Analysis of Lock-in Mechanisms: A Case Study on Rice Integrated Pest Management (IPM) in Cambodia

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Abstract: Integrated Pest Management (IPM), a suite of pest management technologies, has been promoted in Cambodia, but with limited adoption in farming communities. Using theoretical concepts of innovation system and lock-in mechanism, we examined what constrained the spread of IPM in Cambodia through analysis of policies and programs as well as data from a survey of farmers (N=400) across five provinces in Cambodia. Inherent in the practices of varied stakeholders at different levels are mechanisms that lock-in a pesticide regime and lock-out alternative integrated pest management practices in in the country. Targets at the policy level, the institutional structure for extension, and the technological choices of farmers in managing their rice crop all contribute to ensuring it is easy for farmers and other intermediaries to rely on pesticides rather than innovate on alternative technologies.

Key words: Integrated pest management, lock-in, technological trajectory, Cambodia

Introduction

For two decades, national programs in Cambodia have promoted Integrated Pest Management (IPM), an approach to develop alternative forms of crop protection to reduce pesticide use drastically (Ngin 2002). These programmes have involved public, private, and civil sectors. Today, many sectors in agriculture use and promote a concept of 'IPM', but transition towards widespread implementation by farmers of an integrated pest management is constrained; pesticide use remains the predominant technology (Khun and Ngin 2014). In the last decade, pesticides imported into Cambodia increased by 285 times, implying a significant increase in pesticide use (CEDAC 2010, FAO 2012, Khun and Ngin 2014). This trend is continuing, in fact Cambodia formally imported 13,800 tons more pesticides in 2016 compared with 2015 (MAFF 2015, 2016).

Since 1993, nationwide IPM programs introduced the approach through Training of Trainers (TOT), Farmer Trainer Orientations (FTOC) and Farmer Field Schools (FFS) (Ngin 2002). The focus was on farmers to manage pests considering varied ecological conditions. Moreover, an IPM network was established, composed of government and civil society groups including provincial-based government trainers and farmer-trainers. This network supports the dissemination of IPM practice in the country.

In many countries, there is recognition of the entrenched control by the pesticide industry for most of the knowledge and technologies made available for pest management. Cambodia faces a similar situation. This process, for a pest management technology is termed technological trajectory, and specifically technological lock-in (Joly and Lemarie 2002, Perkins 2003, Thorburn 2014). It is important to understand this trajectory, to better support innovations that compete with the predominant technology. Such examination of the technological trajectory of IPM provides insight on institutional frameworks governing innovation processes around pest management. Few studies, however, look into the dynamics of how this process plays out at the level of farming communities (notable examples are Barazza et al. 2011, Rios-Gonzalez et al. 2013).

This paper is a preliminary assessment of the lock-in effect of pesticides in Cambodia. Such lock-in effect is produced by institutional characteristics such as in policies and programs for crop production and pest management at broader levels, as well as practices and other conditions at community level. A better understanding of how pesticide use is entrenched in farming practices, socially and technically, helps to clarify and potentially remove constraints and barriers for a transition towards widespread use of IPM in Cambodia.

Conceptual framework and methodology

Technological change is bound to institutional characteristics that result in a particular view of what innovation is necessary and feasible. From experiences with technologies that have spread successfully, companies or organisations typically repeat the tried and trusted ('normal') pattern of innovation, resulting in a technological trajectory (Dosi 1982, Van Loqueren and Baret 2009). The concept provides a powerful explanation of the functioning of the pesticide industry, and why IPM as an alternative trajectory is beyond the scope of the industry (Joly and Lemarie 2002). A related concept, focusing more on the user side, is technological lock-in. The notion emphasizes the network externalities of a technology, i.e. "external benefits conferred on users of a technology by another's use of the same technology" (Perkins 2003:2). Technologies are thus part of broader networks consisting of multiple, interdependent technologies and supporting technical, social and economic infrastructures.

