


## Review

# Ecological Engineering for Rice Insect Pest Management: The Need to Communicate Widely, Improve Farmers' Ecological Literacy and Policy Reforms to Sustain Adoption

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**Abstract:** Ecological engineering (EE) involves the design and management of human systems based on ecological principles to maximize ecosystem services and minimize external inputs. Pest management strategies have been developed but farmer adoption is lacking and unsustainable. EE practices need to be socially acceptable and it requires shifts in social norms of rice farmers. In many countries where pesticides are being marketed as “fast moving consumer goods” (FMCG) it is a big challenge to shift farmers' loss-averse attitudes. Reforms in pesticide marketing policies are required. An entertainment education TV series was able to reach wider audience to improve farmers' ecological literacy, shifting beliefs and practices. To sustain adoption of ecologically based practices organizational structures, incentives systems and communication strategies to support the new norms and practices are needed.

**Keywords:** ecological engineering; entertainment-education; adoption; sustainability; rice insect pest management; rice farmers; pesticide marketing; policy reform; ecosystem services

## 1. Introduction

Rice is the staple food for the largest number of people on Earth [1]. In Asia rice is grown on more than 200 million small holder farms, producing more than 600 million tons annually. Insects have long been perceived to be constraints to rice production citing annual losses of between 11 to 14% [2]. However, recent research has shown that although the rice ecosystem has abundance of insects, only a few species are of economic importance. A large proportion of the many are beneficial natural enemies. Insect control using insecticides has in fact been shown to provide little or no productivity gains for farmers [3]. Resistant varieties have been developed [4] but they were seldom adopted and farmers' heavy reliance on insecticides had continued [5]. Insecticides were introduced during the Green Revolution in the 1960s and 1970s as prophylactic applications, and farmers have continued this practice till today. Although cultural methods, numerous non-chemical methods [6] and the integration of available methods known as Integrated Pest Management (IPM) [7] have been introduced but most of these have not been adopted sustainably by farmers. Insecticide use is more convenient and farmers have continue to believe that insecticides are needed for increased yields [8]. A review [9] concluded that in tropical rice insecticides are not needed in most cases. In 2011 FAO adopted the concept that rice production under intensification requires no insecticide use. [10]. In addition there are negative externalities

such as damages to ecosystem services [11], fisheries, wildlife, fauna and flora and human health [12]. The destruction of the non-target fauna and ecosystem services by insecticides induces the development of a secondary pest, the brown plant hopper (BPH) (*Nilaparvata lugens*) [13]. Today the BPH is the dominant pest in most rice growing regions. Rice IPM programs have not succeeded in reducing farmers' insecticide use insecticide imports have continued to escalate [3].

This review will re-visit the implementation of rice IPM in the region using Indonesia as an example as IPM was extensively implemented there. The same IPM program was also implemented in Vietnam, Thailand, India, Bangladesh, Cambodia, Laos and China. The review aims to examine some of the factors that contributed to the unsustainable adoption of IPM in the region and the lessons learned. The main objective of the review is to introduce an ecologically based approach known as "Ecological engineering" to improve pest management. Since there millions of rice farmers to reach, another objective of the review is to explore the use of mass media in the form of entertainment-education TV programs to reach and educate farmers on key ecological concepts. Pesticide distribution and marketing policies are important to the sustainability of ecologically based pest management practices. The review will discuss the short comings of these policies and their implementations in the region and suggest intervention opportunities.

### 1.1. Methodology

An integrative review approach was used. The review stages together with the problems and issues identified at each stage are illustrated in Table 1.

### 1.2. Revisiting IPM in Asian Rice Production

Insecticides for rice production were introduced during the Green Revolution in the 1960s and 1970s and packaged with fertilizers as prophylactic applications. Both insecticides and fertilizers then were subsidized by governments and international Overseas Development Programs (ODA), such as the USAID. This led to misuses and research in the Philippines showed that as much as 80% of rice farmers' sprays were misuses [14]. Research of the arthropod communities in rice ecosystems [15] showed that interactions of the diversity of arthropod species could attain ecological stability in rice ecosystems. However, these arthropod communities are vulnerable to disruptions, especially by insecticide use that induces the development of secondary pests such as the brown plant hopper (BPH) [16]. Researchers focused on endlessly developing resistant varieties to this secondary pest but had not addressed the root ecological factors that cause the development of secondary pests [11]. Way and Heong [9] reviewed ecological research conducted in rice and concluded that insecticides were not needed in most cases. This principle was adopted by the FAO in 2011 stating that in rice intensification programs insecticides are not needed [10].

