COMMUNITY PROCESSES IN DEVELOPMENT AND IMPLEMENTATION OF PRACTICES FOR THE MANAGEMENT OF PLANT PESTS AND DISEASES – A DISCUSSION PAPER

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Abstract

A range of community processes contribute to the development and implementation of management practices of plant pests and diseases. The effectiveness of these processes is greater in communities with high social capital, including strong cooperative relationships within the community, and between the community and external agencies. Historically, farmers (including subsistence farmers, farmers of broadacre crops, and pastoralists) have been the producers of this type of knowledge, empowered with dignity and confidence to experiment with farming practices. Developments in the past century, particularly the Green Revolution, have seen technological interventions imposed on farmers. In relation to the control of pests, and diseases, applications of synthetic organo-chemicals were advocated for "revolutionary" improvements to yields in broadacre crops. The limitations and harmful environmental impacts of this approach have subsequently led to a range of "evolutionary" changes in processes for research into pest and disease management practices. There has been growing recognition of the value of farmer participation in research into pest management practices, particularly for more effective implementation. In Asia during the past thirty years, programmes such as Farmer Field Schools and Community Integrated Pest Management have focused on increasing farmers' ecological knowledge to equip them to improve their pest and disease management. Through these approaches farmers are more likely to make management decisions and tailor practices in response to their observations and understanding of ecological processes rather than to follow a prescriptive management package. This discussion paper describes some of the processes underlying the development of pest management practices in Southeast Asia and various stakeholders (including farmers, scientists, community, government) that influence this development.

Introduction

This paper describes some of the community processes that contribute to the management of plant pests and diseases, particularly in rural areas of Southeast Asia. Plant pests and diseases have wide ranging impacts; impacts on agricultural productivity, from broadacre farming and pastoralism to small plot subsistence farming and hunter gathering, but also impacts on biodiversity conservation, home gardens and aesthetics. The management of plant pests and diseases is largely through farming practices however the processes contributing to the development and implementation of these management practices involve a range of stakeholders. These processes and the roles of the various stakeholders in their development will be discussed in this paper. In particular, changes in recent decades in the roles of farmers and scientists in various systems are described with some evaluation of the impacts of these changes on the empowerment of farmers and the efficacy of the implemented practices.

“Community” is commonly accepted to mean a group of people who share a common identity or a special interest (Kenny 1994). “Community participation” can be defined as a process of active involvement of local individuals and groups in assessment of needs, planning solutions, creating structures for and implementing solutions and assessing outcomes (Shiffman 2002, Zakus and Lysack 1998). Community processes, in particular management processes, can be viewed in terms of six types of community capitals; natural, cultural and human capital which can be transformed into social, political, and financial/built capital (Flora 2004). A community’s social capital is a measure of the ability of community members to secure benefits through their membership of social networks, such as local associations and non-formal groupings (Grootaert 2001). Communities have the strongest chance for sustainable development if they have strong social capital, with moderately high levels of both bridging (relationships with external agencies) and bonding (relationships within the community) elements (Flora 2004). Similarly, rural livelihoods and integrated conservation and development (ICDP) projects can be examined within a similar framework (Bebbington 1999, Garnett *et al*. 2007). Community processes for developing and implementing management of plant pests and diseases will be discussed within a community capitals framework.

This paper aims to provide a synthesis of previous studies of approaches to pest and disease management and a bibliographic resource for a project entitled Development of a community-based model for the management of EPP (Emergency Plant Pests) incursions, funded by the Cooperative Research Centre for National Plant Biosecurity and running 2006-2009. This paper focuses on cropping systems in Southeast Asia but includes some comparisons outside this region and this type of management system.

Emergency plant pests are defined as known exotic plant pests with potential to have adverse economic impacts (http:/www.crcplantbiosecurity.com.au). The focus of this paper is farming systems, both for income generation and subsistence, with direct economic impacts on livelihoods. Stakeholders include farmers (broadacre and subsistence), scientists, nature conservation managers, urban dwellers (gardeners, travelers) and policy makers.

This discussion paper describes community processes for pest and disease management and some methodologies for their evaluation. The discussion of processes and roles includes accounts of some traditional knowledge and management practices for pest and disease management, current systems of integrated pest management systems, current processes for the development of knowledge and management systems, and the roles of a range of stakeholders in the development and implementation of pest management systems.

