Relationships of pesticides, agri-aquatic systems and livelihoods; insights from Asia

By

Garry Kenneth Milwain

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Aquaculture Systems Group
Institute of Aquaculture
Stirling University
Stirling
FK9 4LA

Only after the last tree has been cut down,
Only after the last river has been poisoned,
Only after the last fish has been caught,
Only then will you find that money cannot be eaten.

Cree Indian Proverb

Wealth without work
Pleasure without conscience
Knowledge without character
Commerce without morality
Science without humanity
Religion without sacrifice
Politics without principles

The Seven Social Sins

Mahatma Gandhi (1925)

To My Parents

Declaration

This thesis has been composed in its entirety by the candidate and no part of this work has been submitted for any other degree.

Candidate:

Garry Kenneth Milwain

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Abstract

In Asia, the recent rapid growth in production of higher value, more pesticide intensive, horticultural crops and inland aquatic foods in linked agri-aquatic systems poses numerous environmental, health and wider livelihood threats in these often multi-use aquatic systems. ‘Green Revolution’ technologies have enhanced food security and pesticides have been promoted, however, the sustainability of prolonged pesticide use from a functional, environmental and socio-economic perspective is increasingly questionable. Further, despite international pesticide trade agreements and country-specific legislation, illegal practices still prevail. In Thailand and Sri Lanka the influence of pesticide marketing and regulation on pesticide use and hazards was investigated. Community livelihood relationships with three very different agri-aquatic systems (in Central and Northeast Thailand and Northwest Sri Lanka), pesticide use and associated aquatic and health hazards were explored with respect to surface water use and well-being status. Quantitative and qualitative data collection methods utilised participatory community appraisals, household surveys, pesticide fate in surface waters and dietary risk assessment and modelling, key informant semi-structured interviews and stakeholder workshops, to assess these relationships. Enhanced environmental and human pesticide hazards were contributed by pesticide sales incentives and weak regulation allowing illegal practices to prevail. Preliminary risk assessments found greater aquatic and human dietary pesticide hazards within communities, with the poorest at greatest vulnerability from applying pesticide and higher dependency on threatened natural aquatic food resources. The poorest in communities were most likely to overuse pesticide in Sri Lanka and were most vulnerable to illegal practices in the pesticide industry that are often linked with unauthorised traders and credit arrangements. Most horticultural production is for fresh wholesale markets with no food safety controls, and despite growing demand for safer horticultural produce, most farmers perceive pesticides as necessary, the associated hazards low and have little knowledge of safe food production and markets. These circumstances help sustain pesticide use. Some unofficial certification and misleading labelling in the 'safe' fruit and vegetable sector in Thailand potentially misinforms consumers and undermines trust that may threaten pesticide reduction efforts. Good Agricultural Practice (GAP) and vegetable Integrated Pest Management (IPM) are evolving practices and techniques of producing horticultural crops with less or no pesticide, the latter sometimes through Farmer Field Schools (FFS), however, evidence of success varies. Teaching through lectures and more lengthy and costly participatory methods is evident, with the former more successful on GAP and higher educated farmers and the latter with IPM and worse-off farmers, particularly when addressed within livelihood issues as a whole. However, production scale, farmer enthusiasm, produce marketing and facilitator expertise all influence outcomes, particularly with IPM, whilst proper evaluation could improve progress. Growing rural consumer interest in organic produce offers further incentives for small to medium scale farmers to implement IPM and reduce pesticide use and hazards. As value of aquatic resources was an incentive to reducing pesticide use, particularly the most dangerous products, exploration of this component of agri-aquatic systems is another exciting prospect for empowering farming community livelihoods over established and failing fear based chemical practices. Such new practices may lead the way towards affordable and trustworthy agri-aquatic systems produce with ethical certification. Greater pesticide use savings on a wider scale come from use of efficient flat fan spray nozzles compared with conventional pesticide spray nozzles. Complementary policies and stakeholder co-operation could aid pesticide use and hazard reduction efforts. A number of recommendations arose from the research.

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Glossary of terms and abbreviations

ADI	Acceptable daily intake
ARfD	Acute Reference Dose
Baht (Bt)	Thai monetary currency
Bethma	Flexible freehold of paddy lands during drought years
Bt	*Bacillus thuringiensis* (Bacterium, IPM component)
DANIDA	DANish International Development Agency
DFID	Department for International Development
DOA	Department of Agriculture
DOAE	Department of Agriculture Extension
EM	Effective Micro-organism (used in home bio-pesticide production)
EU	European Union
EUREPGAP	International GAP standard
FFS	Farmer Field School
GAP	Good Agricultural Practice
IPM	Integrated Pest Management
JMPR	Joint FAO/WHO Meetings on Pesticide Residues
Maha	Rainy season, Sri Lanka
MAMAS	Managing Agrochemicals in Multi-use Aquatic Systems
MAPET	MAnaging Pesticides in Vegetable Systems in South-east Asia: combining Environment and Trade
NEC	No Effect Concentration
NEDI	National Estimated Daily Intakes
NOEC	No Observed Effect Concentration
PCA	Participatory Community Appraisal
PEC	Predicted Environmental Concentration
PONDLIVE	Improved resource use efficiency in Asian integrated pond-dike systems
PRA	Preliminary Risk Assessment
SCDF	Sustainable Community Development Foundation
TOXSWA	TOXic Substances in Surface WAters model
WHO	World Health Organisation
Yala	Dry season, Sri Lanka

Chapter 1 Introduction

1.1 Introduction

The chapter introduces the background issues pertinent to the study, explains the reasoning behind study site selection, reviews literature on the subjects, presents the theoretical framework, identifies project links and addresses the study objectives.

1.1.1 Background

1.1.1.1 Food resources and population

The research questions posed at the end of this chapter address the increasing global challenges of greater food security and safety demands of a growing population, from an increasingly depleted and damaged environment, hostile climate and scarce and expensive energy resources. As a result, Beddington, Chief Scientific Advisor to HM Government, predicts a future ‘perfect storm’ from an increased demand by 2030 for 50% more food and energy and 30% more fresh water, for an additional six million people per month from present, whilst mitigating and adapting to climate change (Godfray *et al.*, 2010). Furthermore, by 2050 the bulk of the nine billion global population are expected in developing countries, including Asia, where the vast majority of undernourished reside and most people live on less than $2 per day (Chen & Ravallion, 2007; UN, 2013; FAO, 2013). Further, such regions with insufficient natural food and water resources to sustain local populations are at higher risk of experiencing conflict over food resources and populous migrations towards resource richer areas (Warziniack, 2013).

To ensure a future sustainable supply of land and aquatic based food resources, a continual balance has to be achieved between planetary capacity to provide and the needs of a growing population. Aside from the food production limiting factors mentioned, the increasing use of agricultural land for urban expansion and development and biofuel crops further competes with land food production, resulting in increased commodity prices that are most damaging to the poorest (FAO, 2008). Of the aquatic foods available, fish comprise the majority and is an important component of the human diet, particularly in Asia as the region accounts for two-thirds of total global fish consumption (FAO, 2012). Although global marine capture fishery returns have plateaued at around 80-90 million tonnes per year since the 1990s, inland capture fishery production has continued to increase since the 1950s to around 11 million tonnes per year in 2010. Marine and inland aquaculture production also continues to increase with outputs in 2012 of around 20 million tonnes per year and 35 million tonnes per year respectively. Therefore, the growth and sustainability of aquaculture is becoming increasingly important in meeting global needs for food-fish supplies (FAO, 2012).

The poorest in developing countries often have the greatest need for a local healthy environment with adequate natural resources and are at greatest risk from environmental depletion and competition for food. Therefore, developing countries need strategies for providing enough sustainable, affordable, safe and highly nutritional food from their land and aquatic resources for their populations (FAO, 2013). This relates to two of the UN’s eight Millennium Development Goals of the eradication of extreme poverty and hunger and ensuring environmental sustainability by 2015, both of which are intrinsically linked (UN, 2013). Of relevance to these UN goals lies the future sustainable coexistence of the expanding Asian horticulture and inland fishery and aquaculture industries.

1.1.1.2 Food production developments and problems

At a global scale, since our hunter-gatherer history, human food acquisition has developed from subsistence farming, in many regions, towards more commercial mono-crop style agriculture and aquaculture, that has been facilitated by technological advancements and increasing global food demands (Ballantyne & Marrs, 2004). This has been supported by increased use of machinery in place of labour and the introduction of pesticides for crop protection since the invention of DDT for malaria control before, and research on organochlorines during, WW II (Oudejans, 1999). Later bio-technological advances in plant genetics and breeding in the 1960s improved cereal crop strains and yields, which together with irrigation development, synthetic chemicals for pest and disease control and growth enhancers, made food production more efficient and profitable; these changes enhanced developing countries abilities to feed their people and this phase is commonly referred to as the 'Green Revolution' (Glaeser, 2011).

However, experience has revealed often longer-term wider environmental, social and economic consequences associated with the use of synthetic pesticides, including pest chemical resistance, and resurgence of pest outbreaks from the adverse impacts of pesticides on their natural predators (Maredia *et al*., 2003). Both of these scenarios often only encourage more intensive and diverse pesticide application as a solution, with resulting similar problems; thus this cyclical cause-effect behaviour is now termed '*the pesticide treadmill effect*' (Yang *et al*., 2008).

Such increasingly intensive agricultural pesticide applications are particularly prominent in horticulture of which global production has grown rapidly at 3% per year over the last decade. In 2011 almost 640 million tonnes of fruit and 1 billion tonnes of vegetables were gathered throughout the year (FAO, 2013). This world increase in horticultural production has largely been driven by cropping area expansion in Asia (FAO, 2013) resulting in the industry coming into closer proximity with freshwater fisheries and inland aquaculture, the production of which is also highest in Asia (FAO, 2012). The expansion, and closer proximity, of these inter-twining agri-aquatic systems, therefore potentially places these water bodies, aquatic production and water users at higher risk of pollution from pesticides through the processes of spray drift, run-off, leaching, bio-accumulation and direct application (Bandara, 2007; Merrington *et al*., 2002). As these agri-aquatic systems in Asia often have a multiple use function in community livelihoods other than for just food and income provision (Koppen *et al*., 2006), the potential sources and routes of human exposure to pesticides are wide-ranging.

In recent decades, advancements have been made in the assessment of pesticide fate in aquatic systems and associated hazards, through pesticide fate modelling and risk assessment (Van den Brink *et al*., 2003). In reducing adverse risks from agricultural pesticide use, the production and use of selective pesticides (the use of pesticides that are target-specific as opposed to broad spectrum in impact), has become more prominent (Oudejans, 1999; Peshin *et al*., 2009). Further efforts towards pesticide hazard reduction then arose in the form of 'Integrated Pest Management' (IPM) incorporating the use of multiple non-synthetic and mechanical pest control techniques to manage crop pest populations (Oudejans, 1999; Peshin *et al*., 2009). IPM later incorporated Farmer Field Schools (FFS), which utilises facilitator-farmer participatory learning methods and programmes in actual field group settings, and incudes learning and skills development in field crop ecosystem analysis and the use and evaluation of other appropriate IPM techniques. With options for farmer graduation to FFS trainer-facilitator status, such IPM FFS programmes aim to be cost-effective methods of expanding farmer capacity building for more cost-effective, health and environmentally friendly crop protection (Braun *et al*., 2006; Braun & Duveskog, 2008). FFS have developed global interest and found donors for implementation in rice since the 1960s, with further diversification into other crops as a possibility of meeting growing global food demands with minimal environmental and socio-economic consequences (Oudejans, 1999; Peshin *et al*., 2009). Inter-country and national IPM programmes now operate in 30 countries worldwide and have been on-going in Southeast Asia since the 1960s, however, reports of their long-term success vary (Oudejans, 1999; Peshin *et al*., 2009; Maredia *et al*., 2003).

Therefore, the crux of the research problem is that in Asia inland fish capture and production is increasingly important in supplying food fish, is growing and coming into closer proximity with an expanding pesticide intensive horticulture sector. In Asia, pesticide use remains a key component of horticulture, its use is not declining and it poses an increasing hazard to surrounding groundwater and surface waters. Water bodies in these Asian agri-aquatic systems often have multiple uses in their communities and are increasingly at risk of pollution from pesticides with potential economic and health hazards to aquatic food production and the livelihoods of system users. Efforts are being made to improve the assessment of pesticide hazards to aquatic life and humans. IPM has also become an increasingly common aspect of Asian horticulture, however, reports of its effectiveness vary. Research is required into the factors which exacerbate these pesticide hazards to agri-aquatic systems and their users and constraints to pesticide hazard reduction measures employed.

1.1.2 Study regions

The Southeast Asia region was chosen firstly as it ranks 4th amongst eight regions in severity of extreme poverty and hunger and has issues of land degradation, water shortages and loss of natural habitat and species on which the poorest depend most (UN, 2013; Godfray *et al*., 2010). Secondly, a recent expansion in pesticide intensive horticulture in much of this region is largely due to economic growth and limiting climatic conditions with subsequent marked environmental, social and economic problems (Kunstadter, 2007). Additionally, increasing pressure on inland fisheries of Southeast Asia from numerous factors such as habitat destruction, over-exploitation, agricultural pesticides and other pollutants, has encouraged the expansion of freshwater aquaculture to meet growing demand (Belton & Little, 2008; Belton & Little, 2011; Carpenter *et al*., 2011). As such, freshwater food production and pesticide intensive horticultural systems are coming into closer proximity and more intertwined.

Various types of agri-aquatic (horticulture – ‘fish’ production) systems are also evident in Southeast Asia, which have multiple uses and bring benefits to community livelihoods. These uses include food and income provision, but additionally through water provision for animals, bathing and laundry (Koppen *et al*., 2006). Close proximity of these water bodies to pesticide intensive horticulture, however, brings increasing potential environmental and health hazards to aquatic products and aquatic system users. Lastly, inter-country and national IPM programmes have been on-going in Southeast Asia with variable success (Gallagher *et al*., 2009; Ketelaar & Kumar, 2012).

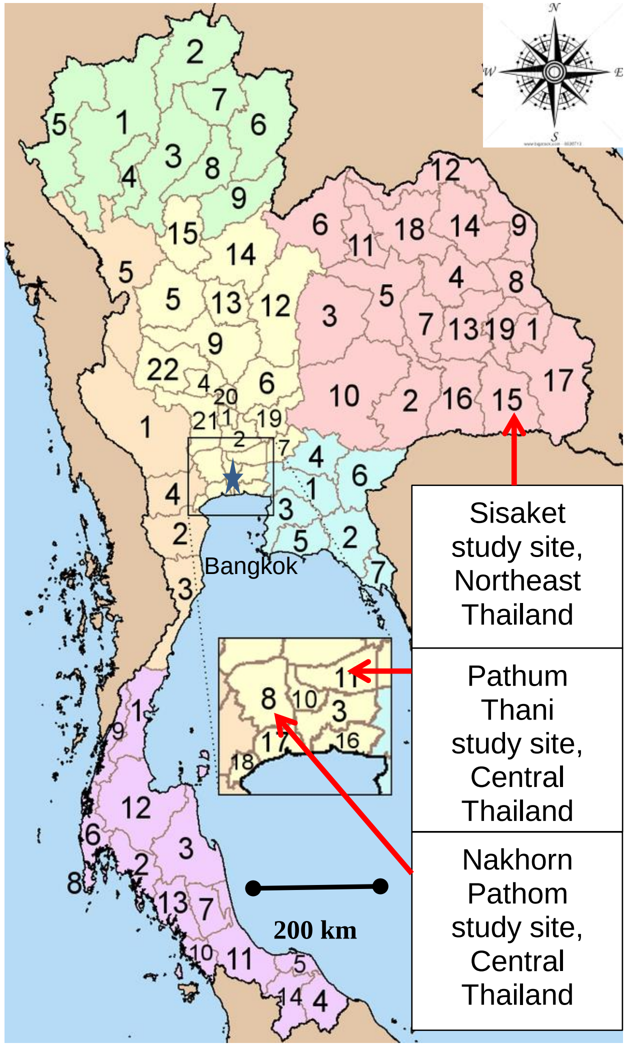
Three study areas were chosen based on their varied agri-aquatic systems and their multiple agricultural, fish production and livelihood uses (Figure 1 and Figure 2). The Central Thailand study region (Figure 1) has raised fruit and vegetable growing beds within a floodplain river-fed canal network with extensive to intensive pond, canal and cage fish culture (Cheyroux, 2003; Jungbluth, 2000). The Northeast Thailand study region has integrated pond-dike farm systems utilised for fish trapping, fish culture, fruit and vegetable growing and rice fields in a largely rain-fed area (Pant *et al*., 2004; Prein, 2002; Tipraqsa *et al*., 2007). Finally, the Northwestern region of Sri Lanka (Figure 2) has upland vegetable plots and lowland rice fields within a rain-fed cascade 'tank' (reservoir) system housing fisheries utilised by local communities (Marambe *et al*., 2012; Renwick, 2001). Study site characteristics are discussed later in this chapter.

1.2 Natural Resources, Food Production and Livelihoods

This section reviews the significance of water resources and horticulture in agri-aquatic systems to rural livelihoods in developing countries, with particular reference to the study sites, including food, income and wider livelihood benefits. The section begins with the definition and components of livelihoods.

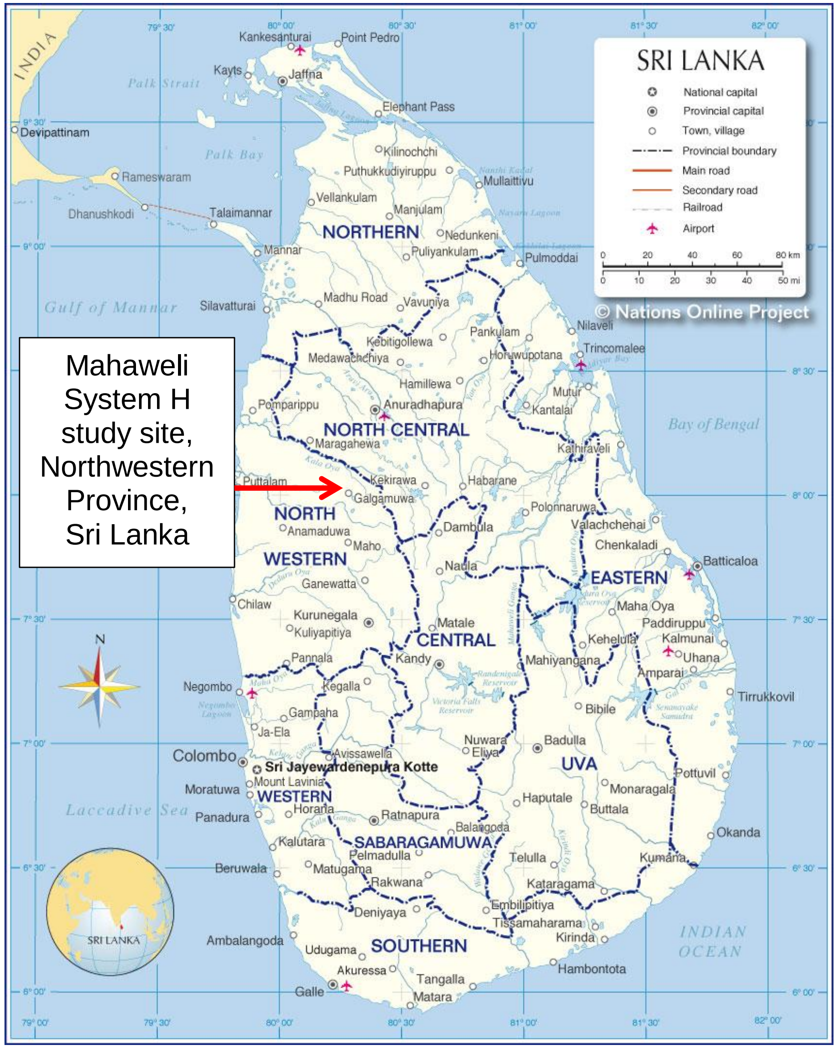
1.2.1 Livelihoods

A livelihood in its simplest sense is a means of gaining a living; adequate stocks and flows of food and cash to meet basic needs (Chambers & Conway, 1992). In this instance, the livelihoods of interest are those of people in communities that are directly linked with and influenced by either, or a combination of, horticulture, aquatic food production and water use in these agri-aquatic systems. Examples of ways in which community livelihoods may depend on, or be linked with, these systems may include farm work, aquatic food production, catching or collection, trade associated with horticulture or aquaculture, consumption or sale of land crops and aquatic crops and use of water bodies for domestic purposes such as bathing and washing clothes.



(Source: Wikipedia, 2014)

Figure 1: Map of Thailand showing regional and provincial borders and study sites



(Source: Wikipedia, 2013)

Figure 2: Map of Sri Lanka showing provinces and study site

The component of interest is horticultural pesticide use, its potential channels and impacts on these livelihoods, identification of hazard enhancing factors and effectiveness of risk reduction mechanisms and programs. Further information on frameworks for understanding and analysing community livelihoods and environmental interactions are described later in the chapter.

1.2.2 Freshwater resources and rural poor livelihoods

Conventionally, water services in developing countries are planned with single objectives in mind: water for crop irrigation, water for livestock, water for domestic use and so on. However, the reality is that in poor communities individual water sources are truly multipurpose and used for a range of activities, often by many people. Wells, ponds, canals and reservoirs may serve for laundry, personal hygiene, drinking water, livestock, crop irrigation, fisheries, sanitation and household occupations such as craftwork and more (Koppen *et al*., 2006 & 2009). Therefore abundant resources of water, and in many cases clean water, are often required to perform multiple roles in communities in provision of nutritious food, domestic needs and additional income that is imperative to sustaining rural livelihoods, in particular the poorest. The specific ways in which water resources benefit rural livelihoods largely vary with region, the type of water resource, needs and skills of the people and stakeholder developmental input and are more significant in water scarce areas (Koppen *et al*., 2009). Freshwater is therefore a key resource for everyone and in particular for those in poverty from its multiple uses, however, its availability and quality are in decline (Mukherji & Facon, 2009).

1.2.2.1 Central Thailand study sites

Central Thailand is the first of the three study regions, which lies in an alluvial plain of which the Chao Phraya River is the primary irrigation source (Figure 1). A network of primary and secondary canals with sluice gates has been constructed to feed agriculture's irrigation needs for the area. The study site farms here are characterised by raised beds for horticultural production surrounded by farm canals that are irrigated by secondary canals (Cheyroux, 2003; Sinsakul, 2000; Molle & Keawkulaya, 1998). Soil here is fertile with high water retention properties and irrigation water is abundant, servicing an expanse of paddy fields and increasingly raised beds of fruit and vegetables, following a national plan for crop diversification (Kasem & Thapa, 2011). Fish nursery and on-growing ponds around farms, shrimp ponds and fish cage culture in larger canals and rivers have also expanded and depend on adequate clean water, however, urban expansion and increased industrial and domestic activity and associated wastewater discharge affect this with various heavy metal, organic and inorganic pollutants (Sajor & Ongsakul, 2007; Belton & Little, 2008). Domestically, canal water is used for aquatic plant production for household consumption, sanitation, washing vehicles and sometimes cooking utensils and watering crops and livestock (Sajor & Ongsakul, 2007; Meinzen-Dick & Van Der Hoek, 2001).

1.2.2.2 Northeast Thailand study site

Northeast Thailand's upland plateau (Figure 1) is drained northeast by the River Mun and east by smaller rivers that flow into the Mekong River. It has the highest population and greatest poverty of the country's regions. The Northeast region is also slightly drier and cooler than other parts of the country and this climate leads to a relatively high level of water use when compared with other regions (Koppen *et al.*, 2009). Characteristically, the region has a high level of outward migration for work and household dependency on remittance income from some family members' urban-based employment (Rigg *et al.*, 2012). The southwest monsoon exerts much influence on the climate over a four - five month period (June / July – October) with corresponding flooding and drought, whilst severe deforestation has also caused soil erosion and irrigation mismanagement has led to saline intrusion of groundwater (Koppen *et al*., 2009). Over the decades various programs have improved agricultural and domestic water availability in the region through construction of wells, reservoirs, village tanks, household ponds and roof runoff storage systems, many of which serve multiple functions (Wangkahart *et al*., 2012; Koppen *et al*., 2009; Pant *et al*., 2004). Household pond construction forms an integral part of integrated farming and farming household self-sufficiency that is endorsed by the King and included in the country's National Economic and Social Development Plan (Koppen *et al*., 2009). Since their construction, which has escalated from the year 2000 following Government financial assistance, ponds have been used by farming communities for irrigating fruit and vegetables for home consumption and market, timber trees, watering livestock, to supplement rain-fed rice and for fish capture and culture (Koppen *et al*., 2009).

1.2.2.3 Sri Lanka study site

The Northwestern Province of Sri Lanka (Figure 2) lies in the Dry Zone that covers two-thirds of the country (Thiruchelvam & Pathmarajah, 1999). This area has ancient and rehabilitated irrigation systems comprising a network of small to large seasonal and perennial reservoirs (*wewa* or tanks) connected through a series of feeder canals. There are about 30,000 tanks covering 40,000 km^2 of the Dry Zone (Marambe *et al*., 2012). Rain-fed water tanks feed lower tanks from which distribution channels feed upland farm vegetable plots and lowland rice fields in cascade style systems (Renwick, 2001). In addition, these tanks are used for bathing, domestic purposes, livestock, fishing and a range of micro-industries and support a diverse ecology and variety of wildlife, some of which are exploited locally for food resources (Murray, 2004). The fisheries sector plays a vital role contributing as much as 65 – 70 % of the animal protein to the Sri

Lankan diet and accounts for up to 81% of animal protein in rural areas of the country's Dry Zone (Pollock, 2005). Inland fisheries have existed on an artisanal basis since the 13th Century BC. Inland and capture fisheries have developed since 1970s from hatchery inputs from international donors. However, introductions of *Oreochromis mossambicus* and *O. niloticus* form most of the tank fisheries and with seed production, stocking initiatives and subsidies for additional pond construction and loans for canoes it provides income and food for the poor despite being weakly regulated by Government (Pollock, 2005).

1.2.3 Inland food production and rural livelihoods

In developing countries agriculture still forms the basis of the majority of rural livelihoods (Stabinsky & Ching, 2012), whilst historically, natural inland fisheries and wild aquatic food resources have comprised the majority of aquatic animals consumed in Asia (Morales, 2007). Both activities have largely been the foundation for, and have defined, rural society (Morales, 2007) and are often most valuable to the poorest in society (Belton & Thilsted, 2014). However, in more recent years, Asian freshwater aquaculture has made a far greater contribution to aquatic food production and consumption in the region than Asian marine aquaculture or inland capture fisheries (Belton & Little, 2011).

Food production benefits rural livelihoods through employment, trade in produce and household nutrition. In the Asia - Pacific region agriculture provides rice, and a variety of fruits, vegetables and terrestrial meats in the diet. The region's freshwater produce also provides a low saturated fat and low cholesterol source of high value proteins and essential micro-nutrients, including various vitamins (D, A and B), minerals (including calcium, iodine, zinc, iron and selenium) and polyunsaturated omega-3 fatty acids (docosahexaenoic acid and eicosapentaenoic acid – commonly abbreviated as DHA and EPA respectively), some of which are scarce in vegetable based diets (FAO, 2012; Funge-Smith *et al*., 2012). The consumption of fish also has beneficial effects in relation to coronary heart disease, stroke, age-related macular degeneration and mental health, with further convincing evidence of benefits to growth and development, in particular for children during gestation and infancy for optimal brain development (FAO, 2012). In fact, fish often comprises the most affordable and preferred source of these nutrients over other animal sources as part of local and traditional recipes in developing nations, providing half of these dietary needs for over 400 million of the world's poorest (FAO, 2012; Belton & Thilsted, 2014).

With respect to employment and income, millions of people around the world find a source of income and livelihood in the fisheries sector (FAO, 2012). In 2010, 54.8 million people were engaged in the primary sectors of capture fisheries and aquaculture of which seven million were occasional fishers and fish farmers and more than 87 % employed were in Asia, which also has the second highest annual increase in employment in this sector (4.8%) over the last decade (FAO, 2012). However, at the aggregate global level, capture fisheries output has stagnated since the late 1980s, and 80% of 523 world fish stocks, for which assessment data are available, are reported as fully or over-exploited (Muir, 2013). Therefore future food fish demands will have to be met by aquaculture, the global output of which is rising. Currently some 16.6 million (30 %) of people employed in the fisheries sector globally are engaged in fish farming, which is also most concentrated in Asia (97 %) (FAO, 2012). Inland aquaculture production in particular has tripled from 3.8 million tonnes in 2000 to 11.0 million tonnes in 2010, with 91% coming from developing countries (Funge-Smith *et al*., 2012).

As well as being most reliant on wild food resources from their environment the poorest are also most dependent on small-scale subsistence farming (World Bank, 2011; Palmer & Di Falco, 2012). However, much of the food production trends in many developing countries since the ‘Green Revolution’ have been towards more intensive large scale commercial mono-crop style production, sometimes contract driven, and usually with high synthetic agro-chemical input (Setboonsarng, 2008). Although this type of food production has been more associated with capital investment and the wealthier sector of the farming society, in such instances where labour is still required in the production or processing of food, the employment opportunities may benefit the poorest (Setboonsarng, 2008). However, where this type of production utilises the indiscriminate use of agrochemicals, it has often been responsible for degrading the natural food resource base, including wild fisheries, aquatic plants and animals (on which poorer people often depend most) through habitat destruction, soil erosion and pesticide pollution (World Bank, 2007; Palmer & Di Falco, 2012).

With continued exploitation of limited resources of natural inland fisheries, pesticide intensive agriculture further risks undermining the natural food resource base and livelihoods of the rural poor. This is particularly the case for Sri Lanka, where although inland aquaculture is not well established, freshwater tank fisheries provides vital food fish and employment sustaining thousands of livelihoods of the rural poor. With respect to Thailand, this threat also extends from inland fisheries to freshwater aquaculture production, and linked livelihoods, which is rapidly expanding to supply growing demand; in the Central region through pond and cage culture and in the Northeast from pond culture. Therefore, despite offering potential benefits to poor people’s livelihoods, nutritionally and economically, agriculture also requires to be environmentally ethical to be of lasting value (Funge-Smith *et al.*, 2012).

1.3 Pesticide Use, Control, Aquatic Systems and Livelihoods

This subsection describes the history of pesticide use and related problems that led to development of pesticide regulation and consideration of alternative pest management strategies.

1.3.1 History of pesticide use and hazard concerns

Pesticides are chemicals that kill or inhibit the growth or reproduction of pests, diseases or weeds, are usually divided into classes and their level of use in agriculture usually increases with the value of the crop (Merrington *et al.*, 2002) One pesticide classification is made by the type of organism targeted where the main classes include herbicides (used to control unwanted plants or weeds), insecticides (used to control insect pests) and fungicides (use to control (moulds and fungi), however the complete classification is more diverse (Smith & Kennedy, 2002). A second method of classification is according to their chemical composition of which the primary classes include organophosphates, organochlorines, carbamates and pyrethroids. Another classification can also be made from their mode of action on their target organisms (i.e. growth inhibitors, nerve poisons etc.) (Merrington *et al.*, 2002; Smith & Kennedy, 2002).

The most widespread use of pesticides is in agriculture for control of organisms that reduce crop yields or post-harvest losses (Smith & Kennedy, 2002). The earliest pesticides were discovered or invented because they had toxic effects, usually on large classes of organisms. ‘Paris Green’, an arsenical, discovered to control Potato Beetle (*Leptinotarsa decemlineata*) in 1867, was the earliest widespread pesticide used to control agricultural pests in North America. Later, WWI stimulated pesticide use for food production and the use of dinitrophenols (Dinitro-ortho-cresols - DNOC) and paradichlorobenzenes (PDB) by-products from explosive and coal tar production (Ballantyne & Marrs, 2004; Smith & Kennedy, 2002). Sulphurous compounds were then used to treat fungus, and herbicides followed the discovery of plant growth hormones in the 1940s. Insecticides were the backbone of pest control despite increasing pest resistance, and then DDT proved effective against a wide spectrum of insect pests of agricultural and public health importance (Ballantyne & Marrs, 2004; Smith & Kennedy, 2002). Chlorinated hydrocarbons followed and insecticide use significantly increased as new classes of insecticides emerged - organophosphates and methylcarbamates. Then the use of 2,4-Dichlorophenoxyacetic acid's ('2,4-D', an ingredient of the herbicide 'Agent Orange' which was used to defoliate crops in the Vietnam War) effectiveness against broadleaf weeds then established chemical weed control as dithiocarbamates did with fungus in the 1930s (Ballantyne & Marrs, 2004; Smith & Kennedy, 2002). Therefore, early pesticide production and use very much evolved as a result of other inventions and findings of the times.

Pesticides were a means of protecting crops, improving yields and increasing profit and GDP and the pesticide production and market grew steadily. However, increasing occurrences of target insect pests' resistance to chemicals, side-effects of pesticide impacts on natural predators of pests and subsequent resurgence of pest outbreaks, became more common. By the end of the 1950s, scholars had voiced their concerns of agriculture's pesticide dependency and adverse environmental effects that were largely ignored. However, in 1962 scientific debate became public and galvanised opinion on pesticides' consequences through Rachel Carson's book '*Silent Spring*' (Carson, 1962) which emphasised "we have put poisonous and biologically potent chemicals indiscriminately in the hands of persons largely or wholly ignorant of their potentials for harm". Citizens' rights for a clean environment led to DDT being banned by the US

Environmental Protection Agency in 1972 and increased public activism since the 1960s led to dramatic changes in pesticide regulations and use restrictions in the USA and Europe (Smith & Kennedy, 2002; Tripp, 2006). These controls strengthened the environmental toxicological standards that pesticides must meet before approval of use, giving strong impetus for the development of safer and environmentally friendly pesticides.

Since the 1960s, USA and European regulations on pesticide production and use that take into account food pesticide residue hazards posed to infants, children and other sensitive sub-populations, have been implemented, and are discussed in more detail in the following subsection (Hussey & Bell, 2004). In addition some major food processors enforced their own pesticide residue standards on the food they purchased (Hussey & Bell, 2004). Reducing effectiveness of pesticides and growing environmental and health problems increased attention towards the development of pesticides that required less active ingredient than earlier forms to achieve their objective (Smith & Kennedy, 2002; Hussey & Bell, 2004). Now biochemists and molecular biologists develop products that target specific physiological and biochemical processes characteristic of a narrow range of pest organisms, whilst causing no apparent harm to other organisms. At the same time interest grew in alternative biological pest control measures that was taken forward by US entomologists and spread globally, eventually establishing the name and concept of 'Integrated Pest Management', discussed in more detail later (Smith & Kennedy, 2002).

1.3.2 Pesticide risks, assessment and regulation

This subsection describes i) the international regulations aimed at controlling the production and trade of pesticides, and ii) the pesticide classification, risk assessment and regulations relating to human and surface waters.

1.3.2.1 Regulating production and trade

The International Code of Conduct on the Distribution and Use of Pesticides was one of the first voluntary Codes of Conduct in support of increased food security, while at the same time protecting human health and the environment (FAO, 2003). Adopted in 1985 by the FAO Conference at its Twenty-third Session, it has been revised since 1999 and it is still the globally accepted standard for pesticide management catering for registration, distribution, application and prior informed consent (PIC) (FAO, 2003). The Code, in conjunction with its supplementary technical guidelines, has been instrumental in assisting countries to establish and strengthen pesticide management systems including pesticide registration and legislation and has increased awareness of pesticide problem issues. It includes the life-cycle concept in pesticide management and also integrates with integrated pest management (IPM) for sustainable agriculture and encourages inter-stakeholder co-operation recently including the application equipment and food industries. However, major weaknesses still exist, predominantly in developing countries, in lack of technical expertise and resources to enforce national legislation, highly hazardous and substandard pesticides still widely sold and end-users insufficiently trained and protected in pesticide use (FAO, 2003).

The Basel, Rotterdam and Stockholm Conventions were also important milestones in the regulation of international trade in hazardous chemicals and waste disposal that includes pesticides and have added to the International Code of Conduct on the Distribution and Use of Pesticides (FAO, 2003; UNEP, 2014).

The Basel Convention in March 1989 set criteria for the control of trans-boundary movements of hazardous wastes and their disposal and entered into force in 1992 (FAO, 2003; UNEP, 2014).

The Rotterdam Convention, entered into force in February 2004, was built on the voluntary prior informed consent (PIC) procedure initiated by UNEP and FAO in 1989 (FAO, 2003; UNEP, 2014). It stipulates that export of a chemical can only take place with the PIC of the importing Party. The Prior Informed Consent (PIC) procedure is a means for formally obtaining and disseminating the decisions of importing countries as to whether they wish to receive future shipments of a certain chemical and for ensuring compliance to these decisions by exporting countries, thus aiming to promote shared responsibility between exporters and importers on protecting human health and the environment from the harmful effects of such chemicals. Participating countries and a current list of pesticides included in the PIC are available from http://www.pic.int. (FAO, 2003; UNEP, 2014).

The Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty, adopted in 2001 and enforced since 2004, to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment. Each party member is required to prohibit or eliminate production of POPs, their import and export and disposal in an environmentally sound manner (FAO, 2003; UNEP, 2014).

Specific details on these instruments in controlling pesticide production, trade and disposal are available at http://www.pic.int. (UNEP, 2014).

However, despite these international agreements, human health and environmental hazards are still increasing from unsustainable chemical management worldwide (UNEP, 2012). This trend reflects the shifts in the production, use and disposal of chemical products from developed countries to emerging and developing economies, where safeguards and regulations are often weaker. As a result international action on chemical management has been slow with insufficient results (UNEP, 2012).

1.3.2.2 Assessing aquatic and human health hazards

The World Health Organisation (WHO) Recommended Classification of Pesticides by Hazard was approved by the 28th World Health Assembly in 1975 and has since gained wide acceptance (WHO, 2010). This publication lists examples of some pesticide active ingredients and their formulations. Member States and pesticide registration authorities suggested further guidance on the classification of individual pesticides. Guidelines were first issued in 1978 and have since been revised and reissued every few years. In 2002 the United Nations Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonised System of Classification and Labelling of Chemicals (UNCETDG/GHS) approved a document called "*The Globally Harmonised System of Classification and Labelling of Chemicals*" with the intent of providing a globally-harmonised system (GHS) to address the classification of chemicals, labels and safety data sheets (UNEP, 2012). The GHS is now widely used for the classification and labelling of chemicals worldwide. The classification system caters for acute oral and dermal toxicity and severe health hazards other than acute toxicity. As of 2009 the WHO pesticide hazard level to human health ranges from "Ia Extremely hazardous" to

"U unlikely to present acute hazard" and GHS classification ranges from Category 1 (most hazardous) to 5 (least hazardous) (WHO, 2010; UNEP, 2012). This classification is useful in establishing the potential health hazard level to those who handle and spray pesticides and in selecting pesticides that require closer monitoring or banning.

With regards to human health protection through the consumption of foods containing pesticides, maximum residue levels (MRLs) for pesticide residues and residues of veterinary drugs are the maximum concentrations of residues legally permitted in or on human foods and animal feeds to protect consumers and ensure fair food trade (WHO, 2014). Through sound science and risk analysis, MRLs are set by the international body of experts, Codex Alimentarius Commission (CAC) implementing the Joint FAO/WHO Food Standards Programme established 1961-1963, amongst its 185 member countries of which Thailand and Sri Lanka are members (FAO, 2003; WHO, 2014).

As for the level of use, fate and impacts of pesticides on the freshwater aquatic environment and its users surrounding horticultural farms and rice fields in Asia, little is known (Van den Brink *et al.,* 2003). Modelling the fate and potential species risks of pesticides in these systems incorporating pesticide, ecological, land use and hydrological characteristics is an interesting prospect for pesticide management. The TOXSWA model used in Europe for surface water pesticide risk assessment is the model used within the project in application to Thailand and Sri Lankan scenarios (Van den Brink *et al*., 2003). Through input of pesticide, physical, hydrological and other environmental parameters the model is able to calculate first tier risk assessments for each pesticide-crop combination for the chosen period of time and chosen surface water body. Where the predicted environmental concentration (PEC) for pesticide-crop combination results exceed the 'no effect concentration' (NEC - the highest pesticide concentration in the water body at which there is no effect on aquatic life), more refined second tier risk assessments are undertaken (Van den Brink *et al*., 2003).

Estimating dietary risks to humans from pesticide residues in food requires comparison of an exposure parameter with an intake amount considered safe. Exposure parameters are defined as IEDI (International Estimated Daily Intakes) and NEDI (National Estimated Daily Intakes). These Estimated Daily Intakes are based upon a defined diet and calculated residue levels in these diets (Van den Brink *et al*., 2003). The WHO defines five regional food diets based upon the FAO food balance sheets (Middle Eastern, Far Eastern, African, Latin American and European diet). Two intake amounts are used to describe the effect side of the equation, the ADI (Acceptable Daily Intake) and the ARfD (Acute Reference Dose). The ADI is defined as: "an estimate of the amount of a substance, expressed on a body weight basis, that can be ingested daily over a lifetime without appreciable health risk" and can be considered as a chronic threshold level. The ARfD is defined as: "an estimate of the amount of a substance in food and/or drinking water, normally expressed on a body weight basis that can be ingested in a period of 24h or less, without appreciable health effects" and can be considered as an acute threshold level (Van den Brink *et al*., 2003).

1.3.3 Unsustainable reliance on synthetic pesticides

The argument for the promotion of large scale, synthetic input intensive farming was that it resulted in higher production yields, greater profits and higher contribution to GDP. However, the external costs are often underestimated, difficult to translate into monetary terms and rarely seriously considered in policy-making (Waibel, 2007; Wilson & Tisdell, 2001, Wilson, 2000). Losses to wildlife, contamination of water bodies used for domestic purposes, contamination or loss of natural food resources (land and aquatic) and human health effects from pesticide spraying or residues on foods (land and aquatic) are examples (Wilson & Tisdell, 2001, Wilson, 2000). Most of these adverse impacts often disproportionately affect the poorest in society, compared with the wealthier, from the greater likelihood of the poorest being involved in agricultural labour and pesticide spraying and their greater dependency on 'free' natural food resurces from their local environment (Gupta, 2012). In addition, there are also valid arguments that use of synthetic inputs in crop production creates an ever increasing dependency on them through pest resistance, encouraging further pesticide use, referred to as the "the pesticide treadmill effect", as explained in the previous section (Yang *et al*., 2008). Such prolonged intensive pesticide use often results in ecosystem damage that inhibits healthy crop production and further pesticide use becomes unprofitable (Yang *et al*., 2008; Grzywacz *et al*., 2010 & Kasem & Thapa, 2011). In fact the constant 'juggling' of different chemicals to control insect pests, giving the illusion of progress but failing to address the root cause of the problem, has become so common that it has been termed 'insect resistance management (IRM)' (Ehler, 2006). With increasing scarcity of natural resources and mounting external consequences of pesticide use, agricultural development and environmental protection are becoming more closely intertwined (World Bank, 2007). Therefore, there is a need to establish the long-term and wider cost-benefit of pesticides and alternative crop protection measures on the environment and community livelihoods of the poor.

1.4 Pesticide Hazard Reduction

This subsection describes i) the introduction and development of integrated pest management (IPM) as a means of reducing synthetic pesticide dependency, and ii) the issue of suitability and efficacy of pesticide application equipment. Circumstances surrounding their adoption and effectiveness are discussed.

1.4.1 Integrated Pest Management (IPM)

One problem in interpretation of integrated pest management (IPM) is that there are over 65 definitions in use; therefore almost any party can find a definition that fits what they are already doing. A broader definition was adopted by the FAO Panel of Experts in 1968. IPM has been defined by the Panel of Experts on Integrated Pest Control at Food and Agricultural Organisation (FAO), Rome, as:

"A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury" (FAO, 1968; Peshin *et al*., 2009).

Another popular all-encompassing definition, by the US entomologist R. J. Prokopy, is that 'IPM is a decision-based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, weeds, vertebrates) in an ecologically and economically sound manner (Ehler, 2006).' For the IPM practitioner, this implies the following:

• simultaneous management of multiple pests;

• regular monitoring of pests, and their natural enemies and antagonists as well;

• use of economic or treatment thresholds when applying pesticides;

• integrated use of multiple, suppressive tactics (Ehler, 2006).

Of all the definitions the authors attempted to capture (a) the appropriate selection of pest control methods, used singly or in combination; (b) economic benefits to growers and society; (c) the benefits to the environment; (d) the decision rules that guide the selection of the control action, and (e) the need to consider impact of multiple pests (Kogan, 1998; Peshin *et al*., 2009).

Overall, this holistic approach to dealing with pests should reduce pesticide use, provide economic savings for the farmer and protect the environment and human health. The term ‘integrated’ implies incorporation of natural enemy/antagonist levels into decision-making, and use of compatible, non-disruptive tactics that preserve these agents. Integration can be viewed as either vertical (i.e., within a class of pests; sometimes called first-level) or horizontal (i.e., among all classes of pests; sometimes called second-level). For example, an insecticide applied for control of an insect pest that also kills natural enemies of that and other insect pests represents a lack of vertical integration; similarly, a fungicide applied for plant disease management that also kills natural enemies of insect or mite pests represents a lack of horizontal integration. Historically, the lack of such integration has been one of the major impediments to the implementation of IPM in agriculture (Ehler, 2006).

The seeds of the IPM movement were planted shortly after WWII after a few far sighted scientists recognised that indiscriminate use of the new synthetic pesticides would prove problematic (Ehler, 2006). Peruvian cotton growers were amongst the first to adopt a combination of pest management practices to manage pests that around 16 different insecticides could not control (Peshin *et al*., 2009). Californian entomologists suggested pesticide use by ‘supervised control’ by qualified entomologists, entailing periodic monitoring of pest and natural enemy populations and insecticide applications only when necessary in contrast to calendar-based or insurance treatments (Ehler, 2006). This was first implemented 60 years ago, however, a decade later problems of indiscriminate insecticide use were becoming more evident including pest resistance, target pest resurgence, secondary pest outbreaks and environmental contamination. In this setting four University of California entomologists proposed ‘integrated control’ defined as ‘applied pest control which combines and integrates biological and chemical control’ and introduced concepts of ‘economic threshold’ and ‘economic injury level’ (Ehler, 2006). The competing 1960s concept of ‘pest management’ gained favour being broader and including multiple suppressive tactics, such as host plant resistance, cultural control and semio-chemicals, the latter of which are chemicals that carry a message for purposes of communication (e.g. pheromones that act by attracting or repelling inspect pests to or from an area) (Ehler, 2006). However, ‘integrated control’ and ‘pest management gradually became synonymous although largely insect orientated (Ehler, 2006) and from the 1980s IPM began to shift to non-pesticidal tactics. A panel of experts from the Food and Agriculture Organization (FAO) put the concept of IPM in operation in 1968 (Peshin *et al.,* 2009). From the incorporation of all classes of pests in the early 1970s the modern concept of IPM was born and over the last 30 years it has been a valuable paradigm for organising research and extension efforts worldwide. Although IPM has a successful history of acceptance by scientists it has not been widely adopted in developed country agriculture due to its time consuming and complicated nature and the availability of cheap pesticides. However, in 2005 the World Bank also reported that IPM adoption remained relatively low in most of the developing world with no convincing evidence for changes in pesticide use in many targeted crops (Ehler, 2006).

1.4.1.1 IPM development and diversification

Advancements made in IPM systems for developing sustainable pest management strategies in the USA, Europe, Australia, Asia, Latin America and Africa have not generally resulted in wider adoption of IPM, though there have been some successes

(Ehler, 2006; Peshin *et al*., 2009; Dhawan & Peshin, 2009). Pesticides remain the mainstay of many IPM programs throughout the globe (Peshin *et al*., 2009). In the USA and Europe, there are government legislation and mechanisms for implementation and evaluation of IPM programs, especially in Europe, where IPM innovation systems involving the government, researchers, farmers, advisory agencies and market forces are part of a system to reduce pesticide use (Peshin *et al*., 2009). In 1972, insecticides based on the bacteria, *Bacillus thuringiensis,* were released for control of Lepidopteran pests (Peshin *et al*., 2009). Transgenic pest resistant crops were released in 1996, representing the biggest step in technology since the development of pesticides in the 1940s (Peshin *et al*., 2009). In the developing countries farmer education in IPM has gained impetus since 1989, through the Farmer Field School (FFS) extension methodology, originally developed for educating farmers in rice IPM (Bartlett, 2005; Peshin *et al*., 2009). FFS provide "education with field based, location-specific research to give farmers the skills, knowledge and confidence to make ecologically sound and cost-effective decisions on crop health" (Peshin *et al*., 2009). The FFS training module is based on participatory experiential learning in a group setting to help farmers develop their analytical skills, critical thinking and creativity, and help them learn to make better decisions and the trainer is more of a facilitator rather than an instructor (Peshin *et al*., 2009). FFS wider impact aims include further FFS led by FFS graduated farmers and natural dissemination of knowledge and skills to non-FFS participating farmers. The FFS model of extension has spread from Asia to Latin America, Africa and Eastern Europe and is a vital instrument in developing countries where there is no significant investment in farmer education and farmers and consumers have been exposed to environmental and health hazards as a result of an induced reliance on synthetic pesticides (Van den Berg & Jiggins, 2007).

In the developed countries the systematic periodic evaluation of IPM programs provides feedback for improving and formulating future strategies, but in many developing countries there is no periodic evaluation of IPM programs for assessing the extent of adoption and long term impact (Peshin *et al.*, 2009). IPM is, however, the main strategy recommended for pest management under Agenda 21 of the United Nations Conference on Environment and Development (UN, 1992). IPM's theory and principles have evolved over the last 50 years. New tools and strategies have been developed to support development of IPM systems: newer more selective insecticides, progress in the development of bio-pesticides, the development of semio-chemical based approaches (attract and kill, mating disruption), improved understanding of the deployment of trap and refuge crops, the use of "push-pull" strategies, techniques to conserve and attract beneficials in systems, use of augmentive biological control and most recently the advent of transgenic crops producing the Cry-proteins (a large family of crystalline toxins) produced by the bacterium *Bacillus thuringiensis* (Peshin *et al*., 2009). There are now many examples of successful IPM systems in research with commercial application that the term is more or less universally understood (Peshin *et al*., 2009). Since 1975 the United Nations Development Program (UNDP) together with the Food and Agriculture Organisation (FAO) has initiated global programs for the development and application of IPM in rice, cotton, sorghum, millet and vegetable crops. All these developments in crop protection have been driven by changing pest problems faced by farmers, options available and changing cash and labour requirements (Peshin *et al*., 2009).

1.4.1.2 IPM programs in Southeast Asia

Widespread outbreaks of the rice pest, brown planthopper, *Nilaparvata lugens* (Stal) in the 1970-80s were caused by insecticides meant to control, through the 'treadmill effect', and triggered the development of IPM strategies for pest management (Peshin *et al.*, 2009). The FAO provided the coordination, leadership and resources to promote IPM, particularly in developing countries. The FAO Inter-country Program (ICP) for the Development and Application of Integrated Pest Control (IPC) in Rice in South and South-East Asia started in 1980. From 1977 to 1987 IPM moved from research towards extension and application by farmers. By 1988, the 'Training and Visit' extension system in the Philippines, Indonesia, Sri Lanka, Bangladesh, India, Thailand and Malaysia attempted to introduce IPM to rice farmers through their system of "impact points" or through strategic extension campaigns (Peshin *et al.*, 2009). The value and integration of fish in field rice production in many Asian countries has also been recognised and adopted as part of many rice IPM programs with widespread success from natural pest control, reduced pesticide use and improved crop yields and profits (Biswas, 2008; Berg, 2001 & 2002; Lu & Li, 2006). From 1988 to the present IPM has moved towards education rather than training and utilised the FFS approach. Success of the first FFS used in rice in Indonesia, after the banning of 57 broad-spectrum pesticides in 1986, led to its implementation in twelve Asian countries and further into vegetables, cotton and other crops. From here the program spread to Africa, Latin America, Middle East and Eastern Europe (Van den Berg & Jiggins, 2007; Peshin *et al.*, 2009). FFS programs are being implemented in 78 countries, have trained 4 million farmers, 91% from Bangladesh, China, India, Indonesia, Philippines and Vietnam (Braun *et al.*, 2006). IPM FFS covered 1-5% of households in Asia 1989-2004. By 2002, ICP spent US $45 million on training activities in Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Nepal, the Philippines and Sri Lanka. ICP also launched regional programs on IPM in cotton and vegetables. From 1989 to 2004 US $100 million in grants were allocated to IPM projects in Asia (Bartlett, 2005).

Preliminary results from five Asian countries showed FFS graduates increased their income by 31% due to 10% improved yields and 39% lower pesticide expenditure in the first year after training in relation to control farmers (Braun *et al.*, 2006; Peshin *et al.*, 2009). A Global IPM Facility with co-sponsorship of FAO, UN Development Program (UNDP), UN Environment Program (UNEP) and the World Bank was established in 1995 and a "Global IPM Field Exchange and Meeting" held in 1993, where participants from Africa, near East, Latin America and Europe observed the success of IPM farmers in Southeast Asia aiding farmer-centred IPM programs in these regions. However, results of impact evaluation studies of IPM-FFS in Asia by the World Bank and FAO provide contradictory results due to methodological problems in impact evaluation (Peshin *et al.,* 2009). As a result Peshin *et al.* (2009) suggests that FAO formulate a policy for extensive evaluation of IPM programs based on evaluation methodologies in the developing countries to measure the adoption, outcome and impact.

1.4.2 Pesticide application equipment

Efficiency and safety of pesticide application equipment are important factors in avoiding pesticide overuse and ensuring sprayer safety. Spraying equipment that does not leak and nozzles that produce droplets at the most efficient size (i.e. not too large to cause run-off off the plant and not too small to be lost in spray drift), reduce pesticide pollution (Sikkema *et al.,* 2008; Gimenes *et al.,* 2012 & Yarpuz-Bozdogan *et al*., 2011). Due to ongoing pesticide management problems, since 1999 the International Code of Conduct on the Distribution and Use of Pesticides has been amended by the FAO Panel of Experts on Pesticides to incorporate recommendations including application standards.

1.5 Research Frameworks and Approaches

This sub-section introduces and discusses the theoretical frameworks and research approaches that underpin, and are used in the methodology of, the study.

1.5.1 Theoretical frameworks

This subsection introduces and describes the main components of the research framework; the concepts, frameworks of understanding and research techniques.

1.5.1.1 Systems thinking

'Systems thinking' forms the overarching ideological framework and approach to the study. This constitutes use of a particular set of ideas, systems ideas, in trying to understand the topic's complexity, whereby 'systems' embodies the idea of a set of elements connected together which form a whole. By making conscious use of the concept of wholeness to order our thoughts and further our knowledge and understanding, the product is used to initiate and guide actions, or 'systems practice'.

At a deeper level, the research approach used here lies between 'hard' and 'soft' systems concepts but more so towards the latter, whereby the researcher acknowledges and appreciates system complexity and confusion for further learning as opposed to viewing system parts singularly that can be engineered to improve the overall system (Checkland, 1999).

Complex systems, such as those analysed in sustainable development research involving social, economic, environmental, political and multi-stakeholder interactive components, are often dynamic and constantly in a flux. In these systems the nature of problems investigated can change in space and time, thus a tendency towards the soft systems approach helps guard against pitfalls of poor assessment of a complex problem from which premature and ill-guided conclusions and recommendations are made, as often occurs in policy-making (Bell & Morse, 2003; Checkland, 1999). This soft systems approach therefore attempts to take into account the '3-dimensional' aspects of systems comprising spatial, temporal and hierarchical elements that form the complexity of the problem investigated. In this context this can be described as consideration of the range of micro level household subsystems up to macro-scale government and higher stakeholder subsystems that influence and can aid understanding of systems dynamics.

Sub-topics and methods of investigation were numerous, both general and specific considering stakeholders' positions and interests, covering technical, socio-economic, environmental and political, but continually evolved during the learning experience.

1.5.1.2 Sustainable Livelihoods Framework

Sustainable Livelihoods (SL) approaches have been developed from other development frameworks (Ashley & Carney, 1999) with the aim of improving understanding of the complexity of livelihoods, whilst assisting in identifying suitable entry points for external support that are compatible with, and appropriate to, vulnerable people's livelihoods strategies and priorities (Farrington *et al.*, 1999). It is now widely acknowledged that poverty is complex and that macro-economic indicators, whilst indicative, do not reveal or help to address the root causes of poverty. The SL approach attempts to account for a variety of these causal factors which create impoverishment by reviewing the individual, household or communities' assets, both in terms of their access to, and ownership of, resources and the way in which micro and macro level policies, institutions and processes affect mobilisation of their capabilities (DFID, 1999).

Sustainable livelihoods approaches also seek to examine ways in which household vulnerability can be managed but largely focus on the availability of assets at the household /community level and look at the factors that affect the accumulation of, or access to, these assets (DFID, 1999). Five asset categories are conceptualised by the framework:

- Human capital: human capacity to earn a livelihood such as their health, education and age.
- Social capital: the degree to which social connections and status can be used to contribute to livelihoods.
- Natural capital: access to land, water or forested areas, which can be exploited in order to earn a living.
- Physical capital: ownership of tools, means of transport, and other assets which could be used to derive an income.
- Financial capital: assets used as a means of saving such as cash, jewellery or even livestock. Access to credit can also be included in this category.

The Sustainable Livelihoods approach has been widely adopted by international development agencies as a means of identifying developmental needs and strengthening capacity at the household, community and institutional levels. Reardon and Vosti (1995), Sen (1997), Moser (1998) and Bebbington (1999) have provided different frameworks for analysing and describing livelihoods. International agencies such as DFID, CARE, Oxfam and United Nations Development Programme (UNDP) developed their own livelihoods frameworks to assess poverty for intervention and monitoring activities. When reviewed, these approaches were found to contain similarities in their foci. All agencies adopted an asset-based approach to classifying poverty status and some addressed capabilities as well as assets and activities. All stressed the need to facilitate effective micro-macro links between the poor and policy makers (Carney *et al*. 1999), so that effective linkages between micro-level interventions and policy could be made.

The DFID SL framework (Figure 3) seeks to quantify livelihoods according to degrees of vulnerability, the quantity and nature of assets and the interaction of these aspects with policies, institutions and processes to establish livelihoods outcomes and strategies employed by households in communities. Understanding these factors provides a broad overview of the nature of livelihoods in a given context. Hence the DFID SL framework was used in this research as the most recent comprehensive framework for assessing community household well-being, its relationship with vulnerability to pesticides, the nature of the transforming structures influencing pesticide livelihood risks and IPM adoption, and influences of community livelihood strategies in determining livelihood outcomes. The framework was thus important in setting the methodology and providing a holistic view of interactions between researched components.

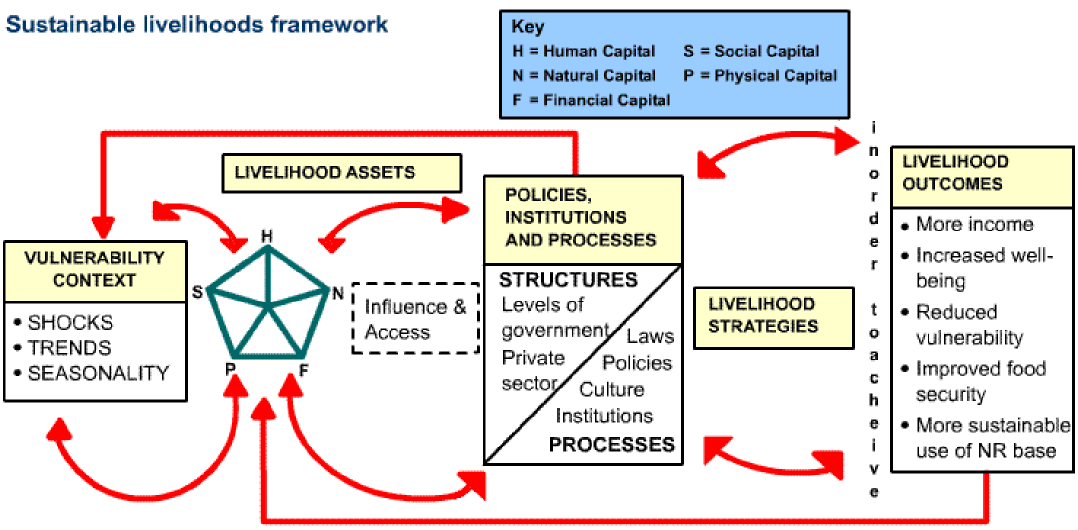


Figure 3: The DFID Sustainable Livelihoods Framework

(Source: DFID, 1999)

More recently, however, in addition to the above mentioned components of livelihood analysis, other issues have gathered importance in supporting and sustaining livelihoods of the poor; governance (stakeholder representation, distribution of power and mechanisms of accountability), wealth (financial resources and access to markets), social and ecological resilience and rights (tenure and human) (Ratner & Allison, 2012; Adger, 2000). Many developing country agricultural and fisheries policies, on which many livelihoods of the poorest depend, are primarily focussed around increasing revenue, however, many stakeholders in international development now claim that greater attention needs to be given to the development *process* over the outcome with consideration of issues mentioned including wider stakeholder involvement with concepts of social legitimacy and ethics, governance and environmental resilience (Ratner & Allison, 2012; Adger, 2000).

1.5.2 Research approaches

This subsection introduces the approaches to data collection. Generally, there are two broad types of research approach being employed by researchers in all fields of evaluation, namely (1) qualitative and (2) quantitative. Researchers who wish to understand the social reality and participants' perspectives often favour qualitative approaches, whilst those seeking to understand relationships without any particular emphasis on the participants' perspective often use quantitative approaches (Bryman, 2012). Both research approaches have their merits and weaknesses (Table 1). Libarkin & Kurdziel (2002) presented a continuum of data and methodology where "pure" qualitative data can be found towards one end of the spectrum and criticised for being too anecdotal and subjective. On the other end of the spectrum, quantitative approaches are more objective and theoretical in nature, providing statistical results without contextual meaning. Although located at the opposite ends of the spectrum, both approaches can shift towards the other depending on the methods of collection and analysis (Libarkin & Kurdziel, 2002). Both approaches are useful and it is best to combine the two in social research to find a balance and make sure social and economic factors are taken in to account to provide statistically valid results supported by contextual meaning. Each approach can therefore complement the other (Bryman, 2012).

1.5.2.1 Qualitative approaches

Qualitative methodologies usually produce data in descriptive forms, mostly nonnumeric. In some cases, the numbers are just arbitrary. The main aim of qualitative approaches is to develop concepts that will help us elucidate social phenomena (Libarkin & Kurdziel, 2002). The approach aims to take into consideration the meanings, experiences, knowledge and perceptions of the participants. This approach is more concerned with exploring the ‘what’ and ‘how’ aspects of investigation rather than ‘how many’ (Bryman, 2012). Common sets of tools used in qualitative research are participatory community appraisal (PCA) and rapid rural appraisal (RRA). Semi-structured interviews, focus group discussions, mapping, modelling, participation observation, trend analysis and well-being ranking are also included in this approach. Seeking to generalise or formulate universal theories are not the main foci of this approach, rather formulating theories grounded in the perspectives of those who participated in the process i.e. farmers/individual households. Critics have challenged the rigour of the data collected using qualitative approaches and have labelled them as subjective, imprecise and ‘soft’. Although qualitative methods cannot be used to draw statistical inference, information can be utilised to draw logical and analytical inference. However, participatory techniques can also produce ‘hard’ data and be used to generate statistics (Bryman, 2012; Morales, 2007).

1.5.2.2 Quantitative approaches

Quantitative approaches usually comprise of methodologies that involve mathematical or statistical techniques used to test hypotheses and validate theories and subsequently produce or generalise knowledge. Such quantitative approaches can usually be replicated in other areas/ fields and mostly deal with large data sets. Examples of this type of research approach are social surveys, structured interviews, experiments, structured observations, content analysis and analysis of statistical information (Bryman, 2012). Aside from the strengths mentioned earlier, quantitative approaches also have some weaknesses. The greatest critique of this approach is its tendency to concentrate largely on the problems that can be easily quantified which eventually neglects socio-cultural and other issues more difficult to quantify (Bryman, 2012).

Table 1: Comparison of some aspects of qualitative and quantitative research

Characteristics	Qualitative		Quantitative	
	Pros	Cons	Pros	Cons
Methodology	Issues can be studied in great detail. Analytical approach is unconstrained.	Results maybe applicable to only a narrow range of individuals or settings. Often no connection to causes.	Results from a variety of individuals or settings can be used to developed a single explanatory model.	Analytical approach is constrained by established standardized methods. Individuals maybe artificially forced into categories.
Interpretation	Interpretation often based on manipulation of raw data and is therefore tied directly to the data source.	Individual beliefs of the researcher may shape the data interpretation.	Statistical analysis although not perfectly free of subjectivity, is typically independent of the researcher's personal belief system.	By the time a quantitative study reaches the interpretation stage, the context in which the data was collected maybe lost.
Validity/ reliability	Validity and reliability are established through logical reasoning and concensus; statistics not required	Researcher acts as the instrument; training and skills of practitioner can bias results.	Validity and reliability are highly controlled variables established statistically; limited training required.	Establishing validity and reliability is time consuming.

(Source: Libarkin & Kurdziel, 2002)

1.5.2.3 Combined qualitative – quantitative approach

A combination of the two approaches can lead to a richer and more useful conceptualization of information (Wayessa, 2013). The quantitative approach can produce data which can be analyzed to illustrate relationships and on the other hand, the qualitative approach helps in probing and explaining the relationships. This combined approach is widely valuable and used in many research disciplines including poverty and community livelihoods (Wayessa, 2013; Lawson *et al*., 2008). The insights from qualitative approaches can also subsequently contribute to the development of quantitative analysis and vice versa. The different approaches have their respective strengths but cannot substitute for each other; their combination can bring both strengths together (Bryman, 2012; Wayessa, 2013).

1.5.2.4 Participatory approaches

Participatory rural / community appraisal (PRA/PCA) approaches have been described by Chambers (1994) as a 'growing family of methods and techniques' to enable a community to let their views and perceptions be shared and take part in the analysis of their life and conditions. These participatory approaches aim to empower local individuals to plan and act for the betterment of their livelihoods. Local people in the community, regardless of literacy level, have capacity to analyse and manage complex and detailed information regarding their community, most of which have been underestimated (Chambers, 1994; Chambers, 2008). PRA/PCA is also a set of tools that emphasises local knowledge and allows development practitioners, officials from the government and the local community to work hand in hand to plan appropriate programmes. Since PCA/PRA evolved in the mid 1980's, there has been a paradigm shift towards more participatory development (Chambers, 2008). Through participatory research, individual participants, farmers, households or even communities have been empowered to manage their own assets and resources (Lightfoot & Noble, 2001). In the development field, particularly in carrying out project assessment, monitoring and evaluation, PRA is now main-stream.

The evolution of PCA/PRA developed from an earlier approach, Rapid Rural Appraisal (RRA), in the late 1980s. Both of these approaches challenged the conventional methodologies of research in terms of producing hard data to be used in generalisation and understanding phenomena (Chambers, 1994). Although both approaches involve the participation of community, these two approaches are completely different in terms of data collection and use. A general difference between two approaches is that PRA is being employed with the aim of enabling local communities to conduct their own analysis and subsequently plan or take action based from their learning, whereas the intention of RRA is for outsiders to learn about the local community (Chambers, 1994; Morales, 2007). Access to natural resources is often dependent on land tenure, which is varied and highly complex but falls under two basic categories; land under state control (70%) and land under private ownership. Of these, land can be categorised as i) subsistence (mainly consisting of rice in the Dry Zone) ii) 'other field crops' (OFC), and iii) plantations. Various tenure practices are followed in the country, however, in the Dry Zone, the *Bethma* system is common with temporary land consolidation and sub-division to meet an *ad hoc* situation of insufficient water in village tanks for cultivating all lands under their command (Thiruchelvam, 2005). Competition for lands between forests, agriculture, human settlements and wildlife increased with rapid population increase, and unemployment and poverty in more recent times have led to encroachment of state lands on an unprecedented scale. Forest depletion and utilisation of ecologically marginal lands for agriculture, especially for unplanned cultivation, have led to land degradation, where temptation to exploit land is associated with lack of tenure security (Thiruchelvam, 2005).

Several participatory tools are now being implemented in social, health and food security, natural resource management, forestry, agriculture and fishery research. In social research, studies on livelihood analysis, poverty assessment and institutional analysis were the most common areas in which participatory approaches were being employed (Chambers, 1994; Chambers 2008). Several livelihood analyses with farmers and fishers have also employed participatory approaches (Martin *et al*., 2013; Lightfoot & Noble, 2001). Amongst the collection of participatory tools used, wealth and well-being ranking, preference ranking and scoring and matrixes were the most commonly practiced in both development and research fields. If the PRA tools were adapted through a process of standardisation i.e. taking into account the requirements of compatibility of data between sites or groups, these participatory techniques can also be tested statistically, particularly the ranking and scoring activities (Barahona & Levy, 2007). Aside from the criticism that participatory approaches only produce soft data, there are several other challenges that this approach faces. These include the constraints that inequalities in power, knowledge, time and money impose on true participation, and the validity of research outcomes. Inexperienced facilitators and cultural differences may also undermine participation, especially of marginal groups, whilst gender or social dominance and outsider influence is a risk. Such issues require consideration in PRA/PCA planning, having influence on outcomes (Chambers, 2005).

1.6 Research Locations and Project Links

This section introduces the study locations and project links.

1.6.1 Country and study site backgrounds

This subsection provides further background information with regards to the main features of the countries and study sites. Thailand and Sri Lanka are situated in the tropics with characteristically warm humid conditions. Their locations and topographies influence their climates spatially and seasonally and they differ in their level of economic development. As mentioned, choice of study sites was based on variation in agri-aquatic systems' functions, layout and size. Individual farms are typically largest in Central Thailand and smallest in Sri Lanka. Hydrology differs between study sites with raised-bed river-canal irrigated horticulture in Central Thailand, largely rain-fed and pond irrigated integrated pond-dike agriculture-aquaculture in Northeastern Thailand, and cascade rain-fed tank-channel irrigation systems in Sri Lanka. Hydrological characteristics show greater potential for water and farm effluent exchange between household farm systems in Sri Lanka and Central Thailand. Whilst fisheries dominate aquatic food production in the Sri Lankan irrigation systems, fish culture dominates in Thailand although shrimp culture is also evident in the Central region. A more detailed comparison of study site characteristics is given in Chapter 3.

1.6.1.1 Sri Lanka

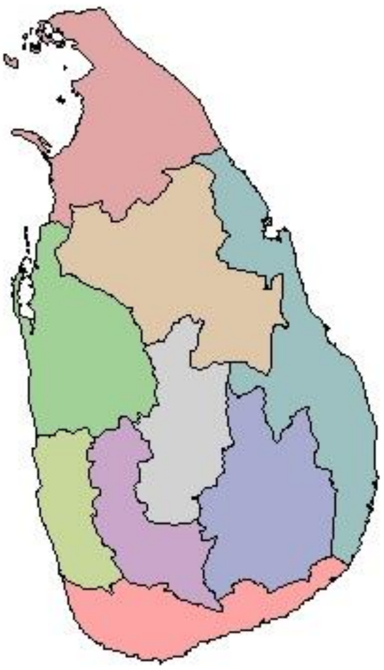
Sri Lanka is located in the Indian Ocean, 6-10° N, 80-82° E, and covers an area of 65,610 km^2 (Murray, 2004). Before the 2004 tsunami, five million people (one-quarter of the population) lived below the poverty line of $12 per person per month, whilst another three million eked out a living on the equivalent of $15 per person per month (IFAD, 2013). Ninety percent of the poorest live in rural areas and 40% are small scale farmers. Malnutrition is common amongst children, infrastructure weak in many parts and almost half the population has no access to safe drinking water (IFAD, 2013).

There are nine administrative regions (Figure 4) and three levels of elevation; low plains below 300m, mid-regions 300-1000m and central mountainous up-country above 1000m (Figure 5). The varied topography and seasonally changeable ocean-wind currents produce different microclimates in regions of the country that have huge influence on temperature, rainfall and subsequently agriculture, aquatic production and many livelihoods. As such there are three agro-ecological zones; Wet, Intermediate and Dry, the latter of which occupies a larger area, some two-thirds of the country (Figure 6). Rainfall is monsoonal and mainly orographic, with convectional rainfall occurring during the first (March-May) and second (October-November) inter-monsoonal periods. Coinciding with these bimodal rainfall periods are two cropping seasons; *Yala* (mid-March to mid-September) which is the drier season and *Maha* (mid-September to mid-March), the wetter season (IFAD, 2013).

The study sites lie in the Mahaweli H region of the Northwestern Province of the Dry Zone (Figure 6). Reduced rainfall restricts agricultural diversity and production, and less water demanding crops are grown in upland plots during drier periods of the year. However, the extensive and complex system of dams, canals and tanks (man-made reservoirs and natural water bodies) in the Mahaweli and Dry Zone areas are collectively managed to aid water storage and distribution to farmland throughout the year. These freshwater tank systems, with an area of 201,800 ha are the largest density of its kind in the world and are vital irrigation resources to rain-fed agriculture (Mahaweli Authority, 2012).

Access to natural resources is often dependent on land tenure, which is varied and highly complex but falls under two basic categories; land under state control (70%) and land under private ownership. Of these, land can be categorised as i) subsistence (mainly consisting of rice in the Dry Zone) ii) ‘other field crops’ (OFC), and iii) plantations. Various tenure practices are followed in the country, however, in the Dry Zone, the *Bethma* system is common with temporary land consolidation and sub-division to meet an *ad hoc* situation of insufficient water in village tanks for cultivating all lands under their command (Thiruchelvam, 2005). Competition for lands between forests, agriculture, human settlements and wildlife increased with rapid population increase, and unemployment and poverty in more recent times have led to encroachment of state lands on an unprecedented scale. Forest depletion and utilisation of ecologically marginal lands for agriculture, especially for unplanned cultivation, have led to land degradation, where temptation to exploit land is associated with lack of tenure security (Thiruchelvam, 2005).