The notion is relevant for understanding pest management practices of farmers. Farming practices are more generally perceived as socio-technical configurations aimed at growing particular crops (or livestock products). A transformed technical practice in farming is mutually constituted by transformations in the social aspect such as in labour arrangements, price incentives, or other mechanisms whereby people access specific tools (Glover et al. 2017). These insights move away from a common understanding of technology use as a decision (by the farmer) to adopt a particular technology after sufficient information and training is provided (Sumberg et al. 2016). Where a single farmer may decide to engage with a particular technology, such as IPM, implementation requires adjustment of not only existing pest management activities but also other farm operations. The notion of technological lock-in conceptualises the interdependencies of different farm operations at the level of a single farm as well as between farms and the wider technical, social and economic infrastructures. Because network linkages and interdependencies are subject to fluctuation and change, the notion of technological lock-in does not suggest a fixed state but rather directs the analytical focus to those connections and interdependencies that slow down or counteract the desired change.

The notion of technological lock-in complements well with the innovation systems approach. Innovations systems likewise perceive innovation as a dynamic socio-technical and multi-level process in which particular higher system actors enable or constrain innovations at lower levels (Schut et al. 2014). The transition process towards having new techniques and tools used widely by many farmers is considered to start from small, seemingly unimportant changes that affect structural configurations, which further influences the direction of related changes (Voß and Kemp 2006, Klitkou et al. 2015). The case of IPM in Cambodia can thus be tackled by adapting theoretical concepts of lock-in mechanisms. These may be related to learning effects, economies of scale, and institutions that affect a pesticide-based regime and IPM (Rip and Kemp 1998, Sanden and Hillman 2011, Klitkou et al. 2015). The networks and organizational aspect is also important; looking not only at the different actors involved but also into collective action or the reproduction of norms and behavioural patterns especially among extension agents, service providers and farmers. Lastly, on the aspect of material technology, technological interrelatedness as well as emerging niche markets affect IPM implementation. This is because rice is a complex crop and pest management technologies have to be interrelated with other technologies such as those for fertilizers, crop establishment and irrigation. More techniques and coordination are required for IPM compared with individual-based pesticide application. Some social norms and arrangements supportive of IPM practices are needed.

The conceptual framework guides investigation towards connections and interdependencies across multiple levels and among various stakeholders, as well as the influences of institutional frameworks governing their interactions. It also guides investigation on the broader rice farming practices affecting IPM. It thus entails methods to examine at broader levels as well as at the level closer to farming practices. First, a review of policy documents and other secondary materials such as project reports and case studies on pest management and IPM in the country will give insights on the landscape and institutional conditions affecting IPM. Since the 1990s, various initiatives have resulted in thousands of trained extension intermediaries and farmers (MAFF 2012). What is the IPM narrative that these initiatives have furthered? Is IPM about the various principles as stated in the recommendations, or is IPM introduced as pesticide reduction or replacement of new or better pesticides? What is the orientation of the learning that is promoted in these initiatives (e.g. is there a stronger orientation towards having a tool such as pesticide or traps etc, rather than towards techniques such as observing pests, community action, synchrony of cropping etc.)?

To cover another important dimension of technological lock-in, we also examine pest management conditions at the community level through the practices and sources of information of farmers. This is done through analysis of survey data of Cambodian farmers from five provinces (N=400). The survey captures pest management practices, including agricultural input use, of randomly selected farmers from provinces representing varied agro-ecological conditions (Battambang, Kampong Thom, Prey Veng, Takeo and Pursat). Looking at social and ecological conditions (e.g. irrigation sources, labour availability) that farmers face, how do these varied conditions affect IPM practice? How do these affect synchrony of cropping, better levelling or other pest management practices in their farms? How do their identified sources of information affect decisions made for pest management?

In looking at the institutional conditions at these different levels, we aim to tease out the mechanisms that lock-in a pesticide regime, and lock-out other technological options.

Results

Programs, policies, and the way IPM has been communicated

Over the years, various programs introduced and supported IPM in Cambodia, but these programs were implemented through the coordination of the national IPM program of the government. The programs had specific goals, but over all, the national IPM program aligned these with the national goal for increased crop production, food security and safety (Table 1).