Generally stakeholders aim to manage established plant pests and diseases in order to minimise the negative impacts on crop yields and the environment. Success of this type of management strategy can be measured relative to economic threshold levels of infestation. The aim may realistically be eradication only for recent or small incursions of exotic pests and diseases. In this discussion paper the focus is on the social processes that can contribute to the development and implementation of management practices.

Discussion

(i) Plant pest and disease management within a community capitals framework

Sustainable development at the community level is dependent on the community identifying and investing in six forms of capital: natural, cultural, human, social, built and financial (Flora *et al*. 2004, Garnett *et al*. 2007). Natural capital includes environmental health (*e.g*. soil conservation) and landscape diversity, and promotes sustainable land productivity. Cultural capital is a human construction that includes perceptions and knowledge systems, and affects the definition of problems. Human capital is driven by demographic trends, and the skills and capacity of the population. Natural, cultural and human capitals make up the “base” of the community in terms of resolving environmental issues (Flora 2004). For a community to develop in a sustainable way these forms of capital are transformed into high levels of social, built and financial capital (Flora 2004). Social capital is highest where tenure is stable, clear and equitable, governance is fair and effective, and interventions are appropriately sequenced across multiple scales and levels of governance (Garnett *et al*. 2007). Built capital may include the trade off of natural for built capital. Financial incentives are a major driver for changes in practices. Garnett et al. (2007) argues that financial incentives are especially important if belief-based constraints have become ineffective, and environmental payments are most effective if administered through contractual arrangements linked to measurable targets and milestones (*e.g*. though payment for environmental services arrangements).

Plant pest and disease management may be considered within a community capitals framework. Community cooperation is required for the effective management of plant pests and diseases. Plant pests and diseases have direct impacts on natural capital, often causing reduced crop yield, reduced biodiversity and adversely altering fire regimes. Management practices can have additional negative environmental impacts, such as pesticide residues or altered fire regimes with increased exposure and loss of topsoil. Human capital may be measured as skills and may appear to be low in small rural communities (Flora 2004), particularly if formal education levels are low. Management practices are largely in the hands of farmers. Although most farmers are generally not highly educated they may have insights into ecological processes and possess considerable skills for developing appropriate and effective management practices. The roles of farmers and scientists in developing management practices are discussed in more detail below.

Social capital within a community may consist of bonding and bridging capital. Strong bonding social capital means strong cooperation within the community but it may be associated with suspicion of “outsiders” and/or the development of cliques and divisions in the community (Flora 2004). Bridging social capital refers to links with agencies and individuals outside the community. Strong bridging social capital can reduce the chances of a few dominant individuals controlling interactions with outsiders (Hernandez 2003). However, if bridging capital is too strong outside interests may control community activities. The most successful systems for developing management practices for plant pests and diseases for the greatest benefits to livelihoods and sustainable community development (described below) appear to be based on local conditions, capacity and ownership (natural, human and cultural capital) and have developed cooperative relationships between farmers (bonding social capital) and between farmers, scientists and local government agencies (bridging capital).

(ii) Processes and Roles

Traditional knowledge and management practices – perceptions intrinsic to human and cultural capital

> "For centuries, traditional farmers have developed diverse and locally adapted agricultural systems, managing them with ingenious practices that often result in both community food security and the conservation of agrobiodiversity. .. Traditional agrosystems and associated plant diversity are the result of a complex coevolutionary process between natural and social systems, resulting in strategies for ecosystem appropriation" (Altieri 2004).

Wellhausen (1970) estimated that 40% of agricultural land is cultivated by farmers using "traditional" techniques. Most of these farmers have failed to benefit from technological advances in farming practice because of lack of knowledge of, or access to, these technologies, resistance to adoption, or because of negative social consequences of their adoption (Trutmann *et al.* 1996). Traditional agrosystems may have advantages, including minimizing risks, providing dietary diversity and maximizing returns with low technology and limited resources (Altieri 2004). Traditional farming systems may incorporate effective preventative pest control practices within traditional mixed cropping systems, such as those of traditional Mayan farmers in Guatemala (Morales and Perfecto 2000). The biological diversity within such systems usually promotes an active population of natural enemies, potentially keeping pests and diseases to a tolerable level.

