751-757.

Heard, T.A. 1999. The role of stingless bees (Meliponinae) in crop pollination. Annual review of entomology, 44: 183-206

Pollinator Partnership Protection and Funding Farm Bill Programs, 2008.

Stinglessbees-Wikipedia, The free Encyclopedia, June 2009. http://en.wikipedia.org/wiki/stinglessbee.

Squidoo. 2000. Stingless bees-2009, http://www.squidoo.com/stingless-bees.

Yousef Ahmad Al-abbadi, S. 2009. Efficiency of different pollination treatments on solanaceae yields grown in Plastic House. J. Biot. Sci., 9P 463-469, http://emkerci.com/articles/ns/pollination_Philippines.htm.

Research article

Socio-Economic Assessment for Proposing Alternative Livelihood Strategy of Minority Villagers, Ratanakiri and Stung Treng Provinces

NARA CHAN*
Graduate School, Royal University of Agriculture, Phnom Penh, Cambodia
E-mail: nara_c86@yahoo.com

NUTH CHUM
Graduate School, Royal University of Agriculture, Phnom Penh, Cambodia

COLAS CHERVIER
Graduate School, Royal University of Agriculture, Phnom Penh, Cambodia

Received 15 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract Ratanakiri and Stung treng provinces are located in northeast of Cambodia. There are riches of natural landscape which is abundant with many rice fields, lakes, waterfalls, rivers as well as vast areas of forest. This research was focused on relative importance of activities related to farming and natural resources collection in terms of revenue and occupation at the household level and the way people benefit from communities and natural resource. 120 samples were selected for household survey. Stratified random sampling was used to interview rich, medium and poor households. Other primary data collection methods including questionnaire survey, observation; key informant interviews were also implemented. This study showed that rice farming and shifting farm (Chamkar) are the main sources of food consumption and supplementary income for their living in the four villages. But non-timber forest product (NTFPs) collection and wildlife poaching are the main sources of income for the rural livelihoods in remote village in the forest. Local communities in the village studied preferred to poach the wildlife by dog hunting and crossbow and collecting malva nut tree by cutting down in average 10 malva nut tree per household in year round. However, livestock production was the other livelihood activities because local communities can raise chicken, duck, pig, cow and buffalo for selling, household consumption, agricultural activities and spirit Areak (Kavet people). The income that came from natural resource was high but this trend was not sustainable for the future. The natural resource is decreased day by day due to the illegal activities, the local communities do not know how to harvest or collect in the sustainable way. By the way, improvement of agriculture sector in the targeted area is the good way to improve their livelihood and avoid the negative affected to the natural resources.

Keywords minority, socio-economic, assessment, natural resource.

INTRODUCTION

Ratanakiri and Stung treng are located in northeast of Cambodia. There are riches of natural landscape which is abundant with many rice fields, lakes, waterfalls, rivers as well as vast areas of forest. Those provinces are place of ethnicities such as Kavet, Lao, Tumpun, Kachock, Jarai, Kroeung, Preo, Kouy, Lun, Islam, Chinese, and Khmer (Ian et al., 1996). Most of them are farmer, who like to live on the mountain and in the forest. They are doing shift culture, hunting, finding NTFPs for their livelihood (Sopheap 2004). Their livelihood depend on forest resource are decrease and start change to agriculture instead (Chea, 2008). The villagers who do not possess domestic animal are involved most in poaching to feed their families. This research need to do base line survey in four

villages. It conducted to the Socio-Economic Assessment for proposing alternative Livelihood Strategy of Minority villagers, Ratanakiri and Stung treng provinces.

Three hypotheses have been set in this research. First, natural resources are contributes significantly to the households' livelihood and income living in the target village. Second, natural resources are managed in such a way that it does not contribute to the development of local communities and conservation in a sustainable manner. Third, income from natural resources use is higher than income from agriculture activities in the village.

Accordingly, the objectives of this study are to assess the relative importance of activities related to farming and natural resources collection in terms of revenue and occupation at the household leve and to describe the way people benefit from communities and natural resource.

The studied topic focuses on socio-economic of the local people get from natural resources (NTFPs, wildlife), farming, and other activities, farming practice and natural resource management. Due to the time and human resource constraints, sample size of the research is not statistically computed. Only 120 households will be randomly selected from the four villages which 2 in Ratanakiri and 2 in Stung Treng provinces.

METHODOLOGY

Site selection: The study (thus) corresponds to a baseline survey. Other justification for selecting these target villages include: high-dependence of local communities on natural resources associated with a depletion of natural resources caused by various causes including illegal activities. Richness in terms of biodiversity makes this area of high priority for conservation: high occurrence of endangered mammals.

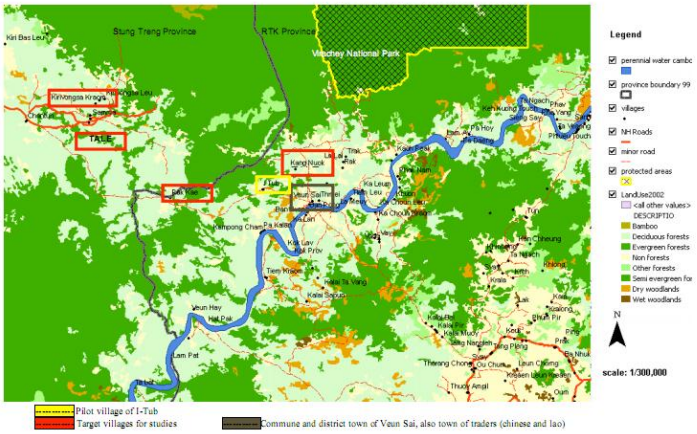


Fig. 1 Map of study area

Household selection: The first step was to do a wealth ranking exercise whereby each village was divided into three wealth levels, namely "poor", "medium" and "better-off". A random sampling approach was randomly selected among four villages (Table 1).

Table 1 Sample size for study

Village	Total households	Sample size	Percentage
Talae	123	30	25
Kapin	88	30	34
Backae	77	30	39
Kang Nuok	84	30	36

Source: field survey, 2010

One hundred twenty households were selected by using the following formula (Yamane, 1967):

$$n = \frac{N}{1+N(e)^2}$$

n: Total numbers of samples to be selected for interview
N: Total number of household
e: Acceptable bias (±7.5%)

Key informants: After the observations have been conducted, key informants have been interviewed by semi-structure questionnaires and the checklist had been used to interview 4 key informants at different institutional levels as forestry officer (2 people), elder people (12 people), village leader (4 people), and trader in the village and in Banlung (6 people).
Primary data collection: Followings have conducted as primary data collection.
- Semi-structured interviews with key informants
- Group discussion with key-informants and transects walk of the area
- Structured interviews with individual households

Secondary data collection: The secondary data has been collected from other reports of both previous and current related study which may be found in the NGOs offices, Department of Agriculture and Forestry, academic and research institutions, journals, and the internet sources.
Data analysis: Data from the quantitative like household asset, labor used natural resource used income and expensed was computerized using Microsoft Excel software.

Qualitative data have been reviewed, summarized and categorized in priory defined parameters which were determined and then entered in a database. In particular, a database for ecosystem services combining both quantitative and qualitative data has been created.

RESULTS AND DISCUSSION

Socio-economic situation

This section presents basic data and information about villages studied, in order to characterize activities in each village. Livelihood activities are economic activities that household takes on to meet their basic needs, including food, clothing and shelter. Most of people in the study area rely on a number of different occupations (Table 2).

Table 2 Main occupation of local people in the villages studied

Occupation/Village	Backae (%)	Kapin (%)	Kang Nuok (%)	Talae (%)
Farmer	3		7	3
NTFPs collector		3		3
Small business		3		
Farmer, NTFP collector	70	80	73	77
Farmer, Small business	7		20	10
NTFPs collector, Small business		4		
Farmer, NTFPs collector, Small business	17			
Farmer, NTFPs collector, Other	3	10		7
Total	100	100	100	100

Note: Other occupation, there are: worker, teacher, trader, and craftworker

Animal production

Animal production is less important in livelihood since farmers are very busy with doing farming and shift culture. Chicken are mostly raised conventionally. Chicken is offered to the spirit, consumed and sold. Duck are raised to get eggs for household consumption and selling in the village. Pig rising is popular in the study area even though they are no plenty of feed stuffs. Cattle are important labor for agriculture for rice farm and also for their cart to transport the rice, crop products, etc.

Local villager benefit from community and natural resource

Right to access natural resource is as follows.
- Utilization on dry wooden, wild forest fruit, honey, resin, and other NTFPs

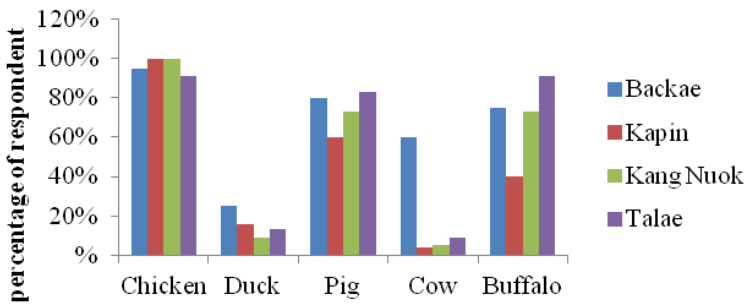


Fig. 2 Percentage of local communities raising animals in the village studies

- Usage of timber for house building, fence, stables for animals, and for making agricultural equipment and harvesting grass or freeing the animal in to the forest
- Utilization of other non-timber forest products consistent with traditional use of minority or family and NTFPs were selling or traded by no need approved latter if is trade affected to the sustainable of the forest.

Table 3 Average income of local communities get from NTFPs in the village studied/year

Source	Backae	Kapin	Kang Nuok	Talae
	Income (US$)	Income (US$)	Income (US$)	Income (US$)
Resin	230	228	96	145
Malva nut	329	363	605	297
Total	559	591	701	442

Note: Resin = 0.30 US$/ L, Malva nut = 4.70US$/ kg, 1 US$ was equivalent to 4250 Riel in 01 June 2010

Table 4 Average income of timber forest product/year

Sources	Backae		Kapin		Kang Nuok		Talae	
	Income (US$)	Expense (US$)	Income (US$)	Expense (US$)	Income (US$)	Expense (US$)	Income (US$)	Expense (US$)
Timber	572	188	180	50	1115	230	1153	187
Luxury wood	800		-		-		282	
Total	1372		180		1115		1435	
Profit	1184		130		885		1248	

Note: 1 US$ = 4250 Riel in 01 June 2011

Household income

There are many kinds of income that the villagers can receive per year such as by farming (paddy rice, shifting culture (Chamkar)), NTFPs (the main are risen, malva nut), wildlife hunting, wood logging, livestock production (cattle, chicken and duck), small business, rice mill, handicraft, and trader (Fig 2).

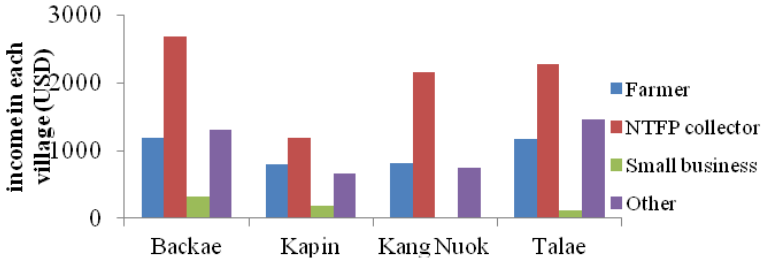


Fig. 3 Average income from each activity (village study)

DISCUSSION

Access right to natural resources: Natural resources that are accessible as common property provide an important livelihood, especially for the poor, as a source of food and additional income. Nowadays, local people still have their own traditional utilization right on that natural resource in the sustainable way, for example, the local community have their traditional ownership on resin tree even though it is not recognized by authority but at the household level, villagers are approved. Similar results were showed in Chea (2008), where the ethnic minority is respected spirit in the forest.

Land use and land tenure: The research found that forest land allocation was open for those who want to do agriculture or shifting cultivation as well as for those who would be affordable to develop plantation by themselves. However, forest land allocation to households entirely depends on the production capacity and the social networks of each household. In other words, the forest land allocation was favored to households who have either financial capital available to cover input costs for plantations or have social networks to gain access to free input supply from plantation. The proportion of forest land received by three different wealth groups and state forest owners as discussed in the result. The poor group gained least from the land allocation process. Lack of capital to invest in plantations is the most critical factor hampering the poor people in gaining allocated forest land. This finding corresponds to those of Tam.V. Le (2008).

Natural resource elimination: Natural resource has plummeted as a result over-exploitation for both legal and illegal export to neighboring country and china for making furniture, other masteries, traditional medicine, domestic consumption and local sale (Luy, 2008). A similar study in Chum (2009) and Chea (2008) reported that the rural community in the forest area commonly logging luxury wood and other value kind of tree, harvest wildlife such as turtle, water monitor, Bengal monitor, Burmese python, cobra, wild pig, red muntjac, Sam bar Pangolin and main NTFPs such as Malva nut tree by cutting down the trees, resin, in the forest, nearby the rice fields, shifting culture, streams.

CONCLUSION

According to research findings in the village studied, it can be concluded that rice farming and shifting farm (Chamkar) are the main sources of food consumption and supplementary income for their living in the four villages. Villagers who lived in Backae, Kapin, Kang Nuok and Talae village can make income in average 420-700 US$ from NTFPs collection per household, especially 300-600 US$ from malva nut collection and 100-230 US$ from resin tree collection in year round.. Besides, local communities in Backae can make income in average 904 US$ from wildlife poaching, especially Sam bar, turtle, Bengal monitor, water monitor, cobra, wild pig and red muntjac. But villager in the Kang Nuok and Talae village can make income in average 550US$ from wildlife hunting, whereas Kapin village can make income in average 442 US$ per household in year round. Moreover, villager can make income from Timber forest product in average 885 $-1154 $ per families. The income that came from natural resource is high but this trend is not sustainable for the future. The natural resource is decreased day by day due to the illegal activities, the local communities do not know how to harvest or collect in the sustainable way. By the way, improvement of agriculture sector in the targeted area is the good way to improve their livelihood and avoid the negative affected to the natural resources.

REFERENCE

Chea Ramsey. 2008. Socio-economic assessment for proposing alternative livelihood strategy of Lao minority villagers of I Tub, Ratanakiri province. 85.

Chum Nith. 2009. Contribution of natural resource to livelihood in two floating villages near Kampong Prak fish sanctuary Tonle Sap Lake, Krokor District, Pursat Province. Royal University of Agriculture, Cambodia.

Luy Rattana. 2008. Study on the issue of forest and wildlife offend in Pursat Province. Royal University of Agriculture (Khmer version), Cambodia.
Tam V. Le. 2008. The Forest land use and local livelihoods.
Yamane, T. 1967. Determining sample size.

Research article

Effect of Using Sun-Dried *Sesbania sesban* Leaves in Concentrate on Growth Rate of Quail

PUTHEANY UNG*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: vet_theany@yahoo.com

KROESNA KANG
Royal University of Agriculture, Phnom Penh , Cambodia

SOKHORN NEANG
Royal University of Agriculture, Phnom Penh, Cambodia

SOPHAL CHEAT
Royal University of Agriculture, Phnom Penh, Cambodia

SEREY MOB
Royal University of Agriculture, Phnom Penh, Cambodia

Received 15 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract This paper dealt with the experiment on "Using sun-dried *Sesbania sesban* leaves with petioles in concentrated feed on growth rate of quail". It took 42 days to completely undertake the trial to evaluate a) quail's growth rate (daily live body weight gain and weekly live body weight), b) feed intake (FI), c) feed conversion ratio (FCR), and d) economic efficiency (EE). *S. sesban* leaves mixed petioles being completely sun-dried and finely ground contains 27.62% crude protein, 19.28% crude fiber in 89.13% dry matter basic. The foliage meal with different level of 0%, 5%, 10%, and 15% was concentrated with a basic diet of maize, dried fish, rice bran and soybean (T0, T1, T2, and T3). Two hundred forty 5-day-old quails were used and then fed with each treatment diet consisting of 27% and alternatively 24% crude protein for the first and the second stages, respectively. Total expense, income, daily feed intake, and weekly body weight were recorded. The result indicated that there were differences ($P<0.05$) of the daily body live weight gain (T0 = 3.94 g, T1 = 3.89 g, T2 = 3.64 g, and T3 = 3.31 g); of the finishing live body weight of quails between all treatments (T0 = 187.2 g, T1 = 184.8 g, T2 = 174.0g and T3 = 160.8 g); and of FCR (T0 = 2.69, T1 = 2.72, T2 = 2.92, and T3 = 3.24). However, there were no significances of FI in which each treatment quail took in 11-12 grams of the feed per day, and of EE in which all treatment diets provided profit around 10-13 cents as expense on the quail product was one dollar. In sum, the inclusion of *S. sesban* foliage meal to a maximum of 5% is recommended for quail rising.

Keywords quail, *Sesbania sesban* leaves, growth rate

INTRODUCTION

This paper dealt with the experiment on "using sun-dried *Sesbania sesban* leaves with petioles in concentrated feed on growth rate of quail" which was conducted for BSc thesis at Royal University of Agriculture (RUA) in 2010.

Quail consumption was estimated to be more popular for supporting food demand because it is a kind of poultry with its very delicious meat and its 22.55% crude protein (Chreng, 2007). Its meat product can readily match market demand because of its short production cycle from four to five weeks (Barrette et al., 1998 cited from Kheang, 2006). Furthermore, quail requires a simple small

space for keeping and it is more resistant to any diseases and environment than other poultry such as chicken and duck (Randall, et al., 2008).

Because of the fact that raw materials for animal food processing in today's market is very expensive, quail production expenses are also affected seriously. Accordingly, to facilitate the quail keepers, especially in rural areas, as well as to alleviate their expenses on the raw materials; inclusion of *Sesbania sesban* leaves with petioles in concentrated feed for quail was conducted. *Sesbania sesban* including its leaves is a kind of plant which is eaten by humans and it is very inexpensive and freely available almost all over Cambodia. Furthermore, it was indicated that CP of its sun-dried leaves (27.62%), which was obtained from Saang district, Kandal province, Cambodia; is high and acceptable for concentrated feed of quail meat production with 86.13% DM and 19.28% CF (RUA, 2010).

For the reasons mentioned above, accompanied with the fact that sun-dried *S. sesban* leaves with petioles had never been used in the concentrated feed in Cambodia, this trial was conducted on "Effect of Using Sun-Dried *Sesbania sesban* Leaves in Concentrate on Growth Rate of Quail" which was mainly focused on a) the quail's growth rate, b) the feed intake (FI), c) the feed conversion ratio (FCR), and d) the economic efficiency (EE).

METHODOLOGY

Study site: The study was carried out at Animal Experimental Station, Faculty of Animal Science and Veterinary Medicine, Royal University of Agriculture (RUA), Phnom Penh, Cambodia. It was conducted with two hundred forty quails over 42 days between from February and March 2010.

Table 1 Concentrate Formula

Ingredient	T0 (%)	T1 (%)	T2 (%)	T3 (%)
1st Stage (0-3weeks)				
Maize	30	29	29	25
Rice bran	16.4	15	12.5	14.5
Dried fish	27	26	24.5	23
Soybean	25.6	24	23	21.5
Sun-dried *S.sesban* leaves	0	5	10	15
Salt	0.5	0.5	0.5	0.5
Premix	0.5	0.5	0.5	0.5
Total	100	100	100	100
Chemical Components				
CP (%)	27	27	27	27
ME (kcal/kg)	3366.8	3058.89(*)	3022.42(*)	2856.66(*)
Ca (%)	1.5	1.44	1.35	1.3
P (%)	1.3	1.2	0.93	1.1
2nd Stage (4-6weeks)				
Maize	38	36.7	35.5	34
Rice bran	17	16.08	15	14
Dried fish	20	17.2	14.5	13
Soy bean	24	24.02	24	23
Sun-dried *S.sesban* leaves	0	5	10	15
Salt	0.5	0.5	0.5	0.5
Premix	0.5	0.5	0.5	0.5
Total	100	100	100	100
Chemical Components				
CP (%)	24	24	24	24
ME (kcal/kg)	3251.3	3197.8(*)	3034.12(*)	2865.3(*)
Ca (%)	1.1	1.0	0.87	0.8
P (%)	0.9	0.96	0.88	0.62

** Note: ME value without including ME value of Sun-dried S.sesban leaves*

Sampling size: It took five days to adapt two hundred forty one-day-age quails and then based on Completely Randomized Design (CRD); they were divided into four dietary treatments comprised

three replications with 20 quails each. The dietary treatments were comprised of T0 (control treatment), T1 (including 5% sun-dried *Sesbania sesban* leaves and petioles in concentrated feed), T2 (including 10% sun-dried *Sesbania sesban* leaves and petioles in concentrated feed) and T3 (including 15% sun-dried *Sesbania sesban* leaves and petioles in concentrated feed).

Concentrate formula: For feeding the quail in the experiment, there are two stages with different CP ratio of their diets over six weeks. Five-day-aged quails in each dietary treatment were fed with 27% CP diet over three weeks; and then alternatively, fed with 24% CP diet for another three weeks (Sam, 2001 cited from So Leakhena, 2007). The formula of concentrated feed is calculated and shown as in Table 1.

Data collection and analysis: Total expenses on each treatment including the price of 1-day-aged quail, housing, health care, and management of; as well as the total income of selling quails in each treatment were recorded in order to calculate the economic efficiency. In addition, feed intake of all experimental quails was recorded daily for determining food conversion ratio and their live body weight was also recorded weekly until the end of experimental periods. All data obtained was analysed using one-way ANOVA in SPSS version 15.0.

RESULTS AND DISCUSSION

Body live weight gain

There was significant difference (P<0.05) of the daily live body weight gain of each treatment. It was observed that quail in T1 and T0 gained similarly high daily live body weight, while those in T2 and T3 gained significantly less (Fig. 1).

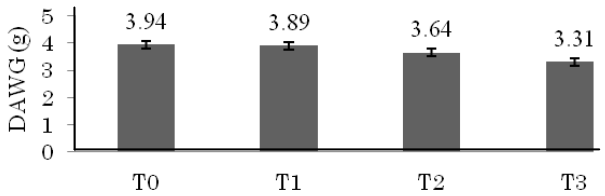


Fig. 1 Daily average weight gain

Table 2 Weekly body live weight

Age (week)	Parameters	T0	T1	T2	T3	P
0	N	60	60	60	60	
	$\bar{X}$	21.6^{ns}	20.5^{ns}	20.3^{ns}	20.3^{ns}	0.399
	S±	0.73	1.31	1.33	0.15	
1	N	60	60	60	60	
	$\bar{X}$	42.9^{ns}	43.4^{ns}	42.7^{ns}	39.5^{ns}	0.122
	S±	1.98	1.53	0.72	2.83	
2	N	60	60	60	60	
	$\bar{X}$	67.2^{a}	64.5^{a}	58.5^{b}	54.0^{b}	0.03
	S±	2.22	0.58	3.07	4.73	
3	N	60	59$^{(*)}$	59$^{(*)}$	60	
	$\bar{X}$	85.5^{a}	84.7^{a}	81.8^{a}	75.4^{b}	0.007
	S±	0.79	0.98	3.56	3.99	
4	N	60	59	59	59$^{(*)}$	
	$\bar{X}$	120^{a}	114^{ab}	108.8^{b}	99.7^{c}	0.004
	S±	2.26	4.75	1.62	7.63	
5	N	60	59	59	59	
	$\bar{X}$	153^{a}	148.2^{a}	140.6^{b}	129.4^{c}	0.001
	S±	3.86	2.01	2.08	6.37	
6	N	60	59	59	59	
	$\bar{X}$	187.2^{a}	184.8^{a}	174.0^{b}	160.8^{c}	0.001
	S±	5.47	1.94	1.62	6.61	

ns is no significance (P>0.05), a, b and c show significant difference (P< 0.05)

Weekly live body weight

By the end of the first week, there was no significant difference (P>0.05) between quail's live body weight in each treatment. Alternatively, from second to sixth week it was significant (P<0.05) (Table 2). It was indicated that the average of the finishing live body weight of quail with dietary T0, T1, T2 and T3 was 187.2 g, 184.8 g, 174.0 g and 160.8 g, respectively. However, in the second week one quail died in T1 and T2; and in the third week in T3. The death was not caused by the concentrated feed impact based on the analysing quail corpses, but instead by mechanic causes.

Feed Intake (FI)

There was no significance (P>0.05) in average feed intake (g/bird/day) between all treatments (Fig. 2). Quail in all of the treatments consumed between 11-12 grams per day.

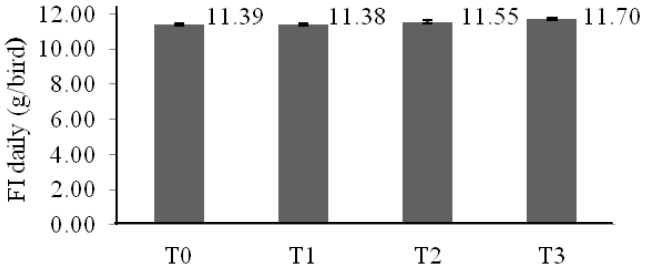


Fig. 2 Average feed intake (g/bird/day)

Feed Conversion Ratio (FCR)

The FCR value was calculated by the following formula.

$$FCR = \frac{\text{Total feed intake}}{\text{The last body live weight} - \text{The previous body live weight}}$$

The FCR of the different dietary treatments during overall experimental period is shown in Fig. 3. It indicates that there was significant difference (P<0.05) in FCR value between the treatments. Though, it was that T0-diet, T1-diet and T2-diet gave the same FCR value; and T3-diet different. According to the meaning of FCR; it takes less than three grams of T0, T1, and T2-diets to create one gram of quail's live body weight; but over three grams of T3-diet.

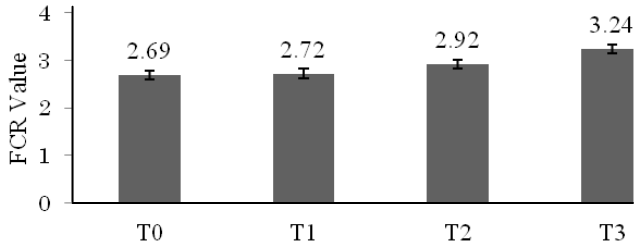


Fig. 3 Feed conversion ratio

Economic Efficiency (EE)

The EE value was calculated by the following formula.

$$EE = \frac{\text{Total income}}{\text{Total expense}}$$

Table 3 reflects that feeding diets with using sun-dried *Sesbania sesban* leaves and petioles for quail raising made no essential difference in profit compared to T0. It shows that one dollar spent on each treatment-diet provides around 11-13 cents of profit as compared to 10 cents for T0.

Table 3 Economic efficiency for each treatment

Treatment	Total income (US$)	Total expenses (US$)	Total profit (US$)	EE (%)
T0	39.00	35.26	3.74	1.10
T1	38.35	34.53	3.82	1.11
T2	38.35	34.13	4.22	1.12
T3	38.35	33.73	4.62	1.13

CONCLUSION

Despite the fact that it provides no difference in profit compared to the control treatment diet, adding up to 5% of sun-dried *S. sesban* leaves mixed petioles in concentrated feed does not harm quail production. However, inclusion of this raw material in the concentrated feed should be limited to 5% due to the significantly lower finishing live body weight at higher levels, which would impact food security. According to Factsheet-*Sesbania sesban* (2007), using *Sesbania sesban* 10% in poultry concentrated feed could kill poultry. In sum, compared to the control treatment and based on the mentioned results, the inclusion of *S. sesban* leaves mixed petioles can be definitely recommended to use at 5% of concentrated feed.

ACKNOWLEGEMENT

There are many people to whom I would like to express gratitude for their contributions to this study. I would like to express great thankfulness to my parents and my siblings for supporting me with financial resources and great encouragement and motivation. Furthermore, I would like to express sincere thanks to my friends as well as classmates at the same academic year for their assisting to build the quail-keeping house and their sharing knowledge and providing me with encouragement.

REFERENCES

Cheeke, P.R. 1999. Applied animal nutrition: Feed and feeding, Second ed. Prentice-Hall, Inc. Simon & Shcuster/A Viacom Company. Upper Saddle River, New Jersey 07458. USA.

Clarence, E.B., and Ronald, V.D. 1968. Livestock and poultry production, Third ed. E. Designed by Carlos N.Crosie. USA.

Chreng, C. 2007. The effect of using sun-dry TARO leaves in feed ingredient on growth rate of quail at Animal Experimental Station. BSc thesis, Animal Science and Veterinary Medicine Faculty, Royal University of Agriculture, Phnom Penh, Cambodia.

Factsheet - Sesbania sesban. 2007. http://www.tropicalforages.info/key/Forages/Media/Html/Sesbania_se. Retrieved on June 27, 2010, from http://betuco.be/coverfodder/ Sesbania%20 sesban.pdf

Kheang, V.T.N. 2006. The effectiveness of using whey protein on growth rate of quail. BSc thesis, Animal Science and Veterinary Medicine Faculty, Royal University of Agriculture, Cambodia.

Randall, M. and Bolla, G. 2008. The raising Japanese quail. Primefact of New South Wales Department of Primary Industries (NSW DPI), 602, Second ed. Retrieved April 20, 2007, from http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/145346/ Raising-Japanese quail.pdf.

RUA. 2010. Analyzing of chemistry components of sun-dried sesbania sesban in chemistry laboratory. Faculty of Animal Science and Veterinary Medicine, Royal University of Agriculutre, Cambodia.

So Leakhena. 2007. Effect of using Kapok tree leaves in concentrate on growing quail. BSc thesis, Animal Science and Veterinary Medicine Faculty, Royal University of Agriculture, Cambodia.

Research article

The Characterization and Activity of Digestive Enzymes in Different Sizes of Common Lowland Frog (*Rana rugulosa* Wiegmann)

RUNGKAN KLAHAN*
University of Phayao, Phayao, Thailand
E-mail: supatcharin5@hotmail.com

BUNDIT YUANGSOI
Faculty of Agriculture, Khon Kaen University, Thailand

Received 15 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract The activity of serine and acid protease, amylase and lipase from a 3-day-old whole-body frog, the gastrointestinal tract of a 10-day-old frog, and the stomach, intestine and pancreas of a 45-day-old and a 60-day-old frog (*Rana rugulosa* Wiegmann) were determined. The results showed that the medium-age frog (45 days) appeared to have higher activity of serine protease and lipase than the old frog (60 days) and tadpoles (3 and 10 days), while the old frog had the highest activity of acid protease. The activity of serine and acid protease from the four ages of frogs had the high activity at pH 8-12 and 3 respectively, while the activity of both amylase and lipase were highest at pH 7. The activity of all kinds of enzymes were shown to have the highest activity in the pancreas while the activity of acid protease was found to have the highest activity in the stomach. These results will be used as the basis for suitable feed formulation and feedstuffs for different sizes of common lowland frogs so that optimum nutritional value and cost-effectiveness can be achieved.

Keywords common lowland frog, acid protease, serine protease, amylase, lipase

INTRODUCTION

Amphibian diets indicate that all adult amphibians are carnivores; most feed principally on insects, although many species eat a variety of invertebrates. The anuran larvae are herbivorous, so the diets include such vegetable matter as aquatic invertebrates (Duellman and Trueb, 1994). Some adult anurans, including *Rana* sp., feed on large prey items, e.g. small mammals, bird and other anurans. Hylid frogs (*Acris crepitans*) during post-metamorphic growth ingest increasingly larger prey items. The same trend for anurans, the function of developmental change from herbivorous to carnivorous feeding, varies. For this reason, digestibility is important and necessary. The digestive enzyme system includes protease, amylase and lipase which are basic enzymes necessary for digestion, especially for frog culture involving artificial feedstuffs, such as frogs and catfish feed that are high in nutrients, particularly protein. Amphibians have a gland in the mucosal lining which secretes mucus in which pepsinogen proliferates. Pepsinogen is the precursor of pepsin, released by the main cells in the stomach, and it degrades food proteins into peptides. Pepsin is one of three principal protein-degrading, or proteolytic, enzymes in the digestive system; the others are chymotrypsin and trypsin, which are alkaline, and serine protease which are produced by the pancreas. During the process of digestion, these enzymes, each of which specializes in severing the links between particular types of amino acids, collaborate to break down dietary proteins into their components, which can then be readily absorbed by the intestinal lining. In amphibians, digestive enzymes are generally considered to be absent in buccal secretions, though low concentrations of diastatic amylase have been reported in the secretions of the intermaxillary, lingual and pharyngeal glands in some species of *Rana* (Reeder, 1964). The digestive enzymes in the small intestine are secreted by the

pancreas (Duellman and Trueb, 1994). Lipase activity has been found in extracts of the pancreas, pyloric ceca and upper intestine, but almost non-existent in the stomach and lower intestine. Digestion is completed in the small intestine in which the content of the lumen is mixed with a variety of digestive enzymes by intermittent contraction of the muscular wall (Duellman and Trueb, 1994). The main aim of this study was to determine the activity of digestive enzymes, including protease (acid and serine), amylase and lipase, in four stages of common lowland frogs, given the fact that these are culture stages. The results from this study will be used as a basis to select feedstuffs and develop feeding formulations that are suitable for different stages of common lowland frogs, so that optimal nutritional values and cost-effectiveness can be obtained.

METHODOLOGY

Frog and Sample Preparation

One thousand 3-day-old frogs, five hundred 10-day-old frogs, one hundred 45-day-old frogs and fifty 60-day-old frogs from the Department of Fisheries, University of Phayao were used in this study. The 3-, 10-, 45- and 60-day-old frogs were fed with 52, 40, 35 and 30% protein feed, respectively, twice a day. The whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs, and the intestine, stomach and pancreas of 45- and 60-day-old frogs were collected and weighed 16 hours after feeding. Samples were stored at -80^{o}C until use.

Crude enzyme preparations

The whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs, and the intestine and pancreas of 45- and 60-day-old frogs were prepared by the method of Gimenez et al., (1999) for the serine protease, amylase and lipase assayed and Klomklao et al., (2007) for pepsin assayed.

Enzymatic assay

Characterization of serine protease: Serine protease activity was monitored in triplicate by measuring the increase in cleavage of short chain polypeptides via the method of Bezerra et al. (2005), but with the slight modification of using azocasein as a substrate. Protease specific activity was expressed as units of change in absorbance per min. per mg. of protein of the enzyme extract (ΔAbs/min/mg protein). Acid protease activity was assayed in triplicate by measuring the increase in oligopeptides via the method of Klomklao et al. (2007), but with the slight modification of using hemoglobin as a substrate. The acid protease specific activity was expressed as units of change in absorbance per min. per mg. of protein of the enzyme extract (ΔAbs/min/mg protein). Amylase activity was determined in triplicate by the 3,5-dinitrosalicylic acid (DNS) method (Bernfeld, 1951) using starch as the substrate. The amylase specific activity was defined as the mmol. of maltose produced per min. per mg. of protein under the conditions specified. Lipase activity was measured in triplicate by a method modified from Markweg et al. (1995) using 0.01 M para-nitrophenylpalmitate (pNNP) dissolved in iso-propanol as substrate. The lipase specific activity was defined as the μmol of p-nitrophenol produced per min. per mg. of protein under the conditions specified.

Protein concentration: Protein concentration was determined by the method of Lowry et al. (1951) using bovine serum albumin as a standard.

Statistical analysis

This experiment was conducted according to a completely randomized design (CRD) and the data obtained from the enzyme activity in various pH buffers and ages of frog were subjected to a one-way Analysis of Variance (ANOVA) followed by a Duncan's new multiple range test.

RESULTS AND DISCUSSION

Optimal pH of serine protease

The activity of serine protease from the whole body of 3-day-old frogs was the highest at pH 11, the serine protease activity from the gastrointestinal tract of 10-day-old frogs was the highest at pH 9, and in the intestine and pancreas of 45- and 60-day-old frogs it was the highest at pH 9 and 10, respectively (Fig. 1). The pH range for the maximal activity of serine protease extracted from the pancreas, intestine and the whole body of small tadpoles (3 - 6-day-old frogs) was in the range 9-11. The results were in line with the work of Teo et al. (1990), who showed that the serine protease activity of common Malayan toads displayed a well-defined optimum at pH 7.2. These results were in line with studies of fish, such as Sheng et al. (2006) also reported that alkaline protease activity remained high over a wide range of pH values (6-11). Klomklao et al. (2011) reported that the optimum pH for Na-p-tosyl-L-arginine methyl ester hydrochloride (TAME) hydrolysis was 8.0 and that trypsin was stable over a pH range of 6.0-11.0. The k_{cat}-pH profile of serine proteinase-catalyzed reactions showed a bell-shaped curve, reflecting a maximum activity close to pH 8 (Wong, 1995). Proteases and other enzymes can also be classified and based on their optimal pH (acid or alkaline) and the tissues of production (gastric, pancreatic and mucosal) (Halver and Hardy, 2002).

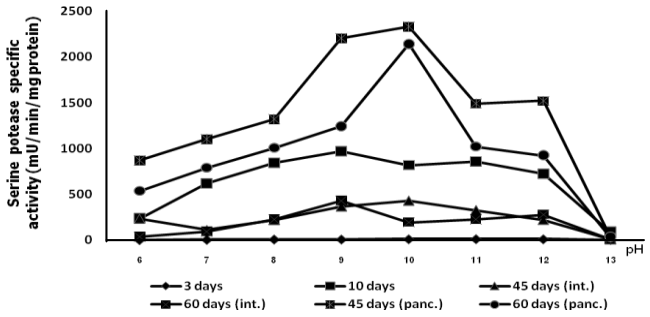


Fig. 1 Serine protease activity (specific activity) in the whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs, and the pancreas (panc.) and intestine (int.) of 45- and 60-day-old frogs at pH 6-13

Optimal pH of acid protease (pepsin)

The pepsin activity from the whole body of 3-day-old frogs was the highest at pH 2 and the activity of pepsin from the gastrointestinal tract of 10-day-old frogs and the stomach of 45- and 60-day-old frogs was the highest at pH 3 but not found to be active at over pH 4 (Fig. 2).