IPM depends not only on farmers' understanding of pest ecology, plant physiology, crop tolerance to pest attacks and naturally occurring biological control but also on their abilities to use the information with confidence to make rational decisions about insecticide use. In Asia the rice IPM training program was implemented through the United Nations Food and Agriculture Organization (FAO) the 1980s to use an intensive season long Farmer Field School (FFS) training [7]. Farmers had gained new knowledge, especially on natural enemies species but their IPM adoption has not been sustainable [17,18] in the region. In this review we will focus our discussion using the Indonesian case as an example.

In Indonesia more than 2 million rice farmers underwent the FFS training in the 1980s. Farmers underwent an intensive 16 weeks' training program and were expected not only to be empowered to make logical decisions but also to return home to educate other farmers in respective villages [7]. Immediately after the training farmers had generally reduced their insecticide use but few tried to educate others [19]. Many trained farmers after a few seasons in fact had discontinued and returned to their prophylactic spraying practices [18]. In Indonesia initially insecticide use was reduced drastically from 1986 to 1990 following a

presidential degree to remove pesticide subsidies [20]. Insecticide use gradually picked up in the 1980s even as FFS trainings were being implemented. From 2000 when the FFS training funding had stopped, insecticide imports in Indonesia escalated by more than 50 times [3]. A recent study conducted in 2019 showed that most rice farmers in Java, Indonesia were spraying their crops 7 to 10 times on average and some as many as 25 times a season. The authors had termed this as the “Pesticide Tsunami” [21].

**Table 1.** Review stages with related problems and issues identified.

Review Stages	Problems and Issues Identified
Problem identification	Research and empirical work in the past 4 decade related to rice pest management suggested that farmers’ pest control decisions and practices in Asia have remained unchanged since the Green Revolution of the 1970s and 1980s. There had been several initiatives to address this problem but they had not been sustainable. Greater understanding of the ecological, social and political dimensions and their integration is needed as a possibly effective way to more sustainable interventions. Thus the purpose of this review was to examine the factors and identify intervention options as related to improving farmers’ pest management.
Literature search	Published papers on rice pest management, ecological engineering and decision making between 1970s and 2018 had been used in the review. Wherever information is lacking the review had relied on unpublished reports and authors’ decades of experiences working on rice pest management in the region.
Data collection	The review have used data published. Newly collected research data on the effects of the TV ecological engineering series in Vietnam was presented to complement the discussion. Information gathered from the numerous focus group discussions (FGDs) authors had conducted between 1990 and 2020 in the region provided valuable qualitative data on rice farmers’ decisions.
Analyses	With regards to the why decades of implementing pest management initiatives had not been sustainable the review used a broad framework to better understanding the root causes. By incorporating concepts from communication sciences, economics, marketing and behavioral sciences issues beyond technical aspects of pest management new innovative intervention can be identified.
Syntheses	Farmers training to increase knowledge seem insufficient to sustain their practices. Further training aimed at increasing their ecological literacy would be essential to build confidence. Pesticide marketing is a major stabling block and requires authorities and new policies to address it. The example of Korea’s Environmentally Friendly Agriculture Act (EFA) 2010 was shown to have changed pest management practices and pesticide use in Korea. Communicating to the millions of farmers is a daunting and expensive and new innovative use of mass media such as using entertainment education principles has been shown to be effective in Viet Nam.