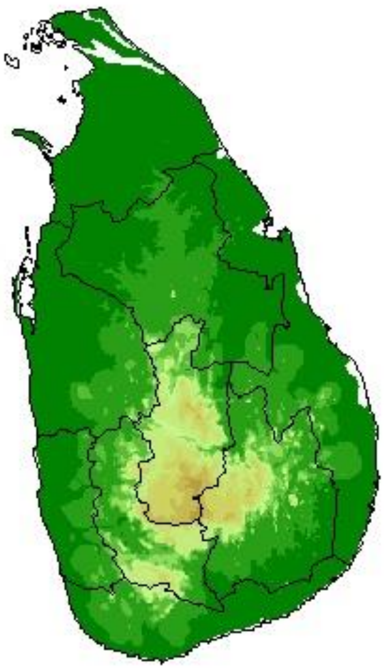
Dams, canals and tanks also serve in providing a vital source of locally cheap fresh fish and valuable protein in inland areas where marine fish availability is scarce (Nawaratne *et al.*, 2002). Previously subsistence based, since the introduction of exotic species into these man-made reservoirs, particularly tilapias (*Oreochromis mossambicus* in 1952 and *Oreochromis niloticus* in the 1970s), inland fishery yields of these introduced species have increased and a more market orientated fisheries sector has developed (Nawaratne *et al*., 2002; Pollock, 2005) supported by regional fish breeding stations (NARA, 1999). Dry Zone tanks are integrally important to rural livelihoods for food and income supporting over 40% of the country’s 12,891 inland fishermen (Nawaratne *et al.*, 2002; Murray *et al.*, 2000).



Administrative regions (Source: IFAD, 2013)

Central	Eastern
North Central	North Western
Northern	Sabaragamuwa
Southern	Uva
Western	

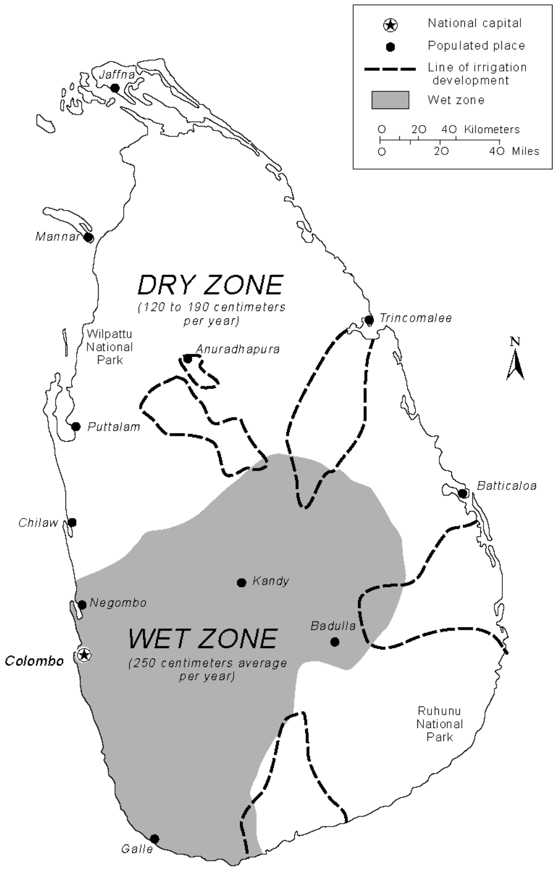
Figure 4: **Regions of Sri Lanka**



Elevation (Metres) (Source: IFAD, 2013)

0-100	500-750	3000-4000
100-200	750-1000	4000-5000
200-300	1000-1500	>5000
300-400	1500-2000	<Sea level
400-500	2000-3000	

Figure 5: **Elevation of Sri Lanka**



(Source: Wikipedia, 2013)

Figure 6: **Climate zones and irrigation development, Sri Lanka**

1.6.1.2 Thailand

Thailand is situated on the Indochina Peninsula of Asia, is bordered by Myanmar, Laos, Cambodia and Malaysia and covers an area of 514,000 km^2 (FAO, 2011). It is still primarily an agricultural country and 60% of the population is classified as ‘agriculturalist’, however, only a quarter of land is suitable for cultivation and almost all arable land has already been used (FAO, 2011). It is more industrialised and developed than Sri Lanka with more domestic and foreign investment in manufacturing. The country has four distinct regions **(**Figure 7**)** of which the Central and Northeast regions house the study sites (FAO, 2011). The Southern region is the smallest and the

Northern and North-eastern regions account for approximately a third of land area, respectively. The North is largely mountainous and forested whilst the North-eastern plateaux region (Figure 7 and Figure 8) that houses a third of the population, largely suffers from greater chronic water scarcity **(**Figure 9**)**, poorer soils, more difficult agriculture and a higher percentage of poverty. The Central region, which accounts for about a fifth of the land area and includes the Bangkok Metropolis, is a great expanse of plains drained by the Chao Phraya River **(**Figure 9**),** important for rice cultivation, industrially diverse and is the geographic and economic heart of the country (FAO, 2011). In contrast with Sri Lanka, there are three seasons; summer hot and dry (March-June), rainy and hot (June-October) and winter cooler (October-February) (FAO, 2011).

Only 20% of the agricultural land area is irrigated of which 48% is in the Central region **(**Figure 7**)**. Most of these areas are used for rice cultivation but only about 2% of the total irrigated area has sufficient water for dry season crop cultivation (FAO, 2011). Non-irrigated, rain-fed agricultural land (80% of agricultural land) is mainly used for rice cultivation and growing all kinds of upland crops, perennial plants, fruit and rearing livestock (Koppen *et al*., 2009). This non-irrigated rain-fed agriculture is most evident in the Northeast region where households typically have pond-dike farming systems in which ponds commonly serve as additional agricultural water sources for dike crops and holding systems for captured wild fish or production systems for cultured fish (Koppen *et al*., 2009; Pant *et al*., 2004; Tipraqsa *et al*., 2007). As mentioned, the Central region and study sites canals irrigate raised horticultural beds, ditch-dike farming systems surrounded by extensive to intensive fish and shrimp culture. Over 50 freshwater species, of which half are indigenous, are cultured although, in terms of production, the main species cultured are Nile tilapia (*Oreochromis niloticus*), hybrid catfish (*Clarias macrocephalus* x *C. gariepinus*), silver barb (*Barbodes gonionotus*), giant river prawn (*Macrobrachium rosenbergii*) and snakeskin gourami (*Trichogaster pectoralis*).

1.6.2 Project links

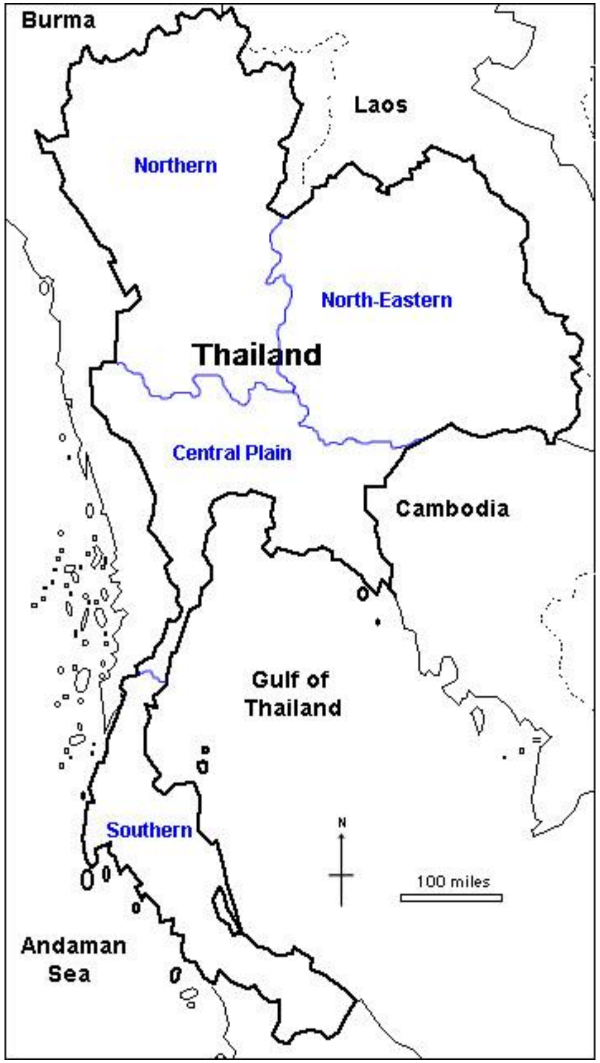
The work conducted was integral to three EU funded research projects (abbreviated as PONDLIVE, MAPET and MAMAS) each with European co-ordinating institutions, other European partners, and Asian project partners in the countries of research. Full details of these projects are available at the following web links:

PONDLIVE: https://www.wageningenur.nl/en/show/POND.htm

MAPET: https://www.wageningenur.nl/en/show/MAPET.htm

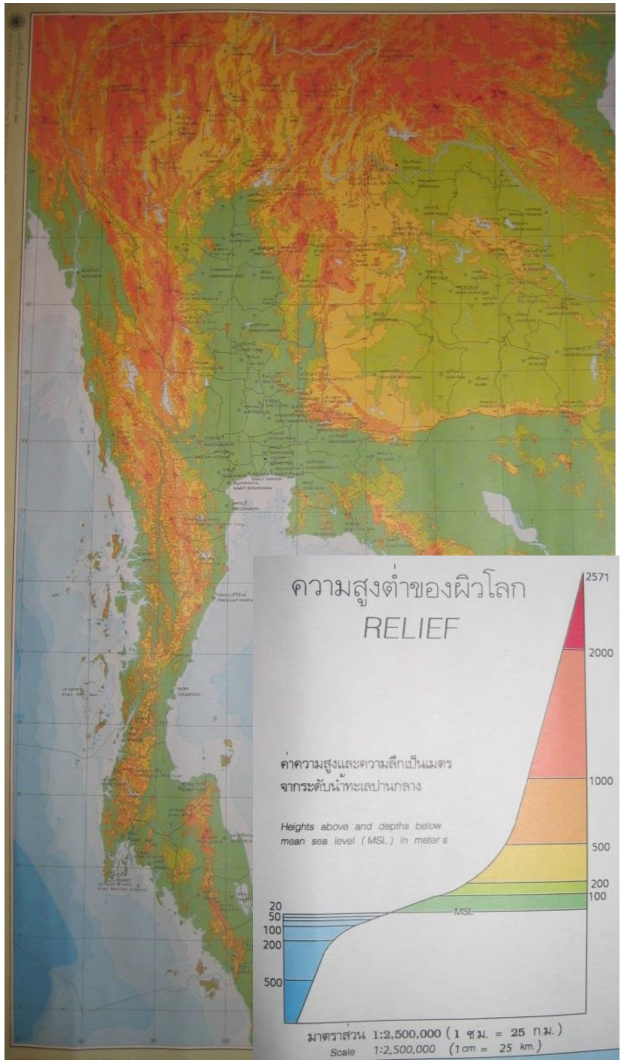
MAMAS: ftp://ftp.cordis.europa.eu/.../22cat2002_10031_mamas_en.pdf

The MAMAS project objectives in Central Thailand and Northwest Sri Lanka were to assess i) farmers' level of pesticide use and underlying motivations, ii) the fate and hazards of pesticides in the aquatic environment and to farming communities through consumption of aquatic foods, iii) other pesticide hazards to farming community livelihoods, and iv) the nature and impact of pesticide marketing and regulation and stakeholder relations on farmers' pesticide use and associated hazards and v) to develop cost effective, simple and ecologically relevant bioassays and a decision support system for pesticide risk assessment. These were carried out using participatory community appraisal (PCA), household survey and semi-structured interview techniques. TOXSWA modelling and dietary values and standards were used to estimate hazards of pesticides to surface waters, and humans from consumption of aquatic foods.



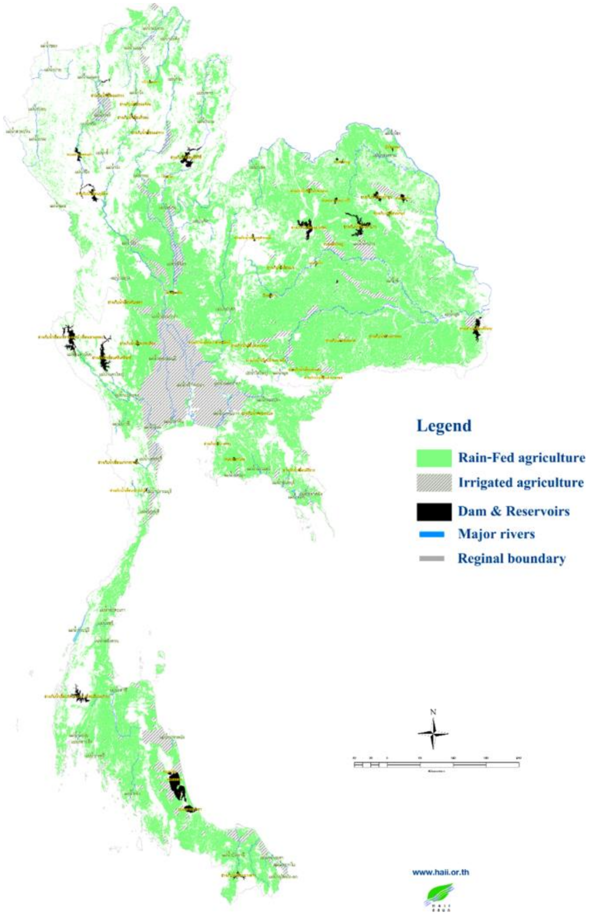
(Source: Wikipedia, 2013)

Figure 7: Regions of Thailand



(Source: Royal Thai Survey Department, 2013)

Figure 8: Land elevation, Thailand



(Source: Thanapakpawin *et al.*, 2011)

Figure 9: Irrigation and water storage, Thailand

The MAPET Project's research areas included Northern Vietnam, Southern China and Central Thailand. The MAPET project objectives in Central Thailand were to assess i) the export sector for vegetables and scope for improvement, and ii) the current level of production of vegetables with reduced or free from pesticide use and the factors influencing failure or success of vegetable IPM programs. This was carried out through secondary data analysis, stakeholder surveys and semi-structured interviews.

The PONDLIVE project objectives in Northeast Thailand, Bangladesh and Vietnam were broadly to i) assess the influence of pond-dike integrated farming systems on livelihoods of farming households, ii) assess the livelihood impact of interventions in fish production intensification, and iii) assess the institutional context of pond-dike development and diversification for future sustainable livelihoods. The project used PCAs, household surveys, and semi-structured interview techniques. PONDLIVE ran from November 2001 to October 2005, MAMAS from February 2002 to February 2005 and MAPET from January 2003 to January 2005.

Aside from the objectives of each project, each contributed to the thesis in their own ways. In general, each project provided a base of farmers within communities and higher tier ex-community stakeholders from which data was derived through various methods.

1.7 Research Issues and Questions

This section introduces and discusses the research problem and questions.

1.7.1 Problem statement and research questions

In many developing countries, Southeast Asia, Thailand and Sri Lanka, horticulture has expanded in recent decades with associated increased pesticide loading to the environment. Simultaneously, the diversity and abundance of inland wild fishery stocks and other aquatic animal life have been affected by over-exploitation, environmental damage and pollution, with potential hazards from agricultural pesticide use (Klemick & Lightenberg, 2008; Relyea, 2009; Wilson, 2000).

Inland extensive to intensive aquaculture production has increased to meet household and consumer demands in Southeast Asia, including Thailand. As such, inland aquatic food production and terrestrial horticulture systems are increasingly coming into closer contact and sharing water resources.

Aside from horticulture, fish and shellfish production, the shared water resources in these intertwined systems also often have important wider local livelihood functions such as in aquatic plant and animal production, personal bathing, washing clothes, food and cooking utensils, amongst other household uses (Palanisami *et al*., 2011; Marambe *et al*., 2012; Nhan *et al*., 2007).

With global pesticide use growing faster than crop production per hectare per year and pesticide use intensity increasing most rapidly in middle-income countries like Thailand (Schreinemachers & Tipraqsa, 2012) there would appear to be an increasing threat from pesticides to aquatic food production and livelihoods in these systems, however, quantifying the nature and level of these hazards is difficult (Wilson, 2000; Relyea 2009).

In addition, despite government policies in many low-income (developing) and middle-income countries, including Sri Lanka and Thailand respectively, becoming more 'pro-IPM' and 'safe use of pesticides', their pesticide production, marketing and use has increased and intensified (Carvalho, 2006; Gupta, 2012; Panuwet *et al*., 2012; Rother *et al.*, 2008; Schreinemachers & Tipraqsa, 2012), In fact, in 2009 the Asia-Pacific region accounted for 23% of global pesticide expenditure, very close behind North America, which has the highest expenditure by global region at 27% (UNEP, 2013). Further, the effectiveness of IPM schemes implemented, including those in the study areas of South and Southeast Asia are sketchy (Peshin *et al*., 2009) whilst farm workers' failure to use formal personal protective measures when spraying pesticide and pesticide exposure related illnesses are still very common and widespread (Devi, 2009; Gupta, 2012; Palis *et al*., 2006; PANAP, 2010; Raksanam *et al*., 2012).

There is therefore a need to establish the pesticide hazards to aquatic food production and livelihoods through an aquatic diet, the factors encouraging pesticide use and mis-use, the reasons for lack of adoption of protective safety measures in pesticide handling, the factors influencing IPM outcomes in a field of uncertainty and mixed reports and scope for improving sprayer efficiency. The dynamics of these institutional, psychological, socio-economic and environmental processes to be investigated which influence the fate of pesticides and their potential hazards to pesticide sprayers, agri-aquatic systems and linked livelihoods are illustrated in Figure 10.

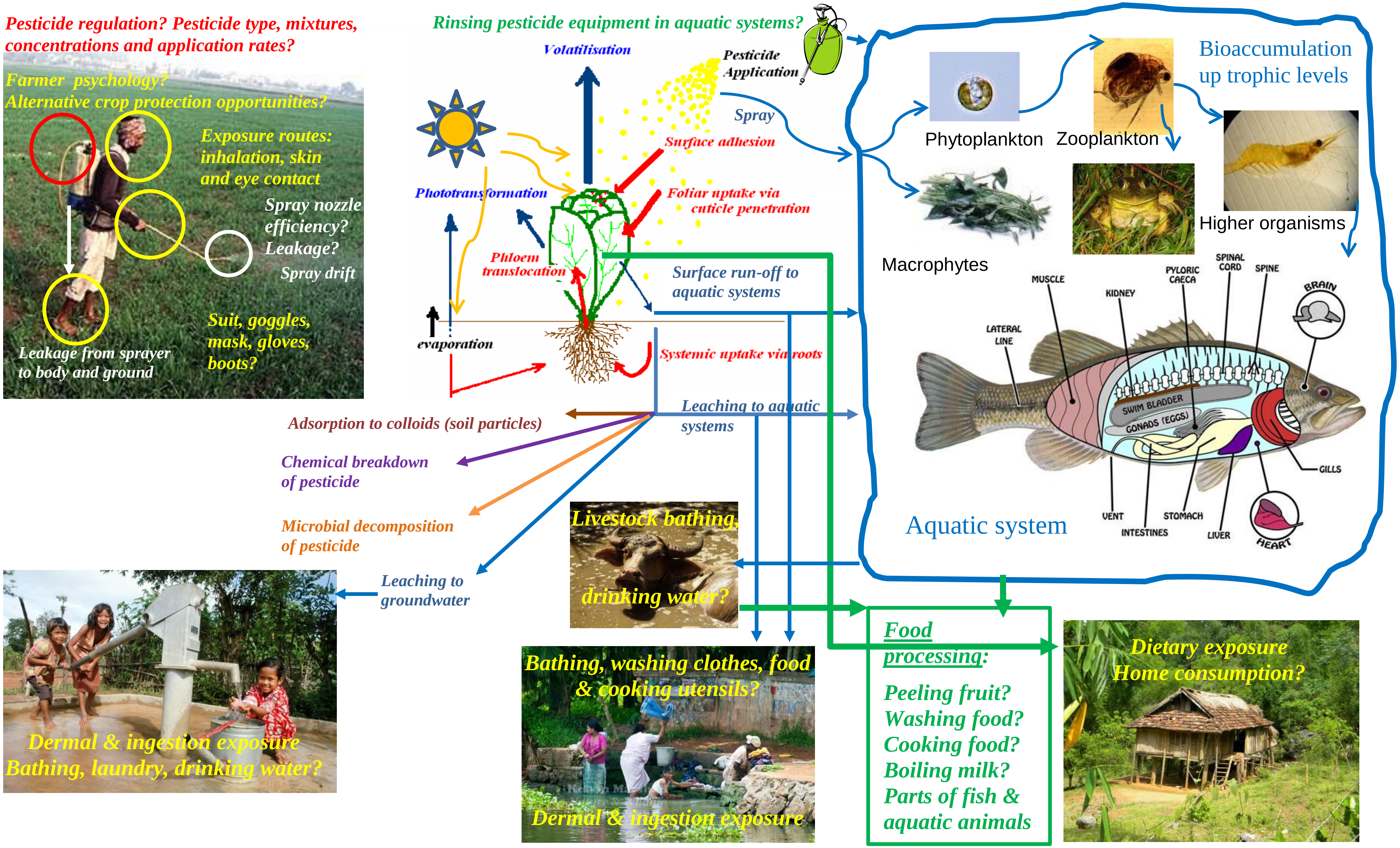


Figure 10: Pesticide fate pathways, transformation processes and factors influencing level of hazard posed to aquatic life and human health

The research aims were to:

i) Establish the differences between, and changes in, agri-aquatic systems and their relationships to livelihoods in the three study regions; Central and Northeast Thailand and Northwest Sri Lanka.

ii) Establish the potential influence of pesticide marketing and regulation on pesticide use and hazards in Thailand and Sri Lanka.

iii) Assess agricultural pesticide use characteristics, and motivations, in agri-aquatic systems of Central and Northeast Thailand and Northwest Sri Lanka and the associated hazards to aquatic systems and communities from pesticide application and consumption of agri-aquatic system produce.

iv) Evaluate the personal protective measures taken by those spraying pesticide in Central Thailand and Northwest Sri Lanka with underlying reasons.

v) Establish and evaluate the methods and outcomes of vegetable IPM training programs operating in the study sites of Central and Northeast Thailand.

vi) Compare the practicality and efficiency of flat fan efficient pesticide spray nozzles with farmers' spray nozzles in Central Thailand study sites.

vii) Establish a consensus on hazard encouraging and hazard reducing factors on agri-pesticides and community livelihoods in Thailand and Sri Lanka and areas requiring future attention.

Chapter 2 **Methodology**

2.1 Introduction

This chapter gives an overview of the methodologies used then describes procedures of each task in more detail.

2.1.1 Overview of methodology framework

The materials and methods used in the study have been widely utilised in scientific research for some time as described in the introduction. The period, location and duration of data collection activities of the research with respect to the specific projects they relate to are shown in Figure 11. Data collection activities have been broadly segregated into those carried out within and those outside the farming communities investigated, and further sub-categorisation illustrates the countries and specific regions of relevance. From the start to the end of data collection, the flow chart shows the direction of flow of information and interconnections between activities. These methods employed, used to obtain both quantitative and qualitative data, are described in turn in this chapter in the sequence they were undertaken. Firstly, however, the sequences and basic concepts of the activities employed are described.

Initially, the situation appraisal identified the stakeholders associated with aquatic systems, aquaculture, agriculture, crop production and pesticides, the current information surrounding the researched topic and potentially feasible field sites for investigation. Field site scoping and semi-structured interviews with key community informants then informed the selection of areas and villages for the next stage of data collection, which involved village level participatory community appraisals (PCAs) in Sri Lanka and one province of Northeast and two provinces of Central Thailand.

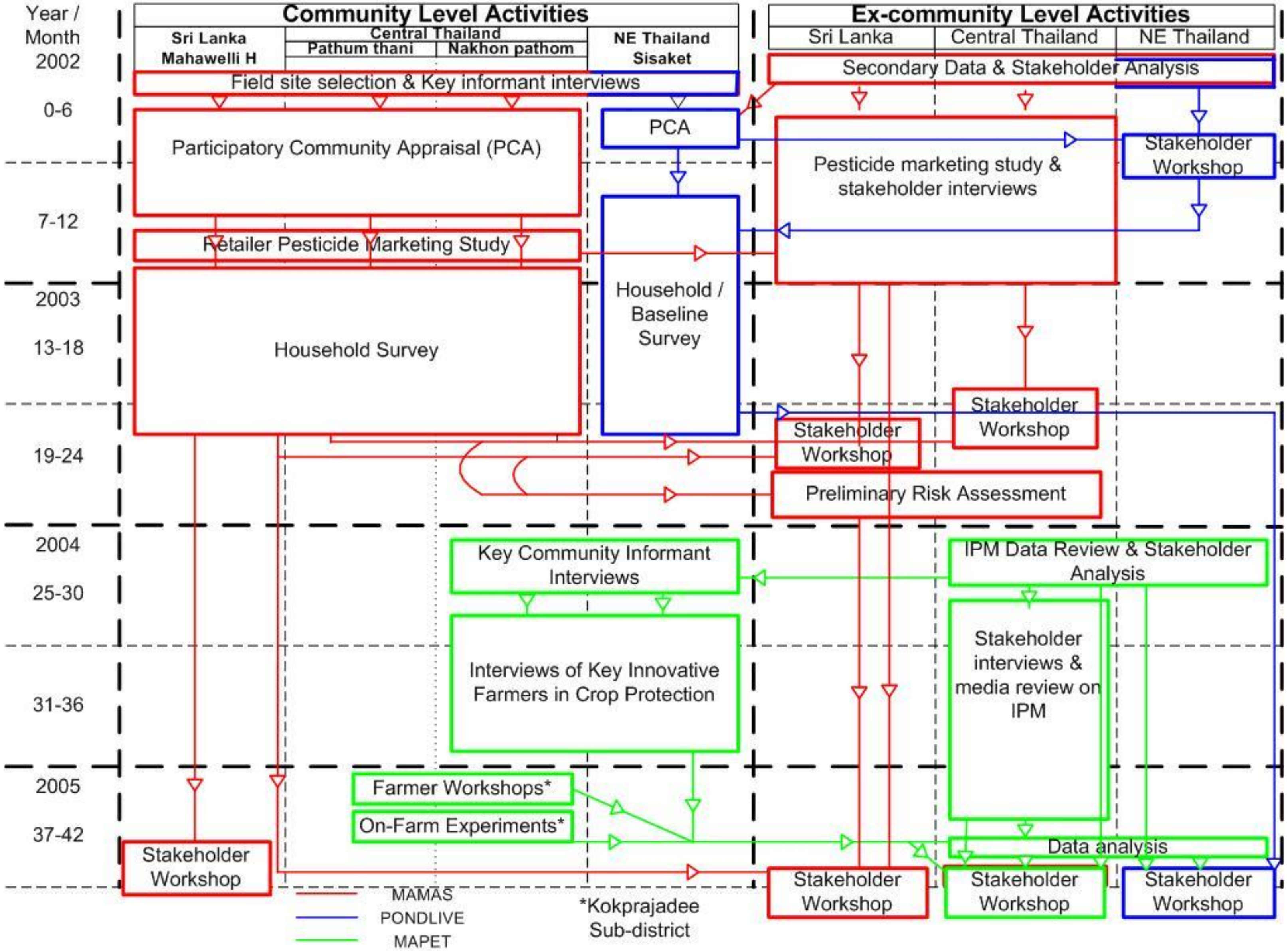


Figure 11: Research methodology framework

PCAs were used to give an overview of communities' facilities, inhabitants' livelihoods and well-being, events and activities with time including those related to agricultural, aquatic production and systems, and to understand the environmental, social, economic and other livelihood influencing factors. Results of these activities were used to inform household surveys that were subsequently carried out in each region with selected households to further explore the issues of relevance to the research. In Northeast Thailand PCA results were first presented to stakeholders in a workshop for their feedback and participation in deciding the issues to be further explored and villages to be involved in the household survey.

The initial secondary information reviews also contributed towards the pesticide marketing study and informed the ex-community stakeholder semi-structured interviews carried out to explore the issues identified and stakeholder relations. The community level pesticide retailer investigation, undertaken in Sri Lanka and Central Thailand, contributed to this study and involved observation of pesticide retail outlets in the vicinity of the researched villages that they supply and interviews of their owners where cooperation was given.

A summary of the methods and outcomes from all these activities undertaken in Sri Lanka and Central Thailand were then presented to community and ex-community stakeholders together in workshops in these respective places and their discussion and feedback recorded as further outcomes. Specific results from the PCAs and household surveys and local physical and environmental parameters in these two regions were then fed into the TOXSWA model that was run to give preliminary risk assessment estimates for the danger of pesticides to surface waters through runoff, and human health through consumption of aquatic foods (Van den Brink *et al*., 2003; Adriaanse, 1996). Up to this point activities in Sisaket were executed as part of the PONDLIVE project and those in Sri Lanka and Central Thailand as a component of the MAMAS project (Figure 11).

Under the auspices of the MAPET project the next task in the research involved another situation appraisal including stakeholder analysis and review of secondary information. In this case stakeholders in the field of alternative crop protection and crop certification, pesticide regulation, marketing, distribution and sales and policy were identified and secondary information on these topics reviewed.

A daily review of media (newspaper articles) on these topics was then initiated and continued for a year. During this period semi-structured interview questions were devised and adapted to suit the appropriate key informants in the study communities in Nakhorn Pathom Province, Central Thailand and Sisaket Province, Northeast Thailand and ex-community stakeholders who were then interviewed.

Community level investigations identified the most innovative farmers in those provinces in the field of alternative crop protection and safe food production, that were subsequently approached and interviewed, again in a semi-structured fashion. In the case of Sisaket Province, a greater number of farmers were approached and selected for interview to give insight into the potential influence of a wide range of variables on safe food production that included farm micro location (rural to peri-urban), pond – dike use, crops cultivated and farmer well-being status, their level and type of training in pesticide reduction and associated outcomes.

Findings from the secondary data review, key informant, farmer and other stakeholder interviews that contributed to our knowledge base on the topic then informed the development of a series of farmer workshops in the remaining study site of interest in Central Thailand; Kokprajadee Sub-district of Nakhorn Chaisri District, Nakhorn

Pathom Province. Workshops were attended by farmers from the three study villages that were willing to participate, to further establish the factors contributing to their pesticide use, their current approaches to crop protection and outcomes, and their interest in experimenting with efficient flat fan pesticide nozzles and trialling protective face masks.

Experimentation with health and safety measures involved most participants, whilst nozzle on-farm experiments were then devised and carried out with participation of three farmers with the intention of reporting back to all participating farmers in a third workshop (Figure 11). At this stage in the research, the media review revealed some successful farmer pesticide reduction capacity building programs in Northeast and Central Thailand which were investigated to distinguish the effectiveness of different training programs, the methodology for which is described in Chapter 5.

The results from all the activities carried out under the MAPET project were then collated to provide a consensus on pesticide reduction techniques and strategies. At this point farmer and higher stakeholder workshops were held in Sri Lanka, where results from MAMAS project activities were presented to participants, and feedback obtained on the significance of the outcomes and the possible future ways forward in policy development. Results from activities executed under MAMAS and MAPET projects in Central Thailand and PONDLIVE in Northeast Thailand were also presented to stakeholders in workshops in these areas respectively and similar feedback obtained.

2.2 Materials and Methods

Following the methodology overview above, the remainder of the chapter describes in further detail the materials and methods used in these activities in the order in which they were undertaken.

2.2.1 Situation appraisal – synthetic pesticides

A review of secondary information was carried out on inland fisheries and aquaculture, agriculture (particularly horticulture), pesticide markets, marketing, legislation and regulation, and related policy for Sri Lanka and Thailand.

Initial identification of suitable field sites for community level research, involved obtaining the advice of key informants in the Department of Agriculture (DOA) and Department of Agriculture Extension (DOAE) of both countries and examining agriculture and irrigation maps, crop and fish production statistics for areas in both countries where daily research trips could be feasibly made from the project field research stations in Sisaket and Pathumthani Provinces of Thailand and Peradeniya, North-central region of Sri Lanka.

With intensive pesticide use on crops and hazards to water resources and livelihoods being of priority, areas were highlighted where crops were likely to receive pesticides in high amounts and were in close proximity to aquatic systems. Within these districts and sub-districts of interest, further exploratory enquiries on site suitability (crop production, pesticide use level and observable effects, uses of aquatic systems in and around farms) and community interest in participation were made with DOAE and local government officials. Working down the hierarchies from central to local government helped focus the observational side of the field site search and instigate meetings with village headmen to assist establishing individual village suitability for, and interest in, participation.

Whilst in the field, informal visits were made to some farming households in each village of interest in order to cross-check the information provided by other stakeholders and get a feel for the potential of the areas and communities for research.

The field sites and specific villages selected each grew crops with frequent use of pesticides of moderate to severe hazard level and close interaction with local aquatic systems serving multi-livelihood uses. These communities also stated their intention to continue with this farming strategy and interest in participating in the research through its entirety. With regards to this, research staff clearly explained to all the stakeholders the aims, activities and limitations of the research to avoid misunderstandings and false expectations of benefits that could not be delivered.

2.2.2 Field site selection and characteristics

Despite having the common characteristics described above, study site observation and discussion with key informants revealed more distinguishing features between the selected field sites.

In Central Thailand a diverse predominantly vegetable (particularly of the leafy *brassica* family) cultivated area was chosen including three villages in Kokprajadee Sub-district of Nakhorn Chaisri District, Nakhorn Pathom Province (Figure 1; Plate 1), where crops with typically 30-45 day lifecycles were grown through the year on raised beds surrounded by farm canals fed by a network of larger river fed irrigation canals. Water was commonly pumped from sub-canals to these farm canal systems during the dry season for irrigation and vice versa in the rainy season to avoid flooding. A second site of three villages was selected in Salakru Sub-district of Nongsua District, Pathumthani Province of Central Thailand (Figure 1; Plate 1) where fruit (predominantly tangerines) was grown on raised ground through the year, again surrounded by farm canals fed by a similar network of larger irrigation channels. In this case predominantly fruit trees of all life stages would typically be grown on farms owned by individuals and worked by community members and the pumping of irrigation water in and out of these farm systems from sub-canals was carried out to manipulate tree and fruit development. In each system the crops grown using synthetic pesticides and fertilisers were sold to middlemen who then traded them at large fresh food markets in and around Bangkok. Canals in and outwith farms also appeared to be sources of wild and cultivated fish and other aquatic produce.

In Sisaket Province, Northeast Thailand, two farming communities (villages) were selected in each of 3 sub-regions (rural, intermediate and peri-urban) (Figure 1; Plate 2), chosen due to the potential influence of distance from markets, environmental, hydrological and topographical characteristics. Soil was generally of poorer quality here than Central Thailand with cash crops typically grown in the dry season, and sold at fresh food markets through middlemen, primarily including chillies, garlic and shallots amongst others. Rice and some other crops were also commonly grown in the rainy season, whilst fruit trees, vegetable gardens, livestock and aquatic produce appeared to also contribute to household resources. Grown on or around farm pond-dikes these plant crops had varied lifecycles, were typically grown using synthetic pesticides and fertilisers, and predominantly rain-fed during the rainy season and irrigated with pumped seasonal pond or agro-well water in the dry season.

In the Mahaweli H irrigation system of Sri Lanka (Figure 2; Plate 3), site maps showed topography to be influential over agriculture and water resource management, and one catchment (Figure 12) was prioritised for site scoping due to the interconnection between the gravity-fed tiered reservoir (tank) and channel irrigation network, local agriculture and fisheries. Figure 12 shows the flow of irrigation water from Kalawewa Tank at the top of the catchment through distribution channels and seepage to other tanks, villages and agricultural land, towards Siyabalangamuwa Tank at the bottom of the catchment. After viewing villages and consulting village head men, five villages, spanning three administrative blocks, were selected in this catchment. The agricultural land of the first two villages at the highest elevation, Medellewa and Mulannatuwa in Block 304's administrative area, received irrigation water from Kalawewa Tank via a distribution channel. Water from this agricultural land then drained into the nearby Kalankuttiya tank (Figure 12). Medellewa was closer to Kalankuttiya Tank and according to the village headman water availability for this land during *Maha* was higher than that of Mulannatuwa. Rice was grown during *Maha* in both areas with other field crops (OFCs) also grown in Mulannatuwa. In *Yala*, OFCs were grown in both areas and rice in Medellewa. The agricultural land of the third and fourth villages, Ihala Kalankuttiya and Kuratiyawa in administrative Block 308 area, received irrigation water from Kalankuttiya Tank via distribution channels with farm wastewater draining into Megalewa Tank. Unlike the land of the first two villages, re-pumping of this drainage water back to farms was commonly practiced in villages 3 and 4 according to village headmen. Ihala Kalankuttiya was closer to Kalankuttiya Tank whilst Kuratiyawa was located nearer Megalewa Tank. According to village headmen water availability was high during *Maha* and low during *Yala* in both areas and rice was grown in both places during both seasons. Other field crops were grown during *Yala* in both areas, but also to a lesser degree than rice during *Maha* in Ihala Kalankuttiya. Finally, Weliyawa village located at the lowest elevation of the selected villages in the system, received water from Megalewa Tank directly through a distribution channel and indirectly through runoff and seepage. With water available throughout the year, the village headman explained that rice was grown all year round. Village headmen explained that farming was the major income generating activity in each selected community with fishing also being important in Ihala Kalankuttiya. Observation found that 'Other Field

Crops' were grown on higher ground by the selected villages except Weliyawa and primarily included chilli and onion, whilst rice was cultivated in lower areas nearer tanks. Whilst rice was largely for consumption, other field crops were also sold at larger fresh food markets through middlemen. Mulannatuwa and Kuratiyawa also had the poorest access to local town centres. The key study site defining features of these selected villages and number of villages studied are summarised in Table 2.

Plate 1: Irrigation and agri-aquatic systems, Central Thailand

Plate 2: Irrigated and rain-fed pond-dike system, Sisaket, Northeast Thailand

Plate 3: Irrigation and agri-aquatic system, Mahaweli H, Sri Lanka

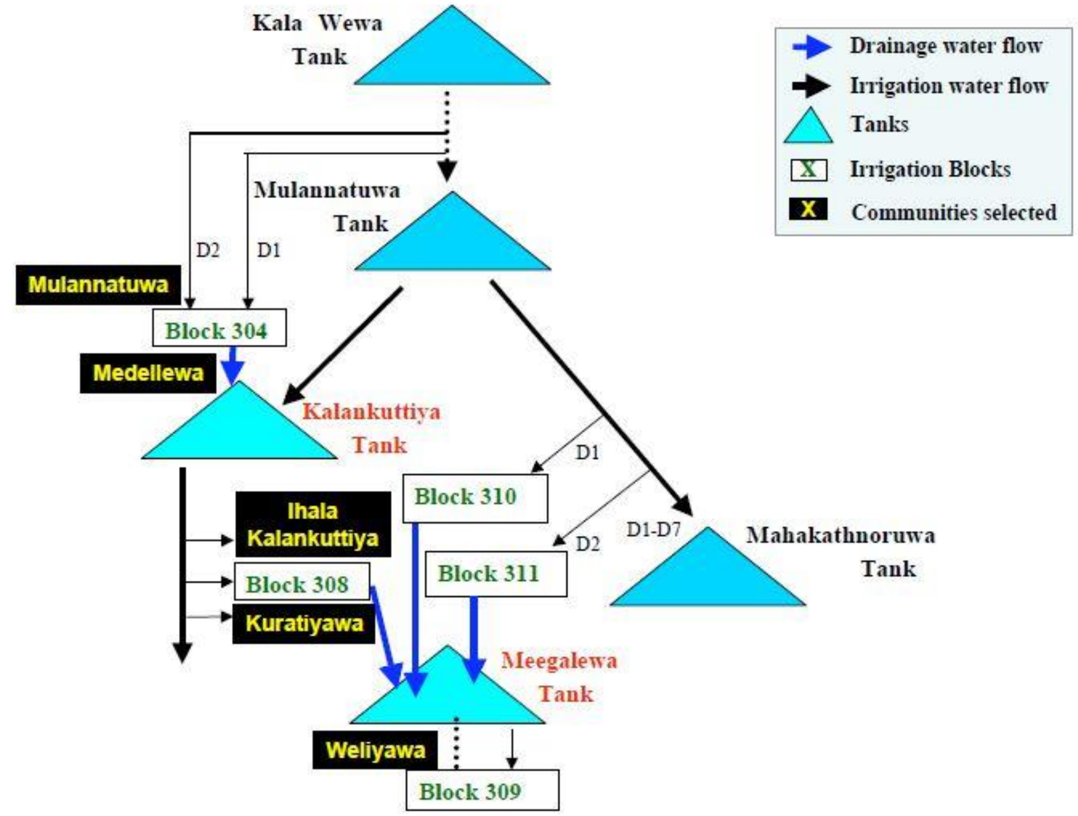


Figure 12: Study sites and hydrology, Sri Lanka

Table 2: Main study site distinguishing characteristics

Region	**Central Thailand**		**Northeast Thailand**	**Sri Lanka**
Study Site	Kokprajadee	Salakru	Sisaket	Mahaweli H
No. villages	3	3	6 (2 rural, 2 peri-urban, 2 intermediate)	5 (2 top, 2 mid, 1 bottom of catchment)
Physical differences	Lowland, raised beds, canal irrigated	Lowland, raised beds, canal irrigated	Upland, rain-fed pond-dike	Rain-fed reservoir-channel cascade catchment
Main crops	Leafy vegetables	Tangerine	Chilli, garlic, shallot, rice	Chilli, onion, rice
Main crop irrigation	River-canal	River-canal	Rainwater fed ponds	Rainwater fed reservoirs
Aquatic resources	Fish (ponds, farm canals, cages) cultured and wild, pond shrimp culture	Fish (canals), cultured and wild fish	Fish (ponds), cultured and wild	Fish (stocked reservoir fisheries)

2.2.3 Participatory community appraisal

The aims of the PCAs have already been mentioned, however further detail is now given on the procedures undertaken highlighting any differences in approach between selected sites. In each study region pilot trials of the whole PCA activity were first conducted in villages that were not selected to participate in the research to establish the suitability of the proposed approach and identify any need for amendments.

Following this, in Sri Lankan and Central Thailand sites, village headmen of each selected village identified five or six elderly key informants of mixed gender in their villages with a good knowledge of their communities. These individuals were then invited to participate in the first five PCA activities. In each village, this first included drawing a map of their village showing land use, crops grown, aquaculture, water bodies, infrastructure, buildings, markets, and other notable features, to get an appreciation of the areas' layout. Secondly, the participants listed the education level categories relevant to the community members which were five, ranging from primary class 4 to Bachelor's degree level. The group then distributed a total of 50 beans amongst the education categories to represent the proportion of community members in each category, from which percentages were calculated. These listing and quantifying procedures were then repeated for community employment to show the proportions of community members' involvement in different occupations. This was followed by logging notable events in a timeline, including changes to agriculture, when pesticide use started and any visible community health or environmental damage, to give an appreciation of the sequence and scale of community change. Finally, these participants in each village individually carried out well-being ranking exercises for each household in their respective villages. This exercise involved the use of cards, where each card represented a specific household and its code from the electoral register. The community households were separated into categories according to their well-being status, ranging from better-off to worse-off with the well-being classification criteria used by participants noted for each group, which commonly included financial wealth, household member occupations, health, material goods and other assets. Household well-being means were calculated from the cumulative results of participants' household grading, which together with the classification criteria, allowed final household classification into better-off, worse-off and intermediate categories. This process enabled the selection of households from worse-off and better-off groups in each village for participation in the next stage of PCAs. In this selection, priority was given to households with well-being values tending towards the middle of that of the better-off and worse-off groups for best representation of the circumstances of all the households in those groups.

For the second stage of PCA activities, four groups each of five villagers from separate households were chosen to represent gender and well-being differences; better-off males, better-off females, worse-off males and worse-off females, with a total of 20 participants per village. Additionally efforts were made to include within each group people of different ages, occupations and education level for diversity of input and one co-ordinator to five participants.

PCA attendees were briefed on the overall activity plans and purposes and separated into their respective groups. First of the second phase exercises were activity matrices, whereby participants within each group listed their typical daily activities, particularly those associated with farming and aquatic systems. After ranking their importance using a set number of beans, activities were categorised as primary and secondary activities according to how many people did them and their level of importance. The process was repeated for food items eaten, their source and frequency of consumption through the year. Each group then drew calendars showing seasonal aspects of livelihoods including agricultural water use, crops grown, labour and pesticide use, fish culture, fishing, finances, water quality, environmental and human health.

As individuals, each group participant then drew a bio-resource flow map of their farm using arrows to indicate direction of flow of water, agrochemicals, crops, fish and other material within the system and with outside places. The next group task involved different components; to rank their agricultural input (labour, seed, fertiliser, pesticide) costs, level of agrochemical use for each crop grown and indicate crops sold and consumed within the household. This allowed comparison of these different input costs between crops, groups and study sites.

Each participant then informed who in their households sprayed pesticides and frequency of application. Finally, each participant was presented with two questions, each with three answers to choose from. The first question concerned their perceptions on the necessity of synthetic pesticides for crop protection and usefulness of other methods. The second question concerned their perception of, and level of concern on, the hazards posed by pesticides to the environment and human health. The final question asked their future aspirations with regards to their level of pesticide use and reasons; aspiring to use more, less or similar amounts for health, environmental or economic reasons.

2.2.4 Stakeholder workshop, Northeast Thailand

The stakeholders identified in the situation appraisal, conducted under PONDLIVE Project for Sisaket Province, were invited to a workshop in Sisaket College of

Agriculture and Technology. These comprised of three groups; representatives of households from the six village communities, Government extension agencies and the research community. Results of PCA activities were presented to these stakeholders as a means of cross-checking and encouraging discussion for feedback.

2.2.5 Household survey

Making reference to PCA well-being ranking results, a number of households in each of the better-off and worse-off groups of villages were selected for visiting to assess suitability for inclusion in the household surveys. Village headmen, familiar with community households, assisted in identifying households that conformed to the selection criteria. The criteria for selecting prospective households in each study area were that the household members were farming, they consumed food from the surrounding environment, they grew a variety of crops that received pesticides, were aware of pesticide hazards to health and the environment and had experienced some of these side-effects whilst some had to be involved in fishing, trapping fish from their local environment or engaged in some form of aquaculture.

In addition, in Sisaket, household selection took in homes from each of the three pond-dike activity categories. An agenda was devised for these visits that comprised a list of observations to be made on-site and topics to explore through discussion with householders to confirm their suitability and willingness and availability to participate. In the case of each Central Thailand and Sri Lankan village, 19 to 20 households were selected per village, based on time and resources available. In Sisaket this was 120 ‘active’ (high attention to the pond-dike in the system and regular transfer of pond water to agriculture), 60 ‘passive’ (irregular transfer of pond water to agriculture and primarily subsistence farming) and 60 ‘non-operational’ (unmanaged pond-dikes with few crops grown on dikes and no use of pond water for crop irrigation) pond-dike households (as identified from PCA) over six villages.

As equal a proportion as possible of better-off and worse-off households were chosen, however in many cases members of worse-off households were not available for participation due to work and other family commitments. In these cases worse-off household numbers were made up by lower mid-range well-being ranked category households. The numbers of households selected and their proportion of total numbers of households in study site villages are shown in Table 3.

In developing questions for the household surveys, attention was given to results of PCAs and preliminary enquires with households in each region. Of particular interest were village crop and water body distribution, seasonal issues, agri-aquatic interactions, and well-being indicators. Bio-resource maps informed of the potential flow of pesticides to land, aquatic systems and through food to households and markets. Well-being rankings illustrated well-being distribution within villages and well-being class indicators including assets and vulnerabilities. The activity matrices and 'responsibilities towards agrochemicals' tasks showed how these groups spent their time, in particular on agriculture and spraying of pesticides. The 'agricultural inputs' tasks indicated the broad level of pesticide use by crop type, and the consumption matrices, the participants' types, sources and intake of different foods and hence potential hazard of pesticide exposure. PCA activities also provided insight, with respect to well-being and gender, on pesticide use, future aspirations and underlying reasons. The questions devised for Central Thailand, Sri Lanka and Northeast Thailand are shown in Appendix 1 and Appendix 2. Heads of the households participating in the survey were then visited, questioned and answers recorded and interpreted.

Table 3: Study site categorisation, household population and sampling numbers with regards to well-being status

Region	Central Thailand		Northeast Thailand			Sri Lanka				
Site defining features	Tangerine	Mixed crops	Active pond-dike farms	Passive pond-dike farms	Non-op pond-dike farms	Upper catchment		Mid-catchment		Lower catchment
Village / Sub-district	Salakru	Kokprajadee	*	*	*	Mulannatuwa	Medellewa	Ihala Kalankuttiya	Kuratiyawa	Weliyawa
No. villages	3	3	12	12	12	1	1	1	1	1
Total No. households	386	336	120	390	167	148	183	96	221	104
No. of households selected for survey	60	58	120	60	60	19	20	20	19	19
% of total No. households	15.5	17.3	100	15.4	35.9	12.8	10.9	20.8	8.6	18.2
No. better-off	25	26	98	26	24	6	8	8	6	9
No. worse-off	35	32	22	34	36	13	12	12	13	10

*= Nonh, Nonhpluy, Samrongnoi, Khumkham, Huykhong, Sansamran, Prasartyuer, Bungmork, Nasila, Khokcharoen, Khoktan village 1, Khoktan village 8 (12 villages in total, however ‘active’, ‘passive’ and ‘non-operational’ pond-dike classed farms were present in each village).

2.2.6 Pesticide marketing study and stakeholder interviews

The study of the synthetic pesticide market and marketing followed the market research methodology of Kotler *et al*. (2013). The main areas researched within this context, which influence the pesticide market were i) socio-cultural, ii) technological, iii) economic and competitive and iv) political and legal aspects, the so called 'STEP factors', which are shown with their sub-topics in Figure 13.

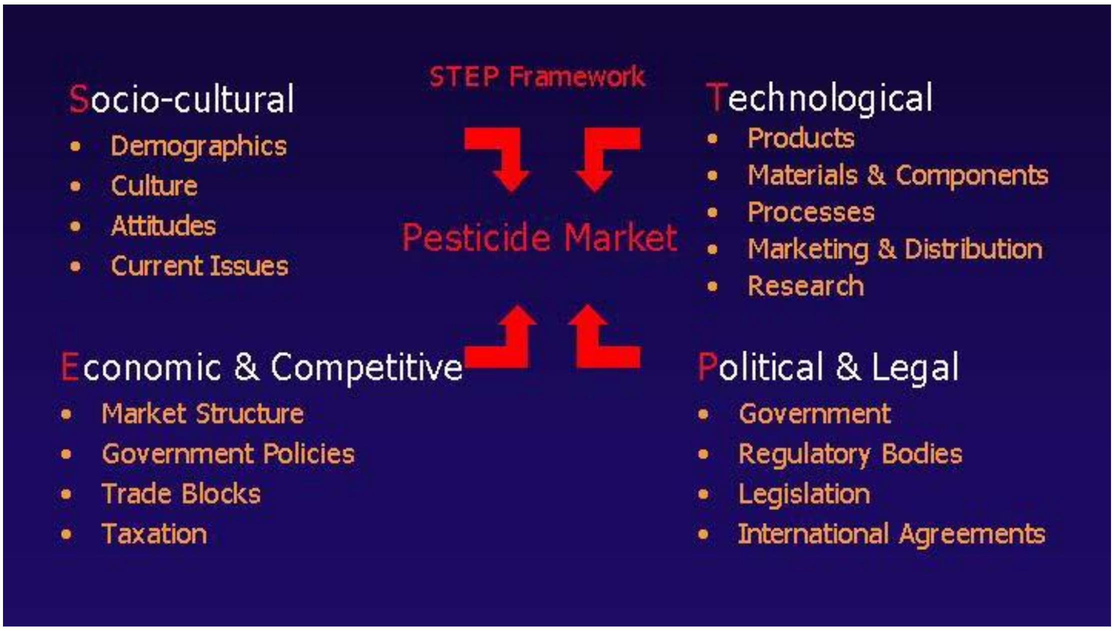


Figure 13: Study framework for the synthetic pesticide market

(Source: Kotler, *et al*., 2013)

The secondary information obtained from the initial situation appraisal and the results of the PCAs and household surveys from Central Thailand and Sri Lanka all contributed to the pesticide marketing study.

Stakeholders in plant protection through the use of synthetic pesticides were identified and listed Appendix 3. In accordance with the study methodology each of the four sectors were considered in this process. The stakeholders identified comprised of synthetic pesticide product manufacturers and distributors (foreign and domestic), pesticide dealers and retailers (village, district and provincial level agrochemical shops), pesticide regulators (Government and Agrochemical Associations) and pesticide users (farmers). Contributions from farmers to the study were made through the PCAs and household surveys, however analysis of the other stakeholders involvement in this sector were proposed to be conducted through semi-structured interviews with people of the highest responsibility and authority that worked for these bodies.

To gain an overview of the processes involved in the pesticide production, marketing, regulation and supply chain and the roles of and interactions between these stakeholders, initial enquiries were made with key stakeholders familiar with this knowledge, the pesticide industry regulators. This was the Agriculture Toxic Substances Division of the Department of Agriculture (DOA) in Thailand and the Registrar of Pesticides of a similar department in Sri Lanka. Prior to visiting these regulators secondary information on their responsibilities and activities were reviewed from which questions (Appendix 4) addressing their expertise were devised to explore the STEP factors and other issues of relevance to their responsibilities, in particular the legislations that underpins their regulatory roles. In addition to their views on the status of the pesticide industry and associated STEP factors these semi-structured interviews enabled preliminary network diagrams to be drawn showing pesticide pathways from production to end use through the actors and processes involved. Semi-structured questions were also developed in a similar way and undertaken with bodies in Thailand that represent the agrochemical industry and promote good practice and compliance with Government legislation with their members (Appendix 5). These were the ‘Thai

Agrochemical Business Association' and 'Thai Crop Protection Association'. In Sri Lanka this body was 'Croplife Sri Lanka', a subsidiary of 'Croplife Asia'.

In selecting pesticide formulators for interview, secondary information was examined on the distribution of synthetic pesticide market shares of foreign and domestic based formulators operating in Thailand and Sri Lanka. In Thailand these were all private sector owned and initial enquiries were made with all companies near the top, middle and bottom end of the market on the possibility of interviewing in order to investigate their business, opinions and outlook on the issues investigated. All companies in the lower sector of the market (domestic companies) and most others declined interviews, however two international companies in the upper end of the Thai pesticide market and one domestic one from the middle end of the market did agree to interviews. In Sri Lanka, secondary information revealed forty companies operating, with 20 having more than 50% of the market share. Most were private sector pesticide formulators, although a government owned one was also operating.

Secondary information on these companies' activities revealed the nature of their stakes, roles and products which were used to formulate generic questions on the STEP factors and more specific questions relating to their stakes (Appendix 6).

From household survey semi-structured interviews in Sri Lanka and Central Thailand farmers provided information on the source of the pesticide products. Enquiries were then made with these pesticide retailers and dealers on their willingness and availability to contribute to the research through semi-structured interviews and examination of the pesticide products they traded. Four pesticide retailers in Nong Saeu District and two in Nakhorn Chaisri District were identified as supplying farmers in the Central Thai study sites and all except one in the latter district agreed to participate. In Sri Lanka, this was two pesticide retailers identified in the study site area. Again, semi-structured interviews were constructed to explore each of the STEP factors (Appendix 7). Additional observations were made in agrochemical retailers to assess pesticide products' compliance with the legislation that regulates their labelling, sale and use. The information to be collected with shop owners' consent therefore pertained to pesticide product storage, health and safety, packaging and labelling. The information from these stakeholders was then collated and analysed for later presentation to all stakeholders.

2.2.7 Stakeholder workshops

After collation of primary data from PCAs, household surveys and pesticide market studies undertaken in Sri Lanka and Central Thailand, logistic arrangements were made for a stakeholder meeting and list compiled of community and ex-community stakeholders that were involved in, or had relevance to, the research. These included four sectors of stakeholders; key farmers and Agricultural Extension Officers from the research sites, pesticide manufacturers and sellers that were interviewed and policy makers some of which had participated. In each country these stakeholders were then contacted, informing or reminding them of the background and objectives of the research, the activities that had been done and the intention to hold stakeholder meetings. The purpose of these meetings was explained; for presentation of results, discussion and feedback for validation, enhancing our understanding of the issues and identification of future approaches for research and action. With confirmation of attendance, specific results were chosen and prepared for presentation to stakeholders as a whole where appropriate to all whilst other results were chosen for presentation to individual stakeholder groups depending on their suitability to their roles.

Following an introduction on the format of the meeting, expectations of the participants and future use of the outcomes, results relevant to all stakeholders were presented to them collectively. A series of questions were then put to the audience from which discussion and feedback was noted. With stakeholders separated into their specific groups, each were then presented with further research results that were of relevance to their disciplines and once again questions put to them and feedback recorded, that included what they deemed important for future research and action.

2.2.8 Preliminary risk assessment

For the Central Thailand and Sri Lankan preliminary risk assessment, data on physical-chemical characteristics of agri-aquatic systems, environmental conditions and pesticides used, level of pesticide use and aquatic plant and animal consumption data from PCA and household surveys were used to produce scenarios and estimate pesticide hazards to surface waters and humans through the diet for comparison with set safe limits (Van den Brink *et al.*, 2003). Recommended applications for each pesticide used were used for Sri Lanka, whilst the mean actual applications for each pesticide were used for Central Thailand sites in the model as recommended applications were not obtained.

With regards to the surface water risk assessment the first tier PEC / NEC ratio (predicted environmental concentration / no-effect concentration) (Van den Brink *et al.*, 2003) risk assessment was calculated for each crop-pesticide water body scenario. Where the PEC (estimated from a simplified standard scenario for a standard freshwater system (stagnant; water depth 30 cm overlying sediment of 5 cm depth) on the basis of the recommended dose used for pest control and the expected drift percentage and runoff or drainage fractions) exceeded the NEC (obtained from laboratory studies on pesticide concentration with 'standard' species) then an effect of the pesticide on the aquatic community was expected. In these cases second tier risk assessments with simulation for the PEC was conducted that takes into account agronomic, climatic conditions and other factors relevant to the crop and local environment. Second tier NECs were calculated from susceptibility indices for local species and half-life of the chemicals used in the field experiments (Van den Brink *et al*., 2003).

In assessment of the human dietary pesticide risks posed to studied households, only aquatic foods (fish and macrophytes) and drinking water were considered. NEDI values were obtained from a hypothetical diet representative of Thailand and Sri Lanka. For most chemicals an ADI could be found in the annual reports of the JMPR (Joint FAO/WHO Meetings on Pesticide Residues). For all compounds except fenobucarb an ADI could be found in one of the literature sources, the one for fenobucarb was estimated to be the 5% level of the log-normal distribution of all ADI values found (worst case estimate). Only for five chemicals an ARfD could be found, for all other chemicals the ARfD was calculated using an extrapolation factor.

2.2.9 Situation appraisal – 'safe' foods, Thailand

In contrast to the previous situation appraisal on aquaculture, agriculture and synthetic pesticide use, informing research site selection, this appraisal, only conducted in Thailand, reviewed secondary information on approaches to reducing synthetic pesticide use in horticulture and the marketing opportunities, certification and labelling schemes and regulations associated with crops marketed as 'safe' to consumers. This was carried out with a view to investigating the status and opportunities for pesticide risk management in Thailand. Literature outlining Government policies, operating procedures and records and stakeholder roles and responsibilities, comprised a major component with scientific literature.

2.2.10 Stakeholder interviews

From the situation appraisal, lists were produced of stakeholders with roles or interests in this field; the techniques associated with IPM and GAP in pesticide reduction and their conveyance to farmers, the certifications used to depict produce safety level with regards to pesticides and ‘safe’ food marketing and regulation. These stakeholders comprised of Government, private sector, academics and non-governmental organisations. A summary of the types and numbers of stakeholders selected for interview are shown in Table 4.

Table 4: Numbers and types of stakeholders selected for interview

Colour code	Yellow	Green	Blue	Grey	Pink
Classification	Bodies primarily associated with general agricultural extension	Bodies primarily focussed on general safe crop protection & production	Bodies primarily focussed on supporting crop production, certification & trade for export	Domestic & export crop markets & traders	Bodies primarily associated with poverty reduction and general livelihood improvement
Stakeholder No.	1-8	9-14	15-24	25-36	37
No. of stakeholders	8	6	10	12	1

In total 37 stakeholders were selected for interviews. They were contacted, briefed on the project and objectives of proposed semi-structured interviews and asked to participate. In generating questions for these interviews, 15 basic important questions were devised that were perceived to be broad and relevant enough to all stakeholders (Appendix 8). In accordance with the study methodology each of the four sectors

(STEP factors) were considered in question development. Where appropriate, additional specific questions were constructed for each stakeholder to further explore their specific roles and responsibilities. Interviews were then carried out with the most appropriate stakeholders in each organisation, recorded, reviewed and answers tabulated.

For twelve months, a review of the Thai media (newspapers) was undertaken to identify relevant issues to the study and related stakeholder opinions and activities. The topics reviewed, covered all those that pertained to the study including agriculture policy and implementation, farmer training programmes, pesticide hazards, marketing and use, safe food production and marketing and consumer awareness of these issues.

2.2.11 Key community informant interviews

Further investigation was made into the most innovative and successful farmers of ‘safe’ horticultural produce (grown with no pesticide or restricted pesticide use, with or without formal ‘food safety’ certification) in the primary study province of Nakhorn Pathom, Central Thailand. This involved locating and questioning key informants (farmer trainers or TOTs) and collecting secondary data at the provincial level and below. Questions were devised to explore farmer training methods and locations, innovative farmer identification, product quality control and certification, markets and actors involved.

Enquiries were initially made with staff at the Nakhorn Pathom Provincial Agriculture Office to establish the locations and contact details of known innovative farmers within the Province of the primary study site. The Provincial Agriculture Extension Officer and a farmer trainer or trainer of trainer (TOT) that contributed to the discussion were briefed on the research project, after which they were questioned and provided details of the farmers trained by them in pesticide reducing techniques, types of systems they manage and their methods of crop protection. During this process it was discovered that there were another eight trainers of trainers (TOTs) in Nakhorn Pathom Province and they were also questioned by telephone for purposes of identifying suitable farmers for interview. Each respondent was asked a series of questions (Appendix 9).

These key informants and literature, identified Kampaeng Saen District of Nakhorn Pathom Province to be the most prosperous and innovative district of the province with regards to the production of certified safe vegetables for export, however the farmer trainers' additionally identified other innovative farmers within the Province. In total, five farmers were identified by TOTS as practicing the techniques taught to them on GAP, IPM and synthetic pesticide reduction.

2.2.12 Interviews of innovative farmers in primary study sites

The selected five farmers in Nakhorn Pathom Province who were trained by DOAE staff in synthetic pesticide reducing techniques were firstly contacted by telephone to brief them on the background and objectives of the project, establish their willingness for cooperation through semi-structured interviews and make appointments for these case study interviews. These exploratory questions covered similar areas to those used for the TOTs as a means of cross-checking and obtaining further specific details. Following this, a checklist of questions were devised for these farmers, tested by staff and modified accordingly for full semi-structured interviews. With some similarity to higher tier stakeholder questions these covered general aspects of aquatic farming and fisheries, crop production and pest control, information and training resources, contact with other stakeholders and bodies and their future farming plans (Appendix 10). These farmers were then visited for interview and observation of their holdings and practices.

This investigative process was repeated in Sisaket by reviewing the 240 household surveyed farmers in the PONDLIVE project in Sisaket Province to find the most innovative farmers in limiting synthetic chemical crop protection, who had been trained by the DOAE in reducing pesticide use. With a total sample number of 20, research staff identified 13 in this category whilst another three farmers were selected who had been 'IPM' trained but were not practicing pesticide reduction measures and also four who were not trained and not practicing such measures for comparison. The trainer of these farmers was also questioned by phone prior to interview using similar questions used for Central Thailand. All 20 farmers selected for these case studies were chosen from the pool of farmers associated with the PONDLIVE project since the research had already accumulated much quantitative data on these farmers' livelihoods whilst they had established relations with research staff. Semi-structured questions exploring similar issues to those devised for the five farmers in Nakhorn Pathom Province were used for these farmers.

2.2.13 Farmer workshops, Central Thailand

This activity was focussed on farmers in the Kokprajadee Sub-district study area, Nakhorn Chaisri District of Nakhorn Pathom Province. In accordance with the objectives of establishing the strengths, weaknesses, opportunities and threats surrounding safe vegetable production, proposing further innovative methods in crop protection and identifying farmers interested in testing these methods, contact was made with these farming communities. Communication with the three village farming communities was initiated through the village headmen. Village headmen were firstly contacted by telephone to brief them on the background, objectives and limitations of the project, with particular emphasis on the proposed procedures of the farmer workshops to be held in Kokprajadee. After their initial interest in participating in the organisation and operation of the workshop, the objective and structure were explained and preparations made with village headmen in dialogue with farmers. The following criteria were associated with the workshop:

1) Explaining the project and workshop objectives to village head men and participants; to identify factors encouraging pesticide use, their methods of crop protection and outcomes, identify farmers interested in testing face masks and flat fan pesticide applicator nozzles.

2) The limitations of the workshop; no financial benefit for attendance and no provision of materials, training or solutions for crop pest problems.

These ensured farmers were not misled on what they could expect from the workshops and reduced results bias.

Two workshops were proposed. The first for establishing farmers' current farming practices, appreciation of pest problems and pesticide use (Plate 4; Appendix 11). The second for feedback and clarification of outcomes from workshop one and to explain pesticide effects on pest – natural enemy balance, pest resistance and recurrence (Plate 5), suggest possible alternative crop protection measures and select farmers to trial four types of protective masks (large and small, with and without filters, total 30) and more efficient flat fan nozzles to use with their pesticide sprayers (Plate 6; Plate 7).

Farmers were separated into groups in workshop one and workshop two according to village, gender and presence or absence of previous IPM training. Following the workshops, data was collated and analysed.

Plate 4: Workshop farmer group, Kokprajadee

Plate 5: Explaining pest-natural enemy relations and 'pesticide treadmill effect'

Plate 6: Farmer's pesticide sprayer

Plate 7: Discussing nozzle trial with farmer, Kokprajadee

Chapter 3 **Agri-aquatic Systems and Livelihoods**

3.1 Introduction

The results in this chapter address the first question outlined in Chapter 1; to establish the differences between, and changes in, agri-aquatic systems and their relationships to livelihoods in the three study sites with respect to pesticide hazard. In this respect, the nature of the systems, their temporal and spatial changes and livelihood links are described followed by a short discussion.

3.2 Results

3.2.1 Farming and irrigation systems

To set the scene for describing the study sites, Plate 8 to Plate 17 show typical farm settings in each study area including crops grown and surrounding aquatic and fish production systems. Figure 14 to Figure 16 show plan views of crop layout, water bodies and water exchange in each study site farming system, while Table 5 provides an overview of some of the main differing criteria between them to which reference is made in this section. The first most significant difference between the two countries is the seasons. Thailand has three seasons; hottest drier summer period February to April, rainy season May to October and moderately cooler winter period of November to February. However, Sri Lanka has two seasons that run in different months from Thailand; the rainy season (*Maha*) from mid-October to mid-March and the dry season (*Yala*) from mid-April to mid-August.

3.2.1.1 Central Thailand

As shown in Table 5, the farming systems in Central Thailand are the largest of the three regions ranging from 0.8 – 4.8 ha residing in alluvial deposits of the Chao Phraya floodplain with high fertility and water retention properties (Sinsakul, 2000). The raised fruit and vegetable beds set within the farm canal systems (Plate 8, Plate 10 and Plate 11) are irrigated by river water via primary and secondary canals in the region and were initially devised by Chinese immigrants (Cheyroux, 2003). Water distribution from rivers to primary and secondary canals is regulated by the Thai Irrigation Authority and from there many farmers choose to regulate their seasonal farm canal water levels by pumping to and from sub-canals and their farms, which is uncoordinated or regulated and common for this Thai region (Van den Brink *et al*., 2003; Sajor & Ongsakul, 2007).

In Kokprajadee Sub-district, rice cultivation covered a small percentage of land area whilst fruit, leafy vegetables and fish ponds comprise most of the land areas as shown in the example of one of the village PCA maps (Figure 17). Leafy vegetables are most commonly grown continuously throughout the year in Kokprajadee and have 30 to 45 day seed to harvest cycles (Plate 8) during which pesticides are applied as frequently as every 4 days, which is common in horticulture in this region (Joannon *et al*., 2001). The most likely routes of pesticide contamination of farm canals is through spray drift, seepage or discarded vegetables fed to fish. However, with pumping of water from sub-canals to farms during the dry season to water crops and in reverse to avoid farm flooding during the rainy season (Van den Brink *et al*., 2003; Molle, 2007), exchange of potentially pesticide contaminated farm water with neighbouring watercourses and other farms exists. Although a diverse variety of horticultural crops are grown alongside each other, particularly in Kokprajadee, they are grown in a ‘mono-culture’ fashion.

In Salakru Sub-district, tangerine production covered most of the land with some longan fruit and rice (Plate 10; Table 5; Figure 18), whilst pond and cage fish culture was also apparent as shown in one village map example (Figure 18). Tangerine trees can survive for up to 20 years, range in size from 3 to 5 m and fruit up to three times per year after 4-5 years post planting (Jungbluth, 2000). Crop protection of tangerine trees, requires frequent application of pesticides to foliage throughout the year during all three phases of tree development – planting and budding, flowering and fruiting (Jungbluth, 2000). Citrus production is high and far higher in this Central Thai region than others (Jungbluth, 2000). Fruit and vegetable cultivation in the Central region is extensive and occupies about half of the land area size that is used for rice production in the Central Region (Sreesunpagit, 2014). Tangerine cycle year one involves land preparation (January to April), planting of trees (May to August), plant maintenance, fertiliser and pesticide application every 7 to 10 days. In year two, plant maintenance and pesticide spraying continues with frequent pumping of water between farm canals and sub-canals to create drought stress to advance tree maturation, flowering and fruiting. This water exchange is more frequent than in Kokprajadee but creates similar pesticide hazard contamination issues with surrounding farms and water bodies. In year three, tree maintenance reduces, pesticide application continues and harvesting is done, sometimes twice per year (November to December and February to March). The trees have a life span of up to 7 years and at any one time trees of all three stages are usually present on individual farms to provide a continuous production cycle as described by Van den Brink *et al*. (2003) and Jungbluth (2000).

3.2.1.2 Northeast Thailand

The study sites of Sisaket, Northeast Thailand, comprise of household farmland smaller than those of Central Thailand, around 0.8 to 3 hectares (Figure 16, Table 5; Plate 12).

The highly weathered sandy soils of this upland plateaux region have low nutrient levels and water holding capacity and are structurally unstable compared with Central Thailand, creating challenges for agriculture and fish production (Suzuki *et al.*, 2007; Tipraqsa *et al*, 2007).

Use of traditional trap ponds for harvesting wild fish is common and rice–fish and pond-fish culture has also been promoted by Government and non-governmental agencies (Little *et al.*, 1996). Government led farm pond construction initiatives, devised to retain rainwater for farming during the dry season, are the basis of the pond-dike integrated agriculture-aquaculture farm systems now typical of this region (Plate 12) and common in Southeast Asia (Nhan *et al.*, 2007; Pant *et al.*, 2004; Prein, 2002).

The pond-dike system is created where excavated earth from pond construction is relocated around the pond perimeter to bed crops. The primary crop, rice, is often rain-fed in fields, however, system ponds and agro-wells (sometimes more than one per household) can provide supplementary irrigation and are integral to fruit, vegetable, livestock and fish production in the dry season, whilst animal manure and additional fertiliser provide nutrition for fish culture and dike crops (Prein, 2002; Setboonsarng, 2002).

Water resources have been bolstered in the region by NGO and Community Development Association (PDA) initiatives for storage of 'roof-rain' in large 'jars' for domestic use and piped water for this and vegetable irrigation managed by village water management committees. However, more recent developments include the drilling of deep bore wells from which water use is available for a fee and managed by district government authorities (Koppen *et al.*, 2009).

Although rice production covered a greater land area in this Northeast region, fruit and vegetables comprised a higher proportion of crop production in Central Thailand (Sreesunpagit, 2014). PCA activities revealed three different pond-dike farming systems in use, subsequently termed ‘active’, ‘passive’ and ‘non-operational’ in which pond-dike use varied. Rice was the main crop grown in each system, however, in ‘active’ systems pond water was intensively used for irrigating dike and sometimes other land crops, in ‘passive’ systems pond water was not regularly used for irrigating dike or other land crops and in ‘non-operational’ systems the pond-dike system was effectively unmanaged for cropping but often functioned as traditional trap ponds.

Village maps are not available, however, figures of average crop production give an idea of land use between these three systems. Figure 19 shows average crop and fish production by pond-dike type, where a greater variety and quantity of crops are produced from ‘active’ and ‘passive’ pond-dike farms. Rice is produced in the highest amount but was excluded from the graph to clearly show differences between other crops. Shallot, chilli and tomato were the next highest land crop quantities produced annually on-farm in each pond-dike system, the former two being the popular horticultural crops for this region, whilst more fish were cultured in ‘active’ and fewest in ‘non-operational’ sites, the latter being household systems with no functional links between crops and pond water. Water is often pumped from ponds to crops during the dry season, however, possible seepage of pesticide contaminated water from rice, fruit and vegetable crops back to ponds and into other local watercourses poses potential hazards for fish culture and water users (Plate 16).

3.2.1.3 Sri Lanka

The selected sites of the Mahaweli H region of Sri Lanka lie within the Kala Wewa catchment with a man-made reservoir (tank) cascade system which harvests and distributes monsoonal water to catchment farmland via a series of distribution channels (Plate 13; Plate 15). Irrigation systems are classified according to the size of their command areas with major (>600 ha) and medium (80-60 ha) systems being the responsibility of the Irrigation Department and minor (1-50 ha) systems under the Department of Agrarian Services (DAS). Larger perennial tanks hold and distribute water throughout the year whilst smaller seasonal tanks function more periodically (Murray 2004). Although the primary function of tanks is agricultural irrigation, they also support fisheries of mainly Mosambique Tilapia (*Oreochromis mossambicus*), and are commonly used for other amenities such as bathing and washing clothes (Plate 16).

These farming households have land sizes smallest of all the study sites, from 0.2 – 1 ha. Crops are pesticide intensive with rice, the crop of choice, mainly cultivated in low lying wetter areas surrounding natural reservoirs (seasonal tanks), particularly during the rainy (*Maha*) season (Figure 20). PCA village maps are not available as respondents described rather than drew features, however, unlike Central Thailand, the types and coverage of different crops grown is highly seasonal and topography dependent; during the drier *Yala* season, irrigation water is regulated and so less rice is grown other than in low-lying areas around seasonal tanks, and so out of necessity other dry tolerant cash crops, mostly chilli and big onion, termed locally as ‘Other Field Crops’ (OFC), are cultivated in upland plots near settlements on higher ground (Plate 13; Table 5; Figure 21).