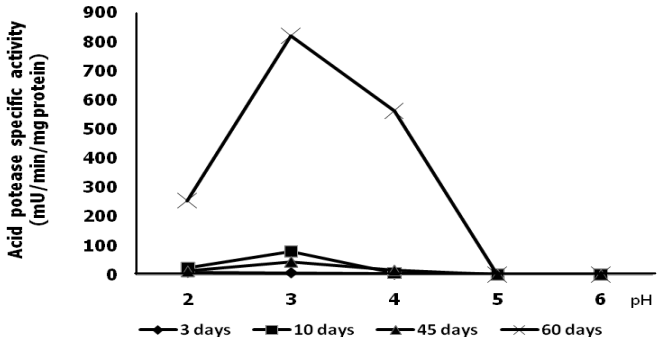


Fig. 2 Acid protease activity (specific activity) in the whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs and the stomach of 45- and 60-day-old frogs at pH 2-6

Pepsin functions best in acidic environments; it is often found in an acidic environments, in particular those with a pH of 1.5 to 2, and pepsin denatures when the pH is more than 5.0. Most digestion of pepsin occurs in the stomach as a result of the action of pepsin (De Silva and Anderson, 1995). The results were in line with the work of Teo et al. (1990) who showed that the pepsin activity of common Malayan toads showed a well-defined optimum at pH 2-2.2. The results were similar with those of Tanji et al. (2007) who found that Pepsin-A from the gastric mucosa of African coelacanths, *Latimeria chalumnae* (Actinistia), had the highest activity at pH 2-2.5.

Optimal pH for amylase

The amylase activity from the whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs and pancreas and the intestine of 45- and 60-day-old frogs was the highest at pH 7 and sub-optimal at pH 12 (Fig. 3). Amylase or α-amylase is a hydrolysis enzyme produced by the pancreas. By acting at random locations along the starch chain, α-amylase can operate anywhere on the substrate and tends to be faster acting than β-amylase. In animals, like frogs, α-amylase is a major digestive enzyme and its optimum pH range is 6.7-7.0.

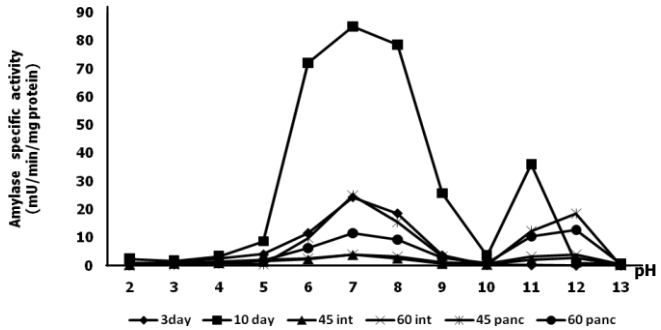


Fig. 3 Amylase activity (specific activity) in the whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs, and the pancreas (panc.) and intestine (int.) of 45- and 60-day-old frogs at pH 2-13

De Silva and Anderson (1995) stated that amylase had been identified in pancreatic juices, the stomach, the intestine and bile; however, the main producers were the pancreas and liver, which is consistent with this report, showing high activity of amylase in the pancreas and that it acts in neutral to alkaline environments in the upper intestine. The amylase activity of frogs lacks data, so these results were compared with those for other animals, such as fish. The amylase activity in all ages of frogs was similar to that in the study of Zeng and Cohen (2000) who showed peaks in amylase activity in the salivary glands of *Lygus hesperus* and *L. lineolaris* at pH 6.5. The maltase activity on carbohydrates in the small intestine of African clawed frogs (*Xenopus laevis*) was shown in the report of Sabat et al. (2005) who studied it at approximately pH 6.5 in their study. The optimal pH for amylase activity varies with the enzyme source and values reported for amylase in mammalians are in the ranges of 6.0-7.0 and 6.0-8.0 with a temperature tolerance of between 20-40^{o}C for porcine pancreatic α-amylase (Wong, 1995).

Optimal pH of lipase

The lipase activity in the whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs, and the pancreas and intestine of 45- and 60-day-old frogs was highest in the range pH 7-9. (Fig. 4). In addition, the highest activity of lipase was detected in the pancreas of 45-day-old frogs. Lipase or pancreatic lipase, also known as pancreatic triacylglycerol lipase, is secreted from pancreas and hydrolyze dietary fat molecules as triglyceride substrates in the digestive system to make monoglycerides and free fatty acids. The principal site for lipase activity is the mucosal layer, but there are no data for anurans. However, the primary site of lipid hydrolysis for most species

appears to be in the pyloric ceca and anterior intestine (Halver and Hardy, 2002), and all fat-digesting enzymes are known to act in alkaline media. The lipase activity data of frogs along with amylase activity have insufficient data so these results were compared with other animals, such as fish. Gjellesvik et al. (1989) showed similar results with cod lipase activity with optimal pH above 8.25, while Sheng et al. (2006) reported maximal activity of lipase in the intestine of hybrid juvenile tilapia (*Oreochromis niloticus* × *Oreochromis aureus*) at a pH of between 6.0 and 9.0. All fat-digesting enzymes act in alkaline environment and optimal pH slightly varies from species to species.

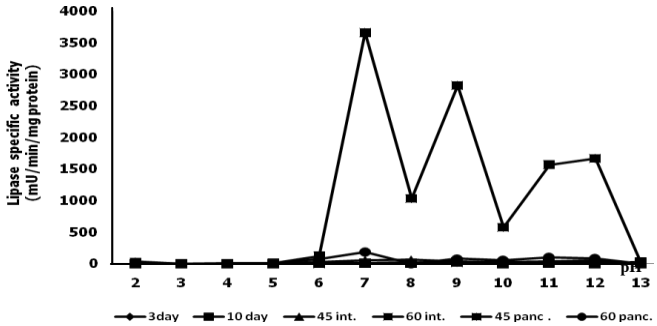


Fig. 4 Lipase activity (specific activity) in the whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs, and the pancreas (panc.) and intestine (int.) of 45- and 60-day-old frogs at pH 2-13

Lipase from the intestinal mucosa has an optimal pH of between 7.0 and 7.5, while intestinal esterase is at its most active between pH 8.0 and 9.0 (De Silva and Anderson, 1995), i.e. in agreement with the values reported here.

Digestive enzyme activity in various ages of frogs

Digestive enzyme activity in the whole body of 3-day-old frogs, the gastrointestinal tract of 10-day-old frogs, and the stomach, pancreas and intestine of 45- and 60-day-old frogs is summarized in Table 1.

Table 1 Activity of digestive enzymes extracted from various ages of common lowland frogs

Age (days)	Specific activity (mU mg protein^{-1})			
	Serine protease	Acid protease	Amylase	Lipase
3	66.39 ± 9.62 ^{d}	22.66 ± 1.68 ^{d}	59.75 ± 10.57 ^{c}	121.51 ± 16.44
10	5,159.2 ± 165.08 ^{c}	118.39 ± 17.09 ^{c}	297.26 ± 29.43 ^{a}	55.68 ± 5.24
45	11,989.57 ± 677.05 ^{a}	116.65 ± 3.60 ^{b}	104.82 ± 3.68 ^{b}	28,325.45 ± 1616.07
60	9,192.59 ± 250.23 ^{b}	1,698.77 ± 120.32 ^{a}	84.29 ± 1.63 ^{bc}	106.09 ± 2.82

^{abcd} *Mean values in the same column with different letters are significantly different (P<0.01)*

Serine protease activity appears to be significantly higher in the pancreas and 45-day-old frogs had the highest activity (P<0.01). The frogs' serine protease is produced by the pancreas which is most active in alkaline environments in the intestine (De Silva and Anderson, 1995). Pepsinogen is the inactive form of pepsin which is secreted by the esophagus, but it functions in the stomach in pepsin form which attacks protein. The old frogs had the perfect stomach to effect the highest rate of pepsin activity. For this reason, the stomachs of 60-day-old frogs showed the highest pepsin activity. A comparison of amylase activity in the four ages of frogs showed the highest activity in 10-day-old frogs. In general, amylase in animals is produced by the pancreas but *Rana spp*. found that low concentrations of diastatic amylase were secreted by the intermaxillary, lingual and pharyngeal

glands also. Amylase is the one of the carbohydrases and looks like the serine protease produced by the pancreas, so they are called pancreatic enzymes. Furthermore, adult amphibians are carnivores; they principally feed on insects, although many species eat a variety of invertebrates.

The anuran larvae are herbivorous while their diet includes such vegetable matter as aquatic invertebrates (Duellman and Trueb, 1994). Therefore, the young frogs had the highest amylase activity at 10 days old. Lipase activity was significantly higher in the pancreas of 45-day-old frogs ($P<0.01$). From the results, the activity of protease and lipase, essential for the utilization of proteins and lipids from feed corresponding to high growth rates at early ages, were high in the 45-day-old frogs. Like serine protease and amylase, lipase is produced by the pancreas and acts in alkaline environments in the intestine. The pancreas in frogs is enclosed in the hepato-gastric ligament and lies between the duodenum and the stomach (Duellman and Trueb, 1994). It is a source of digestive enzymes.

CONCLUSION

The study clearly demonstrates variations in digestive enzyme activity (including pepsin and serine protease, amylase and lipase) in different ages of frogs. Serine protease and lipase activity was the highest in base pH (8-13) in medium-age frogs (45 days old), amylase activity was highest at neutral pH (7) in sub-medium frogs (10 days old), and acid protease (pepsin) was the highest at acid pH (3) in the large frogs. Digestive enzyme activity also depends on the organs studied. Protease amylase and lipase activity appears to be high in the pancreas while pepsin is more active in the stomach. The different rates of digestive enzyme activity in various ages of frogs can be used to select suitable feedstuffs for the highest digestibility and lowest cost in each age of frogs. Thus, the results from this study can be used as the basis for devising suitable feeding formulations that can be effectively utilized by different ages of frogs.

ACKNOWLEDGEMENT

This study was supported by a grant from the University of Phayao.

REFERENCES

Bernfeld, P. 1951 Enzymes of starch degradation and sysntehsis, 379-424. Nord., F.F.(ed.). Advances in enzymology. Interscience Publications Inc. USA.

Bezerra, R.S., Lins, E.J.F., Alencar, R.B., Paiva, P.M.G., Chaves, M.E.C., Luana, C.B.B. and Carvalho, L.B. 2005. Alkaline proteinase from intestine of Nile tilapia (*Oreochromis niloticus*). Proc. Biochem, 40, 1829-1834.

De Silva, S.S., Anderson, T.A. 1995. Fish nutrition in aquaculture. Chapman & Hall. UK.

Duellman E., Trueb, L. 1994. Biology of amphibians. The Johns Hopkins University Press, UK.

Gimenez, A.V.F., Fernandez, I., Preciado, R.M., Oliva, M. Tova, D., and Nolasco, H. 1999. The activity of digestive enzyme during the molting stage of the arched swimming *Callinectes Arcautus* orday, 1863. (Crustacea: decapoda: portunidae). Bull. Mar. Sci, 65(1), 1-9.

Halver, J.E., Hardy, R.W. 2002. Fish nutrition. Academic Press. USA.

Klomklao, S., Kishimura, H., Yabe, M. and Benjakul, S. 2007. Purification and characterization of two pepsins from the stomach of pectoral rattail (*Coryphaenoides pectoralis*). Comp. Biochem. Physiol. B, 147(4), 682-689.

Lowry, O. H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. 1951. Protein measurement with the folin phenol reagent. J. Biol. Chem, 193, 265-75.

Markweg, H., Lang, M.S., and Wagner, F. 1995. Dodecanoic acid inhibition of lipase from *Acinetobacter* sp. *OPA 55*. Enz. Microb. Tech, 17, 512-516.

Reeder, W.G., 1964. Physiology of the amphibia. Academic Press, USA.

Sheng, L.J., Lin, L.J., and Ting, W.T. 2006. Ontogeny of protease, amylase and lipase in the alimentary tract of hybrid juvenile tilapia (*Oreochromis niloticus* × *Oreochromis aureus*). Fish Physiol. Biochem, 23(4), 295-303.

Tanji, M., Yakabe, E., Kageyama, T., Yokobori, S.I., Ichinose, M., Miki K., Ito, H. and Takahashi, K. 2007. Purification and characterization of pepsinogens from the gastric mucosa of African coelacanth, *Latimeria chalumnae*, and properties of the major pepsin. Comp. Biochem. Physiol. B, 146(3), 412-420.

Teo, L.H., Chen, T.W. and Tan, L.L. 1985. The proteases of the common Malayan toad (*Bufo melanostictus*) Schneider. Comp. Biochem. Physiol. B, 96(4), 715-720.

Wong, D.W.S. 1995. Food enzyme: Structure and mechanism. Chapman and Hall. USA.

Zeng, F., Cohen, A.C. 2000. Partial characterization of α-amylase in the salivary glands of *Lygus Hesperus* and *L. lineolaris*. Comp. Biochem. Physiol. B, 126, 9-16.

The Biology of *Lentinus polychrous* Lev. in Nakhon Phanom Province, Thailand and Kwaeng Kham Muan, Laos

SOMCHAI RATTANAMALEE*
Faculty of Agriculture and Technology, Nakhon Phanom University, Nakhon Phanom, Thailand
Email: rathanamalee@hotmail.com

CHANAPORN RATTANAMALEE
Faculty of Liberal Art and Science, Nakhon Phanom University, Nakhon Phanom, Thailand

Received 8 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract This article describes the results of the survey on mushrooms in Nakhon Phanom province Thailand and Kwaeng Kam Muan Laos done from April to November 2010. It was found that there were 13 varieties in Nakhon Phanom and 10 varieties in Kwaeng Kam Muan. The 13 varieties in Nakhon Phanom were College of Agriculture and Technology NPU 1 variety, Amphoe Tha U Ten 4 varieties, Kalasin province 1 variety, Amphoe Pla Pak 2 varieties, Tumbon Wangtamua Amphoe Muang 4 varieties and Amphoe Renunakhon 1 variety. In Kwaeng Kam Muan, Laos there were 10 varieties: 2 varieties in Muang Hin Boon, 2 varieties in Muang Tha Khaek, 3 varieties in Muang Yomarat, 1 variety in Muang Mahachai and 2 varieties in Muang Nagai. Each variety was different regarding cap, gills, scales, stalk, color, and size. The caps of these varieties were 4.0 - 14.5 cm in diameter. The caps of some varieties were thick while those of other varieties were thin. The number of gills was about 85-730, and the length of gills was 2.0 - 10.0 cm. The young gills were creamy white in color but the old gills were dark brown. The weight of dry mushroom was 2.0 - 15.0 g. The weight of wet one was 5.0 - 35.0 g. Scales on caps of mushrooms were different in cold season (October - November) and rainy season (April - July). In cold season skin of caps was scabbed and scattered but in rainy season the skin was smooth. Some stalks were short and others were long. Some varieties had short stalks. Average was 1.0 - 2.0 cm. Some varieties had long stalks. Average was 3.0 - 3.5 cm. The colors of caps were mainly brown, but some caps were white-brown and other caps were yellow-brown. When a mushroom is small, it was young about 1 day but when it grew to big size, it was about 2 or 3 days after primordial of mushroom. So Thailand or Laos varieties were similar, also. It meant that it could be preventive against cancer if you eat it always.

Keywords *Lentinus polychrous* Lev., mushroom, cultivation

INTRODUCTION

Hed Bod (*Lentinus polychrous* Lev.) is in family Polyporaceae (Royal Institute of Thailand, 1996). It is blooming on log of trees in natural. It has very good taste. It is a popular mushroom in the north and northeast of Thailand and in Laos (Pukahuta *et al*., 2006). It is called in the local language Hed Kra Dunk, Hed Kon Dum and Hed Lom etc. (Pegler, 1983). In natural Hed Bod bloom in early and late rainy season between March and October which the mushrooms become mature and suitable for studying about taxonomy and could culture the mycelium (Tianhirun, 2002). Nowadays this mushroom had decreased because of the environment change and the destruction of forest (Panmoot, 2002). So it was important to study about the mushroom such as morphology, taxonomy, environment, period of blooming, species of tree log which gave the basic data and conservation of mushroom varieties in order to have advantage and to be guideline villagers could cultivate this mushroom. The digestion of cellulose by mycelium of the mushroom synthesis enzyme lignocellu-

lase such as laccase which could be stored the mycelium for 2 years. So it is confident that productivity and quality of the mushroom could be improved. (Pukahuta *et al*, 2004) which could help people to become rich and have sustainable life.

So in this study, the four objectives were determined. One is to survey and take samples to investigate characteristics of the mushrooms such as diameter of cap, cap width, height, length of stake, length of gill, amount of gill, dry weight, wet weight, color of cap etc. to get basic information of the mushroom. Second objective is to collect varieties of the mushroom for studying and analyzing start from basic information of biology in nature. The third objective is to cultivate the mushrooms on logs of different species of trees to find the best yield and suitable one. Fourth objective is to eliminate poverty by transfering cultivation technology of the mushroom to local villagers.

MATERIALS AND METHODS

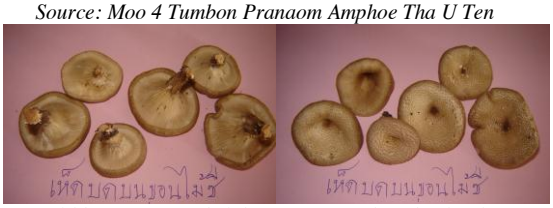
Surveyed, photographed and collected the sample of the mushroom that bloomed on log of trees in forest in area of Nakhon Phanom Province, Thailand and Kwaeng Kham Muan, Laos. Took the samples that bloomed in nature on log of trees from villages of Nakhon Phanom and Kwaeng Kam Muan. The number of samples bloomed on logs of trees were not equal in each area because of different environment. Then they were measured and weighed then dried by the sun or wind or the oven in the laboratory and kept in bags. Characteristics in morphology were investigated. Incubated tissue in PDA media, checked growth rate of mycelium and recorded data. All of these surveys were done from April to November 2010 which was in rainy and early cold season.

RESULTS AND DISCUSSION

The varieties of Hed Bod were investigated in Nakhon Phanom, Thailand and Kwaeng Kam Muan. Laos have many varieties, 13 varieties in Nakhon Phanom and 10 varieties in Kwaeng Kam Muan. The 13 varieties in Nakhon Phanom were found in College of Agriculture and Technology NPU 1. Amphoe Tha U Ten 4 varieties, Kalasin province 1 variety , Amphoe Pla Pak 2 varieties, Tumbon Wangtamua Amphoe Muang 4 varieties and Amphoe Renunakhon 1 variety. In Kwaeng Kam Muan, Laos there were 10 varieties, 2 varieties in Muang Hin Boon, 2 varieties in Muang Tha Khaek, 3 varieties in Muang Yomarat, 1 variety in Muang Mahachai and 2 varieties in Muang Nagai. There were 23 varieties, all of which were similar in shape and characteristic especially in morphology and period of blooming. All of them bloomed between April and July and between October and November (Leumlum, 2004). The logs of trees that Hed Bod can be grown were *Mangifera indica, Shorea obtusa, Shorea siamensis, Sindora siamensis, Anisoptera costata, Hopea odorata*, *Afzelia xylocarpa* and *Shorea roxburghii* which were found in dipterocarp forest at Amphoe Pla Pak and Amphoe Muang (Punmoot, 2002).

Table 1 Varieties of Hed Bod in Nakhon Phanom, Thailand and Kwaeng Kam Muan, Laos

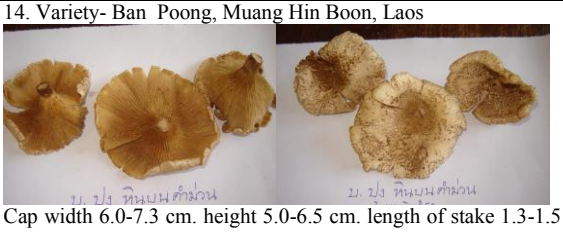
1. Variety- College of Nakhon Phanom Agriculture and Technology, Nakhon Phanom University *Source: Ban Kam Swang Tumbon Guruku Amphoe Muang*  White-brown cap, white-yellow gill, red gill when mature, cap width 4.5-14.0 cm. height 4.0-14.0 cm. length of gill 1.0-10.0 cm. length of stake 1.0-5.0 cm. thick of cap 3.0 mm. amount of gill 180-730 gills, wet weight 2.0-40.0 g.	2. Variety- Ban Pranom *Source: Moo 1 Tumbon Pranaom Amphoe Tha U Ten*  Cap width 5.5-11.2 cm. height 4.0-9.2 cm. length of stake 3.0 cm. amount of gill 85-300 gills dry weight 2.0-15.0 g. face of cap- white-brown, cap edge was brown, white-gray on central cap, white-red brown gills, length of gill 4.0-9.0 cm.

3. Variety- Ban Pranaom *Source: Moo 4 Tumbon Pranaom Amphoe Tha U Ten*  Cap width 5.5-7.5 cm. height 5.0-7.3 cm. length of stake1.0-1.5 cm. length of gill 4.0-7.0 cm. face of cap white-brown, cap edge was light brown, white gills when it was young but had brown gills when it was mature, cap was thickness, cap edge was not broken when it was blooming, dry weight 2.0-5.0 g., amount of gills 184-192 gills	4. Variety Kalasin *Source: Ban Mahachai Tumbon Mahachai , Amphoe Pla Pak*  Cap width 6.5-12.0 cm. height 6.0-9.5 cm. cap face was white-brown, on central cap was brown color, length of stake 1.5-3.5 cm. length of gill 5.0-8.5 cm. white-brown gills, cap was thin, cap edge was dark-brown color and broken, wet weight 5.0-12.0 g.
5. Variety Mahachai1 *Source: Ban Mahachai Tumbon Mahachai , Amphoe Pla Pak*  Yellow-brown cap, central of cap was dark-brown color, cap edge was light-brown, cap width 4.0 cm. height 4.0 cm. dry weight 3.0 g.	6. Variety Mahachai 2 *Source: Ban Mahachai Tumbon Mahachai , Amphoe Pla Pak*  Cap width 4.7-5.5 cm. height 3.0-4.5 cm. length of stake 1.0-1.5 cm. Cap face was white-brown, Cap edge was dark-brown, amount of gills 86-110 gills, Dry weight was 1.0-2.0 g.
7. Variety- Ban Nong Boa Tumbon Guruku Amphoe Muang  Dark brown cap, cap was thick, white gills, amount of gill 98-106 gills , cap width 6.5 cm. length of stake 1 cm.length of gill 3.5 cm. dry weight was 0.5- 1.0 g. Cap edge was broken, wet weight 5.0 g.	8. Variety- Ban Wangtamua Amphoe Muang  Cap width 9 cm. height 7.0 cm. Central of cap was white-brown. Cap edge was dark-brown. white-redbrown gills, amount of gill 82-100 gills, gill thickness 3.0 mm., length of stake 2 cm., wet weight 7 g.
9. Variety- Ban Nong Sang 1 Tumbon Wangtamua Amphoe Muang  Cap width 8.5-10 cm. height 6.5 cm. dry weight 5-15 g. length of gill 5.5- 6.0 cm. red-brown gills, length of stake 0.5-1.5 cm. Cap face was white-gray. Cap edge was yellow-brown. amount of gill 160-225 gills.	10. Variety- Ban Tan Pak Num Tumbon Chi Bu Ree Amphoe Tha U Ten  Cap width 4.5 cm. height 2.0 cm. length of stake 1 cm. wet weight 2 g. amount of gill 149 gills, cap face was white-brown
11.Variety- Ban Tat Amphoe Tha U Ten  Cap width 2.5-8.5 cm. height 2.3- 6.5 cm. length of stake 1.5 cm. length of gill 2.0-5.2 cm. dry weight 1.0-7.0 g. Cap face was white-gray and yellow.	12. Variety- Ban Nong Sang 2 Tumbon Wangtamua Amphoe Muang  Cap width 6.0-8.5 cm. height 6.0 cm. dry weight 2.0-5.0 g. Cap face was white-gray and yellow-brown, brown-gray gills, length of gills 5.0-5.5 cm. amount of gill 167 gills

13. Variety- Ban Phon Tong Amphoe Renunakhon

Cap width 7.2 cm. height 7.5 cm. length of gill 6.5 cm. length of stake 1.5-2.5 cm. Cap face was white-brown, central of cap was yellow-brown, cap was thin, gills color was white-cream, cap edge was light brown, wet weight 2.0- 5.0 g. amount of gill 156-234 gills.

14. Variety- Ban Poong, Muang Hin Boon, Laos



Cap width 6.0-7.3 cm. height 5.0-6.5 cm. length of stake 1.3-1.5 cm. length of gill 3.5-5.0 cm. amount of gill 170-219 gills , wet-weight 4.0-5.0 g. dry weight 0.2-0.5 g. Cap face was white-brown, white brown gills, cap edge was broken.

15. Variety- Ban Wearn Muang Tha Khaek Kwaeng Kam Muan, Laos

Cap width 5.5-6.5 cm. height 4.5-7.5 cm. length of stake 1.5-2.0 cm. white-cream gills, length of gill 4.0-5.0 cm. amount of gill158-328 gills. wet weight 5.0-7.0 g. dry weight 0.5-1.0 g. Cap face was light brown color.

16.Variety- Ban Phon Soong Muang Tha Khaek Kwaeng Kam Muan, Laos

Cap width 6.5-9.0 cm. height 5.5-7.0 cm. length of stake 1.5-2.0 cm. Amount of gill 240-350 gills, length of gill 3.0-5.5 cm. Cap face was white-gray. Cap was thin. Cap edge was broken, dark brown gills, dry weight 5.0-7.0 g.

17. Variety- Ban Phon Dia Muang Tha Khaek Kwaeng Kam Muan, Laos

Cap face was white-gray. Diameter of cap 7.7 cm. length of stake 1.5 cm. length of gill 5.0 cm. cap height 5.0 cm., dark brown gills

18. Variety- Ban Mun Muang Mahachai Kwaeng Kam Muan, Laos

White-yellow gills, cap face was white-gray and brown color, cap width 8.0-11.0 cm. height 6.0-9.3 cm., length of gill 3.5-7.0 cm., amount of gill 112-360 gills, wet weight 5.0 -10 g., dry weight 0.5 g.

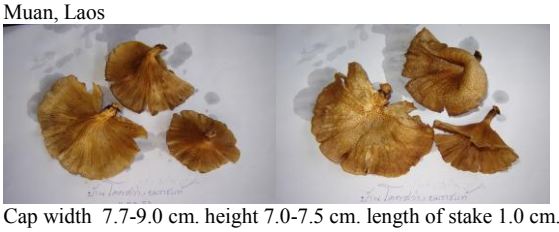
19. Variety- Ban Tha Rung Muang Nagai Kwaeng Kam Muan, Laos

Cap width 7.5-9.2 cm. height 7.3-7.5 cm. length of gill 4.5-7.0 cm. Cap face was white-gray. Cap was thin. Brown gills, length of stake 1.0-2.5 cm. Cap edge was white-gray. Cap deepness 1.0 cm.

20. Variety- Ban North Nagai Muang Nagai Kwaeng Kam Muan, Laos

Cap width 1.7-8.5 cm. height 3.0-8.5 cm. length of stake 0.5-1.0 cm. Cap was thick. Cap face was brown-gray. Central of cap was yellow-brown. brown gills, Length of gill was 2.0-5.5 cm. white brown gills in a young cap but red brown gills in the big size and mature, amount of gill 102-348 gills.

21. Variety- Ban Kog Swang Muang Yomarat Kwaeng Kam Muan, Laos



Cap width 7.7-9.0 cm. height 7.0-7.5 cm. length of stake 1.0 cm. cap was thickness 1 mm. wet weight 8.0-9.0 g. length of gill 4.0-5.0 cm. dry weight 0.2 g. cap face was white and thin, white-brown gills.

22. Variety- Ban Don Du Muang Hin Boon, Kwaeng Kam Muan Laos

Cap face was white-brown. Cap edge was light-brown, white gills, length of stake 1.0-1.5 cm., cap width 2.3-4.5 cm., height 2.0-3.0 cm. amount of gill 172 gills, length of gill 2.0-3.0 cm. wet weight 2.0-5.0 g. Cap was thin and broken.

23. Variety- Ban Yomarat Muang Yomarat Kwaeng Kam Muan, Laos  Cap width 10-11.5 cm. height 7.2-11.0 cm. length of stake 1.0-2.0 cm. Cap face was white-gray. Central of cap was deep and brown color. Dark brown gills, length of gill 6.7-7.0 cm. wet weight 6.0-15.0 g. amount of gill 340-480 gills.	*Totally 23 photos. show the varieties of Hed Bod in Nakhon Phanom, Thailand and Kwaeng Kam Muan, Laos*

Kwaeng Kam Muan, Laos was found same as Nakhon Phanom, Thailand such as at the forest of Ban Tharung Muang Nagai. It was found Hed Poa, Hed Tub Tao or Hed Puearng bloomed at the same time. However, the villagers in both of Mekong River harvest the *Lentinus polychrous* Lev. to be Hed Kra Dung and when you want to cook you will soak it in the water before. Hed Bod could be stored very long time and have rich nutrition. Hed Bod could reduce cholesterol and triglyceride because it has eritadenine substance, which can protect heart disease and high blood pressure disease especially diabetes and HIV (Panmoot, 1994) In addition Hed Bod could induce immuned cells to protect cancer (Sutachit and Sutachit, 2002). Furthermore, Hed Bod could kill cancer cells (Armussa, 2009).

CONCLUSION

Surveying varieties of *Lentinus polychrous* Lev. In Nakhon Phanom, Thailand and Kwaeng Kam Muan, Laos there were many varieties but they had similar characteristics in shape, morphology, and period of blooming. Hed Bod was found on log of trees in dipterocarp forest especially in log of *Mangifera indica, Shorea obtuse, Shorea siamensis, Sindora siamensis, Anisoptera costata, Hopea odorata, Afzelia xylocarpa* and *Shorea roxburghii* was found during April to July and during October to November. The important thing was there were many germplasm of *Lentinus polychrous* Lev.varieties in Nakhon Phanom, Thailand and Kwaeng Kam Muan, Laos. So we can have germplasm resources for cultivation. Furthermore we can use the species of trees that could give high yield and then transfer technology of cultivation to the people

ACKNOWLEDGEMENT

We thank the National Research Council of Thailand that contributed the fund to this research.

REFERENCES

Armussa, N. 2009. Antioxidant activity and cytotoxicity in breast cancer cells line of mushooms extracts *Lentinus polychrous* Lev. compared to *Ganoderma lucidum* (Fr.). Karst. Isan Journal of Pharmaceutical Sciences, 5(3), 243-250.

Leumlum, N. and Pukahuta, C. 2004. Biodiversity of wild mushroom in Phu Jong Nayoi National Park. 41-65. *In* Hed Thai 2003, The Mushroom Researchers and Growers Society of Thailand.

Panmoot, K. 1994. Mushroom spawn and mushroom cultivation. Teaching Document. College of Agriculture and Technology, Nakhon Phanom University. 260.

Panmoot, K. 2002. Cultivation of *Lentinus polychrous* Lev. and *Lentinus squarrosulus*. Publicized Document. College of Agriculture and Technology, Nakhon Phanom University. 6.

Pegler, D.N. 1983. Agaric Flora of the Lesser Antilles. Kew Bull Add. Ser. IX. HMSO. London. 668.

Pukahuta, C., Unpim, U., Bunlue, S., Wuticumpee, P. and Payappanon, U. 2006. Strain of *Lentinus squarrosulus* Mont. at Ubon Ratchathani. 1-12 *In* Hed Thai 2006, The Mushroom Researchers and Growers Society of Thailand.

Pukahuta, C., Suwanarit, P., Shinagawa, E., Hoshida, H. and Nishizawa. Y. 2004. Combination of laccase, xylanase and cellulose in lignocellulose degradation by white rot fungi, *Lentinus polychrous* Lev. and *L. squarrosulus* Mont. Kasetsart Journal (Nat. Sci.) 38, 65-73.

Royal Institute of Thailand. 1996. Edible and poisonous mushroom in Thailand. Royal Institute of Thailand, Bangkok. 180.

Sutachit, S. and Sutachit, M. 2002. Mediclinal Mushrooms: Past, present and future. 1-11. *In* Hed Thai, 2002.

Tianhirun, S. 2002. Diversity of mushroom family Xylariaceae in Doi Inthanon National Park. The Conference Report of Royal Forest Department 2002.

Research article

Agroforestry Systems for Upland People in Lao PDR: Production, Benefit, and Farmers' Satisfaction Analysis

THIPPHAPHONE DOUANGSILA*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: tounic77@gmail.com

SUPAPORN POUANGCHOMPU
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

Received 15 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract With an increasing population and governmental land-use restriction, shortened fallow periods of some traditional farming systems have contributed to the reduction of agricultural production in the uplands of Lao P.D.R. In response, systems which integrate trees, crops, and/or animals, such as agro forestry have been applied. However, the promotion of agroforestry as an alternative choice for upland farmers has become very challenging as a result of long-term economic incentives. The objectives of this study were to identify agroforestry systems employed, cost and returns, and the satisfaction of farmers, aiming to promote more benefits of agroforestry. Information described in this paper came from a survey of 80 agroforestry farms under a project support in nine villages of two northern districts. The results implied that three main agro forestry systems, based on nature components, have been employed. 81 percent of farmers employed Agrisilviculture, where trees and crops were combined in the same parcel. 14 percent applied Agrosilvopastoral (trees, crops, and pasture/animals), followed by 5 percent who applied Silvopastoral (trees and pasture/animals). In terms of production cost, initial investment in Agrisilviculture cost on average US$ 575 ha^{-1}; while Agrosilvopastoral farmers spent around US$ 795 ha^{-1} and Silvopastural farmers, an estimated US$ 282 ha^{-1}. After three-years of establishment, most farmers achieved success meeting their food sufficiency needs and obtained additional income from extra production, with average returns from each system about US$ 186 ha^{-1}, US$ 632 ha^{-1}, and US$ 104 ha^{-1} respectively. With biological and economic advantages produced by natural components in each system, most of farmers were similarly satisfied. Although the systems could not provide immediate-profitable returns, they were able to sustain food production and were profitable for a long-term use. A particular attention and continual technical support from relevant agencies are still required to enhance application of agroforestry.

Keywords upland farmers, agroforestry systems, production cost and benefits, farmers' satisfaction.

INTRODUCTION

In Lao PDR, 80 percent of the land area is classified as mountainous, including much of the Northern region. This is a main obstacle for the development of social infrastructure. Still, the majority of upland population employs shifting cultivation as the main agricultural activity (Seidenberg et al., 2003). Along with the main shifting cultivation, agroforestry, an ancient process of cultivating trees and crops in combination with one another, has also been employed. These practices have been classified as indigenous or traditional agroforestry, practiced in home gardens, intercropping systems, and livestock grazing practices (Sodarak et al., 2004). Under population pressure and government restriction on deforestation, traditional shifting cultivation as well as indigenous agroforestry practices has faced the problem of shortened fallow periods, consequently contributing to the degradation of soil fertility and crop yield (De Rouw, 2005). In response, the government has im-

plemented policies and programs aiming at providing better options for sustainable agriculture in the uplands (GoL, 2004). One of those methods employed is alternative agroforestry. An integration of annual crop, upland rice, with medium-term fruit trees and longer-term fruit trees has been set up for upland farmers (Lai et al., 2004). After several years of introduction, it seems the extension of alternative agroforestry is still limited due to a lack of immediate returns. Thus, this study aims at analyzing the alternative agroforestry systems applied, production, benefits, and the farmers' satisfaction regarding the technology support. Information presented in this study is believed to be useful for farmers who are interested in applying agroforestry as well as development agencies involved in the promotion of agroforestry in uplands.

METHODOLOGY

The study was conducted in two northern districts, Namor in Oudomxay province and Phonxay in Luangprabang province, where alternative agroforestry has been practiced under field-based research of a foreign project. Hence, purposive sampling was applied to collect data. From a project document's review, 120 families had been in the agroforestry trials. However, after the real survey only 80 families continued applying this system, as some had stopped. Thus, the total number of samples interviewed was 80 families. The study used structured interview and randomly visited farms during 20 March to 03 May 2011 in both districts. Questions were asked mainly on agroforestry systems details, production cost and income, and satisfaction of farmers regarding advantages received. All data collected was processed by the computer program SPSS for Windows Version 17.0. Descriptive statistics were applied, such as percentage, means, and figures, to support the qualitative data. The farmers' satisfaction levels for agroforestry advantages were analyzed by using interval mean scores, dividing into five interval levels that were calculated by using the equation.

RESULTS AND DISCUSSION

Agroforestry systems and component species

From the data analyzed, three main systems of agroforestry, based on their nature components, have been employed (Table 1). Agrisilviculture, where only trees and crops including shrubs/vines integrated together, was mostly applied, accounting for 81 percent of agroforestry in the community. Among farmers applying this system, about half preferred to integrate fruit trees like prunes, pomelo, lychee, mango, longan, orange, and others. At least, two kinds of fruit trees were used in a same parcel. Woody trees like rubber tree, agarwood, and teak were also used, but only a single specy was planted with other crops or sometimes with fruit trees and a single crop. In this system, various kinds of crops were applied and the popular crops were pineapple, soybean, galingale, upland rice, maize, and others. Mostly, farmers liked to add only pineapple as it was easy to grow and needed less care compared to other kinds.

Table 1 Agroforestry systems applied

Agroforestry Systems	Percentage (%)
Agrisilviculture (trees and shrubs/tree, or and crops)	81.25
Agrosilvopastoral (trees, crops, and pasture/animals)	13.75
Silvopastoral (trees and pasture/animals)	5.00

Another prevalent agroforestry system found on farms was Agrosilvopastoral, a system in which trees, crops and pasture/animals are planted together, accounted for 14 percent. Within this system, several trees, crops, and animals were incorporated. Over half of the farmlands employing this method planted fruit trees, mostly litchi and longan. Woody trees such as rubber trees, teak,

and agarwood were also applied. With the integration of crops, farmers preferred to grow pineapple, galingale, soy bean, maize, and sesame. The most commonly raised livestock was poultry which was naturally free-grassing. Additionally, 5 percent of farmers employed Silvopastoral, where pasture land or animals are integrated in the tree plantation. The most popular trees were litchi, prunes, orange, and rubber tree, combining with some animals like pigs, goats, and cattle, mostly roaming freely in the day time and confined in a pen at night. As nearly all of the farmlands situated on hillsides, the most common cropping pattern applied in all systems was alley cropping in which trees are planted in rows at wide spacing with companion crops grown in the spaces between the tree rows.