In the early years of IPM introduction, there is consensus in the literature that pesticide reliance in Cambodia was not the norm in farming communities (Jahn et al. 1997, Winarto 2004, Khun and Ngin 2014). Pesticides were applied mostly in the dry season, but not in the wet season where farmers use traditional varieties; pesticides such as fungicides were not used at all (Jahn et al. 1997, Heong and Escalada 1997, Winarto 2004). The trend in pesticide availability confirms this, in that the number of available pesticides in country was much lower: only 30 pesticides were available in 1994 (CEDAC 2000). Pests and diseases were considered less significant concerns in Cambodia compared with neigboring Asian countries (Lando and Mak 1994, Winarto 2005). Thus, compared with other countries, the practices in Cambodia at national level during that time was considered ‘sustainable’.

Table 1. Approach, motivation and outcomes from key programs on IPM and the national IPM program in Cambodia

Program	Years	Approach	Main goals	Documented outcome	Sources
National IPM Program	1993-2002; expanded NIPMP: 2002-present	Coordinates the IPM programs in country; Weekly FFS training, experimental trials by farmers; creation of self sustaining networks	Food security and safety; increase rice production in an environmentally sound and sustainable manner	Increased knowledge on ecosystem and control of pests, social benefits (farmer-to-farmer exchange), rice IPM farmers obtain 24% higher yields and 54% higher incomes (446,900 Riels/ha in dry season and 988,000 Riels/ha in wet season), yard long bean and tomato farmers claim 15% higher yields and 38-45% higher incomes, 48% reduction in spray events of pesticides, 51% reduction in the dose of pesticides and 59% reduction in use of WHO Class 1 pesticides (farmers save 143,00 riels/ha per season from reduction in pesticide use)	Ngin, 2002; Winarto, 2004; http://www.vegetableipmasia.org/pages/5-cambodia-national-ipm-programme; Taylor 2014
IDRC-IRRI-FAO IPM Program	1993-1995	Pilot IPM activities; farming systems approach	Increased production using environment-friendly practices;	Increased awareness of pesticide risks, adoption of alternative pest control techniques (more in Battambang than Prey Veng); reduced use of highly toxic products (although poisoning symptoms still reported), policy reform, majority of the interviewed IPM farmers (Kampong Spue in 2000) found the IPM training was beneficial.	IRRN 18:2 (1993)
FAO Inter-country Program, Srer Khmer Organization	1993-1997; support to national IPM program 2007-2012	Assist the national IPM program for training capacity; community-based farmer IPM activities; established local foundation to sustain IPM activities; policy reform	Sustainable intensification; Developing a structure to sustain IPM in country		Ngin 2002; Morales Abubakar et al. 2013
Cambodia-IRRI-Australia (CIAP) IPM Program	1989-1999	Pilot IPM activities; farming systems approach; FFS	Develop crop protection strategies using environment-sound IPM practices; Capacity development	Developed strategies for IPM; Research infrastructure; survey to understand Cambodian rice-farming households	IRRI, 1999
World Education-IPM in Schools Project	1996-2002	Field schools for rice and vegetables targeting students, teachers and out of school youth at primary and secondary level	Integrating agriculture in national curriculum		Ngin, 202
DANIDA IPM Project	2000-2005; established ATSA 2007-present	TOT, FFS, training of farmer trainers, community IPM activities, refresher courses and other new courses for district and fanner trainers, national and provincial workshops, seasonal planning and evaluation meetings, study tours to neighboring countries, farmer congress, impact assessment study, farmer congress	Consolidate the IPM farmer training processes in 7 provinces (Banteay Mean Chey, Otdor Mean Chey, Kampong Thorn, Kampong Chhnang, Svay Rieng and Prey Veng)		Ngin, 2002; Winarto 2005; http://www.atsacambodia.org/

IPM/APIP Subcomponent	2000-2005	TOT, FFS, training of farmer trainers, community IPM activities, refresher courses and other new courses for district and fanner trainers, national and provincial workshops, seasonal planning and evaluation meetings, study tours to neighboring countries, farmer congress, impact assessment study, farmer congress	Consolidate the IPM farmer training processes in 7 provinces (Kandal, Takeo, Kampot, Kampong Speu, Kampong Cham, Pursat and Siem Reap)		Ngin, 2002