The major soil types in Mahaweli areas are 'Reddish Brown Earths', 'Non Classic Brown' and 'Low Humic Gleys'. Reddish Brown Soils are more suitable for growing OFCs and horticultural crops while the other two types of soils are suitable for growing rice (Mahaweli Authority, 2012). The traditional farmer land sharing '*Bethma'* cultivation system operates during *Yala* when water supply is insufficient to supply all rice fields and the households' one hectare of land is split between OFC and rice cultivation.

Water distribution is controlled by the Mahaweli Authority and Farmer Organisations and issued on a rotational basis between farms via sub-channels (Thiruchelvam, 2005). Any excess field drainage water flows down to the next tank that irrigates crops further down the system (Marambe *et al*., 2012) therefore potentially increasing pesticide loading further down the system with possible implications for perennial tank fisheries and aquatic users (Plate 17). However, if water is in short supply, such as in the dry season, this effluent water is often pumped from drainage ditches back into crop fields by better-off farmers who can afford the equipment and fuel. Less than half of households owned wells, however, seasonal tanks, agro wells (Plate 14), open access private wells, tube wells and public common wells also provided additional water resources, some of which could be used for crops during *Yala*. Both better-off and worse-off farmers also had access to tube wells.

3.2.2 Aquatic food resources

At both sites in Central Thailand fish are commonly held in farm canals for weed control, personal consumption and sometimes local sale, whilst wild fish are mainly caught in the sub-canal and main canal networks by people from households in the worse-off well-being category (Table 5).

In Kokprajadee Sub-district, a network of private sector fish nursing ponds has grown to support commercial and home subsistence orientated pond fish culture (Table 5) throughout the year, with harvesting every 8-10 months over a significant area of land (Figure 17). Nile tilapia (*Oreochromis niloticus*), walking catfish (*Clarias batrachus),* silver barb (*Puntius gonionotus),* small mud carp (*Cirrhina microlepis),* rohu (*Labeo rohita),* pomfret *(Pampus argenteus)* and Chinese carps were cultured. A commercial saltwater black tiger shrimp (*Penaeus monodon)* farm was present (Plate 9) although much of this lucrative business has only had short-term success due to poor management, disease and environmental pollution (Belton and Little, 2008).

In Salakru Sub-district, the species cultured included red tilapia (*Oreochromis aureus x Oreochromis mossambicus* hybrid), climbing perch (*Anabas testudineus*) and walking catfish (*Clarias batrachus*). The nursing of fish fry in ‘hapas’ (small mesh nets) suspended in ponds and canals, occurs between March and June with fingerlings stocked to farm canals, ponds and cages in main canals in April and September / October (Figure 18; Table 5). Commercial and subsistence table-fish sales and harvesting operated throughout the year. With economic and urban development this expansion of diverse aquaculture products in Central Thailand, often through contract farming, has co-developed with conversion of wetlands for agricultural high value crop diversity and resultant wild fishery decline (Belton and Little, 2008).

In Sisaket, farm ponds (Table 5; Figure 16; Plate 12) have multiple purposes including watering livestock, irrigating crops, domestic uses and the culture of fish. Nile tilapia (*Oreochromis niloticus*) was mostly preferred for culture being more cost-effective to produce and easier to consume from having fewer bones than other fish species cultured in the region. Although the species was primarily cultured for home consumption, some households also sold the fish locally. Fish here, make a significant contribution to the population's important dietary protein and lipid requirements (Karapanagiotidis *et al.,* 2010), with fishing of local watercourses and rain-fed rice field trap ponds for wild fish, including walking catfish (*Clarias batrachus*), snakehead (*Channa striatus*) and other self-recruiting species, during the rainy season supplementing provisions (Morales, 2007).

In Sri Lanka, fish is the major source of animal protein in the diet with a high *per capita* consumption for the region; an estimated 96% of the population regularly consume some form of processed or fresh fish (Murray, 2004; Nawaratne *et al*., 2002). The country cannot meet its demands for fish, with imports of marine dried, salted and processed fish filling the deficit (Murray, 2004). Tanks in the dry zone are therefore an important source of cheap locally available inland fish for poor rural farming communities (Murray, 2004). Since their introduction in the 1950s, tilapia (*Oreochromis sp.)* fisheries in perennial reservoirs (tanks), similar to those in the study site (Table 5), constitute some 95% of total landings, reaching 30-40,000 tons annually by the 1980s and supporting a network of local fishermen and mobile vendors for local and more distant market sale and consumption (Plate 17) (Murray, 2004).

Plate 8: Leafy vegetable farm Kokprajadee, Central Thailand

Plate 9: Shrimp farm, Kokprajadee, Central Thailand

Plate 10: Mature tangerine trees, Salakru, Central Thailand

Plate 11: Tangerine farm drained, Salakru, Central Thailand

Plate 12: Pond-dike farm, dry season (Nov-March), Sisaket, Northeast Thailand

Plate 13: Chilli, onion and rice, Mahaweli H, Sri Lanka

Plate 14: Field well, Mahaweli H, Sri Lanka

Plate 16: Kalankuttiya perennial reservoir (tank), Mahawelli H, Sri Lanka, used for watering livestock, fishing, bathing, and washing clothes

Plate 15: Irrigation channel, Mahweli H, Sri Lanka

Plate 17: Tilapia from reservoir 'tank', Mahaweli H, Sri Lanka

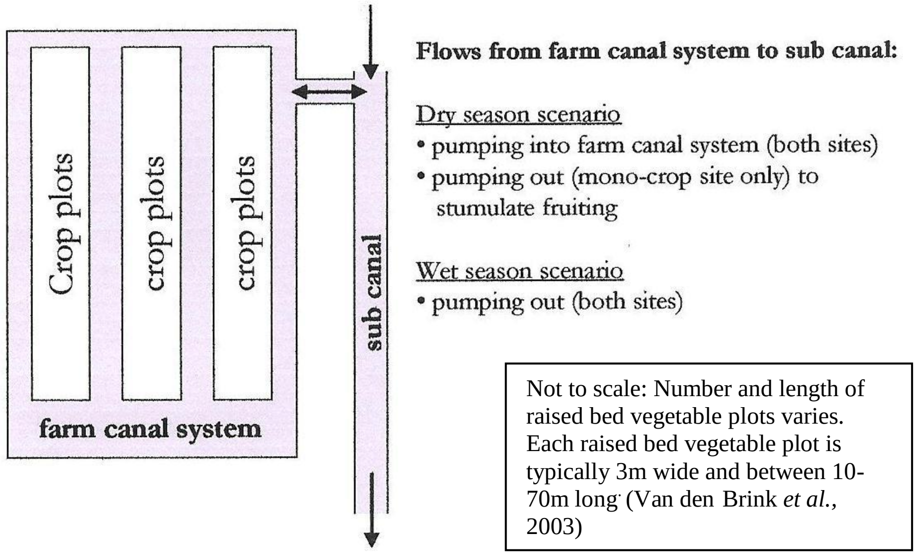


Figure 14: Plan view of typical farm plot and water exchange in Central Thailand

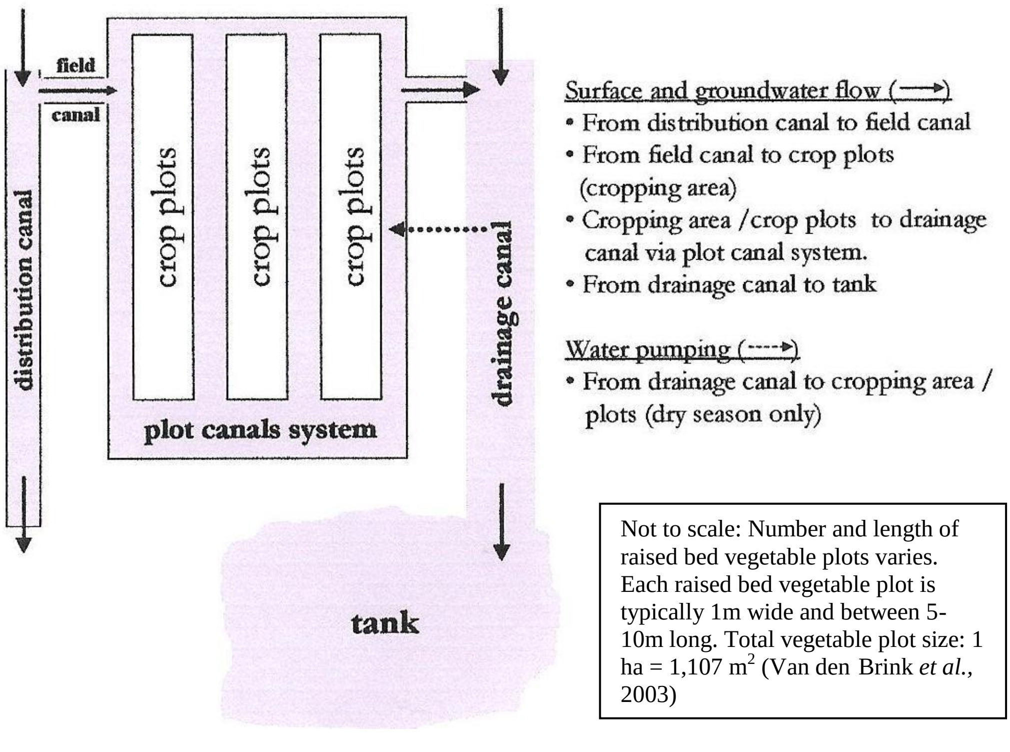
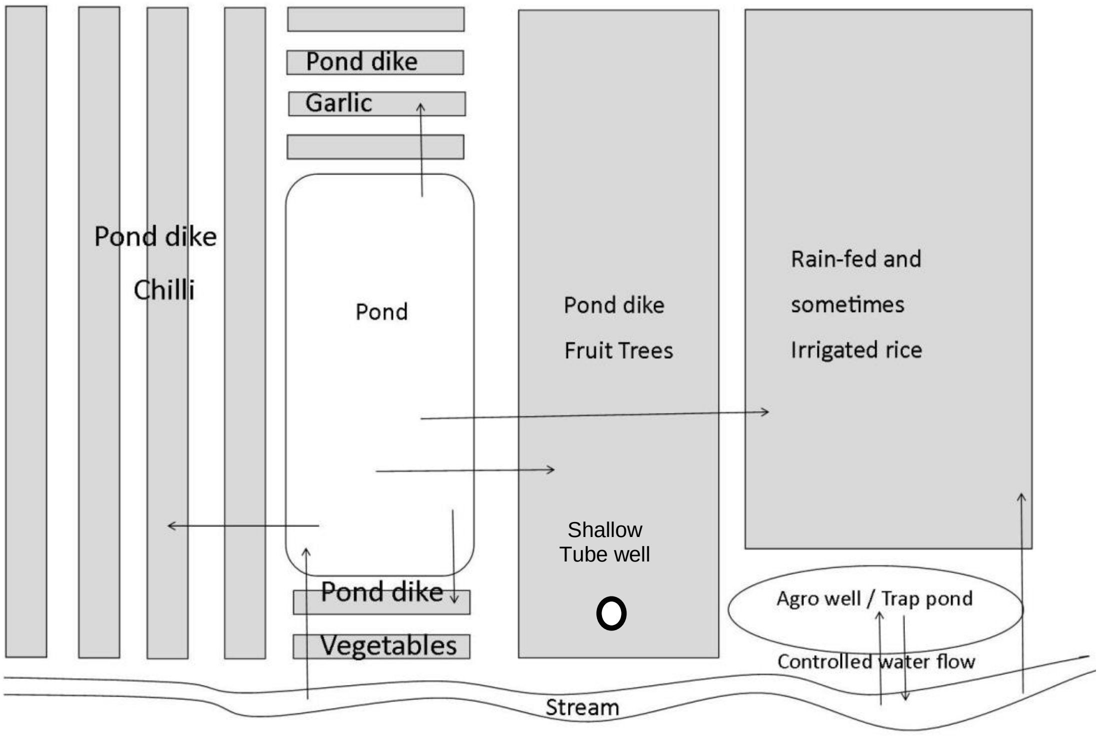


Figure 15: Plan view of typical farm plot and water exchange in Sri Lanka



Not to scale. Layout of systems varies with topography and context. Arrows indicate potential water flow

Figure 16: Plan of typical farm system and water flow Sisaket, Northeast Thailand

Table 5: Study site farm system characteristics

Country	**Thailand**	**Thailand**	**Thailand**	**Sri Lanka**
Region	Central	Central	Northeast	Mahaweli H
Province	Nakhorn Pathom	Pathumthani	Sisaket	Anuradhapura
Sub-district	Kokprajadee	Salakru	10*	Blocks 304, 308, 309
No. villages	3	3	17	5
Farm scale	Medium 0.8-4.8 ha	Medium 0.8-4.8 ha	Small-med 0.8-3ha	Small 0.2-1 ha
Comparative poverty levels	Second better-off of all 4 sites	Most better-off of all 4 sites	Second worst-off of all 4 sites	Worst-off of all 4 sites
Topography	Lowland floodplain	Lowland floodplain	Uplland plateaux	Upland cascade
Production type	Domestic market	Domestic market	Domestic subsistence	Domestic subsistence
Farm system	Raised bed	Raised bed	Pond-dike	Plots
Primary crop type	Leafy vegetables dominate	Tangerines dominate	Chilli and mixed crops & rice	Chilli, big onion, rice
Production period	All year	All year	Mixed (dry) Rice (rainy)	Veg (dry) Rice (rainy)
Crop water supply	Off-farm canal irrigation	Off-farm canal irrigation	Pond, rain-fed & sometimes stream	Off-farm perennial tank
Production drivers	Irrigation development	Irrigation development & incomer knowledge	Pond production & chilli market	Water scarcity & Irrigation development
Primary customers	Wholesale crop traders	Wholesale crop traders	Wholesale crop traders	Wholesale crop traders
Primary crop markets	Near, Bangkok markets & provincial	Near, Bangkok markets & provincial	Distant, Bangkok	Distant, Colombo, Dambulla
Primary irrigation	River and canals	River and canals	Ponds, small canals, rain	Reservoir, channels, rain
Fish production	Cage & canal, wild	Farm canal, wild	Pond culture, wild	Reservoir fishery
Soil quality	Good-average, fertile, low porosity	Good-average, fertile, low porosity	Average-poor, infertile, high porosity	Average-poor, medium fertility, low porosity

Key: * Bhu sung, Bok, Chan, Heuyticshoo, Huachang, Khoktan, Phonkha, Pimay, Prasadyer, Somploy.
OFC – Other field crops (i.e. chilli, onion)

Figure 17: Village 2 map, Kokprajadee, Central Thailand

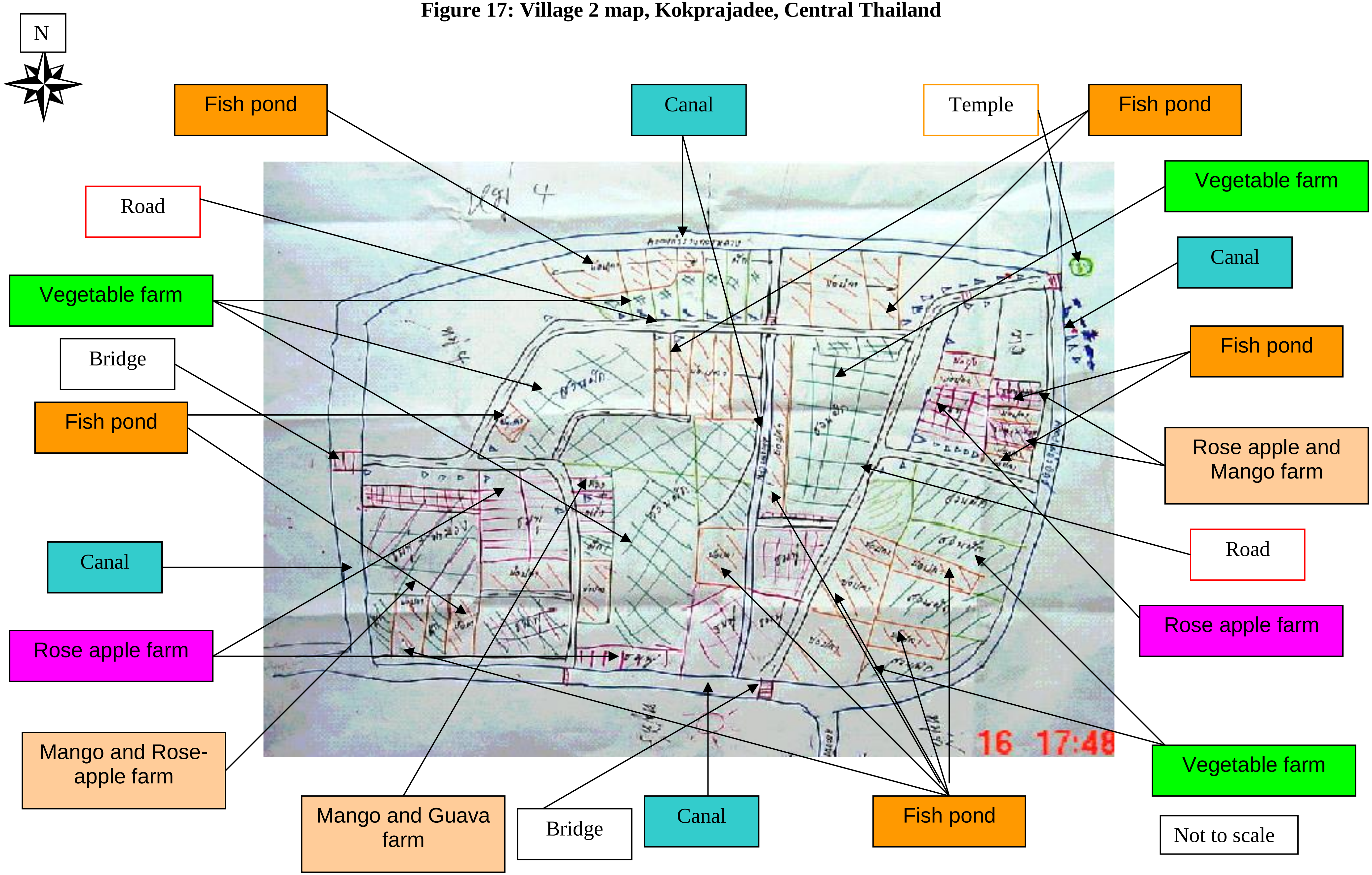
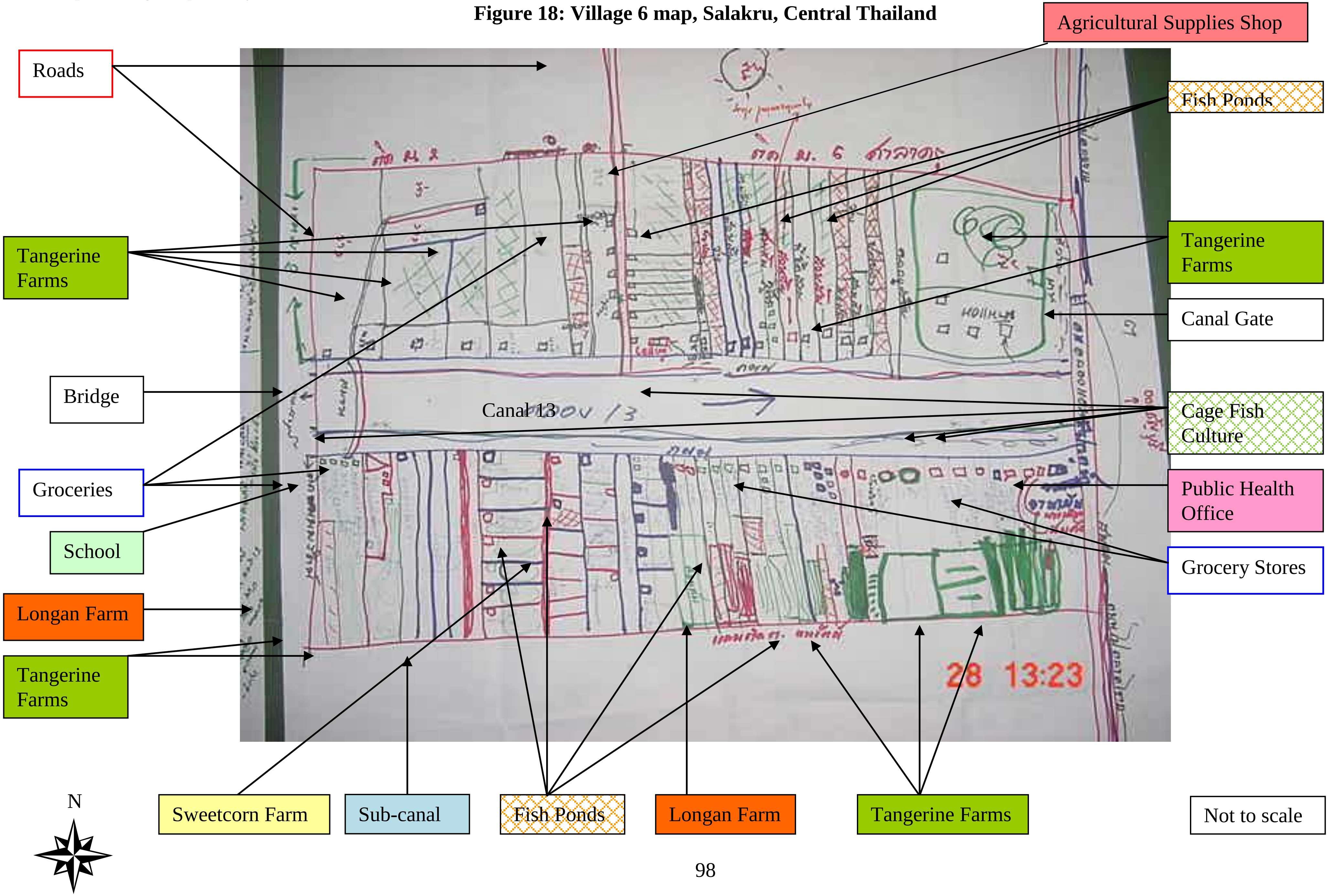


Figure 18: Village 6 map, Salakru, Central Thailand



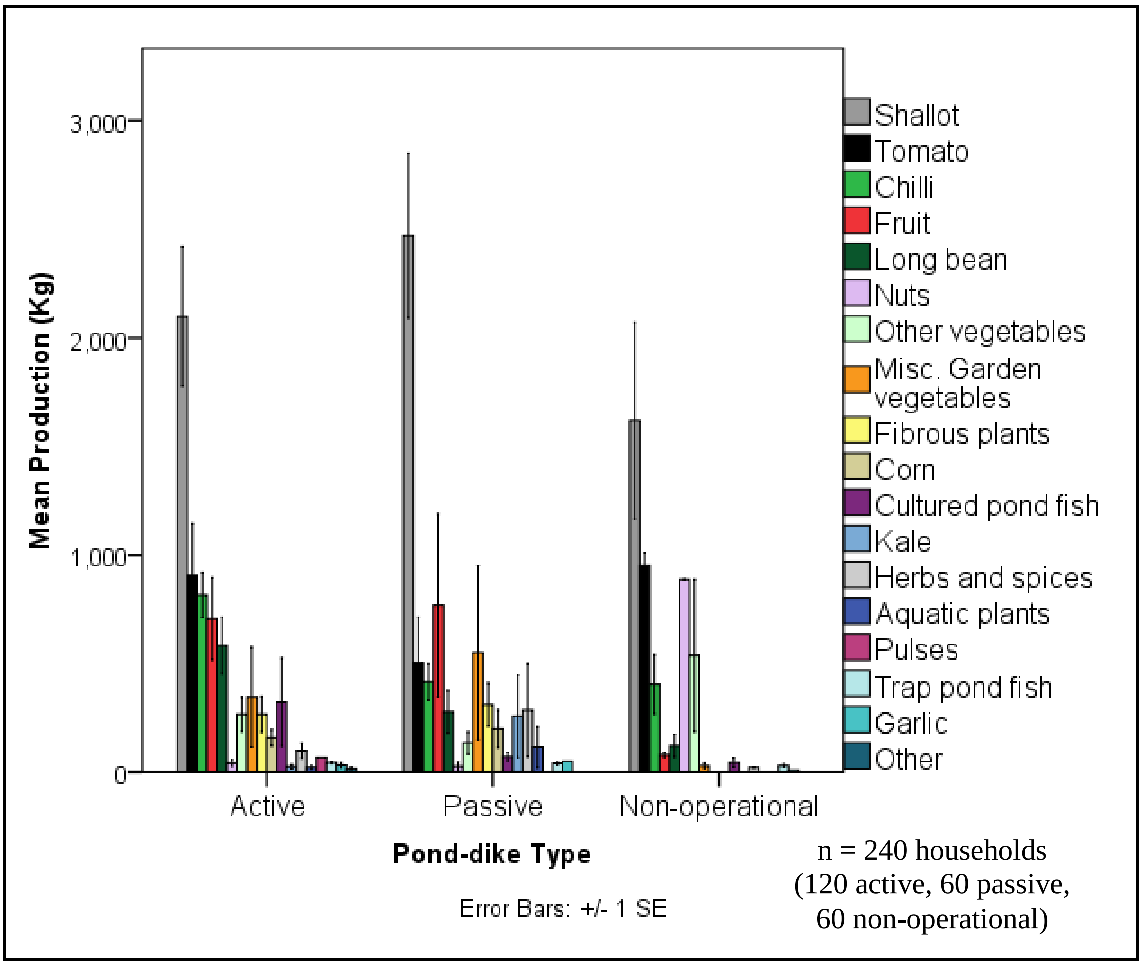


Figure 19: Mean annual household horticultural and aquatic crop production by pond-dike type, Sisaket, Northeast Thailand

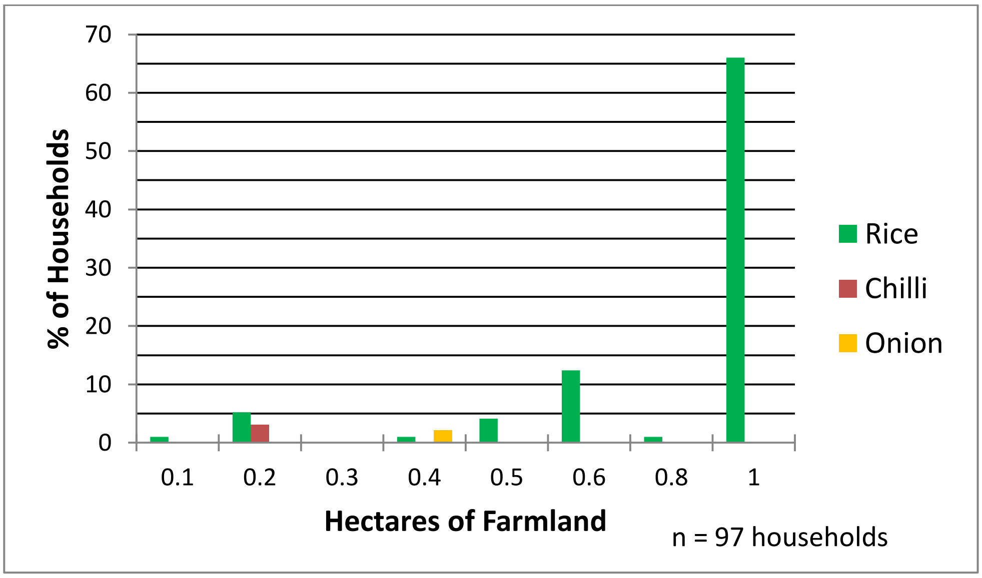


Figure 20: Area of crops grown of studied households during *Maha*, Sri Lanka

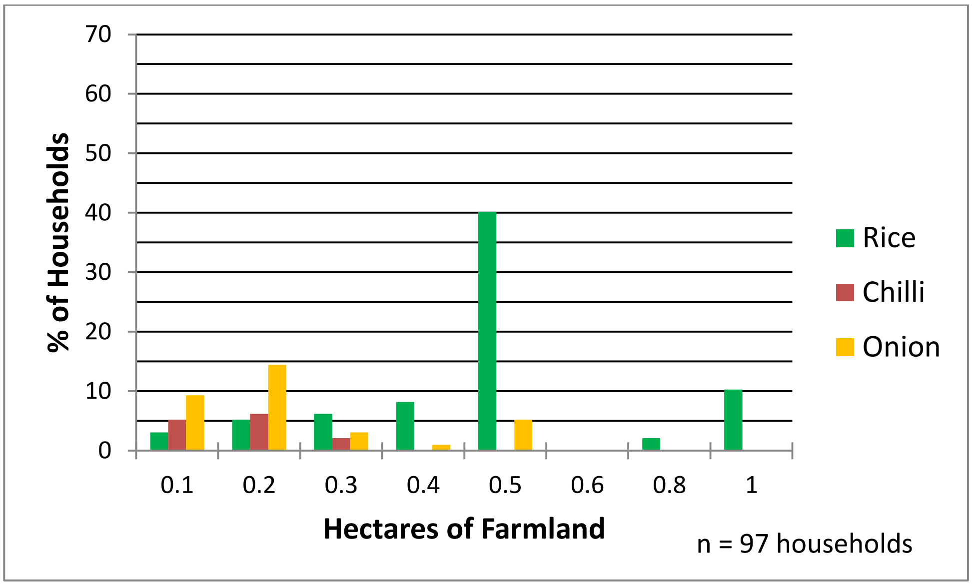


Figure 21: Area of crops grown of studied households during *Yala*, Sri Lanka

3.2.3 Seasonality

3.2.3.1 Central Thailand

For Kokprajadee, a village seasonal calendar for worse-off people (Figure 22) shows vegetables grown all year in 1-2 monthly cycles with greater pest problems and pesticide use during the rainy season. Subsistence fish culture was commonly practiced in farm canals, however, fishing of other canals further supplements household food supplies throughout the year. More intensive commercial cage fish culture and pond fish culture provides income throughout the year. Seasonal colds were the only community health concerns mentioned by respondents.

For Salakru, a village seasonal calendar for worse-off people (Figure 23) shows crop disease problems in drier months and insect pest problems being most severe in the rainy season, the latter season being the period when pesticide is applied most frequently. Subsistence farm canal fish culture, commercial cage culture and fishing of other canals are common for most of the year. Health and social problems included colds, road accidents and drug abuse amongst farm labourers.

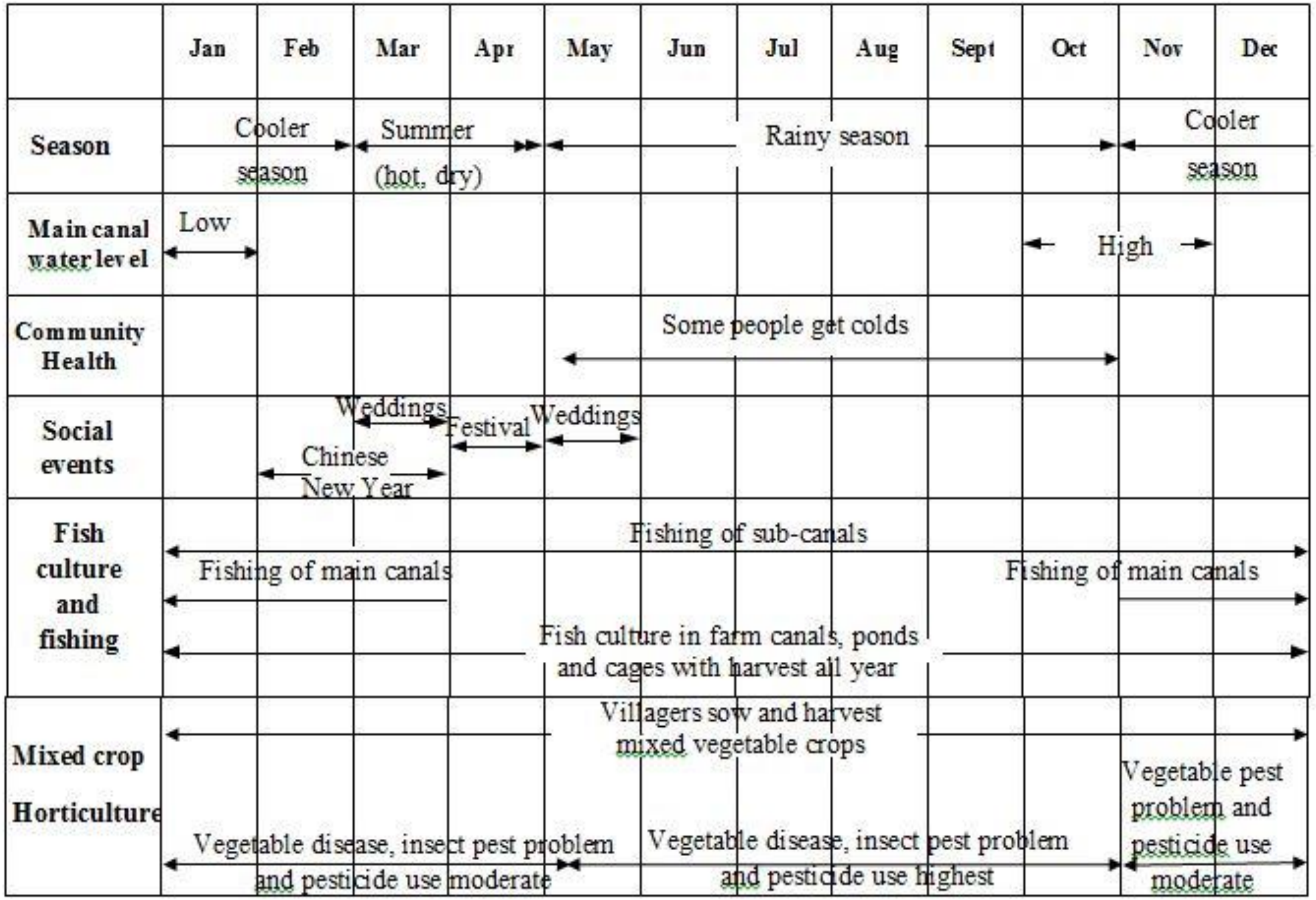


Figure 22: Seasonal calendar of worse-off groups, village 3, Kokprajadee

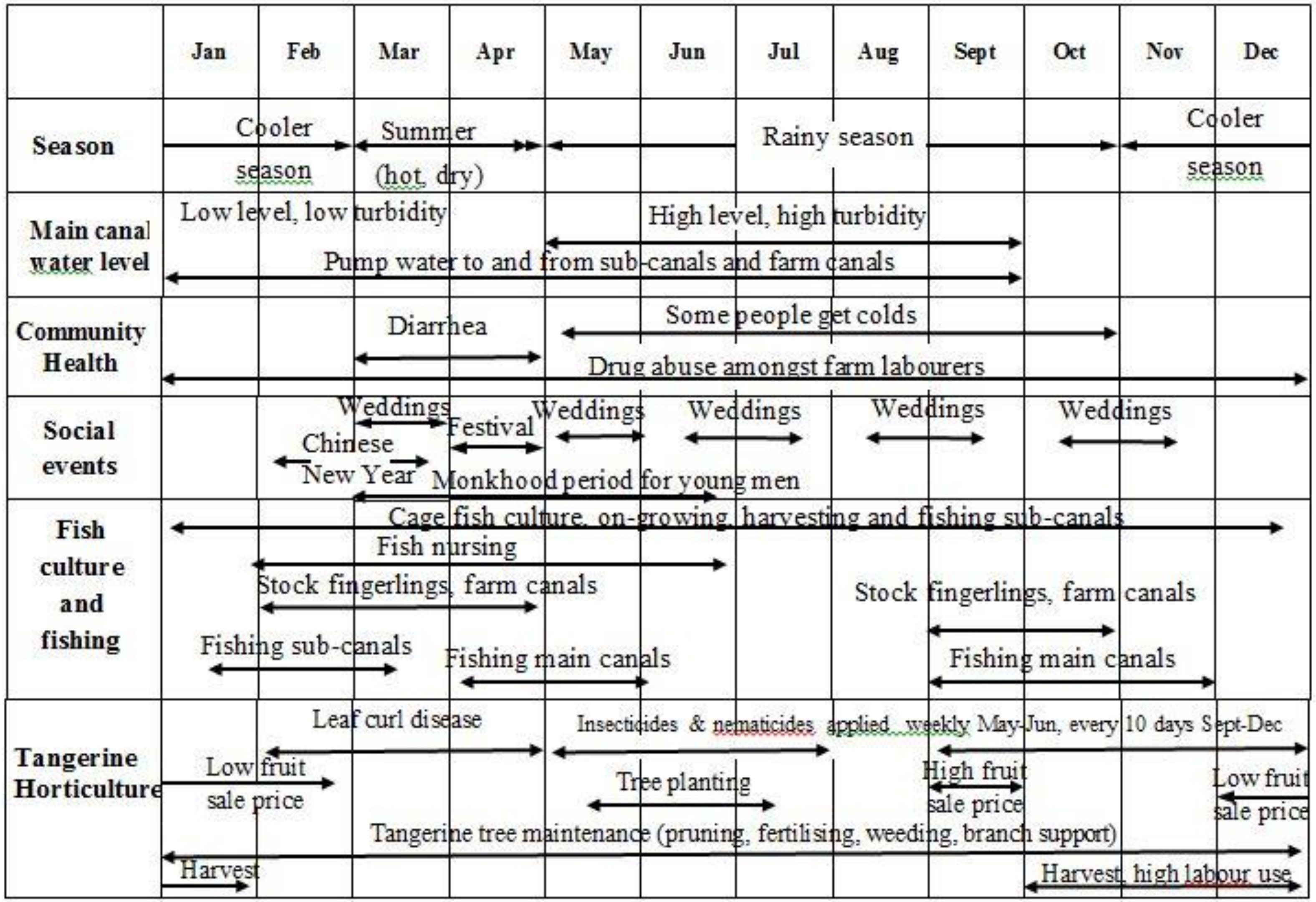


Figure 23: Seasonal calendar of worse-off groups, village 6, Salakru

3.2.3.1 Northeast Thailand

Seasonal activities in Sisaket study sites were largely dictated by seasonal rainfall being largely rain-fed systems; chilli cultivation was more suited to the dry season and fish trapping during the rainy season. Figure 24 shows seasonal activities of better-off and worse-off 'active' pond-dike household members over 10 years old. Activities pertaining to well-being status and contribution or exposure to pesticide hazard were included and were undertaken during most months. Sample sizes vary, however, only better-off people stocked fish fry in their ponds. Overall, pesticide application was more common amongst better-off than worse-off people for most months of the year suggesting a correlation of ability to pay and pesticide use, which was least frequent during the hottest month, April. The collection of wild food and aquatic animals occurred throughout the year but was highest at the height of the rainy season (Sept-Oct) and practiced more by worse-off people who were also more dependent on daily wage agricultural labour work placing them at greatest exposure to pesticides.

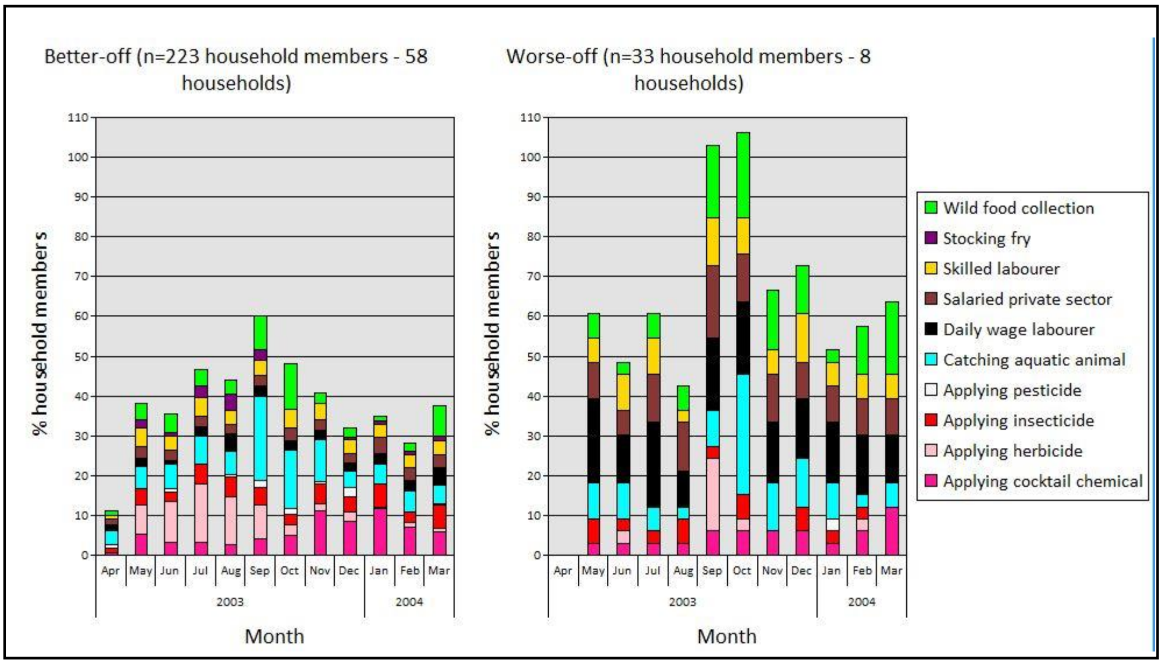


Figure 24: Seasonal activities of household members (>10 years) by well-being, Sisaket

3.2.3.2 Sri Lanka

Seasonal activities in Sri Lankan sites are dictated largely by the two seasons, the wet *Maha* (November to March) and dry *Yala* (May to September).

Rice was grown on most of farmers' one hectare land areas and was the main crop cultivated during *Maha* whilst chilli and onion were only grown by a few on smaller land areas (Figure 20). Worse-off people practiced labour exchange (*Aththam*) in *Maha* to reduce rice production costs. Less of farmers' total land area was used for growing rice during *Yala* than *Maha,* however, more land was used for growing chilli and onion in this season than *Maha* (Figure 21).

Seasonal calendars for better-off females in Ihala Kalankutiya (Figure 25) and worse-off females in Kuratiyawa (Figure 26) illustrate the main season defining factors. Rice is grown during *Maha,* however, pest problems and pesticide use is highest during *Yala* on OFCs and better-off people hire worse-off people for field work during this time. Worse-off people also noted more health problems and less work availability during *Yala* than *Maha* (undertaking other income generating activities like brick-making). With declining water levels after *Yala*, fish were more obtainable. From December to January (*Maha*) poorer people experienced food scarcity and took loans when food prices were highest, but managed finances more poorly with overspending after seasonal harvests, whilst the better-off people were more prudent, storing rice for sale when prices were higher.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	Maha rain		Yala rain (light rain)					Nikini rain		Maha Rain		
Cultivation Season	Maha		Yala							Maha		
Crop production	Maha rice production			Yala Season Chilli, Rice, Onion, Cowpea						Maha rice production		
Social events				Sinhala New year and Wesak festival						Buddhist festivals		
Hired labour		Rice harvesting			Chilli and onion land preparation							
Pesticide and fertiliser use						High				High		
Water level in tanks				High						High		
Elephant attacks												

Figure 25: Seasonal calendar, better-off females, Ihala Kalankutiya, Sri Lanka

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain fall	Maha rain		Yala rain (light rain)					Nikini rain			Maha rain	
Cultivation Season	Maha						Yala				Maha	
Rice cultivation							Half of land area					
OFC cultivation							Half of land area			Little land used		
Water Availability	Rationed water use						Rationed water use (50% *Bethma*)					
Social events				Sinhala New Year and Wesak festival								
Crop pest and weed problems	Rice insect pests					Insect pests and weeds						
Pesticide usage	Low					High						
Health problems					Diarrhea					Malaria and Flu		
ALternative employment availability	High					Low				High		
Food scarcity												
Crop sale price	High				High						High	
Farmers obtain credit or loans												

Figure 26: Seasonal calendar, worse-off females, Kuratiyawa, Sri Lanka

3.2.4 Distinguishing study site characteristics

3.2.4.1 Central Thailand

In Central Thailand the main study site distinguishing features, shaded in Table 6, included coverage of land for crop and fish production and occupation opportunities. In Kokprajadee, some village differences included shrimp culture in one village and more educated people and fish production in one village that employed people from other villages (Table 6) suggesting relationships between well-being indicators and lifestyles. In Salakru, Table 6 shows little variation in education and employment between villages, however, pond and cage fish culture was most prominent in one village and a factory in another, both providing employment in these areas.

3.2.4.2 Sisaket, Northeast Thailand

Amongst the sampled households in Sisaket the primary distinguishing factors included household pond-dike type and proximity to the urban centre. The households straddled 3 zones; the ‘peri-urban’ area at the lowest elevation above sea level and immediately surrounding the provincial town, the ‘rural’ area which sits at the highest elevation above sea level and is furthest from the provincial town and the ‘intermediate’ zone of distance from the provincial town and elevation between that of the ‘peri-urban’ and ‘rural’ areas. The peri-urban zone is closest to the town markets for trading, offering more diverse employment opportunities, and with the lowest elevation has more groundwater and active pond-dikes with commercial ability (Figure 27). In contrast households in the rural area furthest from the town markets, mainly do labouring work and with the highest elevation the lowest groundwater availability. The main site variations are shaded and summarised in Table 7.

Table 6: Distinguishing study site characteristics for Central Thailand

	Kokprajadee Sub-district, Nakhorn Pathom Province			**Salakru Sub-district, Pathumthani Province**		
	VILLAGE 2	**VILLAGE 3**	**VILLAGE 4**	**VILLAGE 6**	**VILLAGE 7**	**VILLAGE 1**
Land Use	Mainly mixed fruit and vegetables and pond-fish culture			Mainly tangerine production		
	More fish culture	Little rice production. Saltwater shrimp farm.	Pond-fish culture prominent and cage culture in canal 13.	Few fish ponds. More amenities	No fish farming. Temple.	Factory present
Education Status	Most people educated to primary class 4			Most people educated to primary class 4 -6, then middle school grades 1-3. Few people have Bachelor degrees.		
	More higher educated people					
Occupation Status	Most are on / off farm labourers, then farming and gov't work.	1/3 of people are vegetable farmers. Some rice farmers, livestock farmers, labourers and gov't work.		Most do farm work, then general labouring, fish culture and gov't work.	Half farm tangerines, then labouring on / off tangerine farms. 30% farm vegetables Fewer rice, mushroom, fish, livestock, gov't and craft work.	Most farm tangerines, then labourers on / off tangerine farms.
		More work in fish culture	More fruit farmers			
	Better-off group: more land, incomes and occupations than worse-off who mainly do on & off-farm labour work					

Table 7: Distinguishing study site characteristics for Sisaket, Northeast Thailand

Pond-dike type	**Pond-dike importance to household**	**Crops produced**	**Production type**	**Use of pond water to irrigate crops**
Active	High – intensive use	Fish (pond) Some fruit & vegetables	Commercial then subsistence	High
Passive	Some	Mixed fruit & vegetable on dike	Mainly subsistence, sell surplus	Little
Non-operational	None – no pond management	Fruit	Subsistence	None

Zone	**Town distance**	**Groundwater**	**% AP**	**Elevation**	**Occupations**
Peri-urban	Close	High	60	Low	Farming and skilled
Intermediate	In between	Intermediate	45	Middle	Mixture
Rural	Far	Low	45	High	Mostly labour

Key: AP=active pond-dikes

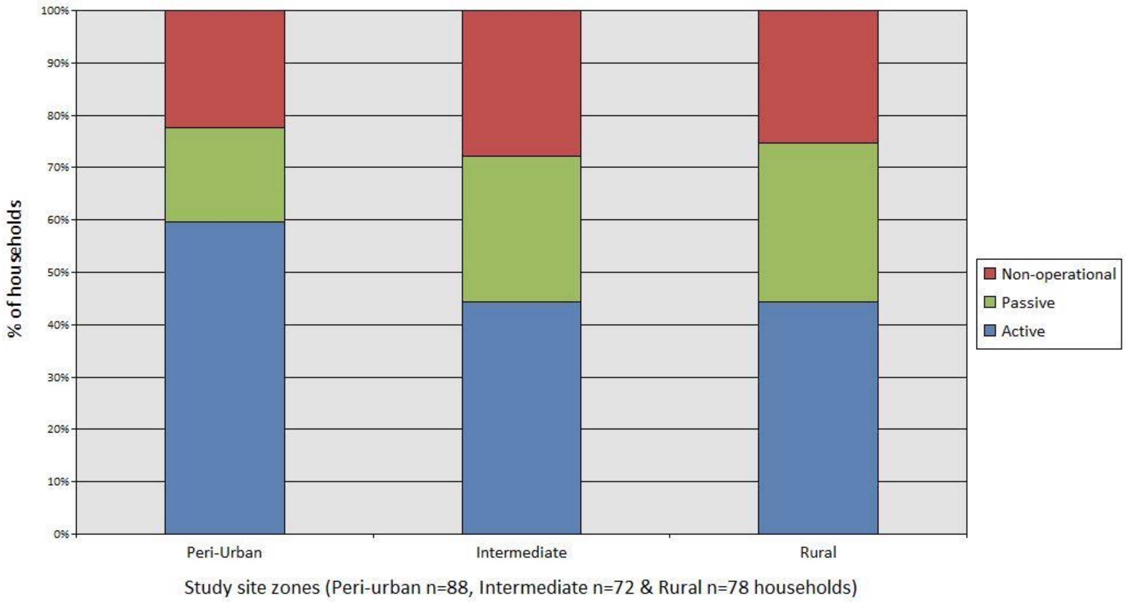


Figure 27: Study site household pond-dike type by zone, Sisaket, Northeast Thailand

3.2.4.3 Sri Lanka

In Sri Lanka, distinguishing village characteristics included irrigation water sources from their location in the catchment (Figure 28), water availability and reuse, proportion of crops grown, income opportunities and proximity to tanks for fishing and towns for trade as highlighted in Table 8. Kala Wewa tank at the top of the catchment feeds Mullanatuwa and Medellawa village plots in Block 304 of which the drainage water enters Kalankuttiya tank which in turn feeds Ihala Kalankutiya and Kuratiyawa village plots in block 308. The drainage water from these villages seeps into Meegalewa tank which also takes drainage water from farms in block 310 and block 311 and feeds Weliyawa village plots at the lowest end of the catchment (Figure 28; Table 8).

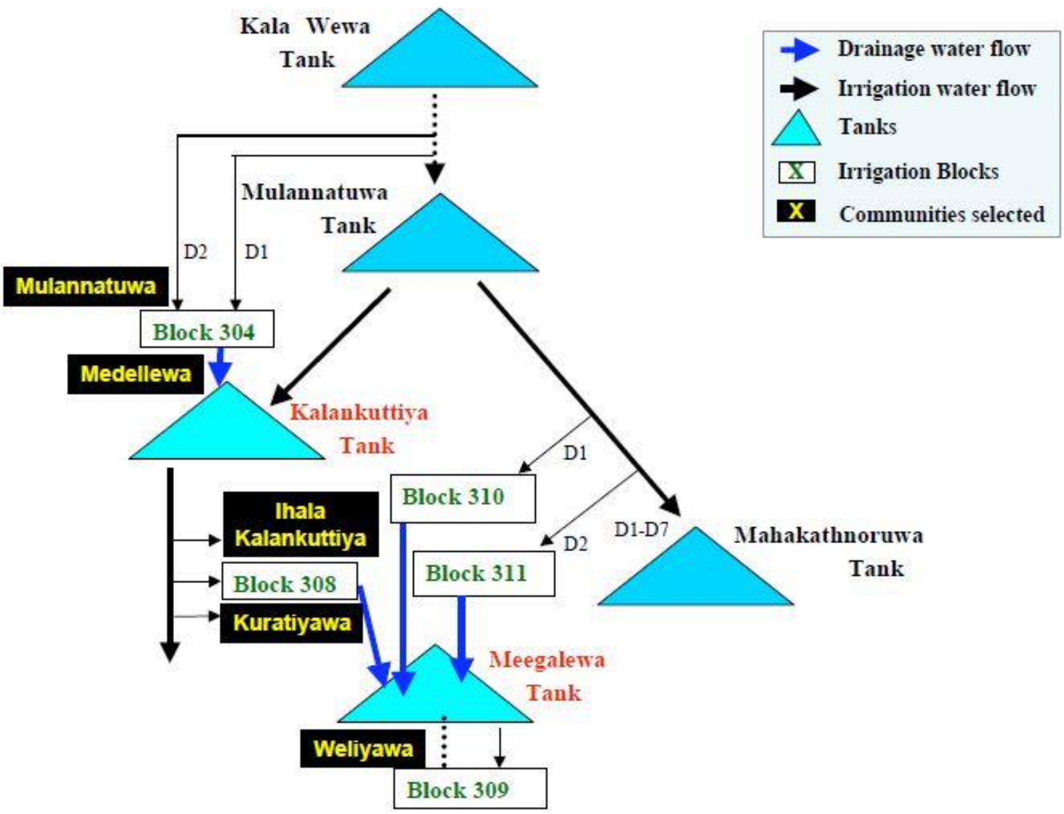


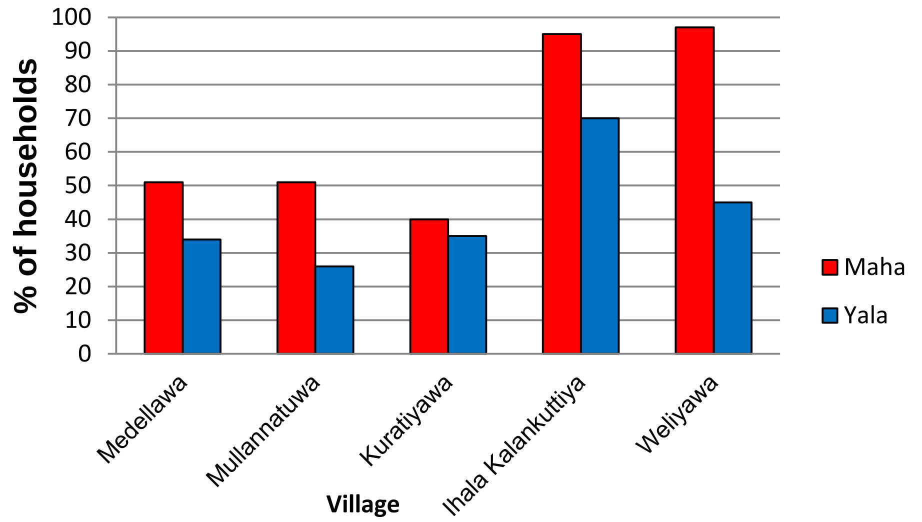
Figure 28: Study village location in catchment and irrigation system, Sri Lanka

Table 8 shows water availability to be lowest in Mullanatuwa village at the top of the catchment where more OFC were produced than rice, whilst only rice was grown year-round in Weliyawa village at the wettest bottom part of the catchment. Pumping and reuse of drainage water was only practiced by better-off people in Kuratiyawa and Ihala Kalankuttiya villages. A higher percentage of land was cultivated in both seasons in Ihala Kalankuttiya village in the middle of the catchment and Weliyawa village at the bottom of the catchment due to greater water availability (Figure 29 and Figure 30). Fishing was also practiced in Ihala Kalankuttiya and Weliyawa villages from closer proximity to perennial tanks and town centres for trade. However, additional income sources were least available in rice producing Weliyawa.

Table 8: Summary of defining village characteristics, Sri Lanka

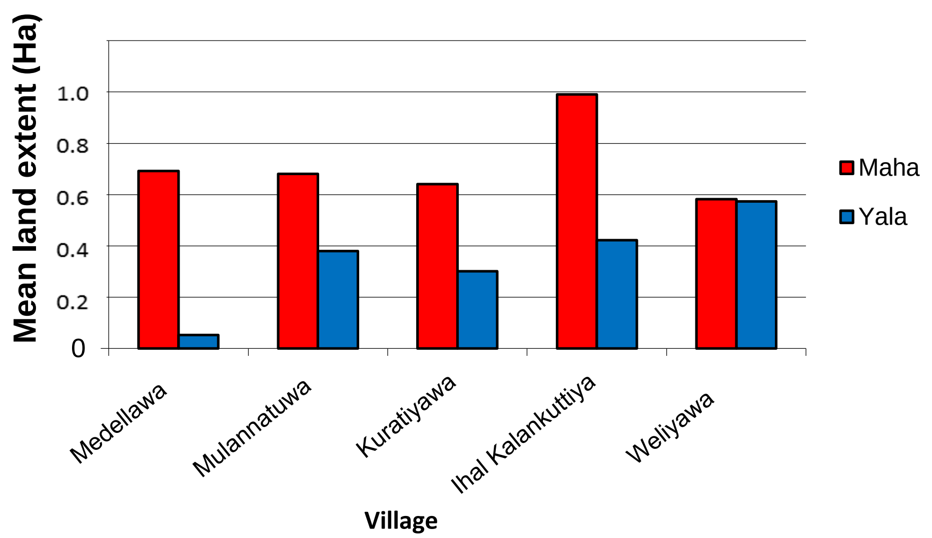
Village	**Medellewa**	**Mulanatuwa ***	**Kuratiyawa**	**Ihala Kalankuttiya**	**Weliyawa**
Block	304	304	308	308	309
Village location	Kalankuttiya catchment	Kalankuttiya catchment	Sharing Kalankuttiya & Megalewa catchment	Sharing Kalan-kuttiya & Megalewa catchment	Megalewa catchment
Tank water source	Kalawewa	Kalawewa	Kalankuttiya	Kalankuttiya	Megalewa
Effluent fate	Kalankuttiya tank	Kalankuttiya tank	Megalewa tank	Meegalewa tank	Rajangana tank
Water availability	*Maha*- High *Yala* - Low	Low	*Maha* – High *Yala* – Low	*Maha* – High *Yala* – Low	High
Effluent	Not reused	Not reused	Reused	Reused	Not reused
Cropping pattern	*Maha* – rice *Yala* – OFC, rice	*Maha* – rice, more OFC *Yala* – OFC	*Maha* – rice *Yala* – OFC, rice	*Maha* -rice, less OFC *Yala* OFC, rice	*Maha* – rice *Yala* – rice
Tank proximity	Close to Kalankuttiya	Further from Kalankuttiya	Close to Megalewa	Close to Kalankuttiya	Closer to Meegalewa
Major occupation	Farming	Farming	Farming	Farming & fishing	Farming & fishing
Town proximity	Easy access	Poor access	Poor access	Easy access	Easy access
Other work	High	High	High	High	Low
Animal husbandry	Not much	Broiler hens	Broiler hens & cattle	Broiler hens	Cattle

***** In this community, the agricultural fields are located in the Mahaweli system H and settlements are located outside Mahaweli system H.



Medellewa n=50; Mullanatuwa n=43; Kuratiyawa n=66; Ihala Kalankutiya n=30; Weliyawa n=36; total n=225 households

Figure 29: Percentage of households cultivating land by season, Sri Lanka



Medellewa n=50; Mullanatuwa n=43; Kuratiyawa n=66; Ihala Kalankutiya n=30; Weliyawa n=36; total n=225 households

Figure 30: Mean land area cultivated by households by season, Sri Lanka

3.2.5 Temporal changes in communities

Each study site community investigated specified local changes relevant to their areas with dates. Summaries of timelines from each region and overall are shown in Table 9. In each case, since the 1940s, agriculture started off as a subsistence activity, mainly rice, with fish widely available in rice fields and watercourses. Economic development, urbanisation, infrastructure and irrigation system development have encouraged expansion of settlements and agricultural development in each region. This has been the tank and channel Mahaweli H system in Sri Lanka, the river and canal system in Central Thailand and ponds in Northeast Thailand (Table 9).

Since the late 1960s Southeast Asian crop production has become more mechanised, with diversification into a variety of horticultural crops suitable for local conditions and markets**.** In Thailand this was much market and government driven (Kasem and Thapa, 2011) whilst in Sri Lanka, limited water availability was the main driver encouraging suitable chilli, onion and soy bean production under the *Bethma* and *Sri* cultivation systems to economise on water usage during *Yala* (Thiruchelvam, 2005). In Northeast Thailand sites, chilli, shallots, garlic and fruit were the main crops widely cultivated, following rice, also due to their low water requirements. In Salakru, Central Thailand, tangerine production started with incomers bringing knowledge and skills after irrigation development but the activity succumbed to disease. Leafy vegetables now predominate in Kokprajadee study sites, although other fruit and vegetables are grown (Table 9). Increased production of these higher value crops led to increased pests, diseases, more pesticide and labour use. In Central Thailand sites, immigrants from poorer neighbouring countries were often seen doing this labour work and Rigg *et al*., (2012) also notes the use of Lao immigrant workers in Northeast Thailand. Freshwater prawn (*Macrobrachium rosenbergii*) culture developed in Central Thailand and then declined due to pollution to be replaced by marine shrimp (*Penaeus monodon*) culture in some places, as also documented by Schwantes *et al*. (2009) and Little and Belton (2008). Surface water pollution locally thought due to increased pesticide use affected wild fish stocks resulting in acceleration in Thailand of the fish culture business, although less so in the largely rain-fed northeast. In Sri Lanka, similar pollution consequences were not mentioned although groundwater extraction was initiated and despite no aquaculture, principally Tilapia (*Oreochromis mossambicus*) were caught from tank fisheries. Governments in these countries now have programmes to reduce farm pesticide use.

The general sequence therefore is agricultural intensification and diversification, intensification of pesticide use, pollution of aquatic environments, persistent pest and disease problems, shift in government policy towards pesticide reduction and in the case of Central Thailand, development of aquaculture.

Table 9: Summary of timelines obtained from PCA activities in study sites

Region	**Central Thailand**		**Northeast Thailand**	**Sri Lanka**	**Summary**
Study Site	**Kokprajadee**	**Salakru**	**Sisaket**	**Mahaweli H**	
Pre 1990	Majority of farmers grew rice				New crop varieties > pumps > pesticides > water pollution (Thailand) > wild fish stock decline (Thailand) > aquaculture (Thailand) > aquaculture conversions (Thailand) > pesticide reduction focus > use of groundwater
	Fish loss in canals, unknown cause	Road and sub-canals constructed	Infrastructure development	Introduction of big onion and chilli farming	
	Water pumps came into use in horticulture	Land reform; incomers grew tangerine & mushroom, used pump	DOAE arrived, new technologies; tractors, pesticides, crop strains		
	Canals polluted; prawn to fish culture conversion, groundwater use started	Pesticide use, water polluted, fish loss and inedible	Wild fish stock decline, aquaculture promoted		
After 1990	Marine shrimp culture started, little success	Fish culture and nursing started (*Clarias* sp., hybrid catfish and Silver barb)	Jasmine rice and commercial chilli adopted. Integrated farming promoted	Additional skilled work available. Commercial OFC production and *Bethma* system	
		Tangerine loss- disease	Government focus on pesticide reduction	Agro-well and tube-well construction and Sri cultivation	

3.2.6 Livelihoods

This section examines relevant aspects of community livelihoods within the study sites with respect to well-being and contribution and exposure to the pesticide hazard in relation to horticulture. In this respect results are shown for household well-being distribution and associated household member occupations, daily and seasonal activities, firstly for Central Thailand, then Northeast Thailand and finally Sri Lanka.

3.2.6.1 Central Thailand

3.2.6.1.1 Well-being

From observations of household assets it would appear that overall Central Thailand households were materially better-off than those in Northeast Thailand with households in Sri Lanka being the poorest of the study sites. Central Thailand's household well-being distribution (Table 10) shows a less equitable and more polarised society of worse-off and better-off groups in Salakru than Kokprajadee.

Table 10: Household well-being distribution in study sites, Central Thailand

Site	Source	Better-off	Intermediate	Worse-off	Total
Salakru	No. from PCA	104	92	190	386
	% of total	27.0	23.8	**49.2**	100
Kokprajadee	No. from PCA	87	148	101	336
	% of total	25.9	**44.0**	30.1	100

In Salakru (Table 11) better-off people had tangerine farms and additional skilled employment, more material assets such as land and vehicles, were more likely to lease land, had less debt, were less likely to do farm labour and many were incomers who brought the knowledge and skills for tangerine farming. By owning more land and being wealthier this group were mostly likely to be buying pesticides for use on their farms. Worse-off people had less or no land, more debt and were more likely to be employed as on and off-farm labourers thus potentially contributing less to pesticide use but being more exposed to pesticides through farm labour work and spraying as also found by Gupta’s (2012) literature review of pesticide use, health and legal issues in Southeast Asia. The scenario was similar in Kokprajadee (Table 12) although farms were of mixed fruit and vegetables.

3.2.6.1.2 Daily activities

Examining PCA daily activity results, Table 13 shows that for Central Thailand sites men and women in each well-being group share activities in farm management and visiting markets, however, better-off people had other skilled work whilst worse-off men and women were more involved in on-farm and off-farm labour work suggesting their greater exposure to pesticides. Cultivating fish in ponds for sale and consumption was relevant to both well-being groups (Table 13) and was more prominent in Kokprajadee than in Salakru from maps of villages with most fish production in each site (Figure 17; Figure 18). However, worse-off men tended to have fish ponds more so than better-off people whilst worse-off women were involved in fish husbandry in Salakru, although only worse-off men practiced fishing in local canals, suggesting a well-being - fish production / acquisition relationship. Therefore findings suggest that worse-off people are potentially at higher risk from pesticides through farm labour and livelihoods links with aquatic organisms through consumption or business.

Table 11: Household well-being distribution and criteria, Salakru

Score Range	Well-being Group	General Grouping Criteria	No. HH in village (from PCA)
Village 1			
19-46	Better-off	Own land over 3.2 ha (20 rai), most villagers are tangerine farmers, some labour very few people in debt.	37
47-73	Between better and worst-off	Own land 0.8 – 2.4 ha (5-15 rai), most do labour work	**56**
74-100	Worst-off	Own less than 0.8 ha (5 rai) or have no land, few with land grow tangerines (mainly labourers work in own and other farms)	34
Total			**127**
Village 6			
24-47	Better-off	Own land over 4.8 ha (30 rai), tangerine farmers, have other sources of income (other businesses, lease land), very few people in debt.	26
48-71	Between better and worst-off	Own land 3.2 – 4.8 ha (20-30 rai), produce tangerines, some produce mushrooms, some lease land and more people in debt	**45**
72-95	Worst-off	Own less than 1.6 ha (10 rai) or have no land, few with land grow tangerines (mainly labourers and also off-farm work), greater proportion of people in debt.	29
Household Status Unknown			20
Total			**120**
Village 7			
30-52	Better-off	Own land approximate 4.8 ha-40 ha (30-250 Rai), most villagers are tangerine farmers. Majority of them are incomers. Not in debt.	24
55-75	Between better and worst-off	Own land 1.6 – 4.8 ha (10-30 Rai), tangerine farmer and in debt. Majority of them have pick-up trucks	**47**
77-100	Worst-off	Own land 0.8-1.6 ha (5-10 Rai) they do labour work on own and other farms, and in more debt than other groups.	38
Total			**109**

Key:HH=households

Table 12: Household well-being distribution and criteria, Kokprajadee

Score Range	Well-being Group	General Grouping Criteria	No. HH in village (from PCA)
Village 2			
31-54	Better-off	Own land 1.6-8 ha (10-50 Rai). Many occupations except labour	28
55-78	Between better-and worst-off	Own 1.6-4.8 ha (10-30 Rai) of land. Many occupations, the majority are fruit, vegetable and fish farmers, and minority do labour work	64
79-100	Worse-off	Own 0.8-1.6 ha (5-10 Rai) of land, some have no land. Practice on and off-farm labour.	**108**
Total			**200**
Village 3			
31-54	Better-off	Live very comfortably. High income, many occupations (farming, trading, governmental work, etc.). Own land > 1.6-2.4 ha (10-15 Rai)	38
55-78	Between better-and worst-off	Land less than 0.8-1.6 ha (5-10 Rai), farm labouring, live comfortably, Own 5-10 Rai of land. Practice on and off-farm labouring	**41**
79-100	Worst-off	Live less comfortably, little income, on and off-farm labouring, no land ownership	**41**
Total			**120**
Village 4			
31-54	Better-off	Live very comfortably, high income, many occupations (farming, trading, governmental work, etc.). Own land > 1.6-2.4 ha (10-15 Rai)	31
55-78	Between better- and worst-off	Land less than 0.8-1.6 ha (10 Rais), farm labouring, live comfortably, own 5-10 rais of land. Practice on and off-farm labouring	**54**
79-100	Worst-off	Live less comfortably, little income, on and off-farm labouring, no land ownership	33
Total			**118**

Key:HH=households

Table 13: Significant daily activities by well-being and gender, Central Thailand

<table>
<tr><th colspan="4">Kokprajadee</th></tr>
<tr><th></th><th>VILLAGE 2</th><th>VILLAGE 3</th><th>VILLAGE 4</th></tr>
<tr><td>Better-off groups</td><td colspan="2">Both genders do farm management and going to markets. Men do more social activities, women have less activities including housework and assisting neighbours on farms.</td><td rowspan="2">Well-being comparison not possible. Men do agricultural work and social activities. Women do housework, purchasing food and farm management.</td></tr>
<tr><td>Worse-off groups</td><td colspan="2">Both genders share activities; visiting markets, farm management, other on and off-farm labour work. Men fish in canals and women mainly do labour and household work.</td></tr>
<tr><th colspan="4">Salakru</th></tr>
<tr><th></th><th>VILLAGE 6</th><th>VILLAGE 7</th><th>VILLAGE 1</th></tr>
<tr><td>Better-off groups</td><td>Men do Government work and socialise. Women work on tangerine farms, do housework and prepare food mostly.</td><td rowspan="2">Well-being comparison not possible. Men do religious activities, visit markets, farming and tending children. Women manage own farms, do housework and visit markets.</td><td>Men manage own farms, labour, housework and visit markets. Women do housework, excluding labour.</td></tr>
<tr><td>Worse-off groups</td><td>Worse-off men had more activities and did other off-farm labour and fishing. Women did activities similar to better-off but have a greater number of major activities, including other labour and fish husbandry.</td><td>Men work on tangerine farms, visit temples and do carpentry and fishing in canals. Women do on and off farm work, housework and visit markets.</td></tr>
</table>

3.2.6.2 Sisaket, Northeast Thailand

3.2.6.2.1 Well-being

The well-being ranking criteria used by key informants are shown in Table 14 and comprise of a range of assets, many similar to those for Central Thailand. The most common criteria used to classify peoples' well-being included their land holdings, main profession, owning livestock, agricultural equipment and vehicles and housing status. Ownership of rice mills, adoption of integrated farming, agricultural income, family stability and health were additional factors.

Table 14: Well-being ranking criteria for six villages used by key informants, Sisaket

	Criteria	Number of village criteria used
Headman	1. Land holding (area)	6
	2. Main profession	6
	3. Number of cattle, buffalo owned	5
	4. Ownership of vehicles	5
	5. Condition of house	5
	6. Ownership of agricultural equipment	5
	7. Adoption of integrated farming	3
	8. Ownership of rice mill	3
	9. Income from agriculture	3
	10. Broken family/single parent family	2
	11. Health	2
Better-off villagers	1. Land holding (area)	6
	2. Main profession	6
	3. Number of cattle, buffalo owned	6
	4. Ownership of vehicles	5
	5. Condition of house	4
	6. Ownership of agricultural equipment	3
	7. Income from agriculture	3
	8. Broken family/single parent family	2
	9. Health	2
Worse-off villagers	1. Land holding (area)	6
	2. Main profession	5
	3. Number of cattle, buffalo owned	5
	4. Ownership of vehicles	5
	5. Condition of house	5
	6. Ownership of agricultural equipment	4
	7. Broken family/single parent family	2
	8. Health	2

Household survey results show a relationship between well-being and pond-dike type (Figure 31). Passive and non-operational pond-dike users were mostly worse-off whilst a greater proportion of active pond-dike owners were better-off, suggesting a positive correlation between pond-dike activity and well-being status.

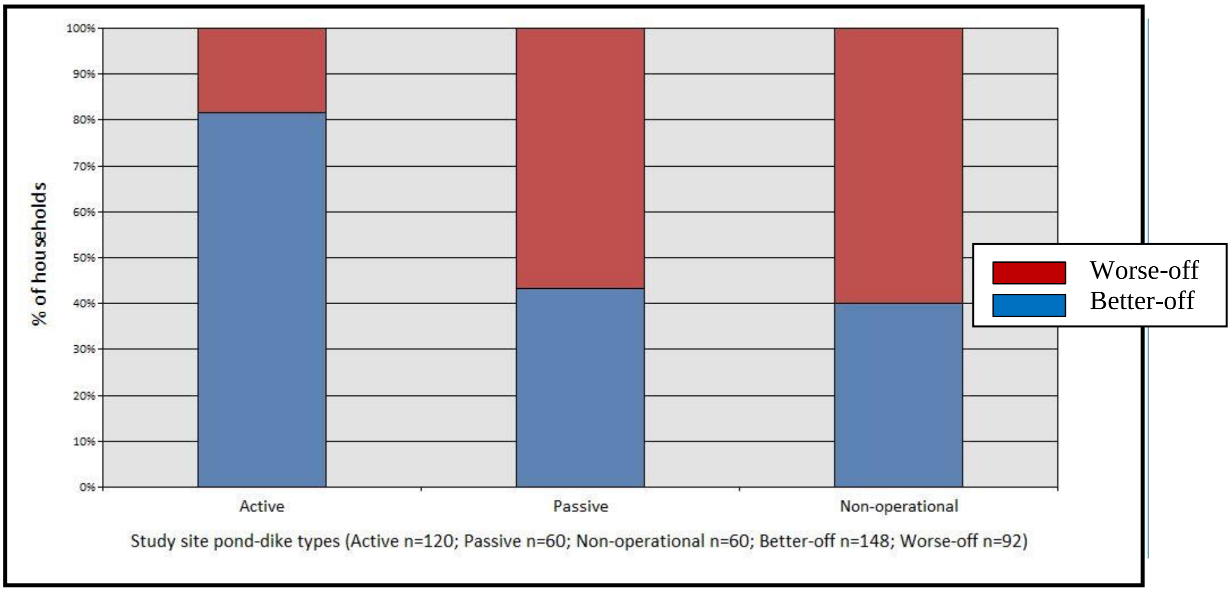


Figure 31: Household well-being by pond-dike type, Sisaket, Northeast Thailand

3.2.6.2.2 Daily activities

The most relevant daily activities by month and well-being have been described and shown in Figure 24. However, activities by well-being from PCA results are also shown in Figure 32 and Figure 33. Here, men are more engaged in commercial vegetable production than women, particularly poorer men and also those in peri-urban areas with more surface water availability due to topography and access to markets. Growing cash crops, particularly pesticide intensive chilli, was done by some better-off women in peri-urban areas near markets and rural areas, however, this was more prominent in the more water stressed latter area and by worse-off women, suggesting greater exposure in this domain. Collecting food from the environment was practiced by both well-being groups in each area although slightly more by women, whilst growing of vegetables and herbs for home consumption was mostly practiced by worse-off people. Worse-off people were most involved in labour work, particularly worse-off men and in rural areas, suggesting greater pesticide exposure there. Fish culture was practiced more by better-off people, particularly men, and fish trapping mostly by better-off women.