Farm Production

In each system, the levels of production were dissimilar, in conjunction with the different amount of trees, crops and animals integrated. Analyzed data in Table 2 showed the average yield, and sale of extra production annually. Genarally, most farmers could harvest the production from fruit trees after three years of farm establishment. While only some rubber plantations were able to reap benefits from sales of rubber cup lump last year. In crop production, farmers could gain benefits within the first year of integration. Farmers indicated that they could sustain food self-sufficiency from harvested crops (i.e. pineapple, maize, soybean, galingale, and sesame) and could also sell some of the crops surplus to generate household income. Combined with animals, some families who raised cattle could generate a very good profit.

Table 2 Average yearly production, amount of consumption and sale per hectare

Systems and components	Yield (kg/ha)	SD	Sold (kg/ha)	SD
Agrisilviculture				
Woody trees	18.61	63.45	18.61	63.45
Fruit trees	129.91	182.16	86.33	168.04
Crops	1,635.68	2,921.40	465.61	702.61
Total				
Agrosilvopastoral				
Fruit trees	338.75	563.70	329.25	569.19
Crops	1,000.00	1,026.37	863.64	914.16
Animals	32.20	46.98	20.60	47.06
Total				
Silvopastoral				
Woody trees	16.50	23.33	16.50	23.33
Fruit trees	196.25	278.05	122.50	157.56
Animals	7.00	2.83	1.50	2.12

** Unit of animals yield was counted in head*

Among the families participating in Agrisilviculture trials, only few families could collect the production from woody trees, due to the fact that most of the rubber tree as well as teak and agarwood were not yet fully formed. Only a few rubber plantations were ready for tapping with the average yield of 18.61 kg ha^{-1}. As fruit trees were mostly grown to sustain food production, the average yield was 129.91 kg ha^{-1}, mainly from prunes, pomelo and lichee. Of these, some was used for home consumption and the extra yield was sold in the local market. The average yield gained from crops, such as pineapple, soybean, galingale, upland rice, maize, and sesame was 1,635.68 kg ha^{-1}. In Agrosilvopastoral, the number of farmers engaged in this system was smaller, so the average of production seemed higher than the first system. For fruit trees, farmers could harvest fruit about 338.75 kg ha^{-1}, largely from litchi, longan, prunes, and pomelo. The production from crops was 1,000 kg ha^{-1}, mainly from pineapple. Besides, several kinds of animals were raised, the most preferred being poultry, goat, and pig, with total offspring averaged from all kinds about 32 head ha^{-1}.

Chicken made up the highest proportion. In the mean time, the Silvopastoral farmers had obtained the production of some mature rubber trees, approximately 16.50 kg ha^{-1} of rubber cup lump. The fruit trees production was mainly harvested from litchi, prunes, and orange, and averaged a combined total of about 196.25 kg ha^{-1}. The most frequently used animals in this system were pig and goat, generally fed by free-roaming in the day time and confined in pens at night. Average animal production from both was about 7 head ha^{-1} $year^{-1}$.

Cost and benefits

Due to the use of various species components applied on each farm, the cost of production was analyzed by the three main systems of agroforestry. Table 3 shows average cost of production per hectare at the time of initial investment by each natural component (trees, crops, and animals), calculated from labor and material input costs. The labor inputs for each system were land preparation, planting, farm management, harvesting, and transporting. The total labor needed for each system varied due to the different amount of trees and crops planted. The material inputs were mostly seeds, including trees seedlings and crop seeds, followed by organic fertilizer, which was applied only in the first two years. The remaining expense was farm equipment, such as knives, hoes, shovels, and spades, which were purchased only one time. The material inputs for animals were different. They included medicine, forage, and fencing. The investment in animals only occurred at the time of the first acquirement.

Table 3 Average cost of initial investment by nature components and annual income

Systems and components	Amount integrated (ha)	SD	Initiative cost (US$/ha)	Annual income (US$/ha)
Agrisilviculture				
Trees (plant)	275	275	372	58
Crops (kg)	1,980	3,406	203	128
Total			*575*	*186*
Agrosilvopastoral				
Trees (plant)	329	305	313	170
Crops (kg)	2,065	2,070	262	146
Animals (head)	20	23	219	316
Total			*795*	*632*
Silvopastoral				
Trees (plant)	387	625	218	85
Animals (head)	7	7	64	19
Total			*282*	*104*

** 1 $UDS=8,000 LAK*

In Agrisilviculture where only trees and crops were integrated, the average number of tree seedlings used at the beginning was about 275 plants ha^{-1}, including both woody and fruit trees. The price of trees varied, depending on species. In fact, all trees were funded by the project. However, the cost of trees seedlings was still calculated as a material input. For intercrops, farmers were supported by the project in the first year. After that, farmers had to invest on their own for the annual crops, excluding pineapple. In total, the initial investment in Agrisilviculture was around US$ 575 ha^{-1}. In Agrosilvopastoral, the cost of production was higher due to the higher quantity of trees, crops, and animals used. Due to the variation of animals applied, the cost of animals was summed up and estimated in average including cost for relevant materials such forage, fencing, and medicine. Total initial expense, estimated for the use of 329 trees, 2,065 kg of different crops and a mixture of 20 animals, was about US$ 795. In Silvopastural, where there were only trees and animals, the initial investment was less compared to other techniques. The total expense was estimated

to be around US$ 282 ha^{-1} for the integration of 387 trees with 7 animals. Farmers stated that normally feed their livestock naturally by free-grazing, and as such, there was no expense for forage. The only fencing cost paid for was nails, as other materials like timber could be taken from the forest.

In each system, monetary returns were dissimilar due to the different amount of trees, crops and animals integrated. Most farmers established farms with the aim mainly to produce food for home consumption. However, they also used surplus fruit and crops harvested to generate additional income. Analyzed data in Table 3 also showed the average income gained annually from the sale of extra production. Among the families participating in Agrisilviculture trials, they could harvest the production from all components and make additional income equivalent to US$ 186 ha^{-1} $year^{-1}$. In the Agrosilvopastoral system, the average income was the highest, estimated at US$ 632 ha^{-1}, in relation to the higher amount of natural components combined, as well as the higher rate of production sold. Silvopastoral obtained the lowest profit, approximately US$ 104 ha^{-1} as the benefit could be reaped only from trees and livestock, particularly poultry. If comparing the cost of production and income in all three systems, although it seems that their cost of initial investment was higher than income, the yearly average return still gave the satisfactory benefits. Particularly, farmers claimed that they could sustain their food production and also increase household income, enabling their ability to purchase more food and daily goods for their families.

Farmers' satisfaction to the agroforestry advantages

This study also examined the differences of farmers' satisfaction with the agroforestry advantages generated by the interaction of its natural components through the use of Chi-square test of difference (Table 4).

Table 4 Satisfaction on biological and economic advantages of agroforestry

Agroforestry advantages	Percentage			N	Mean	SD	X^2
	Agrisivil-culture	Agrosilvo-pastoral	Silvo-pastoral				
Biological advantages							
Satisfaction on trees	81.25	13.75	5.00	80	3.46	.826	$.177^{ns}$
Satisfaction on crops	84.06	15.94	-	69	3.67	.852	4.429**
Satisfaction on animals	-	78.57	21.43	14	3.64	.497	1.479^{ns}
Economic advantages							
Crops production increase	81.25	13.75	5.00	80	3.36	.830	6.311**
Increase food production	81.25	13.75	5.00	80	3.46	.745	1.843^{ns}
Variety of farm production	81.25	13.75	5.00	80	3.20	.818	1.033^{ns}
Save household labors	81.25	13.75	5.00	80	3.53	.927	2.048^{ns}
Increase income	81.25	13.75	5.00	80	3.46	.810	1.034^{ns}
Various income from intercrops	81.25	13.75	5.00	80	3.34	.728	4.798^{ns}
Buy more goods and services	81.25	13.75	5.00	80	3.34	.762	4.123^{ns}

*Note: Differences are compared using Chi-square test; ^{ns} = Non-significant, ** Significant at 5%*

Investigated data indicated that the satisfaction to biological advantages from trees and animals were insignificant differences among three systems. Farmers were commonly satisfied with trees since trees and animals integrated were suitable to the environment. For satisfaction on animals raised, there was also an insignificant difference among three groups since farmers were largely satisfied with an increase of household income from sales of livestock. Nevertheless, there is a significant difference of 5% among farmers who integrated crops. The given reason by farmer who applied Agrisilviculture was that the combination of crops created a good environmental, con-

tributing to the increased of crops yield; meanwhile, farmers who employed Agrosilvopastoral claimed that crops were difficult to take care at the time of fruit-bearing due to damage by insects and rodents, often resulting in crops failure. In addition, some crops like pineapple were small in size and sour in taste, resulting in unsellable production. To economic benefits, the satisfaction of farmers of three systems was not significantly different. Mostly, they were satisfied that the variety of crops could not only sustain food supply but also could make additional cash income from surplus production to buy more goods and services supporting daily life. Yet, there is a significantly different satisfaction at 5% to the crops production increase as Agrosilvopastoral farmers reported differently that crops yield gradually decreased year by year.

CONCLUSION

Through the introduction of agroforestry for farmers in the hilly areas, three main agroforestry systems have been employed: Agrisivilculture, Agrosilvopastoral, and Silvopastoral. The most prevalent system was Agrisivilcuture where only trees and crops were put together in the same plot. In each system, various kinds of trees, crops, and animals were diversely incorporated. The initial cost of production was considerably dissimilar. Among three systems, Agrosilvopastoral farmers had the highest cost of production, due to the fact that all three main nature components, trees, crops, and animals, were integrated. In regards to the estimated profitable returns, all systems could provide levels of production to support the food sufficiency of families and gain additional income from sales of surplus production. The most profitable was Agrosilvopastural, since various kinds of species were applied. In addition, the differences of farmer's satisfaction on biological and economic advantages of all agroforestry systems are mostly non-significant. Only some showed their significant different satisfaction to the benefit of crops integrated, in accordance with the difficulty of farm management during fruit-bearing times as a result of insect and rodent damage, resulting in some crop failure. To this point, the need for farm management techniques are required to prevent the production loss as it is a key motivator to help the expansion of agroforestry systems. Moreover, some on-going technical and advisory assistance from related agencies, especially government and projects, is still needed to facilitate the application of technologies introduced and to provide information about solving problems on farms to enhance effectiveness. Hence, farmers will feel more confident with the new farming systems offered that could help them improve their food production and create better livelihood conditions.

REFERENCES

DeRouw, A.J. 2005. Weed control in shifting cultivation. Improving livelihoods in the upland of the Lao PDR. Initiatives and approaches, Vientiane. 1, 78-84.

GoL. 2004. The national growth and poverty eradication strategy. Government of Laos (GoL), Vientiane. 53-55.

Lai, C., Sodarak, H., Keoboualapha, B. and Linquist, B. 2004. Integrated fruit tree systems in Luangprabang: Scaling-up sustainable technologies and process. Poverty reduction and shifting cultivation stabilization in the uplands of Lao PDR: Technologies, approaches and methods for improving upland livelihoods, Laos, 353-359.

Seidenberg, C., Mertz, O. and Kias, M.B. 2003. Fallow, labour and livelihood in shifting cultivation: implication for deforestation in northern Lao PDR. Geografisk Tidsskrift, Danish Journal of Geography, 103(2), 71-80.

Sodarack, H., Ditsphorn, C., Thammavong, V., Ounthammasith, N. and Forshed. O. 2003. Indigenous agroforestry practices in two districts in the northern part of Lao PDR. Poverty reduction and shifting cultivation stabilization in the uplands of Lao PDR: Technologies, approaches and methods for improving upland livelihoods, Laos, 213-228.

Research article

Status of Blue Swimmer Crab (*Portunus* spp.) Fishing in Chang Hoan and Kep Thmey Fisheries Community, Kampot Province

VICHAR CHHOM*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: chhomvichar@gmail.com

KUONG KOV
Fisheries Administration, Phnom Penh , Cambodia

VANARITH KY
Fisheries Administration, Phnom Penh, Cambodia

KONGHEANG HUOT
Royal University of Agriculture, Phnom Penh, Cambodia

Received 17 December 2011 Accepted 12 March 2012 (*: Corresponding Author)

Abstract Blue swimmer crab plays a significant role for the people living around the coastal zone which provides foods, income for livelihood. Unsustainable use of fishery resources and lack of food security by human activities and environment factors drove the degradation of these species. So, the study aimed to: identify the kind of fishing gears and the way of fishing blue swimmer crab, identify the average yield of blue swimmer crab, and show the blue swimmer crab market. The study selected 2 different Community Fisheries (CFi) from 2 communes and 14 fishermen from Keb Thmey Fisheries Community and 25 fishermen from Chang Hoan CFi, 10 middlemen, 2 chief communities from each Fisheries Communities were interviewed. The simple yields, moreover, were recorded in Chang Hoan CFi every morning and Keb Thmey CFi in the evening for 4 months. The results showed that crab trap and trawling have been used in both areas for catching blue swimmer crab, but trawling is not commonly used. In Keb Thmey CFi, the average yields per day of blue swimmer crabs were caught by crab trap: 15.77 kg/boat in March, 16.45 kg/boat in April, 13.93 kg/boat in May, and 8.09 kg/boat in June. On the other hand, trawling was used to collect blue swimmer crab in Chang Hoan CFi; in average were 1.01 kg/boat in March, 1.09 kg/boat in April, and 0.89 kg/boat in May. Whereas the yield from the crab traps were 6.72 kg/boat in March, 5.05 kg/boat in April, 5.05 kg/boat in May and 4.44 kg/boat in June. Usually, blue swimmer crabs were classified into 3 classes. The first and second classes were purchased by middlemen who delivered to the crab strip shop, retailer and Kampot and Vealrihn markets. The third class was sold to the crab peelers. In conclusion, crab trap is commonly used for catching crab all year round. The variation of total is according to time, weather, place and the number of fishing gears. The average catch in March and April is more than that in May and June.

Keywords blue swimmer crab, crab trap, trawling, fishery community.

INTRODUCTION

Cambodia's coastal zone is an ecological system which provides high potential of mangroves, aquatic plants, fishes, water birds, mollusks, mammals, reptiles and so on that support to economics such as tourism sector, industry sector, ports, navigation. Furthermore, this area has been providing the local livelihood through fishing. Blue swimmer crab is considered as a kind of zooplankton which lives in the marine water that is attractively fished nowadays as it is highly economic both in

local and international market. However, these species are decreasing both in size and in quantity with the modern fishing gears as well as technologies, which affects the livelihood of people in the area. So the study proposed to: (1) identify the kind of fishing gears and the way of fishing of blue swimmer crab; (2) identify the average yield of blue swimmer crab; and (3) show the blue swimmer crab market.

METHODOLOGY

Study site: Two community fisheries such as Chang Hoan and Keb Thmey CFi which are located in Prek Thnot and Teuk Chhou district, Kampot Province were selected to conduct the research, because it is the place where people fish blue swimmer crab and also the place for blue swimmer crab market process.

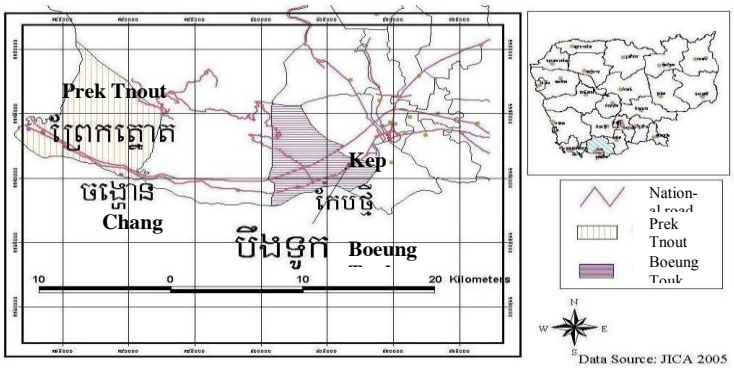


Fig. 1 Map of study area (JICA, 2005)

Sampling size and method: There were two different methods of data collection: conducting interview and yields recording. Also, 3 kinds of questionnaire had been created for household interview including 39 fishermen (14 and 25 fishermen from Kep Thmey and Chang Hoan CFi, respectively), 10 middlemen, and 2 community chiefs from each CFi. These questionnaires were used to compare on the concept and understanding of the fishermen and community chiefs as well as middlemen in the area.

On other hand, the data of blue swimmer crab yields were recording every day during four months with the all of the fishermen who fish blue swimmer crab. The data was recorded in the morning in Chang Hoan FCi from 7 fishermen by using trawling and 3 fishermen by using crab traps. Moreover, 15 fishermen from Kep Thmey CFi were selected to record the yields which hold in the evening. Both primary and secondary data had been collected and analysed by using MS Excel.

RESULTS AND DISCUSSION

Blue swimming crab fishing

In the Chang Hoan CFi, fishermen have been using crab trap and trawling to catch blue swimmer crabs and other fish species. However, fishermen in Kep Thmey CFi use only crab trap as a fishing gear to catch blue swimmer crabs. These fishing gears can be bought from the market or middlemen.

The technique of crab trap using

In the early morning about 4 or 5 a.m., the fishermen drive their boat to the fishing place. A boat owner is responsible for driving and other two crews are responsible for laying the traps into water until completed (in the crab traps they put bait to attract crabs). In order to avoid the traps damage

by other fishing boat, the fishing gave any signal (at the beginning of string and the end of the string). After laying the traps, fishermen park their board for relaxing 4 to 5 hours, then they start to collect their traps, tie the crab with the rubber band, keep it in net, and come back to landing side. After selling crabs to middlemen, fishermen prepared traps and facilities for fishing next day.

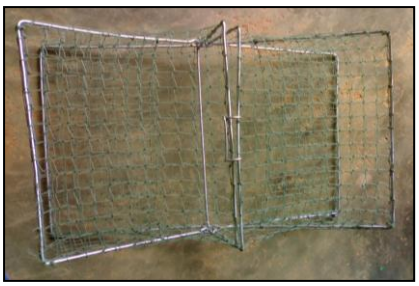


Fig. 2 Crab trap

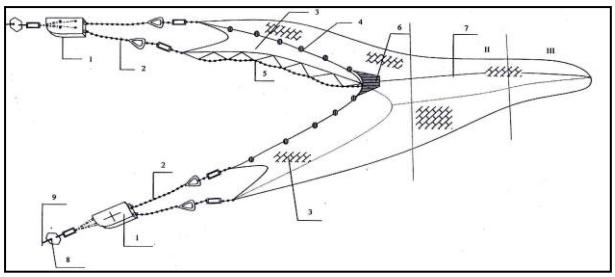


Fig. 3 Trawling

Technique of trawling using

At about 5 p.m., the fishermen go to their usual fishing place. They start to operate their task as they have been doing for catching fishes. First, the fishermen opened the stick and tie it. Second, they dropped the tail of trawling into water until finished. Next, the fishermen starts to drop wooden boards into the water and tie the rope with two sticks to open trawling surface and drove a bite faster than before. To continue, they untied the rope from the sticks and lie on the water and allowing the boat to operate faster. This task took about 3 hours, then the fishermen drive slowly to lift the trawling on the boat and come back to landing side. After selling crabs to the middlemen, fishermen prepared trawling and any facilities for fishing tomorrow.

Time and duration of fishing

The crab trap and trawling can be used all year round: night and day times. For the crab trap, mostly fishermen in the Kep Thmey CFi do their fishing activities a time per day. Generally, they go fishing early morning around 4 to 5 a.m. and come back around 4 to 5 p.m. Although, fishermen in Chang Hoan CFi operate crab catching twice times a day. In the morning, fishermen go to fish around 4 to 5 a.m. and come back around 8 to 9 a.m. About 1 or 2 p.m. fishermen go fishing again and come back about 5 to 6 p.m. in the evening. For trawling fishing gear, fishermen usually go fishing at night from 4 p.m. to 6 a.m.

Table 1 The number of fishing days in the four months

Months	Number of fishing days by crab trap (Kep Thmey)	Number of fishing days by crab trap (Chang Hoan)	Number of fishing days by trawling (Chang Hoan)
March	15	16	18
April	15	16	17
May	20	18	17
June	13	25	-
Total	63	75	52
Mean	16	19	17

Fishermen did not go to fishing every day during conducted research. In Kep Thmey CFi, the highest number of fishing days was in May about 20 days while the lowest was 13 days. In contrast, the highest number of fishing days in Chang Hoan CFi by crab trap was 25 days June which the

trawling was about 18 days in March (there was no data in June) (Table.1). According to the survey, the two major factors that affect the number of fishing days were climate conditions and holidays (New Year, weddings and other ceremonies) as well as lack of baits (for crab trap activities).

Blue swimmer crab yield

The yield of blue swimmer crab by crab trap in Kep Thmey CFi: Fig.4 shows the average catches of blue swimmer crab from March, April and May were not different (15.77 kg/boat/day, 16.45 kg/boat/day, and 13.93 kg/boat/day, respectively), while the average catches in June was decreased (about 8.09 kg/boat/day). During data collection period, which during rainy season, the temperature and salinity were declined between May and June so most crabs move to the depth sea or other places. In March, the average catches of second and third classes of blue swimmer crabs were increased about 8 and 4 kg/boat/day while the first class was decreased about 2 kg/boat/day (fig.5). The average catches of crab size were changed in April, May and June. The variety of average catches by size is depending on life cycle and biology of blue swimmer crab.

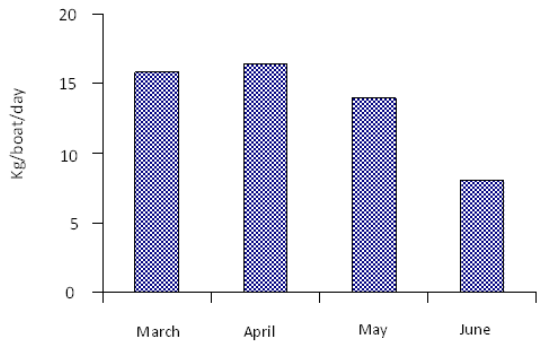


Fig. 4 The average yield of blue swimmer crab in 4 months

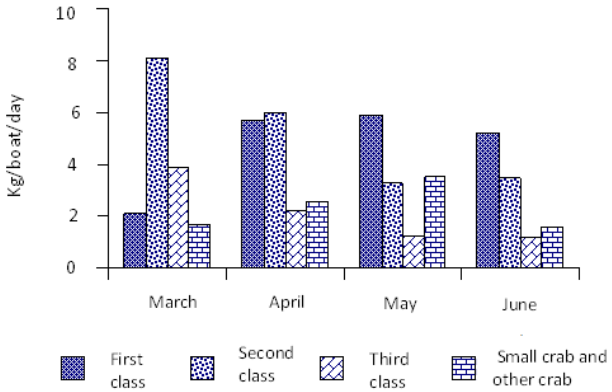


Fig. 5 The average yield of blue swimmer crab by size in average in 4 months

The yield of blue swimmer crab by crab trap in Chang Hoan CFi: Fig. 6 shows that the average catches of blue swimmer crab by crab traps in Chang Hoan CFi were increased in March and April around 7 kg/boat/day, but this yield was declined in May and June around 5 kg/boat/day. The third class of blue swimmer crab was highest amount of all classes because fishermen operated at the shallow water areas (Fig. 7).

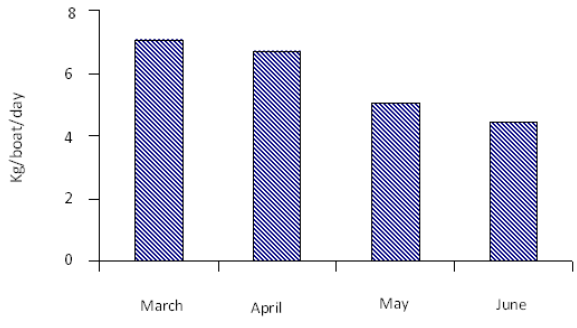


Fig. 6 The average yield of blue swimmer crab in 4 months

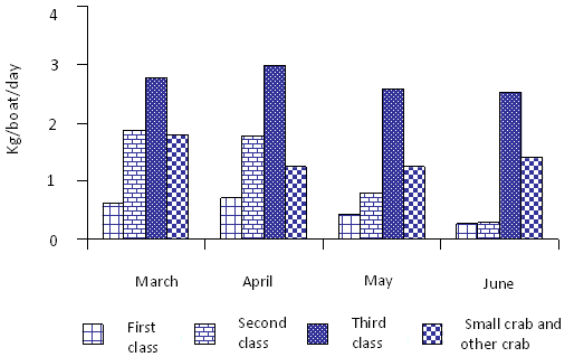


Fig. 7 The average yield of blue swimmer crab by size in average in 4 months

The yield of blue swimmer crab by trawling in Chang Hoan CFi: By using trawling, the average catches of blue swimmer crab in Chang Hoan CFi were not different in three months about 1 kg/boat/day (Fig.8). According to climate conditions, fishermen did not go fishing in June. In addition, most yields were first class (Fig.9). The total catches of blue swimmer crab by trawl gear was

not high compared with crab trap, because the purpose of trawl activities does not catch only crabs but also shrimp, squid, and other fish species.

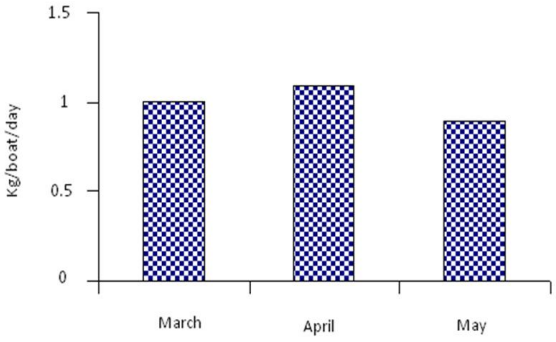


Fig. 8 The average yield of blue swimmer crab in 4 months

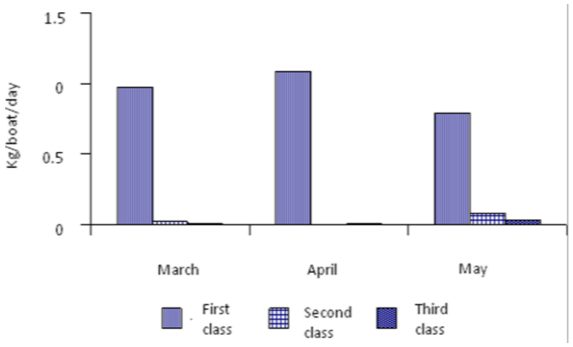


Fig. 9 The average yield of blue swimmer crab by size in average in 3 months

Blue swimmer crab market

Blue swimmer crab market framework (Fig. 10) is related to fishermen, middlemen, crab strip shop owner, consumers, and exportation middlemen.

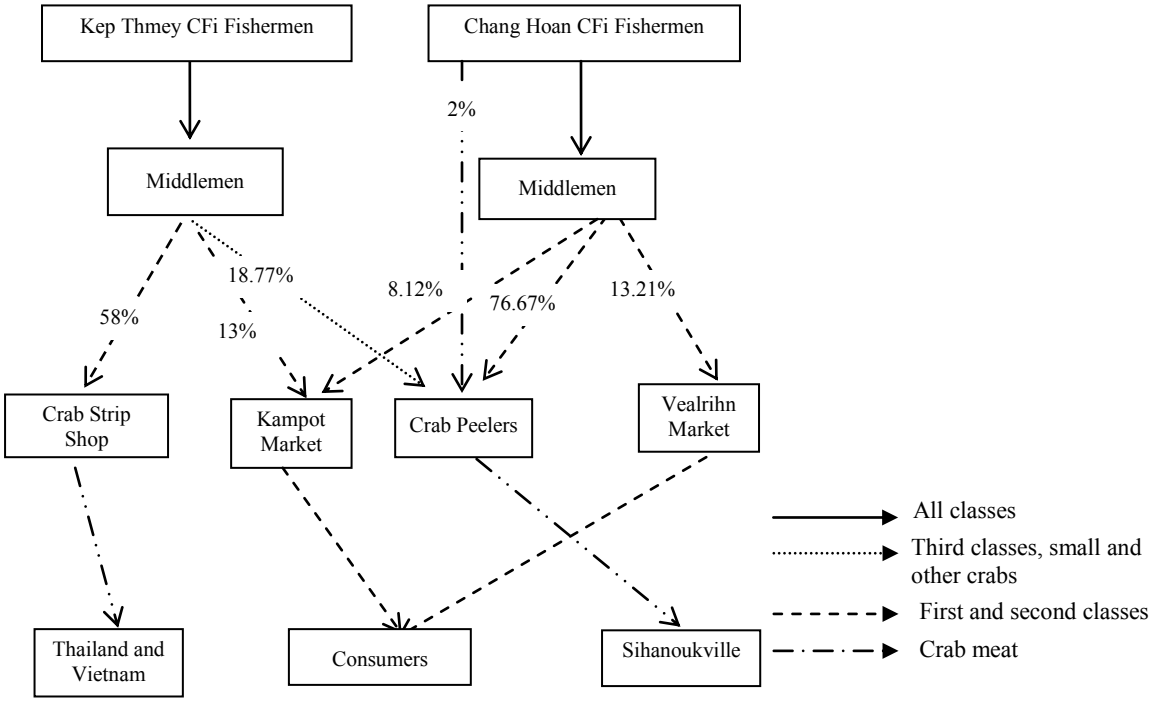


Fig. 10 Blue swimmer crab framework

Blue swimmer crab price

Crabs were priced by the middlemen and it was rarely changed because most fishermen received loans or fishery gears from them. Thus, the crabs should be sold out to the loaners who were the middlemen.

Yet, other fishermen who did not get any loans also sold their crabs to the same person easier than selling it by themselves or selling to others. The prices were different between the fishermen who got loans and did not get loans. The middlemen sold to Kampot and Vealrihn market in higher price. However, the price was not too different between buying from fishermen and selling to the crab strip shop. Generally, the market price for the consumers and crabmeat selling are highest (Table 2).

Table 2 Price change of blue swimmer crab

Price / Market	First Class (riel/kg)	Second Class (riel/kg)	Third Class (riel/kg)	Small Crab (riel/kg)
Bought from fishermen (loan)	15,000	8,500	4,500	500
Bought from fishermen (no loan)	17,000	9,000	4,500	500
Sold to retailers at Kampot market	1,900	10,000	-	-
Sold to retailers at Vealrign market	1,900	10,000	-	-
Sold to crab strip shop	15,300	8,800	-	-
Sold to crab strip shop (no loan)	17,500	9,500	-	-
Sold to consumers	30,000	15,000	-	-
Crabmeat selling	32,000	25,000	20,000	10,000

CONCLUSION

Crab trap is a fishing gear that fishermen in the Kampot Province prefer to use in order to catch blue swimmer crabs. Although, the purpose if trawling is to catch shrimps and squids, but some crabs can be caught by this gear too. The variation of total yield is according to time, weather, place and the number of fishing gears. Moreover, these gears can be use all year round depending on time, place and climate conditions. According to local people surveyed, shows that the cause of blue swimmer crab yields have declined because of fishermen using the small size of crab trap mesh (2a = 4 cm) and the number of crab traps has been increasing in the last few years. Likewise, the use of beach seine is a major cause of destroying the habitats and foods for crab and other aquatic plants and animals. Blue swimmer crabs are clarified into three classes. The first and second classes are counted into high price to sell in markets and the crab strip shop by middlemen and third class are sold to crab peelers. Middlemen play an important role in market finding to fishermen and loan.

REFERENCE

Boal Suong, Ng. 2003. Case study on Trawling Steoung Sen by Using 140 HP of HINO in Kok Kong. Bachelor Thesis. University of Agriculture, Cambodia.

FiA. 2006. Cambodia fisheries magazine. Fisheries Administration. Cambodia.

KetSaNa, K. 2003. Blue swimmer crab fish by using engine board HINO 275 HP in Sihanoukville. Bachelor Thesis. University of Agriculture, Cambodia.

Kunthea, K. 2003. Small-scale fishing in mangrove forest from Prek Ta Som to Prek Kon Kon, Prey Noub District, Sihanoukville. Bachelor Thesis. University of Agriculture, Cambodia.

Kunthy, R. and Guttman, H. 1998. Survey of fish marketing in Svay Rieng Province. Svay Rieng Province, Cambodia.

MAFF. 2002. Blue Swimmer crab and blood cockle fishing in Cambodia Sea. Ministry of Agricultural Forestry and Fisheries, Cambodia.

MoE and DANIDA. 2007. Cambodia coastal zone management in Kampot Province. Cambodia.

Narith, B. 2004. Assessment of fisheries management based community in Prek Tnout Village, Prek Tnout Commune, Kampot District, Kampot Province. Bachelor thesis. University of Agriculture, Cambodia.
Pholine, M. 2002. Fisheries coastal zone management in Poum Thmey Community, Prey Thom Commune, Kep District, Kep City. Bachelor thesis. University of Agriculture, Cambodia.
Potter, I.C., Chrystal, P.J. and Loneragan, N.R. 1983. The biology of the blue manna crab P. pelagicus in an Australian estuary. Marine Biology, 78, 75-85.

Research article

Validated Rice Cultivars for Rice-Based Systems of the Northern Mountainous Region, Lao PDR

KHAMDOK SONGIYKHANGSUTHOR*
Northern Agriculture and Forestry Research Center (NAFReC), Luang Prabang province, Lao PDR
Email: khamdoks@yahoo.com and khamdok.s@gmail.com

HOUMCHITSAVATH SODARAK
Northern Agriculture and Forestry Research Center, Luang Prabang province, Lao PDR

KOUANG DOUANGSILA
National Rice Research Program, Vientiane, Lao PDR

BENJAMIN K. SAMSON
International Rice Research Institute (IRRI), Lao PDR

Received 14 December 2011 Accepted 2 April 2012 (*: Corresponding Author)

Abstracts This study aimed to identify and evaluate appropriate introduced and improved sloping upland rice cultivars for the northern region of Lao PDR (Bokeo, Houphanh, Luangnamtha, Luangprabang, Oudomxai, Phongsaly, Sayabuly, and Xiengkhuang). The study was designed to detect genotype by environment for seven cultivars: 1) Makhinsoung, 2) Nok, 3) Non, 4) Laboun, 5) IR55423-1, 6) B6144F-MR-6 and 7) IR60080-46A in the farmer's field with farmer practices and farmer's preferences analysis. The results showed that both introduced and improved rice varieties consistently produced higher grain yield compared to local varieties, from 157 to 381 kg/ha over years that the experiments were conducted. Local varieties yielded an average of 1700 kg/ha. Most of the varieties were suitable for Oudomxai, Sayabuly and Xiengkhuang provinces. Some varieties were specifically appropriate for some provinces: Non (Bokeo), IR60080-46A (Houaphanh and Luangnamtha). Yield data of all tested varieties were generally significantly different from that of local variety. However, grain yield differences of entries in Luangprabang and Phongsaly were not significant, but almost all the entries cultivars produced more grain than local checks.

Keywords plant characteristics, rice cultivar validation, northern mountainous and upland cultivation

INTRODUCTION

Rice is the primary staple crop of Lao PDR. It accounts for 70% of the diet and supplies about 70% of caloric requirement. Among Lao people, rice self-sufficiency is equated to food self-sufficiency (Linquist et al., 2007). Laos achieved rice self-sufficiency in 1999; upland farmers and households are still rice-deficient.

The uplands of Lao PDR are located in northern part of the country and along the Laos-Vietnamese border in the central and southern regions. The northern uplands form the largest upland environment in Lao PDR, comprising seven, out of eighteen provinces that make up the whole of Laos. It is predominantly mountainous, but there are a number of minor plains and numerous flat intermountain basins and narrow river valleys where water is available year-round, allowing for full or partial irrigated agriculture. Upland farmers grow rice in the intermountain basin, and river valleys as transplanted wetland or lowland paddy rice, and on the sloping uplands as direct-seeded

upland rice. The uplands also provide a range of agro-ecological environments that enable farmers to grow cash crops, paper mulberry, cassava, and beans, among other crops.

Surveys of upland households show that livelihoods are overwhelmingly agricultural in nature. Farmers with more lowland had better food security than farmers who raised their crops purely on upland sloping environments. Seventy three percent of households reported at least 1 year of rice deficiency in 10 years (1995-2005). In contrast, only 17% of households with lowland reported at least one year of rice deficiency during the same period.

The major constraints to improve rice production in the uplands are low productivity of rice varieties, lack of high quality seeds and livestock diseases, inadequate extension services, limited access to public services and advanced technologies, poorly developed transport, irrigation and marketing infrastructures (Roder, 2001).

This paper aims to describe the process and results of a long-term effort to evaluate and identify appropriate rice germplasm for the uplands of Lao PDR through multi-environment yield trials.

METHODOLOGY

Multi-environment yield trials were conducted on farmers' fields, with farmer participation, in eight provinces of the northern region of Lao PDR: Sayabuly, LuangPrabang, Oudomxai, Luang-Namtha, Bokeo, Phongsaly, Houaphanh, and Xiengkhuang. The field research sites were selected to represent the northern region of Lao PDR. Oudomxai and Sayabuly provinces had more farmer participants from 2005 to 2009. Elevation of field sites ranged from 300m to 1300m. Fields were selected to be representative of upland environments.

Seven lines and cultivars were used in the trials. Laboun, Non, Nok, and Makhinsoung are traditional cultivars which have been identified from a series of screening trials to perform well under a range of upland conditions. These cultivars have been purified so that each variety is distinctive, recognizable and produce uniform crop stands in the field. IR55423-1, B6144F-MR-6, IR60080-46A are improved, stable, non-glutinous rice lines which perform well in upland environments. Seeds were direct-seeded on dry soil. Crops were managed according to local practice. Neither fertilizer nor other agricultural chemicals were used on the crop. At the time of harvest, crop cuts were taken to determine grain production of the lines and cultivars. Data from 2003 to 2009 were included in the analysis. Data were tabulated and graphically evaluated.

Preference analyses by farmers were conducted prior to harvest. Farmers were asked to identify the reasons why they liked or disliked particular varieties. These data were tabulated and graphically evaluated.