The early gains attained by the rice IPM program in Asia were unsustainable and contributing factors have been explored by various authors [3,18,19]. Among the key factors identified were farmers’ ecological illiteracy [22], lack in understanding of farmers’ decision behavior [23], unregulated pesticide marketing and the inabilities of existing organizational structures and personnel to support the new model [3]. It was assumed that improving farmers’ knowledge of the rice ecosystem components would improve their ecological understanding and the trained farmers would train others in the village [18]. However, farmers’ inadequate ecological literacy had not given them sufficient confidence to withhold spraying and instead they continued to rely on insecticides [23]. Farmers are generally averse to ambiguity or loss [24,25] and have strong tendencies to overreact to small leaf

damages caused by early season pests and seek insecticide sprays to resolve their loss aversion attitudes. Using the “driving forces, pressures, states, impacts, responses” (DPSIR) analytical framework, Spangenberg et al. [26] highlighted that the weak regulation of pesticide marketing as the root cause for the unsustainable implementation of ecologically based practices. Excessive pesticide use in Asia has been fueled not by pest pressures but by the marketing of the products as FMCGs (Fast Moving Consumer Goods) that are readily available in the numerous unauthorized village stores. In most cases the store-keepers also served as farmers’ main advisors and creditors. These conditions create pesticide market distortions and are in direct conflict with the practice of IPM. In IPM farmers should choose the right pesticides based on accurate information and apply them based on economic thresholds to obtain economic benefits. However, in an unregulated pesticide market place the industry could freely advertise and use numerous attractive trade names to sell their products, often with exaggerated or false information with appeals based on fear [3,27].

In Indonesia FAO had instituted the FFS program with BAPPENAS (Ministry of National Development Planning of Indonesia). At the end of the program, it was returned to the Ministry of Agriculture, which had not been intimately involved. There were inadequate personnel, infrastructure and incentives to continue the program [18]. Vietnam on the other hand built their FFS program within the Ministry of Agriculture and Rural Development and farmers’ IPM adoption persisted a little longer. Instead of adopting FFS training, South Korea built IPM principles into the enacted Environmental Friendly Act (EFA) 1999 [28]. A new organization well equipped with new personnel, equipment, and financing was established to implement the new environmentally friendly model. The EFA has continued to develop and is now part of the Korean sustainable agriculture program.

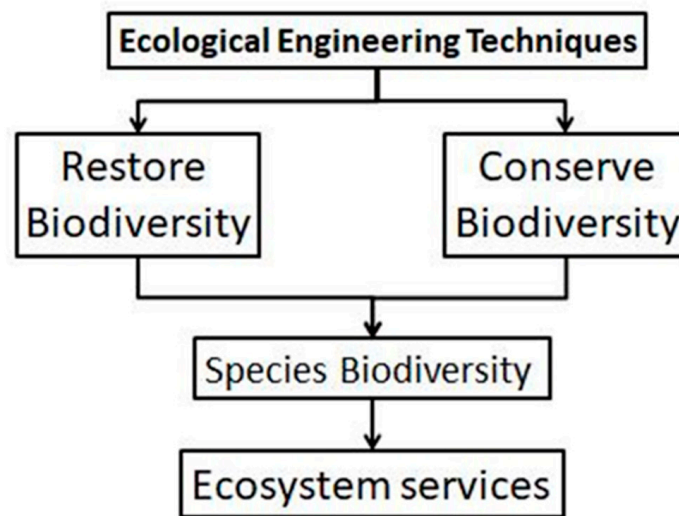
## 2. Ecological Engineering

The review aims to introduce ecological engineering (EE) as the new ecological based method for pest management. EE principles and techniques for pest management were adopted to facilitate improving ecological literacy among rice farmers. The potential for manipulating crop–pest–natural enemy interactions to improve insect pest management has been explored by entomologists [29]. Earlier these practices were known as habitat manipulations or cultural methods. The term “Ecological Engineering”, first coined by Odum [30], was viewed as environmental manipulation to manage ecosystems. Mitsch [31] defined ecological engineering as ‘the design of sustainable ecosystems that integrate human society with its natural environment for the benefits of both. Characteristics of EE include the use of quantitative approaches, ecological theory and viewing humans as a part of the process. The paradigm was extended to insect pest management by Gurr et al. [29] and was first introduced into rice production in China [32]. The EE strategy for insect pest management involves the design and management of rice production systems based on ecological principles that will maximize natural ecosystem services, such as biological control and minimize external inputs, like insecticides to conserve biological control (Figure 1).