Again, fishing was practiced most by worse-off men, then better-off men and worse-off women (Figure 32 and Figure 33).

Figure 32: Activities of better-off and worse-off men in Sisaket, Northeast Thailand

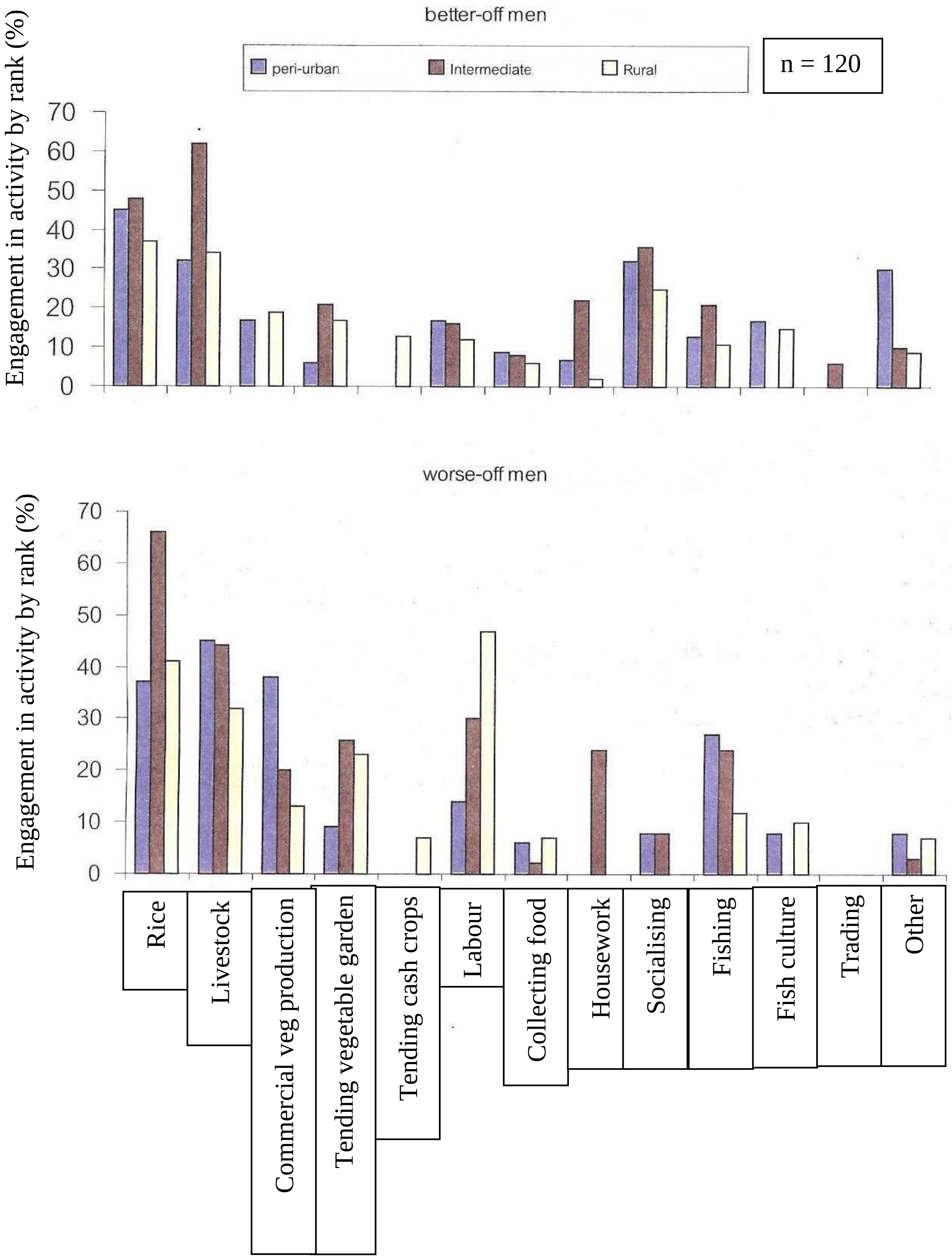
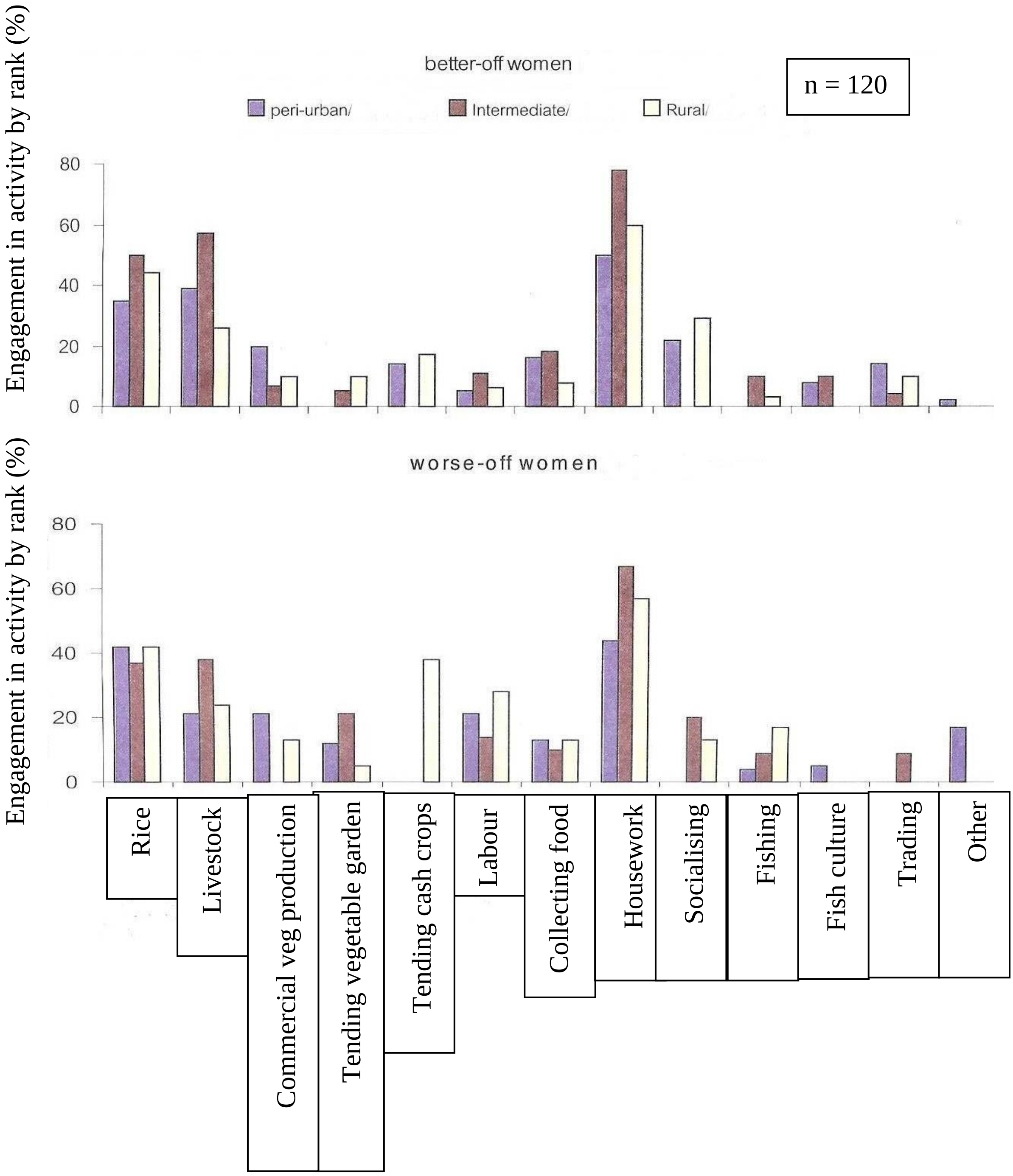


Figure 33: Activities of better-off and worse-off women in Sisaket, Northeast Thailand



3.2.6.3 Sri Lanka

3.2.6.3.1 Well-being

Looking at well-being distribution and the criteria by which people have been classed as better-off and worse-off in Sri Lanka, Table 15 shows the number of households in each village selected for well-being ranking and the villages' mean well-being rankings. Results reveal the majority of households in each Sri Lankan village to be average to worse-off.

Table 16 gives a summary of the criteria given by respondents to distinguish between well-being groups. Amongst the five villages, worse-off people were described to be dependent on the *Samurdi* scheme (subsidy to alleviate poverty), have lower education level, no permanent income, mostly involved in labouring, have smaller often incomplete housing, less land or mortgaged their lands, some alcohol addictions and less social recognition than better-off people. Better-off people also had higher permanent incomes, often owned more than one piece of land, had motorised cycles and tractors, livestock and were more likely to hire worse-off farmers for farm labour, suggesting greater pesticide exposure in this latter group. Hiring of labour was highest during the cultivation of *Yala* season crops such as chilli and onion and at the start and end of the *Maha* season during land preparation and harvesting of rice.

Table 15: Mean well-being rankings per village, Sri Lanka

Communities	Total no. of households	Mean well-being value
Ihala Kalankuttiya	96	68.9
Weliyawa	104	67.3
Mulannatuwa	148	60.7
Medellewa	183	62.9
Kuratiyawa	221	73.7

Values range from between 25 (best-off) and 100 (worst-off)

Table 16: Well-being group defining characteristics in Sri Lanka

Score range	Well-being group	Criteria used	Number of house holds
83-100 (Mu) 70-100 (Me) 79-100 (IK) 92-100 (K) 89-100 (W)	Worse off	• No stable income • Depend on Samurdi scheme (a subsidy scheme) • Lower education • Labourers • Less/mortgaged land • Poor social recognition • Poor housing facilities • Very minimum assets • Alcohol addictions	28 (Mu) 66 (Me) 18 (IK) 26 (K) 21 (W)
43-82 (Mu) 59-69 (Me) 48-80 (IK) 57-91 (K) 57-88 (W)	Average	• Moderate income • Moderate social recognition • Assets such as push bikes • Poor to adequate housing	42 (Mu) 41 (Me) 38 (IK) 139 (K) 24 (W)
25-42 (Mu) 28-58 (Me) 22-24 (IK) 28-56 (K) 33-56 (W)	Better off	• Higher permanent income • Very good social recognition • Land ownership • Hire labour (Worse-off) • Very good housing facilities with tile roof, cement floor, bath rooms etc. • Assets such as motor bikes or vehicles, tractors • Livestock	22 (Mu) 30 (Me) 20 (IK) 45 (K) 19 (W)
Household status unknown 5 (Mu), 23 (Me), 24 (IK), 8 (W)			
Total number of House holds 97 (Mu), 160 (Me), 96 (IK), 210 (K), 72 (W)			

Key: Mu=Mullannatuwa, Me=Medellewa, IK=Ihala Kalankutiya, K=Kuratiyawa, W=Weliyawa

3.2.6.3.2 Daily activities

Farming activities accounted for higher average incomes in Ihala Kalankutiya and Weliyawa due to greater water availability, whilst in the other 3 villages non-agricultural activities contributed more significantly to household incomes than farming, showing significance of irrigation water availability to livelihoods (Figure 34).

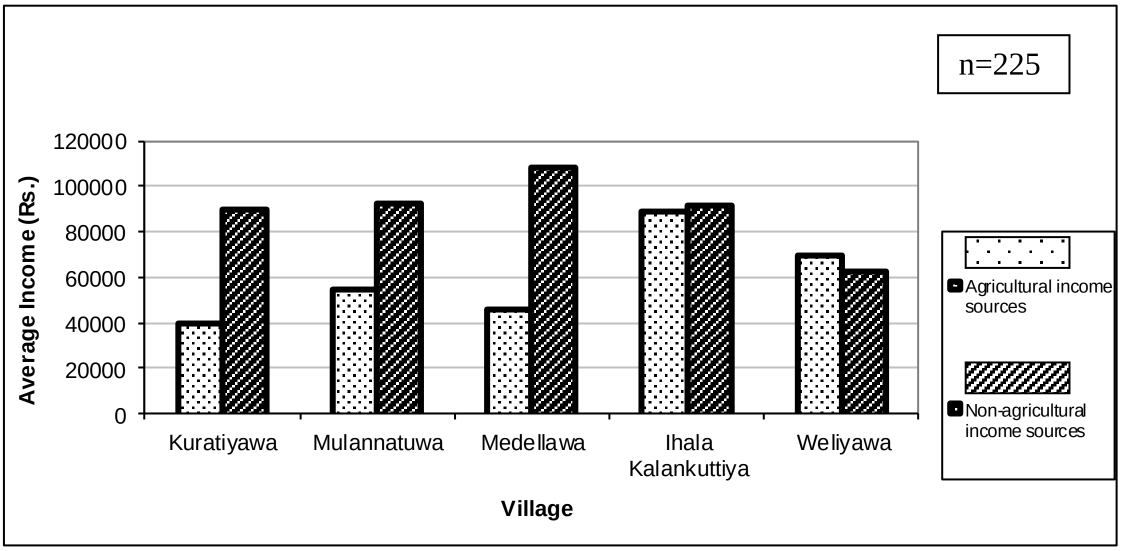


Figure 34: Average household annual income and sources in study sites, Sri Lanka

The secondary income generation activities are shown in Figure 35. Overall seven secondary income activities were described including, Government and private servant work and self-employment which was done by some people in each village, animal husbandry (all villages except Weliyawa), traders and shopkeeping (all villages except Kuratiyawa, but more prevalent in Ihala Kalankutiya being nearer major towns and roads), foreign employment (all villages except Ihala Kalankutiya and Weliyawa, suggesting water scarcity impact on employment migration) and fishing (all villages except Medellewa and Kuratiyawa). Unemployment was highlighted in Medellewa (2%) and more so in Weliyawa (17%) at the bottom of the catchment. Therefore geographical location appears to influence some secondary employment opportunities in the Sri Lankan villages and work migration also noted by Rigg (2012) in poorer communities of Northeast Thailand. Table 17 shows mean ranks of time spent on activities by well-being and gender in Sri Lanka amongst the five village study sites. More time was spent working in fields (particularly the worse-off and men), followed by bathing, washing clothes (particularly the worse-off) and fishing, whilst only worse-off people practiced shared labour.

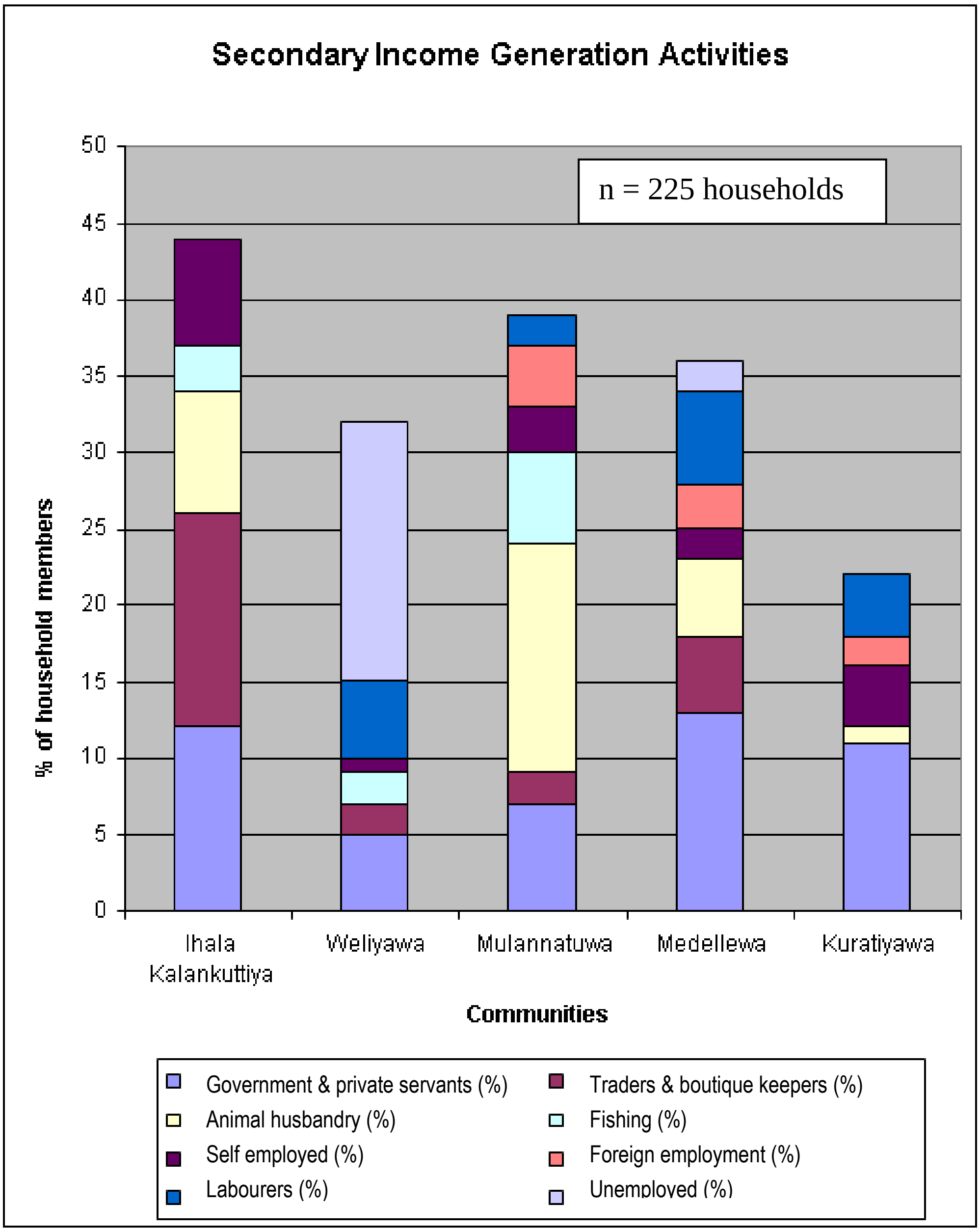


Figure 35: Household members' secondary income generation activities, Sri Lanka

Table 17: Ranking of activities by well-being and gender, Sri Lanka

	Better-off		**Mean**	**Worse-off**		**Mean**
	Men	**Women**		**Men**	**Women**	
Working in fields	5.74	2.46	**4.1**	6.6	5.48	**6.04**
Fishing	0.26	0.662	**0.461**	0.06	0	**0.03**
Bathing, washing	1.66	0.86	**1.26**	3.14	1.8	**2.47**
Shared labour	0	0	**0**	0.2	0.54	**0.37**

Key: greater rank indicates more time spent on activity.

3.3 Discussion

3.3.1 Introduction

The study sites allowed comparison of a broad range of research variants including farm scale and system outlay, geographical location, types of pesticide intensive vegetable crops grown, irrigation systems, soil type, fish production and proximity to urban centres all influencing farming community livelihoods. Seasons largely influence cropping cycles and aquatic systems with differences between the two countries; Thailand's wet season May to October and Sri Lanka's October to March, Thailand's dry season from November to April and Sri Lanka's from April to August (Van den Brink *et al.*, 2003). The discussion compares the influence of climate and agri-aquatic system characteristics on community livelihoods.

3.3.2 Agri-aquatic systems

Most of the differences between the nature of the agri-aquatic systems are related to climate, topography, soil type and water sources. The fertile alluvial deposits of the Central Thai lowlands support vast rice production which was the past main crop cultivated, (Sinsakul, 2000), however, raised crop beds irrigated by river-water via canals regulated at canal gates by the Irrigation Authority and at farm plots by farmers, have expanded horticulture (Molle *et al.*, 1999); in this case, mostly mixed fruit and vegetables in Kokprajadee and tangerines in Salakru Sub-districts. This water exchange between farms has potential implications for pesticide fate and concentrations.

Rice, fruit and vegetable production is most intense and productive in the Central region of the Thailand (Pingali, 2004) with similar trends in peri-urban horticultural expansion in other Asian countries (Lagerkvist *et al.*, 2012). The horticultural sector has also grown rapidly in North Thailand under the Ministry of Agriculture and Co-operative's wider production restructuring programme encouraging diversification into higher value crops. In this region cropping areas are smaller and growing periods shorter than irrigated Central Thailand. Growing a more diverse range of vegetable crops continually in up to two monthly cycles improves cash flow, reduces risk from market price fluctuations and creates farm labour opportunities, however, as observed on site, these highly pest vulnerable crops receive greater amounts of pesticides applied frequently throughout the year (Jungbluth, 2000; Kasem & Thapa, 2011; Schreinemachers *et al*., 2011).

Fish culture in Central Thailand has co-developed with diversification of agriculture since the 1970s and accounts for 58% of national output of cultured freshwater fish (Belton & Little 2008). In the study sites fish are often cultured in farm canals for weed control and local consumption, whilst pond fish nursing and on-growing of Nile tilapia (*Oreochromus niloticus*), rohu (*Labeo rohita*) and Common carp (*Cyprinus carpio*) were present. Cage fish culture was also common in the main canals of Salakru, whilst in Kokprajadee, interests had diversified into black tiger shrimp (*Penaeus monodon*) culture; a species that dominates 3rd in the world in value in Thailand after China and India (Schwantes *et al*., 2009) with the inland Central region accounting for 40-50% of Thailand's shrimp production (Belton & Little, 2008). Prior to fish culture in the Central region, the principle source of fish protein for inhabitants was the floodplain fisheries of the Chao Phraya River and its tributaries (Belton & Little, 2008; Edwards *et al.*, 1983), however, from the study this resource was still valuable to worse-off people**.**

In contrast, Sisaket, in Northeast Thailand's upland plateaux has highly weathered sandy soils with lower nutrient and water holding capacities and structural instability (Suzuki *et al*., 2007). The pond-dike farming systems studied are distributed from high and dry rain-fed dependent rural areas to lower run-off accumulating peri-urban areas and have multiple uses in this area and further afield (Lo, 1996; Nhan *et al*., 2007; Prein, 2002; Tipraqsa *et al*., 2007). In these systems, ponds often service rice, fruit, vegetable, livestock and fish production with water, particularly during the dry season, whilst animal and additional fertiliser provides pond nutrition for fish culture (Setboonsarng, 2002). Crops are mostly rain-fed and apart from rice fields, chilli and other cash crops suited to the dry climate are commonly grown with continual frequent pesticide use on pond dikes. Aside from fish trapping, which is often contracted out to external catching teams for cash, pond fish culture can provide an important food and income source (Pant *et al*., 2004; Tipraqsa *et al*., 2007). Low incomes, high out-migration and high household median age limit further productivity gains and explain the more common subsistence strategies in which ponds are significant in meeting the needs of older people.

In Sri Lanka, farm sites are situated in the large-scale cascade irrigation network of ‘tanks’ and channels in the Mahaweli H catchment. Seasonal and man-made perennial ‘tanks’ store rainfall and distribute water to farm plots, of particular importance during the dry season. Water distribution in major and medium systems is the responsibility of the Irrigation Department and minor systems the Department of Agrarian Services (DAS) (Murray, 2004; Haylor, 1994), however, frequent droughts and poor irrigation management have led to uneven distribution, although in some cases private wells and agro-wells are additional water sources (Thiruchelvam, 2005). Farm effluent water, potentially containing pesticides, cascades down the system potentially increasing pollution downstream, but is sometimes pumped back by farmers to farm plots. In the Mahaweli H region during *Maha,* rice is cultivated on virtually all agricultural land, whilst during drier *Yala* a smaller proportion of land is utilised for rice and the rest for less water dependent and more pesticide intensive other field crops (OFC) grown near upland homesteads (*Bethma* cultivation to ration water). These OFC crops typically comprise of a combination of chilli, onion, soyabean, pulses and other vegetables. Cattle husbandry was also included in some households' farming practices. The members of worse-off households within communities often helped each other with farm work (labour exchange) during labour intensive times of the year to reduce household crop production costs (Thiruchelvam, 2005). In the Mahaweli H, production of OFCs during *Yala* has increased from 39% of the area in 1997 to 70% in 2004 with apparent negative economic effects from chemical overuse (Thiruchelvam, 2005). Whilst rice was mainly for home consumption the OFCs were destined for markets raising issues of food safety.

Although fish culture was not present, fishing in perennial tanks was common by people in three villages, Ihala Kalankutiya, Mulannatuwa and Weliyawa, providing important income for poorer fishermen and food for community households (Murray, 2004; Murray *et al*., 2000). Ihala Kalankutiya was in close proximity to Kalankutiya tank as a fish source in the middle of the catchment and to major towns and the main road for selling fish, whilst Mulannatuwa village was close to Mulannatuwa tank at the top of the catchment and Weliyawa close to Meegalewa tank at the base of the catchment, suggesting significance of tank and town proximity to this livelihood option as also found by Nawaratne *et al*. (2002). Mullanatuwa and Meegalewa villages also had the highest unemployment of the five villages and worse-off people of the latter often benefited from selling fish to bicycle vendors. Fishing was also an activity of worse-off males and done mainly at the start of the *Maha* rainy season and at the end of the dry *Yala* season when water levels are lowest and fish more easily caught. Therefore, physical dynamics associated with this system have important influences on community livelihoods.

3.3.3 Temporal changes

A common theme between study site farming communities were changes from subsistence to a more mechanised commercial agriculture, particularly in Thailand, including more labour and pesticide intensive cash crops for developing urban markets; a general trend amongst many Asian developing countries in the wake of the Green Revolution (Wilson, 2000; Lagerkvist *et al*., 2012; Kasem & Thapa, 2011; Rigg *et al*., 2012). Development of irrigation systems (ponds in Northeast Thailand, canals in Central Thailand and reservoirs and channels in Sri Lanka) and community infrastructure have facilitated this transition and middlemen have become involved in transporting produce to markets and sometimes provision of agricultural inputs and credit services to farmers (Rigg, 1986; Dunham, 1993). Alongside this agricultural change, community members in Central and Northeast Thailand noted wild fish stock decline, locally thought to be due to overfishing and increased pesticide use from evidence of fish kills and declining ecological diversity, with a responsive development and expansion of fish and shrimp culture (Central Thailand). Many household members have increasingly sought additional sources of income from employment in urban based industries, sometimes at considerable distance from home. Amongst better-off households, other changes with time include increased material consumption and purchase of household foods over attaining from the wild. However, increasing pest resistance, agricultural input costs and co-competition have led to increasing debt, particularly amongst worse-off farmers. The Thai Government's developing interest in reducing pesticide dependency increases with its promotion of safer food production (Kasem & Thapa, 2012) whilst in Sri Lanka there is little official support and development of the pesticide free safe food market.

3.3.4 Livelihoods

3.3.4.1 Well-being status and indicators

Comparing well-being status of study sites Central Thailand was evidently the best-off and Sri Lanka worst-off of the three regions. Amongst study sites most households were either of average well-being status or worse-off with fewer better-off. Farming is the main occupation and well-being ranking respondents mainly used household material goods, education level and employment to define community well-being status as also found by Rigg and Nattapoolwat (2001) and Rigg *et al*., (2012) in Northeast Thailand with increasing de-agrarianisation. Social and health issues were less significant well-being indicators as also noted by Jongudomkarn and Camfield (2006) for Northeast Thailand. Land productivity and irrigation water availability was also definitive in well-being classification in Sri Lanka as also found by Murray (2004) and Thiruchelvam (2005). Worse-off people had less land and farm machinery and were more likely to work in ‘on and off’ farm labour, and practice labour exchange amongst themselves, as also mentioned by Bandara (2007), whilst the better-off often had additional skilled work off-farm and were more likely to employ worse-off people to do their farm work, thus suggesting the worse-off had more involvement with pesticide use and exposure. Nawaratne *et al*., (2002) also found households often have members with many sources of income for this region.

3.3.4.2 Other livelihood influencing factors

Village location in the study areas appears to influence household well-being status in Northeast Thailand and Sri Lanka. In Sisaket, farms nearer the urban centre had more surface water resources due to topography allowing for more active pond-dike systems and greater proximity to main markets, enhancing livelihood outcomes. In contrast, less active pond-dike systems and poorer households were associated in some cases with locations in higher, drier land of more rural areas where most low-water demanding cash crops like chilli were grown and tended by worse-off women. Therefore in higher drier rural areas ponds are of greater importance. This topography - surface water availability - farm system use and productivity relationship is therefore significant and also noted in the region by Pant *et al.* (2004).

Similarly, in Sri Lanka, rice field, OFC plot and homestead position in the catchment influenced water availability and land productivity and ease of access to tanks for fish and markets for additional employment and trading as also noted by Nawaratne *et al*. (2002). Making use of topographical influence on water availability, some villages like Weliyawa with plenty water at the catchment base, practiced land lease or exchange during *Yala* rice cultivation. Natural wild resources including fish are important to poorer people's livelihoods, with seasonal fluctuations in availability following the bimodal rainfall pattern; being highest during the dry periods of February-March and July-September (*Yala*). Of Sri Lanka's larger perennial tank fisheries, 74 provide over 90% of commercial inland fisheries production (Murray *et al*., 2000), with 90% of catches comprising tilapia, and the rest, carps, snakehead, eels and tank sardines (*Ambylpharyngodon melettinus*) and 40% of the some 12,800 inland fishers depend on these tanks (Nawaratne *et al*., 2002). However, in addition, poorer subsistence fishermen also benefit from seasonal tanks' periodic provision of small volumes of fish. This sector supports livelihoods of fishermen, farmer-fishermen, a wider network of cycle and motorised fish vendors and wholesalers and is a particularly valuable income and food resource for the poorest as mentioned by Nawaratne *et al*. (2002). In Sri Lanka another well-being related significant livelihood factor was farmers' financial management skills with worse-off people less wise in managing seasonal aspects of finances than better-off people increasing their vulnerability.

3.3.4.3 Well-being status, gender, activities and pesticide exposure

There also appears to be a relationship between well-being status, gender, agricultural work and pesticide use and potential pesticide hazards amongst study sites, with only men spraying pesticide in Sri Lanka, both genders involved in Thailand and poorer people more involved in this on their own farm or employed by better-off people, with corresponding variation in health hazards as also concluded from Gupta's (2012) evaluation of pesticide use in Southeast Asia. Well-being also had relationships with pest attacks during *Yala* OFC cultivation with worse-off people having greater problems and more vulnerability resulting in greater pesticide use. Other hazards from local aquatic systems including bathing and washing clothes, particularly in Sri Lanka, and utilisation of aquatic foods were evident, the latter being most utilised by worse-off people as the better-off tended to buy more. With greater fish availability in tanks during August and September following the highest pesticide use months of June and July this potentially puts aquatic produce, its consumers and fishing dependent livelihoods (of which most are worse-off) at greater risk.

3.4 Summary

There are many similar temporal changes between the three study sites influencing pesticide hazards, however, distinctive differences between the three agri-aquatic system types, their environment and hydrology shape the nature of the hazard in each site. Farm and village location can influence productivity and further livelihood income opportunities. Community well-being is defined by various household and family assets, with poorer people, sometimes gender specific, in more occupations offering pesticide exposure, and having greater reliance on threatened wild natural resources for additional food and income.

Chapter 4 Pesticide Use, Hazards and Regulation

4.1 Introduction

This chapter addresses the second and third research questions on the influence of pesticide marketing, regulation and other motivators on pesticide use and hazards to aquatic systems and community livelihoods. Findings are presented from investigations of pesticide marketing and regulation in both countries, pesticide use relationship with crop type and household well-being status, and significance of application strategies in the study sites. Results are then presented for pesticide fate and hazards to agri-aquatic and community livelihoods with well-being distinction, from bio-resource mapping, environmental and health effect observations and TOXSWA modelling. Finally, the chapter presents findings of study site farming household heads' perceptions on pesticide necessity and associated environmental and human health hazards.

4.2 Results

The main sections that follow are 'pesticide marketing and regulation', 'pesticide use', and 'pesticide hazards to aquatic environment and livelihoods'.

4.2.1 Pesticide marketing and regulation

This section presents results of pesticide legislation and regulation, the pesticide product market and marketing strategies.

4.2.1.1 Pesticide legislation and regulation

In Thailand and Sri Lanka, new pesticide products that companies propose to import, formulate and put on the market have to be checked and tested to comply with country regulations and standards on contents and labelling and to be formally registered, following the FAO International Code of Conduct on the Distribution and Use of Pesticides (FAO, 2003). The Departments of Agriculture implement this under the Hazardous Substances Act B.E 2535 (1992) (Adulyadej, 2008) in Thailand and the Control of Pesticides Act No. 33 of 1980 (amended 1994) in Sri Lanka (FAO, 2014). After registration, legislation further stipulate standards on the production, quality, marketing and sale of agricultural pesticides (Sri Lanka) and hazardous substances that include pesticides (Thailand) to the public, under regulation by government departments.

4.2.1.1.1 Thailand

In Thailand, from semi-structured stakeholder interviews, the chief of the Agriculture Toxic Substance Division (ATSD) (of the DOA) is responsible for agricultural pesticide registration and regulation. The current legislation covers hazardous substances generally and he claimed it was insufficient in catering for the specific issues relating to pesticides, and that a more specific legislation for pesticide was needed. Results from stakeholder interviews revealed perceptions of weaknesses in pesticide registration and legislation in terms of permitting many brand names of pesticides to flood the market, low pesticide registration fees, assessment of pesticide hazard, limited government resources to implement legislation and regulation properly limiting their focus on pesticides that are most hazardous according to the World Health Organisation. This meant limited resources to inspect the large number of pesticide retailers' premises and products and sample as appropriate. The ATSD chief claimed they checked the quality of pesticides from 26 shops from March to May 2002 in ten provinces of which 16 shops were selling 17 types of pesticide (glyphosate, paraquat, atrazine, ametryn, methamidaphos, alachlor, methyl-parathion, endosulfan, phofenofos, dichlorvos, ethion, prophane-carbendazim, 4-D betyl ester, dicrtophos, cypermethrin, diuron and BPMC) of substandard quality in either content (weaker concentration of active ingredient) or package labelling (missing mandatory health and safety hazard information requirements). Similar problems of non-specific pesticide policy and legislation, presence of illegal pesticide products, inadequate regulatory strategies and resources contributing to significant environmental and health issues have also been found by Ecobichon (2001) for other developing countries.

For Thailand, inspections of pesticide formulation plants were said by pesticide producing and regulating stakeholders to be done annually where Ministry of Industry inspectors would take samples from specific products after companies were informed of visits. The Government provides accreditation and logos that inform customers of pesticide products' legitimacy and compliance with Government standards. Some pesticide producers claimed substandard and adulterated pesticide products in content and labelling are on the market, as confirmed from retail shop investigation in the study areas; some products failed to provide application and safety instructions and were sold alongside foodstuffs. Similar findings have been made by other authors (Panuwet *et al*., 2012). The ATSD chief claimed those companies that were not affiliated with any agrochemical association were notorious for business malpractice and according to the Thai Agrochemical Business Association (TABA) chief around 200 companies involved in pesticide formulation and distribution were not affiliated with an agrochemical association that aids regulation.

Many pesticides are banned in Thailand, however, in relation to regulating legal pesticide maximum residue levels on food the DOA identified material and resource constraints for inspection and sample analysis of foodstuffs certified under food safety logos and intended for the domestic and export market, limiting their efforts to the top

10 most hazardous pesticides in use in Thailand and the 13 next most hazardous pesticides on their ‘watch-list’. Panuwet *et al*. (2012) also noted this including further complications from food pesticide residue regulation responsibility being shared amongst three departments of the Ministry of Agriculture and Co-operatives and the Ministry of Public Health.

4.2.1.1.2 Sri Lanka

In Sri Lanka the Control of Pesticides Act No. 6 of (1994) (FAO, 2014) is the legislation relevant to controlling pesticides and the Registrar of Pesticides (ROP) is responsible for issuing licences for imports, formulation, packaging, distribution and sales of pesticides down to the retailer level, registration of new products and imposing rules and guidelines in relation to pesticide application; dosage and length of time advised between crop spraying and harvesting. The Act stipulates that adulterated and deteriorated products cannot be manufactured, distributed or sold and that pesticides should not be stored for sale alongside foodstuffs. It further stipulates the maximum penalties of small fines and short prison sentences for non-compliance which the ROP claimed may be insufficient to regulate this lucrative business. As with Thailand, the ROP had limited resources to properly regulate the industry, particularly at the dealer and retailer level in the checking of licences and inspection and sampling of pesticide products. Investigations with pesticide supply chain actors and study site farmers revealed unlicensed pesticide traders buying pesticide in bulk, modifying and reselling products and some retailers and dealers also operating without training and licences from the ROP. A number of the most dangerous pesticides have been banned or restricted for import and formulation, however, stakeholders noted some banned substances are still available for sale in the country as was evident from study site retailer investigations and in other developing countries by Ecobichon (2001) and Williamson *et al*. (2008).

4.2.1.2 Pesticide products and market

4.2.1.2.1 Market structure

In Sri Lanka, both the Government and private sector are involved in the pesticide business, whilst in Thailand this is solely a private sector operation. In Sri Lanka, fewer pesticide producing companies are present than in Thailand, however, in both countries the multinational corporations hold the largest share of the markets, with locally owned companies taking lower positions. The Sri Lankan pesticide market exhibits more monopolistic and oligopolistic features, where 20 of the 100 firms, including the Government Ceylon Petroleum Corporation, take the lead in a highly competitive business. These findings were also consistent with those of Staring (1984).

4.2.1.2.2 Products

Pesticides are imported either as technical grade (separate ingredients), pre-mixtures (preliminary mixing) or as formulated (active ingredients combined) or finished products (final products) (Table 18), although in Thailand paraquat is completely manufactured within the country. Most products are imported to Sri Lanka as formulated material and in the case of Thailand it varies between finished, formulated or technical grade materials requiring further formulation and they can be in either liquid, solid or powder form. Imported finished products may be sold directly in the market or may first require repacking. Most imported pesticide material requires some form of treatment or formulation to achieve the desired finished product before sale. Products can be broadly categorised into two types. The first of these are ‘specialised’ products, which are more advanced, patented and produced by multinational companies in the upper half of the market. Secondly, commodity products with expired patents are more widely produced amongst formulators and often priced cheaper than 'specialised' products in retail outlets (Staring, 1984; APO, 2002).

Table 18: Forms in which pesticides are imported to Thailand

Form of Pesticide	Description
Technical Grade	Only the raw active ingredient requiring formulation
Pre-mixture	Active ingredients undergone preliminary mixing
Formulated Product	All active ingredients are combined
Finished Product	Final finished product

(Source: Jungbluth, 2000)

4.2.1.3 Pesticide marketing and supply chains

Results for pesticide marketing, distribution and sales are provided for Thailand and Sri Lanka, with a view on their influence on pesticide use and hazards.

4.2.1.3.1 Thailand

The types and numbers of actors involved in the production, distribution and sales of pesticides in Thailand in 1999 are outlined in Table 19, with any one actor sometimes undertaking more than one activity.

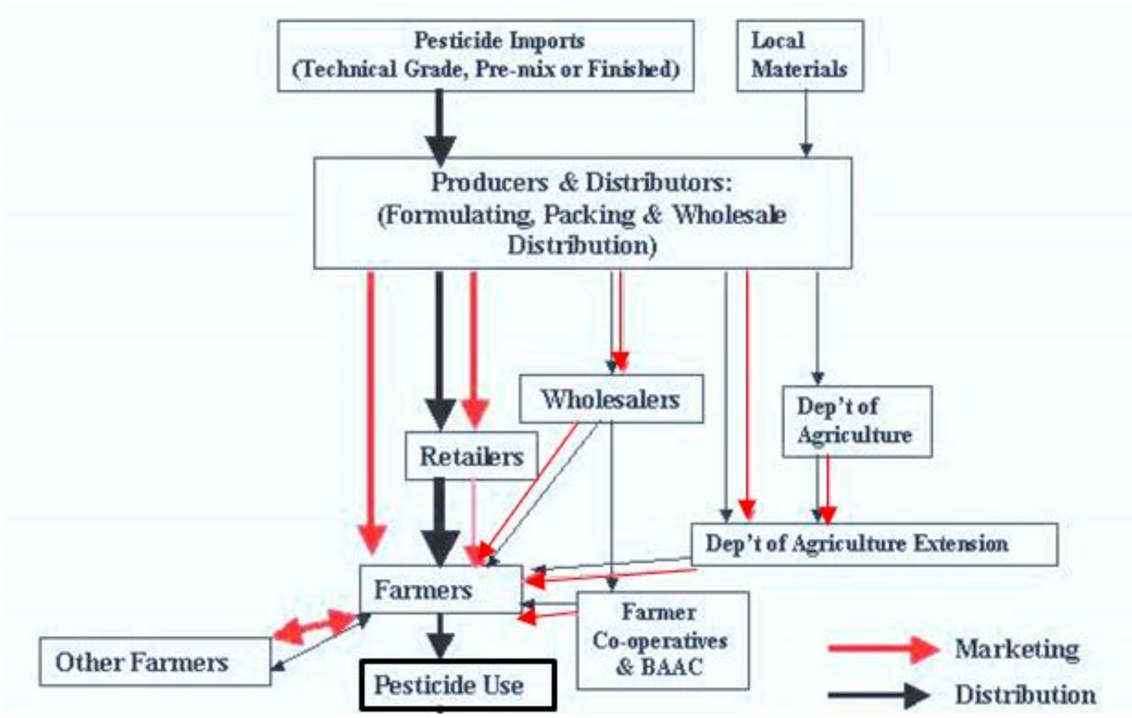
Table 19: Actors in pesticide production, distribution and sales, Thailand

Activity Associated with Agrochemicals	Number of Actors Involved
Importers of agrochemicals and/or components of agrochemicals	96
Manufacturers, formulators and/or re-packers of agrochemicals	63
Wholesalers of agrochemicals (carrying own trade names)	486
Retailers (general outlets) of agrochemicals	4, 788
Unauthorised chemical salesmen ('traders')	Not Available

(Source: Jungbluth, 2000. Original source: Thai Agricultural Regulatory Division, 1999)

The pesticide marketing and supply chain, as ascertained from stakeholder interviews, is illustrated in Figure 36 and shows that from manufacturers / formulators to wholesalers (possibly through re-packers), the majority of pesticides are distributed to retailers for purchase by farmers. Some farmers may also purchase directly from wholesalers and markets (Figure 36). The Ministry of Agriculture Co-operatives, which used to be more influential as a source of agrochemical supply to farmers, are now very weak and insignificant. The government does, however, stockpile pesticide for emergency pest outbreaks, which is available to farmers but again represents a very small percentage of the pesticide used by farmers. Despite regulatory measures other stakeholders also claimed that unauthorised (unlicensed) traders or retailers exist (Panuwet *et al*.,2012) who may obtain pesticides from as early in the production chain as the factory and occasionally these people attempt to sell pesticide directly to farmers (Figure 36). These actors are perhaps the mostly likely of all to be selling poor quality or illegal products and the number of them operating is unknown.

Many pesticide producers in the supply chain down to distributors / dealers are members of either one or more agrochemical associations which aid self-regulation. From stakeholder interviews, the private sector pesticide salesmen are the main links between pesticide producers and farmers, and discounts for bulk purchases and free items are common sales incentives throughout the supply chain. If the pesticide formulator also deals in other agricultural inputs then these may be marketed alongside pesticides. Re-branding and marketing products with similar active ingredients is responsible for the numerous brand names for similar products on the market whilst salesmen market products through village headmen, with meetings and product demonstrations in the field. Pesticide salesmen, retailers and products and more so other farmers are also farmers' main information sources on all aspects of pesticide use. This pesticide information and product marketing system and actors' roles are illustrated in Figure 36 and Figure 37. Those farmers involved in contract farming for larger companies also obtain their pesticides and other agricultural supplies from their agents.



(Arrow size indicates process significance)

Figure 36: The pesticide marketing and supply chain in Thailand

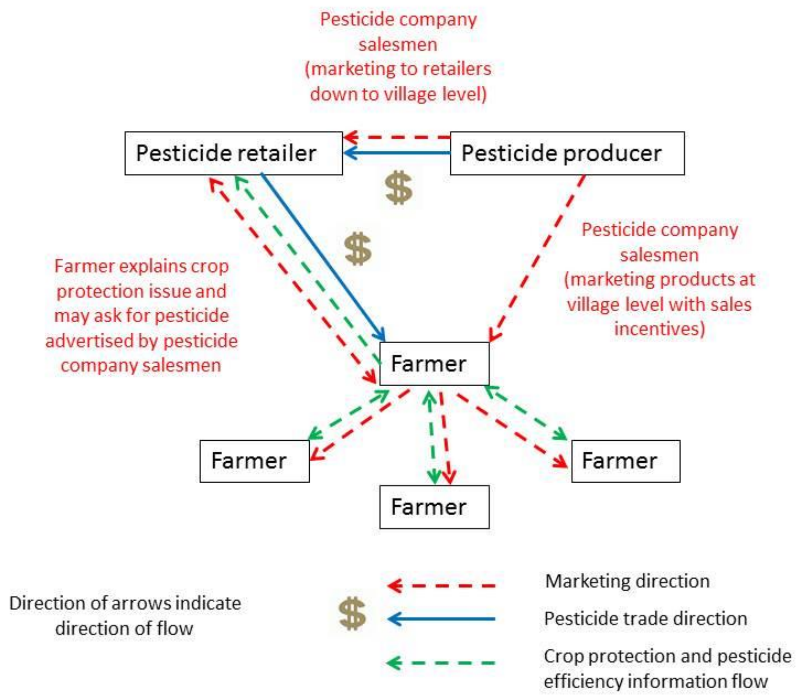


Figure 37: Crop protection and pesticide information, marketing and sales channels in Thailand

4.2.1.3.2 Sri Lanka

Stakeholder interviews allowed construction of the pesticide marketing and supply chain in Sri Lanka (Figure 38). The bulk of pesticide products that are imported and produced are distributed through agents to retailers. There are approximately 40 pesticide importers / formulators that have distributors in each district of the country, although increasingly they bypass their distributors and directly supply dealers, some of which are not authorised to sell to retailers (only district level distributors are authorised to sell to retailers) and farmers purchase pesticides through dealers or retailers. This restriction, however, does not apply to the direct dealers of the Government's Ceylon Petroleum Corporation. Stakeholder interviews also revealed that the plantation sector and Agrarian Service Centres obtain products direct from the pesticide formulator whilst some district level distributors purchase from more than one formulator. Farmer household surveys and pesticide supply chain stakeholder interviews revealed offers of discounts for bulk pesticide purchases and credit by sellers throughout the supply chain. According to the ROP, by the year 2000 about 4000 pesticide dealers had been registered and trained by their department to operate among 13 districts.

The survey of 97 households revealed a higher percentage of farmers purchased pesticides from village shops / retailers (48%), followed by village farmers and unauthorised dealers (27%), then town shops and dealers (23%) (Table 20). Most pesticide purchases were for small rather than bulk quantities. Although cash was used as payment, purchases on credit were more common with products bought from other farmers, unauthorised traders and then village shops and retailers (Table 21) suggesting a more likely use of these credit based services and suppliers by poorer famers and higher risk of illegal and poorer quality products.

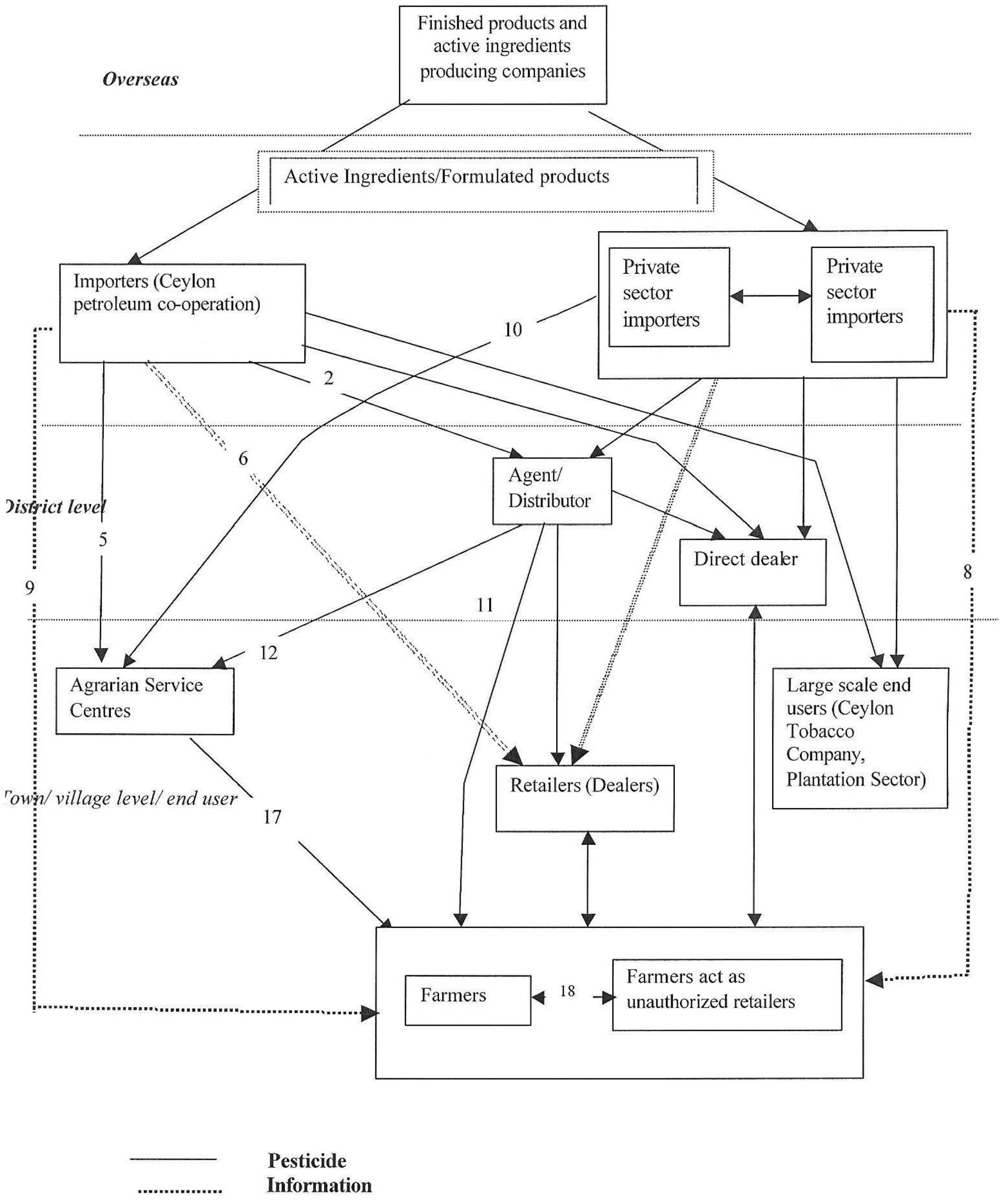


Figure 38: Pesticide market supply chain and actors involved, Sri Lanka

Table 20: Farmers' source of pesticides, household survey, Sri Lanka

Source of purchase	No. households	%
Village farmer/unauthorized dealers	27	27.3
Agrarian service center	0	0
Village shop/retailer	**48**	**48.4**
Town shops / Dealers	23	23.3
Area Agent	1	1.0
Total	99	100

(n=97)

Table 21: Farmers' pesticide purchase, household survey, Sri Lanka

Place	Paying Method	No.	%	Place	Quantity	No.	%
Village farmer / unlicensed dealers in village	Cash	11	40.7	Village farmer / unlicensed dealers in village	Small	21	21.6
	Credit	13	48.1		Bulk	6	6.2
	Pay after harvest	3	11.1		**Total**	**27**	**27.8**
	Total	**27**	**100**				
Village shop/retailer	Cash	20	41.7	Village shop/retailer	Small	27	27.9
	Credit	18	37.5		Bulk	21	21.6
	Pay after harvest	10	20.8		**Total**	**48**	**49.5**
	Total	**48**	**100**				
Town shops / Dealers	Cash	17	73.9	Town shops / Dealers	Small	15	14.4
	Credit	4	17.4		Bulk	8	8.3
	Pay after harvest	2	8.7		**Total**	**23**	**22.7**
	Total	**23**	**100**				
Area Agent	Cash	1	100	Area Agent	Small	0	1.0
	Credit	0	0		Bulk	1	0
	Pay after harvest	0	0		**Total**	**1**	**1.0**
	Total	**1**	**100**				

(n=97)

4.2.2 Pesticide use

This section presents results of pesticide use relationships with crop type, household well-being status and describes farmers' application strategies.

4.2.2.1 Pesticide use by crop type

4.2.2.1.1 Central Thailand

For Kokprajadee Sub-district, Central Thailand, PCA ranking exercises revealed the leafy vegetables Chinese kale and Chinese cabbage as the crops receiving the highest quantities of pesticides per household per year (Figure 39). Low standard errors for the majority of results indicate relatively high consistency between individual PCA groups and high confidence in results. From the household survey, Chinese kale and Chinese leek were the crops identified as receiving the highest number of pesticide active ingredients and pesticide brands (Figure 40). Chinese kale is also noted to receive particularly high amounts of pesticides from Schreinemachers *et al*. (2011) study of 295 farmers in Northern Thailand and Lagerkvist *et al*. (2012) study of 54 farmers in Kenya.

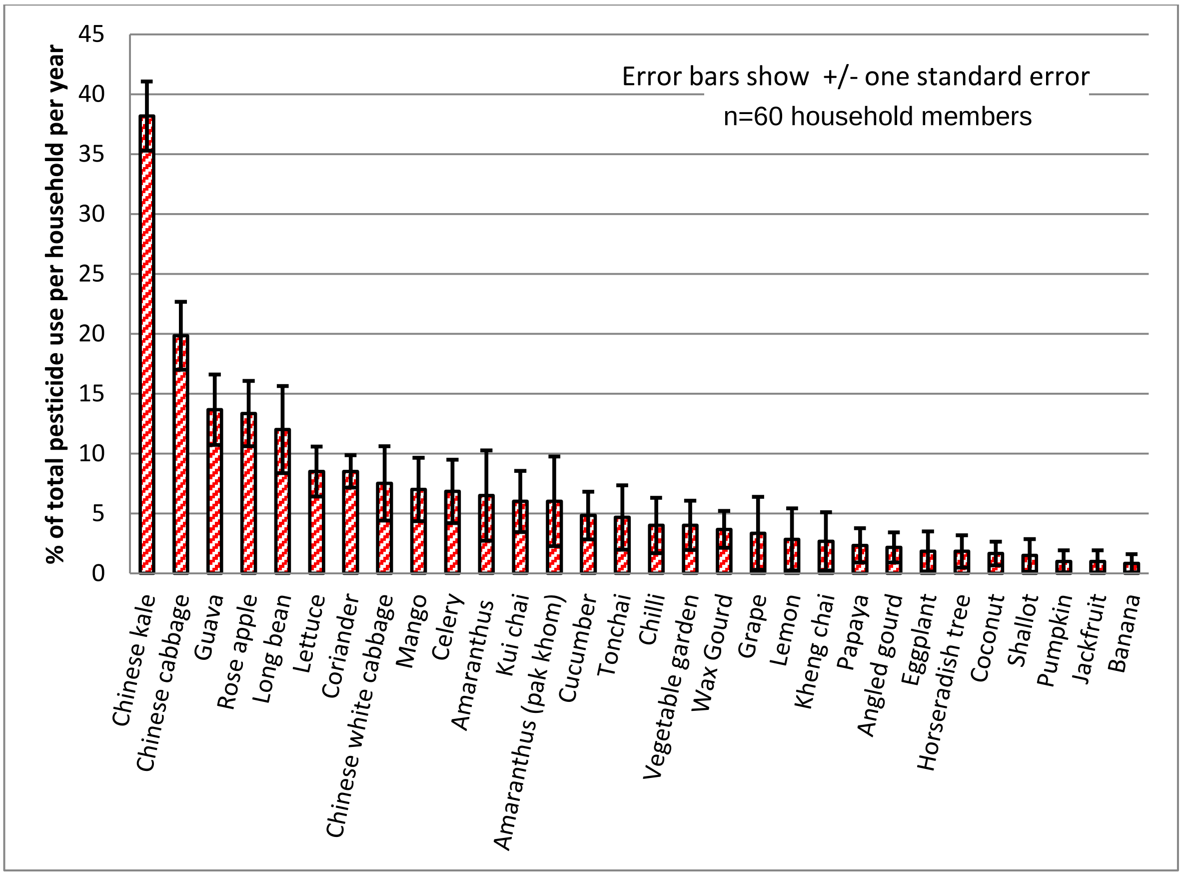


Figure 39: Mean PCA ranked pesticide use level by crop per hectare per year, Kokprajadee, Central Thailand

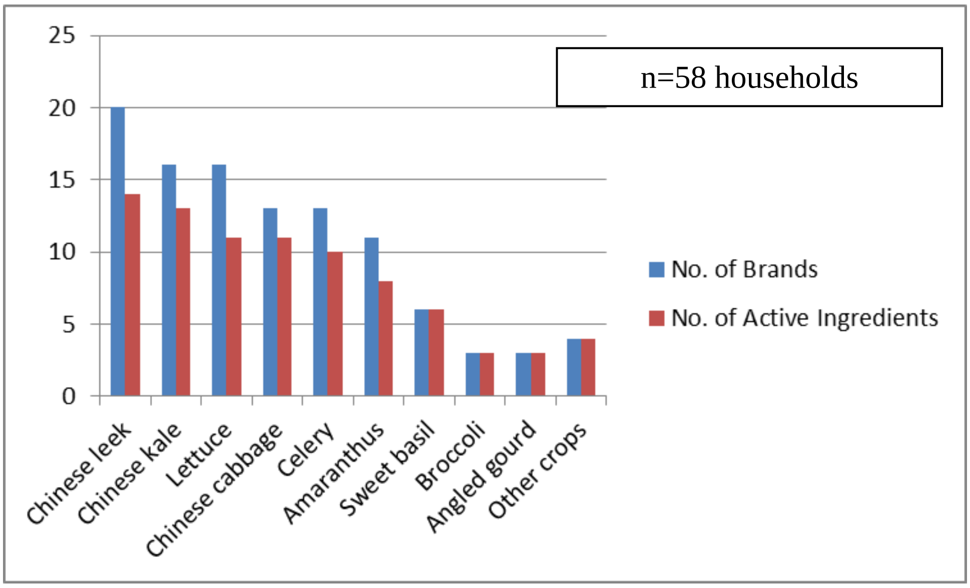


Figure 40: Number of pesticide brands and active ingredients used by crop per hectare per year in Kokprajadee, Central Thailand from household survey

From the PCA activities in Salakru Sub-district, tangerine was the crop ranked as receiving the highest quantities of pesticides per household per year (Figure 41). Again, low standard errors for the majority of results indicate relatively high consistency between individual PCA groups and high confidence in results. Results of 60 surveyed households also showed this crop to receive the highest number of pesticide active ingredients and brands (Figure 42). With the Chalermphol and Shivakoti (2009) survey of 312 tangerine growers in Northern Thailand revealing only 36% using recommended pesticide applications and the rest overusing, intensive pesticide use would appear to be common in Thai tangerine production. In Kokprajadee and Salakru, most crops were destined for ‘wet’ wholesale markets with no food pesticide residue control which suggests potentially higher health hazards to consumers of these products.

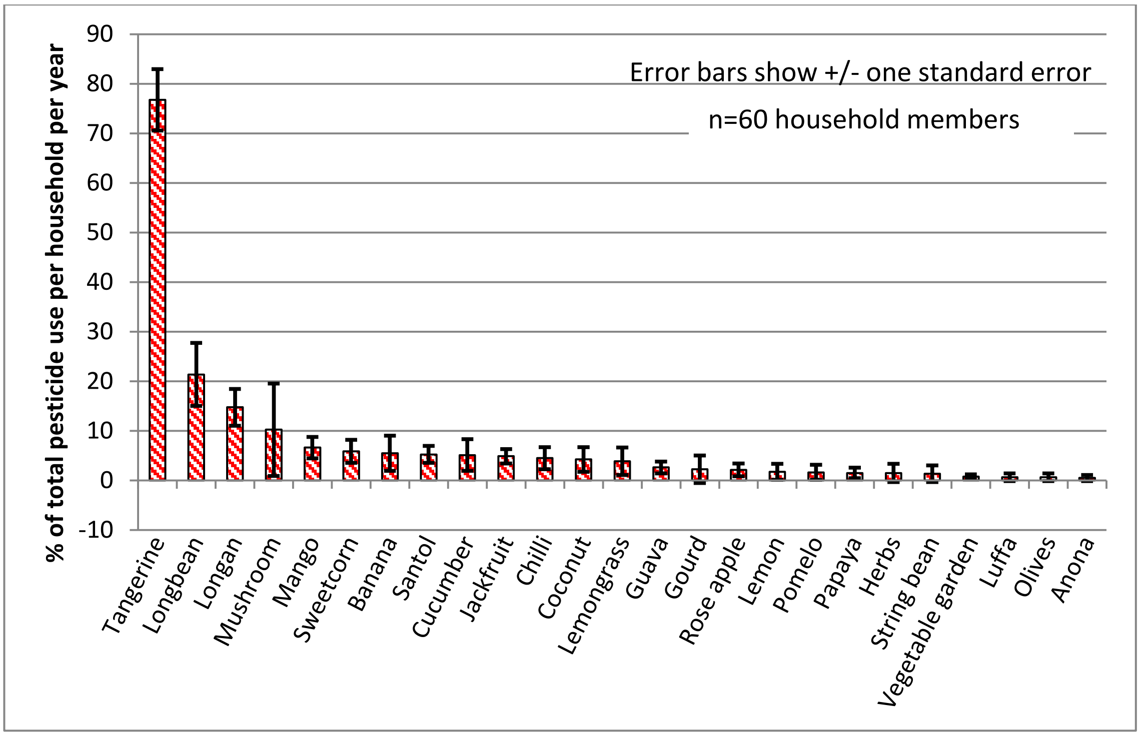


Figure 41: Mean PCA ranked pesticide use level by crop per hectare per year, Salakru, Central Thailand

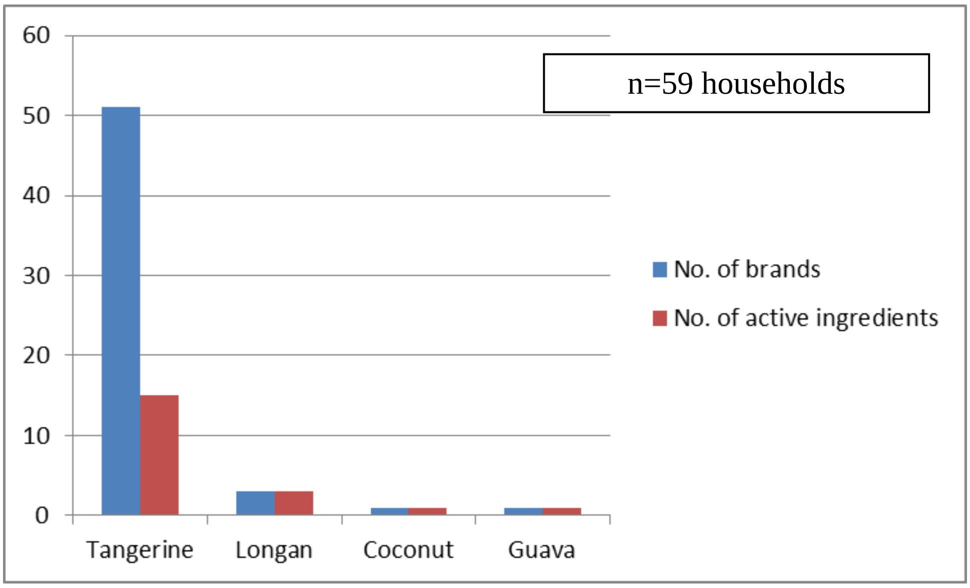


Figure 42: Number of pesticide brands and active ingredients used by crop per hectare per year in Salakru, Central Thailand from household survey

4.2.2.1.2 Northeast Thailand

In the case of pesticide use by crop type in Sisaket, information was provided by farmers on 'insecticide' and 'herbicide' usage and just 'pesticide' usage where they were unable to distinguish between their pesticide use as insecticide, herbicide, fungicide or other. From the household baseline survey it is evident that more crops received insecticide followed by herbicide (Figure 43). Examining insecticide, herbicide and pesticide application together, it is shown that chilli, shallot and fruit are the crops receiving the cumulative highest mean application frequencies. Again, low standard errors for the majority of results indicate relatively high consistency between individual PCA groups and high confidence in results. Standard error bars were highest for insecticide use on longbean and tomato due to high production of, and insecticide use on, these crops by few farmers. Similar studies of 100 farmers in Tamil Nadu by Jeyanthi and Kombairaju (2005) also found pesticide application particularly high on chilli (13 times per month) suggesting this crop's widespread high vulnerability to pests.

In terms of cumulative insecticide, herbicide and pesticide use by crop, chilli and shallot received high mean application frequencies amongst each pond-dike type, although values for fruit and longbean were also high in active pond-dike farms. Active pond-dike farms also had the greatest variety of crops, and non-operational pond-dike farms had the smallest variety of crops, receiving chemicals.

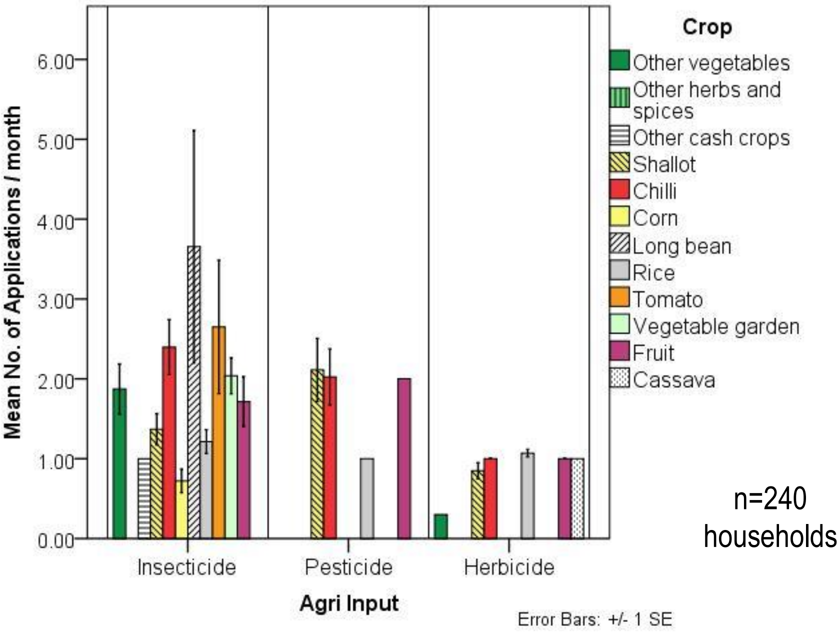
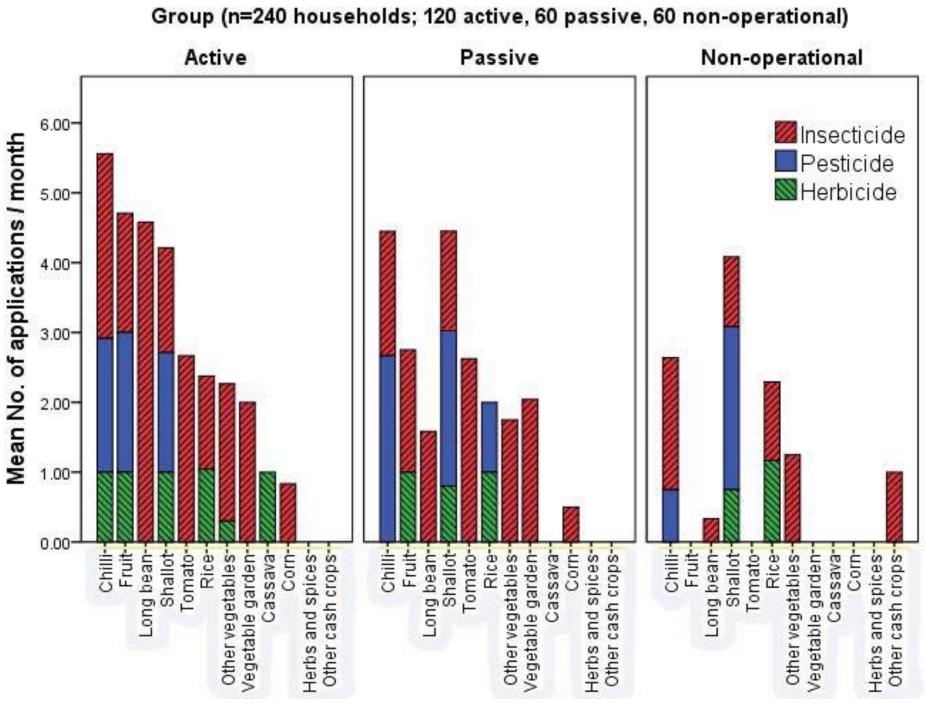


Figure 43: Mean pesticide application per month by crop, Sisaket, Northeast Thailand



Key (Figure 43 and Figure 44): 'Other vegetables' = cucumber, eggplant, mushroom, onion, pumpkin, spring onion, wax gourd, Chinese white cabbage, wild spider flower, meraber nightshade, radish, cauliflower, pak choi, gourd, chives, celery, taro, carrot, *pak nam*, *pak keeleak*, okra, yam bean. 'Other cash crops' = bitter palm, betel vine, cashew nut, groundnut, kenaf, mullbery and tobacco. Vegetable garden = small quantities of mixed vegetables for home consumption.

Figure 44: Mean pesticide applications per month by crop type and pond activity, Sisaket, Northeast Thailand

4.2.2.1.3 Sri Lanka

Figure 45 shows level of pesticide use amongst 97 farmers by crop by season. In *Yala* pesticide applications exceeded the recommended levels, particularly in chilli (55% of applications) and rice (45% of applications) but also for onion (32% of applications). Farmers claimed the reason for excessive use of pesticides on chilli was from high susceptibility to pests and diseases. However, they mentioned their reluctance on growing the crop during *Yala* 2004 and to grow onion instead, as chilli was becoming unprofitable. This was due to recurring pest resistance in chilli and resulting higher input costs of increased pesticide use, and lower sale prices from competition. A similar study by Burleigh *et al*. (1998) of 23 chilli farmers in Elle Wewa block of Northeast Sri Lanka Dry Zone also found, in each case, pest resistance and reduced pesticide efficacy. Excessive pesticide use, however, was widely practiced to reduce risk of crop loss.

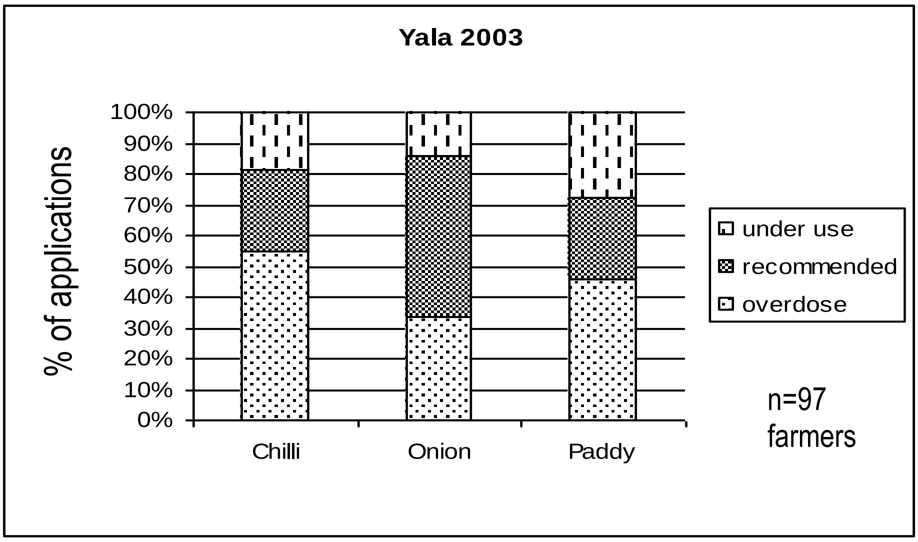


Figure 45: Pesticide application by crop during *Yala* 2003, Sri Lanka

In the 2003-2004 *Maha* season rice was the main crop grown with 54% of pesticide applications by farmers exceeding the recommended levels. Applications at recommended dosages were 33% with fewer underdoses (Figure 46).

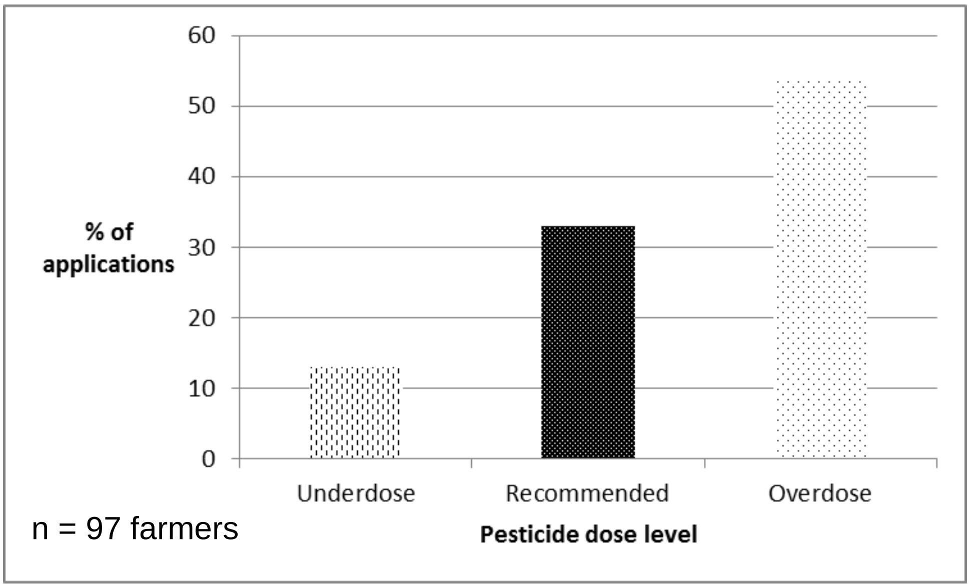


Figure 46: Pesticide application to rice during *Maha* 2003-2004, Sri Lanka

Figure 47 shows pesticide use levels on crops cultivated during *Yala* 2004. The farmers decided not to grow chilli in *Yala* 2004 for the reasons previously mentioned, growing onion instead. Excessive use of pesticide was still apparent, particularly for rice, although application below recommended dosages was more common with onion than rice. Farmers who used pesticides at less than the recommended dosage did so due to water shortages or for economic reasons to reduce additional expense on unnecessary pesticides and risk.