Although traditional mixed agricultural systems minimised the risks of pests and disease, there are also examples of traditional methods of manipulation of natural predator populations to promote biological control. One of the earliest examples is that of weaver ant husbandry in Vietnamese citrus orchards for protection from insect pests (Barzman *et al.* 1996).

Farmers' perceptions of plant disease generally differ markedly from those of scientists, evidence of different perspectives or cultural capital. Farmers of the central African highlands related plant diseases to environmental factors that promote the pathogen (such as rain) and management strategies are based on prevention by managing for conditions that promote plant heath rather than by treating disease symptoms (Trutman *et al.* 1996). The poor adoption of IPM by rice farmers in south Tamil Nadu, India, is partly attributable to the social values that include acceptance of crop pests and diseases as inevitable, due to fate, and resulted in lack of promotion of IPM by existing rural community institutions (Muthuraman and Mangal Sain 2002).

In summary, there may be marked differences between farmers' perceptions and scientists' perceptions that need to be recognized and accommodated in designing and implementing effective plant pest and disease management practices.

Integrated Pest Control and Integrated Pest Management

Integrated Pest Control (IPC), according to the FAO definition (FAO 1968), implies that economic thresholds are established to determine the need for control measures, and natural mortality factors are recognized and enhanced (Brader 1979). Integrated Pest Management (IPM) more accurately describes most responses to pests and diseases in an agricultural setting, as management rather than control is a more realistic aim. Control might be attempted where small incursions have been identified and targeted.

The promotion of IPM by the Indonesian government in 1986 was a major departure from the earlier approaches associated with the Green Revolution since the 1960's. IPM was a breakthrough in national policy because of its referral to natural processes (including conserving natural enemies) and because it aimed to educate and empower farmers (Winarto 1995).

Economic threshold levels (ETL), as measured by pest numbers or extent of disease infestation, can be a trigger for the use of various management practices, including the application of pesticides. Some prescriptive management systems recommend application of pesticides on predetermined dates. ETL provide a more informed basis for pesticide applications. However, interpreting thresholds within a framework of ecological processes and interactions can enable the farmer to tailor practices to maximize crop yields, while minimizing damage to natural enemies and minimizing pesticide applications.

Mangan and Mangan (1998) compared the effectiveness of two different models for pest management in rice in China. The Farmer Field School (FFS) model of training, based on Ecology-Based IPM paradigm, was more effective than another model based on an Economic Threshold IPM paradigm. The former resulted in farmers increasing their understanding of crop ecosystems whereas the latter increased farmers' knowledge of prescriptive pest and disease management practices. Rice farmers in the Philippines and Nepal (Price and Gurung 2006) had limited knowledge of crop pests, for example having difficulties in identifying the lifecycles of insects. These farmers benefited from learning more about entomology and using this knowledge to inform management decisions, rather than following prescriptive recommendations for crop pest management.

In summary, effective strategies for managing plant pests and diseases incorporate an integrated approach to ecological processes.

Roles of farmers and scientists in development and implementation of pest management practices

> "For thousands of years farmers have been the "producers" of knowledge, the primary innovators and experimenters in food-crops farming. The freedom to carry out experimentations and strategies in their world of crop farming has been the basis of their dignity and self confidence" (Winarto 2004).

In the past, there have been relatively few studies of the knowledge of crop diseases held by traditional farmers (Bentley and Thiele 1999), although more recently there is some recognition of the value of farmer-scientist collaboration. Engaging farmers as collaborators in research into farming systems is referred to as farmer participatory research (FPR). Collaboration may be sought particularly during problem definition and setting research objectives. The many benefits of this process include tailoring of practices to users' needs and location, and greater likelihood of implementation of the guidelines developed (see review in Fliert and Braun 2002). Likewise, in pest management, farmer involvement as research collaborators promotes both the development of practices that are practical and culturally appropriate and the implementation of improved practices (Nelson *et al*. 2001). Bentley (1994) claims that FPR has not been successful because it has not led to the development of new technologies or techniques. He describes the creative genius of farmers as innovators through history but outlines limitations to the process of collaborative research by farmers and scientists. It could be argued that this definition of research was too narrow and so the assessment too harsh. Successful collaborations of farmers and scientists have been noted in the bibliography assembled by Bentley and Thiele (1999). For example, Mak (2001) reports the successful introduction of a new rice variety into a Cambodian mixed agricultural system was due to experimentation by farmers using novel inputs, a collaborative process of farmers and researchers involving sequential learning and social change.