Winarto (2005) described this difference as relating to having less intensive rice production – where use of high yielding varieties and chemical inputs (termed Green Revolution type of production) were not widespread in Cambodia. The narrative for IPM in the programs during the early years of IPM introduction, thus focused on pest monitoring as well as research on pest identification, quantification of damage, and testing of alternative pest management techniques (e.g. Jahn et al. 1997). Programs emphasized that IPM was not a packaged technology but a process to help farmers make decisions based on ecological knowledge (FAO 1996).

A preliminary examination of the available extension materials from the programs in early 1990s show a focus on training to coordinate the farmer field schools, and agroecology assessments. These are approaches that support the learning process, communication of key messages and pest monitoring rather than specific recommendations about alternative techniques to manage the pests (e.g. Ngin 2002). A common message is about building the knowledge of farmers on various components of the ecosystem, understanding root causes of pest problems, and simple experiments to evaluate new ideas and techniques (e.g. Heong and Escalada 1997, Ngin 2002). The national programs also promoted these key messages: healthy crop and environment, use inputs based on ecosystem analysis, encourage biological control mechanisms, and pesticide application only as a last resort.

In the late 1990s several changes in the Cambodian context are considered to contribute to the change in pest management in the country. One is recognition of increase in rice production and the subsequent push to further this increase. 'Over the decade to 1997, rice production increased rapidly by over 4.4 percent per annum to reach 3.4 million tonnes...These increases were achieved despite erratic rainfall, shortage of labour and capital, and the war-ravaged institutions and physical infrastructure' (FAO 1999). Another reason is the opening of the country towards pesticide importation (Tickner 1996, Winarto 2005, Taylor 2014). Faced with need to expand markets, selling of pesticides was starting to become the means for generating more profit (Loring 1995 in Taylor 2014). Still another is the experience with pest outbreaks following weather disturbances in 1997-1998 (Fontaine 1998), after which, pest outbreaks became part of the rationale for IPM in Cambodia (e.g. RGC 2010, Khun and Ngin 2014).

In response to these contextual trends, the government used the IPM programme as a promising means to increase productivity while also improving farmers' agroecological knowledge and skills (Ngin 2002, Winarto 2005). In 1998, the Royal Government of Cambodia (RGC) officially declared Integrated Crop and Pest Management Programme (the national IPM program) as the national crop production strategy. The government recognized the risk of shifting towards high-input intensive production, and pesticide abuses, but its policy was clear to target specific percentage of increase production. Over the years, the national IPM program with various international partners and NGOs continued to promote IPM (Table 1). The approaches are still the same, focusing on field schools, training of trainors, and agro-ecosystem analysis. Although there is a limitation of available materials with clear recommendations for IPM techniques, one observable change in the narrative on extension materials is the emphasis on reduction of pesticide use. Among the new techniques for example were: improved seedbed, reduced number of seedlings per hill, reduced chemical and increased organic fertilizer, judicious use of pesticides, and incorporation of straw (Winarto 2005).

Meanwhile, pesticide importation and use dramatically rose in the early 2000s. Cambodia was seen as ‘a dumping ground for unwanted and dangerous pesticides’ (EJF 2002, Khun and Ngin 2014). Although the country does not produce any chemical pesticides, imports were rising (Lorn 2005). Over the years, furthering the IPM programs through policy support is one strategy to stop the rise in pesticide use. This narrative is however countered by a widely held assumption about the relationship between pesticides and boosting yields (Taylor 2014). Moroever, porous borders facilitate the trade for pesticides between countries that have varied laws concerning these materials (Lorn 2005). Although the Cambodian government has implemented some bans on harmful pesticides, those may not be banned in neighboring countries and can continue to be sold in Cambodian local markets. In fact, these gets sold as cheaper brands which make them more appealing to low-income farmers (Taylor 2014). In 2002-2003, the government issued the detailed guidelines requiring registration of pesticides distributed and sold in country. This is also related to labeling and ensuring farmers are able to read and understand the package instructions, as well as to the certification of pesticide sellers. In 2005 however, imports remained uncontrolled and most of the labels of pesticides are not in the national language (Lorn 2005).