### 2.1. Ecological Engineering Methods in Rice Production

Ecological engineering methods include habitat manipulation practices that have been developed to conserve and augment natural enemies of agricultural pests. These strategies include improving the suitability of the crop landscape through vegetation diversification to enhance biological control in the production systems. Floral diversification tends to increase natural enemy diversity and build more resilience to regulate pest population increases. The wider range of resources supporting natural enemy provided by vegetation diversification include shelters, nectar, alternative hosts and preys and pollen (abbreviated “SNAP” after the late Professor Steve Wratten) (Figure 2).





**Figure 1.** Ecological engineering techniques both restore and conserve biodiversity and ecosystem services.



**Figure 2.** Vegetation diversification to provide resources to natural enemies in Vietnam. Photo taken in 2010 by HVC.

An important component of EE implementation is the reduction of insecticide use. Most rice farmers overestimate leaf feeding insects such as the leaf folder *Cnaphalocrosis medinalis* but research has shown that negligible yield loss occurs despite high infestation rates [33]. Economic loss from early season infestations is unlikely, especially if natural enemies remain unharmed. Furthermore, research on the development of the arthropod community [16,34] and on effects of insecticide perturbations [13,35,36] showed that early season insecticide applications greatly favored the “escape” from natural biological control by secondary herbivore species. This led to the conclusion that the prevention of plant hopper pest outbreaks in rice depended on protection of the early-acting natural enemies

by avoiding insecticide spraying during the first 30–40 days after transplanting or sowing known as “no early spray” [9].

#### No Early Spray

Insecticide sprays in the early crop stages have no benefits. Instead they cause disruptions to the rice arthropod community and induce BPH development. It was necessary to persuade farmers to stop this practice and adopt “no early spray”. The avoidance of insecticides in the first 40 days was promoted through farmer experimentation [37] in several Asian countries. In the Philippines participating farmers reduced their insecticide sprays by 89% and their belief that early sprays were necessary was reduced by 90%. In Vietnam a multi-media campaign was used to encourage farmers to stop early season spraying [38]. In provinces where the campaign was implemented, farmers reduced insecticide sprays by 53% and had also changed their beliefs.

#### 2.2. Ecological Engineering Techniques Used in China's Rice Production

EE was first pioneered in China [39] in large fields using Sesame (*Sesamum indicum*) a nectar-rich [40] flowering plant grown on the bunds and field margins. Sesame and assorted flora on the bunds provided habitats to conserve the natural enemy fauna and associated biological control services [32]. Egg parasitoids of plant hoppers could live on alternative hosts in the bund habitats [41] and predators of pest eggs such as crickets, *Anaxiphe longipennis* and *Mechioche vitaticollis* could also breed in bund habitats [42]. In addition generalist predators like spiders also use such habitats for shelter and breeding. In conjunction with abstaining from using insecticide sprays in the early crop stages, biological control services could be further enhanced by the surrounding habitats. A multi-country and multi-season replicated field experiment in China, Thailand and Viet Nam showed that rice fields with flower strips as an ecological engineering practice required less insecticide applications (by 70%), had increased yields (by 5%) and profits (by 7.5%). In addition, the fields had increased biological control (by 45%), and lower pest abundances (by 30%) [43]. A recent study in China [44] using sun flowers, *Zinnia elegans*, *Abelia grandifolora* and sesame for bund vegetation had significant predator increase (+40%) in the EE fields, enhanced suppression of pests and the need for insecticides.

Another technique was to grow a trap plant like vetiver grass (*Vetiveria zizanioides*) on the rice bunds before the crop was established. The grass would attract the rice striped stem borer (*Chilo suppressalis*) females to lay eggs on the leaves of vetiver grass, but the larvae would not survive on them [45,46]. An estimated 270,000 hectares of rice in 15 provinces used vetiver as the trap plant and insecticide use for stem borer management was reduced by 30% (Figure 3).