Genuine collaboration between farmers and scientists is a challenge in developed and developing countries. Bentley (1994) describes barriers to FPR, including social distance and fundamentally different styles of observation and experimenting (little shared cultural capital). The greatest success of FPR, Bentley (1994) observed, has been in setting research agendas and where researchers are dedicated to FPR in the long term. Participatory methods are routinely used by NGOs in Indonesia. There is a danger that apparently participatory methods can be used merely to validate a facilitator's agenda, giving a false impression of bottom-up processes. In such cases, participatory methods may fail to "become a tool for the identification and transformation of structural problems" (Fakih *et al*. 2003). Fakih *et al*. (2003) identified the following prerequisites for conducting participatory rural appraisal (PRA) for social transformation: embedding in deeper educational process for liberation from potentially dehumanizing forms of development, allowing marginal groups to speak about taboo subjects, exposing injustice in the system, and becoming a vehicle for social change. Potential limitations of participatory processes can be partly overcome by developing a shared cultural capital, such as can be achieved through interactive field training modeled on understanding ecological processes (*e.g*. Farmer Field Studies, see below).

Agricultural systems and the impacts of pests within those systems include complex interactions of ecological and cultural processes. An understanding of these processes and interactions is needed to successfully implement biological control and IPM. The 1989 Indonesian National Integrated Pest Management Program was a marked change from transferal of “knowledge packages” to education of rice farmers through “knowledge transmission” (Winarto 1995).

An approach called the Farmer Field School (FFS) has been successful in empowering farmers to develop biocontrol practices since the early 1980’s (Williamson 1998, Nelson *et al*. 2001). Integrated Pest management FFS, based on farmer participatory environmental education, resulted in better pest management than a “No early spray” intervention, a simple rule approach (Price 2001). The FFS approach is based on recognition of farmers as key decision makers in pest management and on the facilitation of a discovery-learning process. FFS activities are based on growing a healthy crop, making weekly observations, conserving natural enemies and, when necessary and possible, manipulating ecological processes to maximise crop yield.

FFS training has led to reductions in pesticide applications and promotion of natural enemies (*e.g*. ADB 1996). Williamson (1998) describes the case of Pakistani farmers trained in FFS later demonstrating the damaging effects of pesticides on natural enemies in a cotton crop to pesticide salesmen and neighbouring farmers. Similarly, vegetable farmers in the Philippines trained in FFS relied less on information from pesticide salesmen and more on their own experiences. The FFS approach also gives farmers the motivation and confidence to apply skills to new pests. For example, Kenyan FFS vegetable farmers used observations of pesticide effects on natural enemies to investigate an unfamiliar podboring pest in dry beans (quoted in Williamson 1998).

The process of developing the training materials for the FFS has been a participative one. For example, in Vietnam a season long training program on rice blast disease was developed based on the FAO IPM program. The field guide was developed through a series of iterations, first based on input from pathologists and extension specialists, and then translated and adapted by FFS facilitators and participating farmers. Training included field experiments testing resistance of rice varieties and the major cultivation methods affecting disease (planting density and nitrogen application), simulations modeling the spread of disease in resistant and non-resistant varieties, card games illustrating the concepts of crop resistance and disease virulence, and discussions and games to reinforce knowledge of the environmental conditions that promote disease. The FFS curriculum and the training for facilitators have been refined with input from facilitators, participating farmers and researchers (Nelson *et al.* 2001).