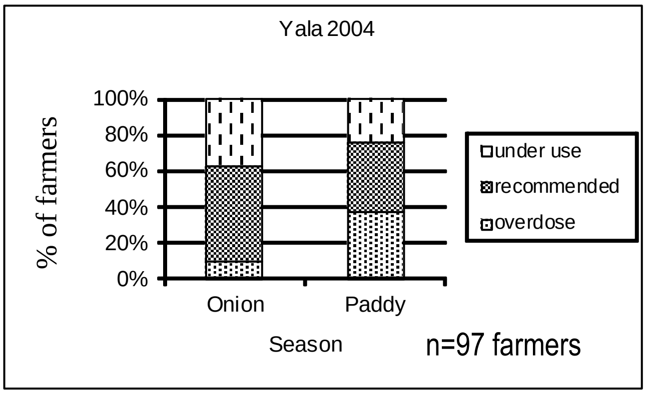


Figure 47: Pesticide application by crop during *Yala* 2004, Sri Lanka

4.2.2.2 Pesticide use by well-being

4.2.2.2.1 Central Thailand

From PCAs with 55 respondents from three Kokprajadee villages and 61 respondents from three Salakru villages, mean pesticide use level was higher for more crops for better-off people than worse-off people, however, low sample numbers limit confidence in results (Figure 48 and Figure 49). Similar well-being differentiating data could not be presented from household surveys due to unequal well-being sample sizes. However, a similar study by Rahman (2003) of 406 Bangladeshi farmers' found pesticide use level increased with farmer affluence, crop market price and credit availability.

4.2.2.2.2 Northeast Thailand

Cumulatively, mean herbicide, insecticide and pesticide applications by crop and wellbeing group varied with better-off people applying chemicals more frequently for some crops and less frequently for other crops, compared with worse-off people. Therefore, the relationship between wellbeing status and frequency of chemical application is not definitive with regards to Sisaket (Figure 50).

4.2.2.2.3 Sri Lanka

Household survey results for Sri Lanka revealed excessive use of pesticides was more frequent amongst worse-off than better-off households, the reason being that worse-off farmers were more fearful of crop loss from pests and perceived the risk to be reduced by pesticide use above recommended levels. Recommended dosages were more frequently used for rice whereas chilli and onion received higher than recommended dosages due to greater pest problems. Use of pesticide cocktails was also practiced by the majority of households and more so by worse-off than better-off households, again related to fear of crop loss (Figure 51).

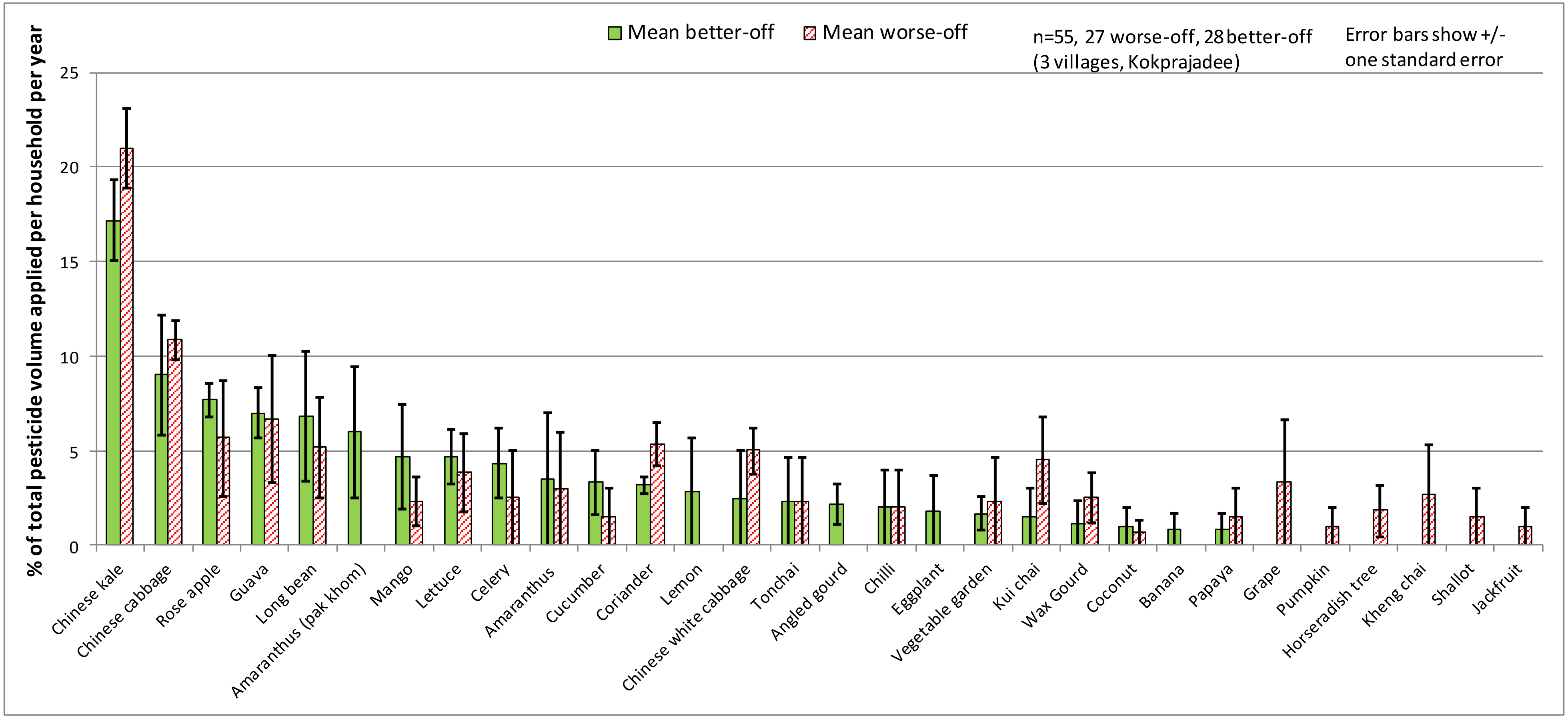


Figure 48: Mean rank of level of pesticide use by crop, per hectare, per year and well-being from PCA, Kokprajadee, Central Thailand

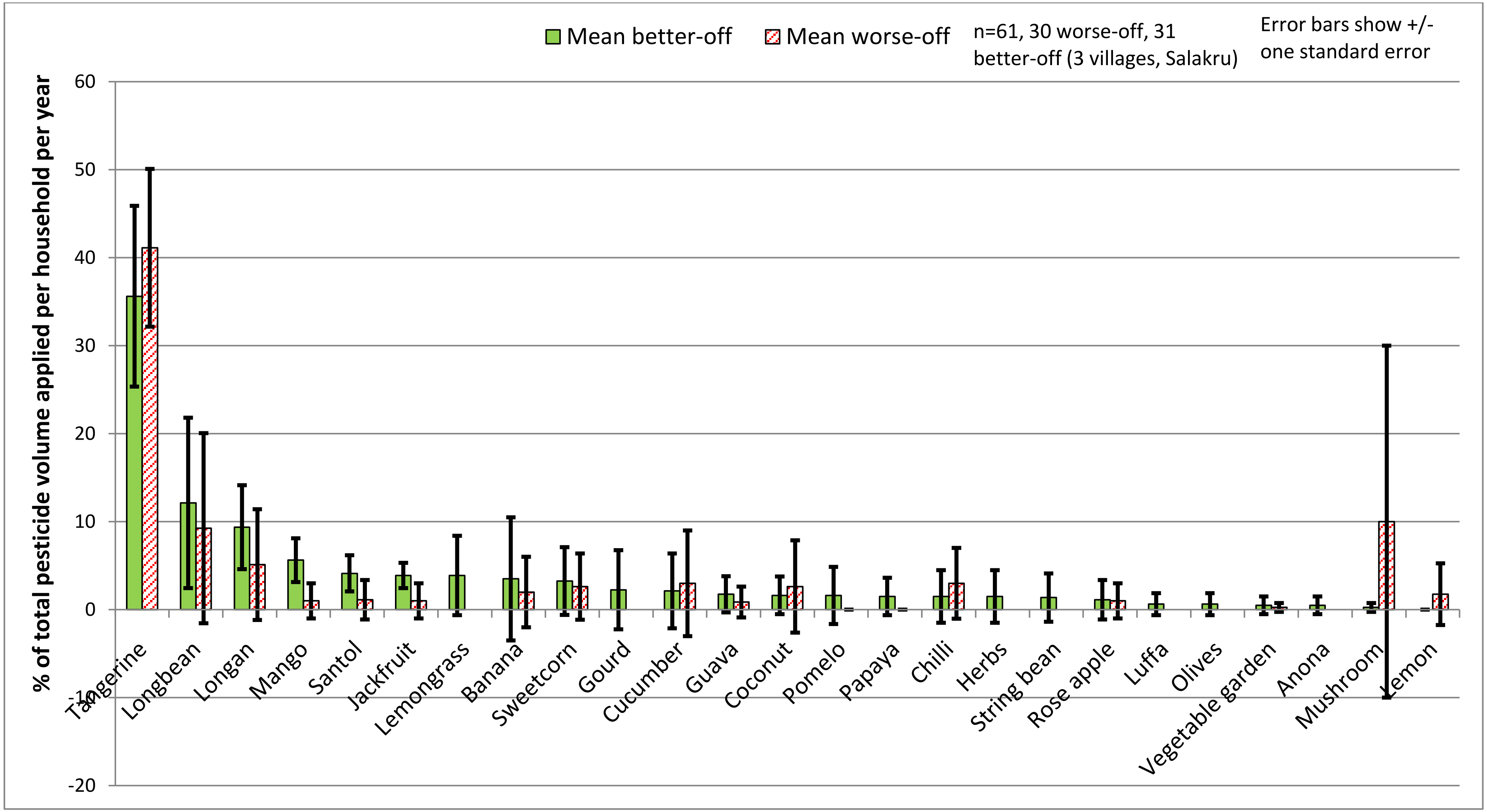
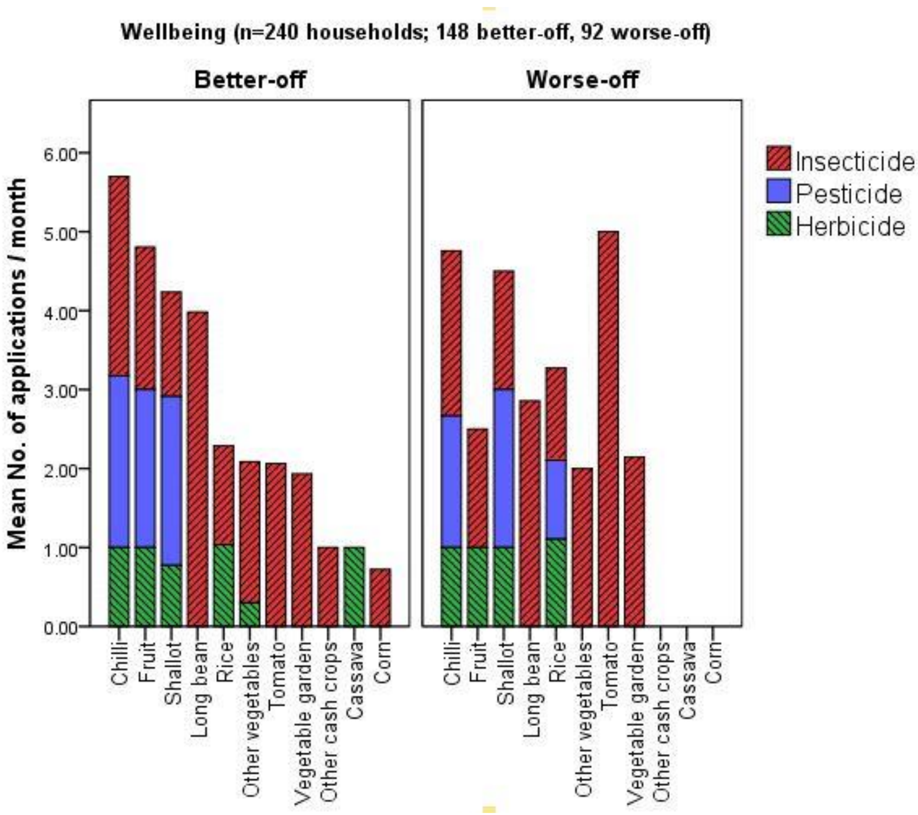


Figure 49: Mean rank of level of pesticide use by crop, per hectare, per year and well-being from PCA, Salakru, Central Thailand



Key: 'Other vegetables' = cucumber, eggplant, mushroom, onion, pumpkin, spring onion, wax gourd, Chinese white cabbage, wild spider flower, meraber nightshade, radish, cauliflower, pak choi, gourd, chives, celery, taro, carrot, *pak nam*, *pak keeleak*, okra, yam bean. 'Other cash crops' = bitter palm, betel vine, cashew nut, groundnut, kenaf, mullbery and tobacco. Vegetable garden = small quantities of mixed vegetables for home consumption.

Figure 50: Mean pesticide applications by crop, per hectare, per month and farmer well-being status, Sisaket, Northeast Thailand

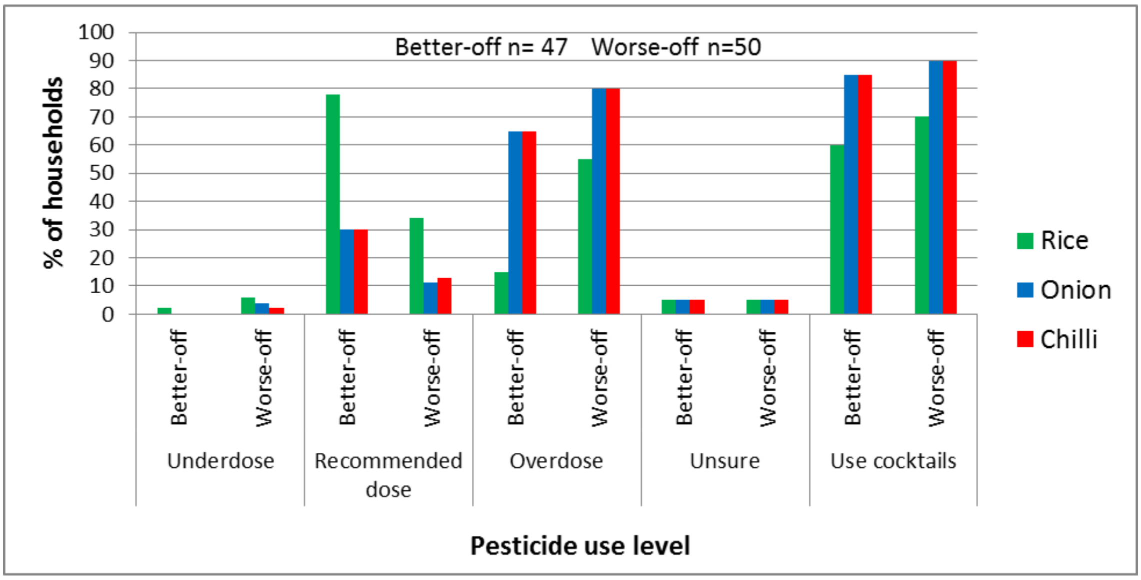


Figure 51: Pesticide use levels by crop, per hectare per year and well-being, Sri Lanka

4.2.2.3 Pesticide application strategies

4.2.2.3.1 Central Thailand

In Central Thailand pesticides were applied throughout the year, by men and women, using manual and motorised pesticide sprayers, with the latter method most common (Van den Brink *et al*., 2003). Most households applied pesticides both prophylactically (every 4-10 days) and curatively when pests were present to reduce risk of crop loss (Table 22) suggesting possible unnecessary overuse. In Salakru, season (50% of households) was the most common factor influencing pesticide application whilst in Kokprajadee 'weather' and 'pest severity' were lesser influencing factors as more farmers carried out pesticide applications at fixed daily or weekly periods (Table 22). Most respondents claimed to follow recommended dosages, but the vast majority also use pesticide cocktails with the perception that this would offer more effective crop protection.

Table 22: Pesticide application strategy by surveyed households, Central Thailand

Study sites and values	% of households	
	Kokprajadee (n=58)	**Salakru (n=59)**
Application strategies		
Prophylactic	2	30
Curative	2	0
Both	**96**	**70**
Total	**100**	**100**
Application criteria		
Fixed – No. / week (all year)	**40**	11
Weather dependent	32	22
Season dependent	0	**50**
Pest severity	28	17
Total	**100**	**100**

4.2.2.3.2 Northeast Thailand

Pesticide application in Northeast Thailand study sites was based on manual backpack or handheld sprayers. Pesticides are used frequently, both prophylactically and curatively, to reduce risk of crop loss and often as cocktails. Unfortunately, data similar to that for Central Thailand was not available due to the research's association with different projects with different methodologies.

4.2.2.3.3 Sri Lanka

In Sri Lankan study sites, pesticides are applied during both seasons by males using manually operated pesticide sprayer back-packs. Table 23 shows household survey results of farmers' pesticide use strategies and awareness of the recommended pesticide application dosages. Although a very high percentage of farmers claimed to be aware of the recommended pesticide dosages and application rates and their use based on many factors, about a quarter of surveyed households applied pesticide as routine practice and a third of households applied them at levels exceeding the recommendations. Most farmers did not provide reasons for this overuse of pesticide, whilst the rest provided various reasons of which the most common (22%) was that they perceived overuse of pesticide would further reduce risk of crop loss (Table 23). Unfortunately, data similar to that for Sri Lanka was not available for Northeast and Central Thailand due to different methodologies undertaken in data collection.

4.2.2.4 Pesticides used in study sites

A full list of pesticides applied to crops over a year in the study sites is shown in Appendix 12 and comprises insecticides, herbicides and fungicides. The table shows 64% of the 39 pesticides used are classed by the WHO as 'highly hazardous to health' or more severe.

Table 23: Farmer awareness, perceptions and practices on pesticide application from surveyed households, Sri Lanka

	Household heads (n=97)	
Awareness of recommended dosages	**No.**	**%**
Aware	**91**	**93.8**
Not aware	2	1.9
Not applicable	4	3.8
Total	**97**	**100**
	household heads (n=97)	
Application strategies	**No.**	**%**
Type of pest	23	22.3
Severity of crop damage	**28**	**27.2**
Presence of pest	21	20.4
Routine practice	**25**	**24.2**
Total	**97**	**100**
	household heads (n=97)	
Pesticide dosage level (dilution factor)	**No.**	**%**
Overuse	**34**	**33**
Underused	4	3.9
Use recommended amounts	**54**	**52.4**
Unsure	5	4.9
Total	**97**	**100**
	household heads (n=97)	
Reasons for not using recommended dose	**No.**	**%**
Lack of information	4	3.9
Cannot afford	3	2.9
Over dose = increased profit	5	4.9
Over dose reduces risk	**23**	**22.3**
As a preventive method	6	5.8
Not answered	**56**	**54.3**
Total	**97**	**100**

4.2.3 Pesticide hazards to aquatic systems and livelihoods

This section describes results on pesticide hazards to aquatic systems and community livelihoods of those spraying pesticides, consuming aquatic foods or using aquatic systems in and around farms.

4.2.3.1 Occupational health hazards from spraying pesticides

This sub-section deals with direct occupational health hazards from spraying pesticide, from inhalation, skin contact.

4.2.3.1.1 Central Thailand

Results from household surveys in Central Thailand revealed that spraying of pesticide was carried out equally by men and women, in particular by worse-off people, either family members or as employees of better-off people (Table 24). Further 42% of household members in Kokprajadee (mostly male) and 31% of household members in Salakru (mostly female) have reportedly suffered adverse health problems immediately after spraying pesticides that lasted for up to a week (Table 24). Figure 52 shows a range of symptoms of which headaches and dizziness were most common, all consistent with Atreya's (2008) findings from a study of 291 farming households in Nepal.

Table 24: Pesticide sprayer gender and perceived health problems from pesticide application, household surveys, Central Thailand

Criteria	% of pesticide sprayers Kokprajadee (n=118 sprayers, 58 households)	% of pesticide sprayers Salakru (n=117 sprayers, 60 households)
Male	52	50
Female	48	50
Perceived health problems	42	31

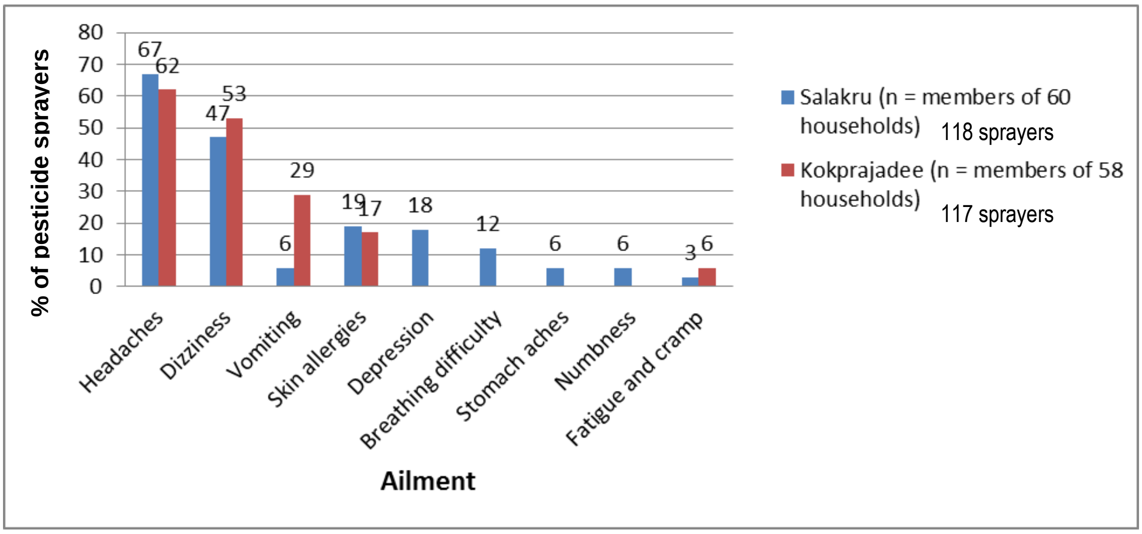


Figure 52: Perceived multiple health problems of pesticide sprayers, Central Thailand

4.2.3.1.2 Northeast Thailand

For Sisaket, both genders sprayed pesticide and a minority of all household members experienced various ailments which they perceived to be related to pesticide exposure (Figure 53). As explained by respondents, these ailments, other than ‘kidney problems’, typically occurred for up to a week after pesticide applications (Figure 53).

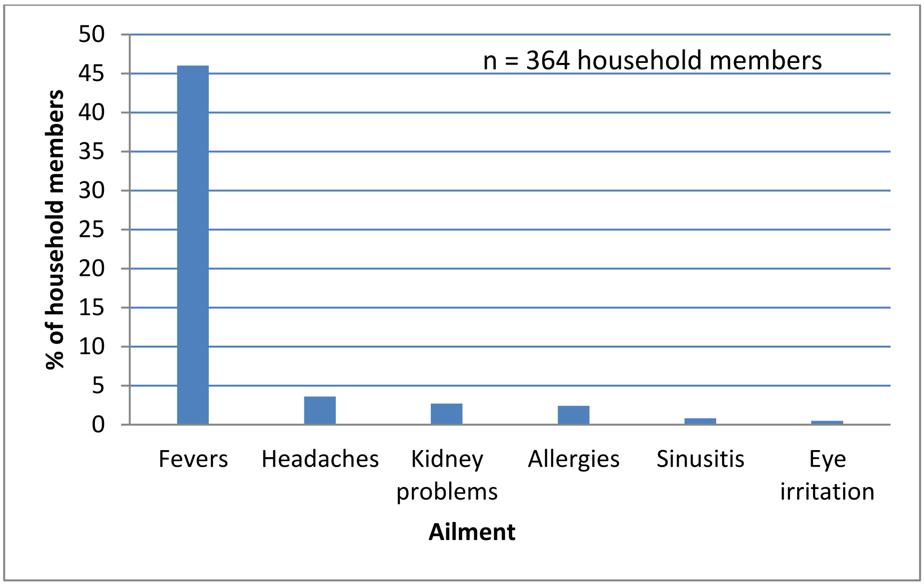


Figure 53: Perceived multiple health problems of household members from pesticide spraying, Sisaket, Northeast Thailand

4.2.3.1.3 Sri Lanka

In Sri Lanka, only males sprayed pesticide of which 24% of sprayers experienced ailments (for up to a week after spraying pesticides) which they perceived were linked to pesticide exposure (Table 25). However, no details are available for specific ailments as in Sri Lankan culture it is deemed impolite to ask personal questions about health.

Table 25: Pesticide sprayer genders and perceived health problems from spraying pesticide, household surveys, Sri Lanka

Criteria	% of pesticide sprayers Sri Lanka (n=97 households)
Male	100
Female	0
Perceived health problems	**23**

4.2.3.1.4 Pesticide human health hazard level

Of the 39 pesticides applied to crops in the study sites, 23% are classed as extremely hazardous to human health and 41% classed as highly hazardous to human health by the World Health Organisation (WHO, 2010).

4.2.3.2 Fate of pesticides in farming systems

The fate of pesticides in the farming systems is important for the assessment of hazard to aquatic systems, their users and public health from consumption of contaminated food. Pesticides may enter the watercourses through horizontal flow of soil particles, spray drift and run-off, and vertical flow through soil leaching or rinsing of pesticide containers or equipment in water bodies, which this sub-section deals with.

4.2.3.2.1 Rinsing pesticide equipment

From the household survey, in Central Thailand, the majority of farming households rinsed their pesticide equipment in farm ditches, whilst a minority did this in Sri Lanka including also tanks and drainage channels (Table 26). Thus this route would appear to be another source of pesticide hazard to these water bodies. Similar data was not available for Northeast Thailand.

Table 26: Place of rinsing pesticide equipment, Central Thailand and Sri Lanka

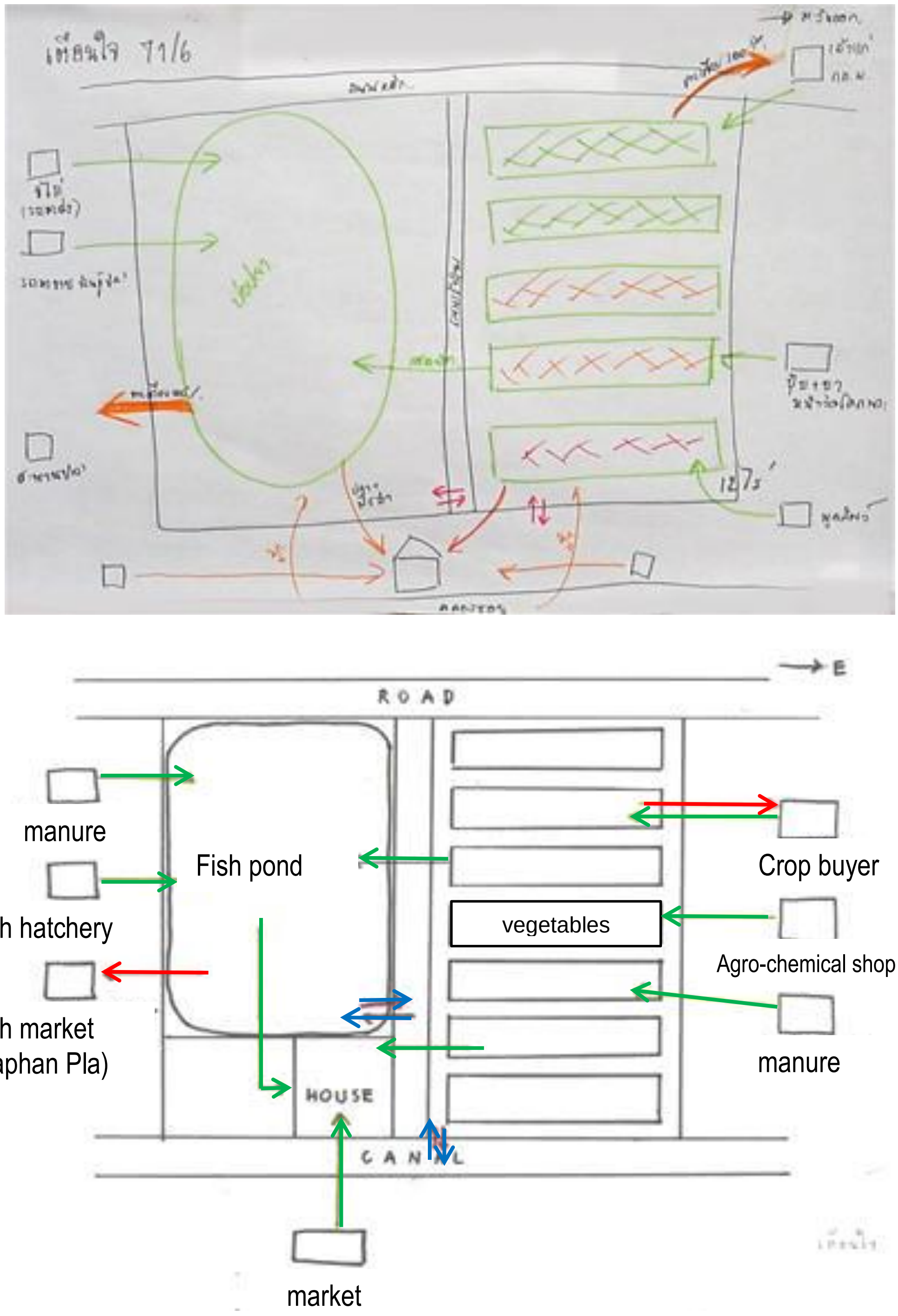
Method of equipment cleaning	**Households Central Thailand (%) n=120**	**Households Sri Lanka (%) n=97**
Rinse with water on land	12	**78**
Immerse in farm ditches	**64**	15
Immerse in tanks	-	1
Immerse in distribution channels	-	2
Do not rinse equipment	24	4
Total	**100**	**100**

4.2.3.2.2 Other routes

Additionally, Figure 54 to Figure 57 are bio-resource maps that show the potential fate of pesticides sprayed on crops within the farming systems of Central Thailand, Northeast Thailand and Sri Lanka. Common pesticide routes to water bodies between each study site include spray-drift, run-off and leaching, however, Figure 54 to Figure 57 show pesticide fate pathways for each study site.

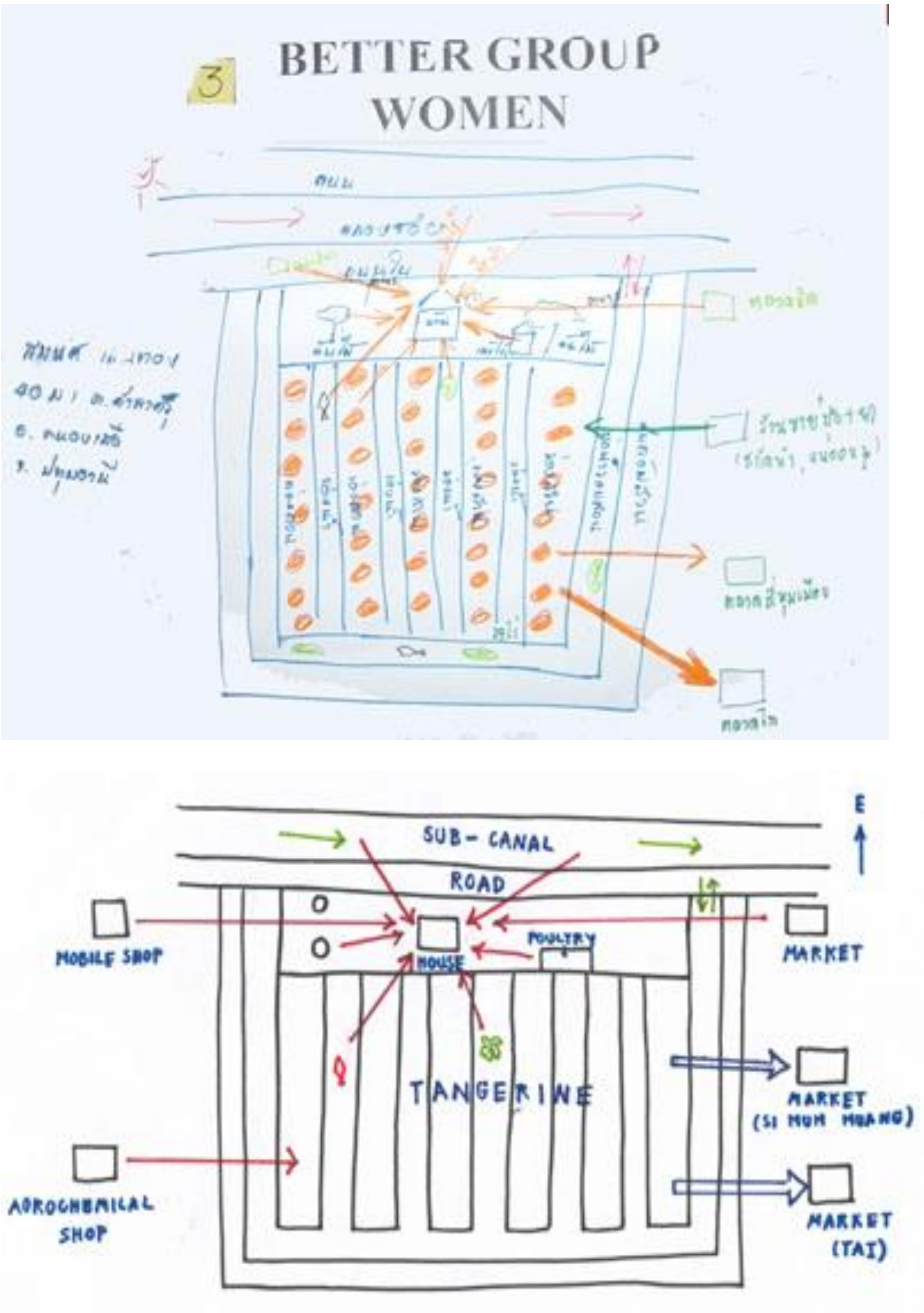
For Kokprajadee Figure 54 shows a farm example where pesticides from the local agrochemical shop are applied to vegetables. Waste vegetables are fed to fish in their fish ponds. Vegetables and fish are also sold at markets or consumed by the household, as stated in Chapter 3, posing a potential health hazard to these people. The farm example for Salakru (Figure 55) shows a somewhat similar situation in that pesticides are applied to tangerines which are mostly sold to markets, then consumed by the household. Aquatic plants and fish from the farm canals and wider canal network may contain pesticides which are consumed by households and poorest of the community (Chapter 3).

Figure 56 shows the bio-resource flow of pesticide and farm materials and produce for Sisaket, Northeast Thailand. Pesticides are frequently applied to commercial crops, such as chilli, which is sold to middlemen who sell them at ‘wet’ markets (open air, fresh food markets) in Bangkok and other provinces. Pesticides are also sometimes applied to rice which is mostly consumed by the household or sold at local markets which may place these consumers’ health at risk. Sometimes pesticides are applied to fruit and vegetable produce grown only for the farm household or shared with neighbours which again may place them at risk. Any waste crops are fed to pond-fish.



Arrows indicate flow of water, raw materials, fish, pesticide and food produce

Figure 54: Original and redrawn farm bio-resource map, Kokprajadee, Central Thailand



Arrows indicate flow of water, raw materials, fish, pesticide and food produce

Figure 55: Original and redrawn farm bio-resource map, Salakru, Central Thailand

Some farmers explained their reluctance to use pesticides, particularly the more hazardous ones, due to possible adverse effects on their fish or themselves, a finding similar to Berg's 2001 study of 120 rice-fish farmers in the Mekong Delta and Xie *et al*. (2011) study of 137 rice-fish farmers in Southern China. Fish are consumed by the household and also sold to local markets if grown commercially, potentially placing these consumers health at risk.

Figure 57 shows the typical bio-resource flow of pesticides and farm materials and produce of study site farms in Sri Lanka. Pesticide is frequently applied to commercial crops, mainly chilli and onion, grown mostly during *Yala* on upland plots near homesteads and sold at major town markets like Dambulla and Colombo. Pesticide is also frequently applied to rice, which is cultivated more in *Maha* than *Yala* and consumed by the household with any excess sold at local markets. Pesticide is sometimes applied to home-grown fruit and vegetables for home consumption and sharing with neighbours. From the processes mentioned, pesticide entering perennial tanks may contaminate their fisheries and potentially their consumers (fishermen, fish vendors and local buyers of fish).

Variations exist amongst bio-resource maps for each site, however, some common themes emerge. Pesticides are applied to cash crops and sometimes crops only for home consumption. Pesticides can enter water bodies through spray drift, run-off and leaching. Fish from water bodies at risk from pesticides, are consumed by households and the wider community. Variations between sites included feeding pesticide sprayed vegetables to fish and consumption of pesticide exposed aquatic plants and wildlife, particularly amongst the poorest Thais. The fate of pesticides in farming systems then leads on to the nature of hazards to aquatic systems and linked community livelihoods.

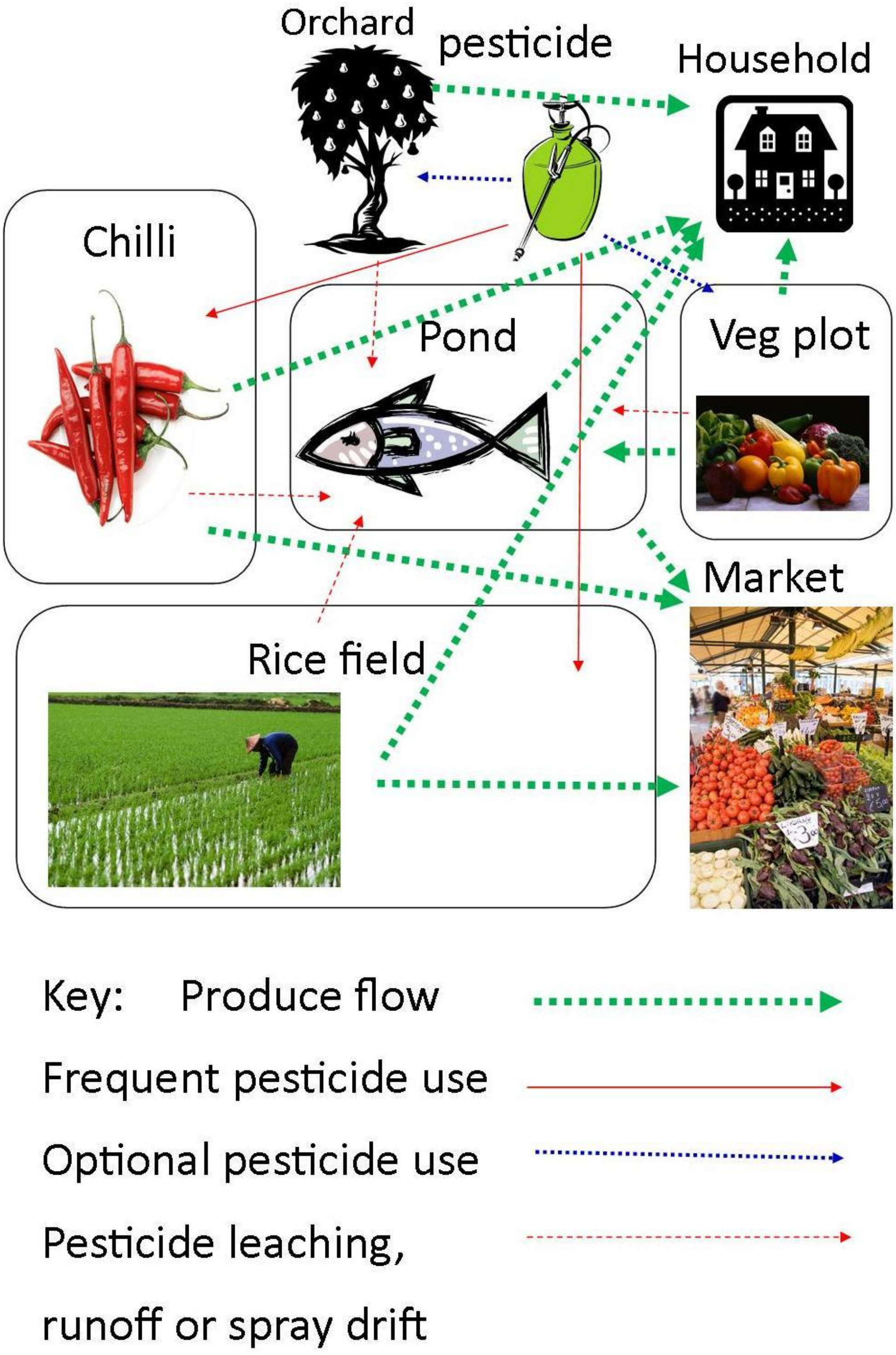


Figure 56: Typical bio-resource flow of pesticide and farm produce for Sisaket, Northeast Thailand

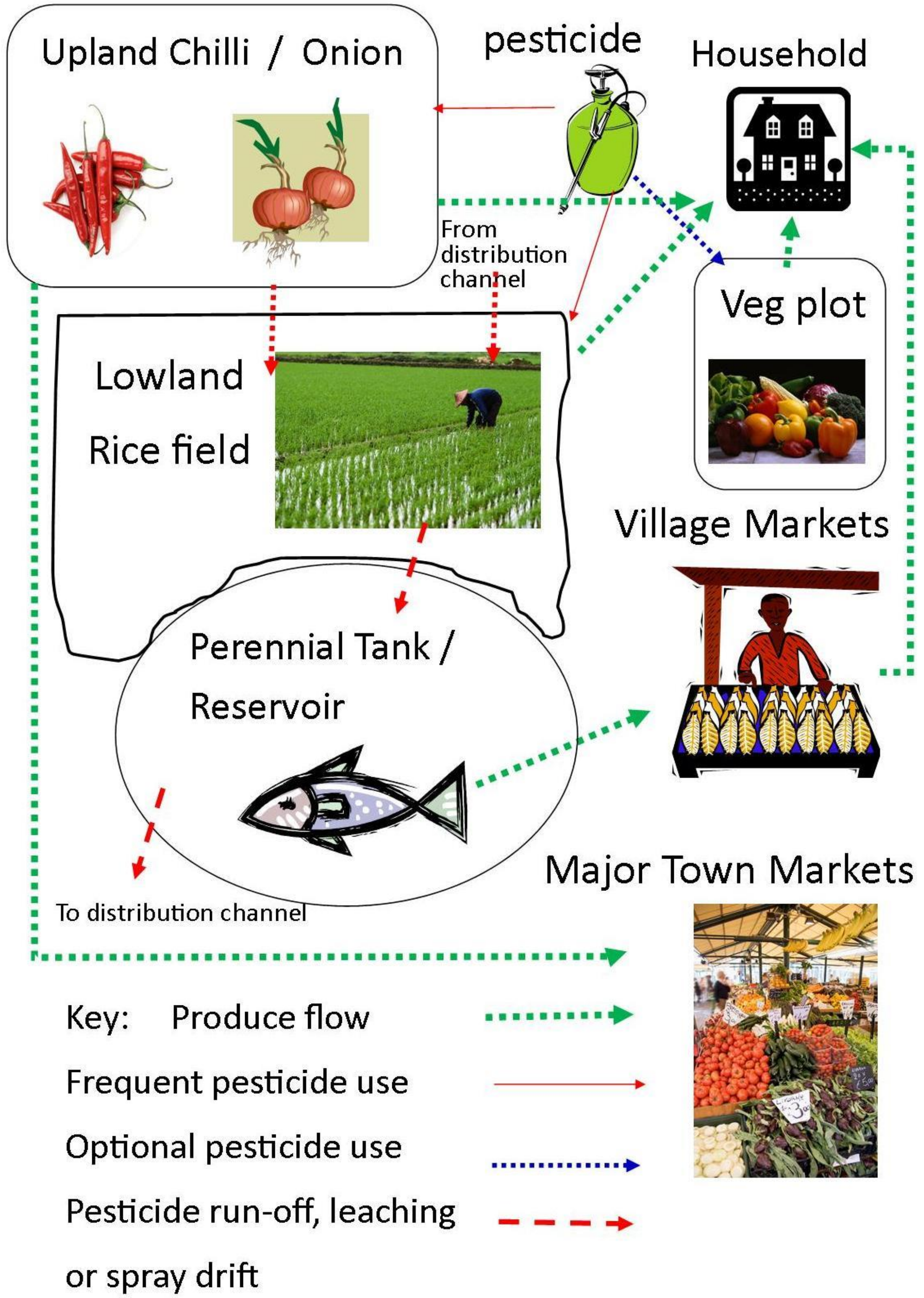


Figure 57: Typical bio-resource flow of pesticide and farm produce for Sri Lanka

4.2.3.3 Pesticide hazards to the aquatic environment

This sub-section presents results for pesticide hazards to aquatic systems from observations by communities and objective estimates.

4.2.3.3.1 Community observations

From results of PCA timelines already described in Chapter 3 for Sri Lanka and Thailand, communities observed a decline in ecological diversity and health which was said to be better prior to mechanisation, changes towards intensive horticultural 'mono-cropping' and increased pesticide use. In Thailand, community members have mentioned that wild fish stocks have declined, in their view due to a reduction in paddy field rice culture and increased pesticide aquatic pollution from horticulture (Chapter 3).

Central Thailand's survey results from 117 households revealed supporting evidence to that mentioned above from the PCA timelines, including 10 of Kokprajadee's 58 households and one of Salakru's 59 households having witnessed fish kills (mostly silver barb) in local water bodies; overall 10 instances in their own farm canals, seven instances in their own ponds, three instances in main canals and two for sub-canals, with their perception that they were a result of, or significantly contributed to by, intensive pesticide use. The subsequent Kokprajadee farmer workshop revealed many village participatory groups' awareness of pesticide's human health and environmental hazards, being able to associate specific pesticide brands ('Cyper 35', 'Silicon', 'Folidol' and 'Fuladan') with fish kills, supporting the theory that pesticides have an adverse effect on the aquatic environment. For Northeast Thailand some farmers perceived that pesticides had contributed to reduced ecological diversity including wild fish stock decline, however, for Sri Lanka, no similar observation was made.

4.2.3.3.2 Objective analysis

More objective analysis of pesticide hazard assessment to surface waters in Central Thailand and Sri Lanka study sites came from running various relevant pesticide and environmental parameters for these study sites through the TOXSWA model. Results were obtained for PEC (Predicted Environmental Concentration), NEC (No-Effect Concentration) and environmental risk quotients.

Thailand risk quotients calculated from the second tier PEC and the first tier NEC indicate a potential hazard for all pesticides. The highest potential hazards are indicated for various insecticides. On a crop level Chinese kale, guava, drumstick moringa and rose-apple were the crops posing highest surface water quality hazards in Kokprajadee (Table 27) and tangerine and longbean in Salakru (Table 28).

For Sri Lanka, the farm channel scenario indicated concentrations of all pesticides exceed the NEC. Risk quotients revealed hazards were particularly prominent for the insecticides carbaryl, chlorpyrifos and dimethoate. For the tanks system scenario for most pesticides, hazards are highest associated with the onion crop (Table 29).

Risk quotients were very high for selected pesticide and crops, particularly for Thailand where actual pesticide application levels were used in the model.

Overall, Appendix 12 shows that most of the 39 pesticides used in the study sites are classed as highly toxic to some form of freshwater life.

Table 27: Second tier PEC / NEC risk quotients for crop-pesticide combinations, Kokprajadee, Central Thailand

Thailand (mixed crop site)

Pesticide name	Crop name	PEC/1st tier NEC	PEC/2nd tier NEC
Mevinphos	Drumstick Moringa (Ma rum)	74737	6174
Malathion	Guava	59278	161667
Abamectin	Chinese kale (Ka na)	57353	No value
Dimethoate	Roseapple	37846	29818
Methamidophos	Roseapple	33455	1314
Profenofos	Chinese kale (Ka na)	15091	1660

(Source: Van den Brink *et al*., 2003)

Table 28: Second tier PEC / NEC risk quotients for crop-pesticide combinations, Salakru, Central Thailand

Thailand (mono-crop site)

Pesticide name	Crop name	PEC/1st tier NEC	PEC/2nd tier NEC
Dimethoate	Tangerine	79462	62606
Cypermethrin	Tangerine	48583	66250
EPN	Longbean	44700	4470
Profenofos	Tangerine	34364	3780
Dimethoate	Longan	10269	8091

(Source: Van den Brink *et al*., 2003)

Table 29: Second tier PEC / NEC risk quotients for crop-pesticide combinations, Sri Lanka

Sri Lanka

Pesticide name	Crop name	Channel PEC/1st tier NEC	PEC/2nd tier NEC	Tank PEC/1st tier NEC	PEC/2nd tier NEC
Carbaryl	Chilli	247143	24140	824	80
Carbaryl	Onion	239286	23372	2393	234
Chlorpyrifos	Chilli	100789	57164	336	191
Chlorpyrifos	Onion	100526	57015	1005	570
Dimethoate	Chilli	27769	21879	93	73
Dimethoate	Onion	22846	18000	228	180
Dimethoate	Rice	22846	18000	23	18

(Source: Van den Brink *et al*., 2003)

4.2.3.4 Community pesticide health hazards from use of aquatic systems

This sub-section details potential hazards to study site community livelihoods through their use of aquatic systems and consumption of aquatic produce.

4.2.3.4.1 Central Thailand

As described in Chapter 3, water is pumped to and from farms and sub-canals in Salakru frequently in tangerine production whilst in Kokprajadee water is usually pumped from farms to sub-canals in the rainy season and in reverse during the dry season. The potential for exchange of water and pesticides from individual farms to off-farm water bodies and between farms linked through the sub-canal network would appear to be greater in Salakru than Kokprajadee. In Kokprajadee, a minority of households used canal water for domestic purposes, whilst this was much higher in Salakru (Figure 58). In both areas, sub-canal water was utilised more than main farm canal water for domestic purposes including bathing, washing clothes and food and watering animals, however in Salakru, farm canals were also used for bathing, washing clothes and watering animals (Figure 58).

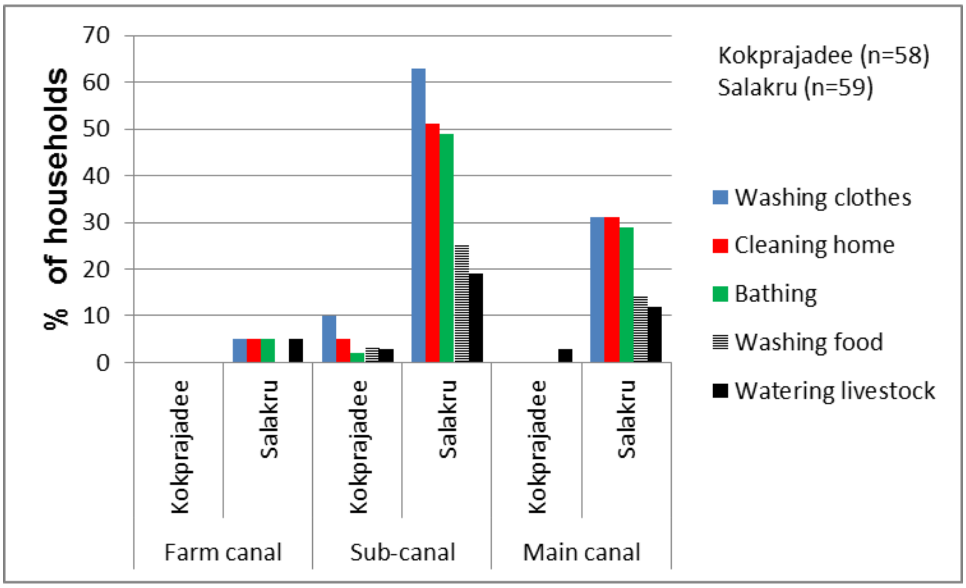


Figure 58: Household water use, Central Thailand

4.2.3.4.2 Sri Lanka

Sri Lankan household surveys revealed a range of water bodies used for domestic purposes, with 'distribution channels' being most used for washing clothes and bathing, followed by 'own wells', whilst 'main tank channels' and 'perennial tanks' were the next most used for bathing (Figure 59). Therefore, the tank-channel cascade system that may be potentially contaminated with pesticides seems to be popular for domestic bathing and washing activities, posing potential health hazards.

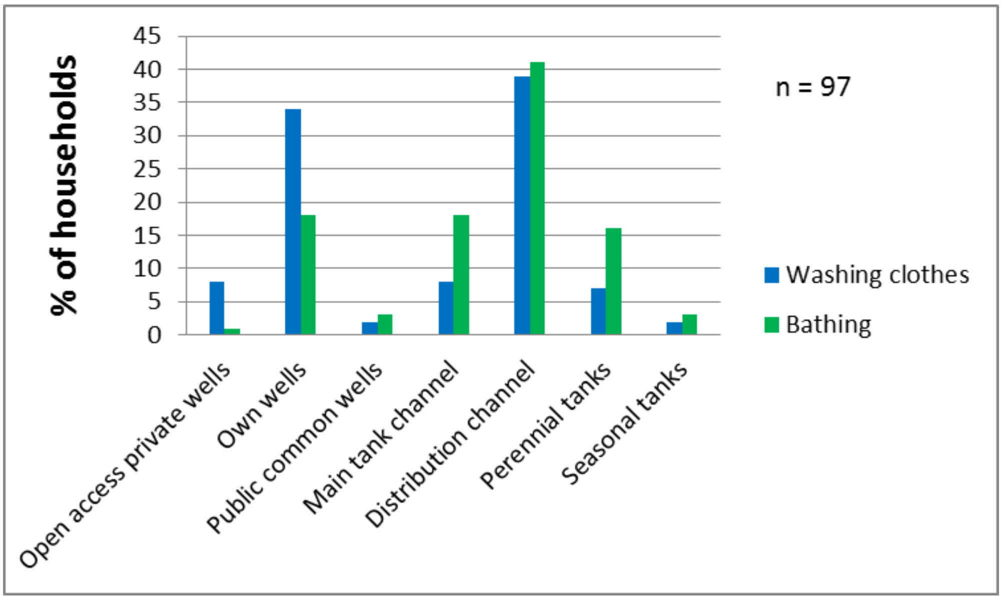


Figure 59: Household water use, Sri Lanka

4.2.3.4.3 Northeast Thailand

In Sisaket, only a minority of households used available water resources other than rainwater for watering livestock, bathing, laundry, cleaning kitchen utensils and other domestic purposes.

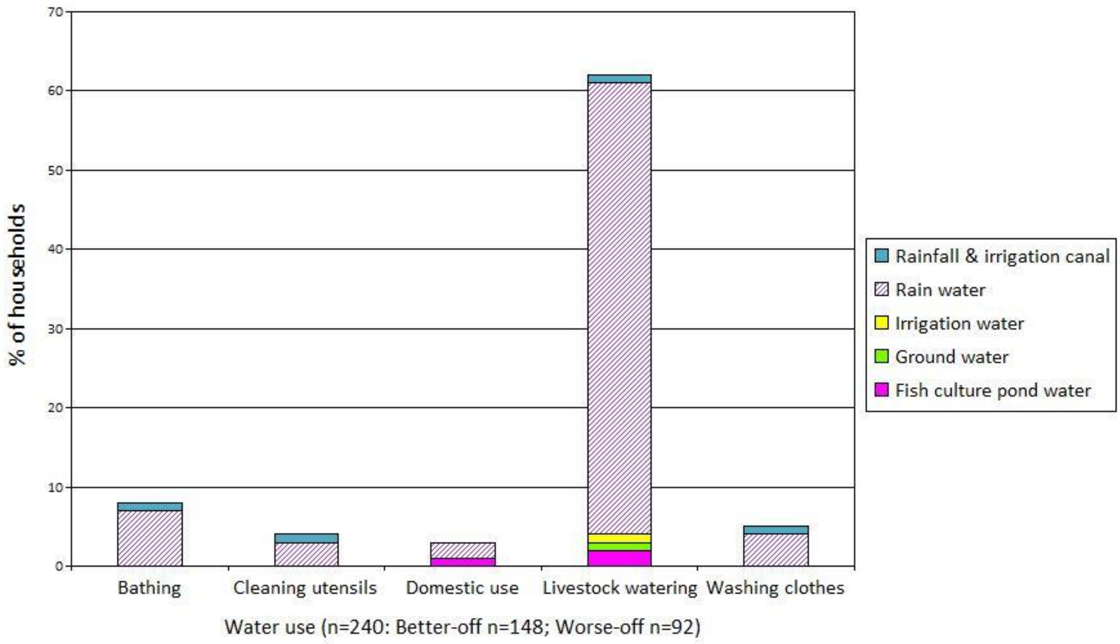


Figure 60: Household water use, Sisaket, Northeast Thailand

4.2.3.5 Community pesticide health hazards from food

This sub-section describes results for potential pesticide health hazards to farming community livelihoods through consumption of land crops sprayed with pesticide and community aquatic plants and animals.

4.2.3.5.1 Central Thailand

Results for Central Thailand (Table 30) showed potential pesticide contamination hazards to people through the consumption of some crops that receive high pesticide levels and also from aquatic plants, animals and fish either purchased locally or collected from the local aquatic environment. Leafy vegetables and other produce eaten daily, which received high levels of pesticides, were mostly collected from homesteads' own plots (that may not be pesticide sprayed). However, this was supplemented by local market and mobile shop purchased produce, which originates from local farms and is likely to be pesticide sprayed. In Salakru, pesticide sprayed farm tangerines were also more frequently eaten by worse-off people. Freshwater fish (most popularly Nile tilapia, Silver barb and snakehead) were eaten regularly and mostly obtained from farm canals and ponds at high risk from pesticide contamination, and mobile shops that suggest a local source, with worse-off people collecting more. Aquatic plants and animals, mostly from high pesticide risk ponds and canals then mobile traders, were also consumed, particularly by worse-off groups (Table 30).

Table 30: Household consumption of food in Central Thailand

Food type	**Source**	**Freq. consumed**	**Well-being distinction**
High pesticide use			
Land crops: Chinese kale, cabbage, lettuce, long bean, guava, longan & roseapple	Local markets & mobile shops (20%) or own plots (80%) (K & S)	Daily	
Tangerines	From farm 100% (S)	Weekly > Daily	More often by worse-off people
Aquatic animals, plants and fish			
Freshwater fish: Nile tilapia (S75%, K 30%) Silver barb (S32%,K40%) Snakehead (S25%,K38%) Catfish (S10%, K30%) Striped catfish (S10%,K10%) Rohu (S 15%, K 10%) Climbing perch (S5%, K20%) S'skin gourami (S5%,K10%)	**% of households:** Farm canal (K 30%, S 70%) Own pond (K 40%, S 10%) Sub-canal (K 5%, S 30%) Main canal K 15%, S 20%) N'bour pond (K10%, S 5%) Markets and mobile traders (K 25%, S 40%)	Twice / week > Daily	Worse-off collect more, better-off buy more
Aquatic plants: Morning glory, ivy gourd & water mimosa*	Local ponds, farm canals and other canals or purchased from mobile shops*	Weekly > Daily	More often consumed by worse-off people
Aquatic animals: Snails, frogs, turtles, shellfish & freshwater shrimps	Local ponds and canals	Monthly > Twice / Week	More often consumed by worse-off people

Key: K=Kokprajadee, S=Salakru. Households: n=58 Kokprajadee, n=59 Salakru

4.2.3.5.2 Northeast Thailand

For Sisaket, household consumption of specific fruit and vegetables is not available, however, Figure 61 shows that most households consume their own cultivated vegetables (which may or may not be pesticide sprayed) followed by sourcing from the wild with fewer purchased. Figure 62 shows better-off ‘active’ pond users consume fruit and vegetables most frequently.

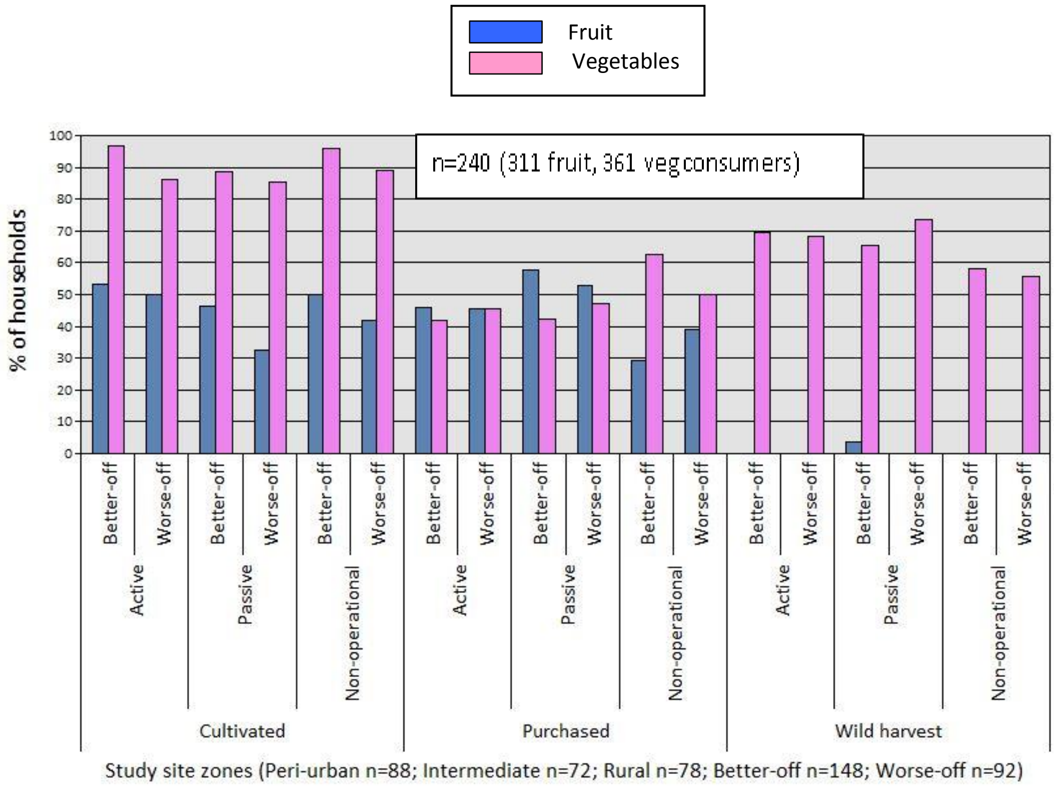


Figure 61: Source of fruit and vegetables consumed by households over a year, Sisaket, Northeast Thailand

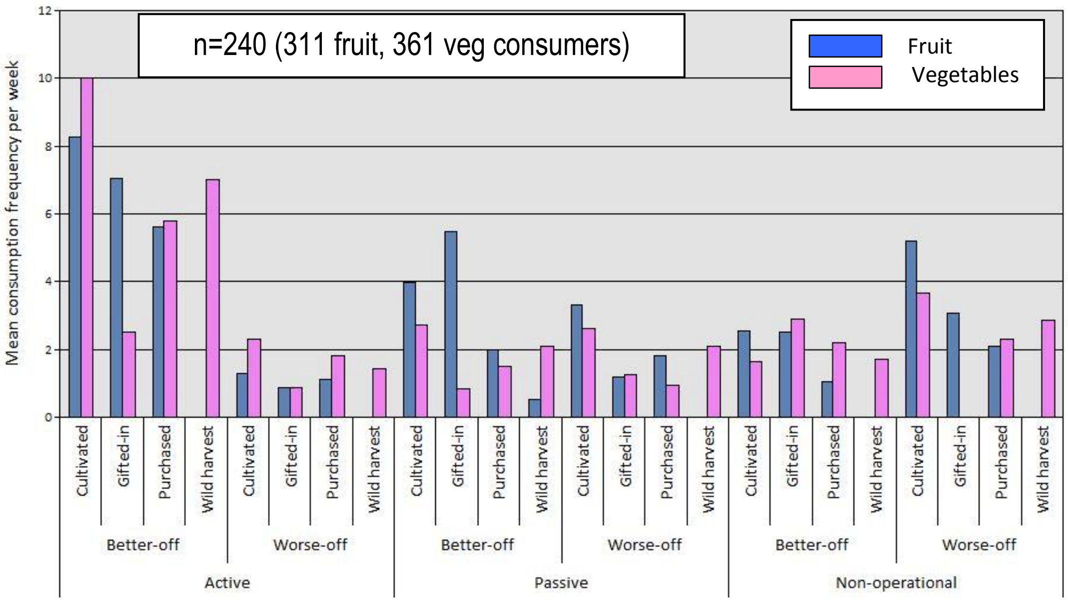


Figure 62: Mean weekly consumption frequency of fruit and vegetables, Sisaket, Northeast Thailand

Figure 63 shows that culturing fish on-farm was done by a high percentage of 'active' pond-dike households and least by non-operational pond-dike farms, irrespective of well-being, whilst wild caught and collected aquatic produce was most sought by 'passive' pond-dike users. Purchasing of aquatic produce was practiced more by better-off than worse-off households and amongst non-active pond-dike households (Figure 63). Figure 64 shows on-farm freshwater fish are most frequently consumed by 'active' pond-dike households, whilst wild caught fish were most frequently consumed by 'non-operational' pond-dike farms, more so worse-off. Purchased freshwater fish were most frequently consumed by 'non-active' pond-dike households, particularly better-off ones. Aquatic animals were most frequently consumed from the wild, particularly amongst 'passive' pond-dike farms, however, better-off 'active' pond users frequently consumed them from rice fields. Therefore pond-dike status and well-being influence the source and consumption level and associated pesticide risks from freshwater aquatic produce.

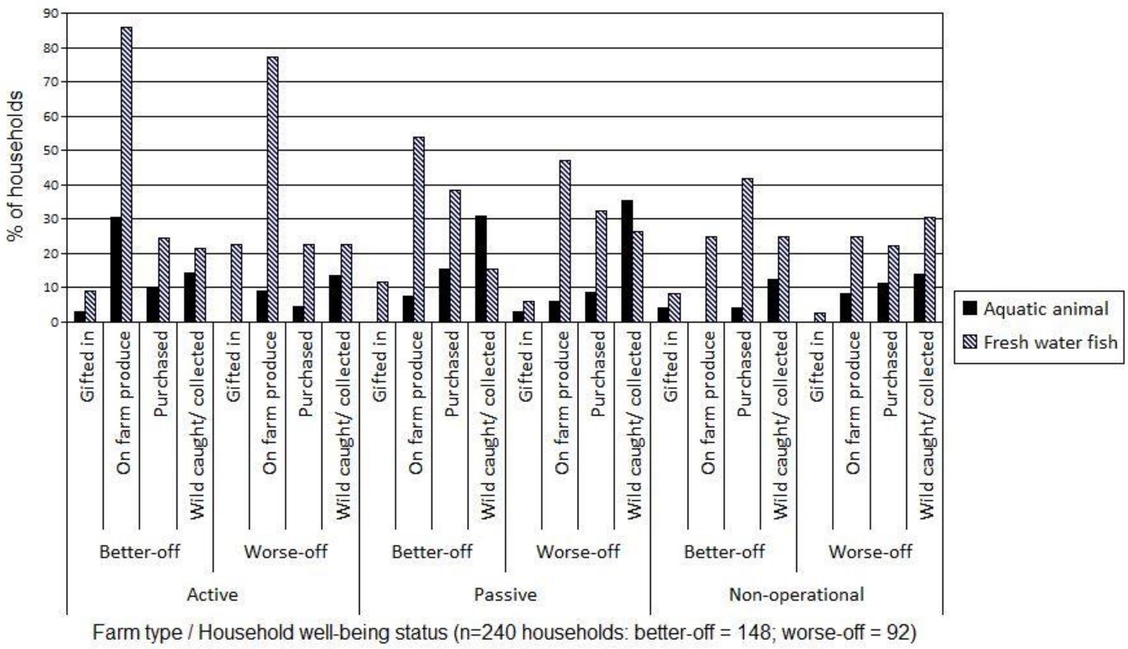


Figure 63: Source of aquatic produce consumed by households, Sisaket, Northeast Thailand

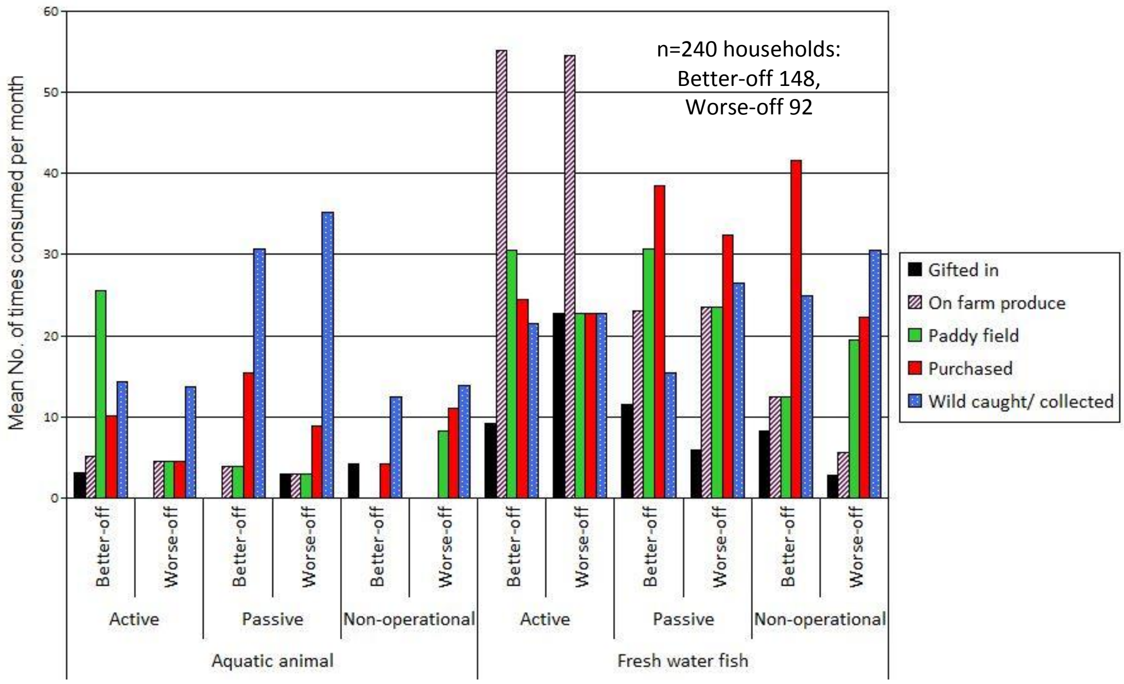


Figure 64: Consumption frequency and source of aquatic produce, Sisaket, Northeast Thailand

4.2.3.5.3 Sri Lanka

For Sri Lanka from the household survey of 97 households among five villages (39 better-off and 58 worse-off) the majority of households consumed their own rice which is sprayed with pesticide, and vegetables mostly from local shops, suggesting a local origin. Freshwater fish and aquatic plants were also consumed frequently by most households and mostly obtained from local tanks, with cycle vendors supplying most of the fish, suggesting potential pesticide exposure (Table 31). There was little well-being distinction other than better-off people were more likely to eat more freshwater fish.

Table 31: Food source and consumption frequency, Sri Lanka

Food type	**Source**	**Consumption Frequency**	**Well-being distinction**
High pesticide use			
Land crops: Rice	**% of households:** 88% From own farm 6% Local shops 6% Town	Daily	
Vegetables	69% Local shops 21% Fair 7% Town	Weekly > Daily	
Aquatic plants and fish			
Freshwater fish: tilapia	**% of households:** Cycle vendors 97% (from local perennial tanks) Town 3%	Twice / week > Weekly	More often eaten by better-off people
Aquatic plants	81% Local tanks (collected) 16% Local shops 3% Fair	Twice / week > Weekly	

n=97 households

4.2.3.5.4 Analysis of aquatic food and drinking water risks

In assessing the community pesticide health risk from drinking water and consumption of aquatic produce, data is available for Sri Lanka and Central Thailand. For Thailand, results of the human risk assessment due to dietary exposure via water and food (fish and aquatic macrophytes) revealed three chemicals considerably in excess (> 10000) of the acceptable daily intake (ADI) by the national estimated daily intake (NEDI) (chlorfenapyr, prothiofos and dicrotophos) (Table 32). For all three pesticides the source is different: chlorfenapyr exposure is high due to macrophyte intake, exposure to prothiophos is high due to fish intake and dicrotophos exceeds the ADI because of exposure through drinking water. The NEDI also exceeds the acute reference dose (ARfD) for numerous chemicals indicating acute risks from the defined diet. The highest excesses are indicated for the same chemicals as above although one should keep in mind that the ARfD levels of these chemicals are all based on extrapolation. For fipronil and mevinphos risks are indicated based on ARfD levels as set by the committee of the Joint FAO/WHO Meeting on Pesticide Residues Committee (JMPR) (Van den Brink *et al*., 2003).

Also for the Sri Lankan scenario a considerable excess of the ADI is indicated for some pesticides although the absolute value is always below 1000 mg/kg body weight / day. The highest excesses are indicated for fenobucarb, alachlor and chlorpyrifos (Table 33). Chlorpyrifos is the chemical with the largest excess of the ARfD level indicating acute risks from the defined diet. When the tank is considered as a source for fish, macrophytes and water all NEDI levels drop below the (extrapolated) ARfD levels and only few exceed the ADI (alachlor, fenobucarb and chlorpyrifos).