In 2006 China introduced the Green Plant Protection policy [47] and in 2014 under China's Green Development Initiative [48] EE using the above techniques was implemented in large fields together with “no early spray”. These demonstration fields in 15 provinces covered more than a million hectares and insecticide use was reduced by more than 30%.



**Figure 3.** Vetiver planted on the bunds (left) as a traps crop for rice stem borer management in China. Photo taken in 2018 by LXZ.

### 3. Entertainment Education

Reaching the millions of rice farmers in Asia to initiate attitude changes in an economic way is a huge challenge. The review introduced the entertainment–education process of designing and implementing programs to both entertain and educate to increase audience’s knowledge, create favorable attitudes, shift norms and change behavior [49]. This communication strategy to bring about change and has been successfully used in public health programs, such as those for HIV-AIDS prevention [50], introducing oral dehydration therapy to reduce infant mortality [51] and improving maternal health [52], as well as in pest management [53].

#### 3.1. Understanding Farmer Decisions

To successfully implement EE practices on a large scale, there is a need to understand farmers’ decisions in order to help design communication strategies that can reach and motivate farmers. In a series of social psychology studies, a psychometric model was developed to assess farmers’ pest management decision-making [23,25]. In making resource management decisions, farmers are always faced with uncertainty, limited time and knowledge, and like most people they use a “satisficing” strategy or a strategy of accepting readily available options, like pesticides, rather than making decisions that would be maximizing outcomes [54]. Farmers generally use “heuristics” (or rules of thumb) under conditions of limited time, knowledge and computational capacities. However, heuristics that farmers have developed through experience, guesswork and local influencers about possible outcomes may have inherent faults and biases. Research to understand farmers’ heuristics and their reasoning can help in developing communication strategies to frame alternative heuristics that can improve their decisions. An entertainment education program on TV to communicate key ecological heuristics was evaluated in Viet Nam.

#### 3.2. The Long an TV Ecological Engineering Program Series

Conserving natural biological control is the key to managing rice pests and some of the most important natural enemies are the egg parasitoids such as *Anagrus flaveolus* and *Oligosita* spp. [41]. From field sociological research [25] rice farmers were found to be unaware of parasitoids. These are small and not easily observable and farmers did



not appreciate their roles since parasitism is not a locally known concept. Farmers, on the other hand, recognize bees as beneficial insects so parasitoids were communicated as bee relatives or “small bees” that “attack pests” and should be conserved. In the TV program we had several episodes with videos of these parasitoids laying eggs into the hopper eggs to explain parasitism. To facilitate communication we created a cluster of three heuristics—“*Flowers along bunds bring in bees and their relatives (small bees)*”; “*The bee relatives attack eggs that plant hoppers lay*”; and “*Insecticides will kill bees and their relatives*”. These heuristics together with others such as “*Flowers in rice environments attract and support bees and beneficial insects to protect rice from invading plant hoppers*”; “*Insecticide use is reduced to avoid killing bees and beneficial insects*”; “*Incomes can be increased*” were communicated through the TV episodes through professional actors.

To commemorate the 2014 International Day for Biodiversity (IDB) on May 22, the Department of Community Ecology at Helmholtz Center for Environmental Research—UFZ, Halle Germany in collaboration with Long An TV (LA34) in Vietnam launched the EE TV program series. The 52 weekly episodes were designed to educate rice farmers about biodiversity, ecosystem services and ecological engineering techniques to conserve biodiversity in rice landscapes. Each 15 min episode, broadcast twice a week, was composed of 3 parts: a short drama by local comedians, explanations and videos of ecological concepts by experts and followed by a summary. We conducted focus group discussions with farmers in the area when the TV program was on air to guide the development of the survey instrument to assess the effects of the TV series. A survey of randomly selected farmers in the province was conducted approximately 12 months after the completion of the series. In the survey, prompt cards were used for farmers to score how correct each of a series of belief statements is using a numerical scale, where 1 = “Definitely not true”, 2 = “In most cases not true”, 3 = “Maybe true”, 4 = “In most cases true” and 5 = “Always true”. The belief scores of farmers were computed into an index using the equation [55]:

$$\text{EE Belief Index} = \frac{\sum \text{belief scores} - \sum \text{minimum scores}}{\sum \text{maximum scores} - \sum \text{minimum scores}} \quad (1)$$

The index varies from zero to 1.0, where zero indicates that the farmer had beliefs antagonistic to adopting EE while 1.0 indicates that the farmer had beliefs that favored adoption.