In the Peruvian Highlands potato is a staple crop and by 1990s about 15% of the crop was lost to late blight each year (Nelson et al 2001). A baseline survey in northern Peru in 1997 (Ortiz *et al*. 1999) 90% of farmers identified late blight as a most important problem. Although most were aware of the weather factors that promoted the disease, only 9% were aware that it is caused by a pathogen and most (88%) were not able to distinguish late blight lesions from other foliar lesions (Ortiz *et al*. 1999). At this time standard management practice for both subsistence and semi-commercial farmers was 6-7 spray applications per year, applied without protection, using dithiocarbamate-type fungicides classified by the US Environmental Protection Authority as probable human carcinogens (EPA 1999). FFS studies were established but differed from those for rice farmers in Vietnam (Nelson *et al*. 2001). Unlike the Vietnamese farmers, the Peruvian farmers had not participated in FFS before the development of the pest management FFS. The Peruvian FFS curriculum was developed through a collaboration of farmers and extension workers to include a range of farming practices especially maintenance of high seed quality. Activities covered a similar range to those of the rice FFS however modifications to the activities and learning games were altered to reflect differences in epidemiology of the two diseases: rice blast results from focal infestations and potato blast can be maintained on other hosts with widespread general infestation in the new crop (Nelson *et al*. 2001).

Following from FFS, the Community Integrated Pest Management (CIPM) Programme in Asia has the aim of "making farmers experts" and decision makers (Winarto 2004). FFS and CIPM programs have resulted in a gradual change in farming practices in several countries in Southeast Asia, with increases in farmers' technical understandings and enhancement of their creativity, dignity and self-confidence (Winarto 2004).

There are many modes of communication of the results of investigations into best practice for pest management. Scientists write formal peer-reviewed papers, extension officers may produce plain language fact sheets and other pictorial information, and farmers generally spread information by word of mouth and demonstration to neighbours. The FFS usually result in the production of a poster that summarises an "agroecosystem analysis", observations of the factors affecting the crop (Nelson *et al*. 2001). The poster is used as a tool for recording observations, communicating this information to neighbours and incorporating this information into planning processes.

Participatory experimentation can be combined with presentation of climatic conditions, disease infestation and farming practices in a Geographic Information System to understand and predict the impacts of pest management systems (Nelson *et al*. 2001). Participatory GIS (Rambaldi *et al.* 2006) encourage participation of farmers, increasing and enabling the integration of farmers', scientists' and extension officers' knowledge, and promoting the development of culturally and environmentally appropriate pest management practices.

In summary, processes which increase human capital can be effective in plant pest and disease management. For example, through Farmer Field Schools, farmers are empowered by increased knowledge and participation in effective pest and disease management.

Community processes in plant pest and disease control - components of social capital

Grootaert (1999) found evidence that local social capital, defined as household membership in local associations, makes a significant contribution to household welfare. Furthermore, long-term benefits of high social capital can be attributed largely to high heterogeneity (mix of gender, ages, ethnic background, wealth) in membership of local associations and the active participation in decision making by the members.

Ecological sound management practices are traditionally passed down the generations, in some cases by local stewards or mythical figures in the local culture (Birkes *et al* 2000). In some traditional management systems local ecological knowledge is used to interpret and respond to resource availability, in some cases encoding new management systems in the ethical and cultural beliefs (Birkes *et al*. 2000). Communities may respond to pest and disease incursions through regulatory action at a localized scale, with restrictions imposed by local authorities. In the Philippines, following the demonstration of improved management for pest control and reduced pesticide use through the FFS, the mayor of Atok town banned all advertising of chemical insecticides in his municipality (Cimatu 1997).

Winarto (1995) describes the “top-down” approaches of Indonesian government policy associated with the Green revolution, with dependence on high technology input in the form of packages of high-yielding rice varieties, fertilizers and pesticides on heavily subsidized credit. Although achieving higher yields, Indonesian farmers were anxious about infestations that were now common. In this situation rural communities had lost power to make decisions about alternative management systems or practices and the communities were dominated by external agencies, had lost much of their decision-making power and had dwindling social capital. The subsequent development of participatory programs such as FFS increased social capital by promoting confidence in community members, and cooperation within the community and between the community and external education facilitators.

Leadership and governance

> “Changes within the Indonesian government and changing relations between the government, civil society and the private sector are opening up new spaces for negotiation – and conflict” (Thorburn 2004).

In the 1960’s the Indonesian government introduced the general Education Program to boost rice production, followed in 1980’s by Supra Insus program which focused on intra- and inter-group cooperation to implement ten technical innovations (Muktasam and Chamala 2001). Consequently a range of community groups were formed to address issues such as health, poverty alleviation and women’s development. Most groups contributed little to community learning and community development because of six key factors: top-down dominance, targeting approach, misuse of incentive, absence of issues, lack of coordination, and misperception of the group roles and development program (Muktasam and Chamala 2001). Factors associated with groups that promoted sustainable rural community development included less formal action learning processes, learning from the field (bottom-up learning), and continuous community and organizational learning (Muktasam and Chamala 2001).