RESULTS

Table 1 shows the mean grain yield of seven rice cultivars in eight northern Lao PDR provinces. Under farmer management practices, grain yields of test cultivars were significantly better than those of local check varieties. Yield advantage of rice lines and selected and purified glutinous landrace varieties ranged from 157-381 kg/ha (9-22%). Improved non-glutinous varieties (IR 55423-1, B 6144F-MR-6, IR 60080-46A) produced 167-334 kg/ha (10-20%) more grain than local checks. Selected and purified traditional cultivars (Laboun, Non, Nok, and Makhinsoung) produced 157-381 kg/ha (9-22%) more grain than checks.

Sites where the trials were conducted were significantly different in mean rice production across the years examined (Table 2). Bokeo had the highest mean annual rice production (2,309 kg /ha) among eight provinces, while Phongsaly and Xiengkuang had the lowest (1,615 kg/ha).

Table 2 also shows that mean rice production, across sites, was more than 1,800 kg/ha from 2003 to 2007. Production declined in 2008 and 2009. The trend of production is shown in Figure 1. IR60080-46A exhibited the best yields in 2003 and 2004, during the "good" years for rice production. However, B6144F-MR-6 did best in 2006 and 2008. Laboun performed best in 2005, 2007 and 2009. These observations may indicate that these lines and cultivars are highly adaptable to both "good" and "bad" rice growing years.

Table 1 Mean grain yield of seven test lines and cultivars and their yield advantage over local varieties

Varieties	Grain yield (kg/ha)		Grain yield advantage (kg/ha)	Grain yield advantage (%)
Laboun	2080	a	381	122
Non	2038	ab	339	120
IR60080-46A	2034	ab	334	120
B6144F-MR-6	2017	ab	318	119
Nok	1887	abc	188	111
IR55423-1	1867	bc	167	110
Makhinsoung	1857	bc	157	109
Local	1700	c	0	100
SE(N= 9)	76			
5%LSD 780DF	210			
PR>F	0.0001			

Table 2 Mean annual rice grain yield in eight northern Lao PDR provinces

Provinces	Annual grain yield (kg/ha)							Mean (kg)
	2003	2004	2005	2006	2007	2008	2009	
Luangprabang	1908	2037	1995	2036	1663	1407	1610	1808
Oudomxai	2239	1861	1604	1336	2881	1057	1771	1821
Houphanh	-	-	1941	2184	1615	-	-	1913
Luangnamtha	1311	1830	2035	1341	1957	-	-	1695
Phongsaly	1783	1351	1860	-	-	-	1467	1615
Sayabuly	1843	2784	2720	2712	-	-	1313	2275
XiengKuang	1886	1497	1383	2128	-	-	1187	1616
Bokeo	2627	2810	1523	1693	2893	-	-	2309
Mean (kg)	1942	2024	1883	1919	2202	1232	1469	1882
SE(N=99)	187							
5%LSD 780DF	518							
PR>F	0.000							

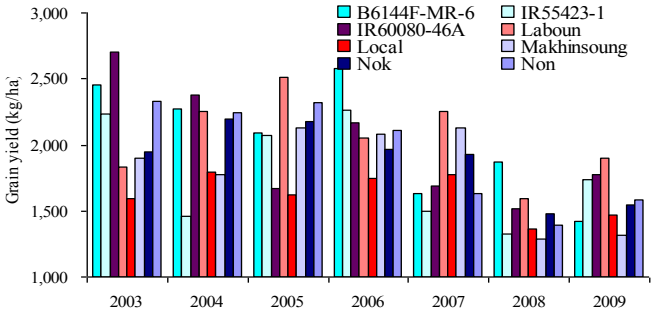


Fig. 1 Grain yield of seven rice lines and cultivars over seven years, averaged across sites

Rice lines and cultivars performed well in Oudomxai, Sayabuly and Xiengkhuang provinces (Table 3). Some varieties performed well in specific provinces, such as Non in Bokeo province, and IR60080-46A in Houphanh and Luangnamtha. However, none of varieties stood out in terms of grain production in Luangprabang and Phongsaly provinces. Almost all lines and cultivars in the test set, except Makhinsoung, and the checks produced more than 2,000 kg/ha in Sayabuly province sites.

Fig. 2 gives a human dimension to the grain yield data. The graphic summarizes farmer opinions and comments on traits that they liked and disliked about the lines and cultivars in the test set. Large panicles, big-sized grain and strong culms were the most commonly referred to positive characteristics. Farmers did not like cultivar that produced few tillers, short and non-uniform panicles.

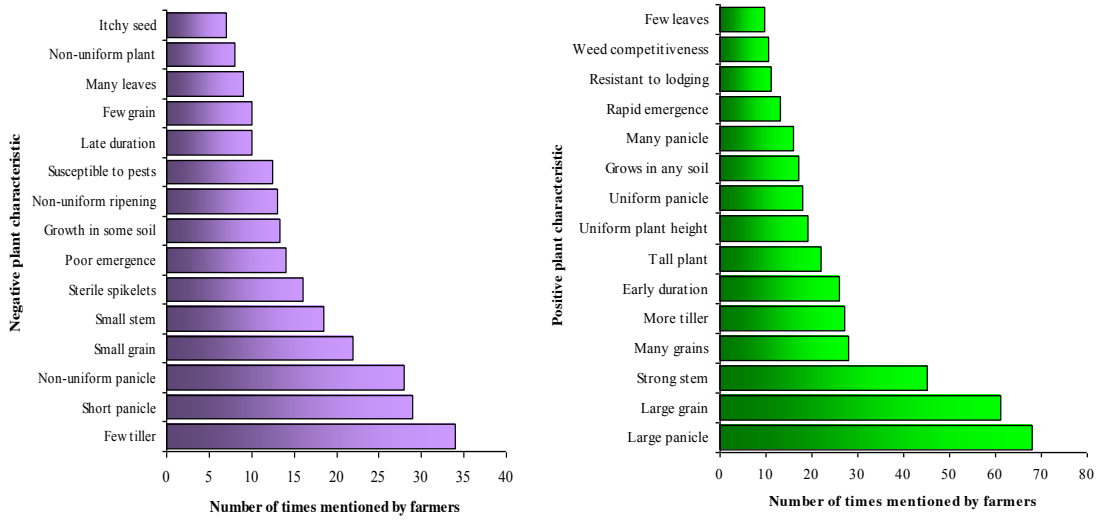


Fig. 2 Positive and negative plant characteristics most mentioned by farmers

Table 3 Grain yield of rice lines and cultivars in eight northern Lao PDR provinces

Varieties	Bokeo	Houa phanh	Luang namtha	Luang prabang	Oudom xai	Phongsaly	Sayabuly	Xieng khuang
B6144F-MR-6	1710	1659	1887	1814	2511	1458	3748	2233
IR55423-1	1706	1974	1789	1753	1508	1091	3595	1344
IR60080-46A	1720	3577	2276	1828	2913	1628	4496	2133
Local	1704	1934	1686	1668	1456	1627	2251	1524
Laboun	1688	1954	1807	2040	2680	1470	3160	2294
Makhinsoung	1789	2148	1817	1697	2108	2052	1761	2366
Nok	1380	1951	1638	1881	2074	1086	2108	2700
Non	2478	1953	1683	1993	2040	2028	2072	1928
SE(N=12)	205							
5%LSD 724DF	570							
PR>F	0.0000							

Based on the preferences of farmers, six (Nok, Makhinsoung, Laboun, Non, IR55423-1 and B6144F-MR-6) were propagated. Production of seeds for distribution to farmers was ramped up from 2005 to 2009 (Table 4). Makhinsoung and Nok distribution to farmers was more than 2 and 3 tons, respectively, in 2009. B6144F-MR-6 distribution peaked at 2 tons in 2007.

Table 4 Amount of rice seed distributed (kg) from 2005 to 2009

Varieties	Seeds distribution in each year (kg)				
	2005	2006	2007	2008	2009
Nok	30	230	220	2585	3317
Makhinsoung	20	100	200	1079	2207
Laboun	20	250	250	340	1145
Non	20	30	-	70	527
IR55423-1	5	20	30	50	163
B6144F-MR-6	10	800	2000	25	165
Total	105	1430	2700	4149	7524

The number of farmers planting the lines and cultivars, and the amount of seeds they used are summarized in Table 5. There was a steady increase in number of farmers planting the lines and cultivars and the amount of seeds that they used, except for IR55423-1. By 2008, fifty farmers were

using Non and Nok, but larger amounts of seeds were being used by farmers using Nok, perhaps implying that larger areas of land were being sown to his cultivar. The number of farmers trying out B6144F-MR-6 increased to 70 by 2008 but the amount of seed used was static from 2008 to 2009 at about 900 kg. This probably means that more farmers were trying out the line, but steady uptake was not yet occurring for this rice line. It is worth noting that these data are limited to the farmers and farm households that could be tracked by the researchers and does not include unreported seed exchanges and sales.

Table 5 Number of farmers planting selected rice lines and cultivars and amount of seed used from 2006 to 2008

Variety	2006		2007		2008	
	Farmers	Amount of seed (kg)	Farmers	Amount of seed (kg)	Farmers	Amount of seed (kg)
Nok	5	2.5	8	220	50	2585
Makhinsoung	5	2.5	7	200	27	1079
Laboun	5	2.5	10	100	20	800
Non	5	2.5	4	100	50	450
IR55423-1	5	2.5	2	30	3	50
B6144F-MR-6	5	2.5	50	900	70	850

DISCUSSION

Results showed that both introduced lines, and selected / purified landraces performed better, under the same environmental conditions, as local varieties (Asai et al., 2009). However, other reported that only the improved rice germplasm produced higher yields in both low and high fertility conditions over a number of locations (Saito et al., 2007). The average grain yield of the test lines and cultivars was higher than that of the local varieties in all sites. This supports the findings (Atlin et al., 2006). Higher productivity may be due to high sink size of improved lines and selected/purified landraces, manifested by their larger panicle number per unit area. Panicle number has been reported to be an essential trait for high grain yield in low as well as high soil fertile uplands in Asia and West Africa (Saito and Futakuchi, 2009). Poor adaptation of tropical japonica rice genotypes to low soil fertility conditions may be the result of reduced sink size and grain-filling percentage.

Our results suggest that improved indica rice and selected/purified traditional rice cultivars can improve productivity without addition of fertilizer, even in low soil fertility conditions (short fallow cycle). This finding is significant and important for resource-poor farmers, who have faced difficulty in maintaining rice productivity in short-fallow slash-and-burn systems in northern Laos. Other reasons for those select/purified traditional rice cultivars were preferred and adopted in large areas by Laos farmers, because they were glutinous rice and big-sized grain. And most of Laos's farmers preferred glutinous cultivars than non-glutinous cultivars.

The use of these genotypes should only be seen as a component for improving upland rice-based cropping systems since continuous rice cropping with such high-yielding genotypes can lead to a greater nutrient withdrawal from the soils as well as a more rapid decline of soil organic carbon in upland conditions (Saito et al., 2006b; Asai et al., 2007). Therefore, integrated soil fertility management practices need to be developed for effective use of sustainable rice production.

CONCLUSIONS

This paper showed that indica and tropical japonica rice genotypes differed in yield response to soil fertility conditions under rainfed uplands in northern Laos. Grain yield of rice genotypes were not stable across low and high soil fertility conditions. Grain yield of introduced improved rice lines, and selected/purified cultivated varieties were generally significantly better than local varieties.

REFERENCE

Asai, H., Saito, K., Samson, B.K., Songyikhangsuthor, K., Homma, K., Shiraiwa, T., Kiyono, Y., Inoue, Y. and Horie, T. 2009. Yield response of indica and tropical japonica genotypes to soil fertility conditions under rainfed uplands in northern Laos. Field Crops Research, 112, 141-148.

Asai, H., Saito, K., Samson, B., Vongmixay, K., Kiyono, Y., Inoue, Y., Shiraiwa, T., Homma, K. and Horie, T. 2007. Quantification of soil organic carbon dynamics and assessment of upland rice productivity under the shifting cultivation systems in northern Laos. In: Proceedings of the 2nd International Conference on Rice for the Future, Bangkok, Thailand, 9-13.

Atlin, G.N., Laffite, H.R., Tao, D., Laza, M., Amante, M. and Courtois, B. 2006. Developing rice cultivars for high-fertility upland systems in the Asian tropics. Field Crops Res. 97, 43-52.

Linquist, B.A., Tro¨ sch, K., Pandey, S., Phouynyavong, K. and Guenat, D. 2007. Montane paddy rice: its development and effects on food security and livelihood activities of highland Lao farmers. Mountain Res. Dev. 27, 40-47.

Roder, W. 2001. Slash-and-Burn Rice Systems in the Hills of Northern Laos PDR: Description, Challenges and Opportunities. International Rice Research Institute, Los Ban˜os, Philippines, 201.

Saito, K.and Futakuchi, K. 2009. Performance of diverse upland rice cultivars in low and high soil fertility conditions in West Africa. Field Crops Res. 111, 243-250.

Saito, K., Atlin, G.N., Linquist, B., Phantaboon, K., Shiraiwa, T and, Horie, T. 2007. Performance of traditional and improved upland rice cultivars under nonfertilized and fertilized conditions in northern Laos. Crop Sci. 47, 2473-2481.

Saito, K., Linquist, B., Keobualapha, B., Phanthaboon, K., Shiraiwa, T. and Horie, T. 2006b. Cropping intensity and rainfall effects on upland rice yields in northern Laos. Plant Soil 284, 175-185.

Research article

Structure and Conduct of the Purple Rice Market in Northern Thailand

PATTANA JIERWIRIYAPANT*
Faculty of Agriculture, Chiang Mai University, Chiang Mai , Thailand
Email: pattanaj@chiangmai.ac.th

ONG-ART LIANGPHANSAKUL
Faculty of Agriculture, Chiang Mai University, Chiang Mai, Thailand

WANWILAI CHULAPHUN
National Pingtung University of Science and Technology, Pingtun, Taiwan R.O.C.

Received 14 December 2011 Accepted 18 April 2012 (*: Corresponding Autor)

Abstract In recent years, health issues are a major concern for consumers. Northern Thai farmers are seeking alternative crops with high nutritional value and market potential. Recent studies show that purple rice (or Thai black rice) is rich in nutrients, such as gamma-oryzanol and natural antioxidants, and therefore, could be potential crop. The main purpose of this study is to investigate market structure and market conduct of purple rice in northern Thailand. Porter's five forces analysis was used to evaluate the competitiveness and relative attractiveness of growing purple rice. The surveying method was used to study market conduct. The result from the estimated Concentration Ratio indicated that market structure of purple rice differ in all three provinces. It was also found that the five competitive forces influence the collectors the most and the farmers the least. Even though the competitive forces aren't very high, survey data indicates that the purple rice market hasn't been found attractive by farmers, collectors or retailers.This study concludes that despite purple rice being a high-nutrient product, its market is still very small in northern Thailand. However, purple rice as a serious commercial crop is still not that attractive to the farmers.

Keywords structure, conduct, purple rice, Northern Thailand

INTRODUCTION

As good health is a growing issue for consumers, many studies have been focusing on finding nutritious foods that can be used as a sort of alternative medicine. Northern Thai farmers are looking for crops with both high nutritional value and high marketability. Research by Boonsit, Kaladee and Phongpiachan in 2006 shows that purple rice (or Thai black rice) has a mean of 55.58 mg of gamma-oryzanol per 100 g, compared to white rice that has a mean of only 30.67 mg per 100 g. Additionally, purple rice contains big amount of natural antioxidants and its extract's antioxidants can be used as a natural preservative in meat products (Min, Chen & Green, 2009).

Due to these nutritional advantages, demand for purple rice may increase; creating an opportunity for farmers in northern Thailand. However, the factors that influence the farmers' decision-making process need to be understood in order to convince farmers to start growing purple rice instead of white rice. The farmers' decision to adopt a new crop is not solely led by economic factors, but socio-economic and psychological factors as well. Purple rice has been grown in Thailand for quite some time and is perceived as a crop for local consumption which hinders its attractiveness as a commercial crop by farmers.

As it is important to understand the production and market of purple rice, this study's purpose is to investigate the current marketing situation and better understand the market's structure and conduct of this crop in northern Thailand. Porter's five forces analysis was used to evaluate the rel-

ative competitiveness and the attractiveness of growing purple rice. The surveying method was used to study market conduct. Additionally, in order to successfully promote purple rice, this study aims to find the factors that could influence the farmers' adoption of this healthy alternative to white rice.

MATERIALS AND METHODS

This study's primary data was collected from all players in the supply chain; farmers who grow purple rice in Chiang Mai, Chiang Rai and Phayao Provinces, local collectors, wholesalers and retailers over the course of the 2010-2011 production. Questionnaires and personal interviews were conducted in order to analyze the market's structure and conduct, and Porter's five force analysis was applied to examine the competitiveness and to analyze the attractiveness and profitability of the industry.

Porter's analysis is used to determine the degree of competition and the attractiveness of a market environment by looking at five forces; threat of new entrants, competitive rivalry, bargaining power of suppliers, bargaining power of consumers and the threat of substitute products (Porter, 2008). Factors of each force were identified and analyzed in order to gain understanding of the supply chain's key players and the influence each force has on them. The questionnaire was designed using the Likert scale that allows participants to measure the influence of each force by selecting a number between 1 and 5; 5 represents the highest level of influence while 1 represents the least influence (Likert, 1932).

The concentration ratio (CR) of the market structure was used to assess the monopoly power or degree of concentration in the system, if any. The CR is a partial index that measures the share of the industry that is made of a few large firms or groups. It is calculated as follows;

$$CR_n = \sum X_n / \sum X_i$$

CR_n denotes the share of the industry accounted for n larger firms in the market, $\sum X_n$ is the volume of product produced by n firms and $\sum X_i$ is the volume of product produced by all firms in the market. The estimated value of CR for any given n should be between 0 and 1 - the higher the CR indicated, the greater the market concentration or monopoly power.

Market structure can be classified based on the size of the market share in the hands of the top firms (Bain, 1968). For example, if the top four firms control more than 70 percent of the market, it's revealed to be a highly concentrated oligopolistic market. Other factors such as barriers to entry, entry conditions and exit conditions are also evaluated. Production and marketing strategies, pricing behavior and policies of purple rice were examined during the personal interviews and surveys. Also, secondary data related to marketing purple rice in northern Thailand was collected from various sources and is listed in the references section of this paper.

RESULTS AND DISCUSSION

Competitiveness of the industry

The threat of new entrants is high for both collectors and retailers, while farmers have a medium level as most purple rice farmers belong to agricultural groups and usually produce under contractual agreement. Since this is the case, the farmer's suppliers of inputs and buyers of outputs are typically the same person - thus reducing their bargaining power as suppliers. The rivalry among competitors is low as there isn't much product differentiation with the same variety of purple rice. Threat of substitutes is also low due to the uniqueness of the product.

The results from the study's Porter's five forces analysis of the competiveness of northern Thailand's purple rice industry can be seen in Table 1. These results indicate that the competitive forces influence the collectors the most (3.2) and the farmers the least (2.4) as shown in Fig. 1.

Even though the competitive forces aren't very high, survey data indicates that the purple rice

market hasn't been found attractive by farmers, collectors or retailers.

Table 1 Influence level of competitive forces of marketing environment for purple rice

Competitive Five Forces	Mean (Likert Scale Rating)		
	Farmers	Collectors	Retailers
1. Threat of new entrants	2.9 (medium)	3.8 (high)	3.7 (high)
2 .Rivalry among competitors	2.7 (medium)	3.1 (medium)	3.0 (medium)
3. Bargaining power of suppliers	2.0 (low)	3.4 (medium)	1.9 (low)
4. Bargaining power of buyers	2.9 (medium)	2.2 (low)	2.4 (low)
5. Threat of substitutes	1.5 (low)	3.6 (high)	2.8 (medium)
Average Mean	2.4 (low)	3.2 (medium)	2.7 (medium)

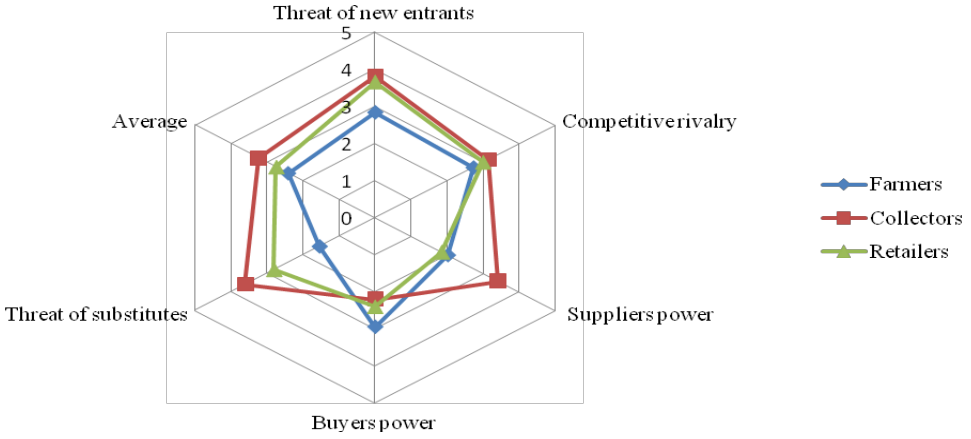


Fig. 1 Weighted score of marketing competitive forces

Market structure for purple rice

After using the CR to measure the purple rice market, it was found that each of the three selected provinces' market concentration differs. However, pricing is set by buyers either through contract farming or the buyers' bargaining power in each market.

In Phayao Province, only one agricultural group, consisting of 33 farmers, exists. The member farmers obtain the seed from the group leader who also serves as the collector, miller and retailer. The Phayao market is monopolistic with the market share of this group accounting for 25.3 percent of northern Thailand.

Two major purple rice producers exist amongst over 100 very small scale farmers in Chiang Rai Province with an estimated CR_2 of 0.08. Despite the low CR, the two major farms run their own rice mills and have an outlet for selling the final product. Purple rice from the rest of other small farmers is sold to four large collectors with an estimated CR_4 of 0.73 which indicates a high oligopolistic market.

Chiang Mai Province's purple rice market is very small scale that allows for perfect competition.

CONCLUSION

This study concludes that despite purple rice being a high-nutrient product, its market is still very small in northern Thailand. However, there are signs of market growth in some areas. Even though

the market structures vary among the three provinces, the bargaining powers of both the buyers and suppliers are quite high for the farmers. It was also found that the concentration ratio was higher at the collectors' level and the pricing is still under the intermediary buyers' power. Purple rice needs to be promoted in order to make it an attractive alternative crop for farmers.

ACKNOWLEDGEMENTS

We are grateful to the National Research Universities Program of the Office of the Commission on Higher Education, Ministry of Education, Thailand, whose funding made this study possible.

REFERENCES

Bain, J.S. 1968. Industrial organization. New York : John Wiley and Sons.

Boonsit, P., Kaladee, D and Phongpiachan, P. 2006. Gamma oryzanol content in purple rice Thailand local genotypes. Prosperity and poverty in a globalized world - challenges for agricultural research, Bonn, Germany.

Likert, R. 1932. A technique for the measurement of attitudes. Archives of Psychology. 22 (140), 55.

Min, B., Chen, M.H. and Green, B.W. 2009. Antioxidant activities of purple rice bran extract and its effect on the quality of low-NaCl, phosphate-free patties made from channel catfish (Ictalurus punctatus) belly flap meat. Journal of Food Science, 74, C268-C277.

Porter, M.E. 2008. The five competitive forces that shape strategy, Harvard Business Review, January, 86-104.

Research article

Role and Opportunities for Foreign Investment and Its Risks for Rural Development in Laos

SATOMI KIMIJIMA*
School of Engineering and Technology, Asian Institute of Technology, Thailand
Email: kimijimasatomi@hotmail.com

MASAHIKO NAGAI
Geoinformatics Center, Asian Institute of Technology, Thailand

Received 16 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract Recently, foreign investment has grown significantly in the Greater Mekong Sub-region (GMS) hence its macro-economic impact has been the subject of numerous research studies. However, there is a lack of studies assessing the micro-economic impact of foreign investment in the rural areas of GMS countries. This paper (a) assesses the change in rural non-farm wage employment as a result of foreign investment and its socio-economic impact on rural people in Laos, (b) highlights the participation of women in a plantation project initiated by a Japanese company, and (c) analyze the effect of foreign investment on people's mobility patterns, the change on their interactions at local level and the risks for rural development. Data has been collected using purposive sampling methods with a total of 80 respondents from two villages and were selected randomly at a household survey in 2009. The respondents comprised 50% of men and also 50% of women in each village. Questionnaire survey, focus-group discussion and field observation were conducted. The results showed a significant change of income for rural people employed by the project, particularly for women. Improved women's participation had provided opportunities for their empowerment and changed their mobility patterns. This, in turn, facilitated women's networking with people with diverse status and experiences outside their village. This resulted in a slight change in women's active participation in community meetings at the local level as well as their relations with men, challenging existing socio-cultural norms. It was concluded that foreign investment can contribute to rural development by creating a non-farm rural employment opportunities. However, it is also cautious to become excessively dependent on foreign investment for rural employment opportunities since foreign investment have a high risk of changing condition in the global market.

Keywords employment creation, foreign investment, Laos, mobility, women's empowerment

INTRODUCTION

Socio-economic change at the community level is one of the factors influencing gender roles and status of women. Rapid socio-economic change has been observed in many developing countries involved in Foreign Direct Investment (FDI). FDI is defined as "an investment involving a long term relationship and reflecting a lasting interest and control of a resident entity in the source county (foreign direct investor or parent firm) in the host country" (Razin and Sadka, 2007). It is argued that through FDI, the host country can be provided with more employment and increase local production growth. However, there is little information regarding the contribution of FDI to socio-economic levels in developing countries especially in Greater Mekong sub-region countries.

FDI has grown significantly with the increasing globalization of the economy since the 1960s that was operated by multi-national companies. This affected third world countries by creating a New International Division of Labor (NIDL), which is the relocation of export-oriented industriali-

zation from developed countries to developing countries. The NIDL has enabled developing countries to export not only primary products, but also competitive products to developed countries thereby shifting the areas of manufacture. This is because of the availability of cheap and obedient labor force such as women engaged in reproductive sectors. Thus, giving rise to feminization of labor. FDI paradigm is believed to be more stable associated with technology and skill transfer.

Southeast Asian countries initiated the Greater Mekong Subregion (GMS) Economic Cooperation Program in 1992 (Ngampramuan, 2008) with the aim to promote socio-economic development within countries sharing the Mekong River through strengthened intra-regional economic cooperation. Such initiatives, in fact, facilitated economic liberalization and deregulation leading to free market policies (ibid) and encouraged various foreign investments in the GMS countries. Several studies regarding GMS regional economic corporation pointed out positive socio-economic impacts at macro level, specifically with the increase in foreign investment (ADB, 2006). However, the dynamic impact of foreign investment at the micro-level in rural areas of the GMS countries is documented only in a few studies.

In Laos, the New Economic Mechanism introduced in 1986 enabled the expansion of foreign direct investment in the country, facilitating the transition from subsistence to a market economy (Mwankusye, 2002). Furthermore, GMS Economic Cooperation systematized the way towards foreign investment (ADB, 2006). Investment in rural Laos is quite significant in the sectors of agriculture, industry, trade/service, hydropower and mining (ADB, 2005). As a result, various types of employment opportunities have been created by foreign investment in Laos.

In 2005, a Japanese company took over a foreign-owned tree plantation, a joint venture company that was set up in 1996. The Japanese investor implemented 112 plantation projects in 150 villages, employing workers in tree nursery, grooming, planting, weeding and fertilizing activities. In Nongboua Noy village of Laos, many villagers are employed in a tree plantation nursery center near the village.

This paper (a) assesses the change in rural non-farm wage employment as a result of such investment and its socio-economic impact on rural people in Laos, (b) highlights participation of women in a plantation project initiated by a Japanese company, and (c) analyzes the effect of such investment on people's mobility patterns and the resulting change in interactions at local level and analyzes risks of such investment for rural development.

METHODOLOGY

This paper discussed the changes in socio-economic status of local people after their employment in the plantation project managed by Japanese company in rural Laos. The study areas are located in Hinboune district, Khammouane province, Lao PDR. The study purposively selected the villages named Nongboua Noy and Hath Yai. Nongboua Noy village was selected as many villagers have been employed at a nursery center established nearby. Furthermore, Hath Yai was selected as there was no significant employment creation in the village. The purpose of selecting these two villages was to compare the socio-economic impact by foreign investment.

A total of 80 individual respondents from the two villages were randomly selected for a household survey through pre-tested questionnaires in 2009. The respondents comprised 50% male and 50% female in each village. The study also employed formal and informal interview to retrieve information from key informants such as the Laos' branch manager and village heads using check lists and from Focus Group Discussions (FGDs). Male and female participants were grouped separately during the discussion on FGDs. Data collection also involved direct field observation. Local language was used as the means of communication with local people assisted by a translator particularly during the interview.

Both qualitative and quantitative types of data were collected. Primary data was collected in order to analyze how the Japanese plantation project affects the socio-economic condition of rural people, influences mobility patterns and household community relations in rural Lao. Secondary data from Asian Development Bank, Japan External Trade Organization, the Japanese Paper Company, and their Laos branch were also collected in order to find out the historical background of the

plantation project. Furthermore, data from the Lao National Statistics Centre were gathered in order to compute gender compositions and to find out the changes in socio-economic conditions after employment at the Japanese company. Quantitative data regarding the gender composition was analyzed using cross tabulation in SPSS version 16. Qualitative analysis was done with extensive review of secondary data and primary information from the FGDs and informal interviews with villagers.

RESULTS AND DISCUSSION

Changes in rural non-farm wage employment and socio-economic conditions

Rural industries hold high potential of employment contribution, especially for women, who are categorized as subgroups of the population. The plantation project has employed more than 3000 daily wage workers throughout Laos, of which men and women have been employed in similar numbers. Approximately 50 daily wage workers have been employed in Nongboua Noy village with a high participation of women. A comparison of household income revealed that non-farm employment contributes to increase the annual household income (Table 1).

Table 1 Comparison of annual household income by villages before-after the establishment of the project

Annual Household Income (Kip)	Nongboua Noy Village		Hath Yai Village	
	2005	2009	2005	2009
<2,000,000	30 (75.0)	0 (0)	18 (45.0)	16 (40.0)
2,000,001 - 4,000,000	8 (20.0)	23 (57.5)	10 (25.0)	8 (20.0)
4,000,001 - 10,000,000	2 (5.0)	15 (37.5)	12 (30.0)	16 (40.0)
>10,000,001	0 (0)	2 (5.0)	0 (0)	0 (0)

Source: Field Survey 2009

Note: - Percentage in the figures (inside brackets) denotes the distribution of the respondents within the column
- Kip: Laos currency (1US $= 8,338.30 Kip in July 2009)

Households in Nonboua Noy village were benefited relatively more in comparison to households in Hath Yai village in terms of annual household income. The increase in annual household income in Nongboua Noy village was noted to be five times higher compared to the period before the establishment of foreign investment. The respondents' active participation in the project was found to be a significant key factor contributing to the increase of annual household income which is not noted in Hath Yai village. Benfica *et al*., (2002) pointed out that plantation projects and agricultural industry play a significant role in rural employment creation and reduce poverty through an increase in wages. Plantation industries are also found to contribute to socio-economic development of rural households.

Participation of women in a plantation project initiated by a Japanese company

Women's contribution to household cash income was minimal before the project. However, there were significant changes after the project started. The survey showed higher percentages of contribution to annual household incomes among male and female respondents in Nongboua Noy village (Table 2). Nevertheless, women's contribution to the annual household income in Nongboua Noy village was much higher than in Hath Yai village. The analysis of Hath Yai village is not presented since there was no significant change in women's economic contribution. An increase in women's contribution to household income is widely observed particularly in the lower to medium annual income from - 2,000,001 to 4,000,000 kip and from 4,000,001 to 10,000,000 kip.

Table 2 Individual contribution to household annual income by sex in Nongboua Noy village

Respondents	Contribution to Annual Household Income (%)				
	<10	11-30	31-50	51-80	>81
Female	1 (5.0)	4 (20.0)	11 (55.0)	0 (0)	4 (20.0)
Male	0 (0)	0 (0)	5 (25.0)	6 (30.0)	9 (45.0)
Total	1 (2.5)	4 (10.0)	16 (40.0)	6 (15.0)	13 (32.5)

Source: Field Survey 2009
Note: - Percentage in the figures (inside brackets) denotes the distribution of the respondents within the row

A study conducted in India found that wage structure in a plantation industry is biased since women workers could not access the same wage as men even though women's work load was more than that of men (Reddock and Jain, 1998). However, in the case of Laos, the study showed positive results as the plantation project positively involved women with the same daily wage of men. The wage differentials and occupational segregation as reported from India was not observed in Laos. Labour market regulation has been considered to play an important role in reconciling the goals of efficiency and equality (Elson, 1999). Such positive economic contribution to household income developed women's self-confidence. According to the respondents, that women's self-confidence had increased with their contribution to household income. The study also found out that a positive correlation between women's household income contribution and their positive attitude at the community level. Thus, through women's development on self-confidence has influenced them to practice actively in community-based activities.

Change in women's mobility patterns and their empowerment

Improved women's participation provided opportunities for their empowerment and changed their mobility patterns. Equal opportunity of women's mobility is not being practiced especially in rural areas, with women, especially having less mobility than men (Jennifer and Mandel, 2004). However, the study found an increase in mobility for women within and outside the village such as traveling to markets, health centers and attending meetings at plantation project. Respondents indicated that there is a positive correlation between mobility development and contribution to household income. Thus, large mobility developments are observed among women contributing to the household income. The change in mobility can be summarized as from household to community, household to near community, household to another community and another community to household (Fig. 1).

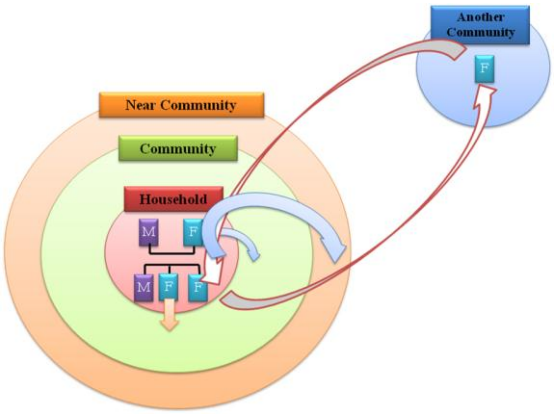


Fig. 1 Change in mobility pattern in Nongboua Noy village
Source: Field Survey 2009

Furthermore, development of mobility facilitates women's networking with people with diverse status and experiences outside their village. Such interactions provided women with alternative sources of knowledge and developed household strategies regarding women's relations with men in the village. Indeed, women further developed self-confidence through such experiences. The qualitative information showed positive relations between mobility development and an active approach to decision making at the community level. In contrast, in Hath Yai village, there were no positive changes. Thus, the economic development has not only empowered women economically but also developed their interaction toward different people. Economic development also means mobility and network development for women and specifically provides them with opportunities to obtain and develop knowledge and strategies to deal with men. This finding is consistent with the findings of Carr, *et al*., (1996), that economic empowerment is a significant factor in the empowerment of women with increased levels of awareness, understanding, unity, mobility and confidence to handle problems outside of the family.

Risks of foreign investment to rural development

While FDI in the plantation sector has led to positive results in terms of increased household income, mobility development and women's empowerment at the local level, it is also important to consider the risks inherent in foreign investment. For example, the global financial crisis in 2008 caused a decline in paper consumption in the United States but the demand for paper in newly industrializing countries like China grew (Paper News, 2010). This became an opportunity for foreign investors to seek and develop new sources of raw material for paper production such as tree plantations in GMS countries. Indeed, the Japanese plantation company in Laos has shifted its target from the world market to East and Southeast Asia, and is planning other plantation projects and new factories in Southeast Asia.

At the same time, the new Foreign Investment Law in Laos aims to attract more foreign investment (ASEAN-JAPAN CENTRE, 2009). An excessive inflow of foreign capital aiming to exploit the subregion's rich human and natural resources would lead to overuse of depleting natural resources. In addition, continuous establishment of foreign investments and industries threaten the local traditional lifestyles through rapid structural changes transforming the subsistence economy to a market economy. Furthermore, this will create over-reliance on foreign investment which is vulnerable to international market conditions.

CONCLUSION

Women's active participation was limited before the establishment of the project due to lack of income and prevalent socio-cultural constraints on women. The socio-economic condition of women, including household income and mobility improved after their engagement in the plantation project and alternative mobility pattern and community relations were slightly restructured. Thus, the plantation project contributed to the overall socio-economic development and women's empowerment in rural Laos. The findings in this paper agree with those in the Benfica, Tschirley and Sambo's study (2002); additionally, this paper shows that increased rural household income also increased women's mobility and their active participation in the community.

Foreign investment can contribute to rural development by creating non-farm rural employment opportunities and economically empower vulnerable social groups such as women, especially in developing countries. This is considerably important in the GMS region. However, it is also prone to become excessively dependent on foreign investment for rural employment opportunities since foreign investment have a high risk of changing according to the conditions in the global market.

ACKNOWLEDGEMENTS

This research was supported by the Iizuka Takeshi Scholarship Foundation in Japan. The authors would like to thank Dr. Kyoko Kusakabe, Asian Institute of Technology and Prof. Dr. Mariko Adachi of Ochanomizu University, for their advice during the research. We would like to thank Mr. Kan Kaewknogkaew for his generous effort as an interpreter during the field study.

REFERENCES

ASEAN-JAPAN CENTRE. 2009. http://www.asean.or.jp/ja/asean/know/country/laos/invest/guide/section01/section01_01.html.

Asian Development Bank. 2005. Report and recommendation of the president to the board of directors: Proposed Loan and Asian Development Fund Grant Lao People's Democratic Republic: Forest Plantations Development Project.

Asian Development Bank. 2006. The Greater Mekong subregion: Beyond border: Regional cooperation strategy program update, 2007-2009. The Philippines.

Benfica, R., Tschirley, D. and Sambo, L. 2002. Agro-industry and smallholder agriculture: Institutional Arrangements and Rural Poverty Reduction in Mozambique. Flash Working Paper Series, 33. Resultados das investigacoes do Departamento de Analise de Politicas.

Carr, M., Chen, M. and Jhabvala, R. 1996. Speaking out, Women economic empowerment in South Asia, UK.

Elson, D. 1999. Labor markets as gendered institutions: Equality and empowerment issue. World Development, 27(3), 611-627.