The evaluation questionnaire was prepared in English, translated to Vietnamese and pretested. Trained local students were employed to interview a sample of 400 farmer households. The completed questionnaires were then encoded using the spreadsheet program Excel® [56], the data cleaned and uploaded into IBM SPSS version 20 [57] for analyses.

The Long An TV reached approximately 54% of the households in the province. Significantly more farmers believed statements that favor EE practices among the viewers than the non-viewers (Table 2). More viewers believed that “*Planting nectar-rich flowers on the bunds will reduce insecticide use*” (57.3% of viewers and 0.5% of non-viewers) and that “*Bees and parasitoids will help me reduce the number of insecticide sprays*” (67.5% of viewers and 0.5% of non-viewers).



**Table 2.** Key farmers' beliefs in the 2016 surveys in % of farmers who believed that the statements were "always true".

Belief Statements	Viewers	Non Viewers	X <sup>2</sup>	Sig <sup>1</sup>
Planting flowers on the bunds will reduce insecticide use.	57.3	0.5	183	**
Flowers on the bunds will attract natural enemies and help protect the rice	63.1	1.0	187	**
Planting flowers on the rice bunds can make the landscape beautiful.	68.0	3.1	179	**
Bees and parasitoids will help me reduce the number of insecticide sprays	67.5	0.5	186	**
The plants around the rice fields provide a home to natural enemies that protect rice.	66.0	2.1	174	**
All useful organisms in the rice field, bees and parasitoids must be protected by not spraying.	67.5	2.1	314	**

<sup>1</sup>, \*\* highly significant.

The Table 3 shows the comparisons of various practices of farmers who had viewed and those who had not viewed the EE TV series. Viewer farmers used less insecticide applications (about 59% less) compared with the non-viewers. In addition viewer farmers also applied their first insecticide spray significantly later and most of them at more than 40 days after sowing. There were no differences in farmers' use of nitrogen and potassium while viewer farmers used slightly more phosphorus. The EE belief index among the viewer farmers was significantly higher than the non-viewers indicating that the TV program series had modified their beliefs. The number of insecticide sprays of farmers was negatively correlated with their belief indices (Spearman rho = 0.34 \*\*  $p < 0.01$ ).

**Table 3.** Comparing farmers who had viewed the TV series and those who had not at 12 months after the completion of the TV series in Long An province.

	Viewers	Non Viewers	F	Sig <sup>1</sup>
Sample size	206	194		
Mean number insecticide sprays	1.06	2.59	228	**
Mean timing of 1st insecticide spray (days after sowing)	39.1	28.5	1799	**
Mean total N kg/ha	89.6	90.2	0.1	ns
Mean total P kg/ha	55.3	50.0	5.1	*
Mean total K kg/ha	42.2	41.6	0.7	ns
Mean EE belief index	0.7	0.4	81.9	**

<sup>1</sup>, \*\* highly significant, \* significant, ns not significant.

The Long An TV series modified farmers' beliefs and practices significantly and these results were consistent with an earlier TV series broadcast in Tien Giang province [55]. The strategic use of entertainment education approaches and mass media is relatively inexpensive. The Long TV had a total budget of approximately USD 150,000 for 2 years and was able to reach more than 240,000 farmer households in Long An province. With frequent repetitions of similar programs using the EE framework the resulting changes in farmers' beliefs and behavior could be extended. Sustaining these changes may require additional social and organizational factors, such establishing a new platform that would house mass media communication programs, include outreach programs with field demonstrations and field days.