Political reforms in Indonesia since 1998 have increased the autonomy of local-level institutions and representative councils have been elected in all Indonesian villages so that the village head is no longer the sole authority in the community (Antlov 2003). An examination of the World Bank-supported Urban Poverty Project (Fritzen 2005) found that the more democratic procedures for selecting local leaders to manage project funds resulted in slightly lower domination by local elite, but more importantly, to greater degree of commitment to serving the poor and greater participation by the poor in the project.

Beard and Dasgupta (2006) examined participation in a poverty alleviation project in Indonesia and described two distinct forms of collective action: the first based on community cohesion, stable social relationships and adherence to social hierarchy and the second based on a shared desire for social change. Both forms were important for positive project impacts for beneficiaries but only the second had potential for social transformation.

Shiffman (2002) presented an analysis of community participation in the successful Indonesian family planning program that began in 1969. This program was initiated and promoted by the Indonesian government agency, BKKBN, and promoted through community engagement. Shiffman (2002) described many factors that contributed to the success of this program. The government's involvement (through BKKBN) was successful for many reasons. The program was operating within an authoritarian political system with the support of President Suharto and the freedom to undertake new initiatives without concern for public approval. Other factors related to engagement with various influential leadership networks, including (i) co-option of the nation's most powerful women's organisation, PKK, with active members and a leadership structure that extended from the wife of the Minister for Home Affairs to wives of village chiefs, (ii) provision of incentives for family planning groups, such as microcredit for cottage industries, (iii) numbers of family planning groups became a measure of performance in the priority area of "population" identified by the Ministry of Home Affairs, (iv) enabling of field workers to take on strategic roles as village family planning group members became self-managed, and (v) assistance with support and implementation through other Ministries and women's organisations. This state initiated program was strengthened because it was a response to community needs and was shaped by community preferences and structures. For example, delivery of contraceptives varied with province: through informal village leaders in West Java, through a member of village head's staff in Central Java and through the banjar leader in Bali (Shiffman 2002). In this way the program responded to the communities' cultural capital.

Parallels with delivery of primary health care

Crop pests and diseases and their treatment are often viewed by farmers in a similar way to human sickness and ailments, i.e. as inevitable problems for which there may be a treatment (Muthuraman and Mangal Sain 2002). There are parallels between the principles of integrated pest management and the community processes underlying human health programs. Primary health care may be viewed in a similar context to the agroecosystems context used for IPM (Peden 2000), with environmental, cultural, political and social factors influencing the development, implementation and impacts of management practices.

The importance of multi-level participation in effective community programs is illustrated in many examples from the health sphere. A successful program of primary health care has been operating in Banjarnegara Regency in central Java since the 1970s. It has combined "the resources and commitment of local government with the flexibility and innovation of the private sector into a quasi non-government organisation Yayasan Pembangunan Pengembangan Sosial Ekonomi (Suwandono 2003), and engaged the participation of some 4000 volunteers across 279 villages (Haliman and Williams 1983). Suwandono (2003) has attributed the success of this program to leadership provided by key policy makers and health managers, and a systematic process through which community groups participated in planning, implementation and budgeting of the program. Similarly, effective collaboration between the health sector, community organisations, and community members is essential to the success of programs in tuberculosis care (Maher *et al*. 1999). In these health programs, as in IPM, community engagement is essential for effective and expanding implementation of improved practices.

Roles of the general public

The general population has a range of influences on the identification of pests and diseases and the development of management systems. People traveling are potential vectors for the movement or spread of pests, diseases and weeds. Urban and rural dwellers can play a significant role in the spread of weed species and plant pests and diseases (*e.g*. Meyer and Florence 1996) and have a potential role in arresting that spread given sufficient awareness (Anderson *et al*. 2003). Communities in remote locations in northern Australia are trained to identify and report incursions to Northern Australian Quarantine Service (NAQS).