Table 32: Results of dietary risk assessment for Central Thailand, NEDI

Thailand (mixed crop site)

Pesticide	Crop	NEDI Fish	NEDI Macr.	NEDI Water	NEDI Total	NEDI/ ADI	NEDI /ARfD
Prothiofos	Guava	1.27E+01	7.87E-01	5.91E-02	14	135694	2887
Chlorfenapyr	Amaranth	3.42E-01	6.89E+02	8.22E-03	690	34479	734
Dicrotophos	Chinese kale	7.56E-05	4.11E-06	6.17E-02	0.062	30873	657
Abamectin	Chinese kale	2.91E-01	8.52E-01	1.63E-02	1.16	580	12
Methamidophos	Roseapple	6.27E-04	8.75E-06	9.20E-01	0.92	230	4.9
Fipronil	Amaranth	1.33E-02	2.53E-03	1.63E-03	0.017	87	5.8
Chlorfluazuron	For all crops	3.19E-01	9.55E-04	1.15E-03	0.32	64	1.4
Carbosulfan	Roseapple	3.54E-01	1.03E-02	2.00E-03	0.37	37	0.78
Profenofos	Chinese kale	2.68E-01	3.75E-03	1.38E-02	0.29	29	0.61
Mevinphos	Drumstick Moringa	4.95E-05	7.88E-07	1.18E-02	0.012	15	4.0
Difenoconazole	For all crops	8.05E-02	2.70E-03	6.64E-03	0.090	9.0	0.19
Dimethoate	Roseapple	1.06E-03	2.77E-04	8.20E-02	0.083	4.2	0.089
Carbendazim	Guava	4.39E-03	4.29E-02	7.01E-02	0.12	3.9	0.083
Carbendazim	Chinese kale	3.83E-03	3.74E-02	6.12E-02	0.10	3.4	0.073
Propineb	Roseapple	3.00E-05	8.11E-03	1.53E-02	0.023	3.4	0.071
Diflubenzuron	Roseapple	1.31E-02	2.42E-02	1.98E-03	0.039	2.0	0.042
Metalaxyl	For all crops	6.58E-03	4.37E-04	6.57E-02	0.073	0.91	0.019
Malathion	Guava	6.31E-02	8.27E-03	8.89E-02	0.16	0.53	0.011
Mancozeb	Roseapple	2.23E-04	3.65E-03	5.06E-03	0.0089	0.30	0.0063
Mancozeb	Amaranth	2.19E-04	3.59E-03	4.97E-03	0.0088	0.29	0.0062
Glyphosate	For all crops	5.08E-06	1.92E-04	3.57E-02	0.036	0.12	0.0025

Thailand (mono-crop site)

Pesticide	Crop	NEDI Fish	NEDI Macr.	NEDI Water	NEDI Total	NEDI/ ADI	NEDI /ARfD
EPN	Longbean	2.25E-01	9.30E-03	3.73E-03	0.24	23761	495
Dicrotophos	Tangerine	6.36E-06	3.46E-07	5.19E-03	0.0052	2599	55
Cypermethrin	Tangerine	6.45E+00	4.16E-01	4.86E-03	6.9	137	2.9
Profenofos	Tangerine	6.10E-01	8.54E-03	3.15E-02	0.65	65	1.4
Zineb	Tangerine	6.74E-03	8.59E-02	1.62E-01	0.25	51	1.1
Methamidophos	Tangerine	1.09E-04	1.53E-06	1.61E-01	0.16	40	0.86
Abamectin	Tangerine	1.19E-02	3.48E-02	6.64E-04	0.047	24	0.50
Abamectin	Longan	1.00E-02	2.94E-02	5.60E-04	0.040	20	0.43
Carbendazim	Tangerine	1.88E-02	1.84E-01	3.00E-01	0.50	17	0.36
Tetradifon	Tangerine	2.09E-01	9.61E-02	7.74E-03	0.31	16	0.33
Dimethoate	Tangerine	2.23E-03	5.82E-04	1.72E-01	0.17	8.7	0.19
Mancozeb	Tangerine	6.26E-03	1.03E-01	1.42E-01	0.25	8.4	0.18
Methamidophos	For all crop	6.35E-06	8.86E-08	9.32E-03	0.0093	2.3	0.050
Dimethoate	Longan	2.88E-04	7.52E-05	2.23E-02	0.023	1.1	0.024
Methamidophos	Guava	2.72E-06	3.80E-08	4.00E-03	0.0040	1.0	0.021
Carbendazim	Longbean	1.07E-03	1.04E-02	1.71E-02	0.029	1.0	0.020
Carbofuran	Coconut	1.04E-04	9.04E-05	1.63E-03	0.0018	0.91	0.20
Methomyl	Tangerine	4.82E-05	2.34E-05	1.23E-02	0.012	0.62	0.62
Carbendazim	Longan	5.56E-04	5.43E-03	8.88E-03	0.015	0.50	0.011
Carbaryl	Tangerine	3.82E-05	5.49E-05	5.22E-04	0.00061	0.077	0.0031
Captan	Tangerine	1.26E-03	1.76E-03	1.62E-03	0.0046	0.046	0.0010

NEDI units (mg/kg body weight/day)
(Source: Van den Brink *et al*., 2003)

Table 33: Results of dietary risk assessment for Sri Lanka, NEDI

Sri Lanka (farm channel)

Pesticide	Crop	NEDI Fish	NEDI Macr.	NEDI Water	NEDI Total	NEDI/ ADI	NEDI /ARfD
Fenobucarb	Chilli	4.20E-02	2.55E-03	5.48E-02	0.10	985	21
Fenobucarb	Onion	3.15E-02	1.92E-03	4.11E-02	0.075	739	16
Fenobucarb	Rice	3.15E-02	1.92E-03	4.11E-02	0.075	739	16
Alachlor	Onion	4.36E-02	2.65E-03	3.16E-02	0.078	156	3.3
Alachlor	Rice	4.36E-02	2.65E-03	3.16E-02	0.078	156	3.3
Chlorpyrifos	Chilli	1.03E+00	6.06E-02	3.19E-02	1.1	112	11
Chlorpyrifos	Onion	1.03E+00	6.05E-02	3.18E-02	1.1	112	11
Carbaryl	Chilli	6.34E-03	9.10E-03	8.65E-02	0.10	13	0.51
Carbaryl	Onion	6.13E-03	8.81E-03	8.38E-02	0.10	12	0.49
MCPA	Chilli	4.79E-02	4.15E-03	6.75E-02	0.12	12	0.25
MCPA	Onion	4.79E-02	4.15E-03	6.75E-02	0.12	12	0.25
MCPA	Rice	4.79E-02	4.15E-03	6.75E-02	0.12	12	0.25
Carbofuran	Chilli	1.24E-03	1.08E-03	1.94E-02	0.022	11	2.4
Carbofuran	Rice	6.39E-04	5.56E-04	1.00E-02	0.011	5.6	1.2
Dimethoate	Chilli	7.78E-04	2.03E-04	6.02E-02	0.061	3.1	0.065
Dimethoate	Onion	6.40E-04	1.67E-04	4.95E-02	0.050	2.5	0.054
Dimethoate	Rice	6.40E-04	1.67E-04	4.95E-02	0.050	2.5	0.054
Captan	Onion	4.23E-02	5.88E-02	5.41E-02	0.16	1.6	0.033
Captan	Rice	4.23E-02	5.88E-02	5.41E-02	0.16	1.6	0.033
Mancozeb	Chilli	1.01E-03	1.66E-02	2.30E-02	0.041	1.35	0.029
Mancozeb	Onion	1.01E-03	1.66E-02	2.30E-02	0.041	1.35	0.029
Mancozeb	Rice	1.01E-03	1.66E-02	2.30E-02	0.041	1.35	0.029
Propanil	Chilli	6.23E-02	2.99E-03	2.99E-02	0.10	0.48	0.010
Propanil	Onion	6.23E-02	2.99E-03	2.99E-02	0.10	0.48	0.010
Propanil	Rice	6.23E-02	2.99E-03	2.99E-02	0.10	0.48	0.010
Glyphosate	Chilli	4.46E-06	1.69E-04	3.13E-02	0.032	0.11	0.0022
Glyphosate	Onion	4.46E-06	1.69E-04	3.13E-02	0.032	0.11	0.0022
Glyphosate	Rice	4.46E-06	1.69E-04	3.13E-02	0.032	0.11	0.0022

Sri Lanka (tank)

Pesticide	Crop	NEDI Fish	NEDI Macr.	NEDI Water	NEDI Total	NEDI/ ADI	NEDI /ARfD
Fenobucarb	Onion	3.15E-04	1.92E-05	4.11E-04	0.00	7.4	0.16
Fenobucarb	Chilli	1.40E-04	8.51E-06	1.83E-04	0.00	3.3	0.070
Alachlor	Onion	4.36E-04	2.65E-05	3.16E-04	0.00	1.6	0.033
Chlorpyrifos	Onion	1.03E-02	6.05E-04	3.18E-04	0.01	1.1	0.11
Fenobucarb	Rice	3.13E-05	1.90E-06	4.08E-05	0.00	0.73	0.016
Chlorpyrifos	Chilli	3.44E-03	2.03E-04	1.07E-04	0.00	0.37	0.037
Alachlor	Rice	4.37E-05	2.65E-06	3.17E-05	0.00	0.16	0.0033
Carbaryl	Onion	6.13E-05	8.81E-05	8.38E-04	0.00	0.12	0.0049
MCPA	Onion	4.79E-04	4.15E-05	6.75E-04	0.00	0.12	0.0025
Carbaryl	Chilli	2.11E-05	3.03E-05	2.88E-04	0.00	0.042	0.0017
MCPA	Chilli	1.60E-04	1.38E-05	2.25E-04	0.00	0.040	0.00085
Carbofuran	Chilli	4.15E-06	3.62E-06	6.50E-05	0.00	0.036	0.0081
Dimethoate	Onion	6.40E-06	1.67E-06	4.95E-04	0.00	0.025	0.00054
Captan	Onion	4.23E-04	5.88E-04	5.41E-04	0.00	0.016	0.00033
Mancozeb	Onion	1.01E-05	1.66E-04	2.30E-04	0.00	0.014	0.00029
MCPA	Rice	4.79E-05	4.15E-06	6.75E-05	0.00	0.012	0.00025
Dimethoate	Chilli	2.60E-06	6.79E-07	2.01E-04	0.00	0.010	0.00022
Carbofuran	Rice	6.39E-07	5.56E-07	1.00E-05	0.00	0.0056	0.0012
Propanil	Onion	6.23E-04	2.99E-05	2.99E-04	0.00	0.0048	0.00010
Mancozeb	Chilli	3.38E-06	5.54E-05	7.67E-05	0.00	0.0045	0.000096
Dimethoate	Rice	6.36E-07	1.66E-07	4.92E-05	0.00	0.0025	0.000053
Propanil	Chilli	2.08E-04	9.99E-06	1.00E-04	0.00	0.0016	0.000034
Captan	Rice	4.24E-05	5.89E-05	5.42E-05	0.00	0.0016	0.000033
Mancozeb	Rice	1.03E-06	1.68E-05	2.33E-05	0.00	0.0014	0.000029
Glyphosate	Onion	4.46E-08	1.69E-06	3.13E-04	0.00	0.0011	0.000022
Propanil	Rice	6.24E-05	3.00E-06	3.00E-05	0.00	0.00048	0.000010
Glyphosate	Chilli	1.48E-08	5.62E-07	1.04E-04	0.00	0.00035	0.0000074
Glyphosate	Rice	4.51E-09	1.71E-07	3.17E-05	0.00	0.00011	0.0000023

NEDI units (mg/kg body weight/day)
(Source: Van den Brink *et al*., 2003)

4.2.3.6 Farmer perception of pesticide necessity and risks

This sub-section presents results for farmers' perceptions on the necessity of pesticides and their risk to human health and the environment, which is integral to how they use them and any risk reduction methods taken.

4.2.3.6.1 Pesticide necessity perception

In terms of farmers' opinions on the necessity of pesticides, PCA activities in Central Thailand revealed that most better-off and worse-off participants believed 'synthetic pesticides were necessary but that other crop protection measures could be used'. In Sri Lanka, this was a similar result for better-off participants, however, the worse-off mostly considered pesticide was necessary, suggesting their greater pesticide dependency (Table 34). Although exactly similar methods were not used in Sisaket, Northeast Thailand, some results of 20 farmer semi-structured interviews (Table 35) revealed a higher percentage using recommended applications of pesticides and fewer using more or less, suggesting a mixed response on necessity of pesticides. Many said they would prefer not to use pesticides but they were generally regarded as necessary.

4.2.3.6.2 Health and environmental risks

On farmers' perceptions of pesticide impacts on human health and the environment, PCA activities for Central Thailand revealed a higher proportion of farmers perceiving that 'pesticides are harmful to health and the environment with concern' further supported in that many could name some pesticides harmful to the aquatic environment, however, a significant percentage thought they were not harmful if used correctly. Most better-off Sri Lankan farmers also thought pesticides were harmful to health and the environment although more worse-off Sri Lankans perceived pesticides posed no harm if used correctly (Table 34), suggesting worse-off people were less aware of such risks.

Of the 20 farmers interviewed in Sisaket, Northeast Thailand, all claimed to be aware of adverse health and environmental effects of pesticides, further supported by some undertaking activities to reduce environmental and health risks (Table 35).

4.2.3.6.3 Future use of pesticide

On future pesticide use, more worse-off farmers in Central Thailand and Sri Lanka were not planning to alter their pesticide use if it remained affordable. However, the better-off in Central Thailand would use more pesticide if affordable, although more better-off Sri Lankans wanted to reduce their pesticide use for health reasons (Table 34). This suggests farmers priorities are mostly for crop protection although the better-off Sri Lankan farmers were more concerned about health than better-off farmers in Central Thailand.

Similar well-being disaggregated results were not available for Northeast Thailand but as most followed recommended pesticide application levels, had high awareness of environmental and health risks and commonly used bio-pesticide this would suggest most farmers would be uninclined to want to increase their synthetic pesticide use.

Table 34: Farmer perception of pesticide necessity, risks and future use, Central Thailand and Sri Lanka

Study site	Central Thailand		Sri Lanka	
Sample number	n=39	n=39	n=50	n=50
Necessity of pesticide	**Better-off (%)**	**Worse-off (%)**	**Better-off (%)**	**Worse-off (%)**
Pesticide is necessary	41	10	22	**65**
Other measures can be used with pesticide	**54**	**64**	**48**	31
Pesticide is unnecessary	5	26	30	4
Pesticide impacts on health and environment				
Have no significant effect	5	15	0	0
No harm if used correctly	41	33	35	**55**
Harmful and concerned	**54**	**46**	**65**	34
Harmful but not concerned	0	6	0	11
Future pesticide use				
Use more if affordable	**31**	15	0	14
No change if affordable	21	**36**	36	**53**
Reduce to protect environment	4	8	0	0
Reduce to protect health	23	28	**48**	0
Reduce for cost reasons	21	13	16	33

Note: Results from one village in Kokprajadee and Sakaru, Central Thailand were omitted due to insufficient participant numbers to split into two well-being groups.

Table 35: Farmers' pesticide use and hazard awareness, Sisaket, Northeast Thailand

	No.	%		No.	%
Total No. of Farmers	**20**	**100**	**Total No. of Farmers**	**20**	**100**
Pesticide use			**Environment and health**		
Above recommended	**3**	**15**	Awareness	**20**	**100**
As recommended	**8**	**42**	Hire others to spray	**4**	**20**
Below recommended	**6**	**30**	Do not spray near home	**2**	**10**
Use pesticides not toxic to fish	**6**	**30**	Do not spray own crops	**7**	**35**
Do not use pesticides	**3**	**15**	Do not spray before harvest	**7**	**35**
Use bio-pesticide	**13**	**65**			

4.3 Discussion

This chapter presented results on the marketing and regulation of pesticides in the two countries, the nature of pesticide use and surrounding circumstances, potential pesticide pathways and hazards to the aquatic environment, community health and livelihoods and farmers' perceptions of these hazards, with respect to livelihood criteria where relevant.

Production and use of pesticides in many countries within the 'low-middle' income bracket (which include Thailand and Sri Lanka) have increased their use of pesticides since their use in farming (Schreinemachers & Tipraqsa, 2012). In the case of the research countries, insecticide and fungicide use, by weight of active ingredient, have fluctuated a little over the past two decades, however, herbicide use has dramatically increased in Thailand and declined markedly in Sri Lanka since the year 2000 (FAOSTAT, 2014). Furthermore, Thailand is amongst the top ten countries in the world with regards to value of imports of pesticide. High competition results in many brands on the market with sales incentives throughout the distribution chain. Many traders in these and other agricultural inputs provide services for farmers, however, unauthorised pesticide traders exist, dealing in illegal, adulterated and sometimes more dangerous, products. These unauthorised dealers often provide cheaper substandard products with credit incentives which worse-off farmers are most likely to use and bear the possible consequences of poorer value for money and greater environmental and health hazards. Evidence also exists of pesticide products that do not conform to labelling standards and regulations in Thailand as also found by Panuwet *et al*. (2012). Thailand requires a pesticide specific legislation to address important regulatory issues and in both countries low product registration rates and penalties, and limited regulatory resources are insufficient to deter and regulate pesticide products and sales. Overall, there are weaknesses in controlling pesticides leaving areas for exploitation as mentioned by Ecobichon (2001) of which worse-off farmers appear to be at greatest risk.

Examining pesticide use relationship with crop type and pond use (Northeast Thailand), the highest intensity and diversity of pesticide product use was mostly associated with leafy vegetables in Kokprajadee, also found to be a pesticide intensive crop by Lagerkvist *et al*. (2012), Lozowicka *et al*. (2012) and Watanasak (2007). Tangerines and longan received the highest level of pesticide use per unit area per year in Salakru, again also found to be a pesticide intensive crop by Jungbluth (2000) in Central Thailand and Chalermphol and Shivakoti (2009) in Northern Thailand. In Sisaket, Northeast Thailand, chilli was the crop receiving the highest intensity of pesticide use per unit area per year, which is common in Asia (Jeyanthi and Kombairaju, 2005; Mariyono, 2013). Further, as more insecticide and pesticide use was associated with 'active' pond users (who intensively use pond-water for crop irrigation round ponds) and 'passive' pond users (with no regular transfer of water between pond and surrounding agriculture) than non-operational, this suggests a positive correlation between pond-dike activity level and pesticide use, and potentially greater hazards to pond life and fish culture. Crop production was more seasonal in Sri Lanka with the majority of farmers using higher than recommended pesticide concentrations and pesticide cocktails, particularly on OFCs including chillies during *Yala*, as also found by Burleigh *et al*. (1998), whilst this was rice during *Maha*. The future of chilli production was also unpredictable from increasing pest problems and pesticide use and declining profits with most farmers opting out of cultivation the following *Yala* season, suggesting the long-term unsustainability of high pesticide use cultivation highlighted by others (Burleigh *et al*., 1998; Waibel, 2007). Therefore the type of crops grown has an influence on the intensity and variety of pesticides used.

There appeared to be little relationship between pesticide use intensity and well-being status in Thailand. However, as worse-off households in Sri Lanka often applied more than recommended amounts of pesticide from greater fear of crop loss with the perception of increased protection, this suggests a possible link between well-being and perhaps education status (a well-being indicator), pesticide knowledge and risk on pesticide use behaviour, noted by Mariyono (2013) and Wilson & Tisdell (2001). In fact a lack of education and awareness amongst worse-off farmers regarding appropriate pesticide use and crop protection economics has been mentioned by other authors for other Asian countries (Matthews, 2008; Ibitayo, 2006; Rahman, 2003). Rahman (2003) gives an example of this irrational pesticide use by explaining its increase with crop prices and substitution of fertilisers for pesticides. However, use of pesticides, often cocktails, preventatively as opposed to pest or disease related was common amongst all regions as found in other studies (Mariyono, 2013), raising questions about the necessity and cost-effectiveness of this strategy.

Other country differences included both genders spraying pesticide and use of motorised sprayers in Thailand and just males using manual pump sprayers in Sri Lanka. However, pesticide spraying health problems were common in a minority of each region including breathing difficulty, skin irritation and other ailments in line with other authors' findings in other countries (Matthews, 2008; Atreya, 2008; Recena *et al.*, 2006), highlighting issues of chronic illness with potential for long-term ailments.

Pesticide entry to watercourses in farming systems occurred through spray drift, leaching and rinsing of pesticide containers and equipment in watercourses which is common in farming practice in Asia (Damalas *et al*. 2008). The influence of various physical, chemical and biological processes that act on pesticides that are exposed to sunlight or present in the soil or water (Figure 10) may alter their composition and effect on non-target organisms (Merrington *et al*., 2002). On pesticide fate, in Thailand, pesticide may enter aquatic systems and fish from pesticide sprayed crops being fed to fish in ponds and canals, which is mentioned by other authors (Pant *et al*., 2005). Pesticide in water bodies may also be absorbed by aquatic plants, animals and fish or enter fish through the food chain (Mihaich *et al*., 2009; Relyea, 2009) posing potential hazard to fish consumers (community households and wider public) in each region (tank fisheries in Sri Lanka and wild and cultured fish in Thailand). Pesticide was also identified to potentially enter consumers from sprayed crops, some of which were consumed by households and some sold through middlemen to markets.

Subjective evidence of environmental effects of pesticides came from community members' observations of reduced ecological abundance since agricultural mechanisation, large scale mono-crop production and intensive pesticide use. However, farmers' association of particular pesticides with fish kills supports their theory and was also found in Berg's (2001) study of rice-fish farmers in the Mekong Delta, Vietnam. In a study of 400 farmers and 80 key informants in sub-Saharan Africa, pesticides were reported to have reduced ecological abundance including livelihood important honey bee populations and killed livestock and domestic animals through water pollution (Williamson, 2003). Model estimated pesticide hazards supported this by finding hazards posed by some pesticides to the aquatic environment in Central Thailand and Sri Lanka.

The activities most associated with potential pesticide health hazards from use of agri-aquatic systems included bathing and washing clothes and food, which is also common in other Southeast Asian countries (Palanisami *et al*., 2011). However, perhaps the greater health hazards came from the frequent consumption of land crops receiving high levels of pesticide and local fish, aquatic plants and animals, whether purchased as mostly the case with better-off people or obtained from the wild, more common for worse-off people. These potential hazards were supported from objective analysis finding human health hazards from some pesticides through consumption of aquatic produce and drinking water, particularly in Central Thailand. This method of uptake is supported by findings of diet sourced pesticide metabolites in children of Northern Thailand (Panuwet *et al*., 2009). In supporting these types of health hazards in Sri Lanka, Bandara *et al.* (2008 & 2010) highlights the increasing problem of renal failure in farming communities around tanks from agrochemical based cadmium poisoning from consumption of aquatic plants (notably lotus root *Nelumbo nucifera*) and tank tilapia (*Oreochromis* sp.).

The foundation of much of the pesticide use and hazards discussed are the perceptions of farmers on these issues. Promoting pesticide use was a general consensus by farmers in each area that they were necessary, particularly amongst worse-off farmers in Sri Lanka who thought more pesticide equalled less risk, perhaps due to a general lower education level as found by Isin and Yildirim (2007) in Turkey, Mariyono (2013) in Indonesia and Ho and Wu (2010) in Nepal. Similarly, the worse-off people tended to believe that pesticide health and environmental risks were averted by 'correct use' of pesticides, with health taking lower priority than crop protection than the better-off. Hence with these perceptions, many farmers, particularly the worse off, were not planning on reducing their future pesticide use, which might otherwise reduce hazards.

4.4 Summary

This chapter found weaknesses in pesticide regulation, allowing unethical pesticide trading practices in both countries and greater vulnerability of poorer farmers to these practices and agriculture related market forces through disempowerment and debt. Pesticide use is prophylactic and curative in both countries and weaker knowledge surrounding pesticides and greater fear of crop loss encouraged more pesticide overuse amongst poorer farmers in Sri Lanka. Many pesticides used pose significant hazards to human health and aquatic ecology on which the poorest most depend for food and income. The worse-off were also most likely to spray pesticide and have higher risk of occupational exposure. Some ailments after spraying pesticide and visible declines in aquatic ecology may be attributed to pesticide use. Therefore a variety of factors converge placing worse-off community members at highest risk from pesticide use.

Chapter 5 **Pesticide Hazard Reduction**

5.1 Introduction

This final results chapter firstly presents results of farmers' pesticide environmental and personal health hazard reduction measures prevailing in the study sites. Farmers' interest in safe food production was further investigated in Thailand, along with an analysis of crop markets. This is followed by results of investigations into the range of Thai 'safe' fruit and vegetable categories and certification that relate to pesticides and potential weaknesses. The results are then described from investigations of different stakeholder-farmer 'IPM trainings' aimed at reducing pesticide use and hazards in Thai study sites. This is followed by explanation of methodology and results from enquiries into, and case studies of, more successful vegetable IPM programs (on leafy vegetables as similar to Central Thailand and chilli as similar to Northeast Thailand study sites) in other provinces outside the study sites. Methodology used and results are then described for the effectiveness trials of flat fan pesticide nozzles compared with the spray nozzles of selected farmers in the Central Thailand study site as a means of reducing pesticide use. Finally, stakeholders' opinions on current capacity building measures in pesticide hazard reduction and improvement suggestions are presented.

5.2 Farmers' Environmental and Health Hazard Reduction

Results are presented for farmers' environmental and personal health hazard reduction measures in the three study sites.

5.2.1 Central Thailand

Table 36 shows 72 participants of the Kokprajadee workshop categorised by village, gender and 'IPM' training status. All participants that cultured fish (64) selected pesticides less harmful to aquatic animals, two of which also used less pesticide to reduce impact on the aquatic environment (Table 36). The value of fish in discouraging farmers' use of harmful agricultural pesticides has also been demonstrated by Biswas (2008) for Bangladesh in Pretty and Hine's (2000) analysis of different sustainable agriculture systems including rice fields and pond-dike systems of eight Asian countries.

With regards to self-protection from pesticides all except one participant was aware of the availability of formal protective clothing, proper masks and rubber boots, however, from the Kokprajadee workshop none of the participants wore them firstly as they were too uncomfortable and secondly too costly. Instead, most used home-made cloth masks and fewer also used old clothes and boots whilst spraying pesticides (Table 36). Mask trial results revealed only 10 of the 15 farmers trialling the masks to have used them and only one considering one mask as useful for use in the future. The remaining farmers thought the masks were too uncomfortable (Table 37). A study of 280 farmers in Kerala by Devi (2009) revealed similar results with no individuals opting to use proper masks and clothing for similar discomfort and cost reasons. Raksanam *et al.* (2012) study of 482 rice farmers in Thailand, Recena *et al.* (2006) study of 250 farmers in Brazil and Zhang & Lu's (2007) study of 350 farming households in China also revealed few farmers using proper protective gear for similar reasons.

Table 36: Farmers' measures to reduce environmental and personal health hazards from pesticides, Kokprajadee workshop, Central Thailand

Village / No. respondents	Village 2 n=28				Village 3 n=13		Village 4 n=30			
Group / No.	6TM	5TF	9NTM	8NTF	6MNT	7FNT	6TM	9NTF	9NTM	6TF
Crops grown	YLB, L, CC, CWC, MG, P, LM, CK, RG, RA, G, M, C.				L, CC, EP RA, G, B.		L, CC, CCB, CWC, MG, P, CK, RA, B, Cr, Gp.			
Fish produced**	TP	TP	Rh	CC	Rh	None	TP, CSB, JGPC.			
Use pesticide less toxic to fish they sell and eat	6	5	9	8	6	0	6*	9*	9	6
No. aware of formal protective measures	6	5	9	8	6	6	6	9	9	6
No. use formal protective boots, clothes & masks	0	0	0	0	0	0	0	0	0	0
No. use home-made cloth masks, boots & clothes	6	5 mk	9 mk	0	6 mk	0	6	0	9	6

Key: **IPM Training / Gender** - T=trained in IPM techniques NT=not trained in IPM techniques M=male F=female
Crops - YLB, Yard-long bean L, Lettuce CC, Chinese chive, CCB, Chinese cabbage CWC, Chinese white cabbage MG, Mustard green P, Parsley LM, Leaf mustard CK, Chinese kale RG, Red ginger RA, Water rose apple G, Guava, M, Mango C, Carambola, B, Basil EP, Egg Plant, Cr, Cucumber Gp, Grape.
Fish - TP= Tilapia; Rh=Rohu, CC=Common carp; CSB=Common Silver Barb; JGPC= Jullien's golden-price carp.
** for home consumption and sale
Pesticide and protection - * use less pesticide, Mk=mask only

Table 37: Results of mask trial in Kokprajadee

Mask type	Small - filter	Large - no filter	Large - filter	Small - no filter
No. famers testing	9	9	6	6
Did not try	2	3	3	2
Useful	0	0	0	1
Not useful	7*	6*	3*	4*
Will use in future	0	0	0	1

N= 15 farmers and 30 masks (each farmer testing 2 different mask types)
* = reason given, too uncomfortable

5.2.2 Sri Lanka

Tank fish and water resources appeared not to influence farmers' pesticide selection or use as famers' choice of pesticides was based on fear of crop loss, effectiveness and cost (Table 38). Evidently, land crop protection is a farmer's priority and without supporting data it may be surmised that the pesticide hazard posed to bathing, washing clothes or tank fish health and consumption were not perceived or considered important. However, another reason may be that in Sri Lanka, tank water and fish resources are more of a common property and off farmers' land, whilst in Thailand these water resources and fish are on famers' land and belong to them. However, awareness of health hazards and safety measures from spraying pesticide was high (91%) (Table 38), although less than half (41%) understood basic product label colour coding on hazard level and only 27% practiced safety methods (Table 38). Devi's (2009) study of 280 farmers in Kerala also showed a similar majority awareness of safety measures but minority awareness of the meaning of pesticide hazard label colour coding, giving wider credence to the question of value of such measures in communicating pesticide health hazard level to farmers.

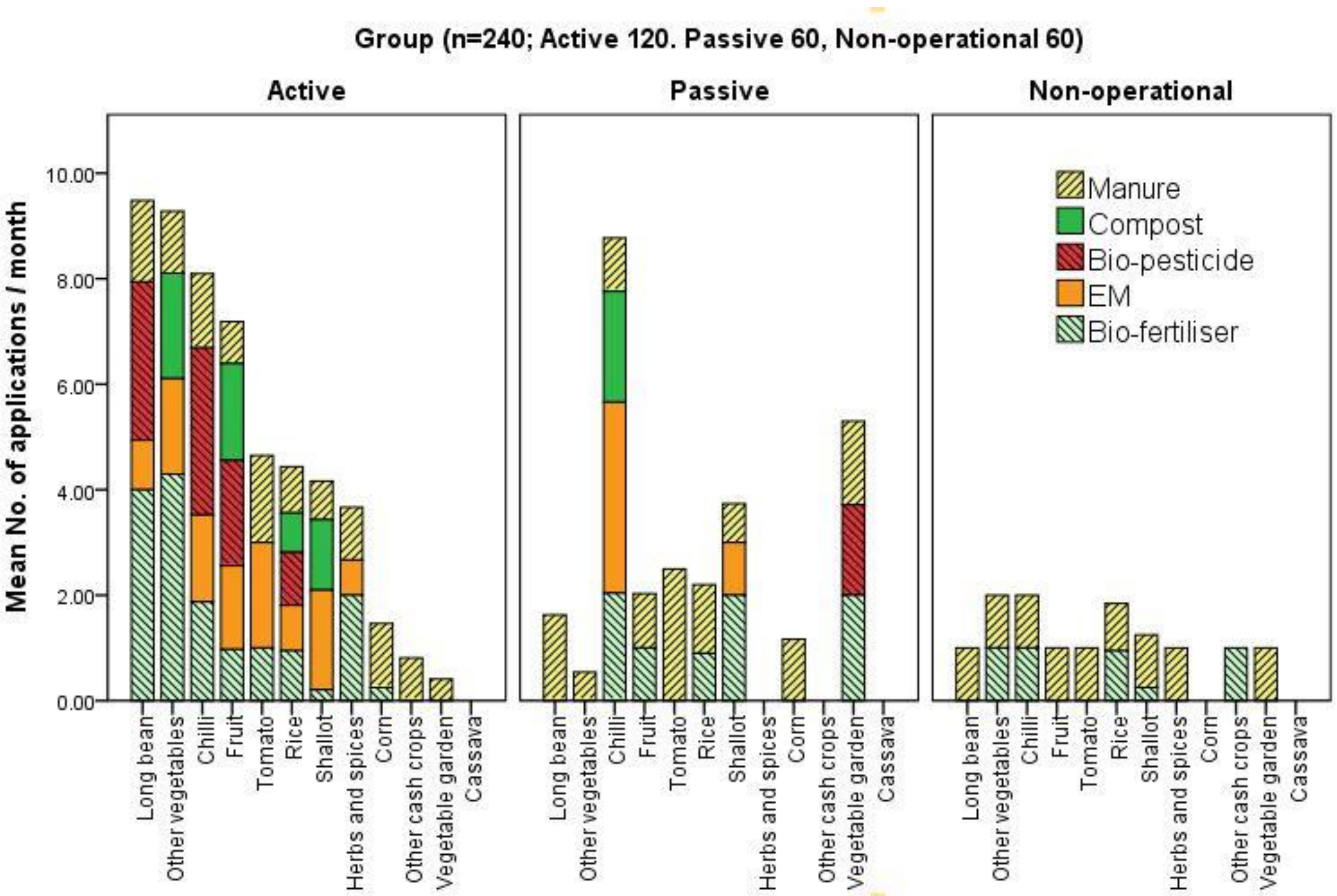
Table 38: Farmers' awareness of safety measures in handling pesticides and label colour coding and practice of safety measures, Sri Lanka

Answer	Use less pesticide or less aquatic toxic products (%)	Aware of safety methods (%)	Aware of label colour coding (%)	Practice safety measures (%)
Yes	0	**91.8**	41.2	27.8
No	**100**	4.1	**55.7**	**67.0**
No answer	0	4.1	3.1	5.2
Total	100	100.0	100.0	100.0

(n=97)

5.2.3 Northeast Thailand

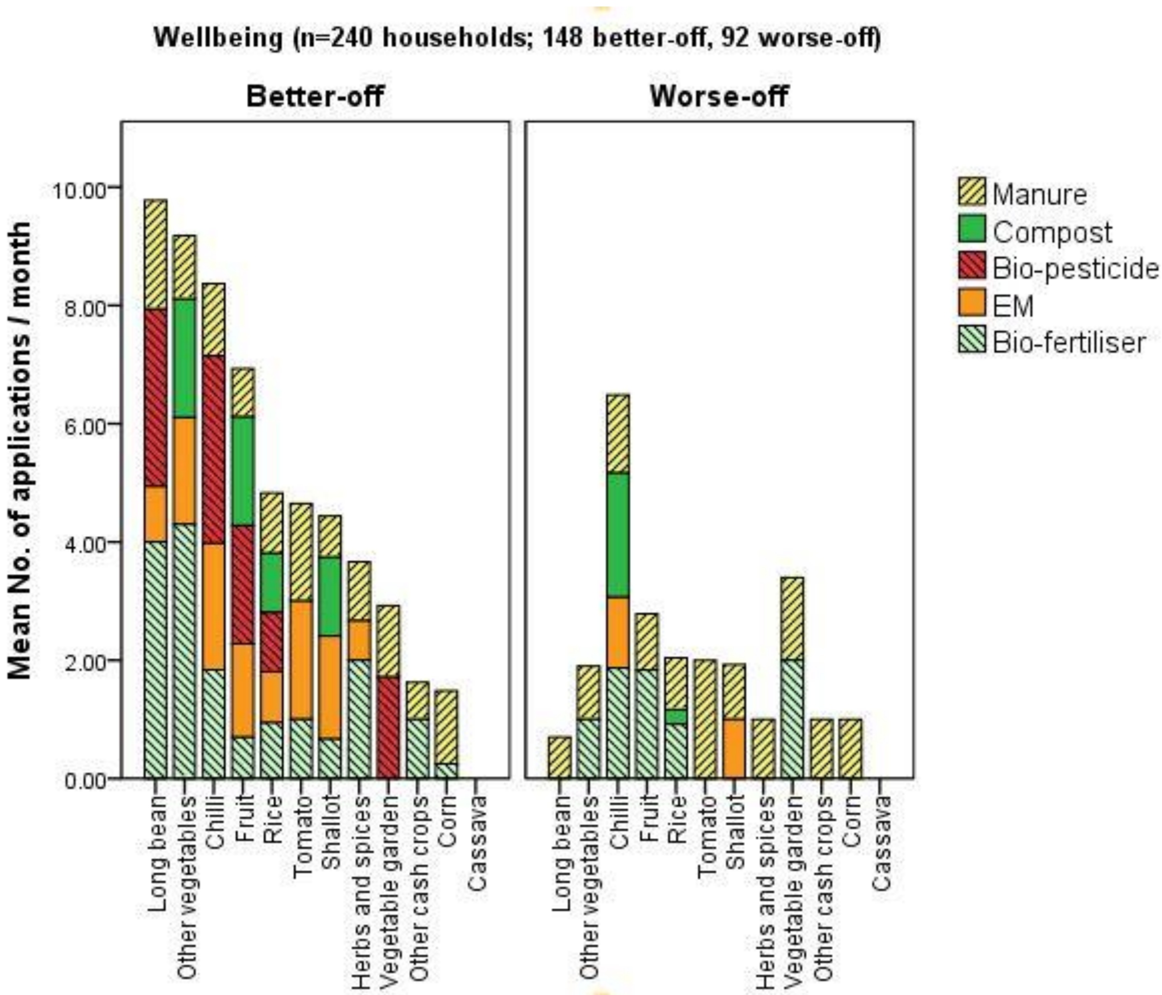
Sisaket household survey results (Figure 65) show 'active' pond-dike farms (using pond water to irrigate pond dike crops), applying bio-pesticide and effective micro-organism (EM) to more crops and often more frequently to crops than other pond-dike groups which do not regularly irrigate crops with pond water. EM was also applied to chilli and shallot and bio-pesticide was applied to vegetable gardens amongst passive pond-dike farms. However, it is not certain whether these IPM pest control measures were influenced by threat of pesticide contamination of pond fish or other factors.



Key: 'Other vegetables' = cucumber, eggplant, mushroom, onion, pumpkin, spring onion, wax gourd, Chinese white cabbage, wild spider flower, meraber nightshade, radish, cauliflower, pak choi, gourd, chives, celery, taro, carrot, *pak nam*, *pak keeleak*, okra, yam bean. 'Other cash crops' = bitter palm, betel vine, cashew nut, groundnut, kenaf, mullbery and tobacco. Vegetable garden = small quantities of mixed vegetables for home consumption. EM = Effective Micro-organism, enzyme facilitated bio-pesticide production.

Figure 65: Mean organic fertiliser and bio-pesticide applications per month by crop type and pond-dike type, Sisaket

Bio-pesticide and EM was also applied to more crops and more frequently by better-off farmers than worse-off farmers, although EM was used on chilli and shallot by worse-off farmers (Figure 66).



Key: 'Other vegetables' = cucumber, eggplant, mushroom, onion, pumpkin, spring onion, wax gourd, Chinese white cabbage, wild spider flower, meraber nightshade, radish, cauliflower, pak choi, gourd, chives, celery, taro, carrot, *pak nam*, *pak keeleak*, okra, yam bean. 'Other cash crops' = bitter palm, betel vine, cashew nut, groundnut, kenaf, mullbery and tobacco. Vegetable garden = small quantities of mixed vegetables for home consumption. EM = Effective Micro-organism, enzyme facilitated bio-pesticide production.

Figure 66: Mean organic fertiliser and bio-pesticide applications by active pond users / month / crop type and well-being, Sisaket

However, semi-structured interviews with 20 farmers, 11 of which were ‘active’ pond farmers, from the household survey **(**Table 39**)** revealed that farmers who did not use pesticide, also fully practiced IPM techniques taught to them and cultured fish. Reduced levels of pesticides and use of products less toxic to fish and home-made bio-pesticides were also practices of most farmers that were taught and partially practicing IPM who also cultured fish. However, farmers not practicing IPM and a minority of those partially practicing IPM but who also cultured fish used pesticides at recommended, sometimes higher dosage levels (Table 39). Therefore, perhaps farmers’ appreciation of pesticide hazards to fish is a key factor influencing pesticide use intensity. In a similar manner Berg’s (2001) study of 120 farmers in the Mekong Delta, Vietnam also showed the significance of fish in pesticide reduction with less pesticide use amongst rice-fish farmers compared with rice farmers alone, whilst Nhan *et al*. (2007) study of 280 Vietnamese farmers showed pesticide use in fruit and vegetable pond integrated systems to significantly affect farmers’ reluctance to invest in pond-fish culture, thus highlighting the link.

On pesticide personal health hazards, all 20 farmers were aware, although none used formal protective gear for similar reasons found in the other study sites and most used some form of home-made protective clothing and masks, as found at the other sites. Additional mitigation measures included hiring others to spray pesticides and avoiding spraying near homes or crops for home consumption, supporting their claims of awareness of pesticide health hazards (Table 39).

Table 39: Farmers' measures to reduce environmental and personal health hazards from pesticides, case studies, Sisaket, Northeast Thailand

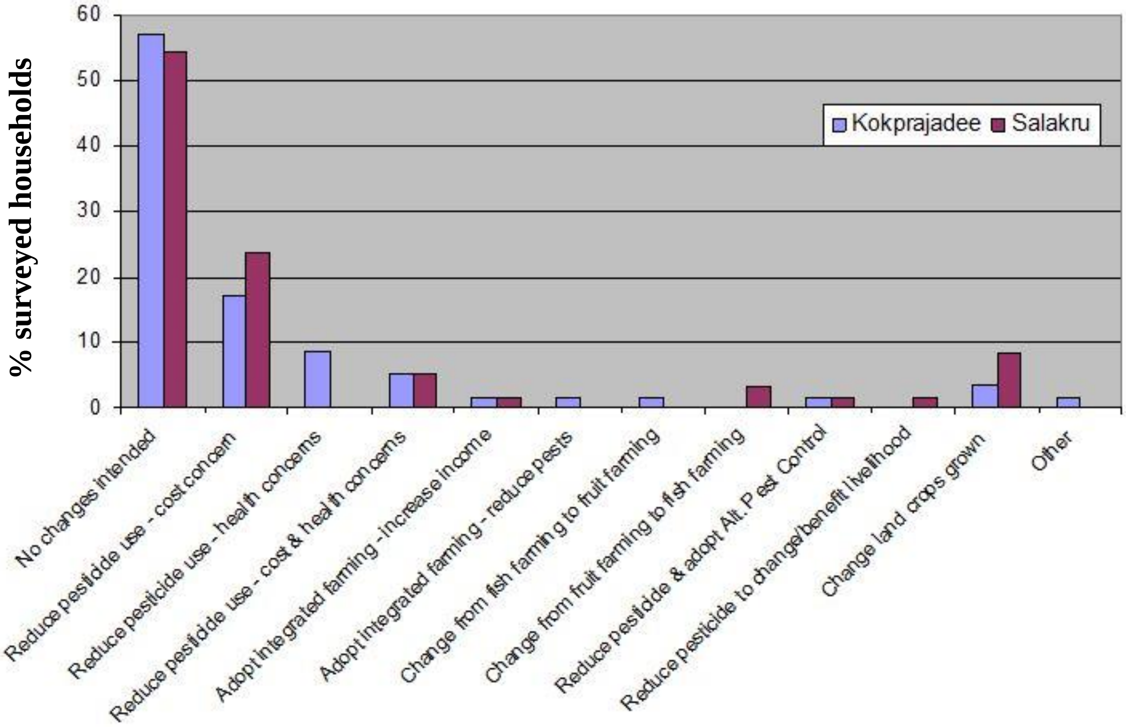
	Number of farmers (n=20)					
IPM						
IPM Training	**Trained**			**Not trained**		**Total**
IPM Practice	**Fully**	**Partly**	**None**	**Partly**	**None**	
No. of farmers	**3**	**9**	**4**	**1**	**3**	**20**
Aquatic production						
Trap fish	2	4			2	**8**
Culture fish	3	9	4	1	3	**20**
For self	3	9	4	1	3	**20**
For sale		2	2			**4**
Pesticide use						
Above recommended			**2**		**1**	**3**
As recommended		3	2	1	2	**8**
Below recommended		**6**				**6**
Use product non-toxic to fish		**6**				
Do not use	3					**3**
Use bio-pesticide	3	**9**		1		**13**
Protective measures						
Awareness	3	9	4	1	3	**20**
Use proper protection	0	0	0	0	0	**0**
Too uncomfortable	3	9	4	1	3	**20**
Use cloth mask		7	3		2	**12**
Use own clothing		7	3		3	**13**
Hire others to spray	1	1	2			**4**
Do not spray near home	1	1				**2**
Do not spray own crops		5	1		1	**7**

5.2.4 Farmer interest in safe food production, Thailand

Another way of reducing pesticide use and hazards is through production of safe food of which farmers' interest in the study sites is presented here.

5.2.4.1 Central Thailand

From the household survey of 58 households in Kokprajadee and 59 in Salakru, Central Thailand, most in each area had no interest in changing their farming practices with only a minority wanting to reduce pesticide use primarily for cost and secondarily for health reasons. Fewer were considering fish production, integrated farming and alternative crop protection measures (Figure 67).



(n=58 Kokprajadee n=59 Salakru)

Figure 67: Household future farm production plans for Central Thailand

Later results from farmer workshops in Kokprajadee Sub-district gave further insight to their thoughts on producing safe vegetables for the domestic market. Half of the farmer groups were interested in producing safe vegetables with most interest coming from the better-off (village 2) participants. However, low prices for safe foods in the domestic market and perceived increased production costs were the main concerns of most groups on safe food production (Table 40).

Table 40: Farmer thoughts on producing crops for safe food markets, Kokprajadee, Central Thailand

Village		Village 2				Village 3		Village 4			
Group (n=71)		6TM	5TF	9NTM	8NTF	6M	7F	6TM	9NTF	9NTM	6TF
Crops grown		YLB, L, CC, CWC, MG, P, LM, CK, RG, RA, G, M, C.				L, CC, RA, G, B, EP.		L, CC, CCB, CWC, MG, P, CK, RA, B, Cr, Gp.			
Fish cultured								T, CSB, JGPC.			
Farmers' thoughts on producing for safe food markets	Interested	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No
	Pests & diseases	1					4	1			
	Low crop sale price	2	4	1	2	2	2	2	1	3	2
	Rising input costs	3	1, 3	3	1	1	1		2	1	1
	Labour scarcity	4								2	
	Lack skills		2								
	Much hassle						3				
	No profit										3

T=trained NT=not trained M=male F=female YLB, Yard-long bean L, Lettuce CC, Chinese chive, CCB, Chinese cabbage CWC, Chinese white cabbage MG, Mustard green P, Parsley LM, Leaf mustard CK, Chinese kale RG, Red ginger RA, Water rose apple G, Guava, M, Mango C, Carambola, B, Basil EP, Egg Plant, Cr, Cucumber Gp, Grape, T, Tilapia CSB, Common Silver Barb JGPC, Jullien's golden-price carp. Ranking: 1 most important to 4 least important

5.2.4.2 Northeast Thailand

Semi-structured interviews with 20 farmers in Sisaket revealed many were interested in growing safer crops with less or no pesticides and some were already producing organic rice and rice seeds for sale at higher prices and pesticide-free vegetables for home consumption. However, difficulty producing unblemished pesticide-free vegetables in large enough quantities for sale, poor local consumer awareness and / or demand for these products and lack of marketing and certification infrastructure were constraints **(**Table 41**).** Some respondents noted the Provincial Governor had shown recent leadership in addressing these issues through establishing an organic market again after the first attempt failed, however this was in its infancy.

Table 41: Farmers' perceptions on safe crop production, Sisaket

	Number of farmers (n=20)					
IPM						
IPM Training	**Trained**			**Not trained**		**Total**
Vegetable IPM Practice	**Fully**	**Partly**	**None**	**Partly**	**None**	
No. of farmers	**3**	**9**	**4**	**1**	**3**	**20**
Aquatic production						
Trap fish	2	4			2	**8**
Culture fish	3	9	4	1	3	**20**
For self	3	9	4	1	3	**20**
For sale		2	2			**4**
Safe food production						
Interested	3	7	2		1	
Produce organic rice / seeds	2	2			1	**5**
Produce pesticide-free veg for sale						
Produce pesticide-free veg (for home)	3	9				
No consumer awareness / demand		3	1		1	**5**
Not economically viable	2	2			1	**5**
Not enough producers	1					**1**
No marketing or certification		3	1			**4**
Difficult to grow unblemished			1			**1**

5.3 Fruit and Vegetable Markets in Thailand

Consumer awareness of, demand and willingness to pay (WTP) for, 'safe' food and the integrity of 'safe' food certification and regulation all influence crop production and pesticide use. This section describes results of investigations into fruit and vegetable markets, trading and 'safe' food certification and regulation.

5.3.1 'Fresh' markets

Fresh markets, sometime referred to as 'wet' markets in literature, are open air general wholesale or retail fruit and vegetable markets where traders can lease space for selling their produce, often with no produce safety requirements.

5.3.1.1 Central Thailand

Bio-resource maps, discussed in previous chapters, from the PCA activities (Figure 54, Figure 55) showed that most farmers' crops are sold to large wholesale fresh ('wet') fruit and vegetable markets, in and around Bangkok (*Pak Klong Talad, Si Mum Muaeng* and *Talad Thai)* and smaller 'wet' markets within the production provinces *(NakhornPathom)*. Smaller amounts were sometimes consumed by the households.

Qualitative information from the Kokprajadee workshop revealed that most commonly middlemen buy crops at the farm gate and sell them at these markets, although one farmer transported his own crops. Farmers explained that middlemen and consumers at these markets preferred undamaged food and did not enquire about food safety. This was also confirmed by traders interviewed at *Talad Thai*, *Pak Klong Talad*, *Si Mum Mueang* and *Nakhorn Pathom* markets.

Farmers described three types of farmer-middlemen relations shown in Table 42. Worse-off farmers tended to buy agri-inputs on credit from middlemen but have to sell their crops to them at a low pre-arranged price whilst better-off farmers purchased their own agri-inputs and negotiated crop selling prices with a choice of middlemen. Similar trading relations are described by Rigg (1986) and have been commonly used since the paid expansion of markets for cash crops began in Thailand in the 1960s.

Table 42: Farmer-middlemen trade relations, Kokprajadee, Central Thailand

	Nature of trade relationship	Farmer criteria
1	Farmer and middleman unrelated. Middleman supplies agri-inputs to the farmer on credit at set rates with farmers bound to sell crops to middleman at a set price prior to production	Poorer, have less control, more risk
2	Farmer and middleman related, loyalty aspect, negotiate prices at which they trade agri-inputs and crops	Intermediate
3	Farmer and middleman unrelated. Farmer chooses middleman offering highest price for crops	Wealthier, have less risk, more control

Outcomes of key informant trader and market manager interviews at these markets (*Talad Thai*, *Pak Klong Talad*, *Si Mum Mueang* and *Nakhorn Pathom*) also revealed there was no mandatory pesticide residue testing of non-certified market produce. However, pesticide residue analysis facilities and government officials were available at the larger markets of *Talad Thai* and *Si Mum Mueang* for random checking of pesticide residues in fruit and vegetables certified organic or pesticide-free to export standard and for market users wanting to have produce tested**.** The market manager at '*Talad Thai*' market explained that regulation happens at farm level and most safe food traders are well known but it appears crops do not have to be sold with certification at the market and that most fruit and vegetables certified as safe for consumption with regards to pesticides or organic are for direct export. He explained that food safety checks were usually done in response to any public complaints and random sampling of safe food pesticide levels is infrequent (2-3 times / year for the market as a whole) and information is freely available to traders on when food inspectors will visit the market. This, according to traders, allowed them to shift between markets in order to avoid possible pesticide residue sampling of their goods and any trade restrictions and penalties, thus undermining the purpose of regulation.

Supporting farmers' workshop statements, differences in sale prices of non-certified and pesticide-free crops at these markets were minimal (5-10%) which reduces farmers' safe food production incentives. A workshop held by FAO (Shepherd, 2005) also revealed a small price difference of around 10% between 'wet' market and supermarket fruit and vegetables in Thailand whilst Gorton *et al.* (2011) survey of primary and secondary data of 'wet' (fresh) markets and supermarkets in Thailand found similar minimal price differences. However, 'safe' fruit and vegetables were less abundant than 'conventionally' produced vegetables and 'safe' produce was more likely to be exotic to

Thailand and the traditional diet. This was a reflection of the market demand and the greater difficulty in producing undamaged safe fruit and vegetables.

5.3.1.2 Northeast Thailand

For sites in the pond-dike systems of Sisaket, Northeast Thailand, rice, fruit and pesticide dependent cash crops, primarily chilli and shallot, were produced. Farmers explained that most cash crop produce is sold to middlemen in the province, who have a base in the town from where it is distributed to other provinces, particularly Bangkok with some going to other SE Asian countries, with no food 'safety' certification or pesticide restrictions as with Central Thailand. Farmers perceived that consumers were either not aware of pesticide health hazards or were not willing to pay for higher priced safer products. A study of 608 Northeast Thai consumers by Posri *et al.* (2007) revealed that given adequate awareness of food pesticide residue health hazards even northeast consumers, generally poorer than Bangkok consumers, were willing to pay premium prices for certified safe vegetables. They concluded that limited availability rather than the price of safe vegetables is a more purchase significant factor.

5.3.2 Supermarkets and safe vegetable production

The study revealed a range of supermarkets in Thailand with foreign-domestic partnerships, including 'Carrefour', 'Tesco-Lotus', 'Tops' and 'Big C' which all stocked locally produced and imported fruit and vegetables, both conventionally grown with pesticides and certified with some category of food safety.

In Kokprajadee Sub-district, village headmen and provincial Department of Agriculture Extension (DOAE) key informants revealed that very few farmers grew vegetables certified as safer to eat. These farmers reduced their pesticide use by protecting their crops using nets, supplied by the DOAE through a past scheme to promote safer food production. In this case vegetables could be certified and packaged with the Department of Agriculture's (DOA) 'Hygienic Food' logo that is shown and described by Roitner-Schobesberger *et al*. (2008) and Boselie & Buurma (2003) and were sold at slightly higher prices through the DOA to some supermarkets. Farmers and middlemen from the workshop claimed that minimal farm sale price differences between 'conventionally' grown produce and DOA certified 'Hygienic' vegetables under this scheme hindered expansion of safe vegetable production as well as the lack of capital, skills and market access.

In Sisaket, Northeast Thailand, interviews with the Provincial DOAE Officer and 20 farmers in the case studies revealed that some farmers produced organic rice sold at a higher price than conventionally grown rice. There were no farmers producing vegetables that were certified as 'safe' and the most innovative farmers in pesticide reduction used home-made bio-pesticides made from organic matter and molasses fermented, sometimes with the aid of effective micro-organism (EM), an anaerobic bacteria. A past government scheme for the production and marketing of organic fruit and vegetables in Sisaket was tried but collapsed due to production problems. From interviews it was clear that farmers in this region were less familiar with safe vegetable production, certification, markets and related government schemes, but surmised that the main constraint was that city consumers were either not aware of pesticide health hazards or were not willing to pay higher prices for safer crops. In support of the latter, a study of 848 Bangkok consumers by Roitner-Schobesberger *et al*. (2008) found that awareness of pesticide-related health and environmental issues and purchase of organic foods increased with consumers family income, education level and age.

5.4 Pesticide Reduction Capacity Building, Thailand

This section presents results of investigation into the influence of capacity building measures taken in Thailand to reduce pesticide use in vegetable production. This comprises domestic safe vegetable certification, labelling and regulation related to pesticides and farmer 'training' programs in IPM run by stakeholders in the study sites and further field. Results are also presented from the Central Thailand study site farmer experiments on the effectiveness of efficient pesticide applicator nozzles. Finally, Thai stakeholders' relations and opinions on progress and constraints to pesticide hazard reduction are presented.

5.4.1 Food safety certification and labelling

Thailand's market for 'safe' healthier foods is expanding, and food certification, labelling and regulation that relate to pesticides has evolved over recent years and is summarised in Table 43. There were many types of logos, certifications, regulations and food safety levels in relation to pesticides in fruit and vegetables in Thailand that are provided by different stakeholders. The most stringent pesticide standards relate to private then DOA certified organic produce, the former regulated by an independent body and the latter by the DOA. DOA certification requires farm record inspection, soil, water and crop analyses for pesticide residues and covers production, processing and handling operations. Next, the 'Q' mark logo with GAP (good agricultural practice) and 'safe food' wording provided by the DOA distinguishes crops grown under ThaiGAP with restricted pesticide use, the 'Q' mark identifying the produce as compliant with international food quality and safety standards. This incorporates standards for water used, suitability of site, use of agrochemicals, product storage, data recording, pest-free products, quality management, harvesting and post-harvest handling. Good management practice (GMP) sometimes accompanies the logo incorporating high management and product quality standards from farm to end-consumer sales. Food pesticide residues are regulated by the DOA through on-farm record checking, auditing and crop pesticide residue testing using sophisticated gas chromatography methods.

These organic and other higher food safety certifications have been a step forward from the other domestically used certification logo for 'Hygienic Fruit and Vegetables' provided by the DOA, which is awarded for satisfying internationally recognised Codex FAO/WHO food safety standards including proper use of pesticides, regulated by farm record checking and crop pesticide residue testing **(**Table 43**)**. The 'Pesticide Safe Vegetables' certificate and logo is provided by the Ministry of Public Health for produce that is safe for consumption based on their own health and safety criteria but does not mean that produce was grown without pesticides, with crop residue testing being carried out at harvest by the DOA. Another logo is provided for food stalls by the Ministry of Public Health and there are other 'Pesticide Free' logos found to be placed on products by producers, wholesalers and retailers to indicate foods that are safer to eat than other products however they have no formal recognition by government or professional body. The main constraints to these labels reducing pesticide use are potentially consumer confusion with so many labels for similar food safety standards and misleading logos claiming pesticide-free status when they are not as also found by Roitner-Schobesberger *et al.* (2008) survey of food safety labels and 848 consumers in Bangkok. Wyatt's (2010) results of 320 Chiang Mai consumers also found instances of lack of formal food safety certification and some food safety label wording undermining consumer trust. Lack of supporting information at point of purchase may further limit consumer decision-making and confidence with consequences for growth in safe food production.

Table 43: Safe food labelling, certification and regulation, Thailand

Label	Label name and provider	Certification criteria and training	Pesticide regulation
	Organic Agriculture Certification Thailand (ACT) through approval of International Federation of Organic Agriculture Movements (IFOAM). The 'Splendid' logo is a logo for organic produce provided by ACT.	Private sector led and certified. From community-based organic farming. Started from simple standards based on practicality by Thai farmers, developed to equivalent of IFOAM Basic Standards. Officially approved in 1999**. C**overs crop production, processing and handling.	Independent inspectors check organic vegetable production methods and analyse soil, water and crops to internationally recognised standards associated with IFOAM.
	The **Organic Thailand** logos certify growers according to Thai standards for organic farming. Approved by the Department of Agricultural Commodity and Food Standards. Provider: DOA.	Product has meets organic standards set by the Department of Agriculture (DOA)**.** Chemical-free and GMO-free.	DOA inspectors check organic vegetable production methods and analyse soil, water and crops
	Crops grown using 'Good Agricultural Practice'. Provided by the Ministry of Agriculture and Cooperatives	GAP standards. Q indicates quality and safety to international standard. Certified producers coded for traceability, record-keeping, personnel qualifications, sanitation, cleanliness, equipment verification, process validation and complaint handling.	-DOA check farm record books and crops for pesticide residues using gas chromatography. Problems have to be rectified within 30 days. Auditing by Government team. Certificate renewed annually.

Label	Label name and provider	Certification criteria and training	Pesticide regulation
	Logo for "hygienic" produce ("*Phak Ponlamei Anamai*") of the Hygienic fresh fruit and vegetables production pilot project of DOA, 1994. To be replaced by the new Food Safety logo of the Ministry of Agriculture and Cooperatives, DOA, DOAE	Farmers apply for production and sale permit. Taught by DOAE on crop production using GAP, natural farming and IPM e.g. sticky trap, Bt, nematodes, NPV, etc. Farm practices and food safety inspection and crop sampling by DOA project officers on restriction and regulation of pesticides. If results meet Codex Standard of FAO/WTO permit is granted for a year by DOA Director and given logo packaging and code. Need to inform DOAE to alter production. Producer and seller must have facilities for random sampling.	-Restricted pesticide use -Farm record keeping, inspection -Crop pesticide residue sampling and analysis at farm, market and laboratory during harvest-time. The project had 305 member farmers, 1994-April 2002 covering 40,000 rais of 50 provinces; 10,000 rais veg, fruit 16,000 rais, mixed fruit and veg 7,500 rais and mulberry tree 4,500 rais.
	Pesticide safe vegetables logo provided by the Ministry of Public Health.	Provided to retailers who test their produce for toxic substances including pesticide residues before selling produce. Must meet MOPH safety standards.	-MOPH toxic substances standards for fresh produce including pesticide residues

Label	Label name and provider	Certification criteria and training	Pesticide regulation
	This logo is to certify food safety in shops and market places. Ministry of Public Health	Given to fresh food stalls or ingredients available in the market including vegetables and fruits that don't have FDA registration. A safe food logo for food stalls that have been checked three times with no contamination above allowed levels. Substances tested include borax, formalin, salicylic acid, pesticides, sodium hydrosulphide and synthetic colours.	-Regulation done through food testing for various food contaminants. Done mainly by food market owners and food stall owners, with spot checks by the Ministry of Public Health due to resource constraints.
	Pesticide free logo. Provided by producers, wholesalers or retailers.	It's aimed at indicating these foods are safer than other products, but the standards are not published or officially approved.	Unknown

5.4.2 Farmer pesticide reduction training programmes

This sub-section describes results of investigations into farmer IPM and GAP training in the study provinces of Nakhorn Pathom and Sisaket and the methods and results of further case studies of other successful programs in some accessible neighbouring provinces.

5.4.2.1 Nakhorn Pathom, Central Thailand

Table 44 shows results of training that household surveyed farmers had received. A minority of households in each area had received training in bio-fertiliser and bio-pesticide production and some alternative pest control techniques although further details were not obtained from the survey.

Table 44: Farmer training in IPM, from household survey, Central Thailand

Study area	Sample no. households	No. trained	Training type	Training provider	Training duration
Kokprajadee Nakhorn Pathom	58	19	Alternative pest control, making bio-fertiliser & bio-pesticide	DOAE	1 day
Salakru Pathumthani	59	17	Alternative pest control, making bio-fertiliser & bio-pesticide	DOAE	1 day

From Kokprajadee farmer workshops, farmers were grouped according to IPM training and gender **(**Table 45**).** Eighteen farmers were trained in some IPM techniques, which mostly involved home bio-pesticide production and use. The DOAE had provided some farmers with pest traps and a few with nets for crops (for farmers prepared to purchase the framework), the basis of farmer selection being those interested. Two farmers not trained had also received nets. Of the 20 total, half claimed the techniques were beneficial in terms of reducing pesticide use, improving health and profit whilst half claimed nets were costly to maintain and IPM techniques were too time consuming, not very effective and less practical for large cultivated areas as also stated in a bio-pesticide review by Glare *et al.* (2012). Bio-pesticide required a large amount of material and limited post-training support also hindered uptake **(**Table 45**).**

Table 45: Farmers' IPM training and practices, Kokprajadee workshop, Central Thailand

Village / No. respondents	**Village 2 29**				**Village 3 13**		**Village 4 30**			
Group / No.	6TM	5TF	9NTM	8NTF	6NTM	6NTF & 1TF	6T	9NTF	9NTM	6F
Crops grown	YLB, L, CC, CWC, MG, P, LM, CK, RG, RA, G, M, C.				L, CC, EP RA, G, B.		L, CC, CCB, CWC, MG, P, CK, RA, B, Cr, Gp.			
Fish produced**	TP	TP	Rh	CC	Rh		TP, CSB, JGPC.			
Had IPM training	6	5	0	0	0	1	6	0	0	0
Net	1						0	1	1	
Bio-pesticide	5	5				1	6			
Traps	2						2			
Beneficial	3	4				1	1	1		
Impractical	3	1					5		1	

Key: **IPM Training / Gender** - T=trained in IPM techniques NT=not trained in IPM techniques M=male F=female
Crops - YLB, Yard-long bean L, Lettuce CC, Chinese chive, CCB, Chinese cabbage CWC, Chinese white cabbage MG, Mustard green P, Parsley LM, Leaf mustard CK, Chinese kale RG, Red ginger RA, Water rose apple G, Guava, M, Mango C, Carambola, B, Basil EP, Egg Plant, Cr, Cucumber Gp, Grape.
Fish - ** Home consumption or sale; TP= Tilapia; Rh=Rohu, CC=Common carp; CSB=Common Silver Barb; JGPC= Jullien's golden-price carp. Numbers = number of farmers.

5.4.2.1.1 Most innovative farmers in Nakhorn Pathom Province

Interviews with nine farmer trainers (Trainers of trainers - TOTs) of IPM/GAP programmes in the province identified five farmers in this area as being the most innovative and successful in reducing synthetic pesticides in vegetable production for the domestic market and results of these trainer and farmer interviews are shown in Table 46. From these farmers interviewed their land was 0.3-3.2 ha, one attended a one day training course and received nets to produce safe vegetables, two farmers had received FFS training by the DOAE of which one also used nets and two farmers had received training by the Kyusei Foundation using the DOAE FFS training methods and all had received home bio-pesticide and bio-fertiliser production use training. Training included GAP and some IPM techniques. The objectives of these training courses were for farmers to reduce their synthetic pesticide use and if possible, eliminate their use. The main crops grown were leafy vegetables, yard-long bean, sweet potato (Taro), chilli, asparagus, sugar cane and 'garden vegetables' for home consumption. All farmers were aware of natural enemies - birds, dragonflies, stink bugs, spiders, grasshoppers, black ants and other pest enemies and used a homemade bio-pesticide made from cherry snails, fish, vegetation, EM (Effective micro-organism) and molasses.

Only a single farmer, Mr Boonsong, produced vegetables without synthetic pesticides for health reasons (from synthetic pesticide use) using only home-made bio-pesticides, made from fermentation of organic matter in solutions of EM and molasses, of which he had a selection but had no safe food certification. Without synthetic chemicals, the resulting pungent foul odour of the final diluted bio-pesticide works as a natural pest repellent. The others still used synthetic pesticides at lower amounts than before and two used purchased bio-pesticides although the farmer, Mr Aksorn, using nets, received a higher price for his crops from the DOAE supplying supermarkets than the middlemen supplying fresh ('wet') markets. Mr Durian, using nets, said local customers, aware of his practices, chose his crops over others for health reasons.

Problems in IPM implementation were that it was less practical for large areas in terms of the implementation time involved, purchased bio-pesticides such as Spinosad and Bt were expensive, and that insect traps also caught natural enemies. Additionally, the success of sticky traps was weather dependent, nets were high maintenance and costly and continued synthetic pesticide use destroyed natural enemies of pests. Home-made bio-pesticides were effective if prepared properly and applied frequently (minimum once / week) at high enough concentrations, however, this required much material, storage space and effort in preparation and application. However, farmers who reduced pesticide use claimed to have benefited from improved health from reduced pesticide use and they also either did not spray crops for home consumption or washed them in salt water with the perception that this would expel any pesticide residues. Experimentally this procedure has proven successful in significantly reducing pyrethroid residues in chillies and tomatoes (Chauhan *et al*., 2014). Farmers claimed that of those who attended training sessions few practiced the techniques. Two of the farmers lectured farmers on IPM and GAP for the DOAE, but one claimed not to entirely believe in it and the DOAE trainers did not provide post-training support or evaluate outcomes, whilst the other claimed that most farmers were too lazy to learn and practice the techniques.

5.4.2.1.1.1 Vegetable IPM trainings in Nakhorn Pathom

Further results are presented for vegetable IPM training and uptake in the wider Nakhorn Pathom Province that Kokprajadee Sub-district lies within. All nine trainers incorporated IPM techniques and GAP together with farmer groups through FFSs, the number and length of which depended on budget. Content varied with crop type and pest problems, but included agro-ecosystem analysis (AESA) and often proper seed selection, water and fertiliser management, composting, biological pesticides (including Neem *Azadirachta indica*, lemongrass *Citronella sp. Cymbopogon nardus*, *C. saapsuea, C. asteraceae* and Asteraseae *Chromolaena odorata*), Nucleopolyhedrovirus (NPV), *Bacillus thuringiensis* (Bt), antagonistic fungi such as *Trichoderma sp.*, breeding of natural enemies, use of hormones, good practice crop harvesting and preservation techniques. Five trainers implemented training with leafy vegetable crops and one with chilli over three districts of Nakhorn Pathom outside of the study district, Nakhorn Chaisri. Other crops targeted by FFS included asparagus, okra, indigenous vegetables like winged pea, cucumber, celery, onion, yard-long bean, parsley, fruits and rice.

Evidence of any success from these nine trainers was limited as no formal evaluation was conducted by themselves or any other body. One trainer mentioned that few farmers sell safe vegetables to the Provincial DOAE Office for 'hygienic vegetable' certification and another said some farmers adopt bio-pesticide use from taught techniques, but that was all. The trainer for asparagus and okra said his farmers were certified by the Provincial DOAE Office for safe food '*pakpodpaijaksarnpit'* production including traceability with produce sold in local district markets whilst others supplied larger Bangkok markets such as *Si Mum Muaeng*, *Pakklongtalad* and *Talad Tai* or exporting merchants. Seven trainers were unsure of success rates, claiming they "only had to teach" and used no formal evaluation system. Braun's *et al*. (2006 & 2008) global review of FFS also found a widespread lack of evaluation. All trainers said evaluation was difficult and suggested only 30% of trained farmers adopted some practices. Reasons given for limited success were lack of farmer interest and participation aside from those growing for export and problems in independent implementation**.** Three trainers revealed that some farmers who had not been trained were using home-made bio-pesticides and / or nets, suggesting some level of secondary adoption had occurred.

From detailed interviews with one trainer of leafy vegetable IPM and the District Agriculture Extension Officer of the study district Nakhorn Chaisri revealed in 2004, 600 farmers were to be trained in that district (40 per sub-district) in fruit, vegetable and rice GAP. They checked trained farmers' GAP practices twice per crop cycle but usually farmers failed to fully comply with GAP regulations from lack of or substandard record keeping on chemical use and being disorganised as also found in another GAP study of 295 farmers in North Thailand by Schreinemachers *et al*. (2011).

The trainer Mr Picheit Namtien, had carried out FFSs in leafy vegetables in 2003 in Bang Kaen District, with 40 participants meeting on one farm eight times during a crop cycle. His target was for 25 of 40 farmers to complete the whole training session. Other farmers were invited to attend a one day demonstration on what the others had been taught under the King's FFS programme which is not included in the DOAE vegetable IPM FFS programme. 30-70% of farmers completed the course, but according to farmers they did not implement the techniques fully due to the time required, higher costs involved, slower and less successful impacts on pest control compared with synthetic pesticides, no increased crop price offer and no marketing assistance. The general idea in these trainings is that farmers who adopt the teachings fully then become trainers themselves, however, the trainer explained that no farmers were elevated to trainer status from lacking confidence, whilst farmers claimed not to fully believe in it.

5.4.2.1.2 Sisaket, Northeast Thailand

Of the 20 farmers selected from the household survey for semi-structured interviews with mean land holdings of between 0.16 ha and 0.8 ha in Sisaket, Northeast Thailand, 16 had received training by the DOAE in bio-pesticide and bio-fertiliser formulation of which three were taught more IPM techniques. Of these 16, two were practicing fully, 11 partially and three were not (Table 46**)**. One farmer was also trained by *Santi Asoke* (a strict order of monks) in farming attitude that involved chemical free production which he fully practiced. Three were not trained in vegetable IPM and not practising although one grew organic rice, bought at a premium price by a Buddhist group (*Si-sah-aso*). Aside from cash crops, most farmers had vegetable gardens (grown without pesticides) and grew rice for their own consumption. Fish, mostly tilapia, was grown, for home consumption or sale and encouraged pesticide use reduction.

Many of the farmers partially and fully practicing IPM noted that poor health from pesticide exposure was the main stimulus for interest and perseverance. Some benefited from improved plant health and fewer pest problems, requiring less pesticide use. An APO (2000) review of IPM on 18 vegetable crops in Thailand also found significantly lower pest infestation in chilli, asparagus, shallot and onion. Local demand for healthy food was said to be growing with some consumers paying more for pesticide-free crops despite no formal certification and farmers wanted more effort in local safe food market development. However, most farmers claimed IPM was impractical for similar reasons mentioned by farmers in Kokprajadee, Central Thailand and thought that the DOAE could do more with IPM other than just bio-pesticide and bio-fertiliser promotion. Farmers also claimed that often the people who need and would benefit from DOAE training were not invited due to a biased selection process towards headman favoured community members.

5.4.2.1.3 IPM and GAP training scheme case studies further afield

5.4.2.1.3.1 Introduction

Chapter 2 has already described the methods used for identification and investigation of IPM trainers, IPM trained farmers and the most innovative farmers in pesticide reduction techniques within the Thai study provinces. However, in order to establish the wider scope, implementation and uptake of pesticide reduction training and to see how this may benefit study site farmers, investigations were made into training on similar crops as those grown in Kokprajadee and Sisaket (leafy vegetables and chilli) in other neighbouring provinces of which the methods employed and results are described below.

5.4.2.1.3.2 Methods

Secondary information was obtained from the DOA head office on IPM and GAP programmes on leafy vegetables and chilli in other Central and Northeast Thai provinces within a day’s reach of the Pathumthani research base for investigation. IPM and GAP trainers in provinces where this was undertaken were questioned by telephone on details of the training and outcomes. Successful programs, by trainers’ opinions, were identified with mixed vegetables in Khon Kaen, Northeast Thailand and leafy vegetables in Nonthaburi, Central Thailand. Training in Nonthaburi was carried out in collaboration with DANIDA with DOA ‘hygienic vegetable’ certification and sale to supermarkets whilst in Khon Kaen, training also included input by Khon Kaen University with no food certification and produce sale to local fresh food markets.

These DOA enquiries and stakeholder interviews also revealed successful EUREPGAP training and certification run by exporters with the DOA in Nakhorn Ratchasima (Korad) and Roi-Et Provinces of Northeast Thailand on chilli primarily for export, then supermarket sale. The supermarket ‘Tesco-Lotus’ also ran ThaiGAP training with farmers in Suphan buri for chilli for sale in the supermarket.

A review of local media also revealed successful NGO led GAP and IPM training on mixed fruit and vegetables in Khon Kaen, Northeast Thailand with non-certified pesticide-free produce sold in district fresh markets in the province. The program was initiated by local medical doctors following pesticide related health issues and farmer debt issues in the province.

In each case semi-structured interviews were held with trainers and farmer groups; those practicing fully and those partially or not practicing. The range of training providers, their training programs and farmers investigated, including those in Nakhorn Pathom and Sisaket Provinces are shown in Table 46.

5.4.2.1.3.3 Variables

Overall, the media, stakeholder interviews and DOAE IPM and GAP trainer enquiries in selected provinces identified a selection of potentially successful training programs in chilli, leafy vegetables and mixed vegetable GAP and IPM, from farms of different sizes in a range of locations, with different training providers, levels of food safety, value and markets supplied (Table 46). The five farmer training categories distinguished by colour coding are shown in Table 46**.** Within the study areas of Central and Northeast Thailand, short DOAE GAP training sessions were implemented for small to medium scale farmers for pesticide-free certification for supermarkets and fresh (‘wet’) markets, covering chilli and leafy vegetables (grey category). Outside the study areas, exporter led short EUREPGAP training sessions on small to large farms for chilli export and domestic supermarkets are indicated in yellow in Table 46. A supermarket also led short ThaiGAP training sessions on medium sized farms for sales of chilli in their shops indicated in pink in Table 46. Longer GAP with IPM FFS training sessions were administered by the DOAE on small to medium sized farms for reduced pesticide certification of leafy vegetables for supermarket and fresh (‘wet’) market sales (green category, Table 46), whilst similar training sessions were implemented by an NGOs on similar sized farms and mixed crops for district fresh markets with no certification (blue category, Table 46). Selection of these farms for case studies therefore provided a number of variables for investigation to highlight areas reasons for success or failure of pesticide reduction programmes.