Jennifer, L. and Mandel, L. 2004. Mobility Matters: Women's strategies in Porto Novo, Benin. Gender, Place and Culture. Balancing the Load: Women, Gender and Transport. London: International Forum for Rural Transport and Development.

Mwankusye, J. 2002. Do intermediate means of transport reach rural women balancing the load: women, gender and transport. London: International Forum for Rural Transport and Development.

Ngampramuan, S. 2008. Subregional cooperation in the Greater Mekong Subregion (GMS). Transborder issues in the Greater Mekong Sub-region, 13-32. Ubon Rachathani University, Thailand.

Paper News. 2010. Further development corporation supply-demand industry.

Razin, A. and Sadka, E. 2007. Foreign direct investment: an analysis of aggregate flows. Princeton University Press. ISBN-13: 978-0-691-12706-4.

Reddock, R. and Jain, S. 1998. Plantation women: An introduction. Women Plantation Worker: International Experiences. New York. Oxford.

Research article

The Effectiveness of Farmer Organization Management in Kamchaymear and Baphnom Districts, Prey Veng Province

SAVOEURN MEANG*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: meangsavoeurn@gmail.com

MOM SENG
Royal University of Agriculture, Phnom Penh, Cambodia

Received 13 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract 'Farmer organization' is a new concept for Cambodian people, and capacities to effectively manage farmer organizations are limited. Thus, a study was conducted with two objectives, (1) to explore aspects of management and leadership capacities of management committees, and (2) to look into the management processes for farmer organizations. After finishing an interview with all stakeholders, the results showed that educational level of the management committee is so low, with 64.50% finishing primary school and only 1.4% university. Even though they have low education, among 95.1% of the management committees had the ability to write their small project proposals to be submitted to supporting non-government organizations or other donors for both financial and technical support. After their assessment, each farmer organization received 1-3 grants for implementing their own economic initiatives, 62% of the management committees and the members interviewed were provided with technical trainings. All farmer organizations have all the necessary characteristics such as logo, organizational chart, by-laws, recording tools and they conducted meetings regularly. Furthermore, they maintain good relationships with all stakeholders and also received official recognitions from the local authorities. Overall, we can say that the management capacity of the committees have improved even though they still need further support from outsiders in terms of capacity building, working capital, etc. so as to make sure they continue to function well to serve the interest of the members in the long run.

Keywords farmer organization, committee, Prey Veng province, Cambodia

INTRODUCTION

The Cambodian government is focusing on the reduction of poverty of the people. Over 80% of Cambodian population is living in rural areas and more than 70% of labor force in the whole country do farming (MAFF, 2006). Even though many farmers are self-sufficient, 86% of them are below the poverty line (NPRS, 2002; MOP, 2003).

The government is now trying to improve the livelihood of people and develop the national economy through the implementation of government and civil development projects, in order to get effective success and sustainability. Government, non-governmental organizations and other institutions have been organized and used many new strategies to support and develop more effectively farmer groups, associations, communities, cooperatives and federations. All of them were defined as farmer organizations (FO) and facilitated with managing, funding, training and so on. In the inventory of Cambodian farmer organizations, it has been found that before 1995 there were 616 FOs, between 1995 and 2000 3,785 FOs, and after 2000 there were 10,157 FOs (Couturier et al., 2006). The type of farmer organizations in Cambodia can be divided into 10,487 farmer groups, 662 farmer associations, 1,769 farmer communities, 93 farming business communities, and 6 farmer federations, and a total of 13,017 FOs (Couturier et al., 2006).

In 2001, a Royal Decree on Agricultural Cooperative, Union of the Agricultural Cooperative and the Pre-Agricultural Cooperative was published, giving a legal framework for farmer economical organizations. Also in 2003, Prakas of Ministry of Agriculture, Forestry and Fisheries on statute and regulation format was used on Agricultural Cooperatives.

Farmer organizations can be successful or fail. It depends on the leading of committee members, members' participation and supporting agencies or stakeholders. Committee members have enough management qualifications. They can well manage their FOs such as meeting facilitation ability, planning activities annually, strategy plan preparation, knowledge transfer, experience sharing, bookkeeping, and implementing, monitoring and evaluating of farmer organization projects etc.(Sophany, 2010). On the other hand, to become a good manager, the applicant has to be honest, self-sacrificing, try to learn what he is weak at, and good internal and external communication. Most farmer organization leaders are lacking abilities such as general management, financial management, communication, bookkeeping, and agricultural techniques (Couturier et al., 2006).

METHODOLOGY

The research was conducted in Prey Veng province with the target area of Komrong Daikou of Agronomes et Vétérinaires Sans Frontières, that have been working in Baphnom and Kamchaymear districts. There are 33 farmer organizations (2 agricultural cooperatives, 29 rice bank associations, and 2 village animal health worker "VAHW" associations).

The sample selection for interviewing was divided into 3 parts:

1. All farmer organization committee members were interviewed (100%), the total sampling being 142 persons.
2. All project implement staff and commune councils collaborating with project were interviewed (100%), being the total sampling 8 persons.
3. Farmer organization members' samplings were selected by stratified sampling method based on the scoring evaluation of farmer organization types in 2009. Each type of farmer organization limited 50%, but not less than 2 farmer organizations. The formula of Yamane Taro (1967) by randomized method was used. So, a total of 314 members were interviewed.

The primary and secondary sources of information were compiled together for analyzing by SPSS and SWOT.

RESULT AND DISCUSSION

The research results showed that farmer organizations that were successful in its development rely on the committee members' capacities mainly, because committee is the leader of farmer organizations responsible to achieve progress and sustainability. So, many non.government organizations and institutions have been trying different approaches to support farmer organizations such as training by theory and actual practice, conducting exchange visits, etc. in order to improve the committee's capacity in accordance with their situations.

Through questionnaires it was observed that committee members' education as well as the opportunity to get capacity building and institutional strengthening was different among farmer organizations.

Table 1 Educational attainment of committee members

Type of FO	No. of FO	No. of committee (person)	Education (%)			
			Primary	Secondary	High school	University
Agriculture cooperative	2	16	62.50	25.00	12.50	-
VAWH association	2	12	33.30	41.70	8.30	16.70
Rice bank association	29	114	68.40	26.30	5.30	-
Total	33	142	64.80	27.50	6.30	1.40

Most of the committee members' education in the three types of farmer organizations was low, with 64.80% finishing primary school, 27.50% finishing secondary school, 6.30% high school and only 1.4% university. The reason why many administrative committee members studied only at primary schools was that most of them are farmers. Furthermore, if they have higher education, they do not want to be administrative committee members because of little interest in the benefits. As shown in Table 1, we found that only committee members of Village Animal Health Worker Association have university degrees since they got income from animal treatment. They want to strengthen their capability and be more effective in their profession.

Regarding administrative committee members who have low education, many institutions of development agencies started changing their approaches not only focusing on providing fund, materials and technical training support but also strengthening the committee capacity building of farmer organization in leadership and management. As a result, 76.1% of administrative committee members received farmer organization management training, 61.3% financial training, 32.4% communication and marketing trainings, 34.5% leadership training and 88% proposal writing training. With these approaches, 50% of administrative committee members had participated in various exchange visits on animal raising, vegetable growing, farmer organization management and other enhancements.

Table 2 Administrative committee capability of funding proposal writing

Education	No. of administrative committee chief (person)	Fund proposal writing from 2007-2010	
		Success (%)	Failure (%)
Primary school	18	88.90	11.10
Secondary school	11	100.00	-
High school	2	100.00	-
University	2	100.00	-
Total	33	93.90	6.10

Based on the support and strengthening from various development agencies, the capacity building of administrative committee members was improved. The committee has improved its ability of leading farmer organizations, preparing clear organizational charts, communicating with donors and stakeholders. Because of the improved ability, they now got 1 to 3 grant(s) from donors through proposal writing for implementing micro-projects from 2007 to 2010. Table 2 shows that administrative committee chiefs who studied only at primary school got 88.90% of success and only 11.10% a failure. Compared to others who studied at secondary school or above, they now could get 100% of success. As a result, this success contributed as an idea from other committee and members in their farmer organizations. They now not only receive funds, but most of committee members get various training also, for example, rice seed production, 21.80%; fertilizer use, 26.80%; pig rearing, 36.60%; marketing, 32.4% and proposal writing 88%, etc.

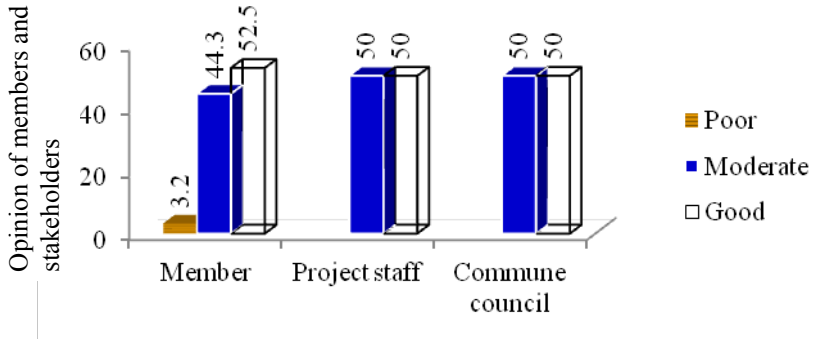


Fig.1 Opinion of members and stakeholders about committee capability

The result showed that only 3.2% of the members said that committee capacity was not good, but others (44.3%) said that it was moderate and 52.5% that it was good. For the project staff and commune councils, 50% replied moderate and the other 50%, good. In accordance with the results

shown, the committee's capability was not good enough in leading farmer organizations yet. They still need more support on capacity building and other skills that involve development agencies and other stakeholders.

The process of farmer organization establishment depends on the types of farmer organization, objectives, and steps taken by farmer organization creators. There were different steps/methods referring to the aims of the creation of projects or laws. If someone wants to be a member of a farmer organization, he has to pay membership fee or share buying, and anyone who wants to be a committee member has to go through an election process.

Table 3 Recruitment of administrative committee members of FO

Type of farmer organization	No. of committee members (persons)	Assignation to a committee	
		Election (%)	Appointment (%)
Agricultural cooperative	16	100	-
VAHW association	12	91.70	8.30
Rice bank association	114	75.40	24.60
Total	142	79.60	20.40

According to the results of Table 3, 100% of Agricultural Cooperative committee, 91.70% of Village Animal Health Worker association committee and 75.40% of Rice Bank association committee were selected by election. Only 20.40% of committee members were selected by appointment as it was based on the criteria selection rule. For example, rice keepers were selected by appointment because they provided their lands for rice store construction and also because it is difficult to move the rice store from one place to another. The mandate of election is 3 years, but some farmer organizations do not apply the written statute and internal rules because of no new candidates. Members let old committees to continue, and sometimes committees do not organize elections.

Table 4 Application of duties and responsibilities to administrative committee members

Education	No. of committee (person)	Organizational chart (%)		
		Not done	Partly done	Well done
Primary school	92	4.30	58.70	37.00
Secondary school	39	2.60	48.70	47.70
High school	9	-	55.60	44.40
University	2	-	50.00	50.00
Total	142	3.50	55.60	40.80

In order to have a more effective management of farmer organizations, each farmer organization committee as well as its members must apply organizational charts to divide the duties and responsibilities among members. The questionnaires showed that all farmer organizations created organizational charts, but their duties and responsibilities stated in the organizational chart were not done well. In the results of the survey, 40.80% of the duties were well done, 55.60% partly done and 3.50% not done. One reason is that some committee members could not do their duties alone, such as organizing bookkeeping or conducting meeting, etc.

Table 5 Application of statute and internal rules of administrative committee members

Education	No. of committee (person)	Statute and internal rule (%)		
		Not done	Partly done	Well done
Primary school	92	3.30	53.30	43.50
Secondary school	39	-	43.60	56.40
High school	9	-	44.40	55.60
University	2	-	50.00	50.00
Total	142	2.10	50.00	47.90

Table 5 shows that 100% of farmer organizations have conducted meetings and made statutes and internal rules to be followed and performed. As a result, there were only 47.90% well done, 50% partly done and 2.10% not done.

To be easily recognizable or identifiable by donors, development agencies and other stakeholders, 93% of farmer organizations had to have logos, and only 7% didn't have. Farmer organizations at least got a recognition letter from the commune office.

Table 6 Committee capability for conducting meetings

Type of farmer organization	No. of committee members (person)	Meeting duration		
		1-month	3-month	6-month
Agricultural cooperative	16	50.00	50.00	-
VAHW association	12	66.70	33.30	-
Rice bank association	114	24.60	72.80	2.60
Total	142	31.00	66.90	2.10

A meeting is very important for all committee members and members or stakeholders to have time for discussion, sharing information, planning preparation, or participating to solve any problem and other matters. Even though the committee education is low, they have sufficient capability to conduct meetings at least for their own farmer organizations. In Table 6 it is expressed that meeting duration depends on their activities. If they have many activities, more meetings will be conducted. As a result, 66.90% of farmer organizations conducted a 3-month meeting. By the support from development agencies, committees did not only have the ability to facilitate the meeting but also could prepare agenda for meeting, and take minutes.

Referring to research results, relationship between farmer organization committees and members depends on the point of views of each one. Overall, the opinions of project staff and commune councils about committees and members relationship were moderate and good.

To encourage administrative committee members in farmer organization that can manage well, members and committee members also discussed and agreed to provide salaries for committee members under facilitation of local authority or development agencies. As a result, each committee member can get 80 kg to 120 kg of paddy rice per year or get cash. It depends on the resource or income of the micro-project activities.

CONCLUSION

A farmer organization is a type of farmer group that was n created to be responsible for the overall objectives and interest of farmers and to serve the interest of economic and natural resource management that involved direct and indirect agricultural activities implemented by farmers. In Cambodia, farmer organization was divided into 5 types, such as group, association, community, agricultural cooperative and federation.

In accordance with the research results, we can conclude as follows.

- Leading capability of farmer organization committee members were improved, even though they were selected from farmers and had low education as well.
- Leading and managing farmer organizations improved, as they set up organizational charts, statute, internal rules, logo, and conducted meetings regularly as well as they were able to get grants and trainings through proposal writing. Furthermore, their knowledge on how to manage and process farmer organization was also improved.

Finally, farmer organizations' success or failure depend on how good the committee members and participating members as well as development agencies function and manage.

ACKNOWLEGEMENT

We would like to deeply acknowledge and give thanks to the Royal University of Agriculture for facilitating and writing the manuscript, to Agronomes et Vétérinaires Sans Frontières Cambodia for providing the place to research and to my relatives.

REFERENCES

Couturier, J., Sam, O. and Phalla, H. 2006. Overview of the situation of farmer organization in Cambodia. Ministry of Agriculture Forestry and Fisheries-2006, Cambodia.

MAFF. 2003. Prakas 547 on statute and regulation format use of agricultural cooperative. Ministry of Agriculture Forestry and Fishery, Cambodia.

MAFF. 2006. Master plan for national agriculture research. Ministry of Agriculture Forestry and Fishery, Cambodia.

MOP. 2003. Cambodia millennium development goals report, 2003. Ministry of Planning, Cambodia.

NPRS. 2002. National poverty reduction strategy, 2003-2005. Council for Social Development, Cambodia.

Royal Decree. 2001. On agricultural cooperative, union of the agricultural cooperative and the pre-agricultural cooperative, Cambodia.

Sophany, P. 2010. The support of NGO agronomes et Vétérinaires Sans Frontières (AVSF) for farmer organization. Master degree thesis. Royal University of Agriculture, Cambodia.

Research article

The Impact of Changes in Crop-Livestock Interaction in Banteay Chmar Commune, Thmar Puok District, Banteay Meanchey Province, Cambodia

SOVATNA PHON*
Royal University of Agriculture, Phnom Penh, Cambodia
Email: ruasovatna@yahoo.com

SOPHAK THUN
Royal University of Agriculture, Phnom Penh, Cambodia

LYNA KHAN
Royal University of Agriculture, Phnom Penh, Cambodia

PHANNA NEN
Royal University of Agriculture, Phnom Penh, Cambodia

Received 14 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract Banteay Meanchey Province is located in the northwest of Cambodia with agricultural, tourism, and handicraft economic sectors. The main agriculture products were crops (rice, cassava and banana) and livestock (cattle, buffalo, pigs and poultry when water is available). In between 750-1,500 families raised livestock for cash income, field operation, transportation and other uses. In the last few years, the number of livestock heads significantly decreased because of the introduction of hand tractors, lack of feed, and diseases. The observation of such decreases led to a study focused on income flow through different farming systems, linkages between crop and livestock production and analyzing strengths, weaknesses, opportunities and the huge challenges in the region. Appropriate samples were used according to spatial/grid-cell method from Googleearth. GPS was used to identify the locations based on the grid-cell data. Many tools such as Participatory Rural Appraisal (PRA and Rapid Rural Appraisal (RRA), were included. Local authorities, relevant NGOs such as Economic and Social Relaunch of Northwest Provinces in Cambodia (ECOSORN) and Agricultural Development Denmark Asia (ADDA), agricultural extension workers and farmers were involved. The results revealed that there were two kinds of farming systems - with livestock and without livestock. It indicated that farming with livestock could produce much more income than without livestock because farmers could sell both crop and livestock production to the market. Moreover, livestock could be fed easily with crop residues. In most of the cases, livestock's manure could also be used to fertilize fields. Although livestock production was economically important for farmers, the shortage of water and feed throughout the year and the existence of diseases discouraged farmers from raising livestock in great numbers even if there was intervention from NGOs, local authorities, or veterinarians. Such conditions led most of the farmers to change to the use of hand tractors as a means of transportation and field work.

Keywords farming system, crop-livestock interaction, SWOT

INTRODUCTION

Banteay Meanchey Province is located in the Northwest corner of Cambodia, bordering with Thailand, Oddar Meanchey and Siem Reap and Battambang Province. Its economy was based on agricultural, tourism, and handicraft sectors (SOLD, 2006-2007). The main livestock products were cattle (buffalo, oxen, and cows), pigs, and poultry, (mainly chicken and ducks when water was

available) (Vinvien, 2004). Banteay Chmar is the commune of Benteay Meanchhey Province with the highest number of families. Between 750 and 1,500 families were engaged in feeding cattle and pigs for substantial daily life (Cambodia, 2007; ECOSORN, 2007).

The number of livestock increased in previous years mainly as a reflection of improved production and income. The main livestock were cattle, pigs, and poultry. Cattle were most often raised as draft animals for field operations and transportation, and were also seen as an important investment/insurance in terms of urgent cash needs. Pigs, however, were mainly a cash enterprise for farm families. Chickens and ducks were kept by most families for their own consumption, and were probably the most important animal protein after fish (Cambodia, 2007).

Cattle are important as a source of draft power, and the use of manure was an essential crop-livestock interaction. Dried manure or manure-based compost was often important for crop production, particularly on the low fertility soils in the area (Cambodia, 2007).

The importance of crop-livestock interactions were, however, challenged by a number of factors in the last few years. In the case of more resourceful farmers, animal draft power was outcompeted by motorized mechanization (hand tractor). In addition, subsidized fertilizers displaced more labour-intensive animal manure application. Finally, the lack of fodder in the wet season restricted the number of cattle, and was further constrained by the expansion of agriculture (primarily cassava cultivation) instead of the previous important grassing areas (Cambodia, 2007).

The purpose of this study of crop-livestock interaction is to identify the income flow through different farming systems, the linkages between crop and livestock production, and achievements and difficulties in the agriculture of the study area.

METHODOLOGY

The study site was proposed in Banteay Chmar Commune, Thmar Puok District, Banteay Meanchey Province, as the site was economically based on crop-livestock production.

The following approach was used to sample the study area. A spatial/grid-cell method was applied using a map from Google Earth mapping software. The map was split into columns and rows. Selected households were pointed in yellow colour and the latitude/longitude coordinates were obtained from the points. GPS was then used to identify the sampling locations in the field. Moreover, some tools such as Participatory Rapid Appraisal (PRA) including Seasonal Calendar, Ranking Matrix, Map Sketching/Mapping, and Rural Rapid Appraisal (RRA) including Semi-Structured Interview, Structured Interview, Focus Group Discussion (FGD), and Direct Observation were applied.

37 households were selected to be interviewed, two FGDs (10 persons/FGD) were conducted, and other individuals were consulted and interviewed such as local guides, communal heads, ECOSON staff, and agricultural extension workers. The findings were presented at the local, district, and provincial levels and in Royal University of Agriculture.

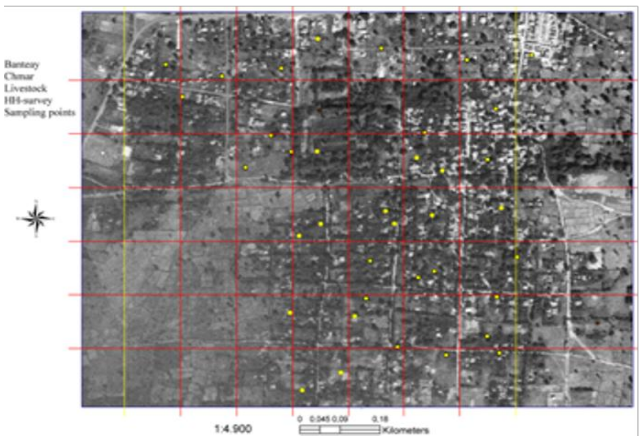


Fig. 1 Map of the research zone

RESULT AND DISCUSSION

Situational information

The Banteay Chmar Commune has had a large decrease in livestock since 2005. The decrease in livestock is due to the introduction of hand tractors, lack of feed caused by land use change, and diseases. Many actors were involved in supporting livestock production such as NGOs, local authorities, agricultural extension workers and local veterinarians. However, their involvement still did not encourage farmers to focus on the reproduction of livestock.

Hand tractor use

Hand tractors have been introduced in the region since 1999. The increase in use of hand tractors was caused by the perception of local people that there have been big losses in animal draft power, and that hand tractors are useful substitute. In some cases, the use of a hand tractor spread from one farmer to another as an effective tool.

Only about 6 percent of the total local people were using hand tractors at the starting time in 1999. In 2001, however, the number of tractors was slightly increasing. Many local farmers were starting to recognize the importance of hand tractors for field operations and other purposes.

By 2005, the number of hand tractor was rapidly increasing as farmers recognized their effectiveness. Moreover, shifting land use from grasslands to agricultural land decreased the feed available to livestock and potentially increased the use of hand tractors. This negative experience led local people to change their way of life from livestock-based farming to hand tractor-based farming.

It could be summed up that most farmers switched to hand tractors from livestock. Hand tractors could be used for land preparation, transportation, pumping. Some people were using tractor as a method of fishing (by pulling a net connected behind the tractor) as well.

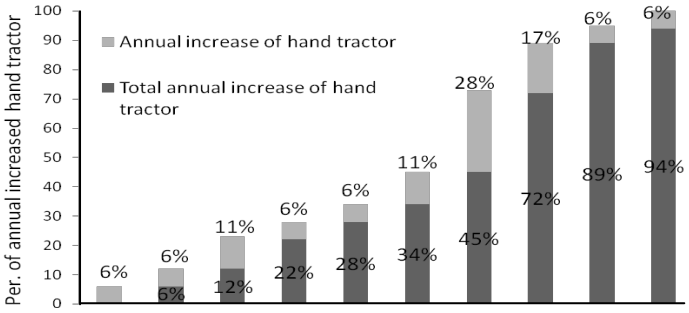


Fig. 2 Annual increase of hand tractors (1999-2008)

Land use change

Based on information from the field surveys, land use could be classified into six categories: settlement land, rice field, cassava field, crop field, grassland and rest land. The land use change has been occurring since 1996; however, a huge amount of change emerged in 2005 when the price of cassava was increasing and the diseases of livestock were a serious problem. Since 2005, land use has changed remarkably in the region, shifting from settlement land and grassland to cassava land. This significant land use change caused the shortage of feed for livestock, especially cattle. Even the rice fields, which provide a subsistence food source for the local people, were reduced.

The increases in cassava crops and livestock diseases had a negative impact on land use types such as settlement land, rice field, and grassland. Also, the decreases in grassland land use reduced the amount of feed available for cattle.

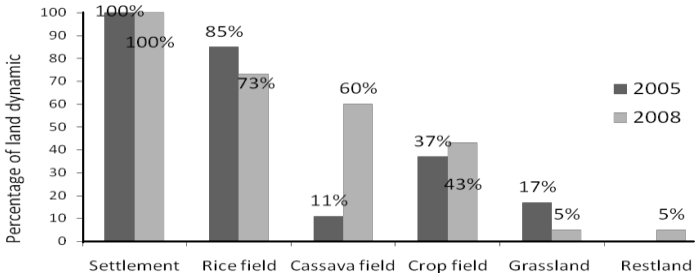


Fig. 3 Dynamic of land ownership

Land classification

In accordance with this classification, the land area of all categories changed. The amount of settlement land decreased slightly as well as the amount of rice fields. However, there was a significant increase in the land area of cassava fields. This is due to the market demand for cassava product.

Table 1 Land classification

Land classification	2005 (%)				2008 (%)			
	< 0.5ha	0.5-<1ha	1-<3ha	>3ha	< 0.5ha	0.5-<1ha	1-<3ha	>3ha
Settlement land	73	27	0	0	92	9	0	0
Rice field	8	27	41	24	11	37	29	23
Cassava field	11	0	0	0	11	11	37	41
Crop field	19	23	37	19	19	23	37	19
Grassland	0	17	0	0	5	0	0	0
Rest land	0	0	0	0	0	0	0	5

Disease status

The rearing of livestock in the local area decreased due to several diseases that infected livestock throughout the region. The diseases which infected pigs and cattle included Foot and Mouth, Hemorrhagic Septicemia, Swine Fever, and fowl cholera and fowl pox infected poultry. The occurrence of serious diseases has increased greatly since 2005. The impact of this bad issue was locally and internationally considered. Although there were no intervention from others stakeholders, the damage of livestock was still happening. The bad experience to the local people did not encourage farmers to raise livestock in large amounts.

Still, in some cases, farmers continued to raise pigs and chickens. These types of livestock could be easily kept, grow quickly, and produce high income, so some farmers continued to raise these animals.

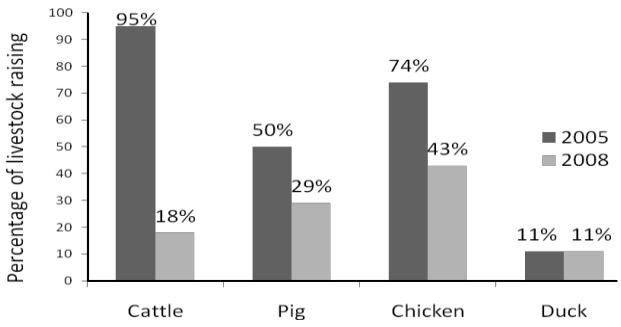


Fig. 4 Tendency of livestock rearing

Income flow through the farming system

Mostly, farmers in the region were growing rice, cassava and banana. According to the farming system classification, many types of products from the crops were used for both subsistence consumption and marketing. Out of the three sources of income, farmers were also fishing to supply their families. Moreover, it seemed that the outputs from crop production were not handled properly. Some farmers burned or left crop residue in the fields as an organic fertilizer. However, this is not an efficient way to improve soil fertility because if they had livestock, some kinds of crop residue could be effectively used as forage for the animal, which in turn produced manure to fertilize the fields. In addition, the animal can provide food and cash income.

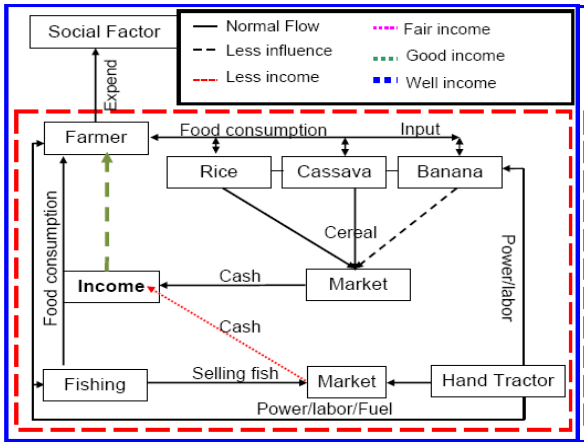


Fig. 5 Farming system without livestock

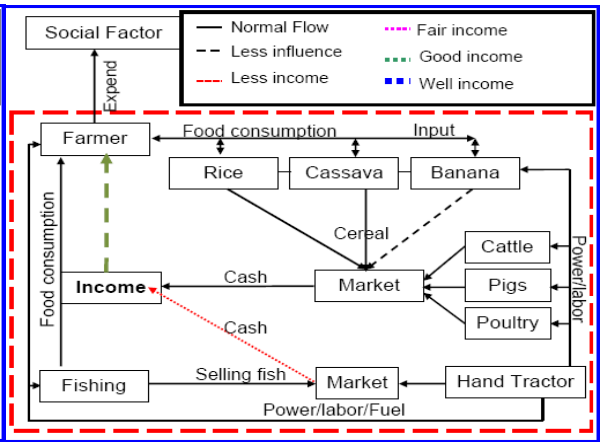


Fig. 6 Farming system with livestock

Crop-livestock linkage

Crop-livestock interaction was classified into two categories: with livestock and without livestock. In the local area, most farmers were growing rice, cassava and banana. Banana was found only in gardens while the other two crops were cultivated in the field. Farming without livestock did not effectively use crop residues and larger amounts of chemical fertilizers were applied in fields where livestock were absent. Information from the survey suggests that the soil became gradually less fertile with the application of inorganic fertilizers, indicated by the fact that some farmers bought manure from neighbors to re-fertilize their fields.

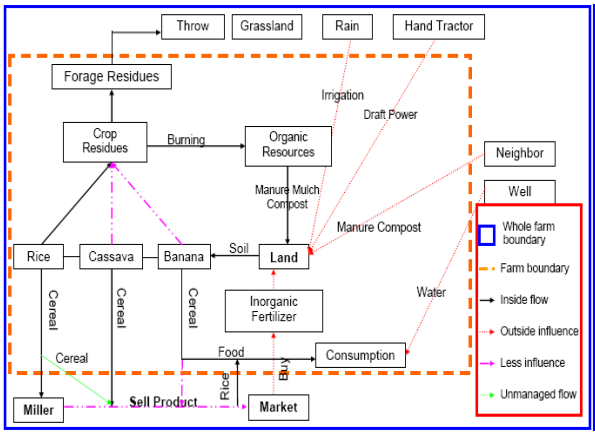


Fig. 7 Cropping without livestock

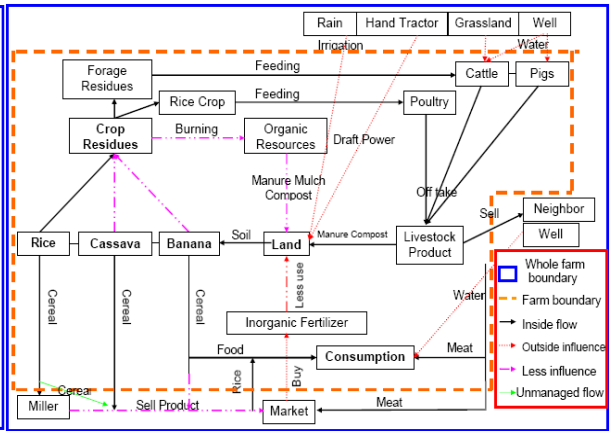


Fig. 8 Cropping with livestock

However, farming was more effective where farmers had livestock. Crop residue was used for animal feed, and manure, in return, was used as an organic fertilizer to enrich the field. Therefore, farming with livestock balances crop-livestock interaction and provides an additional source of cash income.

SWOT analysis

The SWOT analysis was used to determine proper strategies to deal with weakness and threats of the local farmers by using their strength and opportunities. After SWOT tool was analyzed, farmers suggested using their local resources in order to make better their livelihood.

Table 2 SWOT analysis for improving the crop-livestock interaction and livelihood

STRENGTH	THREATS
• Variety of crops were cultivated in the region • Crop residue was used for animal feed • Manure was used to improve field instead of chemical fertilizer application • Farmers had a lot of free time	• Soil pollution by using chemical fertilizers • Water pollution from chemical fertilizers negatively affected human and animal health • Increased new diseases from pesticide use • Lake of water supply in the dry months
WEAKNESSES	**OPPORTUNITIES**
• Lack of water in the dry season • Lack of forage for cattle in the wet months • Lack of prevention of animal diseases • Poor management of manure • Crop residue was burned in the field • Hand tractors played more important role than cattle in term of field operation	• Many NGOs were supporting local farmers • Full availability of local veterinarians • Water source around temple and Cheongcrosh Lake was used in dry months • Crop residue should be kept for animal feed • Local cattle should be considered and Manure should be kept for soil enrichment

CONCLUSION

Most farmers cultivated rice, cassava, and banana. At the same time, they raised cattle, pigs, and poultry. Since 1996, the linkage between crops and livestock had become more effective. They primarily used manure for their fields, and crop residue for feeding animals. In 2005, however, the increases in diseases, the market demand of cassava, and shortage of feed drove down the number of livestock. Farmers tended to rear animals in small numbers for home consumption and cash income only. Moreover, the introduction of the hand tractor positively affects the field work, and reduced the importance of animals in terms of farm operation.

Many farmers who did not engage in livestock rearing used chemical fertilizer instead of manure. Moreover, pesticides were applied throughout the area which has negatively affected the fields and water, and it impacted human and animal health. The soil fertility became poorer, so the farmers started recovering the soil by applying manure. The farmers without livestock bought manure from the neighbors to apply to their fields.

ACKNOWLEDGMENT

The authors would like to sincerely thank to the Graduate School of Royal University of Agriculture and France Solidarity Priority (FSP) for funding and inspiring us in this field survey. In addition, we would like to thank to all lecturers and Denmark students for their well cooperation in field survey. Last, I would greatly thank to Prof. Cindy Thatcher/s that afforded to edit my full paper.

REFERENCES

Cambodia. 2007. Agriculture productivity improvement project.

ECOSORN. 2007. Newsletter. 1 (1).
The second office of local department and land collectivity (SOLD). 2006-2007. Pocketbook on the information of statistic situation research, the fourth region, Battambong, Banteay Meanchey, Siem Reap, Odormeanchey and Pielen Vill.
Vinvien, K. 2004. Livestock section report. Cambodia, Lao PDR, Thailand, and Vietnam.

Research article

The Diffusive Gradients in Thin Films Technique (DGT) for Trace Metals versus Active Sampling

TATIANA KOMAROVA*
Queensland Health Forensic and Scientific Services (QHFSS), Inorganic Chemistry Division
E-mail: tatiana_komarova@health.qld.gov.au

HENRY OLSZOWY
Queensland Health Forensic and Scientific Services (QHFSS), Australia

BARRY NOLLER
The University of Queensland, Centre for Mined Land Rehabilitation, Australia

GARY GOLDING
Queensland Health Forensic and Scientific Services (QHFSS), Australia

Received 19 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract The diffusive gradient in thin films (DGT) technique is an in situ passive sampling method that is designed to accumulate labile metal species in environmental systems. DGTs were applied for the determination of time integrated concentrations of low level dissolved metals in waters in areas of ecological concern. The data revealed heavy metal contamination of waters and tracked the contamination to the source. A comparison of DGT-derived water concentrations with water concentrations measured from grab samples highlighted the effectiveness of passive water samplers for detecting ultra-trace levels of metals. Comparing active and passive sampling techniques showed that both methods produce similar results when used simultaneously at the same sites. The use of DGT technique along with traditional methods offers an extra cost effective method of independent evaluation of environmental sites as well as more sensitive and inexpensive way of obtaining additional information about sites which would be very hard to obtain using active sampling techniques.

Keywords passive sampling, ultra-trace levels, labile metal species, accumulation, time integrated concentrations.

INTRODUCTION

In recent years, passive sampling techniques have been developed to measure dissolved organic and inorganic compounds in waters at sub-nanogram per litre levels. "Passive" samplers are defined as human-made devices where sample collection occurs in a non-active, inert manner.

DGT technique is designed to accumulate labile species in environmental systems (Davison and Zhang, 1994; Davison et al. 2000; Zhang and Davison, 1995; Zhang and Davison, 2000). The currently available DGTs still require further method development and field validation (Warken et al., 2006).

The DGT technique employs an adsorbent (e.g. Chelex-100), usually immobilized in a polyacrylamide gel (the binding or resin gel), to adsorb analyte species from solution. Chelex-based resins can be used for simultaneous collection of many metals in water including silver (Ag), aluminium (Al), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn). The binding gel is separated from the bulk solution by a permeable polyacrylamide gel (the diffusive gel) and a solution diffusive boundary layer.

DGT devices are deployed in an environmental system for a time period ranging from days to months to accumulate analyte species of interest. Following deployment, the binding gel and the

diffusive gel are separated and the accumulated analyte is eluted from the binding gel. The concentration of analyte in the eluant is then determined by an appropriate analytical technique, usually inductively-coupled plasma mass spectrometry (ICPMS). The time-averaged concentration of a species in the bulk solution, C, is then calculated using the DGT Equation below, which is derived from Fick's first law of diffusion (Zhang and Davison, 1995); M is the accumulated mass of analyte on the binding gel; Δg is the thickness of the diffusive gel, D is the diffusion coefficient of analyte in the diffusive gel, t is the deployment time, and A is the surface area of the diffusive gel exposed to the bulk solution.

$$C = M \Delta g / D t A \quad (1)$$

The assessment of water quality for the protection of the aquatic ecosystem requires the use of a combination of analytical methods based on the Australian ANZECC/ARMCANZ (2000) decision tree process for assessing metal toxicity in water. An initial step is to calculate site-specific trigger values for metals by using a correction for hardness, calculated from the calcium plus magnesium concentrations expressed as mg/L $CaCO_3$, to the default ANZECC/ARMCANZ (2000) guideline value. The aquatic toxicity decreases with increasing water hardness as soluble metal is precipitated. The next step in the decision tree process uses the measurements of metals in labile or bioavailable forms and metals and metalloids in particulate and insoluble colloidal fractions that can be measured through filtration (<0.45μm) and ultra-filtration (<0.003μm) to determine the bioavailable fractions of metals in waters. DGT samplers offer an alternative to conventional active sampling techniques.