The attitudes of consumers and farmers to the potential hazards of pesticide use can create pressure to reduce pesticide use in pest management. Studies of consumers in USA have indicated a moderately high level of concern over the safety of pesticides but recognition of the necessity for some pesticide use (Dunlap and Beus 1992), and that trust in information about pesticides was a significant predictor for perceptions of safety but not acceptability (Coppin *et al*. 2002). Increasing concern amongst farmers of USA regarding safety of pesticides from 1940s to 1990s was illustrated in the changes in imagery used in chemical advertising (Kroma and Flora 2003).

International agreements/ cooperation and national and local policies and regulations

When pests and diseases cross international borders, international cooperation has taken the form of conventions followed by publication of journals (Ling 1974). Perhaps the earliest formal efforts in international cooperation were in 1881 in Europe in response to grape phylloxera introduced into France from America about 20 years earlier. A conference held in Switzerland resulted in an international agreement to impose quarantine regulations to prevent further introductions and the spread of existing infestations (Ling 1974). Various European publications were established over the next 30 years for dissemination of information relating to prevention of the spread of plant pests and diseases. Throughout history there have been many organisations, agreements and publications set to address problems of pests and diseases, particularly those that cross international boundaries (Ling 1974). Many have been reorganized and divided into groups with a regional focus; for example for locust control in Africa and the division into regional sections in 1971 of the International Organisation for Biological Control of Noxious Animals and Plants (IOBC) (Ling 1974). Ling (1974) also reviews the roles and achievements of international agencies (such as the UN's FAO, WHO and UNDP) and international research institutes (such as International Rice Research Institute, IRRI) in developing and disseminating information about the biological control of pests in crops.

The Northern Australian Quarantine Service (NAQS) has a mandate to identify incursions of pest, diseases and weeds in the coastal area of northern Australia, from Broome in the west, to Cairns in the east, including the Torres Strait (http://www.daf.gov.au/aqis/quarantine/naqs). NAQS engage with remote Indigenous communities and employ community members to monitor sections of this area. NAQS also works with Australia's nearest neighbours to map changes in pest, disease and weed infestations in Indonesia, New Guinea and neighbouring islands.

(iii) Methods for evaluating processes, and indicators of success

Many studies (some outlined below) have evaluated educational intervention programs for improved pest and disease management but few studies have assessed the community processes outside these intervention programs. Winarto (2004) used observations and in-depth interviews of participants and non-participants in an IPM program in his ethnographic field work to discover the mechanisms and processes leading to changes in knowledge and practices, to gain understanding of local meanings, and to contextualize findings.

Evaluation of educational intervention programs generally includes assessments of farmer knowledge before and after the program. Nelson *et al*. (2001) described baseline surveys of farmers from which to measure impacts on farming practices, inputs, yields, farmers' knowledge and application of their understanding of the ecological processes they observe in their fields to management decisions. Price (2001) describes a methodology for assessing farmers' entomological knowledge and changes in the knowledge base through different interventions. Price emphasizes the importance of understanding the farmers' knowledge base, which often illustrates the perspective or cultural capital of the group. Ideally, the existing knowledge base and nomenclature is understood and used to develop new participatory environmental education interventions. The scientific system can serve as a road map to describe the existing farmer knowledge base rather than to subsume it.

Evaluation has a potential role in informing adaptation throughout the course of the program. Evaluation in participatory systems is an essential part of the on-going adaptation of the FFS program (van de Fliert and Braun 2002).

Sustainability of action research or educational intervention beyond the period of formal activities is highly desirable. This sustainability may be manifested in continued implementation of new management practices, expansion of their application, or continued refinement of these practices. Potato varieties resistant to late blight had proven successful in trials in FFS in Peru. The subsequent planting of these varieties was a measure of success: the resistant varieties were planted by 35% of participating farmers as well as 10% of non-participating farmers, a flow on benefit to the wider farming community (Nelson *et al*. 2001). Feder *et al*. (2004) evaluated FFS and found that although participating farmers used less pesticide and gained some knowledge, there was no significant diffusion of knowledge to other farmers.

Training of technical personnel in pest and disease management from developing countries has been a role of UN agencies (Ling 1974). Evaluation of this type of training may be crudely measured by the later employment of those trained; for example 85% of people trained in pest control in 1960-1970 remained employed in locust control and plant protection in 1971 (FAO 1971). Evaluation of factors relating to the translation of this training into improved pest management is more complex and challenging. This evaluation could include assessment of the appropriateness (culturally, socially, environmentally) of the training materials, training methods and the personnel chosen for training, the subsequent engagement of trainers with farmers and policy makers, and the range of constraints (*e.g*. institutional, cultural) to using training to influence management practices.