Table 46: Summary of trainer interviews and farmer group case studies outcomes, Thailand

Colour	Cases	Study province	Farm size	Trainers	Crop	Techniques	Length	Certification	Markets
Grey	2	Inside	Small-Med	DOAE, NGO	Chilli, leafy veg	GAP	Short	Pesticide free (1) / none (1)	Super & fresh
Yellow	2	Outside	Small-Large	Exporter, middleman supermarket,	Chilli	GAP	Short	GAP (2) & Q (1)	Export, super & fresh
Pink	1	Outside	Med	Supermarket, middleman	Chilli	GAP	Short	None	Super & fresh
Green	2	Outside	Small-Med	DANIDA, DOAE, NGO	Leafy veg	GAP, IPM, FFS	Long	Hygienic Veg (1) & Pesticide Free (1)	Super & district fresh
Blue	1	Outside	Small-Med	DOAE, NGO, University & local wisdom farmers	Mixed	GAP, IPM, FFS, IAA	Long	None	District fresh

Region	**Central Thailand**				**Northeast Thailand**				
System	**System 1**	**System 2**	**System 3**	**System 4**	**System 5**	**System 6**	**System 7**	**System 8**	**Outcomes**
Stakeholder location	KCF Korad	Tesco lotus Suphan buri	DOAE DANIDA Nonthaburi	DOAE Nakhorn Pathom	ITC Roi-Et	Study Site Sisaket	DOAE Khon Kaen	SCDF Khon Kaen	
'Training' provider	Exporter, DOAE, middleman	Supermarket, middlemen	DOAE, DANIDA	DOAE, Kewsay foundation	Exporter, DOAE	DOAE	DOAE, university	NGO, wisdom farmers, Uni,	
Training / marketing package	Short, lecture, GAP, chilli, limited post-support, price guarantee, exported	Short, GAP, chilli, post-support, no price guarantee, domestic supermarkets & city markets	Long, GAP, IPM, leafy veg, limited support, price guarantee, domestic safe food market	Short, bio-pesticide, nets, long, GAP,FFS, little post support, supermarkets	Short, GAP, chilli, little support, supermarket, no price guarantee	Short, bio-pesticide, no support or guaranteed prices, city markets	Long, GAP, IPM FFS, mixed crops, support, no price guarantee, district markets	Long, IPM, integrated farming, ponds, trees, support, network, local markets	Different stakeholders and training types, regions, crops, support and price safety.
Monitoring & evaluation	Middleman 2 / month, observation & records	None	Visit, check residues in soil, water, crops for 6 months.	DOAE test veg for market, No evaluation	No formal evaluation DOAE check logbook/month	No evaluation	Informal, DOAE visit monthly. Pre & post-test.50%+pass	No formal evaluation but being organised.	No formal evaluation, residue testing, record keeping
Success rate	Trainer -1 Of 20, 7 trained 2 practicing	Trainer -1 Of 10, 1 farmer partly doing	Trainer - 1 Of 25, 10 trained 5 partly doing 5 not doing	Trainer - 1 Of 5, 1 uses net 3 partly IPM 1 not doing	Trainer – 1 Of 30, 12 partly doing, 5 fully doing - 5	Of 16, 2 fully doing, 11 partly, 3 not	Trainer - 1 Of 27, 23 partly doing, 9 fully doing	Trainer – 1 Of 57, all doing (G2), of 43, 17 part doing (G1)	
Farm size	2-300 rai	4-10 rai	4-10 rai	2-20 rai	1.5-4 rai	1-5 rai	0.25 – 2 5 rai	G1 >2 G2 1-2	<1-300 rai
Farm Scale	Large	Medium	Medium	Medium	Small-Med	Small-Med	Small	G1Med G2 Sm	Small-large
Irrigation	Groundwater	Canals & ponds	Canals	Canals	Groundwater	Ponds	Ponds	River & ponds	Various
Farm Owned	Owned	Rented	Owned	Owned	Owned	Owned	Owned	Owned	Owned / rented
Contract	Formal	Informal	None	None-informal	Informal	None	None	None	Varied
Safe food	GAP (+ net for	GAP (not certified	GAP (not	GAP	GAP	some organic	Hygienic	Little or no	GAP

Practice	Pak tsoi)	yet)	certified yet)			crops for home	vegetables	pesticide use	
Certification	GAP & Q mark in process, not EUREPGAP - expensive	GAP in process by DOAE	Sell 'Hygienic vegetables', to mall, DOAE - no certification	4 had none, 1 had GAP by DOAE	GAP in process by DOAE	None	Pesticide free (pak pod pai jak sarn pit) certified by DOAE	None, but local consumers aware produce is pesticide free	EUREPGAP, GAP, Pesticide free, hygienic, none.
Regulation	Keep log book, residue testing by buyer	Tesco lotus do pesticide residue tests	Log book, not sure if checked for residues before sale.	DOAE tests pesticide residues in vegetables for super-markets	Tested using standard test kit at sorting factory & by DOA for export	No regulation of food safety	DOAE use GT test kit to test veg residues, farm & markets	none	GAP log books, residue testing, exports – residue testing
Outcome successes / failures	Hired spraying, health ok Soil, yield improved Cheaper production Pesticide salesmen changed to selling bio-pesticides Complex >2 rai uneconomic More profit Difficult to grow enough to standard	Less odour Those practicing GAP, better water / fish quality, keep canals clear, catch eat fish from ponds Those not practicing GAP: use illegal toxic pesticide available from shop; kill fish in farm canal within 8 hours, don't eat canal fish More profit	Pesticide marketing salesmen pressure reduced Safe crop prices not much higher than conventionally produced crops Biopesticide products expensive, less economical Damaged crops More profit Less pesticide antibodies in blood	Few reduced pesticide, 1 totally and now multicrop & fish producer, improved health Environment, yield improved No support, marketing help IPM impractical for large areas More profit	Chilli group established 2004, initiated by DOAE. Now sell through middleman to supermarkets & exporters Improved soil, yied Complex, time consuming IPM impractical for large areas More profit	Few have changed to reduce pesticide, use no spray periods, most increased due to pest problems Soil condition reduced Only poor health is stimulus Time consuming, IPM impractical for large areas Good local demand for organic	No pesticide for those practicing IPM, GAP, improved health, yield, water quality, socially from no competition 2004 DOAE 27 trained in (pak pod sarn pit) hygienic veg production, more profit Trainers have links with Alternative Agriculture Network (AAN) Local consumers not fussy on food appearance	Gp 1: Reduced pesticide Gp 2: No pesticide for health, env & fish protection Grow for eating, sell locally, high demand farmer-farmer trade, improved health, more profit network of 60 farmers, 30 villages in District Improved soil, socially, less competition, greater harvest from aquatic environment	Indicators are pesticide level use, IPM / GAP adoption, exposure to pesticide, health, environmental, local fish consumption, economic, social factors, pesticide marketing strategies Exporters & supermarkets need medium to large farms or well managed smaller farmer groups. Smaller farmers can supply local markets. Farmer interest key.
Training time & techniques	-1 day lecture by University: -Suitable pesticide use -Health & safety -Record keeping -Soil preparation -Farm	-Intercropping chilli & Chinese kale -No spray hervest period 120 days after planting -Use manure	-Agro-ecosystem analysis -Ploughing -Suitable pesticide use -Crop rotation -Intercropping experiments.	- Duration 1 week - Nets - Bio-pesticide & bio-fertiliser making & use - Agro-ecosystem	-Duration 3 days (theory, practical, farm visit) -DOAE - pest & diseases -Bio-control of chilli	- Duration 1 day - DOAE: Short-lecture & demonstration - bio-pesticide & bio-fertiliser making & use.	DOAE FFS; each farmer has experimental plots & rotational weekly visits. Land prep, Bio-extract, natural enemies,	Buddhist principles,IPM, integrated farming, water management, record keeping, local markets, monthly FFS	Exporter & supermarket led training - GAP, short, key farmers & middlemen manage farmers. DOAE led use

	management -No spray harvest period -Natural enemy education -Follow KCF management plan		-8 weeks. -IPM; Bt, Neem, Sticky trap (flying insect control) trichoderma (fungus control) Spinosad, -assassin bugs (natural enemy), -bio-pesticide (plant ferm'tion, - -manual pest removal garland roses. -1 used net	analysis - sticky traps for aphids - yellow light attractant for airborne pests - purple light for butterflies.	- No spray harvest period	-Few other techniques have been taught including sticky traps.	predators, parasitoids, pest identification, disease, weeds, sticky traps, trichoderma, Bt, neem, from Pest management Centre, Khon Kaen.	meetings, sharing plants. Create network. Self-supporting. Wider asset development, grow for home then local market.	nets, short, making bio-pesticide & bio-fertiliser, also FFS, more costly, < 8 weeks - agro-ecosystem analysis, IPM. Some certify & market crops. The SCDF use religion, LWF, GAP, IPM, integrated farming, networking, self-support, home & local markets.

Key: 1 rai = 1,600 m sq. KCF-Kampangsaen Commercial fresh Co. Ltd. ITC – International Trading Co. Ltd. DOAE – Department of Agriculture Extension. SCDF – Sustainable Community Development Foundation. IPM – Integrated Pest Management. GAP – Good Agricultural Practice. DANIDA – Danish International Development Agency. PONDLIVE – Improved resource use efficiency in Asian integrated pond-dyke systems (EU funded project). Obotor – Head of Sub-district level government administration.

5.4.2.1.4 Results

5.4.2.1.4.1 Exporter farmer training outcomes

Exporter led training involved exporters and DOAE lectures on GAP (ThaiGAP for supermarkets and EUREPGAP for export as appropriate) and other export certification requirements via a few short lectures at an institution **(**Table 46**).** Participating farmers joined voluntarily, were educated and usually farmed on a medium to large scale (0.24-48 ha). Some post-training support was provided by middlemen, there was no evaluation and DOA or middlemen visited monthly to check farm log books. Export production gave farmers a higher product price guarantee. A small percentage of farmers adopted the techniques fully, some partially and a significant amount rejected them. Those who adopted noted cheaper production, improved environmental conditions and improved yields and profit. Those who rejected the techniques did so due to their complexity or impracticality for use in large areas.

5.4.2.1.4.2 Supermarket farmer training outcomes

Supermarkets also used lecture style farmer teaching by the DOAE on ThaiGAP, bio-pesticide and bio-fertiliser production and application and use of nets **(**Table 46**).** Farmers had 0.64-1.6 ha, were supervised by middlemen crop traders in implementation, however, there was no training evaluation and no guaranteed premium product price. Of 10 farmers trained only one partly implemented, noting environmental and economic benefits around his farm including increased fish numbers and eating quality from his ponds and neighbouring canals. Previously, due to pesticide use, fish were not abundant or nice to eat from this area. Most farmers rejected the scheme as too complex, risky and time consuming.

5.4.2.1.4.3 DOAE farmer training outcomes

The DANIDA (Danish International Development Agency) supported DOAE training sessions investigated in Central Thailand farms of 0.64-1.6 ha included ThaiGAP, bio-pesticide and bio-fertiliser production and use and wider IPM techniques (agro-ecosystem analysis, use of pest antagonists and pathogens, sticky, light, bait and pheromone pest traps), using the Farmer Field School (FFS) participatory approach **(**Table 46**).** This training was longer, more detailed and expensive than lecture type training with trainer-farmer meetings weekly in the field lasting over one or two crop cycles. This allowed farmers' continual problem sharing, solving and re-assessment. DOAE 'Hygienic produce' certification, marketing and sales assistance was provided with some distant post-training support. Of the 25 famers initially interested, 10 continued with training of which five practiced it fully and five partially after training. The benefits for adoptees were improved profits and health from less pesticide use and less hassle from pesticide salesmen whilst those not adopting did so due to recurring crop damage and crop sale price not high enough to compensate for increased effort. There was also no formal training evaluation to test its success and inform improvements.

The university supported DOAE farmer training sessions in Khon Kaen, Northeast Thailand, were similar in content and duration to that of the DOAE training sessions in Central Thailand and trainers were members of the Alternative Agriculture Network (AAN). The 27 trained farmers had more ponds on farm and smaller land areas (0.04-0.4 ha) than those trained in Central Thailand, and of the 27 trained, nine adopted the techniques fully and 16 partially. Those who adopted noted improved health and water quality from reduced pesticide use, increased crop yields from better soil quality and social cohesiveness through co-operation rather than isolation and competition.

Regulation was done by DOAE checking of farm log books and testing of produce for pesticide residues on-farm and at local markets where traded. Consumers in this area were less fussy about product appearance and more concerned about food safety making adoption easier.

Both DOAE training sessions run by trainers of trainers (TOTs) aimed at producing trainers of farmers to enable spread of the teachings as described by Braun & Duveskog (2008) however, there was no evidence of this due to farmers' reluctance to teach.

5.4.2.1.4.4 NGO farmer training outcomes

A media review revealed an apparently successful further training method used by the NGO 'Sustainable Community Development Foundation' (SCDF), initiated by two medical doctors in Khon Kaen, Northeast Thailand and stimulated by farmers' poor health and social problems from pesticide use and modern agricultural practices **(**Table 46**).** The facilitators included Ubon Rat District Hospital medical staff, Khon Kaen University Agriculture academics, Local Wisdom Farmers (elderly experienced farmers with knowledge of traditional farming methods before pesticide introduction) and sometimes DOAE staff. The training included similar techniques and methods as the DOAE – university led training sessions in this region already discussed, included basic economics for self-assessment of management decisions and also encouraged integrated farming, plant diversity, propagation, grafting, tree planting for long-term investment, growing bio-pesticide materials and cultivating for consumption and then local markets rather than middlemen and larger wholesale markets. The SCDF agenda was wider than the DOAE in addressing wider livelihood issues, such as health, social and economic issues with Buddhist principles at the foundation of the scheme - principally the 4 noble truths, as described by Gyatso (2007) that follow four basic steps; diagnosis of problems faced by the individuals and the group (i.e. the mental afflictions), identification of problem causes (i.e. their desires), prognosis for remedy (i.e. towards cessation) and effecting the cure (i.e. a path of practice). Thus a 'systems thinking' approach to problem solving was used in groups that would meet monthly and inter-relate to create a wider powerful self-sustaining network of information and resource sharing and support. Of the 57 farmers with land 0.16 – 0.32 ha that participated all practiced fully and stopped pesticide use, whilst of the 43 farmers with over 0.32 ha that participated, 17 practiced partially reducing their pesticide use **(**Table 46**)**. Improved health, greater crop yields and profit, improved soil and water quality, fish health and abundance and social cohesiveness benefits from sharing amongst the 30 participating villages of the district. Despite lack of formal certification, local consumers also built trust in the produce and began selecting it as awareness of the group activities spread.

5.4.3 On-farm nozzle trial, Kokprajadee, Central Thailand

5.4.3.1 Methods

A series of on-farm experiments originated from the farmer workshops in the primary study site. At the end of the second workshop six farmers were identified as showing interest in testing the effectiveness and practicality of different approaches to their current crop protection methods under the terms and conditions explained to them before the workshops.

Prior to the experiment, preparatory activities were carried out that included:

i) Establishing the six farmers' expected plans for crop management over the next three months (crop types grown and number of plots used, pests, diseases and weeds associated with these crops, crop cycle duration, expected doses and frequency of application of current crop protection products and other methods used for each crop and the cost of plant protection products per unit currently used).

ii) Establishing the type of spray equipment used by these farmers, working pressure and suitability, and the possibility of the farmers using spray equipment provided for experimental purposes.

iii) Establishing the farmers’ cooperation in record keeping and dialogue on a weekly basis during the experimental procedure.

iv) Identifying suitable methods for testing alternative crop protection methods (efficient pesticide sprayer nozzles suitable for proposed pesticide spraying equipment and their working pressures, disease and weed problems mentioned by the farmers, based on recommended application calculation of the cost-effectiveness of alternative methods to farmers current methods of crop protection).

v) Farmers’ agreement on the plots to be used as control and experimental plots in the experiment and in testing nozzles from start to finish of the experiment or as far as possible without economic loss to themselves.

vi) Development of a farmer log book for initial baseline information and also data entry during the experiment, preliminary trial of this logbook with farmers and final modification. The information to be collected in the logbook included type and level of pest problems, crop damage from pests, types and quantities of crop protection products applied, quantities and prices for crops harvested.

vii) Measuring areas of plots and preparation of signs for plots indicating number, crop type, crop protection methods used and dosages, planting date and expected harvest date.

Of the initial six farmers who decided to cooperate, only three agreed to continue with the experiment on their farms as two thought it was too risky to attempt and another had ceased production for personal reasons. The experiments consisted of three farmers testing efficient flat fan pesticide spray nozzles against controls each for three crops; ‘pak tsai’, Chinese kale and lettuce (all leafy vegetables) that are commonly grown. One of the experimental plots is shown in Plate 18.

During the experiments farmers kept records of their material inputs to the plots that were part of the experiments. Weekly visits were made to farms to check data, assess the progress and problems associated with the experiment, modify procedures as necessary and observe and photograph the crops. Data was entered into a spreadsheet.

After the experiments, an evaluation question checklist was constructed and used on each farmer through interview and completed by staff. Information from this was collated whilst spreadsheet data was analysed to show changes in the variables assessed for each plot during the experiment and overall cost-benefit results from the different crop protection methods used in the experiments. Preparations were made to provide feedback of this information through a third workshop to the wider farming community in Kokprajadee Sub-district. However, it was advised by each village head man that farmers were not interested to attend another workshop due to the limited value they perceived them to have in improving their economic situation.

For measures that were effective in reducing pesticide use that were economical, calculations were made of potential pesticide savings at the three village levels using the following procedures:

Estimation of potential impacts of flat-fan nozzles at sub-district level

1. Raised-bed vegetable plot numbers and dimensions often varied between farms within the Kokprajadee Sub-district study site and individual household farmland ranged from less than 0.8 to 8 ha. On-farm crop growing is usually continuous although commonly 4-6 plots were often fallow at any one time on individual farms. Such factors make the upscaling of experimental results to all farms at the sub-district level difficult.

2. Information from PCA (from few people in each village) and household surveys (15% of the households in the three villages) enabled estimates of land area by well-being group, number of households by well-being group and percentage of crops they grew that were leafy vegetables, all within each of the three villages. Means were taken to get best estimates for each village household and worked up from there for values for the three villages.

3. The frequencies at which different pesticides were applied vary in accordance with the nature of the pest. From farm experiments, spraying insecticide for cabbage looper, which is specific to lettuce, was approximately every 10 days, whilst for other pests on other leafy vegetables, it was normally every 4-7 days. The crop cycle (spraying period) for lettuce was around 30 days and for other leafy vegetables 40-45 days.

4. The number of insecticide applications for lettuce on experimental farms was every 4-6 days and less frequent for fungicide as fungus normally appeared in later stages of the crop production cycle and was also most common during the rainy season.

5. Leaving out lettuce and taking Pak tsai and Chinese kale which have similar pest problems, crop cycle durations and pesticide frequency applications, results from these latter two crops could estimate larger scale outcomes. Seven days were given for leaves

to develop, eight as a figure for number of pesticide applications in a crop cycle and seven as number of crops from a plot in a year giving time for land preparation in between.

6. Some farmers use more pesticide than others so the outcomes from these few experiments can hardly be viewed as representative of hundreds of farmers. However, average pesticide use savings for the three farmers for the two experimental crops for a crop cycle could be up scaled (using assumptions) and estimated for all farms at the sub-district level for a year.

Plate 18: One nozzle experiment plot, Pak tsai, Kokprajadee

5.4.3.2 Results

Results from comparing the use of flat fan design nozzles with farmers' standard nozzles on five experimental plots with five control plots of three farmers are shown in Table 47. In each nozzle – crop combination experiment, although equal numbers of pesticide applications were planned for flat fan and conventional nozzles, due to greater pest problems in three of the control plots compared with their corresponding experimental plots, one extra application had to be carried out in these control plots resulting in extra pesticide use as highlighted in Table 47. From using the flat fan nozzles farmers achieved an average to high level of crop protection, whilst four of the five experimental plots gave pesticide use and associated economic savings compared with control plots.

Table 47: Pesticide nozzle trial results, Kokprajadee, Central Thailand

Experimental v control plots	Farmer	Farmer 1			Farmer 2	Farmer 3
	Pesticide No.	Chinese Kale	Pak Tsoi	Lettuce	Pak Tsoi	Pak Tsoi
Pesticide use ml./ m^2	1	Supercorn +0.02	Supercorn +0.02	Acabon +0.02	Supercorn -0.18	Dicrotophos +0.01
	2	Spinosad -0.11	Spinosad +0.02	Lidomin +0.03	Grammaxon +0.12	Rampage +0.01
	3	Mancoceb +0.06	Mancoceb +0.22	Paraquat -0.21	Hallo -0.12	n/a
	4	Lidomin +0.01	n/a	n/a	n/a	n/a
Pesticide economic difference (baht/m^2)		+ 0.21	+0.17	+0.04	-0.07	+0.08
Crop quantity (kg/m^2)		-0.03	-0.93	+1.04	-0.19	-2.78
Crop protection level		High	Average	High	High	High

\+ = pesticide use saving / economic gain / extra crop produced compared with control plot
\- = extra pesticide use / economic loss / less crop produced compared with control plot

5.4.4 Stakeholders' opinions and relations

The nature of interactions between stakeholders in the areas of horticulture, pesticides, GAP, IPM and food safety, influence individual and collective capacity building towards producer, consumer and environmentally friendly fruit and vegetable production. This sub-section describes the key results of stakeholders' opinions on pesticide marketing and use and system capacity building and stakeholder relations through Venn diagrams (Figure 68).

Stakeholders revealed potential areas of improvement in reducing pesticide use and hazards through the following mechanisms:

i) enhancing resources in the regulation of production and sale of pesticides and certified 'safe' horticultural produce,

ii) simplifying, consolidating and officialising 'safe' food certification and labelling and regulation with additional clear interpretation and explanation of these standards for produce buyers at all points of sale,

iii) tougher penalties for illegal practices associated with pesticides and the food industry, and

iv) improved stakeholder co-operation and inter-complementary Ministerial policies that support a sustainable master plan.

Four different types of farmer-stakeholder scenarios were found, explained below:

1. Small to large scale untrained farmers producing fruit and vegetables for 'wet' markets using uncontrolled pesticide use and middlemen.

2. NGO, with or without DOAE assistance, trained small scale rural farmers using GAP and IPM to produce uncertified organic fruit and vegetables for home consumption and local district markets without middlemen.

3. Supermarket or DOAE trained medium to large individual farming systems using GAP, bio-pesticide, bio-fertiliser and / or nets producing certified pesticide controlled ‘hygienic’ fruit and vegetables for domestic supermarkets without out middlemen.

4. Exporter, with or without DOAE assistance, trained medium to large scale farmers using GAP and controlled pesticide use to produce certified ‘safe’ vegetables for export markets and local supermarkets.

Venn diagrams **(**Figure 68**)** illustrate stakeholder relations in these scenarios. Centre circles represent farmers. Stakeholders’ increased significance is illustrated by increased circle size, and their closeness of contact with farmers by proximity to farmer’s circles.

The diagrams show increased significance and closeness of other farmers for advice, pesticide retailers and middlemen in supplying inputs, providing credit and buying produce of those farmers producing fruit and vegetables with uncontrolled pesticide use for ‘wet’ markets.

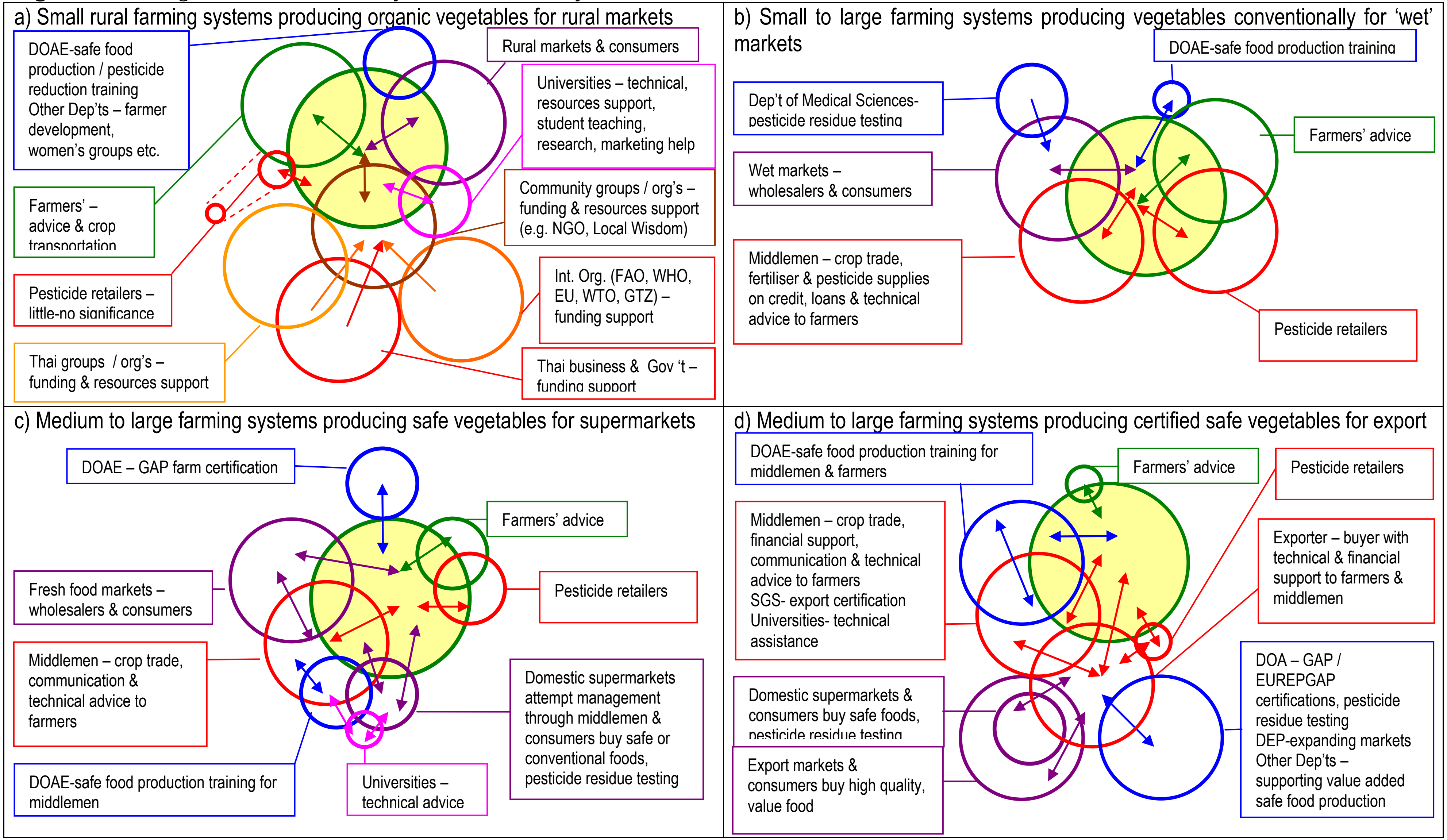
Middlemen’s significance is also apparent in advising and monitoring, supermarkets in buying produce, wet markets for taking sub-standard produce and the DOAE in providing certification for medium to large farms trained in and using GAP. Pesticide retailers have less influence.

For the medium to large scale farmers producing for export, exporters, DOA, independent middlemen auditors and academics were all very important and close in aspects of technical assistance, monitoring, certification, trade and transport.

For the small scale rural organic fruit and vegetable producers, NGO groups, academics and DOAE were all close and very significant in aiding IPM and GAP production training, crop marketing and continued support. Local consumers were also very important being aware of farming practices and their preference to buy these farmers' produce. Pesticide retailers' influence was non-significant to minimal.

Figure 69 was devised from the outcomes of the research to show the broad differences between the types of producers and consumer links identified, including producer size and number, market size, market distance, use of middlemen, information exchange and trading volumes and conditions. Closest producer-consumer relations are evident with small scale producers supplying local market consumers, followed by exporters and supermarkets through certification. In contrast the most distant relations are illustrated by those between producers of conventionally grown produce with no pesticide restrictions and wet market consumers. The diagram helps illustrate the relationship and suitability between produce scale, the ideal market type and facilitating stakeholders required.

Figure 68: Linkages between community and ex-community stakeholders



Yellow filled circle = primary stakeholder (farmer); Circle size (other than yellow filled circle) denotes size of stakeholder body – size of circle increases with size of body; degree of circle overlap denotes level of interaction between stakeholders – greater overlap represents more interaction

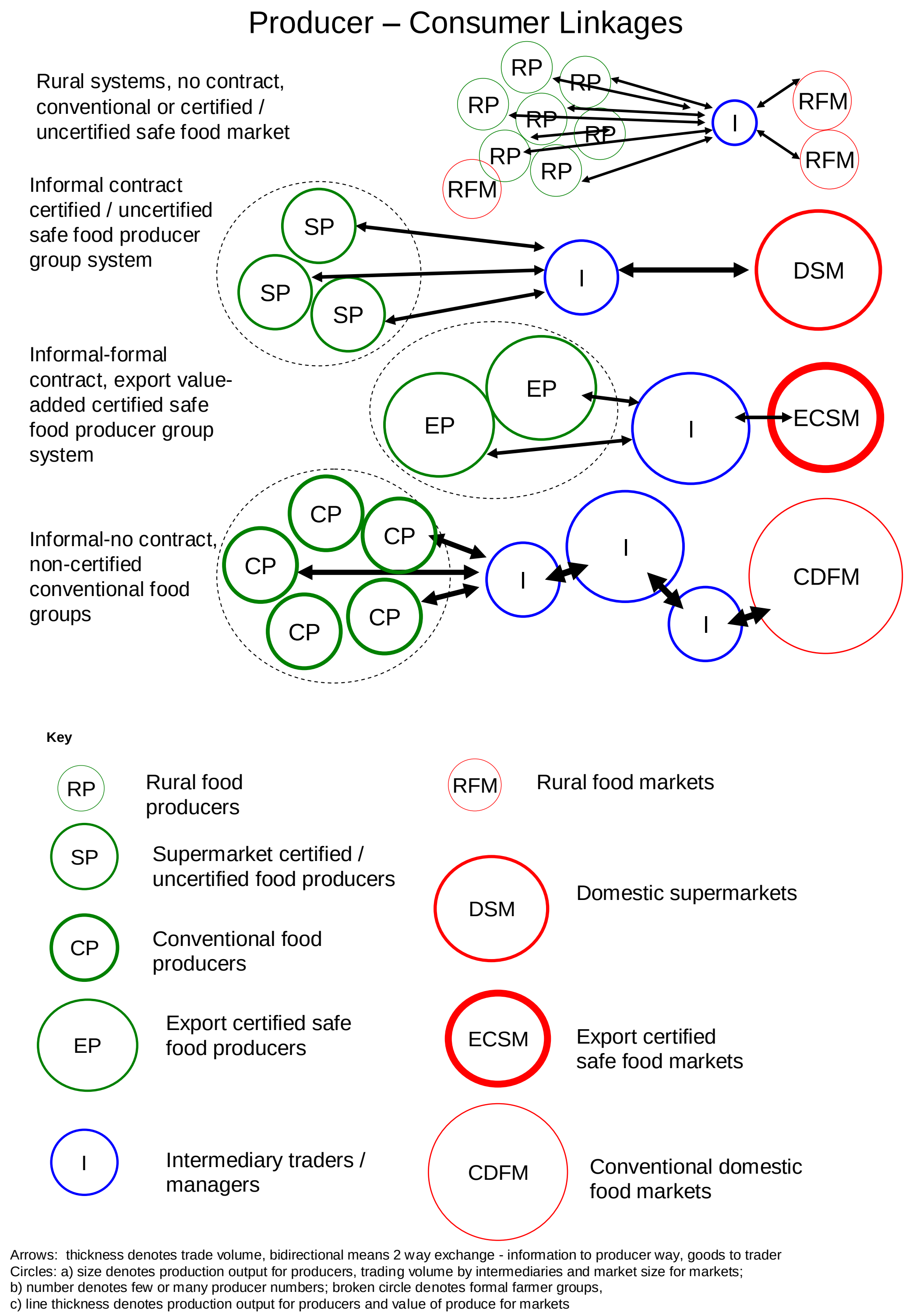


Figure 69: Producer – consumer linkages in different farming systems

5.5 Discussion

This section discusses the results in the order that they were presented and within the context of findings from other research.

5.5.1 Farmers' environmental and health hazard reduction measures

The study revealed that where fish were most valued by farmers in Thailand (Kokprajadee and Sisaket) in and around farms, farmers opted to use less pesticide and / or less hazardous pesticides, or only used synthetics when biological ones failed to control pests, suggesting fish health and productivity could act as an incentive to reducing pesticide use. This benefit of fish value in pesticide reduction in various agri-aquatic systems in Southeast Asia has also been documented by Nhan *et al*. (2007), Bosma *et al.* (2012), Berg (2001), Xie *et al.* (2011) and Lu & Li (2006).

Thai farmers appeared to be more aware of pesticide health hazards than Sri Lankan farmers although none used proper protective clothing due to cost and discomfort. A minority of farmers in Sri Lanka and the majority in Thailand only used home-made cloth masks for occupational protection when spraying pesticides. The vast majority did not use any item of formal protective gear such as proper breathing masks, goggles, waterproof suits, rubber boots and gloves. Further, similar findings have been made in these and other developing countries by Panuwet *et al*. (2012), Recena *et al*. (2007), Sivayoganathan *et al*. (1995) and Zhang & Lu (2007), suggesting a widespread need for more efficient, affordable and practical personal spray protection options. Pesticide hazard level colour coding was also largely not understood in Sri Lanka by most farmers, which also appears to be widespread as it is also mentioned by Waichman *et al.* (2007) with regards to farmers in Brazil.

Personal occupational health hazards from spraying pesticide in Thailand were reduced by employing younger people or lower class immigrants to spray pesticides, which highlights higher occupational hazard to more vulnerable groups, and leaving no-spray periods before harvest. Additionally, the use of children to spray pesticide varies with culture but is widespread as reported in various developing countries by Ismail *et al.* (2010). Bandara (2007) for Sri Lanka notes the higher vulnerability of children to pesticides than adults and Gupta (2012) the widespread employment of poorer marginal farmers as applicators. Home garden produce for personal consumption was also not sprayed with pesticides by some farmers.

5.5.2 Farmer interest in safe crop production in Thailand

A few farmers in Kokprajadee had produced safer vegetables in the past using netting provided by a DOA scheme to produce pesticide ‘risk free’ crops. These crops were labelled with the DOA ‘hygienic produce’ logo and sold at slightly higher prices to supermarkets through them as described by Roitner-Schobesberger *et al.* (2008). Few farmers in Sisaket had also reduced pesticide use with health and environmental benefits by receiving guidance from monks in the area using traditional knowledge which is common in Thailand and neighbouring countries. Some farmers studied in Kokprajadee and Sisaket were interested in producing safer healthier vegetables in Thailand for pesticide related economic or health reasons, however, lack of available guidance and marketing assistance were limiting factors.

5.5.3 Crop markets and trading in Thailand

Most crops are grown with uncontrolled pesticide use and sold at large ‘wet’ markets through middlemen. Various farmer – middlemen power relationships exist whereby the poorer the farmer is, the greater the role and control the middleman has in providing agri-inputs, credit and setting prices for buying crops. The wealthier the farmer the greater control the farmer has in sourcing his agri-inputs and choosing middlemen to sell crops to. The widespread issue is that poorer farmers are thus more likely to gain less profit from their farming and use unauthorised traders offering credit and poorer quality pesticide and other products as also found by Williamson *et al.* (2008).

The wholesale market for fruit and vegetables in Thailand largely prioritises aesthetic quality over food safety, reflected in the 5-10% minimal price difference in markets between crops grown with uncontrolled and controlled pesticide use. This consumer prioritisation hampers safe food production and appears to be widespread with similar findings from other countries by other authors (Lagerkvist *et al*., 2012). Thai farmers in Kokprajadee and Sisaket surmised that city consumers were either not aware of the scale of pesticide use in crop production and the health hazards and / or were not willing to pay higher prices for safer fruit and vegetables. This limitation to safe food production is supported by other research in Thailand through Sangkumchaliang and Huang's (2012) findings of a lack of consumer information on food production methods.

Additionally, despite supermarket expansion offering various standards of safe fruit and vegetables, farmers studied in Kokprajadee and Sisaket were not aware of how to access these markets and past government attempts to establish organic vegetable production and market in Sisaket failed. So there still appears to be limited availability of local safe food markets in some parts of Thailand and limited farmer awareness of opportunities in this area.

5.5.4 Pesticide reduction capacity building

This discussion section covers food safety certification, labelling and regulation, farmer training in pesticide reduction techniques, effectiveness of efficient pesticide nozzles and stakeholder opinions and issues on system capacity building in reducing pesticides.

The problems of a large range of labels for similar levels of food safety in Thailand, some with misleading claims and some not officially endorsed relating to pesticide residues were also found by Roitner-Schobesberger *et al*. (2008) highlighting issues of consumer confusion and mistrust.

On food safety regulation in Thailand, pesticide residue testing for pesticide residue MRLs is not mandatory or frequent in ‘wet’ markets for uncertified fruit and vegetables. Most domestic produce pesticide residue testing was also concentrated randomly on produce that was to have some level of ‘safe’ food certification. Although with testing mostly done in response to consumer health complaints and traders being able to avoid testing this undermines the integrity of the label, and possibly gives a reason for Roitner-Schobesberger *et al*. (2008) discovery that that MRLs are frequently exceeded in Thai fruit and vegetables certified as ‘safe’ or ‘pesticide free’. Again, this undermines consumer trust and safe food labelling integrity, promotion, demand and uptake by farmers.

As only a minority of farmers in the Thai study sites had received some components of pesticide reduction training and practiced it, knowledge and practice of this was weak. However, more substantial teachings and practice of GAP and IPM techniques through FFS and some farmer DOA ‘hygienic’ vegetable certification and in the wider study province of Nakhorn Pathom, Central Thailand clarified that some efforts have been made to reduce synthetic pesticide use and promote safer food. Again, only a few farmers in the Sisaket study sites had received some basic DOAE training in use of a few IPM components, mostly partially practiced, however, some farmers had also been taught and practiced pesticide free farming by monks. Therefore government input into the content and farmer coverage of IPM farmer training seems sporadic between and within some provinces, which is partly due to budget. Adoption by farmers is generally weak for various reasons discussed below.

The key findings are discussed from the case studies on exporter, supermarket, DOAE and NGO led farmer trainings. Exporter and supermarket led training included use of GAP, manufactured bio-pesticide and controlled pesticide use. Farmer capital, education level, ability to follow guidelines and farm size were influential in success with few adopting it. Of the few studies of public GAP in Thailand, similar problems have been reported; some papers describe reduced pesticide use whilst others claim pesticide use has increased, resource constraints in auditing and lack of conveyance to farmers the underlying rationale (Schreinemachers *et al.,* 2011; Schreinemachers & Tipraqsa, 2012).

Other DOAE led FFS vegetable IPM training investigated outside the study provinces including wider IPM techniques and AESA were more successful in terms of a greater percentage of farmers adopting some of the techniques. Presence or absences of marketing assistance, having a local consumer base, farmer interest and farm size, were also influential over uptake. Weaknesses of DOAE led training sessions were sometimes biased farmer selection and lack of proper evaluation for feedback and improvement. The NGO led GAP, IPM FFS had a significant partial adoption by farmers, again with farmer interest and land size being influential, with some fully adopting. Marketing assistance, local consumer awareness of the scheme, use of local wisdom farmers, farmer network creation, having a wider livelihood approach and continued support all contributed to success.

In each training scenario those who did not practice techniques did so because they thought IPM was too time consuming, less effective than pesticides, bio-pesticide required large amounts of material, was impractical in large areas and lacked continued support as also found in Glare *et al*. (2012) review and in many other countries by Yorobe *et al*. (2011), Tripp *et al.* (2005) and Yang *et al.* (2008). Consistent with research findings, Braun & Duveskog (2008) also highlight the significance of trainers' participatory appraisal skills, mind-set and attitude in influencing the outcomes of IPM FFS. The lack of wider IPM adoption in the community, farmers as trainers and training evaluation have also been found in other countries (Braun & Duveskog, 2008; Feder *et al*., 2004; Friss-Hansen & Duveskog 2012; Tripp *et al.*, 2005; van den Berg & Jiggins, 2007; Yang *et al*., 2008; Yorobe *et al*., 2011). Braun & Duveskog (2008) explain this is usually the case when IPM FFS are treated as a quick technological transfer operation of standardised recommendations rather than participatory development of problem solving and innovation skills in site specific agro-ecosystems.

Partial and full adoptees of training claimed health, economic and environmental benefits including improved fish health and abundance for those with aquatic resources. These economic and nutritional benefits are also mentioned by Horstkotte-Wesseler (1999). Promotion of fish culture and integrated farming may therefore encourage pesticide reduction. Farmer interest and dedication also seemed to increase with incentives such as health problems from pesticide use. Small scale farmers adopting IPM FFS techniques also noted improved community relations through increased sharing of resources and co-operation. Consistent with Braun & Duveskog (2008) findings, real success and sustainability come from farmers' change in perspectives through discovery and reflection, self-empowerment through enhanced self-confidence in problem solving and decision-making and reduced dependency on outside actors. Also when it mobilises community interest it can strengthen social capital at the village level.

The consensus from farmers' spray nozzle experiments is that flat fan nozzles can sometimes offer more efficient pesticide application compared with some applicator nozzles and thus may reduce pesticide loading to the environment, as also found by Sikkema *et al.*, (2008). More efficient pesticide application brings further potential economic benefits and reduced pesticide health hazards to farmers by reducing leakage. This pilot study result raises the question on the efficiency of pesticide application equipment available to farmers, the need for further investigation, potential for improvement to suit farming conditions and inclusion in policy.

Venn diagrams illustrate the significance of wider stakeholder involvement with farmers in reducing pesticide use and hazards. Stakeholders felt that more resources for pesticide and safe food regulation, simplification and clarity on reduced pesticide foods, policies that complement each other and national policy and inter-ministry co-operation would improve pesticide reduction.

5.6 Summary

Farmers with on-farm fish resources tended to opt for pesticides less toxic to the aquatic environment suggesting an awareness of pesticides' environmental hazards. Although apparent awareness of occupational health hazards from spraying pesticide was high, few farmers adequately protect themselves in this activity with associated discomfort and cost being significant underlying reasons. In Nakhorn Pathom Province the most significant pesticide reduction programmes were associated with a few export crops although some farmers had experimented with nets and bio-pesticide formulation with some success in crop protection. Many private sector and government led IPM and GAP programmes fail to convert the majority of participating farmers for various reasons, however, others succeed where market issues, post-training support and farmer network creating are included. However, many Thai food safety labels are misleading on the level of protection provided from pesticide residues and random testing of certified pesticide safe food for pesticide residues is infrequent in some major markets of Bangkok. Many farmers use archaic inefficient pesticide application equipment. More efficient and safer application equipment and nozzles may reduce pesticide use and hazards. Greater input and co-operation by a wider range of stakeholders facilitates problem solving by addressing the varied factors that influence farmers' livelihoods.

Chapter 6 **Discussion**

6.1 Introduction

This chapter brings together the outcomes from each results chapter and discusses, with reference to other literature, how they answer the research questions set out in the introductory chapter. This chapter begins with a recap of the research problem issues, questions and strategy used for finding these answers, then discusses study site farming system and livelihood differences followed by the research findings relating to each question in preparation for the concluding chapter.

6.2 Recap of Research Issues, Questions and Strategy

6.2.1 Research problem

The foundation of the research problem is the increasing global challenge of satisfying increasing food and fresh water security and safety demands of a growing population from an increasingly constricted and depleted environment (Godfray *et al*., 2010). Furthermore, this anticipated future crisis is expected to be most severe in developing countries where the poorest and most undernourished reside and can lead to civil unrest (Chen & Ravallion, 2007; Valdes *et al*., 2009; FAO, 2005; FAO, 2008; Thorpe & van Anrooy, 2009).

The availability of safe plentiful food depends on the environmental integrity and sustainability that is necessary in the eradication of extreme poverty and hunger, both part of the UN Millennium Development Goals (UN, 2013). Despite levelling marine catches, global food fish supplies are increasingly being sustained from inland fishery and aquaculture contributions of which most is produced and consumed in Asia (FAO, 2012).

The development and use of pesticides and biotechnologies for improved crop yields and pest control have met past food security needs, however, growing environmental, social and economic problems, and pest resistance and outbreaks exacerbate the 'pesticide treadmill' effect (Maredia *et al.*, 2003; Yang *et al.*, 2008). Increasing urban sprawl and land use change towards pesticide intensive horticulture, that is coming into closer proximity with inland fish production growth in Southeast Asia, has potential consequences for wild aquatic foods, aquaculture and dependent livelihoods. Such trends have been increasing demand for newer more sustainable solutions to crop protection, particularly where water resources are shared in agri-aquatic production systems and have household and community multiple uses, such as watering livestock, bathing and washing clothes (Koppen *et al.*, 2006).

Banning of some of the most harmful pesticides, modelling pesticide fate and effects to estimate impacts and controlling their use such as through GAP have been steps in that direction, however, despite international agreements and domestic legislation on pesticide production and sales in Asian countries, breaches are still common (Schreinemachers & Tipraqsa, 2012; Panuwet *et al.*, 2012; Gupta, 2012). The widespread growth and development of IPM and FFS globally for many crops has offered much optimism for reducing the agri-pesticide 'addiction', particularly amongst developing country small-scale farmers including those in Southeast Asia. However, with reports of varied implementation methods and success, there is an important need to identify the reasons behind the outcomes for clarification and improvement (Oudejans, 1999; Gallagher, *et al.*, 2009). There are growing prospects of the Asian market for food ‘safe from pesticides’ reducing pesticide use, although some query its influence (Roitner-Schobesberger *et al*., 2008; Wyatt, 2010).

The arena for investigation of these areas included relevant stakeholders, markets and three different agri-aquatic systems based in Central Thailand, Northeast Thailand and Sri Lanka.

6.2.2 Research questions

The research aims were to:

i) Establish the differences between and changes in agri-aquatic systems and their relationships to livelihoods in the three study regions; Central and Northeast Thailand and Northwest Sri Lanka.

ii) Establish the potential influence of pesticide marketing and regulation on pesticide use and hazards in Thailand and Sri Lanka.

iii) Assess pesticide use characteristics, motivations and hazards to communities from use of pesticides and farm aquatic systems in Thailand and Sri Lankan study sites.

iv) Evaluate the protection used by those spraying pesticide in Central Thailand and Northwest Sri Lanka with underlying reasons.

v) Establish and evaluate the methods and outcomes of vegetable IPM training programs operating in the study sites of Central and Northeast Thailand.

vi) Compare the practicality and efficiency of flat fan efficient pesticide spray nozzles with farmers' spray nozzles in Central Thailand study sites.

vii) Identify and evaluate hazard encouraging and reducing factors with regards to agri-pesticide threats to community livelihoods in Thailand and Sri Lanka and areas requiring future attention.

6.2.3 Research strategy

The research strategy utilised a mixture of structured quantitative and semi-structured qualitative methods; the former being advantageous in giving an idea of scale of outcomes and the latter beneficial by providing important contextual information and reasons for research findings. These techniques worked well in complementing each other in providing a broad and detailed picture of answers to the research questions.

6.3 Study Site and Livelihood Characteristics

Before comparing and discussing research outcomes of study sites it is necessary to highlight the key fundamental differences between the climate, farming systems, histories and community livelihoods of the study sites.

The most distinctive differences between the three study sites included topography, climate, general status of economic development, the scale of individual household cultivation areas, types of agri-aquatic systems, water resources and fish production, types and diversity of crops grown and proximity to major markets. Many of the historical changes that occurred in these agri-aquatic systems and community livelihoods were similar.

In summary, Central Thailand household farming systems are set in the main Thai Chao Phraya River floodplain of fertile soil and are fed by river water fed via flow-controlled channels. Farmers can also regulate their farm water levels by pumping water to and from their farm-canals and sub-canals, creating much water exchange between farms and the wider environment (Molle *et al*., 1999). Following irrigation channel, road, communications and other infrastructure development, many rice fields have been converted to raised-bed horticultural production (Cheyroux, 2003; Jungbluth, 2000). Most farms here, ranging from less than 1 to 50 rai (<0.16 – 8 hectares) in Kokprajadee and less than 5 to 300 rai (<0.8 to 48 hectares) in Salakru, cultivate a variety of fruit (mainly tangerine) and vegetables (mainly leafy) and primarily in a mono-cropping fashion, to feed the growing demands of the Bangkok population, whilst orchid cultivation for the domestic and export market was evident in some places. In addition, selected vegetable cultivation (asparagus and babycorn), under EUREPGAP for export was also prominent in some districts of the Central Thai study provinces and successfully supported by exporters and the DOA, giving evidence of the feasibility of high food safety standards from large scale production with GAP and pesticide management. Extensive fish production in farm canals for home consumption or sale at local fish markets, and more intensively in cage culture in main canals, is also increasingly prominent as mentioned by Belton and Little (2008). Surrounding industry and other institutions often provide employment for family members that make significant household income contributions, yet have contributed to the ‘fracturing of agricultural communities to dormitory settlements’ (Rigg *et al*., 2008) and some farms themselves also employ locals or migrants for labour.

In contrast, Northeast Thailand household farming systems are usually smaller (1-5 rai or 0.16 – 0.8 hectares) placed at a much higher elevation, on a plateaux region with poorer, sandier soil and less abundant surface water resources. As a result most farms rely on rainfall during the rainy season and rain-fed farm ponds and wells for water storage and irrigating crops during the dry season when rainfall is sparse. A variety of crops, mostly suited to the dry climate and common in the Thai diet, particularly shallots, garlic and chilli, are grown on dikes around farm ponds that are mostly sold in domestic markets, whilst rain-fed rice is often grown on neighbouring lower lying fields for home consumption and sometimes sale. These pond-dike systems often include fish culture sometimes providing manure for crops and valuable animal protein for households or income from local sale (Pant *et al*., 2004; Prein, 2002; Tipraqsa *et al*., 2007). Usually small vegetable gardens with a variety of fruit, vegetables and herbs also augment home food supplies, also noted by Rattanasuteerakul & Thapa (2012). As with Central Thailand households, local towns may provide additional employment, however, often teenage and middle aged family members favour employment or education in more distant large towns or cities and are away from home for long periods, which sometimes conflicts with farm duties and family life and is becoming more widespread in rural Thai communities (Rigg & Nattapoolwat, 2001; Rigg, 2006).

Sri Lankan study site farming systems are situated within a large rain-fed reservoir-channel irrigation cascade system of the Mahaweli H region which irrigates crops. Each household has a designated cultivation area of one hectare which is composed of two cultivation components; upland plots used for growing low water requiring cash crops (usually big onion and chilli) mostly in the dry season (*Yala*) and lowland rice grown throughout the year but mostly during the rainy season (*Maha*) and mostly for home consumption. The cultivation of up to half of household land for rice and the remainder for these cash crops during the dry season results from irrigation water rationing and is locally termed *Bethma* cultivation (Thiruchelvam, 2005). Household preference is to grow rice and unlike Central Thailand and somewhat similar to Northeast Thailand, dry season crops are chosen due to water restrictions rather than market demand. Cultivation drainage water from higher catchment regions feeds back into the cascade system which waters crops further down (Marambe *et al*., 2012), with potential farm to farm water exchange as in Central Thailand. Reservoirs also support productive tilapia fisheries that support local fisherman and fish vendors and this water also appeared to be more widely used for domestic uses than Thailand, such as bathing and washing clothes as confirmed by Renwick (2001). As with Northeast Thailand, family members were sometimes separated for long periods for similar reasons with some working abroad.

The three types of agri-aquatic system therefore show some variation in crop production, use of aquatic systems and potential hazards from pesticides, influenced by climate, topography, water resources, markets and livelihood strategies.

6.4 Pesticide Promotion, Regulation and Hazard

Since before the 'Green Revolution' many governments, including Thailand and Sri Lanka, have promoted pesticide use to aid food production, however, resulting environmental, social and economic problems have increased and led to many international treaties and codes of conduct surrounding pesticide trade, use and disposal, including its registration, content and labelling standards (FAO, 2003; WHO, 2010). Thailand and Sri Lanka are signatories to these conditions (Gupta, 2012) yet with environmental and health hazards still increasing from unsustainable chemical management worldwide, their effectiveness is questionable (UNEP, 2012). Thailand and Sri Lanka have further developed their own legislation and regulatory systems to manage agricultural pesticides in their countries (Gunnell *et al*., 2007; Panuwet *et al*., 2012; Thapinta & Hudak, 2000), which is mostly a private sector business but with some government interests in Sri Lanka. Sri Lanka's legislation is specific to pesticides covering many aspects from import to retail sale and use, however Thailand's is less comprehensive covering hazardous substances generally and not setting standards for advertising and sale conditions. However, cheap pesticide registration and lack of thoroughness in assessing pesticides' potential environmental and human health hazards, add to the problem. In both countries, abuse after point of sale and many unregistered traders and products was common with banned pesticides smuggled through Thai borders, verified by farmers, retailer shelf inspection and other authors (Panuwet *et al*., 2012). However, these problems appear to be widespread in developing countries with adulterated pesticide products and unlicensed pesticide traders also documented for sub-Saharan Africa (Williamson, 2003). Limited resources hamper regulation of all aspects of legislation (pesticide product contents, storage and labelling in all retailers, inspection of formulation plants, permits to sell and food MRLs), with efforts concentrated on the most dangerous pesticides, whilst weak penalties are not much of a deterrent (Ecobichon, 2001). Meanwhile intensive pesticide marketing with attractive financial arrangements and other incentives down to the village level is often successful in encouraging pesticide use, which conflicts with government pesticide reduction policies and leaves the poor more vulnerable to exploitation as also found in other Asian countries (Shetty *et al*., 2010). Therefore a range of legislative and regulatory factors contribute to unnecessary pesticide hazards.

6.5 Pesticide Use and Hazards to Aquatic Systems and Livelihoods

This subsection pertains to both countries and firstly discusses the factors associated with pesticide use levels including crop type, farmer well-being status and their application strategies. From there the discussion addresses the fate of applied pesticides, the nature of hazards to aquatic systems and associated livelihoods of farming communities and farmers' perception of these hazards.

Firstly, a relationship was found between the crops grown and pesticide use levels due to their susceptibility to pests and 'high' value with leafy vegetables in Kokprajadee, tangerine in Salakru, chilli in Sisaket, and chilli (dry season) and rice (wet season) in Sri Lanka receiving more varieties and volumes of pesticide. This is supported on a wider scale from similar studies and findings in Asia and Europe by Lagerkvist *et al*. (2012), Grzywacz, *et al*. (2010); Lozowicka *et al*. (2012), Jungbluth (2000), Chalermphol & Shivakoti (2009), Jeyanthi & Kombairaju (2005) and Burleigh *et al*. (1998). As these were also the most popular crops grown by farmers covering more land area, considering seasonality in Sri Lanka, this exacerbates the potential pesticide hazards to health and environment and raises their profile for potential reduction targeting. With a positive relationship between pesticide use and pond water use for irrigating crops in Sisaket there is greater pesticide hazard to pond life on farms with dike crops, again highlighting farms most requiring pesticide reduction. The profit loss and opting out of chilli production by many Sri Lankan farmers typifies the economic dangers of government recommending production of one type of crop and the potential consequences of the 'pest resistance' and 'pesticide treadmill' effect and long-term sustainability of mono-crop style farming raised by other authors (Maredia *et al*., 2003 & Yang *et al*., 2008). Therefore crop type, diversity and coverage all appear to influence pesticide loading and associated hazards.

On relationships between livelihood factors and pesticide exposure, culture, gender and well-being status were most significant in Sri Lanka with females excluded from pesticide spraying and pesticide overdosing increasing with lower well-being status and greater livelihood significance of crop loss. In Thailand, worse-off community members being more involved in spraying pesticide, were also at highest risk. Poorer illiterate Indian farmers have also been shown to be at highest risk through spraying activity and lack of knowledge and awareness of pesticide hazards (Shetty *et al*., 2010) with similar findings for other countries (Wilson & Tisdell, 2001; Isin & Yildirim, 2007; Hou & Wu, 2010; Matthews, 2008, Ibitayo, 2006 and Rahman, 2003 & 2013). Nevertheless the fear factor appears to prevail amongst the vast majority of famers due to their widespread regular preventative applications of pesticide cocktails, which is common in developing countries (Mariyono, 2013). However, some authors (Rahman, 2003 & 2013) have shown positive relationships between pesticide use and crop sale price and substitution of pesticides for fertiliser that further support the argument of irrational pesticide use. Similarly when it comes to awareness of hazards, worse-off farmers were also less aware of pesticide hazards to their health and the environment.

However, farmers really only took notice of pesticide health hazards when illness developed which usually included a range of respiratory, skin, stomach and other minor ailments which is widespread in developing countries (Atreya, 2008; Jensen *et al*., 2011; Jintana *et al*., 2009; Matthews, 2008; Raksanam, *et al*., 2012 & Recena *et al.*, 2006), and highlights the potential for widespread long-term health issues. In fact farmer pesticide related illness was the instigator for the medical doctor NGO led farmer training group in Khon Kaen discussed in chapter 5. Therefore, lack of farmers' pesticide awareness and knowledge, translates into lack of confidence and empowerment and greater risk of financial exploitation and health hazards that is grounded in poverty and low education levels.

Aside from direct pesticide threats from spraying, pesticides were also found to enter farming system water bodies through spray drift, leaching and rinsing of pesticide containers and equipment as also mentioned by Damalas *et al*. (2008). Additionally, pesticide sprayed crops were often fed to on-farm fish in Thailand which is common in this region (Pant *et al*., 2005) although pesticide can also be absorbed by aquatic plants and fish or enter fish through the natural food chain (Mihaich *et al*., 2009). Subjective evidence of environmental effects of pesticides came from many farmers' observations of declining ecological diversity and abundance, including some fish kills in Thailand thought to be due to heavy pesticide use, as also found by Berg (2001) whilst Relyea (2009) has shown low pesticide concentrations kill amphibians. This trend was also said by longstanding community residents to have increased since the onset of 'mono-cropping' style horticultural farming and intensive pesticide use. In support of this, other objective research has proven significant direct and indirect impacts of low dosages of individual pesticides and cocktails, similar to those used by this study's farmers, on many aquatic and semi-aquatic species at all trophic levels (Relyea, 2009).

Aside from consumption of land crops sprayed with pesticide, aquatic plants and animals and fish from in and around agri-aquatic systems, particularly in Thailand, were frequently consumed by farming community households, and others when sold at market, with potential health hazards. These hazards appear higher amongst worse-off Thai households being most likely to consume wild aquatic food resources and in the Northeast amongst families consuming pond produce surrounded by pesticide sprayed and pond irrigated crops. In Sri Lanka however, better-off people being highest consumers of local aquatic produce would appear to be at highest risk, therefore aquatic produce dietary risk seems to vary with well-being and location relationships with food sources and level of integration in pesticide using agri-aquatic systems.

To strengthen the dietary risk argument, with the exception of Sisaket, calculated estimated risks from an aquatic diet were apparent in Sri Lanka and more so in Central Thailand with worse-off people potentially at highest risk by consuming more wild fish, aquatic animals, and in Thailand also aquatic plants. Panuwet *et al*. (2009) findings of significantly higher selected pesticide metabolites in school children of farmers than other family occupational groups in Northern Thailand, thought to be due to diet, gives further credence to the links between pesticide health hazards from farm-sourced foods.

The use of agri-aquatic systems for bathing and washing clothes and food, which is common in Southeast Asia (Palanisami *et al*., 2011) was another pesticide health hazard, particularly in Sri Lanka, requiring further investigation.

6.6 Pesticide Hazard Reduction

This section first discusses study site farmers' pesticide health and environmental hazard reduction measures. Then, in Thailand, the pros and cons of the safe vegetable market in hazard reduction, impact of vegetable IPM programs run in study sites and further afield and usefulness of efficient pesticide nozzles are discussed.

6.6.1 Farmers' pesticide hazard reduction

Some farmers in the study site villages took measures to reduce the effects of their pesticide use on the environment, their health and sometimes the health of others. In Thailand farmers' interest in environmental damage limitation often increased with greater value placed on on-farm fish resources; this phenomenon appears increasingly common in Asia as found by Nhan *et al*. (2007), Bosma *et al.* (2012), Berg (2001), Xie *et al.* (2011) and Lu & Li (2006). As such, these Thai farmers often reduced their pesticide use and used pesticides perceived as being less harmful including home-made biological ones with some only resorting to synthetic pesticide use when these other options failed. In contrast, this behaviour was not found in Sri Lanka perhaps related to the lack of fish culture, tanks being significantly larger water bodies and the comparatively few farmers' involvement in fishing. This highlights the potential of developing aquatic food production and associated food safety certification in reducing synthetic pesticide use and hazards.

Thai farmers appeared to be more aware of pesticide health hazards than Sri Lankan farmers and home-made masks were worn more so by the former, however, proper protective gear was never worn due to cost and discomfort, which appears to be a widespread problem in developing countries that needs addressing (Devi, 2009; Isin & Yildirim, 2007; Raksanam *et al.*, 2012; Recena *et al.*, 2006; Zhang & Lu, 2007). Although gas mask respirators are more effective than home-made cloth masks (Ueda *et al.*, 1992) the efficacy of the latter is questionable and ironically may possibly increase health hazards by absorbing pesticide droplets which are then inhaled. This would appear to be a significant area requiring study due to the large scale use of cloth masks in some areas and farmers' perceptions of them providing adequate protection, as noted by Jensen *et al*. (2011). So, for farmers in the study sites and seemingly further afield, there first appears to be a need for communication on the health hazards of pesticides and effectiveness of used and available protective measures, and secondly the need for affordable and practical protective gear as noted by many other authors (Mathews, 2008; Ibitayo, 2006; Palis *et al*., 2006; Raksanam *et al*., 2012).

6.6.2 Vegetable IPM programs

In Thailand, various stakeholders, including government, the private sector, academics, religious groups and charities, all have interests in and contribute to farmer capacity building to reduce synthetic pesticide use and hazards. Their reasons and interests may differ from economic in terms of expanding crop production and value for export, the health of farmers or the public, or be environmental towards preserving ecosystems and wildlife and the study provided an insight into many of their methods and outcomes.

The main difference between these ‘IPM training’ scenarios were two styles of educating farmers; 1) a short lecture and demonstration style training and visit disseminating information with little or no post-training support, and 2) longer participatory trainer – farmer group problem identification and solving sometimes with post-training support. Investigations revealed private sector exporter and supermarket involvement in training style one, NGO use of training style two and government utilisation of both training methods sometimes options for ‘hygienic produce’ certification and sale to supermarkets.

With regards to implementation, for training style one, exporters and government GAP trainers taught requirements for exporting crops over a few days, whilst supermarkets used middlemen to instruct and supervise farmers. The DOAE further taught home-made bio-pesticides and provided nets for farmers willing to make a financial contribution.

With training style two, NGOs sometimes including roles for ‘local wisdom farmers’, health professionals and academics participated with farmers in problem identification and resolution using IPM techniques and agro-ecosystem analysis during weekly meetings in fields over a crop cycle, with inclusion of wider livelihood aspects and creation of farmer communication networks. The DOAE IPM FFS programs, sometimes with donor agency collaboration, also included numerous techniques and agro-ecosystem analysis, however the NGO was the only organisation offering continued support through organising farmer group meetings.

In terms of the scale of implementation of these programs, it appeared that the type one DOAE training on the production and use of home-made bio-pesticides and protective nets were the most widely available type of pesticide reduction training for Thai farmers in general. Type one training on GAP for export crops appeared to be available to farmers already achieving high production and demonstrating interest. DOAE type two training was not as widely available as their type one being more time consuming, costly and resource consuming. The NGO type two training was limited to interested farmers but aimed to raise key individuals' skills and experience, acting as a resource for social learning in rural areas and informal dissemination.

As type one export GAP training was more successful with more educated farmers due to farmers' requirement to follow guidelines and keep records this would seem most suitable for this group of farmers, as also found by Olajide-Taiwo *et al*. (2011). Type one bio-pesticide training was more easily adopted by farmers from a wider social class and range of education levels, but less practical with increased cultivation area it would appear to be most suited to farmers without large land areas. Overall, with nets costly to maintain and minimal price differences between 'hygienic' certified foods and conventionally produced food also made this option less attractive with increased farm scale. Again, success of type two DOAE training was reduced with IPM impracticality with increased farm size, lack or limited marketing assistance and post-training support and therefore a focus on small to medium sized farms and marketing support may improve cost-effectiveness of these programs, as found by Braun *et al*. (2006). NGO type two IPM trainings were also less practical with increased farm size but had greater success rate from local wisdom farmers, marketing assistance, addressing wider livelihood issues, promoting sharing and linking farmer groups.

Common to training scenarios was greater success with increased farmer interest for economic, health or environmental reasons, including value of aquatic resources as noted by Braun *et al*. (2006) and Braun and Duveskog (2008), whilst type two training success increased with greater number of participating stakeholders. With no proper evaluation, outcomes of success were vague from trainers and DOAE trainers' attitude of "job done when training course finished" and success measured by 'number of participants and training sessions completed', addressing these issues could potentially improve program design and cost-effectiveness as found by Braun *et al*., (2006). However, with adoptees of training practices noting improved finances, health or environment further examination of reasons for success could improve future programs. With some farmers' reports of similar success and having stopped synthetic pesticide use from 'training' by monks further investigation may prove useful in informing improvements for other pesticide reduction programs.

6.6.3 Pesticide application

The findings of improved efficiency of flat fan pesticide nozzles compared with the applicator nozzles normally used by farmers, as also found by Sikkema *et al.*, (2008), highlights a few issues. Firstly, the potential widespread inefficiency and possible health hazards associated with some pesticide application equipment available to Thai farmers. Secondly, the potential for equipment improvement and reduction of farmers' costs, environmental and health hazards and lastly raising the question as to why the Thai pesticide regulatory bodies have not enforcing guidelines for sprayer manufacturers.

6.6.4 Safe food market influence and integrity

A major incentive for pesticide use and hazard reduction in Thailand is its growing domestic and foreign safe food markets and indeed the significance of food to Thailand's culture and image as 'kitchen of the world' as reflected in its Government's drive and focus in 2004 on food production, diversity, quality and safety (Panuwet *et al*., 2012).

The vast majority of farmers supplied attractive cheap crops to meet consumer demands at large fresh or 'wet' markets in and outside their provinces, through middlemen often providing services with trade arrangements that disadvantage worse-off farmers. The higher value 'safe' food market in Thailand is expanding with a huge growth in supermarkets over the last few decades (Schipmann & Qaim, 2011). However, consumers' lack of WTP significantly higher premiums for DOAE certified 'hygienic' fruit and vegetables, also supported by Lagerkvist *et al*. (2012), and most farmers' unfamiliarity with these market opportunities appear to be hindrances to the growth in safe fruit and vegetable production.

Producer – consumer distance and type appeared to be significant issues with regards to awareness of 'conventional' and 'safe' horticultural production practices and market issues; Central Thailand farmers' closer to major cities like Bangkok appearing to be more aware of the workings and opportunities in the 'safe' food sector than more city distant and marginalised farmers of Sisaket whilst most city consumers were thought to be less aware than rural village consumers, due to distance, of 'conventional' crop production as found by other authors (Sangkumchaliang & Huang, 2012). However, despite this, some research on major Thai city consumers has shown positive correlations of food safety interest and purchasing behaviour with income and education level (Roitner-Schobesberger *et al*., 2008; Sangkumchaliang & Huang, 2012). Therefore, consumer education by media on pesticide farming practices can potentially increase their demand for safer foods and assist production.

Other significant findings in this sector thought to influence pesticide use and hazard reduction related to safe food certification, labelling, regulation and consumer information. The discovery of a number of labels by different providers for similar grades of pesticide food safety, unofficially endorsed industry food safety labels and labels with misleading claims were thought to likely confuse and mislead consumers. Therefore rectifying these could also improve safe food's integrity and demand, aiding pesticide reduced production. Similar improvements could be made from increased pesticide residue screening of certified market produce with random sampling Roitner-Schobesberger *et al*. (2008).

6.7 Stakeholder Relations and Opinions on Future Needs

It was clear that the type and number of different stakeholder involvement with farmers and greater inter-stakeholder collaboration positively influenced efforts to reduce environment, health and socio-economic risks. With opinions of poor collaboration between stakeholders, limited resources in various sectors and non-complementary policies it is clear that more attention towards resolving these issues would improve pesticide hazard reduction efforts.

Finally, key findings of varied long-term economic and external costs of pesticide use, and in many cases positive emergence of greater co-operation and cohesion within rural communities incorporating key stakeholders and developing and maintaining networks of self-support groups, highlight the importance of ecological and social resilience in coping with multi-faceted community change (Adger, 2000). Other major outcomes of significance included weak pesticide industry, sales and food residue regulation, vulnerability of the poorest from low education, unethical credit sources and exposure to astute players in wider market forces, and largely limited farmer adoption of government and private sector led IPM trainings. The transition of soil and crop production back to an organic state after long-term agrochemical use often takes a number of years. During this period, the soil-plant system undergoes ‘organic transition effects’ including lower crop yields as it replenishes itself to provide the services previously served by agrochemicals (Lamine & Bellon, 2009). From the study, many farmers that had been practicing long-term intensive pesticide use and experiencing declining profit margins from increasing agri-inputs and lower crop yields, were reluctant to commit to long-term change towards pesticide-free crop production from the perceived higher risks involved, recurring debt cycles, lack of land tenure rights and short-term occupancy. These findings highlight the other wider development issues of the appropriateness and cost-efficiency of state interference and effectiveness of governance and rights of the poorest to land and resources that are so significant in complementing the Sustainable Livelihoods Framework in poverty alleviation (Ratner & Allison, 2012).

Chapter 7 **Conclusions**

7.1 Introduction

This final chapter summarises the research issues, questions and findings and concludes with recommendations for future research and action.

7.2 Conclusions

7.2.1 Research issues

The reasons for, and importance of, this research lies within the broader context of present and future global food safety, accessibility and sustainability; namely every person’s access, especially the poorest and most vulnerable, to terrestrial and aquatic foods that are safe, nutritious, socially and environmentally ethical and continually abundant. This relates to two of the UN’s eight millennium development goals, of ensuring environmental sustainability and eradicating extreme poverty and hunger by 2015 (UN, 2013).

Global food supplies are sustained from terrestrial, marine and freshwater resources. The global livestock population and production of cereal grains, fruits and vegetables has continued to increase since the 1960s (Godfray *et al*., 2010). Global marine capture fishery landings have plateaued since the 1990s, however, global marine and inland aquaculture production and inland capture fishery landings have continued to increase (FAO, 2012). Nevertheless, Godfray *et al*., (2010) warn of significant future challenges in feeding an expanding global population due to increased wealth and consumption, growing competition for land, water and energy resources, environmental destruction, over-exploitation of fisheries and climate change.

With regards to terrestrial food production, historically, various discoveries and scientific advances in crop production and protection including selective cultivation, transgenic manipulation, and use of synthetic fertilisers and pesticides, have improved crop diversity and yields to supply a growing world population (World Bank, 2008). However, the ethics and future sustainability of some of these farming practices remain questionable.

Considering agricultural pesticides alone, which are a major component of crop protection in almost every country on the planet for over half a century, they have been hailed for increasing crop yields and food security. However, widespread recurring crop pest and disease chemical resistance and adverse impacts on many natural enemies of crop pests and resultant ‘pesticide dependency syndrome’ and ‘pesticide treadmill effect’, further challenge the ethics and sustainability of pesticide use (Williamson, 2003; Yang *et al*., 2008).

Evidence has also been mounting, particularly in developing countries, of pesticides’ negative social impacts, environmental and public health hazards and longer term economic risks (Waibel, 2007; Wilson, 2000; Wilson & Tisdell, 2001). As illustrated in the conceptual model (Figure 10), the most obvious hazards posed by agricultural pesticides include the health of pesticide sprayers and consumers of pesticide sprayed crops, and the disruption of, and bio-accumulation within, complex land and aquatic ecosystems that support ‘free’ natural food resources that are often so vital to the poorest and most vulnerable in society (Palmer & Di Falco, 2012). As shown in the conceptual model (Figure 10), human pesticide exposure can occur through contact with the body, inhalation or food consumption. Crops can uptake pesticides through surface absorption and adsorption or systemically through the roots. Although some pesticides can be lost to volatilisation after application, some can be transported to the aquatic environment through spray drift, run-off and leaching through the soil. The fate and toxicity of pesticides may also be influenced by adsorption to soil particles and soil chemical and biological breakdown processes (Figure 10).

Further, the use of agricultural pesticides poses potential hazards to neighbouring inland aquatic systems which themselves play important and diverse roles in global food security (Figure 10). With many marine fisheries being almost fully exploited, pressure has increased on aquaculture and inland fisheries to supply the food fish demands of an increasing global population. However, in many developing countries including those in Southeast Asia, the concurrent expansion of inland aquaculture and pesticide intensive horticulture under limited land availability, has brought the two practices into closer proximity with potential pesticide consequences for aquatic systems. The shared water resources, which are the interface of exchange in these intertwined agri-aquatic systems, often also have wider multiple uses to community livelihoods, other than for just food production. Therefore, these scenarios potentially pose elevated pesticide hazards to agri-aquatic systems, inland aquatic food production and the livelihoods of those linked with these systems (Figure 10). The nature and level of the pesticide hazard posed to aquatic systems and linked livelihoods is further influenced by the physical, hydrological and surface water use dynamics of these agri-aquatic systems which are diverse in Southeast Asia.