Training, extension, and the influence of the private sector

Since the 1990s, initiatives coordinated by the national IPM program have resulted in 160,000 farmers trained, involving a mechanism of 2530 farmers-trainers, and 673 district staff trainers from the agricultural department (MAFF 2012). While this may seem substantial, of 400 farmers surveyed in 2016, only 13% reported to have been trained on IPM.

Winarto (2005) notes that the national IPM program differentiated itself from the national policy in that the national policy is considered ‘top-down’ and geared towards increasing production, whereas the IPM program promoted learning-by-doing for farmers and making decisions that address their own needs. This is rhetoric because the structure in which national IPM program is implemented lent itself to a ‘top-down’ approach for technology transfer, rather than furthering a ‘bottom-up’ learning process for farmers. The national program provides the structure for IPM extension through its network. As described by Ngin (2002), from the national level, the IPM extension activities are supervised through the national coordination office. Then at the provinces they collaborate with the Provincial Department of Agriculture, Forestry and Fisheries (PDAFF). At this level, a provincial IPM Coordinator manages and leads the activities. Finally, at district and commune levels district trainers and farmer trainers implement the IPM activities, and work together with farmers.

The flexible nature of IPM as a techology, also allowed for it to be defined in specific ways by the extensionists. In the literature on IPM, the programs emphasized management of different pests including insects, weeds, diseases, and rats. This does not clearly come through in the implementation however, as many of the local extension activities emphasized insect pest management, as well as pesticide reduction. Although an ‘integrated’ pest management was aspired for, the implementation becomes largely focused on insect and disease management, or simply reducing pesticide use (Lorn 2005).

Meanwhile, the private sector has been vigorously promoting pesticides. There is a broad network of producers, dealers, retailers and private-funded extension disseminating not only the products but also knowledge about using pesticides (Dinham 2010). Local retailers have relationships with farmers on providing information about pests and pesticides, as well as on credit for inputs. Much of these pesticide products marketed to farmers have remained labelled in foreign languages that are incomprehensible to farmers (FAO 2013). Thus farmers over the years, have increased their dependence on the retailers who have access to knowledge about pesticide products through their network with companies, extension staff and dealers. Of the farmers surveyed (N=400), 90% included the advice of pesticide retailers as basis for their decision on pest management. Of these farmers 60% source their pesticides from these local retailers. Lastly, the reference of pesticide as 'medicine' (in local terms, *thna saam leab satvalait*), construe it as less risky and necessary. This has been pointed out to support pesticide use by farmers (e.g. Winarto 2004, Taylor 2013).

There are also extension projects that partner with various government agencies to specifically target the private companies to help disseminate pest management knowledge to farmers through the retailer networks. One example is a project that has produced the rice pest and disease diagnostic tool (RaPiD) (CAVAC 2014). The tool is developed specifically for pesticide and fertilizer markets, so that these will be taken up by companies and provided to their retailers. These retailers will use RaPiD to assess pest problems brought to them by farmers and to give appropriate pesticide recommendations. The app ensures the recommendations are of reliable brands of pesticides, to prevent farmers from getting fake ones. Retailers can then sell these pesticides.

Farm-level practices

There has been much documentation on pesticide imports, and anecdotal evidence of the rise in pesticide use by farmers. From a survey in five provices, we find this is indeed the case (Table 2) compared with those documented in literature (e.g. Heong and Escalada 1997:229). This pesticide reliance is furthermore evident in the way very few farmers (3%) mentioned they implemented other practices for pest management. Farmers often applied a mix of pesticides in one application, in the idea of obtaining a more effective concoction.