#### 4. Policy Support Needed for Ecological Based Pest Management

In Asia pesticide subsidies were part of the Green Revolution implementations of the 1960s and 1970s. This input subsidy practice still continues in many countries. To sustain the adoption of ecologically based pest management, there is need to shift from input subsidies to subsidies that favor farmers who reduce insecticides and use ecological methods. “Payments for ecosystem services” (PES) [58] where farmers are incentivized to adopt practices that increase positive environmental externalities as public goods can be usefully employed. In 2010 Korea enacted the Environmental Friendly Agriculture Promotion Act (EFA Act) that shifted subsidies from chemical inputs to environment-friendly alternatives, such as EE, growing other crops or plants around the rice fields. The EFA also provided structural support and incentives and organized programs to motivate farmers to adopt ecological friendly practices [28]. In addition, the EFA Act tightened pesticide marketing regulations, resulting in a reduction in pesticide use in rice of greater than 50%. Policy approaches that favor the strategic use of mass media through entertainment-education programming to motivate changes in farmer attitudes towards ecological approaches can have great potentials.

Parallel policy interventions to address pesticide marketing and structural reforms in plant protection services are urgently needed. Current pesticide marketing practices in most developing countries violate the FAO-WHO International Code of Conduct on Pesticide Management [59], formally endorsed by most Member States of the United Nations and the pesticide industry. Furthermore, insecticide marketing is driven by the use of attractive product packaging, deceptive brand names and sales incentives such as free trips and gifts. Calendar-based applications promoted through insecticide marketing appeal to farmers as they require no knowledge of ecological interactions. Pesticide sales agents also enjoy handsome sales commissions and incentives such as overseas holiday trips and even sponsored trips to Mecca for the Haj. In most Asian countries, pesticide sale agents far outnumbered government officials promoting pest management alternatives. For instance, in Thailand there were about 200 government extension officers, while the pesticide industry employed more than 35,000 sales agents. Similar disproportionate differences between promoters of pesticides and ecologically based practices occur in the region. Thus governments will need to consider using mass media to have wider and faster reach. Some extension agents might also earn extra cash from chemical companies by promoting the use of their insecticides. For instance, in Viet Nam, extension staffs often earn extra money by selling inputs to farmers and thus tend to bias the information they provide to farmers [60]. Pesticide legislation and regulations have not been developed in response to the recent large increase in usage and there is urgent need for reforms [61]. Agricultural extension agents in China had been generating most of their salaries and office operating costs through pesticide sales [62]. However when the Green Protection Initiative [47] was implemented from 2006 such practices had stopped and EE became the new recommendation [48]. Extension agents’ salaries and benefits are now provided by the government and they are expected to implement government policies and programs and not sell pesticides.

#### 5. Concluding Remarks

EE practices have been shown to be ecologically and economically viable, but they need to be socially acceptable, which calls for shifts in social norms of rice farmers from the “*insecticides are necessary*” attitudes to that of “*insecticides are only as the last resort*”. It will be a big challenge to initiate and sustain such norm shifts in the region where pesticides are still marketed as FMCGs and pesticide marketing regulations are weak. Pesticides are poisons to humans and the environment and should be classified under the Poisons Act. Reforms in pesticide marketing regulations are urgently needed. One suggested reform is to classify all pesticides as poisons and thus placing them under the Poisons control. Pest management research often focuses on developing new tools such as resistant varieties, IPM methods and ecologically based methods. However, there is limited research that addresses the

issues surrounding pest management such as farmer decision-making, implementation needs and constraints, and organizational and policy needs to sustain ecologically based practices. The development of innovations in pest management organizational structures, incentives systems, communication strategies and reforms in pesticide marketing policies is now necessary. Besides revising and enforcing pesticide marketing regulations, there is need to work towards the enactment of environmentally-friendly laws, like the Korea's EFA Act 1998 [59] to create a new sustainable platform for ecological methods. Initially governments may need to implement PES schemes where farm subsidies are shifted from input subsidies to environmentally friendly practices. Direct subsidies to cover income differences between conventional and ecologically based practices may also be considered. Governments may also need to begin setting policy objectives in 5-year plans with pesticide and fertilizer reduction targets that are reviewed and adjusted periodically.

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