The objective of the present study was to enhance and consolidate DGT applications for monitoring low levels of dissolved metals in water. The study seeks to address the following research questions: (i) how will DGT and active sampling techniques compare in a real world study of a contaminated water body in different environmental conditions; (ii) could the DGT technique be incorporated into the trace metal monitoring programs in waters together with traditional methods and replace them in the future; and (iii) will bioavailability results from DGT analysis add more value to the current analysis by conventional sampling techniques?

MATERIAL AND METHODS

DGT samplers were deployed for 2 days at the Woodcutter mine area in Northern Territory (Fig.1), Australia and in the Tosno river area in St. Petersburg (Fig. 2), Russian Federation.

The major silver-lead-zinc deposits at Woodcutters were mined from 1985 (Noller et al. 2003) to May 2000. Initial deployment of DGTs in Woodcutters Creek at the rehabilitated mine site was undertaken in June 2010 and a further more extensive deployment took place in September 2010 (Noller et al. 2011).

To compare DGT and active sampling techniques in a real world study of contaminated waters in different environmental conditions various experimental designs were established in a major industrial areas of the Russian Federation in January 2011 (Fig.2).

The diffusion coefficient of metals in the diffusive gel D (see Equation above) is dependent on the temperature. Therefore the average temperature of the water at all sites during DGT deployment was estimated. It ranged between 23.4-25.6 °C in the first round and 25.6-27.6 °C in the second round of deployment in the Woodcutter Creek and between 0-1 °C in the Tosno river deployment. At the completion of the deployment period, DGTs were delivered to the QHFSS laboratory where they were kept below 4 °C until prepared for analysis. During the extraction procedure the DGT device was opened, the binding gel and the diffusive gel were separated and the binding gel was submersed in 1 mL nitric acid for over 24 hours to elute the accumulated metals. Then 0.5 mL of extract was made up to 5 mL with nitric acid and water and analysed for metals by ICPMS (ICPMS 7700X, Agilent). At the time of DGT deployment 1L water samples were collected (active sampling) from all sites. Some water samples were filtered through 0.45 and 0.003 μm filters and analysed for metals by ICPMS.

RESULTS AND DISCUSSION

Woodcutter mine site in Australia

Initially 5 sets of DGTs were deployed in Woodcutter Creek in the vicinity of Woodcutters mine site in June 2010 to identify the bioavailable fraction of metals in the creek water (Fig. 1A). The DGTs collect the soluble or labile metal only and enable a comparison to be made with ecotoxicity measurements previously undertaken on creek water.

The measured DGT concentrations were generally higher than some of the filtered fractions. Table 1 shows the data for two major metals: lead and zinc. The grab water samples were collected at the beginning of DGT deployment and therefore represent the concentration of lead and zinc at this particular time. Concentrations of lead and zinc estimated from the DGT data represent their average concentrations over the deployment period (i.e. time integrated concentrations and may differ from spot sampling). Further experimental work performed at this site showed that the concentrations of lead and zinc in water may change significantly within 2-3 days (up to 5-10 times). This can explain the difference between the data.

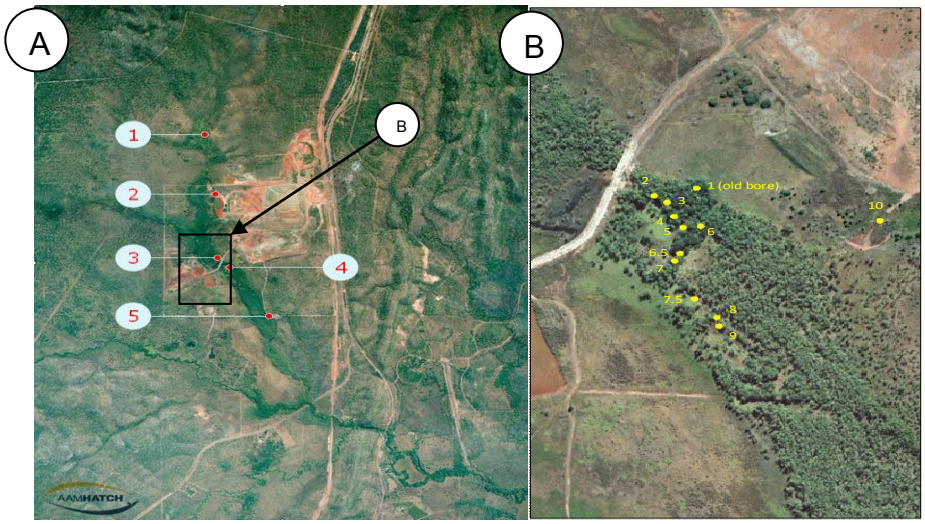


Fig. 1 A Sampling sites at Woodcutter Creek June 2010

1. upstream site
2. new polishing pond outflow
3. above Huandot crossing
4. seepage below former Tailings Dam 2 at Huandot crossing
5. Mine lease boundary

B. Shallow seepage sampling sites at Woodcutters Creek

September 2010 Site 1 corresponds to June 2010 Site 4

In the second DGT deployment undertaken at Woodcutters Creek in September 2010 (Fig. 1B) grab water samples were collected before and after DGT deployment and the average concentrations of lead and zinc were measured in filtered and unfiltered water. There were insignificant levels of lead present in water at all sites. Good agreement was found between the concentrations of zinc in 0.003 µm filtered grab water fraction and zinc DGT concentrations (Table 2). The minor difference in these values is attributed to the different approach applied with passive and active sampling techniques; that is time integrated water concentration of dissolved metals vs. "single point in time" concentrations. The overall findings from September 2010 were as follows: (i) increased zinc concentration was accompanied by increases in electrical conductivity and sulfate in water; (ii) for an observed hardness range of 800-2200 mg/L $CaCO_3$ the zinc filtered concentration (<0.45µm) marginally exceeded the hardness-adjusted ANZECC/ARMCANZ (2000) trigger value for 95% protection of aquatic species of 72 µg/L; (iii) the zinc DGT concentrations

did not exceed the trigger value of 72 µg/L; and (iv) further investigation of actual ecotoxicity is warranted to confirm this finding.

Tosno river in St Petersburg, Russian Federation

DGTs were deployed in Tosno River situated around one of the major industrial areas of St. Petersburg (Fig.2). The deployment of DGTs in this area was aimed at the identification of the contamination source which was suggested to be downstream of site ϕN1 (small arrow, Fig. 2). DGTs were deployed at four different sites (ϕN1, ϕN2, ϕN3 and ϕN4) following the direction of the river flow (large arrow, Fig. 2) for 2 days. At their deployment 5 L water samples were also taken at the corresponding sites (active sampling).

Table 1 Metals in surface water at Woodcutters Creek (16 June 2010)

Site	Metal	Active sampling (µg/L)			Passive sampling (µg/L)
		Total	0.45µm	0.003µm	C from DGT
1	Pb	0.4	0.1	0	0.02
2	Pb	5	0.4	0	0.5
3	Pb	0.4	0.2	0.1	0.06
4	Pb	1	0.1	0.1	0.04
5	Pb	0.3	0.1	0.1	0.5
1	Zn	25	22	20	0.6
2	Zn	31	7	4	29
3	Zn	47	40	25	2
4	Zn	7	5	6	1
5	Zn	33	22	13	22

Table 2 Zinc in shallow seepage entering Woodcutters Creek and nearby groundwater (September 2010)

Site	Sulfate (mg/L)	Zinc (µg/L)			
		Total	<0.45µm	<0.003µm	from DGT
WC1	1200	66	25	9.1	7.5
WC2	701	109	27	16	13.1
WC3	789	850	63	47	16.6
WC4	1490	94	26	23	18.3
WC5	1920	356	73	59	47.6
WC6	1260	271	24	24	15.9
WC7	581	70	32	12	10.5
WC8	628	90	25	12	10.3
WC9	1590	97	47	29	25.1
WC10	509	31	9.6	8.9	3.7

After deployment and recovery the DGTs were delivered to QHFSS by air freight and analysed for the following metals: aluminium, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead and zinc. Based on the obtained data the concentrations of these metals in water at different sites of the river were estimated using Eq. (1). The results presented in Table 3 showed that a number of metals (aluminium, cadmium, cobalt, chromium and lead) on grab water analysis were not at detectable levels. In contrast DGTs revealed their presence at all sites. Copper, nickel and zinc were only detected in grab water samples collected at Sites ϕN4 and ϕN3 though their presence at all sites was proven by the DGT data.

Only two metals, iron and manganese, were found above detectable levels at all sites for both active and passive sampling (Table 3). Despite the difference in the concentrations of these metals found by the two methods, the change of the concentrations from site to site was similar. As the

grab water samples were not collected in a time integrated manner, the concentrations of metals differed from the time averaged DGT-derived concentrations.

It is important to note that DGTs accumulate dissolved phase metals and the estimation of the concentrations is based on diffusion through the gel followed by uptake of dissolved phase metals. The DGT results are therefore more appropriate in terms of environmental risk since they represent an immediately available fraction of the chemical or bioavailable fraction. The estimation of metal concentrations by grab or active sampling is based on their total amounts in water including particle associated and colloidal metals. This could also explain the difference in iron and manganese concentrations found by comparing the two methods. The results obtained by two independent methods (active and passive sampling) draw us to the same conclusion - the source of the iron and manganese contamination of Tosno river is most likely situated somewhere between Sites ϕN1 and ϕN2.

Table 3 Metal concentrations in water from grab samples and by DGTs

	Passive sampling (µg/L) (DGT)					Active sampling (µg/L) (grab water)			
	Site ϕN1	Site ϕN2	Site ϕN3	Site ϕN4	95% Confidence interval of mean ± $t_{0.05}$ se[a] Sites ϕN1 - ϕN4	Site ϕN1	Site ϕN2	Site ϕN3	Site ϕN4
Al	16.00	77.00	65.00	63.00	68±19	n/d	n/d	n/d	n/d
Cd	0.26	0.17	0.09	0.09	0.12±0.11	n/d	n/d	n/d	n/d
Co	0.09	0.18	0.17	0.18	0.18±0.01	n/d	n/d	n/d	n/d
Cr	0.62	0.41	0.10	0.10	0.20±0.44[b]	n/d	n/d	n/d	n/d
Cu	9.40	8.70	6.60	5.70	7±3.8[b]	n/d	n/d	n/d	2.7
Fe	51.00	216.00	253.00	245.00	238±48	1300	1900	1500	1800
Mn	1.20	89.00	85.00	84.00	86±6.6	150	290	220	210
Ni	11.00	3.80	0.81	1.40	2.0±3.9	n/d	n/d	3.4	n/d
Pb	0.58	0.52	0.13	0.19	0.28±0.52[b]	n/d	n/d	n/d	n/d
Zn	0.62	65	48.00	45.00	53±27[b]	n/d	n/d	n/d	7.5

Note: a. $t_{0.05}$ = 4.303 from t-distribution table for degrees of freedom (n-1) =2 where n=number of results and standard error (se) = s/√n; b. not significantly different from ϕN1.

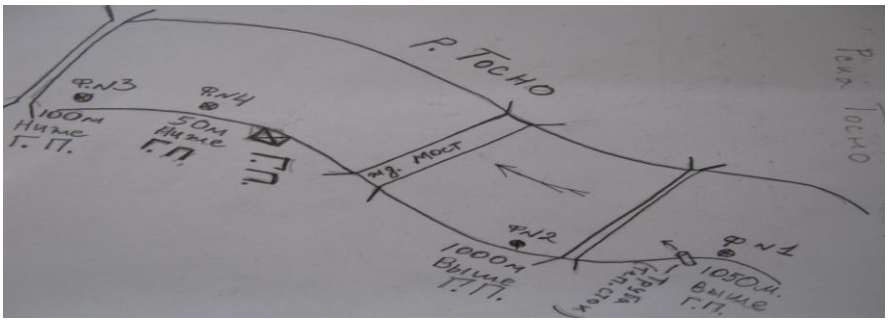


Fig. 2 Deployment sites on Tosno River

The DGT data for the upstream Site ϕN1 was compared with the 95% confidence interval of the mean of the downstream Sites ϕN3 and ϕN4 (Table 3). This comparison showed that, compared with Site ϕN1, there was a significant increase for aluminium, cobalt, iron and manganese going downstream and a significant decrease for chromium, copper, lead and zinc indicating their origin from another source upstream. Thus the DGT data in Table 3 showed that: (i) aluminium, cadmium, cobalt, chromium and lead were present in the water; (ii) aluminium and possibly traces of cobalt were most likely released into the water along with iron and manganese by the same source as their concentrations changed in a similar manner from site to site; and (iii) the source of contamination of water with cadmium, chromium, copper, nickel, lead and zinc was most likely situated upstream of Site ϕN1 as the concentrations of the metals were slowly decreasing

from Site ϕN1 to Sites ϕN3 and ϕN4. The use of DGTs in this experimental work provided a more complex picture of contamination of the river with heavy metals than could be achieved by using any conventional active sampling techniques.

CONCLUSIONS

The results obtained in this study show the potential of the DGT technique to measure ultra-trace levels of metals in water reliably at a range of temperature and environmental conditions. Comparison of active and passive sampling techniques showed that both methods produce similar results when used simultaneously. The use of DGT technique along with traditional methods offers an extra cost effective method of independent evaluation of environmental sites as well as more sensitive and inexpensive way of obtaining some further information about sites which would be very difficult to obtain using any conventional active sampling techniques.

This technique allows measurement of time integrated water concentration of dissolved pollutants in contrast to grab sampling techniques which only represent single points in time. DGTs require relatively inexpensive and simple materials for their preparation and there is no power source or active sampling equipment (e.g. pump, flow meter etc) needed during their deployment. The post deployment process of DGT extraction and clean up takes several minutes using minimal consumables and chemicals and can be done in the field if necessary.

The DGT results represent an immediately available fraction of the chemical. DGTs mimic the accumulation that occurs in aquatic biota allowing toxicologists to estimate the actual levels of toxicities of different metals under the specific environmental conditions and their impact on environmental health and health of biological organisms including humans.

ACKNOWLEDGEMENTS

The authors thank Clinical and Statewide Services (CASS), Queensland (Australia) for the financial support of this work and staff of Inorganic Chemistry Division of QHFSS (Australia) especially Michael Peters and Tetyana Krasnoff for assistance with sample analyses and data interpretation, Prof. N. N. Bobrovitskaya, the Chief of Department of Monitoring surface water of State Hydrological Institute (Russian Federation) for help with experimental work performed in St. Petersburg, Drs. Mansour Edraki and Trang Huynh for assistance with the Woodcutters mine studies and Newmont Mining Asia Pacific for access to the Woodcutters site.

REFERENCES

Davison, W., Fones, G., Harper, M., Teasdale, P. and Zhang, H. 2000. In situ monitoring of aquatic systems: Chemical analysis and speciation, John Wiley & Sons, Inc., New York, 495.

Davison, W. and Zhang, H. 1994. In situ speciation measurements of trace components in natural waters using thin-film gels. Nature, 367, 546-548.

Noller, B.N., Edraki, M., Huynh, T., Komarova, T. and Haymont, R. 2011. Evaluation of a DGT approach to develop toxicity models of metal speciation in shallow seepage from a rehabilitated lead-zinc mine to an ephemeral tropical creek. EnviroTox., 201, 31.

Noller, B.N., G. Parker and G.H. Gao. 2003. Metal transportation through a wetland at a lead zinc mine in the Northern Territory, Australia. European Journal of Mineral Processing & Environmental Protection, 3(1), 15-35.

Warnken, K.W., Zhang, H. and Davison, W. 2006. Accuracy of the diffusive gradients in thin-films technique: diffusive boundary layer and effective sampling area considerations. Anal.Chem., 78, 3780-3787.

Zhang, H. and Davison, W. 1995. Performance characteristics of diffusion gradients in thin films for the in situ measurement of trace metals in aqueous solution. Anal.Chem., 67, 3391-3400.

Zhang, H. and Davison, W. 2000. Direct in situ measurements of labile inorganic and organically bound metal species in synthetic solutions and natural waters using diffusive gradients in thin films. Anal.Chem., 72, 4447-4457.

Research article

Determinants of Good Agricultural Practices (GAP) Adoption in the Chili Production System in Northeastern Thailand: A Case of Participatory Approach

THANAPORN ATHIPANYAKUL*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: thanaporn_k@hotmail.com

WEERA PAK-UTHAI
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

Received 15 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract A participatory research approach has been conceptually proposed as an effective method for introducting knowledge-intensive technologies. This approach was adopted for the promotion of Good Agricultural Practice (GAP) in the chili production system in Thailand. However, some farmers still use conventional practices that often result in an overuse of chemicals. This study projected the impact of participation and improved knowledge of farmers, which can encourage the program adoption. Other conventional factors such as farming characteristics were also considered. Research was carried out involving 179 chili farmers both participants and non-participants in the GAP program located in the Northeastern part of Thailand. A treatment effect model was used in the identification of factors affecting the program adoption. Results showed a significant effect on program participation and farmer's knowledge that was the precursor of adoption. Farmers' experience in chili production significantly affected adoption. Age was a negative determinant of adoption. The conclusion can be drawn that adoption of knowledge-intensive technologies such as GAP needs an effective approach such as the participatory research program, which can improve farmers' knowledge and encourage them to adopt innovative technologies. This approach allows farmers to learn from the experience of other farmers.

Keywords chili production, knowledge intensive technologies, treatment effect model

INTRODUCTION

The participatory research approach program has been developed to overcome the hierarchical structure of the training and visit system (Krasuaythong, 2008). Hussain, et al. (1993) had confirmed that the adoption did not live up to its expectations seven years after the introduction of the extension program using the training and visit approach. Therefore, the participatory research approach was adopted as an effective way to transfer innovation, particularly for knowledge-intensive technologies (Feder, et al., 2003). It also has been adopted as the introduction of good agricultural practices (GAP) for Thai farmers. The objective of the GAP program is to reduce the use of pesticides, and increase the production and marketing standards of agricultural commodities. It has been firstly applied in rice, vegetable, and fruit production systems; especially in the areas where most farmers grow in commercial enterprises with high level usage of pesticides.

Chili is among the vegetable commodities, playing a major role as an important ingredient in Thai cooking. Also, it is a high value crop providing a major source of income for small scale farmers in Thailand. However, chili farmers in Thailand have overused pesticides both pre and post-harvest, to control pests and diseases (Pak-Uthai, 2010). This still occurs even though several organizations have been introducing practices that rely less on the use of pesticides and were more benign for the environment and human health. Adoption of GAP seems to be at a very low scale.

Recently, chili exported from Thailand was banned from European countries, because it was found to be contaminated with banned pesticides (Ariesen, 2011).

Adoption of innovation was a complex issue. Many factors were identified as determinants of adoption of innovation. Among those factors, the farmers' knowledge was important to the adoption of new technologies, particularly knowledge-intensive technologies (Krasuaythong, 2008). The result of Krasuaythong (2008) was consistent with the suggestion of several studies, which stated that producers with more knowledge will increase the probability of technology adoption (Praneetvatakul et al., 2007; Waibel and Zilberman, 2007). However, this was not clear for the case of GAP adoption in chili production. The objective of this paper, therefore, was to determine the factors that affect the adoption of GAP. The results of this research thus can guide policy makers in developing strategies suitable to achieve a more rapid and efficient introduction of such practices.

DATA COLLECTION

The Thailand Research Fund (TRF) is a non-government organization that provided the budget for Khon Kaen University to develop the GAP program in chili production system to farmers in the Chaiyaphum province of Northern Thailand. This paper is a part of that research. Purposive sampling was used for the selection of the study area. A multistate sampling technique was used for data collection. The first stage consisted of the selection of four districts. In the second stage, simple random sampling was used for the selection of a sub-district and, subsequently, a village. Stratified random sampling was involved in the final stage. Farmers were divided into two stratums, namely those participating in the GAP program, and those who were not participating in the program. Each farmer was interviewed to determine the socio-economic characteristics of their household by using a structured questionnaire. A total of 200 farmers were interviewed, but only 179 questionnaires were completed.

SPECIFICATION OF THE EMPIRICAL MODEL

A matrix $\mathbf{z}$ demonstrated the factors affecting the farmers' decision to participate in the program, and $\mathbf{p}$ was a vector of two parameters for participation and non-participation. The expected utility of farmers was measured through their decision making, and was formulated as a dummy variable P. It was identified as 1 if farmers participated in the program and 0 otherwise. The probability of farmers' decision for participation in the program was derived as Eq. (1).

$$\begin{aligned} Prob(y_{i=}/z) &= Prob(U_1 - U_0 > e_1 - e_0) \\ &= F(\mathbf{p_i} \times \mathbf{z}) \end{aligned} \quad (1)$$

Green (1997) stated that $F(\mathbf{p}_i \times \mathbf{z})$ was the cumulative distribution function for a random disturbance term, or the error term (e_i). The distribution of this term proposed the functional form of $F(\mathbf{p}_i \times \mathbf{z})$, which can be of logistic distribution or a normal distribution. In this study, a probit model was adopted, because this assumption was more efficient for the treatment effect model (Hechkman, 1979). Notation Φ is normally distributed with a mean and zero unit of variance, and $(\mathbf{p}_i \times \mathbf{z})$ was called as the probit score.

$$Prob(y_{i=}/z) = \Phi(\mathbf{p_i'} \times \mathbf{z}) \quad (2)$$

Estimation of Eq. (2), a nonlinear maximum likelihood was used and the functional form was derived as Eq. (3).

$$\ln L = \sum_{y_i=0} \ln 1 - \Phi(\mathbf{p}_i' \times \mathbf{z}) + \sum_{y_i=1} \ln \Phi(\mathbf{p}_i' \times \mathbf{z}) \quad (3)$$

However, in practice; farmers who decided to participate in the GAP program are not randomly selected. It implies that factors affecting the farmers' decision to participate in the GAP program also

determine the adoption of GAP, which means that the direction of causality obtained by simple regression can be biased. To cope with these biases, the treatment effect model developed by Heckman (1979) was used. This model assumes that the unobserved variables (ε) of the utility function parameter of adoption are correlated with the unobserved variables affecting the farmer's decision to participate in the program (e), but not with the factors (X) determining the value of parameters (Heckman, 1979). Therefore the conditional expected value of the utility function observed when individual farmers decide to adopt GAP can be represented as Eq. (4).

$$E(ADOPT \mid participation = 1, X, z) = P \times \gamma + X \times \boldsymbol{\beta} + \rho \times \sigma_{parameter}[-\Phi(\mathbf{z} \times \mathbf{p}) / (1 - \Phi(\mathbf{z} \times \mathbf{p}))] \quad (4)$$

$\sigma_{parameter}$ is the standard deviation of the utility function, and ρ is the correlation between the unobservable independent variables (ε, e) . $\mathbf{z}$ is the vector determining the farmer's decision to participate in the program, $\mathbf{p}$ is an unknown parameter, and $\Phi(.)$ is normally distributed with a zero mean and unit variance. The final term in the brackets is the inverse mill ratio (IMR) that represents a correlation between ε and e . The Hypothesis for testing this correlation was carried out using chi-square. If there was no correlation between those terms, the formulation was reduced to a multiple linear regression model.

DESCRIPTION VARIABLES

The adoption variable was a dependent variable, and identified by the cumulative practices which the farmers adopted. The GAP introduced by the researcher was a set of practices. It contained 17 practices in total. During the survey, chili farmers were asked whether they have knowledge, and in-depth understanding about these practices or not. Also, they were asked to identify many practices they adopted, non-adopted, and dis-adopted. The independent variable used in the treatment effect model contained five variables including participation, knowledge, asset, land-labor, and meeting (Table 1).

The *participation* variable was expressed as a dummy variable, and was used as a proxy of a major source of knowledge for farmers who participated in the GAP program. It was expected to have a positive and direct effect on practice scores. The *meeting variable* was the number of meetings with neighbors. The knowledge scores, measured from a number of in-depth practices, determined the farmers' understanding. This factor encouraged farmers to adopt new technologies.

Table 1 Description of dependent and independent variables

Variables	Variable type	Expected sign	Description
Dependent variable Adoption	Continuous		Practice score that is the cumulative total of GAP practices applied in chili production system.
Independent variable			
Participation	Dummy	+	1=if farmers participated in GAP program; 0=otherwise.
Knowledge	Continuous	+	Farmers' knowledge scores.
Meeting	Continuous	+	Number of farmers meeting with neighbors and discussing chili production practices.
Asset	Continuous	+	Value of farmers' asset.
Land-labor	Continuous	-	The ratio of household labor working full time on chili production to total land area (manday/rai*).
Age	Continuous	-	Farmers' age (years).

Note: 1 ha = 6.25 rai

The variable *asset* expressed the wealth of the farmers, and was expected to increase with the number of practices adopted by farmers. *Age* was expected to have a negative effect on adoption. In this paper, the *land-labor* variable was the land to labor ratio. It was used as a farm resource, as

endowments use neither farm household labor nor land size. Gebresekassie and Sanders (2006) pointed out that farmers with a larger farm size tend to be more likely to adopt new technologies, but Feder et al. (2003) argued that small scale farmers were more likely to adopt labor intensive technologies. In this study, the set of practices promoted by the GAP program were suggested as labor-intensive technologies (Pak-Uthai, 2010).

RESULTS

Table 2 shows results obtained from the descriptive statistics of variables used in the model. Statistical analysis using the t-test showed significant differences between participants and non-participants, except *asset*, *meeting* and *age*. A correlation matrix was carried out between knowledge and program participation. This may bring to light the problem of multi-co-linearity.

Table 2 Descriptive statistics of variables used in the model

Variable	Mean		All samples
	Participants	Non-participants	
Practices	12.12***	3.99	8.11
Participation [1]	49.72%	50.28%	100.00
Knowledge	14.61***	5.81	10.23
Meeting	8.14[ns]	5.97	7.06
Asset (Thai Baht; 30 Thai Baht =$1)	14,026.50	57,747.98	,674.17
Land-labor	5.29***	7.92	6.59
Age	50.00 [ns]	48.89	49.46
N	90	89	179

Note: [1/] Percentage of total farmers
*[2/] *Significant at the level 0.1 **Significant at the level 0.05; ***Significant at the level 0.04*

Table 3 Correlation matrix of independent variables

Variable	Part	knowledge	meeting	asset	land-labor	Age
Participation	1					
Knowledge	0.56	1				
Meeting	0.09	0.14	1			
Asset	-0.32	-0.15	-0.01	1		
Land-labor	-0.23	-0.05	0.0009	0.17	1	
Age	0.08	-0.11	-0.06	0.05	0.09	1

Table 4 Determinants of GAP adoption estimated by treatment effect model

Variables	Coefficient	Standard error	Z	P-value
Constant	0.72388	1.35430	0.53	0.593
Participation	14.35064	1.05897	13.55	0
Knowledge	0.22935	0.05896	3.89	0
Asset	-0.01795	0.01390	-1.29	0.196
Meeting	0.00001	0.00000	4.34	0
Land to labor ratio	-0.27156	0.41812	-0.65	0.516
Age	-0.04460	0.02114	-2.11	0.035
Wald chi^2			978.40***	
Log likelihood			-526.963	
Test of selection bias (IMR)			Chi^2 = 14.56***	

*Note: [1/] *Significant at the level 0.1 **Significant at the level 0.05; ***Significant at the level 0.04*

Table 3 shows a non-correlation between knowledge and program participation. Results obtained from the treatment effect model showed that the estimated model had selection biased prob-

lems, because the null hypothesis was rejected (IMR≠0). Therefore, they were appropriate for identification of factors determining adoption of GAP (Table 4).

The *participation* and *knowledge* variables have had a significant effect on the number of practices (measured by practice scores) with a high level of significance. However, the magnitude of *participation* was greater than that of the *knowledge* variable. This suggests that participation in the GAP program that applied the concept of a participatory research approach was more pronounced in adoption of knowledge intensive-technologies such as GAP. During participation, farmers can gather information and exchange their experience with other farmers. This can affect the farmers' decision making about whether to adopt GAP practices. The *meeting* variable that used as a proxy of social network increase the number of GAP practices adopted by farmers, as farmers can learn from the experience of others (Foster and Rosenzweg, 1995). Therefore, farmers who were non-participants were able to adopt some practices gained from those neighbors who participated in GAP program. Richer farmers were more likely to adopt an increased number of practices, because they were more inclined to experiment with new technologies (Krasuaythong, 2008). This was supported by the study of Jayasinghe-Mudalige and Weersink (2004). They pointed out that rich farmers tend to adopt as many environmental management practices as possible. However, this study showed it significantly affected GAP adoption. The younger farmers tended to adopt more practice in the set of GAP. They opened their minds to innovation and tried to gather more information as well as improving their knowledge.

Results of this paper support findings in several publications, which stated that program participation has a direct effect on adoption of GAP (Krasuaythong, 2008). Moreover, the process of knowledge gathering was a major factor affecting adoption of technologies that related to natural resource management (Waibel and Zilberman, 2007). However, adoption of knowledge-intensive technologies depended upon other factors as well. Farmers' risk attitude and their behavior were also suggested from the study of Krasuaythong (2008).

CONCLUSION

This study aimed at identifying factor affecting adoption of GAP. The treatment effect model was applied. The results finding in this were similar to many publications. Farmers' characteristics such as age and wealth play a major role in determining the adoption of technologies. An important finding drawn from this paper was that using the participatory research approach can be an effective tool to enhance farmers' knowledge and increase the rate of adoption. In this case, it was measured by the number of practices being adopted from the set of GAP. However, practices may have different levels of complexity. This may suggest one reason for non-adoption or ceasing a practice. Additionally, other factors such as farmers' risk attitude and behavior should be involved in the adoption model as they may affect adoption of innovation. This paper does not discuss these issues, and is therefore recommended for further study.

ACKNOWLEDGEMENTS

This paper is a part of the research funded by the Thailand Research Fund (TRF).

REFERENCES

Ariesen, M. 2011. Newsflash: Precautionary Ban on Thai veggies to the EU. http://www.cbi.eu/?pag=55&nid=992.

Defrancesco, E., Paola Gatto, P., Runge, F. and Trestini, S. 2008. Factors affecting farmers 'participation in agri-environmental measures: A Northern Italian perspective. Journal of Agricultural Economics, 59, 114-131.

Feder, G., Murgai, R. and Quizon, J.B. 2003. Sending farmers back to school: The impact of farmer field schools in Indonesia. Review of agricultural economics, 26, 45-62.

Foster, A.D. and Rosenzweg, M.R. 1995. Learning by doing and learning from others: Human capital and

technical change in agriculture. The journal of political economy, 103, 1176-1209.
Gebreselassie, N. and Sanders, W.J.H. 2006. Farm-level adoption of sorghum technologies in Tigray, Ethiopia. Agricultural Systems, 91, 122-134.
Heckman, J.J. 1979. Sample selection bias as a specification error. Econometrica, 47, 153-161.
Hussain, S.S., Byerlee, D.and Heisey, P.W. 1993. Impacts of the training and visit extension system on farmers' knowledge and adoption of technology: Evidence from Pakistan. Agricultural Economics, 10, 39-47.
Jayasinghe-Mudalige, U. and Weersink, A. 2004. Factors Affecting the Adoption of Environmental Management Systems by Crop and Livestock Farms in Canada. Sri Lankan Journal of Agricultural Economics, 6, 25-36.
Krasuaythong, T. 2008. Technologies adoption in vegetable production in Northern Thailand. Ph.D. dissertation, Institute of Development and Agricultural Economics, University of Hannover, Germany.
Pak-uthai, W. 2010. The study chili supply chain management in the Kasetsomboon and Jaturas Districts of Chaiyaphum Province, Thailand. Research report, Thailand Research Fund.
Praneetvatakul, S., Waibel, H. and Meenakanit, L. 2007. Farmer field schools in Thailand: History, economics and policy. Leibniz University of Hannover, Germany.
Walbel, H. and Zilberman, D. 2007. Productivity enhancement and NRM, International research on natural resource management: Advances in impact assessment, edited by H. Waibel and Zilberman, D. Oxford university press, 43-81. USA.

Research article

Changes in Turfgrass Leaf Chlorophyll Content and Some Soil Characteristics as Influenced by Irrigation Treatments

THEMBINKOSI MATHOWA*
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand
Email: tmathowa@yahoo.com

WILAILAK CHINACHIT
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

PONGSAK YANGYUEN
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

SUPAT ISARANGKOOL NA AYUTTHAYA
Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand

Received 14 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract In plants, less water causes photosynthesis reduction whereas excessive water reduces the soil nutrients. These effects induce stunted plant growth. The aim of this work was to study the changes in leaf chlorophyll content and some soil characteristics of the native common bermudagrass (*Cynodon dactylon* L.) as influenced by irrigation treatments. Two experiments, open bottom 4 x 1 m concrete blocks and closed bottom pots were set up during the dry season from January to May 2011 at the Horticultural Section, Faculty of Agriculture, Khon Kaen University. The experimental designs were randomized complete block design (RCBD) with 4 daily irrigation levels; 0.50 evaporation pan ($0.50E_{pan}$), $0.75E_{pan}$, $1.00E_{pan}$ (control) and $1.25E_{pan}$. The results showed that $1.25E_{pan}$ irrigation in open bottom concrete blocks significantly increased leaching of essential soil nutrients and decreased leaf chlorophyll content. The $0.50E_{pan}$ irrigation treatment in pot experiment which was meant to resemble drought conditions had the lowest values in leaf chlorophyll content for the first two months. However, there were no differences in leaf chlorophyll content in all the treatments for the last two months. Moreover, the soil nutrients in all the treatments were not leached out in the closed bottom pot experiment. Therefore, the optimum watering amount should be taken into consideration.

Keywords photosynthesis, soil nutrients, water logging, water stress

INTRODUCTION

Chlorophyll is a molecule that performs photosynthesis, and it is found in the chloroplasts of green plants. This molecule is also responsible for the visual green colour in plants (Cheng et al., 2007; Fu and Dernoeden, 2009). Changes in chlorophyll content could occur as a result of nutrients deficiencies or exposure to environmental stress such as water stress (Mohesenzadeh et al., 2006) and soluble salts (Hameed and Ashraf, 2008). Generally, high soil fertility has been associated with the increase in total chlorophyll concentration (Minotta and Pinzauti, 1996; Cheng et al., 2007). Moderate soil drying and infrequent irrigation was reported to have increased leaf chlorophyll content (Jiang and Huang, 2001; DaCosta and Huang, 2006; Fu and Dernoeden, 2009). However, Alshehhi et al. (2010) found out that chlorophyll *b* and total chlorophyll (*a*+*b*) contents did not present significant differences on the three warm season turfgasses studied under different irrigation regimes in arid region, which reflects that there was no water stress.

Irrigation is an important factor in achieving the desired functions and aesthetics of the turfgrasses. It is aimed at sustaining turf quality and performance by maintaining a favorable soil

water balance which can be achieved with a well-scheduled irrigation together with other appropriate inputs such as fertilizers (Kneebone et al., 1992). Water is utilized by the turf for the transportation of organic molecules, inorganic molecules and in overall structural support (Decoteau, 2005). However, less or excessive water can have some detrimental effects on turfgrass growth due to water stress and the environment such as water logging and salinity problems (Qadir et al., 2003; Rose, 2004). Moreover, soil characteristics which are fundamental to turfgrass growth such as pH, EC, CEC, the rate of organic matter decomposition, nutrients and exchangeable cations are affected by either excessive or insufficient water (Decoteau, 2005; Barton et al., 2006; Harivandi et al., 2009).

Despite chlorophyll being an important parameter for plants growth and soil characteristics playing a major role on plants growth as well, an observation of inconsistent reporting by the previous researchers along these areas was noticed. Therefore, the present study was aimed at evaluating the changes in native common bermudagrass leaf chlorophyll content and some soil characteristics as influenced by the irrigation treatments. Moreover, soil nutrients leaching were confirmed by 2 experiments in open and closed soil systems.

MATERIALS AND METHODS

Two experiments were set up during the dry season. In both experiments native common bermudagrass (*Cynodon dactylon* L.) was propagated using rhizomes. In experiment 1, 16 concrete blocks with open bottoms were used, each measuring 4 x 1 m while experiment 2 was comprised of 12 pots with closed bottoms buried to ground level, each measuring 0.55 m surface diameter and a depth of 0.35 m. The experiments were designed according to a randomized complete block design (RCBD) with four blocks and four replications for experiment 1, and three blocks and three replications for experiment 2. Four daily irrigation treatments were applied as follows; 50, 75, 100-control and 125% ($0.50E_{pan}$, $0.75E_{pan}$, $1.00E_{pan}$ and $1.25E_{pan}$) replacement of the evaporation pan (Class A pan; E_{pan}) which was installed at the study area for treatments 1-4 respectively. The watering was done manually.

Experimental units were filled up with a well prepared mixture of soil, chicken manure, rice husk and rice husk ash (1:1:1:1, v/v) to provide uniform soil conditions. The bulk density was 1.10 g cm^{-3} at 0-15 cm soil depth, and it contained 87.8% sand, 8.1% silt and 4.1% clay. The soil mixture was fermented for a month and some soil physical and chemical properties were determined as follows; pH (1:1 soil: distilled water extract) and electrical conductivity (EC; 1:5 soil: distilled water extract) were measured by conductivity meter (model: MPC227), cation exchange capacity (CEC) by ammonium saturation (Schollenberger and Simon, 1945), organic matter (OM) (Walkley, 1947), total nitrogen (N) content by Kjeldahl method and measured by flow injection analyzer (model: 5012 Analyser) (Bremner, 1965), available phosphorus (P) by Bray II method (Bray and Kurt, 1945), and both exchangeable potassium (K^+) and (Ca^{2+}) were measured by flame photometer (model: 410) after extraction with 1 N ammonium acetate pH 7.0. Also, soil characteristics were determined at the end of the study. The turf was maintained at 1 cm canopy height by cutting and removing the clippings from the experimental units.

Meteorological data was obtained from the agronomy section weather station, located 150 m away from the study area (Table 1).