Several crop management practices are entwined with this pesticide practice. The first relates to establishment method and choice of varieties. Most of the farmers, due to lack of labor or water scarcity prefer to establish their rice crops using broadcast direct seeding (Table 3). This is the case for both wet and dry seasons. Farmers then have an average seed rate of 215kg/ha (range of 157-259) across the different provinces. This practice does not allow for easier weeding, but farmers prefer high seed rates as insurance because they think snails and other pests will still eat the seedlings. Furthermore, among the top preferred varieties for dry season are IR504, Sen Kra Ob and OM 4900. In the wet season, especially for Battambang and Kampong Thom, traditional aromatic varieties such as Phka Romdoul or Phka Malis were preferred. These are not pest resistant varieties.

Table 2. Mean pesticide applications for each type of pesticide (S.E. mean), including minimum and maximum applications, per province and for all respondents (N=400); Dry season 2016.

Province	**Herbicide** *min,max*	**Insecticide** *min,max*	**Fungicide** *min,max*	**Molluscicide** *min,max*	**Rodenticide*** *min,max*
Battambang	3 (0.2)	2 (0.3)	2 (0.3)		2 (0.1)
	1,9	*1,11*	*1,4*		*1,3*
Kampong Thom	2 (0.1)	2 (0.2)	1 (0.2)		2 (0.4)
	1,4	*1,5*	*1,2*		*1,12*
Prey Veng	2 (0.1)	4 (0.4)	2 (0.7)	1 (0.1)	1 (0.20
	1,6	*1,15*	*1,16*	*1,2*	*1,3*
Pursat	2 (0.1)	2 (0.3)	1 (0.2)		1 (0.2)
	1,6	*1,5*	*1,2*		*1,2*
Takeo	2 (0.2)	3 (0.3)	2 (0.5)	1 (0)	2 (0.3)
	1,7	*1,7*	*1,3*	*1,1*	*1,3*
All provinces	2 (0.1)	3 (0.2)	2 (0.3)	1 (0.1)	2 (0.2)
	1,9	*1,15*	*1,16*	*1,2*	*1,12*
% Farmers who applied	**70**	**48**	**13**	**7**	**20**

*Some farmers noted they applied more times than they reported but could not recall how many

Table 3. Percentage of farmers and their crop establishment method for wet and dry season.

Province	Wet season		Dry season	
	Transplanted	Direct seeded	Transplanted	Direct seeded
Battambang	0	100	0	100
Kampong Thom	29	71	2	98
Takeo	14	86	1	99
Prey Veng	4	96	0	100
Pursat	18	82	0	100
Total	13	87	1	99

Many of the farmers also said they do not synchronize the start of their cropping season with other farmers because ‘their conditions are different’. This is brought about by diverse sources of irrigation. In all but one of the villages surveyed, farmers have 2-3 sources of irrigation per village. This means there is no coordinated control that could enforce synchrony in the cropping season, such as in gravity irrigation systems where water scheduling enforces a common start for farmers in an area. Only 4% of the farmers surveyed said they followed activities or rituals that signal the start of the season. The majority do not follow this if not for concerns of ensuring that harvesting is coordinated for better access to combine harvesters.

Furthermore, the most common fertilizer used by 67% of farmers surveyed is Urea (46-0-0). They use an average of 179 kg/ha of Urea per season. Few farmers (7%) use DAP (18-46-0) at 87 kg/ha in addition to Urea. Fewer still (4%) add Ammonium phosphate (16-20-0) at 89 kg/ha.

Some 10% of farmers also use manure with mean application of 4 tons per ha, although these are limited to areas where farmers also have livestock. If we take only Urea application into account (not the added N from other chemical and organic fertilizers), most farmers use at least 82 kg N per ha.

These practices, alongside conditions around labor, sources of information and inputs, the way irrigation is managed support the way farmers look to pesticides for most of their pest management needs. These are discussed further in the next section.

Discussion and Conclusion

To attribute the constraint on adoption of IPM in Cambodia to the so-called lack of education and skills of farmers (e.g. Taylor 2014) is too simplistic. Using the concept of innovation systems and lock-in mechanisms, we examined policy and contextual events that contributed to the spread and subsequent dominance of pesticide as pest management technology. We also examined the dynamics in extension systems as well as farming communities that support the lock-in of pesticides as the dominant pest management technology in Cambodia.