Globally, the agri-pesticide industry is a large and lucrative market with many players from multi-national to domestic companies. Despite an ever increasing number of nations consenting to international agreements on the trade, use, disposal and banning of the most harmful pesticides, and developing their own national legislations, reports of their adverse impacts still prevail and particularly in the developing world where the vast majority of the poorest reside (Gupta, 2012; Schreinemachers & Tipraqsa, 2012; Shepard *et al*., 2009; UNEP, 2012). Additionally, despite the spread and popularity of GAP and IPM programs amongst developing nations, there is still an abundance of reports of limited success and adoption by farmers (Dhawan & Peshin, 2009). Similarly, despite the availability of proper personal protective gear for pesticide application and advances in pesticide spraying equipment, the use of such equipment and gear by farmers still appears to be limited (Recena *et al*., 2006; Zhang & Lu, 2007).

7.2.2 Research questions

The research therefore sets out to investigate and answer a series of questions and issues relating to pesticide use, hazards and livelihoods in three distinctly different Southeast Asian agri-aquatic systems in Northwest Sri Lanka, Central and Northeast Thailand. The first task was to examine the similarities and differences between the three selected types of agri-aquatic systems and linked community livelihoods. This was followed by examination of the aquatic and community livelihood pesticide risks and influencing factors including pesticide marketing and regulation in the two countries, farmers' pesticide use characteristics and motivations. The research then continued to assess the influence of pesticide hazard reduction measures including GAP and IPM farmer training programs, safe food certification, labelling and regulation with regards to pesticides, use of personal protective gear and the efficiency of flat fan pesticide application nozzles. These investigations provided an overview of the relationships between pesticides, agri-aquatic systems and linked community livelihoods and the influence of aquatic system and livelihood hazard enhancing and reducing factors.

7.2.3 Research findings

The scale and dynamics of the agri-aquatic systems and nature of community livelihoods varied between each system. Exchange of water and potentially pesticides between farm systems was most prominent in Central Thailand via the sub-canal network and in Sri Lanka through the tank – channel cascade system with potentially greater accumulation at lower elevations. In Central Thailand there was a trend towards the conversion of land to pesticide intensive horticulture and aquaculture, potentially increasing the pesticide hazard to aquatic systems and linked livelihoods. Overall, Central Thailand households were better-off and Sri Lankan households worst-off amongst the three regions. Typically, farming household income was supplemented through additional employment of some family members, which in Northeast Thailand and Sri Lanka was sometimes considerably distant from home. Family members of worse-off households were most likely to be employed in farm labour work including pesticide application thus potentially placing then at greatest risk from direct exposure to pesticides. Aquatic systems linked to horticulture were commonly used for a variety of domestic purposes and fish production, although aquaculture was only evident in Thailand.

Intense competition, marketing and sales incentives down to the farming community and retailer level in the two countries promote pesticide use as the ‘one stop and only solution’ to crop protection, whilst since the spread of IPM many products are now advertised unethically as ‘IPM compatible’. Some agrochemical companies provide synthetic fertiliser, seed and other agri-inputs with pesticides as packages, often with credit and harvested product sale conditions which entrenches pesticide use and hinders farmer capacity building for self-management. Most farmers also hold the perception that pesticides are a necessary component of horticulture and use them in a mandatory and liberal fashion, often as cocktails. Effective domestic pesticide regulation is hindered by cheap product registration, limited regulatory resources, weak penalties for offenses and Thailand's lack of a pesticide specific legislation. As a result, unauthorised pesticide traders and illegal pesticide products exist which the poorest in society most frequently use and are most at risk. In retail shops pesticides were commonly illegally sold alongside foodstuffs and many pesticide products failed to provide adequate information on associated hazards and safe use. All these factors contribute to the economic, environmental and human health risks associated with pesticide use.

Higher pesticide use and associated risks were associated with crops most vulnerable to pest attack, in particular leafy vegetables, tangerines and chilli. Level of pesticide use was also related to household well-being status with overuse of pesticides more commonly associated with increased wealth and ability to pay in Central Thailand and poverty in Sri Lanka motivated by fear of crop loss in latter case.

Human health hazards from pesticides through application, and consumption of aquatic produce, appeared to be highest amongst worse-off people being the group most likely hired to apply pesticides and consume aquatic produce from around farms. Additional pesticide human health hazards were also identified through other uses of aquatic systems including bathing and washing clothes, cooking utensils and food. Estimated risks of some pesticides to aquatic life in these agri-aquatic systems and consumers of aquatic produce were also high and reinforced by community observations of fish kills and a decline in ecological diversity and abundance since the onset of pesticide use.

In both countries, farmers' awareness of the potential effects of pesticides on the environment and human health were low, showing limited awareness, education and empowerment, which itself contributes to the pesticide hazard and is common in the developing world. This was further expressed by pesticide applicators' not using proper protective gear, partly due to discomfort and cost which are common issues in tropical countries.

Many different stakeholders have interests in reducing farmers' pesticide use for various reasons and have devised and implemented training for farmers on this. In Thailand, training is either short lectures with demonstrations based on GAP, or longer interactive more practical and participatory including some GAP components, IPM techniques through FFS. The former methods were favoured by the food industry, the latter by NGOs whilst both were utilised by the DOAE. The suitability of these methods varied with farmer class and education level; wealthier and more educated farmers being more suited to the lecture and demonstration style GAP training, and other methods more suitable to less educated and worse-off farmers. Training outcomes also varied with farm size, with IPM participatory methods more successful in small and sometimes medium sized farms in our classification and the other methods in a wider size range of farms. However, farmers with reasons for, and interest in, reducing pesticide use were most successful, whilst crop marketing assistance, wider stakeholder input and creation of self-support networks aid success and sustainability. Overall, a lack of proper evaluation of training programs was a hindrance to their purpose. Value of aquatic produce was also instrumental in reducing farmers' use of pesticides and products more toxic to aquatic life.

This study also raised questions on the efficacy of pesticide application equipment on the market from the pesticide reductions achieved from the use of efficient flat fan nozzles compared with the nozzles farmers were using.

A further Thai pesticide reduction incentive comes from the growing domestic and international safe food market. However, findings of some misleading food safety labels, the presence of numerous certifications for similar food safety standards of which some were not officially endorsed and weak regulation potentially risks consumer confusion, mistrust and pesticide hazard reduction efforts.

Stakeholders' opinions largely complement these findings. They further suggested more complementary policies, clearer defined duties and closer co-operation in research and development, farmer training and pesticide regulation could improve overall pesticide management.

7.2.4 Recommendations

A series of recommendations can be made from the findings of the study.

With regards to pesticide product manufacturing, marketing and sales regulation, Thailand would benefit from pesticide specific legislation and policy. In both countries, the monitoring and regulation of pesticide products at source of manufacture and distribution would prove beneficial in reducing the prevalence of sub-standard and adulterated products that fail to conform to contents and labelling criteria. Pesticide regulation could be further enhanced by spot checks, carried out by provincial DOAE officers, of pesticide products and sales in agrochemical retail shops for compliance with laws. Legislation and stricter regulation on the advertising of pesticide products as 'compatible with IPM' would also benefit pesticide hazard reduction policy and efforts by discouraging farmers' use of pesticides falsely claiming to be IPM compatible. Higher pesticide registration costs and higher fines for pesticide related crime would also aid pesticide hazard reduction. The provision of low interest government loans for farmers may also reduce worse-off farmers' dependency on trade arrangements with the agrochemical industry and illegal pesticide traders which would aid pesticide hazard reduction.

The inclusion of livelihood relevant education within schools in farming communities which includes farm economics, pesticide use safety, pesticide health environmental and economic issue awareness, livelihood activity related hazard awareness and reduction (e.g. source of water for drinking, bathing and washing clothes, food preparation etc), would also aid farming household capacity building in sustainable farm management, environmental and personal health pesticide risk reduction. This would particularly benefit worse-off farmers in Sri Lanka who were the group most likely to overuse pesticides and without rational basis. Pesticide sprayer health hazards may also be reduced from the availability of affordable protective gear which is appropriate for the climate. Similarly, the availability of efficient pesticide nozzles and pesticide spraying equipment which is safe and efficient and regulation of such would aid pesticide hazard reduction.

With level of pesticide use being crop type dependent, concentration of stakeholder efforts on pesticide reduction strategies on the most pesticide intensive crops would aid pesticide hazard reduction. Similarly the use of interactive methods (lecture or participatory FFS) suited to the education level of farmers to examine and resolve crop protection issues and reduce pesticide use would aid their cost-benefit. The focussing of FFS on small and medium sized farms and only interested farmers, and the incorporation of crop marketing assistance, local pesticide free produce market development and farmer group development would aid sustainability and cost-efficiency. The co-development of aquaculture production and value in farm agri-aquatic systems alongside IPM programmes would also act as a further incentive to pesticide use reduction. In Southeast Asia many religious groups have extensive interaction and influence with farmers on ethical farming and living, however, little is documented on the detail of their input, methods and outcomes. Further investigation of these interactions may highlight additional methods and IPM components of benefit to IPM FFS. Proper and independent evaluation of IPM and other farmer livelihood interactive programmes that assess the methods used, economic, health, environmental and social outcomes would aid programme improvement and cost-effectiveness.

Finally, the regulation of unofficial safe food labelling and misleading labelling would aid consumer trust in safe food produce, further encouraging safe food production and pesticide hazard reduction. Regular sampling of certified safe foods at wholesale ‘wet’ markets for pesticide residues would also help in this respect.

Therefore, reducing the pesticide hazard to agri-aquatic systems and linked livelihoods requires a holistic approach involving community education, more carefully targeted holistic and evaluated farmer capacity building approaches, tougher pesticide and safe food industry regulation, the availability of low cost loans for the poorest of farmers to reduce the negative influence of the agrochemical industry and illegal pesticide traders, the availability of more efficient pesticide application equipment and affordable and practical protective gear, increasing incentives for pesticide use reduction such as agri-aquatic system aquaculture and local organic market development and complementary policies.

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Appendices

Appendix 1 Household survey question sheet, Central Thailand and Sri Lanka

Socioeconomic Data

1. General information

1.1. Name of the respondent: (if different from the HH head in the name list):

1.2. Well Being Rank: (Fill this question from PRA results; check ranking agrees with assets)

1.3. Village:

1.4. HH profile

Member	Sex	Age	Employment[*1]	Education	activities related to agro-chemicals	Average income range (month)[*2]
HH head						
Spouse						
Sons						
Daughters						
Others						

*1 If members have on-farm and off-farm employment, note down both
*2This is a difficult question to ask. The objective is getting some information on income status is to triangulate PRA data on Well Being Ranking. This question should be posed at the end of interview. (You can prepare ranges of income i.e. <5000, 5000- 10,000, 10,000 etc and request the respondent to select an appropriate card)
*3 Use following codes: 1 = purchase; 2 = transportation; 3 = storage; 4 = preparation/mixing; 5 = spray; 6 = cleaning equipments; 7 = others (please specify)

2. HH consumption patterns

2.1. Water and food consumption

Type of food	Collecting method							
	Buy				Collect			
	Who	Where	How often[*4]	How much? (quantity)	Who?	Where	How often	How much
Water[*3]								
Food								

*3 How does HH obtain drinking water (rainwater, groundwater, bottled water etc. and do they eat their own fish and crops (how often and how much) *4 record daily, weekly, once/twice week etc.

2.2. Domestic water uses

Use	Yes	No	Who does it?	How often	Source (Main/ sub/ farm canal)
Washing clothes					
Washing food					
Cleaning house, vehicles					
Giving water to animals					
Personal Bathing					
Bathing children					
Cooking					
Drinking					
Others					

3. Activity profiles (Men and women separately)

Time of the day	Activity	Total hours

4. Health issues

4.1. Have anyone in HH experience any of the following symptoms after agrochemicals use?

Symptom[*4]	Yes	No	Who suffer from it?	How often?	Measures to reduce health imapcts
Headaches					
Vomiting					
Skin allergies					
Dizziness					
Numbness (hand)					
Stomach aches					
Muscle fatigue (cramps)					
Cough					
Breathing problems					
Depressions (mental health)					
Cancer among family members or people apply pesticides					
Others					

*4 Illness/ symptoms (yes/no/who affected?/treatment, if any/ relate this to pesticide type & application method)

4.2. Have you been tested for effects of pesticide on your health? (yes/no)

4.3. Have any member of your family or neighbours been treated for pesticide poisoning? Who?

4.4. Have you heard of any one (HH or neighbours) attempted making suicide by drinking pesticide? (yes/ no/ who)

5. Pest management/ agrochemical use training (gender related)

5.1. How do you identify pests?

5.2. Have you participated in any training courses on pesticide use and application (when to apply, which dose etc.)?

Type of training	On what?	Who provided?	How long?	When?	How often?
Formal					
Informal					

* Formal training might have provided by the government or private sector. Non-formal training might have provided by retail shop and other farmers

6. Farming system

6.1. Farm maps

- Draw a map of the farm with the ditches, dikes and ponds on it. Show its relation to the main/ sub canals. Show the resources flow.

6.2. Farming calendar

- Make a timeline for a field for a year. Indicate type of crops, management practices (seeding, ploughing, harvesting) for each crop, land preparation, growth, & harvesting periods (months), growth stages of the crop (emergence, fruiting etc.), irrigation and sprinkling/ watering pattern, application of fertilisers and pesticides.
- When more than one crop is grown at the same time, assign the activities to each of the crops.

- Try to find out what determines the practice either for the dominant crop or all crops together.
- Find information about crop rotation between years.

6.1. Water management & irrigation practices

Water system e.g. Ditch, pond	Farm size	L (m)	W	D	No. of farm canals*1	Vol of water pumped in	When & How often?	Vol of Water pump out	When & How often?	Sediments removed, put on the dyke?	How often

*1 if canals are not straight, measure the total lengt; *2. e.g. about 5 cm increase in water level OR Number of hours used x pump capacity; *3 e.g. two times in March

6.4. Pesticide applications

Crop	Area	Pesticides (product name;)*	Conc. (e.g. 30% A.I)	Dilution by farmer	dose on field	application method (manual)	Frequency (e.g. 3)	Storage duration

* Ask whether farmers use the same pesticides on a certain crop every time the crop is grown (each season, each year). If different write down details in the rest of columns

6.5. Are pesticides sprayed curatively or preventively, or a combination of both?

6.6. Where do you buy pesticides?
- Village shop, District market,Provincial market, wholesale distributors, Others

6.7. Are the amounts of pesticides used fixed, or adapted to the intensity of the pest, or adapted because of the weather conditions (or weather forecast)
- Fixed, Change according to pest density, Change according to weather conditions

6.8. How is the equipment cleaned?
- By rinsing it several times with water (on land), Immerse in farm ditches, others

6.9. How much time taken between spraying pesticides and sprinkling/ watering of the crop?

Pesticide	Where do you store?	How do you store?	Where do you prepare?	Accidental spill, where does it go?*1	What do you do with left over?*2

*1 = whether the spill contaminate water or soil; *2 = Ask first whether they sometimes prepare more than required.

6.10 Do you have any relationship with following people in relation to agrochemicals use?

Person	**Yes/ No**	**If yes, describe the relationship**
a) Agriculture Extension Officers		
b) Agrochemical Company Sales People (e.g. at farmer meetings)		
c) Agrochemical Shop Retailer		
d) Other Farmers		
e) Banks, in terms of obtaining loans and other financial services		

6.12. What form of advertising most influences your decision on choice of agrochemical products? (e.g. radio, posters, product label)

Media, tv, radio, poster, flyers, newspaper, other	Rank*

*** Rank 1,2.3,4,5,6 etc. according to most influence to the least influence**

6.11 Sources and Usefulness of Information which Farmers Obtain Pertaining to Agriculture and Agrochemicals

In the shaded area: 1. **Tick** each box where **information is obtained** 2. Use **1,2,3,4….. etc. to show most useful to least useful**

Information / Advice Details									**If so what type?**
	Extension Officers	Company Sales Representative	A.C.I Wholesalers	Agrochemical Shop Staff	Informal Traders	Other Farmers	Agrochemical products or advertising	Do you feel you need more information?	
Crop production techniques/ methods									
Agrochemical use in pest control									
Other pest control practises (other than agrochemicals)									
Suitability of Agrochemical types/ products									
Agrochemical Preparation & Application									
Safe use of agrochemicals									
Frequency of visits, if any (e.g. meetings per year)									
Totals									

6.13. Are you a member of a farmer organisation, if so how does this benefit you?

Influence of Marketing Strategies on Farmers Choice of Agrochemicals

6.14. What are the criteria you use in selecting an agrochemical product?

Criteria	Level of Importance to Farmer				
	Important 4	3	Considered 2	1	Not Important 0
Convenience					
Stock Variety					
Product Reliability					
Product Price					
Advice Provided					
Discounts or Credit					
Other…..					

6.15. What are the criteria you use in selecting an agrochemical supplier?

Criteria	Level of Importance to Farmer				
	Very Important 4	**3**	**Considered 2**	**1**	**Not Important 0**
Product Price					
Product Efficiency / Reliability					
Discounts or Credit					
Brand name					
Advertising					
Advice from others					
Other…….					

6.16. Do agrochemical suppliers set terms and conditions with you or your organisation (business relating to sales e.g. you have to sell crops to the company/ middlemen?)

6.17. If yes to 6.16, what are the conditions?

Product Quality

6. 18 Ever purchased a pesticide which was advised for a particular crop/pest, but did not work?

Type of the product	What type of pest/ crop?	Purchase from where?

7. Fish types and observed mortalities

7.1. Types of aquatic animal

Type of animal	Main canal	Sub canal	Farm canal	Ponds

7. 2 Are there any observations of sudden fish kills or non-targeted crops that were harmed, which might have been related to the use of particular pesticides (which pesticide, what happened?)

Type of animals	Main canal	When*	Sub canal	When	Farm canals	When	Pond	When

* relate to pesticide use

Future Aims & Goals

8. Are there any future changes would you like to make to your agriculture practises?

Appendix 2 Household survey question sheet, Northeast Thailand

Baseline questionnaire

Date		Interviewer		Checked by	

Family head		Father/Husband	

Other persons present during the interview				

Group (put ✓)	pond		Pond-dike		Non pond	

Pond close to house	yes		no	

Well-being (put ✓)	1		2	

Village		Union		Sub-district (upazila)		District	

1. Household profile

	Name	Age	Education	Gender	Occupation								
					1st			2nd			Others (--------------------)		
					Place of work	What you do	Income	Place of work	What you do	Income	Place of work	What you do	Income

(income/ (last month/year/ month(average) ? based on the pre-test

2. Farming system

Plot	Area	Ownership	Use	pesticide use	Water Source	Cultivation period	Total production		Marketing				
							Qty (kg)	Value (tk)	Qty(kg)	Value(tk)	Where sell	Who bought	When sell

3. How you decide where to sell
4. Asset (livestock & poultry)

Category	Total Number	number						Current value(tk)	Sell (tk) (last 12 months)	Own consumption
		adult		young		offspring				

5. Asset (orchard)

Name of tree	age	Where located					Current value(taka)	Sell (tk) (last 12 months)
		Pond dike	Next to the pond	Away from the pond	Close to house	Total number		

6. Asset (equipment)

Housing		*House equipment*		*Transportation*		*Farm equipment*	
House status	*No.*	equipment	*Number*	Transport	*No.*	equipment	*No.*

7. Institutional context; Do you know what are the agencies/anybody (formal/non formal) working in your village? *(Collect information as far back as the farmer can remember)*

Name of the agency	Activities carrying out by the organisation	When they started working	Do you have any affiliation	What are the benefits you are getting

8. Any member of the family involves in any of the above agencies*
(Collect information as far back as the farmer can remember)

Who	Agency	What do the farmers do	Position	Benefits

*Agency includes – organisations/institutes/ club/ GOs /NGOs/ any body

9. Information flow

From where/whom you get information about farming?	Type of information	Method used by the organisation	Who get the information?

10. Have you ever had to pay? (put ✔ as appropriate)

	Training	Advise		
Yes				
No				

11. Do you further share your knowledge with any body? (put ✔ as appropriate)

Yes		No	

12. Input flow (last 12 months)

*Input	Source	Frequency (times/month)	When (month)
		Rice	
		Vegetable	
		Pond	

*Input includes all seed, fertilisers (organic/inorganic), feed, residue, water, soil, rice-bran etc.

13. If the farmer have no pond; Why you didn't prepare a pond? Reasons for no pond-

1. --
2. --

14. Do you think that pond (question for all three systems farmer) is an important source of income?

Yes		No	

15. (for pond dyke farmers)? ----------------------------

a.From which year you have started watering vegetable fields by pond water-----------------

b.From which year you have started watering tree garden by pond water------------------

16. Do you have any idea about integration? if yes and not practised, why ?

----

17. (farmers perception)

a. In what way pond & pond dike crops is important?

B. What social benefits do pond/pond dike cropping bring in the community?

----

18. (farmers perception)

A. What are the problems of integrated farming system?

B. Have you heard any social problems associated with pond culture or dike cropping in the community?

Health & nutrition issues:

19. Did any of the your family members get sick (last 12 months) Yes ☐ ☐No

Name of the member	Frequency	Duration (days)

20. Consumption pattern of nutrient dense food(last week) (write number of meal per weak)

Food	Numbers of meal	Source				
		Culture	Open water	Market	Rice-field (cultured)	Rice-field (connected with rice field)
Fish						

21. Consumption pattern of vegetable (last week) (write number of meal per weak)

Name of the vegetable	Numbers of meal	Source					
		Pond dike	Next to the pond	Away from the pond	Close to house	Natural source	Market

22. Why do you grow vegetable/fruit by yourself in your own farm? , if yes why? (put ✔ as appropriate) Easy to grow, Pesticide free,Good for health,To avoid going to market,Can be sold, Own consumption, No money required

23. Why do you grow fish by yourself in your own farm? If yes, why ?(put ✓ as appropriate)
Easy to grow, Pesticide free,Good for health,To avoid going to market,Can be sold, Own consumption, No money required

24. Average range of expenditure per month (considering the whole year)

25. Do you/any of the family members borrowed money (last 12 months)?

a. *Loan without interest*

Who	From whom	When	Amount	Refund process	
				duration	% interest

b. Loan with interest

Who	From whom	When	Amount	Refund process	
				duration	% interest

Appendix 3 Ex-community stakeholders subject to semi-structured interviews

Stakeholders	Respondent	Country
Pesticide Industry / Associations		
Pioneer Dupont Ltd.	Deputy Director	Thailand
Bayer (Thai) Co. Ltd.	Deputy Director	Thailand
Ladda Ltd.	Director	Thailand
Thai Agrochemical Business Association	Deputy Director	Thailand
Thai Crop Protection Association	Deputy Director	Thailand
Ceylon Petroleum Corporation	Deputy Director	Sri Lanka
Crop Life	Deputy Director	Sri Lanka
Lankem Ceylon Ltd	Deputy Director	Sri Lanka
Baurs & Co. Ltd.	Deputy Director	Sri Lanka
Pesticide Sales Outlets		
2 Salakru, 4Kokprajadee retailers	6 Managers	Thailand
2 Pesticide retailers, Mahaweli H	2 Managers	Sri Lanka
Agrarian Service Centre	Provincial Officer	Sri Lanka
Pesticide Regulatory Bodies		
DOA Agriculture Toxic Substances Division	Director	Thailand
Registrar of Pesticides	Director	Sri Lanka
IPM and GAP		
DOAE Office, Nakhorn Pathom	Provincial Officer	Thailand
9 IPM trainers, Central Thailand	9 IPM trainers	Thailand
3 IPM trainer, Northeast Thailand	IPM trainer	Thailand
1 GAP trainer, Central Thailand	GAP trainers	Thailand
2 GAP trainers, Northeast Thailand	GAP trainers	Thailand
Office of Agricultural Extension & Development; Region 2 (Pest management Centre, Suphan buri Province)	Director	Thailand
Agriculture Development		
Bureau of Farmers' Development	Director	Thailand
Bureau of Technology Transfer Development	Director	Thailand
Bureau Of Agricultural Extension Research & Development	Director	Thailand
Planning Division	Director	Thailand
School of Agricultural Extension & Co-operatives	Professor	Thailand
Bureau of Seed Multiplication	Director	Thailand
Plant Protection Research & Development Office	Director	Thailand
Asian Regional Centre (ARC)	Deputy Director	Thailand
International Agriculture Centre	Technical expert	Netherlands
Bureau of Agricultural Product Quality Development	Director	Thailand
Bureau of Agricultural Commodities Promotion & Management	Director	Thailand
Post-harvest & Products Processing Office	Director	Thailand
Planning & Technical Division	Deputy Director	Thailand
Office of Secretary, DOA	Senior expert	Thailand
National Bureau of Agricultural Commodities and Food Standards (Head office)	Director	Thailand
Office of Consumer Protection Board	Depty Director	Thailand
Food & Drug Administration	Deputy Director	Thailand
Department of Export Promotion's One-Stop Service Centre	Deputy Director	Thailand
Tissue Culture Centre of Maha Sarakham Province	Director	Thailand
Markets		
Nakhorn Pathom Market	1.Manager 2.Trader	Thailand
Prathomongkorn Market, Bangkok	1.Manager 2.Trader	Thailand
Si Mum Mueang Market, Bangkok	1.Manager 2.Trader	Thailand
Talad Tai Market, Bangkok.	1.Manager 2.Trader	Thailand
Tesco Lotus, Head office, Bangkok.	Technical Manager	Thailand
Tesco, Head Quarters, Cheshunt.	Technical Manager	U.K.

Appendix 4 Semi-structured questions for pesticide regulators

Discussion points for Government Pesticide Regulatory Authorities

(i) When was the Division/Department established?

1. What are the needs, aims and strategies of the Division/Department with regards to:

a) the agrochemical market in………..?
b) agriculture in …………?
c) wider development issues?

(ii) In what way are they and their institution connected with good agricultural practice (GAP), alternative pest, disease and weed control, IPM etc? List what do they do and have done? (Get reports/literature?

(iii) What dictates / drives what research / extension / other work they decide to do and how they do it?

2. What role does the division have in the agrochemical and farming industry?

3. In what ways does the Division implement these roles?

4. If not described above, what services does the Division provided?

(iv) What are their achievements/successes and failures? (give details)....(Add to SWOT table)

(v) What is his/her perception of agriculture in the area generally and the development of farming practices? (What are S.W.O.T. associated with this? Enter in table)

(vi) What is his/her perception of farmers' pest, disease and weed control in the area generally? (What are S.W.O.T. associated with this? Enter in table)

(vii) What is his/her perception of the influence of the type and method of training given to farmers and trainers of farmers by different organisations? (What are S.W.O.T. associated with this? Enter in table)

(viii) What is his/her perception of the influence of the market for safer / pesticide free foods on farmers pest, weed and disease control strategies?

(ix) What is his/her perception of the influence of pesticides and the way they are marketed on farmers pest, weed and disease control strategies? (What are S.W.O.T. associated with this? Enter in table)

f) Relations with other Institutions and Individuals:

List all the people, departments, sectors and institutions, that they and the institution they belong to, has communication with in this field (within and outside their own institution)*. How does she/he feel about <u>relations between them?</u> What is the <u>nature of communication between them both ways</u>; <u>what do they communicate</u> with each other? <u>How do they communicate</u> with each other? <u>How often do they communicate</u>? <u>How effective is this</u>? (*e.g. Government regulatory authorities, Universities, Farmers, Extension Services, NGOs, Foreign Governments Projects, Researchers, Food Markets, Traders, Food Safety, Other Pesticide Market Businesses and Retailers, Certification Bodies, Organisations, Associations etc)……………………………………………………………..……………… …………………(What are S.W.O.T. associated with this? Enter in table)

In particular, consider:

g) *Other Government regulatory authorities* (i.e. Dept. of Agriculture & Co-operatives, Dept. of Industry, etc.) *Pesticide businesses having membership of recognised Associations Pesticide businesses without membership of recognised Associations*. *Farmers*. *Research Institutions*. *Development organisations (NGOs etc.)*. *Recognised Associations*. *Market Organisation for Farmers*. *Agricultural Co-operatives*. *Other……………*

Draw a Venn diagram on attached page, if appropriate, to illustrate the closeness and strength of stakeholder relations and vice versa.

(xi) What do they think they can do to improve what they are doing?.(Add to SWOT table)

(xii) What do they need to make these improvements? (What are S.W.O.T. associated with this? Enter in table?)

(xiii) What are the future aims and goals of this institution / stakeholder and strategies of implementation (What are S.W.O.T. associated with this? Enter in table?)

Registered Business Details:

5. Obtain a list of addresses and contact details of businesses (i.e. formulators, manufacturers, wholesalers, retailers etc), which hold membership with the Association

6. What criteria must businesses satisfy for registration?

7. What fees do businesses pay for registration of the business, products and services provided and how often are payments made?

Background Data

8. If possible, can information be provided on:
   the origin, quantity and types of active ingredients imported to … over a few years?
- the origin, quantity and types of finished agro-chemical products produced in… over a few years?
- the quantity and types of finished products formulated and manufactured in .. over the last few years?
- the toxicity classification of agrochemical products used in ……..?

h) 9. If possible, provide samples of the registration forms for businesses and agro-chemical product production, storage and distribution.

Appendix 4

i) 10. Describe the procedures for:
- registration of businesses
- registration of production of agro-chemicals
- registration of storage, supply and distribution of agro-chemicals
- inspection of manufacturing and formulation facilities
- inspection of facilities in storage, supply and distribution of agrochemical products
- collection and analysis of samples of agrochemical products and ingredients

j) Research and Development Aspects

11. If not mentioned above, is the Division involved with any research and development?

k) What is the objective of this and what role does the Division have?

l) Views on Relevant Legislation and Compliance

Legislation relating to the agro-chemical industry:

Examples from Thailand, however the legislation in Sri Lanka will be different.

The Hazardous Substances Act, B.E. 2535 (1992)
The Patent Act, B.E. 2522 (1979) amended 2535 (1992)
The Labour Protection Act, B.E. 2541 (1998)
The Consumer Protection Act, B.E. 2522 (1979)
The National Environmental Quality Promotion Act, 2535 (1992)

12. With respect to above, what is the Division's / Department's opinion of (where possible):

a) the advantages and disadvantages of legislation regulating agrochemicals in…?
b) the effectiveness and efficiency of the implementation of this legislation?
c) the changes it would like to see in the legislation and implementation?

m) Problems within the Agro-chemical Industry

13. List, if possible, the present problems that inhibit good practice and jeopardise the sustainability of the agro-chemical industry, taking into consideration the legislation, farming practices, environmental, health and other relevant issues.

14. If possible, without specifying business names, can information be provided on the number and types of breaches of legislation found within the agrochemical industry over the last few years?

15. What percentage of these breaches resulted in penalisation?

16. Explain what a typical penalty would be for each type of breach of legislation……

(xi) What do they think they can do to improve what they are doing?

(xii) What do they need to make these improvements? (What are S.W.O.T. associated with this? Enter in table?)

(xiii) What are the future aims and goals of this institution / stakeholder and strategies of implementation? (What are S.W.O.T. associated with this? Enter in table?)

(xiv) How did they decide on these future aims goals and strategies.(What are S.W.O.T?)

(xv) List other institutions and briefly describe their contributions / relevance to this area

Use the timeline to illustrate anything of significance from any responses given

Sample Stakeholder Interview Recording Sheet
Stakeholder Type………………………..
Stakeholder Institution………………..Respondent
Name…………………………Respondent
Position………………………Date……………

Topic	Comments	Past and Present: Strengths	Past and Present: Weaknesses	Future: Opportunities	Future: Threats
Their organisation's work					
Perceptions on agriculture development, farmers' pest, disease and weed (PDW) control strategies, training methods, safe food market, pesticide marketing					
Relations - stakeholders: *…………					
Relations - stakeholders: *…………..					
Relations - stakeholders: *………….					

Timeline, Venn Diagram of Stakeholder Relations, Literature and Data Collected

Appendix 5 Semi-structured questions for Agrochemical Business Associations

Primary Points for Discussion and Information Required from Associations:

Thai Agro-Chem Business Association

Croplife Asia (formerly Asia-Pacific Crop Protection Association)

Thai Crop protection Association

Standard Information:

When was the Association established in Thailand?
What are the needs, aims and strategies of the Association with regards to:
a) the agrochemical market in Thailand? b) agriculture in Thailand?
c) wider development issues?

What role does the Association have in the agrochemical market?
In what ways does the Association implement these roles?
If not described above, what services does the association provided for its members?

Member Details:

Obtain a list of addresses and contact details of businesses (i.e. formulators, manufacturers, wholesalers, retailers etc), which hold membership with the Association

What criteria must businesses satisfy for membership with the Association?

What fees do members pay for membership and how often are payments made?

Members Products, Quality Assurance, Market Shares, Distribution and Sales:

Describe, if possible, the distribution of the shares of the agrochemical market, amongst the members of the Association, in Thailand?

What criteria influence differences in market shares and success of these businesses?

Does the Association practice any quality assurance of products or standards?

With reference to diagram, describe the distribution channels of agrochemicals

Describe, if possible, the general technological differences in technology, procedures processes, product quality and presentation between member businesses?

Describe, if possible, the formulation procedures and manufacturing procedures undertaken in agrochemical production, indicating the types of differences existing between member companies?

Do members advertise their membership with the Association on their products?

Appendix 5

The Market and Competition:

Circle the term which you think best states the agrochemical market in Thailand:

Expanding	Constant	Decreasing	Fluctuating

Circle the terms which you think best describes the level of competition in sales in the agrochemical market in Thailand:

Low	Moderate	High	Fluctuates

Circle the term which you think best describes the ease with which companies can sell agrochemicals in the market?

Very easy	Easy	Sometimes difficult
Difficult	Very difficult	Impossible

Relations with other Institutions and Individuals:

Describe the nature of the Association's relations, advantages / disadvantages, with : *Government regulatory authorities* (i.e. Dept. of Agriculture & Co-operatives, Dept. of Industry, etc.). *Association Members, Non-Member agro-chemical production, supply and distributors, Farmers, Research Institutions, Development organisations (NGOs etc.)Other Associations, Market Organisation for Farmers, Agricultural Co-operatives.*

Research and Development Aspects

If not mentioned, is the Association involved with any research and development projects? What is the objective of this and what role does the Association have?

Views on Relevant Legislation and Compliance

Legislation relating to the agro-chemical industry:
The Hazardous Substances Act, B.E. 2535 (1992) The Patent Act, B.E. 2522 (1979) amended 2535 (1992) The Labour Protection Act, B.E. 2541 (1998) The Consumer Protection Act, B.E. 2522 (1979) The National Environmental Quality Promotion Act, 2535 (1992) The Industrial Works Act, B.E. 2535 (1992) The Land Traffic Act, B.E. 2522 (1979) The Thai Maritime Act, B.E. 2456 (1913)

With respect to the above, what is the Association's opinion of (where possible):

d) advantages and disadvantages of legislation on agrochemicals in Thailand?
e) the effectiveness and efficiency of the implementation of this legislation ?
f) the changes it would like to see in the legislation and implementation?

Problems within the Agro-chemical Industry
List, if possible, the present problems that inhibit good practice and jeopardise the sustainability of the agro-chemical industry, taking into consideration the legislation, farming practices, environmental, health and other relevant issues.

Appendix 6 Semi-structured questions for pesticide formulators, Thailand / Sri Lanka

(Importers, Formulators, Manufacturers and Distributors – but not retailers)

A. General Information

1. Company name and address:
2. Interviewee name and position:
3. Date when company established:
4. Company Activities: *(circle and delete as appropriate)*

* Importer of (formulated product / technical grade / pre-mix / finished product)

* Manufacturer of pesticide * Formulator of pesticide

* Pesticide packager and labeller * Distributor (wholesaler of pesticide)

5. Ownership of the company: *(circle the relevant details)*

* Privately owned * Owned by parent company

* Partnership with another company * Other……………..

6. Owner(s) name(s) ?

8. How did the business develop and what factors influenced the business to become involved in agrochemical production?

9. How has agriculture and the agrochemical market changed over the years?

10. In consideration of these changes, what problems does the company find in the agrochemical business and how does the company address these problems in finding solutions? What drives what they do and how they do it? (Enter in SWOT table)

    What are their achievements/successes and failures? (give details).........................(add to SWOT table)

    What is his/her perception of agriculture in the area generally and the development of farming practices?................. (add to SWOT table)

    What is his/her perception of farmers' pest, disease and weed control in the area generally?........................ (add to SWOT table)

B. Products, Distribution and Sales

11. Does the company produce both 'commodity agrochemicals' and 'specialised agrochemicals'?

12. Can you provide information of the % of sales from each category of pesticide?

12. Other than pesticides, what other products / services does the company sell?

13. How do profits from agrochemical sales compare with profits from other company products / services?

14. What is the degree of variation between the profit margins from different types of pesticides?

15. For companies in general, do the quantities of different types of pesticides sold have any relation with particular regions of ……… if so why?

16. For companies in general, what pack sizes / quantities of pesticides are sold in the general market?

17. Are there any limitations on pesticide pack sizes or quantities sold in the market?

18. Does the company undertake any quality control relating to production or products? If so, what?

19. What measures does the company take to protect its products from copying or adulteration by others in the agrochemical market?

C. The Market and Marketing

20. Circle the term, which you think best describes the agrochemical market in…:

Expanding Constant Decreasing Fluctuating Other – specify …………

21. Circle the terms which you think best describes the level of sales competition in the agrochemical market in…….:

Low Moderate High Fluctuates Other – specify ……….

22. Circle the term which you think best describes the ease with which the company can sell agrochemicals in the market in………?

Very easy Easy Sometimes difficult Difficult
Very difficult Impossible Other – specify ……….

23. What criteria determines the price of agrochemical products in the market? (e.g. other companies, farmers income, etc.)

24. What methods and incentives does the company use for marketing and selling pesticide products?

25. What methods / techniques of advertisement does the company use for marketing agrochemical products? (circle as relevant)

Television Radio Newspapers Posters Flyers

Using representatives Field Demonstrations Other – specify…………

26. Which of the above is the most effective method of advertisement and why?

27. What types of information do salesmen give to customers to help product sales?

28. What criteria do you think determines a company's sales success in the agrochemical market?

What is his/her perception of the influence of pesticides and the way they are marketed on farmers pest, weed and disease control strategies?................................

29. Agrochemical substances are banned every year which can cause problems for stock control, sales and chemical disposal. How does the company deal with these?

D. Technological Aspects

30. Has the company been involved in any type of research? Explain….

31. Does the company aim to make technological advances in the future? Explain…

E. Relations with other Institutions and Individuals

List all the people, departments, sectors and institutions, that they and the institution they belong to, has communication with in this field (within and outside their own institution)*. How does she/he feel about relations between them? What is the nature of communication between them both ways; what do they communicate with each other? How do they communicate with each other? How often do they communicate? How effective is this? (*e.g. Government regulatory authorities, Universities, Farmers, Extension Services, NGOs, Foreign Governments Projects, Researchers, Food Markets, Traders, Food Safety, Other Pesticide Market Businesses and Retailers, Certification Bodies, Organisations, Associations etc)…………………………………………………………………..…………………
………………(What are S.W.O.T. associated with this? Enter in table)

Draw a Venn diagram on attached page, if appropriate, to illustrate the closeness and strength of stakeholder relations and vice versa.

F. Views on Relevant Legislation and Compliance

33. What is the company's opinion with regards to the advantages and disadvantages associated with the legislation that controls pesticides in …………?

34. What problems does the company find in complying with this and other types of legislation?

35. How frequently does the company receive inspections from government officials and which departments do they come from?

36. What do these officials check / record / do when visiting the company?

G. Environmental and Human Health Aspects of Agrochemicals

37. What is the company's opinion of the association of agrochemicals with human illness and damage to the environment?

38. Do human and environmental issues influence business practice?

39. What measures does the company take to minimise or prevent adverse health and environmental effects from its agrochemical products? (e.g. choice of ingredients, formulation method, labelling, advisory capacity) Have they contributed in any way to IPM or GAP in any way?

What is his/her perception of the influence of the type and method of training given to farmers and trainers of farmers by different organisations?....................................(add to SWOT table)

What is his/her perception of the influence of the market for safer / pesticide free foods on farmers pest, weed and disease control strategies?..... (add to SWOT table)

H. Other Comments?

What do they think they can do to improve what they are doing?............................

What do they need to make these improvements?................................(What are S.W.O.T. associated with this? Enter in table?)

What are the future aims and goals of this institution / stakeholder and strategies of implementation (What are S.W.O.T. associated with this? Enter in table?)

How did they decide on these future aims goals and strategies?...........(What are S.W.O.T. associated with this? Enter in table?)

List other institutions and briefly describe their contributions / relevance to this area.

40. Any other points which the company would like to note?

Appendix 6

Agrochemical Suppliers: Agrochemical formulation, sales and distribution summary table

Pesticide Type	**Pesticide Trade Names ***	**Pesticide Common Names**	**Form e.g dust**	**Technical Grade Substances ***	**Countries of Origin (tech. grade / pesticide)**	**% of active ingre-dient**	**Quantity produced / sold per year**	**% of Pest-icide Sales**	**Provinces in which sold**	**Direct Customer Types and Numbers: Dealers, Retailers, DOA, MPCS, Others.**
Insecticides										
Herbicides										
Fungicides										
Molluscicides										
Acaricides										
Rodenticides										
Other										
Total Numbers / Amounts										

*: circle the technical grade materials and formulated products which are imported

Appendix 6

Topic	Comments	Past and Present Strengths	 Weaknesses	Future Opportunities	 Threats
Their organisation's work					
Perceptions on agriculture development, farmers' pest, disease and weed (PDW) control strategies, <u>training methods,</u> safe food market, pesticide marketing					
Relations and communication with other stakeholders *………… *………….. *………….					

<u>Timeline, Venn Diagram of Stakeholder Relations, Literature and Data Collected</u>

Appendix 7 Questions for supply chain pesticide traders, Thailand / Sri Lanka

A. General information

1. Owner(s) name(s) and address:

2. Are you a retailer or wholesaler of pesticide?

3. (i) Date when your business / shop was established:

4. Does you operate as an agent for another company? If so which company?

B. Agriculture

(v) What is his/her perception of agriculture in the area generally and the development of farming practices? SWOT?

(vi) What is his/her perception of farmers' pest, disease and weed control in the area generally? SWOT?

(vii) What is his/her perception of the influence of the type and method of training given to farmers and trainers of farmers by different organisations? SWOT?

C. The Market and Marketing

5. Circle the term which you think best describes the pesticide market in ……..:

Expanding	Constant	Decreasing	Fluctuating

Other – specify …………..

6. Circle the terms which you think best describes the level of competition in sales in the pesticide market in ………..:

Low	Moderate	High	Fluctuates

Other – specify …………..

7. Circle the term which you think best describes the ease with which the organisation / business / you, can sell pesticides in the market?

Very easy	Easy	Sometimes difficult
Difficult	Very difficult	Impossible

Other – specify …………..

8. What criteria determines the price at which the organisation / business / you can sell pesticides products to purchasers? (e.g. supplier's discount levels, farmers income etc.)

Appendix 7

D. Pesticide Suppliers

9. Do pesticide suppliers provide advice, information or training to you on any of the following?

Information / training on:

pest control pesticide preparation and application

the appropriateness and effectiveness of agrochemical products IPM

crop management marketing and sales other……………….

10. Who, from the pesticide supplying business / organisation, supplies this information on pest and disease control and pesticide use to you / your business and what is their background and level of experience in these areas?

11. If marketing and sales is circled above what type of this advice do pesticide suppliers provide?

12. How often do you / your business, receive visits from your pesticide suppliers sales representatives, indicating what category they belong to? (e.g. dealers…twice per month, chemical company……once per month)

13. What do you think of the information supplied by the people above and how does this influence your / business decision on choice of pesticide to sell / purchase ?

14. Circle the incentives used by your suppliers of pesticides for marketing and selling pesticide products. (indicate which group of pesticides each applies to or if applies to all pesticide products)

Offer of rewards for high levels of pesticide sales within certain time periods (specify type of rewards and level of sales required)

Offer of discounts for bulk purchase (specify amount purchased and discount levels)

Offer of discount for every purchase, regardless of quantity

Offer of credit over a period of time (specify the level of credit and time period)

Other method – specify……………

15. What other incentives are provided by your pesticide suppliers?

Discounts on other agricultural products (e.g. fertiliser) from the same supplier

Discounts on other non-agricultural general supplies from the retailer

Other-specify………………

16. Do pesticide suppliers set terms and conditions with you / your business relating to sales? If so, what?.......

17. What methods of advertisement / techniques has influenced your decision on your choice of purchase of agrochemical products? (circle methods below and rank starting from 1 the most influential method, stating reasons)

Television Radio Newspapers Posters Flyers

Supplier Representatives Field Demonstrations Other – specify…

Reasons:

18. Who from your business makes decisions on which, where and how much, pesticides are purchased?

19. Do any other people in the business influence the above person's decisions on pesticides purchase? Who?

20. What factors determine your choice of pesticides supplier? (circle reasons below and rank starting from 1 the most influential factors)

Convenience of supplier Reliability of supplier Stock variety

Product prices Credit availability with product Discount offers

Other – specify…………

21. What ultimately determines which type of pesticides you / the business purchases? (rank below, starting with 1, the most important to least important factors)

It's effectiveness It's cost Brand name Discount level

Credit level/extent Advertising Supplier's advice Others peoples advice

Health safety aspects of product Environmental safety aspects of product

Other – specify…….

22. What quantity of pesticides do you / the business purchase at any one time and why?

23. Where do you store pesticides and specify if the facility is locked or also contains food items?

24. Do you feel you need more information to help you / the business in your choice of pesticide products?

(ix) What is his/her perception of the influence of pesticides and the way they are marketed on farmers pest, weed and disease control strategies? SWOT?

Appendix 7

E. Business Outputs

(iii) What dictates / drives the way they work and how they do it? (SWOT?)

25. (ii) Does the business / you, provide any of the following advice, information or training to purchasers of your agrochemicals (i.e. to farmers and other customers)?

Information / training on:

pest control pesticide preparation and application GAP

the appropriateness and effectiveness of agrochemical products IPM

crop management marketing and sales other……………….

26. Who, from the business supplies this information on pest and disease control and pesticides use to pesticide purchasers / farmers and what is their background and level of experience in these areas?

27. Circle the methods used by your business / you for marketing and selling pesticide products (indicate which group of pesticdes each applies to or if applies to all pesticide products)

Offer of rewards to dealers / retailers / traders for high levels of pesticide sales within certain time periods (specify type of rewards and level of sales required)

Offer of discounts for bulk purchase (specify amount purchased and discount levels)

Offer of discount for every purchase, regardless of quantity

Offer of credit over a period of time (specify the level of credit and time period)

Offer of repayment for agrochemicals in the form of crops

Other method – specify……………

28. What other incentives are given to purchasers of the business's products ?
e.g. discounts and credit on other company products (e.g. fertiliser)

29. What methods of advertisement / techniques does the organisation / business / you, have for marketing agrochemical products (circle methods below and rank in order starting from number '1', the most effective methods of advertisement for the business, stating the reason for their effectiveness below)

Television…. Radio… Newspapers…. Posters…. Flyers

Verbal liaison….. Field Demonstrations…. Other – specify…………

Reasons:

30. What other services do you provide for pesticide customers? (circle as relevant below)

Loans Credit Delivery service(mobile) Pest control advice

Agrochemical advice Other-specify………..

31. Do you / the business set terms and conditions with purchasers on sales? (e.g. farmer has to sell crops to you / the business)

32. What periods of time do pesticides remain on the shelf before they are sold?

33. Do you carry out exchanges of pesticides with other suppliers in order to increase your range of pesticides?

34. What criteria do you think determines an agrochemical outlet's (shop's) sales success in the agrochemical market?

iv) What are their achievements/successes and failures? (give details) SWOT?

G. Relations with other Institutions and Individuals

List all the people, departments, sectors and institutions, that they belong to and have communication with in this field (within and outside their own institution)*. How does she/he feel about relations between them? What is the nature of communication between them both ways; what do they communicate with each other? How do they communicate with each other? How often do they communicate? How effective is this? (*e.g. Government regulatory authorities, Universities, Farmers, Extension Services, NGOs, Foreign Governments Projects, Researchers, Food Markets, Traders, Food Safety, Other Pesticide Market Businesses and Retailers, Certification Bodies, Organisations, Associations etc)………………………………………………………………..…………………………
………(What are S.W.O.T. associated with this? Enter in table)

Draw a Venn diagram on attached page, if appropriate, to illustrate the closeness and strength of stakeholder relations and vice versa.

35. Does the company have memberships with any associations, if so which?

H. View on Environmental and Human Health Aspects of Pesticides

36. What is your opinion on the association of pesticides with :

a) human illnesses and health concerns

b) damage to the environment

37. How do you / the business view publicity on human and environmental damage from pesticides ?

38. Does this publicity influence the attitude of the business / you in its / your approach to stocking, marketing and sales of pesticides? If so, how?

39. Does the company take any measures in business practice to minimise or prevent adverse health and environmental effects from its pesticide products? (e.g. choice of purchases, advisory roles)

(viii) What is his/her perception of the influence of the market for safer / pesticide free foods on farmers pest, weed and disease control strategies? SWOT?

I. Technological Aspects

40. Does your business have any involvement with research and development, if so in which areas and what are the objectives?

41. What technological advances would the company like to make?

Views on Relevant Legislation and Compliance

42. What is the business's your opinion of:

g) The legislation controlling pesticides, listing the advantages and disadvantages to the business you are involved in ?
h) The efficiency of the implementation of regulation to control pesticides?
i) what changes would the business / organisation / you like to have in the legislation?

43. What other legislation does the business / organisation / you have to comply with?

44. How frequently does the company receive inspections from:
a) Pesticide Regulatory Officials
b) Other government officials (name the department they are from)

45. What do these officials check / record / do when visiting the business / you?

(xi) What do they think they can do to improve what they are doing?

(xii) What do they need to make these improvements? (SWOT?)

(xiii) What are the future aims and goals and strategies of implementation? (SWOT?)

(xiv) How did they decide on these future aims goals and strategies? (SWOT?)

(xv) List other institutions and briefly describe their contributions / relevance to this area.

Using the legislation to determine the sections of the Act which relate to the company, check the level of compliance with legislation as appropriate and where practical, with the permission of the business / organisation management or individual.

If checks on products etc for compliance with legislation are not permitted politely ask the reason why and take note.

Appendix 7

Agrochemical Purchasers and Suppliers: Agrochemical origins, sales and distribution summary table

Pesticide Type	**Pesticide Trade Names**	**Pesticide Common Names**	**Form e.g dust**	**% & names of Active Ingredients**	**Source of Purchase (business name, type & location)**	**Quantity purchased & sold per year**	**% of Pest-icide Sales**	**Locations of customers / purchasers**	**Direct Customer Types and Numbers: e.g. Dealers, Retailers, MPCS Retailers, Traders, Farmers, Others.**
Insecticides									
Herbicides									
Fungicides									
Molluscicides									
Acaricides									
Rodenticides									
Other									
Total Numbers									

Appendix 7

Topic	Comments	Past and Present Strengths	Past and Present Weaknesses	Future Opportunities	Future Threats
Their organisation's work					
Perceptions on agriculture development, farmers' pest, disease and weed (PDW) control strategies, <u>training methods,</u> safe food market, pesticide marketing					
Relations and communication with other stakeholders: *………… *………….. *………….					

<u>Timeline, Venn Diagram of Stakeholder Relations, Literature and Data Collected</u>

Appendix 8 Generic questions for ex-community stakeholders

General Details: Date:
Name…………………………Position………………………Institution………………

1. Stakeholder interests and involvement in pest, weed and disease control in agriculture

i) When was their institution established?..

ii) In what way are they and their institution connected with good agricultural practice (GAP), alternative pest, disease and weed control, IPM etc? List what do they do and have done? (Get reports/literature)……………………………………………

iii) What dictates / drives what research / extension / other work they decide to do and how they do it?..
…………………………(What are S.W.O.T. associated with this? Enter in table)

iv) What are their achievements/successes and failures? (give details)........................
……………………………………………………………………………………
……………………………………………………………………………………
…………………………..(What are S.W.O.T. associated with this? Enter in table)

v) What is his/her perception of agriculture in the area generally and the development of farming practices?...
....
....
....(What are S.W.O.T. associated with this? Enter in table)

vi) What is his/her perception of farmers' pest, disease and weed control in the area generally?..
....
....……………………………………………………
……………………….......(What are S.W.O.T. associated with this? Enter in table)

vii) What is his/her perception of the influence of the type and method of training given to farmers and trainers of farmers by different organisations?...................................
....
……………………….......(What are S.W.O.T. associated with this? Enter in table)

viii) What is his/her perception of the influence of the market for safer / pesticide free foods on farmers pest, weed and disease control strategies?.......................................
....
……………………….......(What are S.W.O.T. associated with this? Enter in table)

ix) What is his/her perception of the influence of pesticides and the way they are marketed on farmers pest, weed and disease control strategies?................................
……………………………………………………………………………………..
……………………………………………………………………………………..
……………………………………………………………………………………..
……………………….......(What are S.W.O.T. associated with this? Enter in table

x) List all the people, departments, sectors and institutions, that they and the institution they belong to, has communication with in this field (within and outside their own institution)*. How does she/he feel about <u>relations between them?</u> What is the <u>nature of communication between them both ways</u>; <u>what do they communicate</u> with each other? <u>How do they communicate</u> with each other? <u>How often do they communicate</u>? <u>How effective is this</u>? (*e.g. Government, Universities, Farmers, Extension Services, NGOs, Foreign Governments Projects, Researchers, Food Markets, Traders, Food Safety, Pesticide Market and Retailers, Certification Bodies, Organisations, Associations)……………………………………………..
……………………………………………………………………………………….
……………………………………………………………………..…………………
……………………………(What are S.W.O.T. associated with this? Enter in table)
Draw a **Venn diagram** on attached page, if appropriate, to **illustrate** the closeness and strength of stakeholder relations and vice versa.

xi) What do they think they can do to improve what they are doing?............................
………………………………………………………………………………………

xii) What do they need to make these improvements?..
………………………………………………………………………………………
…………………………(What are S.W.O.T. associated with this? Enter in table?)

xiii) What are the future aims and goals of this institution / stakeholder and strategies of implementation?..

…………………………(What are S.W.O.T. associated with this? Enter in table?)

xiv) How did they decide on these future aims goals and strategies?..............................
………………………….(What are S.W.O.T. associated with this? Enter in table?)

xv) List other institutions and briefly describe their contributions / relevance to this area……………………………………………………………………………….
………………………………………………………………………………………

Appendix 8

Topic	Comments	Past and Present Strengths	Past and Present Weaknesses	Future Opportunities	Future Threats
Their organisation's work					
Perceptions on agriculture development, farmers' pest, disease and weed (PDW) control strategies, training methods, safe food market, pesticide marketing					
Relations and communication with other stakeholders *………… *………….. *………….					

Timeline, Venn Diagram of Stakeholder Relations, Literature and Data Collected

Appendix 9 Initial contact questions for IPM trainers by telephone, Thailand

A) Introductions B) Questions

i) Training Methods and Locations

1. What exactly do they teach farmers (e.g. GAP, IPM, Organic etc)?
2. What specific techniques do they teach farmers (e.g bagging, bio-pesticide)?
3. What methods do they use to teach these farmers (e.g T & V, FFS, demonstration)?
4. In what regional areas have they trained farmers?

ii) Farmer Sample Identification

5a. Can they give examples of cases of successful outcomes from their training?
5b. Why successful?
5c. What crops were they growing then?
5d. Can they give contact details of these farmers?
6a. Can they give examples of cases of unsuccessful outcomes from their training?
6b. Why unsuccessful?
6c.What crops were they growing then?
6d. Can they give contact details of these farmers?
7a. Are they aware of any farmer(s) who may be doing IPM, GAP or organic farming by themselves without any formal training in these methods?
7b.Can they provide contact details of these farmer(s)?

iii) Quality Control and Certification

8a. Do any of these farmers', mentioned in 4a – 6b, have crops that are certified for quality and / or safety?
8b.What certificate labels (logos) do they acquire? (many labels we know about)
8c.Who provides these labels?

iv) Market Supply and Actor Identification

9a.What types of markets do the farmers, mentioned in 4a – 6b supply (e.g. supermarkets, conventional informal market)?
9b.Who / what body purchases the crops from the farmers mentioned in 4a – 6b?
9c. Can they provide contact details of these people / bodies?

v) Secondary Data, Gratitude & Future Contact

10. Thank them and ask them if it is possible to have a discussion with them in the future and get secondary data.

Appendix 10 Farmer case study discussion checklist

Respondent Details: Name:…………….. Village……………… Sub- District………………….District

Farming Class: Subsistence Cash Crop Both

Status: Better-off Worse-off Middle Well-being rank:………………….

A. General Farming Practices and Culture / Trapping of Fish

1. What's his view of the general trends in farming and fish culture/trapping, the reason for these trends, and how does he feel about it? Add to timeline.

………

2. What trends (over many years) has his own farming and fish culture/trapping practices been taking, why, and how does he feel about that? Add to timeline.

………
………

3. Can he add to the SWOT table what his opinions are on the current strengths and weaknesses and the future opportunities and threats are in farming practices and aquaculture?

B. Crops and Fish Production and Trading

4. Can he describe the trends (over many years) in the types and amounts of crops and fish produced generally for the area, why it is like that and what he feels about it? Add to timeline............................
5. Can he add to the seasonal calendar the types of crops and fish he grows through out the year?

6. What factors does he consider when deciding on what types of crops and fish to plant/grow through the year and can he describe which is most important and which is least important in this decision making process? …………………………………………………………………………………………….
7. If not mentioned above, where the crop market demand and farm gate price lies in importance to his decisions over choice of cropping pattern?...

8. How does he market (advertise) his crops and fish? ……………………………………………………

9. Which markets does he supply for these crops?...

10. Who and how does he transfer his crops and fish to the purchaser / market? ………………………

11. Who are his customers? (e.g. wholesalers, retailers, DOAE, public)…………………………………

12. What price does he get for the different products he produces and who does he sell them to (Can give contact details?)………………………………………………………………………………………
13. What does he feel about (happy with?) the price for the sale of his different crops and fish, his access to the market and the service provided by middlemen for transportation, if used?.......................
……….

14. If a middleman buys his produce is he aware of where he takes his crops / fish for sale and the prices these consumers pay?...

15a. Is he aware that pesticide free and low pesticide risk crops attract premium prices in Bangkok supermarkets and also that some foreign consumers pay much more for these products?

15b. If so, has he ever considered producing for these markets?...

15c. If not, or decided not to do it, why not?...
…….

15d. If he had this information what would he do?...

16. What strategies does he use, if any, to improve his return / income from the crops he produces?...

17. Can he add to the SWOT table what his opinions are on the current strengths and weaknesses and the future opportunities and threats are to the system of choosing crops, consumer demand, marketing and sales.

C. Pest, Disease and Weed Status

18. List the types of pests, diseases and weeds that you have found on your farm, the types of crops and period of time where they are found, the amount and level of the problem caused and why it is a problem, in the table below. Also indicate on seasonal calendar.

If farmer not sure about something enter 'NS'

Item	Name of PDW	Crop	Period	Amount*	Problem		Notes
					Level**	Why?	
Pests							
Diseases							
Weeds							

Amount * = None, Few, Average Numbers, Many, Not Sure.
Problem Level * = No Problem, Small Problem, Average Problem, Big Problem, Not Sure.

19. Additional Notes……..……………………………………………………………………………………
20. What are the trends (over many years) in pests, disease and weed types and levels of problems they caused on your farm?...
....Indicate on timeline.

D. Pesticide Use

21. What pesticides do you use to control which pests, diseases and weeds, throughout the year, how much and what are the impacts? Indicate on table below and on seasonal calendar.

	Pesticide Spraying			PDW	Crop	Impact level*	Comment
Product #	Period	Frequency	Conc.				

Impact Level* = Very Effective, Some Benefit, No Difference, Problem Worse, Not Sure.
PDW: Pest, Disease and Weeds #: Collect labels or details.

22. Could the pesticide product instructions better explain/give advice on safety, preparation, storage, application and dosage, disposal of used container, symptoms of poisoning and treatment or is it ok for you?………
……

23a. Do you follow the directions as instructed on the container for safety and application dosages?...

23b. If not, what do you do different and why do you do this?..
....

24a. Do you i) use mixtures / cocktails of pesticides?..

24b. If Yes, why do you do this?...

25. What factors do you consider when you have to decide:

i) what pesticides to use (type / brand)?..
ii) how much to use each time you spray?...
iii) when to spray?..
iv) how often to spray ?.. ………………………………

26. What are the advantages and disadvantages of your pesticide use to your livelihood and how do you feel about it?...
……
……

27. Does your pesticide application levels to crops that you sell and those that you consume within the household differ? If so, how much and why?...

28. If you ever used a pesticide that had little or no effect (indicated in table above) why did it not have effect?...

29. Have you ever seen any damage to the environment that you thought may have been caused pesticides?.................................Describe……………………………………………………………………
…….

30. Have you ever seen fish kills in your pond that you thought may be due to pesticides?..................
Details………

E. Pesticide Purchase

30. Who or what most influences (best info) your decision on choice of pesticide product? ....
31. Does advertising have any influence on your choice?..
32. If so what type of advertising?..
33. What criteria do you consider when selecting a pesticide supplier?...
34. Where or who do you purchase pesticides from and why?...

F. IPM and Alternative Pest, Disease and Weed Control Practices

35a. What beneficial animals / organisms (that control pests, diseases, weeds) can you identify on your farm? Indicate in the table below why beneficial, where and when they are found and amounts. Add to timeline and seasonal calendar.

If farmer not sure about something enter 'NS'

	Name	Why good? ***	Crop	Period	Amount*	Benefit level**

Why Good*** = what do they do? What pest, disease, weeds do they control?
Amount * = None, Few, Average Numbers, Many, Not sure.
Benefit Level * = No Benefit, Little Benefit, Average Benefit, Big Benefit, Not Sure.

35b. Additional Notes……..………………………………………………………………………………

36a. What are the trends (over long time) in beneficial animals/organisms types, amounts and benefits on your farm?.. Indicate on timeline.

36b. Why have they changed like that?..

37. Have you done anything to reduce your need for, and use of, synthetic pesticide (e.g. IPM techniques, use disease free seeds, bio-pesticide, good farm management, sticky traps, lights traps, nets or barriers, attractants and repellents, intercropping, crop rotation, apply pesticide according to PDW problem and beneficial organism level))? If so what do you do? If not why not?.…………………
(Add to seasonal calendar).

38a. How, when and from whom did you learn about these techniques (if from training enter in the table below)?...……………………………………………………………………………………………..

38b. What crops was the training focussed on?..

38c. What method was the training (farmer field school, one day training etc.)?.................................

38d. How long did the training last for?...

38e. How many farmers completed the full training and how many dropped out?..................................

38f. Why did some farmers complete the training and why did some farmers drop out?......................

38g. Of the farmers who completed the training, how many still continue to use the techniques and how many do not continue to use them?...

38h. Why did some farmers continue to use the techniques and some do not?...................................

38i. What are the strengths (good points) about the training and what are the weakness (things that could have been improved)?...

39. How do these techniques function (mechanism for working)?...
……

40. How effective are they?...

41. Did you share the information with anyone else?.............Who?...

42. Are there any products that you would like that you cannot get - too expensive or not available?
……

What do you view as the current strengths and weaknesses and future opportunities and threats with your pest control measures, comparing pesticide use only with a combination of different pest, disease and weed control strategies? Indicate on SWOT table **(crop yield, health, profit margin, environment etc).**

G. Training and Information Received in Agriculture and Aquaculture

43. Have you received any training on methods of reducing pesticide use, IPM or alternative pest control? If so, enter in the table below and provide further details here……………………………………
……

44. Enter any other agriculture and aquaculture training and information received in the table below

When?	Info	Type?	From?	Method, Duration, freq.	Usefulness / Impact	What think of training?*	Tell anyone?

* Advantages / disadvantages

45. Is there information that you would like that you cannot get?..
……

H. Farm Monitoring

46. Enter in the table below the details of the people who monitor / record things on your farm of or your products (e.g. extension officer, pesticide salesmen, etc.)

Name	Position	Organisation	What did they record / monitor	Where? Farm/Market?	Frequency of visit/recording?

47. Detail any opinions you may have on what these people do?..

48. Do you do any monitoring or recording of your own? If so, what?..

I. Memberships of Organisations

49a. Are you a member of any organisation, such as farmer organisation?...
49b. Does this benefit you?...............How?...

J. Stakeholder Relations

50. What stakeholders do you have contact with? (e.g. Sub-district Head, extension officers, pesticide salesmen, pesticide retailers etc.) (Enter in Stakeholder SWOT table and draw a **Venn diagram** on attached page, if appropriate, to **illustrate** the closeness and importance of stakeholder relations).

51. How often do you see them?...

52. Describe what you do for them or they do for you?..

53. What are the current strengths, weaknesses and future opportunities and threats with your relationships with these stakeholders (enter in table attached)?..

K. **Future Needs, Aims and Goals**

54. Would you like to change about your farming practices?........If so, what?....................................
………
55. What are your future aims and goals?..
………

56. What do you think you need to help your farming and livelihood?...
....

L. Other Points

57. Is there anything else that you would like to tell us / discuss that you feel is important to you? If so, describe…………………………………………………………………………………………………….

*Use the **timeline** to illustrate anything of significance from any responses given*

Timeline

Seasonal Calendar

Topic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec

Appendix 11 Farmers' Questionnaire, Kokprajadee workshop

Name of farmer……………………………………………………………………………….
Main types of crops grown…………………………………………………………………

1. Frequency of pesticide use

a) Generally do you agree with the research findings for this section ☐ yes ☐ no

b) What influences your decision for the frequency of pesticide applications?
- Experience (both your own and other farmers)
- It changes based on; time of year, climate, pest type and density, crop type, other

c) How do you assess the level of risk to the crops and how much to apply (concentrations) – *DISCUSSION*

2. Pesticide cocktails

a) Generally do you agree with the research findings for this section ☐ yes ☐ no
b) Please tick which statement applies to you
I always use pesticide cocktails. I never use pesticide cocktails. I use both cocktails and single pesticide applications.

c) What are the reasons for your use of pesticide cocktails;
To control only one main type of pest. Only to control multiple types of pests.
I use pesticide cocktails to prevent the outbreak of many different pest types
other, please specify ………………………………………………………

d) Please tick the statements that you agree with;
Pesticide cocktails used to control more than one type of pest
Pesticide cocktails used when unsure about the effectiveness/ suitability of single pesticides
In coordination pesticides are more effective
It saves time to apply when mixed together

Health risks

a) Generally do you agree with the research findings for this section ☐ yes ☐ no
b) What is the reason for stating health as the most important factor to reduce pesticides compared with financial reasons – *DISCUSSION*
c) Do you consider there to be enough information on protective clothing for pesticide applications? ☐ yes ☐ no
d) What is the time interval you would leave between spraying crops and harvesting them …………………………………………. (number of days)

Salesmen

a) Generally do you agree with the research findings for this section ☐ yes ☐ no
b) How frequently do you talk with pesticides sales representatives ………………
c) Are their demonstrations/ advice useful ☐yes ☐ no

d) Do you trust what they have to say ☐yes ☐ no

e) Do they influence your choice of brand ☐yes ☐ no

Information sources

a) Generally do you agree with the research findings for this section ☐ yes ☐ no
b) Why is the information received from other farmers more valuable than from other sources – *DISCUSSION*
c) Do you think the information provided by government and private sector services is sufficient.
d) What else could be done to provide useful information on more efficient pesticide use (more training? More health related information – protective clothing info?
- *DISCUSSION*

Training on pesticides and their use.

a) Have you received any formal training about pesticides and their use

b) If yes, who provided the training?
……………………………………………………………………………………

c) What was the training method?
…………………………………………………………………………………….

d) How relevant was the training to the farmers and generally was it useful or not?
(i.e. Many drop-outs during the training? many continue with the techniques on own?
e) What advantages did it have – (e.g. yield, income, health, environment?)
f) What problems were encountered?

Name of farmer………………………………………………
Main types of crops grown……………………………

Market related pesticide issues

Please list, in order of importance, the major problems you face in terms of your farm and your livelihoods,
(*eg. Low market prices, lack of useful information, market transportation, pests etc*) .

2. Please list, in order of importance, the factors that contribute to the quantity and frequency of synthetic pesticide that you apply to your crops. (*e.g. 1-customer demands, 2-difficulty of controlling a particular pest, 3- the type of crop and sensitivity to the pest / disease, 4- supply exceeding demand in the market and high competition, 5- lack of knowledge and skills on alternatives to / integrated pesticide use, etc.)*

What markets do you supply vegetables to (safe food markets or conventional) and what are the needs / desires of these market and the customers with regards to quality of the crop visually and safety from chemicals?

How much does the market you are supplying, influence your pest, disease and weed control strategies?

Pest related issues

What crops do you grow and what pests, diseases and weeds affect these crops?

Crop and Pest (list)	Seasonality? (Rainy, dry or all year)	Problem scale (1=high, 5=low)

What methods do you use to help reduce the level of synthetic pesticide used.
(*i.e. things that make their crop healthier to withstand attack, prevent the pests, diseases, weeds from becoming a big problem, protecting the crop, managing the farm).*

List them and find out how useful you think they are (voting).

Risks from pesticide use

Aware of links between pesticide and contamination of the aquatic environment?
What role does the aquatic system play in terms of your choice on the type and level of pesticides used and desire for use of alternatives?
(i.e. if you culture, eat / sell fish from the canals / ponds or use the canals for other purposes then how does this influence their pest control practices / pesticide use?)

Does this affect your pesticide use?

--Discussion--

Opportunities

If you were given the opportunity to supply these safe food markets and obtain a higher price for your crops, would you consider supplying them if it meant changing what you do, by reducing pesticide use etc?
If so, what would they see are the problems in doing so?

---Discussion---

Thank you, and we realise that this workshop is taking information from you about the problems you face with regards to using pesticides, but we would like to make it clear that between this workshop and then next one (in approximately 10days) we will provide suggestions, based on the problems you have raised, that will aim to reduce the amount of pesticides so that you, if you wish, have the ability to access higher value markets for your produce and reduce your expenditure based on pesticide costs.

This will then have numerous advantages, not only for your finances but for the environment and for the health of the community as a whole.

Many thanks for your participation.

Appendix 12 Pesticides used in study sites with health and aquatic hazard ratings

Active Ingredient	Pesticide Type	Class	WHO rating	Notable risk level to organism groups		Country using
				Freshwater plant risk	Freshwater animal risk	T-Thailand SL-Sri Lanka
Abamectin	Insecticide	ML	1b	Population	Insects, fish, zooplankton	T
Alachlor	Herbicide	CH	III	Population	Amphibian, fish, molluscs	SL
Azoxystrobin	Fungicide	S	U	Population	Zooplankton	T
2,4-D sodium salt	Herbicide	CA	II	Population	Zooplankton, fish	T
Benomyl	Fungicide	B	U	Population	Zooplankton, fish	T
Captan	Fungicide		U	Population	Fish	SL, T
Carbaryl	Insecticide	C	II	Accumulation, population	Insects	SL, T
Carbendazim	Fungicide		U	Growth, population	Zooplankton	T
Carbofuran	Insecticide	C	1b	Accumulation, population	Crustaceans, insects	SL, T
Carbosulfan	Insecticide	C	II		Fish	T
Chlorfenapyr		PY	II		Insects	T
Chlorfluazuron	Insecticide		U			T
Chlorpyrifos	Insecticide	OP	II	Accumulation, population	Amphibians, annelids, fish, crutaceans	SL
Cypermethrin	Insecticide	PY	II	Accumulation, population	Zooplankton, insects, fish, crustaceans	T
Dicrotophos	Insecticide	OP	1b		Zooplankton, insects	T
Difenoconazole	Fungicide	AZ	II		Zooplankton	T
Diflubenzuron	Insecticide	BZ	III		Zooplankton, crustaceans, insects	T
Dimethoate	Insecticide	OP	II		Zooplankton, molluscs, annelids, crustaceans, insects	SL
EPN	Insecticide	OP	1a		Zooplankton, molluscs, annelids, crustaceans, insects	T
Fenobucarb		C	II		Zooplankton, crustaceans	S
Fipronil	Insecticide	PY	II		Crustaceans, fish, insects, zooplankton	T
Glyphosate	Herbicide	PG	III	Bio-accumulation	Crustaceans	SL, T
Lufenuron		BZ				
Malathion	Insecticide	OP	III		Fish, crustaceans, amphibians, insects	T

Appendix 12

Active Ingredient	Pesticide Type	Class	WHO rating	Notable risk level to organism groups		Country using
Mancozeb	Fungicide	C	U	Population	Amphibians	SL, T
MCPA	Herbicide	PAA	II	Population	Amphibians, fish, molluscs, zooplankton	SL
Metalaxyl	Fungicide	Z	II		Fish, zooplankton	T
Methamidophos	Insecticide	OP	1b		Crustaceans, zooplankton	T
Methomyl	Insecticide	C	1b		Crustaceans, insects, zooplankton	T
Methyl parathion	Insecticide	OP	1a	Bio-accumulation	Crustaceans, Insects,	T
Mevinphos	Insecticide	OP	1a		Crustaceans, zooplankton, fish	T
Omethoate	Insecticide	OP	1b		Zooplankton	T
Paraquat dichloride	Herbicide	BP	II		Crustaceans, zooplankton	SL
Profenofos	Insecticide	OP	II		Zooplankton, crustaceans, molluscs, fish, insects	T
Propanil	Herbicide	A	II		Fish	SL
Propineb	Fungicide	C	U			T
Prothiofos	Insecticide	OP	II		Fish, zooplankton	T
Tetradifon	Insecticide		U		Fish, zooplankton	T
Zineb	Fungicide	C	U		Annelids	T

KEY: A=Anilide; AZ=Azole; B= Benzimidazole; BP=Bipyridylium derivative; BZ= Benzoylurea C=Carbamate; CA=Chlorophenoxy acid or ester CH=Chloroacetanilide; ML=Macrocyclic Lactone OP=Organophosphorous compound; PAA=Phenoxyacetic acid derivative; PG=Phosphonoglycine; PY=Pyrethroid; S=Strobin; Z= Xylylalanine

	WHO Class LD50 for the rat (mg/kg body weight) Oral	Dermal
Ia Extremely hazardous	< 5	< 50
Ib Highly hazardous	5–50	50–200
II Moderately hazardous	50–2000	200–2000
III Slightly hazardous	Over 2000	Over 2000
U Unlikely to present acute hazard	5000 or higher	

(Source: WHO 2010 The WHO recommended classification of pesticides by hazard and guidelines to classification: 2009)

Yellow=slight toxicity
Orange=moderate toxicity
Red=high toxicity

Aquatic toxicity information source http://www.pesticideinfo.org/Detail_Chemical.jsp?Rec_Id=PC35110#Ecotoxicity