Leaf chlorophyll content was measured on monthly basis following a method described by Arnon (1949). Chlorophyll was extracted by manual grinding 0.05 g of fresh leaf tissues with 80% acetone using a pestle and mortar in dark room at room temperature. After extracting the chlorophyll, the extract was topped up with 80% acetone to 20 mL, and filtered through a filter paper into a glass tube wrapped with aluminum foil. Residues were discarded, and the resulting solution was then transferred into a rectangular glass cuvette (path length 10 mm) and the absorbance was measured at 663 and 645 nm with a spectrophotometer (model: G10S UV-Vis). Final chlorophyll *a*, *b* and total chlorophyll (*a*+*b*) were calculated using the following equations.

$$Ca = [(12.7 \times D663) - (2.69 \times D645)] \times DF \quad (1)$$
$$Cb = [(22.9 \times D645) - (4.48 \times D663)] \times DF \quad (2)$$
$$Total\ chlorophyll\ (a+b) = [(8.02 \times D663) + (20.20 \times D645)] \times DF \quad (3)$$

Where *Ca* is leaf chlorophyll a (mg g^{-1} fresh weight), *Cb* is leaf chlorophyll *b* (mg g^{-1} fresh weight), *DF* is dilution factor, in this case was (20.05/50), *D663* and *D645* are spectrophotometer absorbance at *663* nm and *645* nm respectively.

The data collected was subjected to analysis of variance (ANOVA) using the STATISTIX-8 program, where a significant F-test was observed and means comparison test was carried out using Least Significant Difference (LSD) at $p \leq 0.05$ to separate treatment means.

RESULTS AND DISCUSSION

The temperature ranged from 14.5°C to 34.6°C and average relative humidity was 79.6%. The weekly E_{pan} reading was 33.4 mm or approximately 4.77 mm day^{-1} (Table 1). However, there was rainfall in mid March and April; so, compensation for rainfall by reducing the amount of watering was done when rainfall occurred.

Table 1 Weekly averages of meteorological data measured during the period of the study

Month	Week	Min_Temp (°C)	Max_Temp (°C)	RH (%)	Epan (mm)	Rainfall (mm)
Jan	3	14.5	27.9	85.6	34.0	-
	4	16.2	29.4	81.9	48.0	-
Feb	1	15.9	28.5	83.6	30.0	-
	2	19.1	33.8	80.0	30.0	-
	3	19.3	33.7	82.1	33.0	-
	4	22.7	33.5	85.1	25.0	-
Mar	1	22.4	34.6	75.9	37.0	-
	2	20.6	33.5	76.9	36.0	-
	3	18.6	29.4	76.9	33.0	-
	4	18.9	28.4	76.9	32.0	12.0
Apr	1	19.8	34.5	77.0	37.0	-
	2	19.7	33.3	76.1	24.0	18.0
	3	18.7	32.9	77.3	38.0	-
	4	17.6	33.1	79.4	30.0	6
Total					467.0	36.0

Note: Dates for total evaporation in January week 3 and week 4 ranges from 12th - 21st and 22nd - 31st respectively. Total rainfall in March week 4 was from 22nd - 31st

Soil characteristics

pH, electrical conductivity (EC), and cation exchange capacity CEC: The pH tended to increase in high irrigation treatments in both experiments. The values in this work were in the range of the general suggestion, which recommends soil pH between 5.5 and 7.5 for nutrients uptake by turfgrasses (Bell, 2011). The comparison between open and closed systems clearly differed in EC parameter. The open system had lower EC while the closed system had higher EC as compared to the composite soil sample value. This evidence indicated that the open system had soil nutrients leaching in the root zone to the deeper soil profile. The consideration in the 4 treatments for both experiments showed that high amount of watering ($1.25E_{pan}$) decreased the EC (Table 2). Nevertheless, the observed increase in EC from the closed system experiment could be attributed to the fertilizer applied two times in March and April.

The CEC in open system decreased with the increase in irrigation amount while the opposite was revealed in the closed system. Also, the reduction in CEC with high irrigation could be related with nutrients leaching out from the root zone (Qadir et al., 2003; Rose, 2004; Bell, 2011).

Organic matter (OM), Nitrogen (N) and Phosphorus (P): In open system experiment, OM significantly decreased in $1.25E_{pan}$ irrigation and all treatments were under the composite soil sample (Table 2). This evidence may be the same with EC and CEC; where high leaching of the soil nutrients was observed in open system experiment. Normally, OM is related with N in the soil. Our results revealed that the open system had the lowest OM and N as compared to the closed system. In addition, high irrigation in open system had the lowest OM and N. Comparing OM and N with the composite soil sample, and with the standard soil value (Bell, 2011), the values in this experiment were higher in OM and N levels.

Similarly, the closed system experiment had higher P when compared to open system. Also, for the high irrigation treatment in open system, P was leached out (Table 2).

Exchangeable cations; Potassium (K^+) and Calcium (Ca^{2+}): When comparing exchangeable K^+ of the two experiments, the results revealed high decrease in open system which was lower than the composite soil sample. This relates to the observed decrease in EC (Table 2). The watering induced leaching of exchangeable K^+ from the top soil. Bell (2011) reported that it is more difficult to maintain K^+ levels on soils with very high sand contents because K^+ is not tightly bound and leaches out easily. However, the closed system had accumulated exchangeable K^+. In detail, the treatments in closed system experiment, $0.75E_{pan}$ and $1.00E_{pan}$ irrigation had lower exchangeable K^+ as compared to $1.25E_{pan}$ irrigation. Mathowa et al. (2011) reported increase in shoot biomass in $0.75E_{pan}$ and $1.00E_{pan}$ irrigation treatments as opposed to the $1.25E_{pan}$ irrigation. Therefore, the observed decrease could also be attributed to exchangeable K^+ being utilized for shoot biomass production.

On the contrary, the irrigation treatments seem to have had no effect on exchangeable Ca^{2+} leaching (Table 2), because of the characteristic of Ca^{2+} as an immobile nutrient.

Table 2 Soil characteristics as influenced by irrigation treatments in both open bottom concrete blocks and closed bottom pots experiments

	pH 1:1 H_2O	EC 1:5 H_2O dS m^{-1}	CEC (cmol kg^{-1})	OM (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K^+ (mg kg^{-1})	Exchangeable Ca^{2+} (mg kg^{-1})
Composite	7.2	0.7	9.9	3.9	0.12	2199.5	1461.0	1300.0
SD	0.3	0.1	1.6	0.4	0.02	430.3	114.4	127.3
Treatments	Open bottom concrete blocks							
$0.50E_{pan}$	7.0^b	0.5^a	11.0^a	3.4^b	0.12^b	1852.4^c	1051.9^b	1900.0^a
$0.75E_{pan}$	7.1^b	0.5^a	10.6^b	3.5^a	0.13^a	2275.0^a	1149.3^a	1450.0^c
$1.00E_{pan}$	7.0^b	0.4^c	10.3^d	3.3^c	0.11^b	2142.3^b	1042.2^b	1400.0^d
$1.25E_{pan}$	7.3^a	0.2^d	10.4^c	3.2^d	0.10^b	1749.2^d	866.9^c	1850.0^b
F-test	*	**	**	**	*	**	**	**
LSD 0.05	0.18	0.01	0.02	0.02	0.02	10.73	17.79	8.22
CV (%)	0.80	0.62	0.05	0.15	4.73	0.17	0.54	0.16
Treatments	Closed bottom pots							
$0.50E_{pan}$	7.0^b	1.8^a	10.0^d	3.9^c	0.15^c	2893.6^a	3141.1^d	1452.5^c
$0.75E_{pan}$	7.0^b	1.7^b	10.8^c	3.9^c	0.16^b	2771.2^c	3335.9^c	1550.0^b
$1.00E_{pan}$	7.1^b	1.7^b	11.7^a	4.6^a	0.18^a	2845.8^b	3555.1^b	1150.0^d
$1.25E_{pan}$	7.6^a	1.4^c	11.4^b	4.2^b	0.15^c	2412.5^d	4139.5^a	1700.0^a
F-test	**	**	**	**	**	**	**	**
LSD 0.05	0.13	0.05	0.02	0.01	0.01	15.16	17.08	8.88
CV (%)	0.57	0.87	0.05	0.10	2.17	0.17	0.15	0.19

** significant at p≤0.05, ** highly significant at p≤0.01, standard deviation (SD). Means separated by LSD Test at p≤0.05, means within columns followed by the same letters are not significantly different.*

Leaf Chlorophyll content

Chlorophyll a, b and total chlorophyll (a+b): In open system, chlorophyll *a* seemed to be positively correlated with the treatments for the first two months with $0.50E_{pan}$ irrigation significantly reducing the content. Contrary to the first two months, $0.50E_{pan}$ and $0.75E_{pan}$ showed the highest content (Fig. 1A) The same trend was revealed for chlorophyll *b* and total chlorophyll *(a+b)* contents (Fig. 1B and 1C). Similar results; that is, the increase in chlorophyll content in $0.50E_{pan}$ and

$0.75E_{pan}$ irrigation treatments were reported by Jiang and Huang (2001), and DaCosta and Huang (2006) found out that drought or lower amount of irrigation increase the chlorophyll content. It seems as if turfgrass chlorophyll contents increase serves as an activator for biochemical processes such as photosynthesis. Moreover, a sharp decrease in chlorophyll content for the control and $1.25E_{pan}$ irrigation at the end of the study could be attributed to the excessive irrigation which led to some essential soil nutrients such as N and exchangeable K^+ being leached out to the deeper soil profile as shown in Table 2.

Similar trend in closed system (Fig. 2) to the one shown in open system (Fig.1) was revealed for the first two months. However, there were no differences in the third and fourth months (Fig.2). Water moves downwards to the deeper soil profile after rain or irrigation and it moves upwards to evaporate or transpire from the soil surface or plant leaves (Plaster, 2003). Therefore, the closed bottom pot experiment was set up to counteract the upward movement of water. As a result no compensation for less water in closed system, hence water stress could possibly explain the high differences among the treatments as opposed to the open system for the first two months (Fig.1 and 2). Due to the fact that the closed pots were able to retain essential soil nutrients such as N, P and K^+ (Table 2), this could be attributed to the increase observed in chlorophyll contents at the end of the study. In support of our findings, Minotta and Pinzauti (1996) and Cheng et al. (2007) suggested that chlorophyll content progressively increase in high fertility soils.

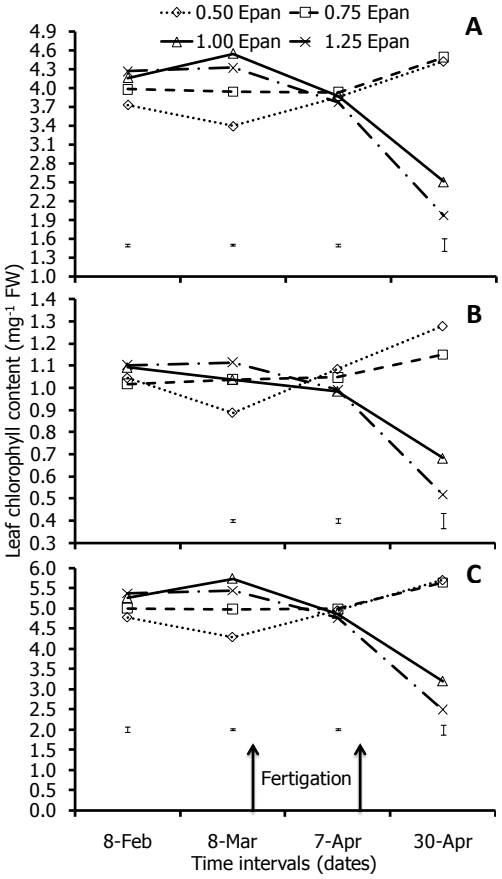


Fig. 1 Effect of irrigation regime on leaf chlorophyll content

chlorophyll a (A), chlorophyll b (B) and total chlorophyll (a+b) (C) of native common bermudagrass in open bottom concrete blocks. Vertical bars are LSD values (p≤0.05)

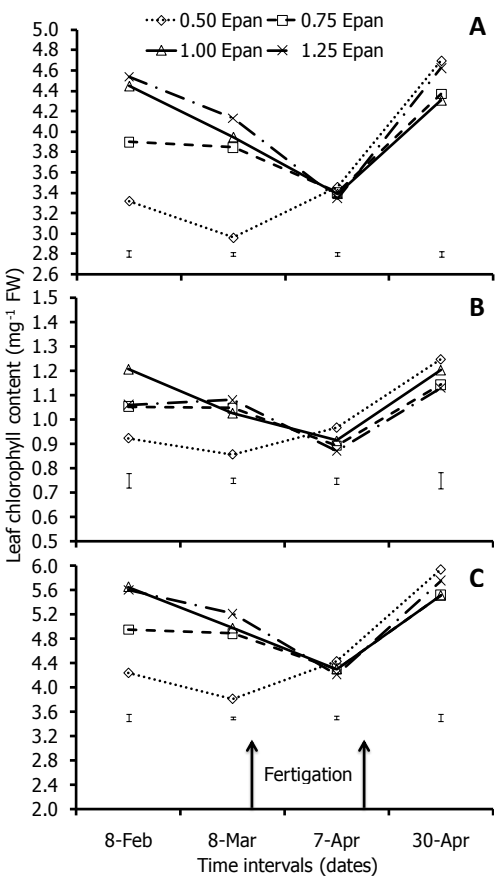


Fig. 2 Effect of irrigation regime on leaf chlorophyll content

chlorophyll a (A), chlorophyll b (B) and total chlorophyll (a+b) (C) of native common bermudagrass in closed bottom pots. Vertical bars are LSD values (p≤0.05)

CONCLUSIONS

Excessive irrigation in open system experiment led to leaching of essential plants nutrients and resulted in a significant decrease of leaf chlorophyll content. On the contrary, the closed system had no leaching of essential plants nutrients as proved by the increase in chlorophyll content in the third and fourth months. Therefore, optimum irrigation can retain nutrients and increase chlorophyll content; this should be taken into consideration for irrigation amount.

ACKNOWLEDGEMENTS

Thanks to the Graduate School, Khon Kaen University for financial support, TICA scholarship, and Agronomy Soil and Plant Analysis Laboratory technicians for technical assistance.

REFERENCES

Alshehhi, A.M.H., Khan, I.A., Al-Said, F.A., Deadman, M.L., Al-Khanjari, S. and Ahmad, T. 2010. Evaluation of warm season turfgrasses under different irrigation regimes in arid region. Notulae Scientia Biologicae, 2, 30-38.

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts polyphenoloxidase. *Beta vulgaris*, Plant Physiology, 24, 15-22.

Barton, L., Wan, G.G.Y and Colmer, T.D. 2006. Turfgrass (*Cynodron dactylon L.*) sod production on sandy soils: Effects of irrigation and fertilizer regimes on growth and quality. Plant and Soil, 284, 129-145.

Bray, R.H and Kurtz, L.T. 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Science 59, 39-45.

Bremner, J.M. 1965. Isotope ratio analyses of nitrogen-15 traces investigations. Methods of soil analysis. American Society of Agronomy, Madison, Wisconsin, 1256-1286.

Bell, G.E. 2011. Turfgrass physiology and ecology: Advanced management principles. Cambridge University Press, UK.

Cheng, H., Xu, W., Liu, J., Zhao, Q., He, Y. and Chen, G. 2007. Application of composted sewage sludge (CSS) as a soil amendment for turfgrass growth. Ecological Engineering, 29, 96-104.

DaCosta, M. and Huang, B. 2006b. Minimum water requirements for creeping, colonial and velvet bentgrasses under fairways conditions. Crop Science, 46, 81-89.

Decoteau, D.R. 2005. Principles of plant science: Environmental factors and technology in growing plants. Pearson Education, Inc., Upper Saddle River, New Jersey.

Fu, J. and Demoeden, P.H. 2009. Creeping bent grass putting green turf responses to two irrigation practices: Quality, chlorophyll, canopy temperature, and thatch-mat. Crop science, 49, 1071-1078.

Hameed, M. and Ashraf, M. 2008. Physiological and biochemical adaptations of *Cynodon dactylon* (L.) Pers. from the salt range (Pakistan) to salinity stress. Flora, 203, 683-694.

Harivandi, M.A., Baird, J., Hartin, J., Henry, M. and Shaw, D. 2009. Managing turfgrasses during drought. Division of Agriculture and Natural Resources, University of California. http://ancatalog.ucdavis.edu.

Jiang, Y. and Huang, B. 2001. Drought and heat stress injury to two cool season turfgrasses in relation to antioxidant metabolism and lipid peroxidation. Crop science, 41, 436-442.

Kneebone, W.R., Kopec, D.M. and Mancino, C.F. 1992. Water requirements and irrigation. Waddington, D.V. et al. (eds.), Turfgrass. Agron. Monogr. 32. ASA, CSSA, and SSSA, Madison, WI, 441-472.

Mathowa, T., Chinachit, W., Yangyuen, P. and Isarangkool Na Ayutthaya, S. 2011. Influence of irrigation regime on some growth characteristics and water use efficiency of native common bermudagrass (*Cynodon dactylon* L.). Acta Horticulturae (In press).

Minotta, G. and Pinzauti, S. 1996. Effects of light and soil fertility on growth, leaf chlorophyll content and nutrient use efficiency of beech (*Fagus sylvatica* L.) seedlings. Forest Ecology and Management 86, 61-71.

Mohsenzadeh, S., Malboobi, M.A., Razavi, K. and Farrahi-Aschtiani, S. 2006. Physiological and molecular responses of *Aeluropus lagopoides* (Poaceae) to water deficit. Environmental and Experimental Botany, 56, 314-322.

Plaster, E.J. 2003. Soil science and management. Delmar Learning, Inc, Clifton Park, NY.

Qadir, M., Boers, Th.M., Schubert, S., Ghafoor, A. and Murtaza, G. 2003. Agricultural water management in water-starved countries: challenges and opportunities. Agricultural Water Management, 62, 165-185.

Rose, C. 2004. An introduction to the environmental physics of soil water and watersheds. Cambridge University Press, UK.
Schollenberger, C.J. and Simon, R.H. 1945. Determination of exchangeable capacity and exchangeable bases in soils-ammonium acetate method. Soil Science, 59, 13-24.
Walkley, A. 1947. Organic carbon by Walkley-Black oxidation procedure. Soil Science, 63, 251-264.

Research article

Changes in *Escherichia coli* Efflux from Farmland by Surface Runoff and Percolation under Different Application Methods of Manure

YUTA ISHIKAWA
Graduate School of Agriculture, Tokyo University of Agriculture, Japan
Email: y_i4kawa@yahoo.co.jp

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
Email: m-mihara@nodai.ac.jp

Received 15 February 2012 Accepted 18 April 2012 (* : Corresponding author)

Abstract The application of cattle manure in farmlands was considered as a proper treatment from a viewpoint of organic agriculture. However, pathogenic bacteria known as *E. coli* in immature fermented manure happen to spread out from farmlands. So, the objective of this study is to investigate *E. coli* efflux under different application methods of cattle manure. Slope modeling experiment was conducted under an artificial rainfall simulator. Slope plots were filled with soil then fresh cow dung and 2 weeks fermented manures were applied into the plots. Cow dung and manure were applied with 2 application methods: the broadcasting method and the incorporating method. Based on the experimental results, it was found that *E. coli* efflux increased with soil loss through surface runoff. Moreover, it showed that the amounts of *E. coli* efflux were higher than that of input in either plot broadcasted or incorporated with cow dung. In addition, there were tendencies that *E. coli* had been transported by percolation although it was smaller in number than that by surface runoff.

Keywords *Escherichia coli*, total suspended solid, soil erosion, cow dung, manure

INTRODUCTION

Large amount of dung has been produced from cattle farms. So, making manure was considered as one of the proper treatments for utilizing cattle manure from a viewpoint of organic agriculture. However, most of manures produced from cattle farms may include immature fermented manure. The pathogenic bacteria known as *E. coli* may survive and remain in immature fermented manure (Chun-Ming et al., 2005). It was reported by Islam et al. (2005) that *E. coli* applied through immature fermented manure survived in longer days at farmlands. Also, some reports mentioned that the efflux of *E. coli* occurs through surface runoff from grazed land and farmland where cattle manures were applied (Mishra et al., 2007; Yagura et al., 2006) and large amounts of *E. coli* were transported along with soil erosion from farmland where fresh dung was applied (Ishikawa and Mihara, 2010). In addition, *E. coli* efflux remarkably influences environmental pollution in watersheds as well as contamination of potable water source affecting human health (Tamura et al., 2006; Mishina et al., 2007). However, only few studies has been carried out concerning the efflux of *E. coli* from farmlands where immature fermented manures were applied.

In this study, the objectives were to investigate the relationship between the efflux of *E. coli* and total suspended solids under broadcasting and incorporating methods of manures, to evaluate the difference between *E. coli* efflux through surface runoff and that through percolation, and to compare the efflux of *E. coli* with the input amounts of *E. coli*.

METHODOLOGY

Cow dung and manure used in this experiment were collected from Fuji Farm, a cattle farm of Tokyo University of Agriculture located in Shizuoka Prefecture. There were two types of cow dung collected for the experiments, the fresh cow dung (Fig. 1a) and the 2 weeks fermented manure (Fig. 1b) with water contents at 84 and 72%, respectively. For sanitary reasons, collected cow dungs were kept in a close container under anaerobic condition. Organic matters were 89% in fresh cow dung and 87% in 2 weeks fermented manure as shown in Table 1. The colony forming unit (cfu) of *E. coli* was 19×10^6 cfu/g in fresh cow dung and 21×10^3 cfu/g in 2 weeks fermented manure.

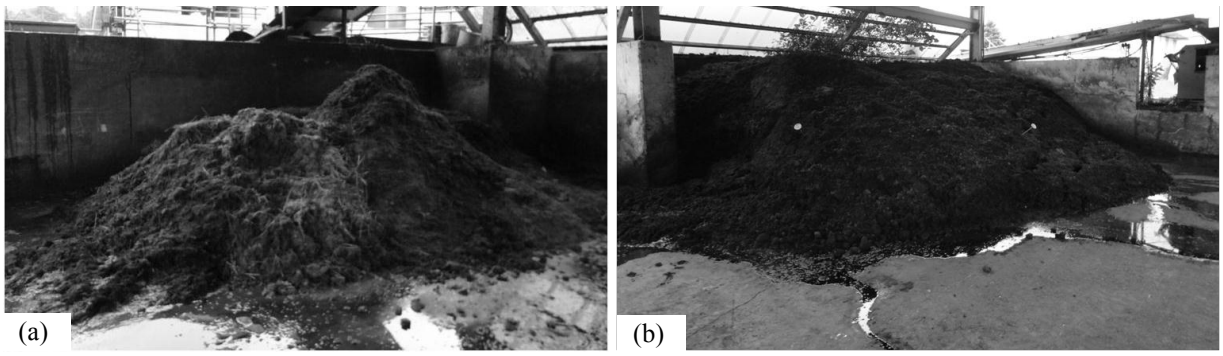


Fig. 1 Piles of fresh cow dung (a) and 2 weeks fermented manure (b) at Fuji Farm

Table 1 Properties of cow dung and fermented manure

	Period of fermentation	*Escherichia coli* (cfu/g)	Water content (%)	Organic matter (%)
Cow dung	0 days	19×10^6	84	89
Manure	2 weeks	21×10^3	72	87

Stainless slope model plots of 130 cm long and 11 cm wide were filled up with light clay soil, andosol, at 5 cm deep (Table 2). The plots were set up at 8 degrees in slope then cow dung and 2 weeks fermented manure were applied. The amounts of cow dung and manure applied into each plot were 1000 g/m^2 (10 t/ha) in dry mass. Both of fresh cow dung and fermented manure were applied by broadcasting method and incorporating method into each designated slope model plot. Broadcasting method is spreading fresh cow dung or fermented manure on soil surfaces, while incorporating method is mixing fresh cow dung or fermented manure with soil. The prepared slope model plots were kept to make soil the 24 hour field capacity moisture before starting the rainfall simulation.

Table 2 Physical properties of soil

Specific gravity	Particle size distribution (%)					Soil texture
	Gravel	Coarse sand	Fine sand	Silt	Clay	
2.68	2.0	12.3	27.8	30.2	27.7	LiC

Table 3 Chemical and biological properties of soil

Ignition loss (%)	Total nitrogen (10^{-5} kg/kg)	Total phosphorus (10^{-5} kg/kg)	*Escherichia coli* (cfu/g)
13.41	226.31	30.36	0

Artificial rainfall simulation was carried out at rainfall intensity of 60 mm/hr for 2 hours. Suspended water samples through surface runoff were collected from each plot (Fig. 2). Suspended water samplings were done every 15 minutes for the first one hour and every 30 minutes for the second one hour of the simulation. Percolation water was sampled only once after 24 hours passed from the end of simulation.

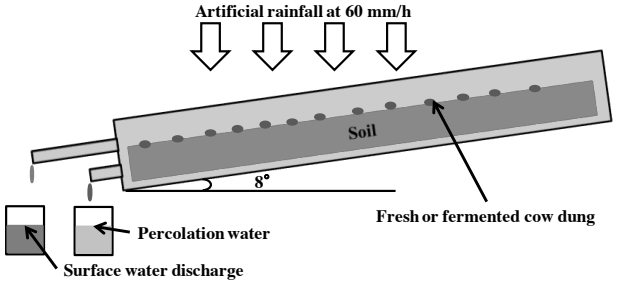


Fig. 2 Slope model plot and suspended water collected by surface runoff and percolation water

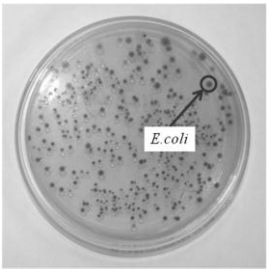


Fig. 3 Propagated *E. coli* by culture media in petri dish

The colonies of *E. coli* in the collected suspended water samples were evaluated through laboratory analysis. The analysis was carried out by bacteria culture medium XM-G as shown in Fig. 3. The mass of solids in surface runoff and in percolation water were also measured by oven drying method.

RESULTS AND DISCUSSION

The relationship between *E. coli* efflux and total suspended solids loss from the plot applied fresh cow dung was summarized in Fig.4. It was observed that *E. coli* efflux significantly increased with total suspended solids in surface runoff from both application methods. A confidence interval at 99% was also observed in surface runoff from the plots broadcasted and incorporated with cow dung. However, *E. coli* efflux tended to be very low in correlation with suspended solid losses for percolation water.

The relationship between *E. coli* efflux and suspended solids loss in the plots applied 2 weeks fermented manure was shown in Fig. 5. There was a tendency that *E. coli* efflux increased with suspended solids losses in surface runoff. It was also observed that *E. coli* efflux was very low in broadcasted plots comparing to that in incorporated plots. The tendency of *E. coli* efflux with suspended solids loss was very low in percolation water. Therefore, it was considered that *E. coli* efflux had a remarkable tendency to be transported along with suspended solids loss for surface runoff, but that tendency was not clear for percolation water.

Additionally, Fig. 6 shows the total input and efflux of *E. coli* through surface runoff or percolation from the plots applied cow dung. The experimental results of fresh cow dung indicated that the number of *E. coli* efflux was higher than that of input in both broadcasting and incorporating methods. However, the significant difference was not observed between the input and the efflux of *E. coli*. In the plots applied 2 weeks fermented manure, it was observed that *E. coli* efflux was higher than that of input in incorporation methods as shown in Fig. 7. Although a significant difference was not observed, the number of *E. coli* efflux from incorporated plot was higher than that from broadcasted plot. The tendency of *E. coli* efflux being higher than that of *E. coli* input was considered that *E. coli* may be facultative anaerobic pathogens which may propagate for a certain period after applying into an open land. Hence the condition before applying *E. coli* was an anaerobic then it changed to aerobic condition after applying.

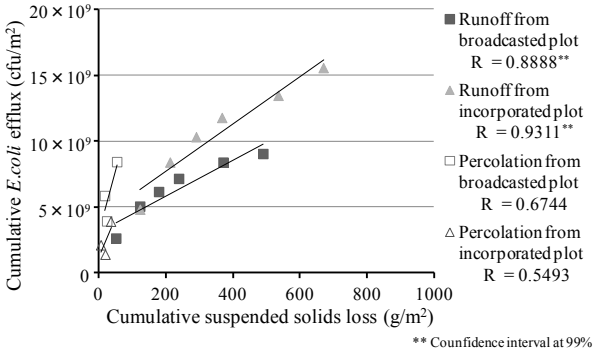


Fig. 4 Relationship between *E. coli* efflux and suspended solids loss from plots where fresh cow dung was applied

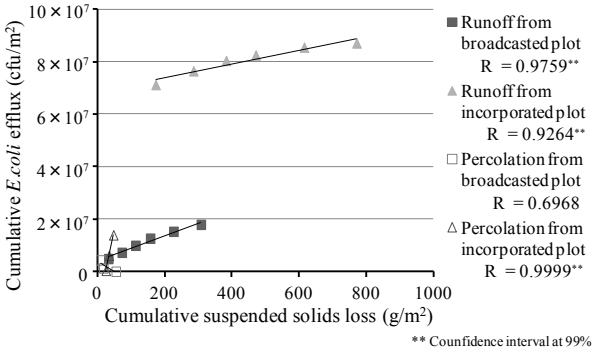


Fig. 5 Relationship between *E. coli* efflux and suspended solids loss from plots where 2 weeks fermented manure was applied

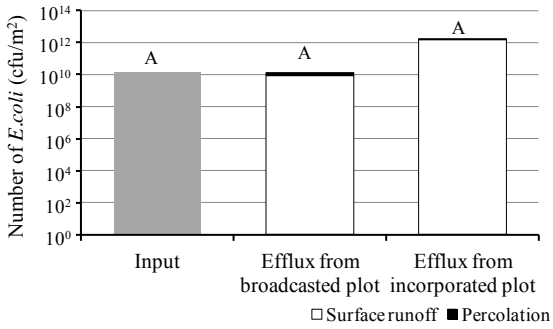


Fig. 6 Number of *E. coli* input in fresh cow dung and *E. coli* efflux through surface runoff and percolation

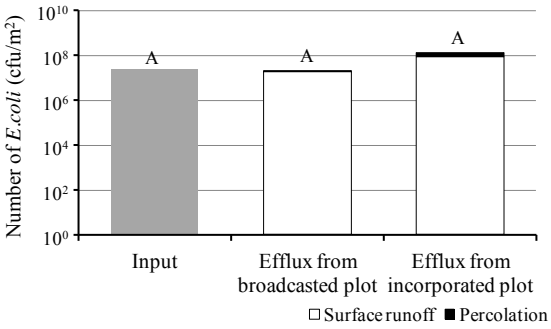


Fig. 7 Number of *E. coli* input in 2 weeks fermented manure and *E. coli* efflux through surface runoff and percolation

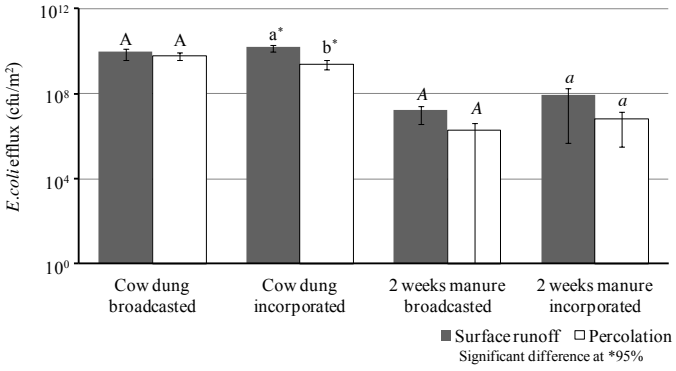


Fig. 8 Total efflux of *E. coli* from plots applied fresh cow dung or 2 weeks fermented manure by broadcasting or incorporating

The total efflux of *E. coli* through surface runoff and percolation are shown in Fig. 8. It was indicated that the efflux of *E. coli* decreased with the fermentation. The tendency of *E. coli* efflux through surface runoff to be larger than that through percolation was also observed. It was clearly indicated that *E. coli* efflux occurred not only through surface runoff but also through percolation. A significant difference at 95% was observed in only the case fresh cow dung applied by incorporating method.

CONCLUSION

Based on the experimental results, it was clearly observed that *E. coli* efflux significantly increased with the increase in total suspended solids in surface runoff from the plots applied fresh cow dung and from the plots applied 2 weeks fermented manure. Also, the same tendency that *E. coli* efflux increased with the increase in total suspended solids by broadcasting and incorporating methods.

The efflux of *E. coli* through percolation was significantly lower than that of *E. coli* efflux through surface runoff. It was also observed that the number of *E. coli* efflux was higher than that of *E. coli* input from both plots applied fresh cow dung and 2 weeks fermented manure.

The existence of *E. coli* were found even in the 2 weeks fermented manure indicating a potential of *E. coli* efflux after applying into farmlands particularly by incorporating application method. Therefore, fermentation of cow dung for more than two weeks before applying into farmlands is highly suggested.

REFERENCES

Gong, C., Koshida, J., Moriyama, N., Xiaodan Wang, Udou, T., Inoue, K. and Someya, T. 2005. Occurrence and survival of coliform bacteria, *Escherichia coli* and salmonella in various manure and compost. Journal of the science of soil and manure, 76(6), 865-874.

Ishikawa, Y. and Mihara, M. 2010. Characteristics of *E.coli* loss under different fertilization of manure. International Journal of Environmental and Rural Development, IJERD, 1-2, 84-87.

Islam, M., Doyle, P.M., Phatak, C.S., Millner, P. and Jiang, X. 2005. Survival of *Escherichia coli* O157:H7 in soil and on carrots and onions grown in fields treated with contaminated manure composts or irrigation water. Food Microbiology, 22, 63-70.

Mishina, M., Takahashi, E., Sasaki, M., Hatakeyama, T., Uemura, H., Yatsu, J. and Saito, N. 2007. Clarification of infection route in the frequently outbreak regions of enterohemorrhagic *E.coli* infection disease in Miyagi prefecture. Annual Report of Miyagi Prefectural Institute of Public Health and Environment, 25, 34-37.

Mishra, A., Benham, L. B. and Mostaghimi, S. 2007. Bacterial transport from agricultural lands fertilized with animal manure. Water Air Soil Pollut. 189(4), 127-134.

Tamura, H., Sasaki, M., Hatakeyama, T., Kawano, M., Yatsu, J. and Akiyama, K. 2006. Verification of incident preventions against outbreak incidences of enterohemorrhagic *E.coli* infectionin Miyagi prefecture. Annual Report of Miyagi Prefectural Institute of Public Health and Environment, 24, 50-54.

Yagura, H., Tada, N. and Yasutomi, M. 2006. Nitrogen, phosphorus and coliform contamination of outflow in cattle grazing land. Research Bulletin of the Kyoto Prefectural Livestock Technological Research Center, 3, 71-73.

Research article

The Nitrate Nitrogen Concentration in River Water and the Proportion of Cropland in the Tokachi River Watershed

TOSHIMI MUNEOKA*
Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan
Email: muneoka@obihiro.ac.jp

HIROMU OKAZAWA
Faculty of Regional Environmental Science, Tokyo University of Agriculture, Tokyo, Japan

OSAMU TSUJI
Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan

MASATO KIMURA
Obihiro University of Agriculture and Veterinary Medicine, Hokkaido, Japan

Received 14 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract It is widely known that nitrate pollution of river water and groundwater in agricultural regions has become severe in Japan and in other agricultural countries around the world. On the other hand, in the Tokachi River Watershed, where large-scale upland field cultivation with dairy farming is the main form of agriculture, few surveys and little research have addressed the impact of agriculture on water quality in the area. This study examined the relationship between the nitrogen concentration in river water at normal water level and the proportion of cropland in the Tokachi River Watershed with taking notice of both maintaining sustainable agriculture and conserving water quality environment. At 37 locations on the Tokachi River main stream and its tributaries (their downstream ends), the NO_3-N concentration in river water and the proportion of cropland in the watersheds were surveyed for three years. Nitrate nitrogen as a percent of total nitrogen in river water ranged from 84% to 91%. The maximum T-N in water from the tributaries was approx. 8.8 mg/L. There was a correlation (significance of 1%) between the NO_3-N concentration in river water and the proportion of cropland in the watersheds. The correlation coefficients ranged from 0.80** to 0.95** in the water from the main stream. It was confirmed that the impact factor, or the slope of the regression curve that represents the relationship between the two, ranged from 0.037 to 0.075, which was greater than the values reported for various other locations in Hokkaido. Future studies on conserving the water environment by reducing the nitrogen loading into the river system while maintaining the cropland in the Tokachi River Watershed in favorable condition will need to explore the feasibility of land use assessment methods based on the new viewpoint.

Keywords Tokachi River, NO_3-N concentration, proportion of cropland, impact factor

INTRODUCTION

It is widely known that nitrate pollution of river water and groundwater in agricultural regions has become severe in Japan and in other agricultural countries around the world. The close relationship between agricultural land use, which causes nitrogen loading, of the watershed in particular and the nitrate nitrogen concentration in river water has been pointed out (Carpenter et al., 1998; Shimura and Tabuchi, 2000).

In Hokkaido, where large-scale agriculture predominates, surveys and research on agricultural land use and river water quality have been conducted in many areas since the 1990's. In Eastern

Hokkaido, where the scale of dairy farming is particularly large, it has been reported in numerous studies that the high density of pasture and cattle population in the watershed tends to result in a high nitrate nitrogen concentration in river water. (Tabuchi et al., 1995; Nagasawa et al., 1995; Inoue et al., 1999).

In the Tokachi River Watershed, where large-scale upland field cultivation with dairy farming is the main forms of agriculture, few surveys and little research have addressed the impact of agriculture on water quality in the area. Tabuchi et al. (1995) and Anbumozhi and Yamaji (2001), for example, attempted to assess the impact of land use on the water quality of the northwestern area of the Tokachi River Watershed, by using the nitrate nitrogen concentration of river water as an index of land use. In each of these cases, however, investigation was based on only one water quality survey or on only a short period of such survey. Accurate understanding of secular or annual fluctuations in river water quality (N concentration in particular) has not been attempted in the Tokachi River Watershed, which possesses local characteristics that are distinct among regions with an Asian monsoon climate.

This study examined the relationship between the nitrogen concentration in river water at normal water level and the proportion of cropland in the Tokachi River Watershed based on a three-year observation. To ensure sustainable agriculture by maintaining the water quality, this study also investigates a new land use assessment method for the region, taking the current proportion of cropland in the Tokachi River Watershed into account.

METHODOLOGY

The Tokachi River Watershed measures 9,010 km^2, making it the second largest watershed in Hokkaido and the sixth largest in Japan. A map of the Tokachi River Watershed and basic data of the survey sites are shown in Fig. 1 and Table 1. In the watershed, where survey site No. 17 (Tokachikakouhashi) is located, 30% of the land is used for cropland and 62% is forests. The major upland crops in this area are wheat, sugar beets, legumes and potatoes. Feed crops are also grown.