The narratives on IPM at policy level has been changing over time which affected the way IPM messages were communicated, and which technologies were supported. In the early years, there were not many pest problems, so the clear message was just building agro-ecological knowledge, with limited or no emphasis on recommended ‘alternative’ tools or techniques. This focus of the IPM narrative in Cambodia has shifted however, in the face of changing context in national crop production targets and influx of pesticides. Many of the programs emphasized risk from pesticides and need for pesticide reduction. Although varied IPM programs had specific thrusts, the national IPM program coordinates all of those and aligns those with the national policy, especially on increased production. In this context, although the risks from pesticides were recognized, there is an underlying sense that pesticides are needed to maintain production. Since the different projects, implemented by international and civil sector stakeholders were mediated by the national IPM program, their IPM messages were couched in the national policy towards production and intensification concerns. Thus, the idea of ‘limiting’ pesticide use, ensuring that farmers have the right pesticide, focusing on pesticides safety supersedes the idea of ‘pesticides as the last resort’. Furthermore, the national IPM program works with and accepts these competing narratives. Hence, what then trickles to the extension system as recommendations are quite different from the IPM recommendations from the programs (e.g. the FAO, and JICA IPM kits used in Cambodia). In this context, the dominant logic of innovation around pest management is not supportive of experimentation on alternative pest management techniques and tools; instead, it favors the technological trajectory of pesticides (Joly and Lemarie 2002).

Furthermore the linkages with the private sector, which is already an established network of importers, distributors and retailers that effectively get products to the farmers, is not about influencing alternative IPM products. Many of the documented linkages were on regulation, which is recognizably limited. There are also projects that support the private sector to provide more effective pesticide recommendations. In comparison, although extension materials mention IPM products, not all of these options are supported to become readily available in local retail stores.

As an effect of these policy and extension linkage trends, there is no clear recommendation that supports the spread of IPM concepts as well as varied IPM techniques. IPM remains simply 'pesticide reduction'; but if pests are observed, no alternative methods are clearly promoted or supported. There is recognition of the adverse effects but current practices ensure that pesticides remain key in the suite of options. Aside from these influences on the innovation context for IPM, the approach taken for IPM in Cambodia is on paper 'bottom-up' encouraging discovery learning for farmers and extension staff. The existing extension structure however that is supposed to implement this is more likely to coordinate a 'top-down' flow of knowledge. It is only in the recent years that more NGOs have been involved to promote IPM.

It is not only the institutional and broader context but also the practices in farming communities that is locking-in pesticide as the dominant technology. Limited coordination for community-wide implementation of pest management activities, or at least for synchronous cropping, have implications for rodent as well as insect pest management. High seed rate and crop establishment through broadcasting also entail that farmers have limitations in hand weeding or use of mechanical weeders. High nitrogen use has been proven to affect pest and diseases, and the N per ha commonly applied is higher than the 20kg/ton of produce recommendation (IRRI, Knowledge Bank). These technological paradigms for the different pest management activities, similar to what Perkins (2003) described are all related to the ease in which farmers could make decision to use pesticides as opposed to other management techniques.

Thus, the mechanisms that lock-in a pesticide regime in Cambodia, and lock-out alternative integrated pest management practices are inherent in the practices of varied stakeholders at different levels. It is in the policy environment as well as in the day-to-day practices of farming. To change the current situation and promote an innovation environment that is supportive of integrated pest management, addressing at different levels is necessary. At the policy context, there is a need to balance the narrative of IPM as merely reducing pesticide use, or replacing with another more effective product. The institutional mechanisms that support IPM need to be strengthened and perhaps emphasized on the sustainability aspect rather than as part of intensification. There are other players such as NGOs that could help to balance the top-down extension infrastructure in place. Furthermore, it can help to strengthen institutions that enable coordination for pest management at community level such as irrigation groups. Through this, information on not only pesticides but also good agronomic practices can be learned and shared. Lastly, broadening the involvement of the private sector, especially retailers, should not be limited to enhancing their knowledge on pesticides, but expanding portfolio and product base to include IPM technologies.

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