Mangan and Mangan (1998) carried out a longitudinal study of the effectiveness of two models of farmer training for pest and disease management, with interviews before, immediately on completion of, and several years after the training. Effectiveness was measured in terms of the consistency and correctness of responses, completeness of responses, use of pesticides, and yields after training.

Indicators of success

Success of the processes of developing pest management systems are evident in implementation and capacity of the farmers, scientists and agencies/institutes involved, as well as efficacy of the improved practices. Indicators or measures of success can include increased farmer participation, increased crop yields and reduced inputs (especially seeds, nutrients and chemicals). Desirable increases in farmer participation include greater engagement as well as greater numbers of participating farmers. Nelson *et al*. (2001) describes increased farmer participation in FFS both through rapid increase in the number of farmer groups participating, increased geographical range of application, and through adoption by farmers of experimental methods and use of these to improve disease management strategies. Farmers were enthusiastic about having greater understanding of a plant disease which had been “dangerously mysterious”.

Empowerment of farmers as informed decision makers is a feature of the more successful processes for improved pest and disease management, such as FFS, described in this paper. Corbett and Keller (2005) evaluate a framework for analyzing empowerment. They describe an assessment of a Participatory Geographic Information System however this evaluation methods could be adapted to evaluate empowerment through IPM programmes.

Implementation of improved practices has been demonstrated to be promoted by farmer engagement. Positive farmer participation has benefits in terms of increased dignity and self esteem of farmers as well as greater ability of farmers to adapt practices to changing environmental conditions, pest populations and crop varieties. Through FFS, farmers were able to evaluate management practices using parameters such as nitrogen inputs as well as observations of crop health (Nelson *et al*. 2001).

Indicators of success of the processes of development and implementation of pest and disease management practices include effective farmer participation, increased capacity of farmers to observe and understand ecological processes, adjustment of management practices in response to changing conditions, and evidence of these indicators beyond the period of intervention programs.

Summary, conclusions and implications

Farmers were the original investigators of management systems for pests and diseases in crops. With technological developments, such as the Green Revolution, scientists and policy makers usurped that role and farmers were increasingly given prescriptions for crop management. In the past thirty years there have been greater opportunities for farmers to play an active role in the development of management practices: through Farmer Participatory Research (FPR) and Farmer Field Schools (FFS) in developing countries and Landcare in Australia.

The advantages of these participatory programs include:

- Farmer input into research design leads to development of practices that are more appropriate culturally and economically and presented in ways that are consistent with farmers' perceptions and belief systems.
- Greater ownership by farmers increases implementation
- Increased farmers understanding of ecological processes equips them, and gives them confidence, to adapt practices according to current observations including maximizing natural enemies and minimizing chemical applications.
- Farmers working with extensions and research staff can become strong advocates for improved management practices, potentially influencing other farmers, government agencies and politicians

Key elements of successful participatory programs for developing and implementing pest and disease management practices are:

- Participation and active engagement of local land and resource managers (farmers and community members) and external agencies with relevant expertise (building social capital).
- Recognition and incorporation of existing knowledge systems and perspectives (cultural capital) of communities and potential collaborators including scientists, local government officers and policy makers.
- Enhancing knowledge base of farmers, and scientists, particularly in ecological processes through observations and experimentation in the field.

- Empowerment of farmers to make management decisions on the basis of observations, ecological knowledge and assessments of costs and benefits of a range of management practices

International cooperation for controlling the spread of plant pests and diseases is established between northern Australia and the nearest neighbours. Success is dependent on sustained cooperation and goodwill.

Evaluation of success of pest and disease management practices in terms of crop yields is relatively straight forward. Elucidation and evaluation of the key processes for successful identification and management of pests and diseases are more elusive. Key processes include:

- Farmer participation in the identifying research questions, designing research and implementing and evaluating improved practices
- Increasing ecological knowledge of farmers and researchers
- Raising awareness of issues relating to pests and diseases amongst farmers, general public, policy makers

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