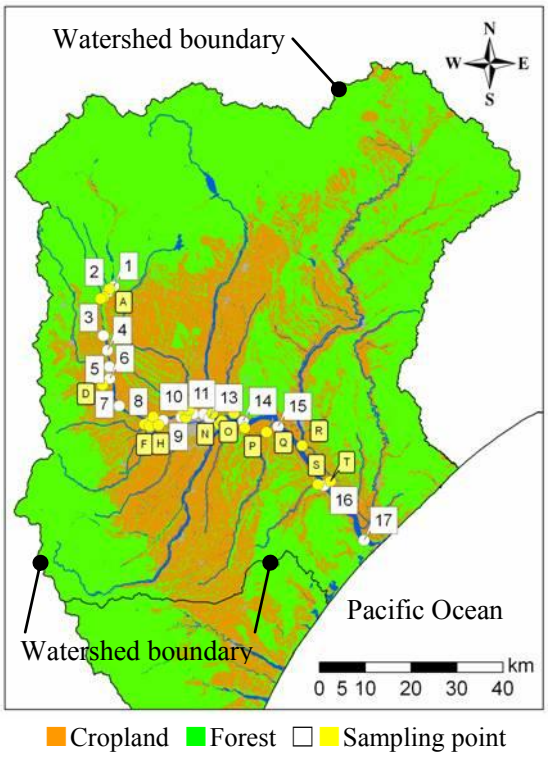


Fig. 1 Location and sampling points of the Tokachi River Watershed

In the Tokachi River Watershed we conducted river water sampling at ordinary water level, water quality analysis and land use evaluation. The survey sites numbered 37: 17 on the main stream of the Tokachi River (No. 1 to No. 17), and 20 on tributaries that flow into the Tokachi River's main stream. The tributary sites were all at the downstream end of the tributaries (A to T; Fig. 1, Table 1). The samples were kept in airtight containers at low temperature and carried to the laboratory for analysis of total nitrogen (T-N) and nitrate nitrogen (NO_3-N) according to the Japan Industrial Standards (JIS). The period for water sampling was the three years from 2007 to 2009, nine times in total. Samplings for each year were done in late June, late August (or early September) and late October.

The GIS software application ArcGIS Desktop (Ver9.3, ESRI) was used for analyzing the land use of the Tokachi River Watershed. The data on land use and watershed boundaries were extracted from digital national information (National and Regional Planning Bureau, Ministry of Land, Infrastructure, Transport and Tourism). The data on administrative boundaries, rivers and elevations were extracted from 1/25000 national digital cartographic data (Geographical Survey Institute). Land was categorized as forest or agricultural land based on the digital national land data (1997). Vector data were created for the land use in each watershed. These created data were then converted into raster data with 100-m grids.

Table 1 Land use of the Tokachi River Watershed

Sampling point		River name	Area	Land use (%)		
No.	Bridge name		(km^2)	Cropland	Forest	Others
Main stream						
1	Oojikahashi	Tokachi River	632	1	88	11
2	Iwamatsuhashi	Tokachi River	658	1	88	11
3	Shinseihashi	Tokachi River	801	2	88	10
4	Kyoueihashi	Tokachi River	806	3	87	10
5	Kamikawahashi	Tokachi River	840	5	85	10
6	Shimizuoohashi	Tokachi River	858	7	84	10
7	Tokachihashi	Tokachi River	1,289	15	77	8
8	Shoueihashi	Tokachi River	1,531	19	72	8
9	Memurooohashi	Tokachi River	1,777	21	70	9
10	Nakajimahashi	Tokachi River	1,798	21	70	9
11	Heigenoohashi	Tokachi River	2,669	31	60	9
12	Suzuranoohashi	Tokachi River	2,683	32	59	9
13	Tokachioohashi	Tokachi River	2,686	32	59	9
14	Tokachichuuouoohashi	Tokachi River	4,479	32	58	10
15	Chiyodaoohashi	Tokachi River	5,098	36	54	10
16	Moiwaoohashi	Tokachi River	8,224	30	61	8
17	Tokachikakouhashi	Tokachi River	8,982	30	62	8
Tributaries (downstream ends)						
A	Pennaihashi	Penkenai River	23	0	98	2
B	Penkenikorobetsuhashi	Penkenikorobetsu River	48	1	98	1
C	Minamiiwamatsuhashi	Penkenikorochin River	72	1	98	1
D	Sahorohashi	Sahoro River	337	26	68	2
E	Kenenakajimahashi	Memuro River	210	38	56	6
F	Motomachihashi	Piuka River	26	71	12	17
G	Bimanhashi	Bibaushi River	35	79	19	3
H	Biseihashi	Bisei River	180	16	74	8
I	Kitanisenhashi	Shinobihiro River	164	74	16	10
J	Shinshibusarahashi	Shibusarabibaushi River	33	53	43	3
K	Kunimihashi	Shikaribetsu River	667	48	45	8
L	Houraihashi	Otofuke River	693	19	69	12
M	Satsunaihashi	Satsunai River	704	30	61	9
N	(Downstream end)	Obihiro River	197	66	14	20
O	Asahihashi	Shihoro River	316	64	29	7
P	Senjyuuhashi	Tobetsu River	127	79	13	8
Q	Yamuwakkahashi	Sarubetsu River	449	69	26	5
R	Kawaioohashi	Toshibetsu River	2,850	20	75	5
S	Noyaushihashi	Ushisyubetsu River	173	24	61	3
T	Houeihashi	Rebunnai River	66	43	51	6

For the main stream and tributaries (the lowest reaches), tests for noncorrelation for the regression coefficients (significance of 1% to 5%) were conducted to clarify the relationship between the NO_3-N concentration in river water and the proportion of cropland in each watershed.

RESULTS AND DISCUSSION

When the data from the main stream and tributaries of the Tokachi River were examined, a high correlation was found between the T-N concentration and NO_3-N concentration of the river water (significance of 1%). The coefficients of determination $\mathbf{r^2}$ were 0.93** and 0.97**, respectively (Fig. 2 (a), (b); Table 2 (a), (b)). NO_3-N as a percent of T-N in the river water ranged from 84% to 91%, which is extremely high.

The relationship between the NO_3-N concentration in river water when the water level is normal and the proportion of cropland in the watershed will be examined.

First, there was a positive correlation (significance of 1%) between the NO_3-N concentration in the river water and the proportion of cropland in the watershed of the Tokachi River main stream. The coefficients of correlation **r** showed extremely high values, ranging from 0.80** to 0.95** (Fig. 3 (a); Table 3(a)). The same relationship for the tributaries was also positively correlated (significance of 1%) (Fig. 3 (b); Table 3 (b)). The coefficients of correlation **r**, however, were not very high, ranging from 0.66** to 0.82**.

As discussed above, regardless of the survey year or season, for the watershed with a high proportion of cropland, the NO_3-N concentration in the river water at the ordinary water level is high. The correlation between the two is remarkably high in the Tokachi River Watershed as a whole. The difference between the data for the main stream and its watershed and that for the tributaries and their watersheds seems to be because the size of the watershed and the distances of croplands from the river greatly varied according to the history of development of each area. These differences seemed to be reflected in the difference between the coefficients of correlation of the two.

The slopes of the regression curves that represent the relationship between the NO_3-N

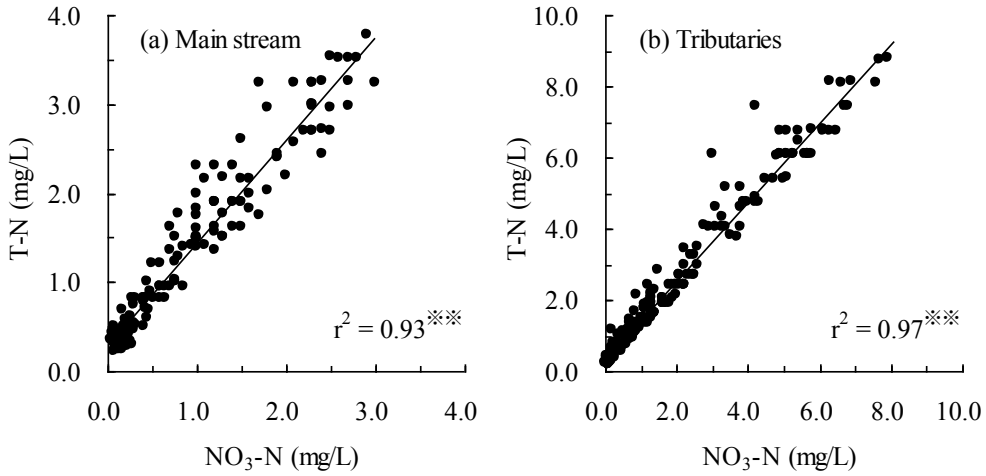


Fig. 2 The relationship between T-N and NO_3-N (2007-2009)

Table 2 The regression curve between T-N and NO_3-N (2007-2009)

Sampling point	Regression curve	Coefficient of determination $\mathbf{r^2}$	Number of data
(a) Main stream	T-N = 1.2 NO_3-N + 0.28	0.93 **	147
(b) Tributaries	T-N = 1.1 NO_3-N + 0.34	0.97 **	180

*** significance of 1%*

concentration in the river water and the proportion of cropland in the watershed (Table 3 (a), (b)) were examined. The values were evaluated as the impact factors (IF values). The IF values reported in the studies on the watersheds in the agricultural areas of Hokkaido ranged from 0.0052 to 0.040. (Tabuchi et al. 1995; Woli et al. 2002; Woli et al. 2004; Okazawa et al. 2009).

Our survey shows that the IF values for the Tokachi River main stream were between 0.037 and 0.075, and those for the tributaries were between 0.042 and 0.071. The highest IF value (0.075 and 0.071) was observed for the main stream and tributaries in 2009 respectively. One thing to note here is the high IF values in the Tokachi River Watershed. Nitrogen components in the chemical fertilizers that are applied to cropland in large amounts and nitrogen components in cattle manure in the watershed ultimately turn into NO_3-N and seep into the ground. Because of these agricultural activities, NO_3-N constantly flows into rivers in relatively high concentrations at the ordinary water level in the Tokachi River Watershed.

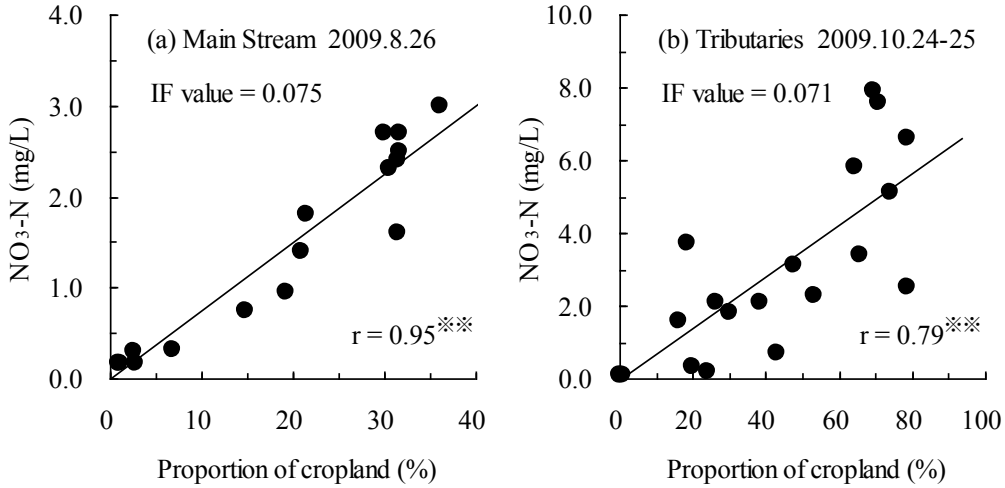


Fig. 3 The relationship between NO_3-N and proportion of cropland

Table 3 The impact factor between NO_3-N and proportion of cropland

Sampling date			IF value※ (Impact factor)	Coefficient of corelation **r**	Number of data	N.B.
(a) Main stream						
2007	June	22	0.039	0.87※※	17	
	August	20	0.048	0.90※※	17	
	October	23-24	0.044	0.87※※	17	
2008	June	28	0.037	0.81※※	16	
	September	9	0.045	0.80※※	16	
	October	28-29	0.044	0.80※※	16	
2009	June	30	0.062	0.92※※	16	
	August	26	0.075	0.95※※	16	Fig. 3 (a)
	October	24-25	0.068	0.91※※	16	
(b) Tributaries						
2007	June	22	0.055	0.77※※	20	
	August	20	0.042	0.70※※	20	
	October	23-24	0.048	0.82※※	20	
2008	June	28	0.049	0.74※※	20	
	September	9	0.049	0.74※※	20	
	October	28-29	0.044	0.66※※	20	
2009	June	30	0.058	0.71※※	20	
	August	26	0.064	0.77※※	20	
	October	24-25	0.071	0.79※※	20	Fig. 3 (b)

※ IF value = NO_3-N concentration / Proportion of cropland ※※ significance of 1%

Generally, the greater is the proportion of forested area in the watershed, the lower is the NO_3-N concentration in the river water, because the water from the forest dilutes the NO_3-N-polluted water from the cropland. To reduce inflow into rivers of nitrogen components that are not used or fixed in cropland, it is worth considering changing the uses of land adjacent to the rivers. Such changes would include the establishment of buffer zones such as riparian forests (Okazawa et al., 2010). In recent years, some basic research has addressed the influence of land agglomeration in watersheds on the nitrogen concentration of the river water (Okazawa et al., 2009, 2011). Incorporating the new viewpoint of the positional relationship between cropland and forests in watersheds into assessment of the impact of land use, we will investigate desirable land use in the Tokachi River Watershed from the standpoint of conserving the water environment, which will make it possible for us to provide ideas for better land uses.

CONCLUSION

The relationship between the NO_3-N concentration in the river water and the proportion of cropland in the watershed was investigated for 37 locations on the Tokachi River main stream and its tributaries (their lowest reaches). The maximum slope of the regression curve (IF value) that represents the relationship between the NO_3-N concentration and the land use was found to be 0.075. It was clarified that the IF values for the investigation locations were far greater than those for other areas in Hokkaido. In future study, it will be necessary to explore the feasibility of land use assessment methods that are based on the new viewpoint, in examining water environment conservation by reducing the nitrogen loading into the river system while maintaining the cropland in the Tokachi River Watershed in favorable condition.

ACKNOWLEDGEMENTS

We would like to express my gratitude to Prof. Dr. Yasushi Takeuchi, Faculty of Regional Environment Science, Tokyo University of Agriculture. The authors are also grateful for the research assistance provided by the students of the Laboratory of Hydro-structural Engineering, Tokyo University of Agriculture, and the Environmental and Rural Engineering Unit, Obihiro University of Agriculture and Veterinary Medicine.

REFERENCES

Anbumozhi, V. and Yamaji, E. 2001. Riparian land use and management of nonpoint source pollution in a rural watershed. Transactions of rural planning, 3, 55-60.

Carpenter, S., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. and Smith, V.H. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Issues in Ecology, 3, 1-12.

Inoue, T., Yamamoto, T. and Nagasawa, T. 1999. River water quality and landuse of watersheds in Hamanaka, eastern Hokkaido, Japan. Trans. of JSIDRE, 200, 85-92.

Nagasawa, T., Inoue, T., Umeda, Y. and Muneoka, T. 1995. River water quality of daily farming area in eastern Hokkaido, Japan. J. Japan Soc. Hydrol. & Water Resour., 8(3), 267-274.

Okazawa, H., Takeuchi, Y. and Samura, I. 2009. Relationship between land-use agglomeration and nitrate nitrogen concentration of river water in the Shari and Abashiri region of Hokkaido, Japan. Trans. of JSIDRE, 259, 53-59.

Okazawa, H., Yamamoto, D. and Takeuchi, Y. 2010. Influences of riparian land use on nitrogen concentration of river water in agricultural and forest watersheds of northeastern Hokkaido, Japan. International Journal of Environmental and Rural Development, 1(2), 1-6.

Okazawa, H., Muneoka, T., Kudo, Y. and Takeuchi, Y. 2011. Effect of land use agglomeration on nitrogen concentrations in river water in the Tokachi River. International Journal of Environmental and Rural Development, 2(1), 37-42.

Shimura, M. and Tabuchi, T. 2000. Characteristics of nitrogen outflow from a high stocking density area. Rural and Environmental Engineering, 39, 94-103.

Tabuchi, T., Yoshino, K., Shimura, M., Kuroda, S., Ishikawa, M. and Yamaji, E. 1995. Relation between land use and nitrate concentration of outflow water from watersheds of agricultural and forest area, Japan. Trans. of JSIDRE, 178, 129-135.

Woli, K. P., Nagumo, T. and Hatano, R. 2002. Evaluating impact of land use and N budgets on stream water quality in Hokkaido, Japan. Nutr. Cycle. Agroecosyst, 63, 175-184.

Woli, K. P., Nagumo, T., Kuramochi, K. and Hatano, R. 2004. Evaluating river water quality through land use analysis and N budgets approaches in livestock farming areas. Sci. Total. Environ, 329, 61-74.

Research article

Use of BioClean and Liquid Biofertilizers in the Temples for Enhancing a Natural Environment

SITTISAK UPARIVONG*
Faculty of Technology, Khon Kaen University, Khon Kaen, Thailand
Email: sittisak@kku.ac.th

Received 14 December 2011 Accepted 18 April 2012 (*: Corresponding Author)

Abstract BioClean is the brand name of a liquid bioproduct, which had been produced by using various types of flowers. Liquid biofertilizers had been produced by using local available materials such as vegetables, fruits, herbaceous crops, etc. and molasses as substrate, especially added with 18 species of zymogenic synthetic microorganisms. This generation of bioclean products and liquid biofertilizers are aimed to serve to the environmental cleaning sector and the liquid biofertilizers sector for planting trees in the temples and green areas near the region of Khon Kaen University. The board of 18 zymogenic synthetic microorganisms was transferred from the original microorganisms seeding of previous research products of liquid biofertilizer, such as kku-1 and/or liquid biofertilizer biotech-1. The product composition of bioclean and liquid biofertilizers were investigated by standard methods for standard products, and the quality of products was determined by field testing with crops such as water convolvulus; flowers, and water quality treatment for fish living before servicing products to the temples for natural environment. The services project of both products were designed to treat the two temples of Wat Adulkaewmordee and Wat Nonmuang near the region of Khon Kaen University on the event of "Temples big cleaning day 2011" for natural environment treatments by utilizing bioclean products at 1:2000 (0.05%) for cleaning and wastewater treatment, and utilizing liquid biofertilizer products at 1:500 for planted trees and green areas. Furthermore, liquid biofertilizer products had been utilized to plant trees along the main road at Khon Kaen University. The evaluation results of satisfactory services rating of projects of bioclean and liquid biofertilizers to the both temples and green areas had satisfactory results as 4.26 average score value or 85.3%, evaluated by the expert board of ten committees's considerations.

Keywords BioClean, liquid biofertilizers, 18 zymogenic synthetic microorganisms (18 ZSMs), temples, environment

INTRODUCTION

BioClean is an original brand product that plays an important role as a liquid bioproduct of various flowers. Liquid biofertilizers are liquid bioproducts of various local available materials such as vegetables; fruits; some herbaceous crops; etc. Bioclean and liquid biofertilizers are produced under a similar process but only from different raw materials. The name of bioclean was used in order to solve an odour problem of liquid biofertilizers that responded the interested users. The original bioclean had been produced by using 14 diversities of odoriferous flowers since 2003 (Uparivong, 2009). The original liquid biofertilizer kku-1 had been produced since 2002 (Uparivong, 2002). For this generation products, bioclean was produced by using various flowers donated during the graduated ceremony of Khon Kaen university in 2010, meanwhile liquid biofertilizers biotech-1 and liquid biofertilizer biotech-2 were produced by using the previous research stocks of the original liquid biofertilizer biotech-1 and biotech-2 since 2003-2004 (Uparivong, 2004). The targets of this project were aimed to serve for environmental and healthy living places to the two temples of "Wat Adulkaewmordee" and "Wat Nonmuang" near the region of Khon Kaen university, in order to utilize bioclean services for reducing odours such as floor;

sewerage; bathroom/lavatory; wastewater treatment; water quality treatment; etc., and utilizing liquid biofertilizers services for encouraging the plantation of trees and creation of green areas. Moreover, project services had supported the promotion of green areas and plant trees along the main road at Khon Kaen University. Furthermore, bioclean could be applied for agricultural sectors as liquid biofertilizers. Thus, the utilization of liquid biofertilizers may solve the problem of degradated soil by increasing organic biofertilizers applied into soil land, and to increase the quality of organic agriculture products (Pairintra, 1991), and to improve the quality of life and health safety, and to respond the policy for agricultural products safety to kitchen of the world (Uparivong, 2004). The board of 18 zymogenic synthetic microorganisms (18 ZSMs) was selected and invented by Prof. Dr. Chaitat Pairintra, former professor at Khon Kaen University to our research project of "Improvement of the theparuge's liquid biofertilizer product" since 2002. The 18 ZSMs consisted of 9 bacteria, 6 fungi and 3 yeast species (Uparivong, 2002).

METHODOLOGY

Materials

The originality of raw materials to produce "BioClean" was obtained by selecting 14 types of odoriferous flowers such as rose; marigold ; orchid; lotus; etc. since 2003 (Uparivong, 2009), and using organic biomaterials such as vegetables; fruits; herbaceous crops; etc. to produce "liquid biofertilizers biotech-1" and "liquid biofertilizer biotech-2" since 2003-2004 (Uparivong, 2004). For this study, raw materials to produce this generation of "BioClean (v.2010)" were various flowers donated during the graduated ceremony at Khon Kaen University in 2010, and by using the previous research stocks of original microorganism seeding of liquid biofertilizer biotech-1 and liquid biofertilizer biotech-2 to produce "liquid biofertilizers biotech-1 (v.2010)" and "liquid biofertilizer biotech-2 (v.2010)". Thus, the original microorganism seeding of liquid biofertilizer biotech-1 and liquid biofertilizer biotech-2 were produced by utilizing the group of 18 zymogenic synthetic microorganisms (18 ZSMs) which consisted of 9 bacteria, 6 fungi and 3 yeast species, and transferred from the original microorganism seeding of liquid biofertilizer kku-1 (Uparivong, 2002). Molasses were supplied from sugar cane factories at the local areas of Udon Thani and Khon Kaen provinces.

Biofermentors and liquid biofermentors

Biofermentors and liquid biofermentors to produced this generation products of bioclean and liquid biofertilizers had been supplied by using the previous research equipments of biofermentors and liquid biofermentors such as a 500-L liquid biofermentor model BT-1 equipped with a motor 1 hp and with/or without a compressor air supply (Uparivong, 2004); a 500-L liquid biofermentor model BT-2 equipped with a stirrer motor 1 hp and with/or without an air pump supply (Uparivong, 2006) and a 500-L biofermentor or liquid biofermentor model BT-3 equipped with a stirrer motor 1 hp and with/or without an air pump supply (Uparivong, 2007), as shown in Fig. 1.

Fig. 1 Liquid biofermentors BT-1, 2, 3

Process methods

Methods to produce bioclean and liquid biofertilizers were the same excepting only for the different raw materials (Uparivong, 2009; 2010). For these generation productions, bioclean (2011) used the diversities of donated odoriferous flowers as mention above, meanwhile liquid biofertilizer biotech-1 (2011) and liquid biofertilizer biotech-2 (2011) utilized the previous research stocks of original fermented liquid bioproducts of liquid biofertilizers biotech-1 and biotech-2 that had been produced by using vegetables; fruits; some herbaceous crops; etc. (Uparivong, 2004; 2005; 2006; 2007). The 3 steps of this processing method are explained below.

First step, preparation: All available materials were cleaned and cut into small pieces for fermenting as the ratio as "Materials : Molasses : Microorganism seeding of liquid biofertilizer kku-1 or liquid biofertilizer biotech-1 or liquid biofertilizer biotech-2" = 3 : 1 : 1 or 3 : 1 : 2 (w/w/v), and filling clean water within biofermentors such as 20; 30; 40 gallons (75.7; 113.55; 151.4 liters) or more etc., during the retention time more than 2 weeks.

Second step, fermentation: The original liquid bio-extracted product of the first step process was separated from residues (to become solid biofertilizers), and then fermented with molasses and clean water as the ratio as "Liquid bio-extracted product : Molasses : Clean water" = 1 : 1 : 40 or 2 : 1 : 40 (v/v/v) within liquid biofermentors such as 500; 1000; 1500 liters or more etc., equipped with/or without a stirrer motor to produce the fermented liquid bioproduct during the retention time of 1-2 weeks.

Third step, filtration: the fermented liquid bioproduct of the second step process was filtered to obtain the final products as so called "BioClean" or "Liquid Biofertilizers" depending on the differential types of raw materials.

Methods to utilize bioclean and liquid biofertilizer kku-1 and liquid biofertilizers biotech-1; biotech-2; biotech-3 were utilized for environmental and agricultural sectors as follows.

For agricultural utilization: Using the dilution ratio of liquid biofertilizer products at 1:2000 by spraying or pouring to the growth crops every 5-7 days, and the dilution ratio of 1:500 to the plant trees and green areas for living places.

For environmental utilization: Using the dilution ratio of bioclean product at 0.05% (1:2000) for floor cleaning, the concentration ratio of 70-80% for reducing odour treatment of bathroom/ lavatory/ toilet/ w.c./ sewerage etc., and the concentration ratio of 0.05% for wastewater treatment and water quality treatment or water flood treatment.

Methods to quality test bioclean and liquid biofertilizers were determined before servicing to the temples and the green area at the regions of Khon Kaen University as follows:

For agricultural test: Both products were tested by cultivating for various crops to evaluate the growth rate of crops by pots and/or fields testing such as water convolvulus; flowers, etc.

For environmental and healthy test: Both products were tested by treating for sanitary systems such as reducing odour treatment for bathroom/ lavatory/toilet/wc.; sewerage; wastewater treatment and especially water quality treatment for goldfish and nile tilapiafish living, etc.

Analysis methods to investigate the composition products of bioclean and liquid biofertilizers were investigated as the same analysis methods as previous research (Uparivong, 2002; 2004; 2005; 2006; 2007) as follows:

Investigation of optimized microorganism populations: Both products were investigated by the method of standard plate count (using agar powder, peptone, bacteriological *HIMEDIA RM001*) at a laboratory of the Faculty of Technology, Khon Kaen University.

Investigation of composition of the products: Both products characteristics were analyzed, such as pH; EC (electrical conductivity, ds/m); %OM (organic matter); Total N; P; K; Na; Ca; Mg; etc. by the standard methods at a laboratory of Faculty of Agriculture, Khon Kaen University.

Methods to evaluate the satisfactory services rating of bioclean and liquid biofertilizers on the event of "Temples big cleaning day 2011" at both temples of Wat Adulkaewmordee and Wat Nonmuang, including project services to green areas and along the main road at the region of Khon Kaen University were designed by using the applied forms of the Academic Service Center of Khon Kaen University as follows:

- First, evaluation by temple's persons and monks at both temples

- **Second**, evaluation by general persons/home/shop owner or members/ etc. around the regions of both temples
- **Third,** evaluation by inviting the expert board of ten committees's considerations

RESULTS AND DISCUSSION

Properties of bioclean and liquid biofertilizers

This generation of bioclean (2011), liquid biofertilizers biotech-1 and biotech-2 (2011) were contained into bottom and tank containers such as 1-L; 10-L; 20-L; etc., as examples shown in Fig. 2. The results of effective microorganism populations of bioclean, liquid biofertilizers biotech-1 and biotech-2 obtained 1.0 x 10^8 - 3.4 x 10^{13} cfu/ml, 1.0 x 10^8 - 3.8 x 10^{13} cfu/ml and 1.0 x 10^8 - 4.0 x 10^{12} cfu/ml respectively, after the retention time more than 7-8 day, as in Table 1, which optimized biomass populations were more than the standard products (10^7-10^8 cfu/ml). The composition properties of bioclean products obtained were pH=3.76, EC=4.31 ds/m, N=0.018 ppm, P=25 ppm, K=561 ppm, Na=73 ppm, Ca=254 ppm and Mg=200 ppm, and liquid biofertilizers biotech-1 and biotech-2 obtained were pH=3.45-4.19, EC=3.00-5.43 ds/m, N=0.025-14 ppm, P=28-38 ppm, K=881-1023 ppm, Na=108-225 ppm, Ca=175-271 ppm and Mg=0.50-142 ppm, as in Table 1. These results obtained were similar as the previous research products of bioclean and liquid biofertilizers (Uparivong, 2002; 2004; 2005; 2006; 2007; 2009; 2010).

Fig. 2 BioClean and liquid biofertilizer biotech-2 (2011)

Table 1 Properties of bioclean and liquid biofeftilizers biotech-1, 2

Product Sample (2011)[a]	Optimize cfu/ml	pH_w	EC (ds/m)	OM (%)	N (ppm)	P (ppm)	K (ppm)	Na (ppm)	Ca (ppm)	Mg (ppm)
BioClean (original)	6.0x10^{12}	4.32[b]	2.50	-	10	26	598	82	205	131
BioClean	3.4x10^{13}	3.76	4.31	-	0.018	25	561	73	254	200
Liquid biofertilizer Biotech-1	3.8x10^{13}	4.19[b]	3.00	-	14	28	811	108	271	142
Liquid biofertilizer Biotech-2	4.0x10^{12}	3.45	5.43	1.43	0.025	38	1023	225	175	0.50

[a]The generational products had produced since 2011, [b]The pH_w (1:5)

Quality testing of bioclean and liquid biofertilizers

Quality of bioclean and liquid biofertilizers biotech-1, 2 were tested for quality standard products before distributing to general users by the pots and/or fields testing. For agricultural testing, both products of bioclean and liquid biofertilizers were tested by the growth rate of various crops such as water convolvulus; flowers, etc. during 45 days (data not shown). For environmental and healthy testing, both products were satisfactorily evaluated by testing for sanitary systems such as reducing odour treatment for the bathroom/ lavatory/ toilet/ wc./ sewerage of distributed general households by responding feedback of users. For wastewater treatment, the efficiency of chemical oxygen

demand (COD) of pond treatment was 61.90% and 89.80% by using the dilution ratio of 0.05% bioclean product during the retention time of 7 days and 14 days respectively, at a pond treatment of Wat Nonmuang near Khon Kaen University, including water quality treatment for goldfish and nilefish, as shown in Fig.3.

Fig. 3 BioClean and liquid biofertilizers testing (2011)

Table 2 Properties of original liquid biofertilizers[1]

Compositions	Biotech-1	Biotech-2	Biotech-3
pH	4.28	4.73	4.64
EC (mS)	13.23	8.72	7.30
N (%)	0.24	0.075	0.376
P (%)	0.083	0.070	0.037
K (%)	0.20	0.193	0.135
Ca (% or mg/L)	1629 mg/L	0.023	0.071
Mg (% or mg/L)	570 mg/L	0.042	0.026
Na (% or mg/L)	303 mg/L	0.003	-
SO^{-4} (%)	-	-	0.024
OC (%, g/100mL) C/N	-	1.16	0.97
	5.33	15.47	2.78

[1] *Source reference: the development of biofermentor BT-3 (sittisak, 2007)*

Evaluation rating by temples on the big cleaning day

Project products of bioclean and liquid biofertilizers were supplied to the two temples of "Wat Adul kaew mordee" and "Wat non muang" near the regions of Khon Kaen University on the event of "Temples big cleaning day 2011". The results of evaluation services rating after used for floor cleaning; sewerage; toilet/wc.; wastewater treatment and water quality treatment by using bioclean products, and supplied to plant trees and green areas by using the products of liquid biofertilizers biotech-1, 2 at the both temples were satisfactory, which overview obtained satisfactory results as 4.26 average score value or 85.3%, evaluated by the expert board of ten committees's considerations.

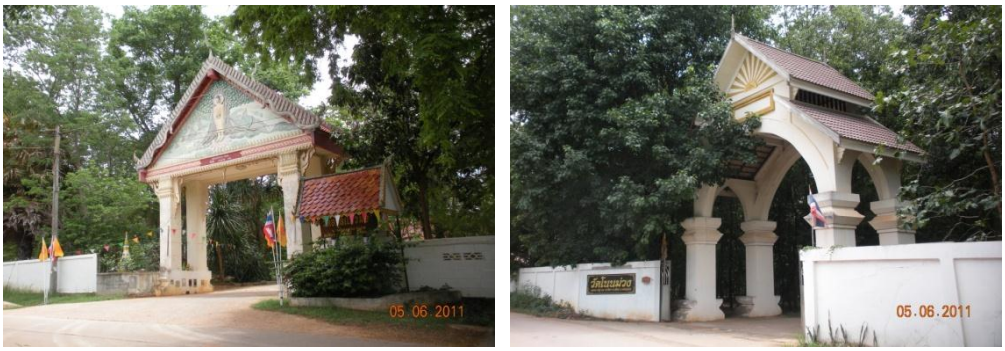


Fig. 4 Big cleaning services to the two temples

Service products applied along the main road and green areas

The serviced products of liquid biofertilizers biotech-1, 2 were satisfactorily appliedas liquid biofertilizers for plant trees along the main road (Kaenkallapaphruek road) and green areas, living places at Khon Kaen University, during proceeding services as shown in Fig. 5.

Fig. 5 Liquid biofertilizers services along the main road and green areas

CONCLUSION

BioClean services to the temples: BioClean services consisting of 18 zymogenic synthetic microorganisms (18 ZSMs) could be used as an odour treatment for sanitary systems and environmental and healthy living places, and for temples.
Liquid biofertilizers services along the main road and green areas: Liquid biofertilizers services, consisting of 18 zymogenic synthetic microorganisms (18 ZSMs) could enrich much more to the plentiful trees along the main road and green areas for natural environment living places and related to climate change.

ACKNOWLEDGEMENTS

This research was financially supported by grants from the Academic Service Center of Khon Kaen University, Thailand. Acknowledgements are extended to the expert board of ten committee's considerations, to Mr. Boonyarit Sombutlai, Mr. Rachaporn Patawanit, Mr. Soontorn Sarapanich, Asst. Prof. Dr. Araya Ahromrit, Asst. Prof. Dr. Somsak Pitaksanurat, Assoc. Prof. Dr. Sirinda Yunchalard, and Assoc. Prof. Dr. Pinit Wangsomnuk, Pol. Sub. Lt. Suwith Nampan, Pra Petcharat Kachapanyo, and Pra Veerasak Jantemduang.

REFERENCES

Pairintra, C. et al. 1991. Zymogenic synthetic soil and crop "Agricultural in the next new century". ISBN 974-55-251-3.
Uparivong, S., Prachankanchana, S. and Pairintra, C. 2002. Product development on liquid biofertilizer of the theparuge's agricultural community. J. of Academic Service Center KKU, 11(3), 37-41.
Uparivong, S. et al. 2004. Production of liquid biofertilizer to kitchen of the world. The 16th Annual Thai Society for Biotechnology. Phitsanulok, Thailand.
Uparivong, S. 2005. The production of liquid biofertilizer. Asian Wetland Symposium 2005. Innovative Approaches to Sustainable Livelihood. Bhubaneswar, India.
Uparivong, S. et al. 2006. Liquid biofertilizer fermentor and microorganism biofermentor of model BT-2. Int. Conf. on TISD. 2006. Technology and Innovation for Sustainable Development Conference, Khon Kaen, Thailand.
Uparivong, S. 2006. 18 Zymogenic synthetic microorganism of liquid biofertilizer Biotech-3 for agricultural and environmental. The 18th Annual Thai Society for Biotechnology, Bangkok, Thailand.
Uparivong, S. 2007. The development of biofermentor BT-3. Int. Conf. on IAEC2007 International Agricultural Engineering Conference. Asian Institute of Technology (AIT), Bangkok, Thailand.

Uparivong, S. 2009. BioClean. Int. Conf. on Innovations in Agricultural, Food and Renewable Energy Productions for Mankind. The 10th Annual Conference of Thai Society of Agricultural Engineering, Surasammanakhan, Suranaree University of Technology, Nakhon Ratchasima, Thailand, 173-175.

Uparivong, S. 2009. Utilization of liquid bioferilizer for mankinds. Int. Conf. on XXXIII CIOSTA CIGRV Conference 2009. Technology and Management to Ensure Sustainable Agriculture, Agro Systems, Forestry and Safety. Reggio Calabria, Italy, 1391-1395.

Uparivong, S. 2010. BioClean a new friendly environmental cleaning product. Int. Conf. on Workshop on "Livelihood and Health Impacts of the Climate Change: Community Adaptation Strategies", Pullman Raja Orchid Hotel, Khon Kaen, Thailand, 122-128.

Uparivong, S. 2010. BioClean for environmental biotechnology of canteens and green area. Int. Conf. on Biotechnology for Healthy Living. The 22nd Annual Meeting of the Thai Society for Biotechnology. Prince of Songkla University, Trang Campus, Trang Province, Thailand, 849-857.

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, Institute of Environment Rehabilitation and Conservation (Japan) or 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.

President

Prof. Dr. Mario T. Tabucanon, United Nations University, Institute of Advanced Studies, Japan

Deputy President

Prof. Dr. Bunthan Ngo, Royal University of Agriculture, Cambodia

ISERD Secretariats:

Institute of Environment Rehabilitation and Conservation (ERECON)
2987-1 Onoji Machida-Shi, Tokyo 195-0064, Japan
Tel/Fax: +81-42736-8972
E-mail: iserd.secretariat@gmail.com, iserd@int-erd.org
Webpage: www.int-erd.org

Association of Environmental and Rural Development (AERD)
93/64 Moo.3, Sinsab village 2, Bungyeetho sub-district, Thanyaburi district,
Pathum Thani 12130, Thailand
Tel/Fax: +66-2957-8064
E-mail: iserd.secretariat@gmail.com, iserd@int-erd.org
Webpage: www.int-erd.org

UNITED NATIONS
UNIVERSITY

UNU-IAS

Institute of Advanced Studies

All articles and reports published in this journal were accepted through a peer-review process. However, most articles and reports published in this journal were presented at the 3rd International Conference on Environmental and Rural Development that was co-organized by United Nations University-IAS.