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Pesticide use in Vietnamese vegetable production: a 10-year study

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Vietnam has had varying success over the past decade with its pesticides policy. Some of the most toxic pesticides have been banned from the market. But while many countries have successfully decreased agricultural pesticide use per hectare, this has not (yet) happened in Vietnam. Due to insufficient pesticide management capacity of the Vietnamese government, pesticide types and quantities registered and distributed on the market have substantially increased in Vietnam over the last 10 years. A 10-year monitoring programme at farm level showed that pesticide use follows the increasing pesticide availability on the market, and many toxic and illegal pesticides are still being used. In an agricultural country dominated by millions of small-scale farmers and with limited state capacity for control at farm level, reduction of the use of the most toxic pesticides can best be achieved by more effective pesticide market control through stricter and more effective state regulations and implementation, aimed at eliminating illegal, low quality and counterfeit pesticides from the market. But even then, better state and private extension services, and greater state capacity for control and enforcement remain essential in enabling farmers to make better decisions about pesticide use.

Keywords: pesticides; regulation; uses; vegetables; Red River Delta

1. Introduction

Pesticides were first imported and used in Vietnamese agriculture in the late 1950s, when they were promoted by the centralized government for use in the collectivized production that dominated agricultural policies and practices between 1959 and the early 1980s (Xuan, 1995). By the mid-1980s, Vietnam started to reorient its economy and agriculture towards a market-based system, which allowed private entrepreneurs to participate in the import, formulation, distribution and use of pesticides for the agricultural sector. Pesticide use increased from just 100 tons a year in the 1950s (Anh, 2002) to 35,000 tons in 2002 and to about 105,000 tons in 2012 (ILS, 2013). The total costs of pesticide imports rose to US$744 million in 2012. The sudden increase in pesticide imports in 2008 was associated with the rice brown planthopper bloom occurring between 2005 and 2007 (Hoang et al., 2011; Vietnam Academy of Agricultural Sciences, 2007). However, the planthopper bloom was much less severe in 2008, which resulted in large imported pesticide stocks remaining in the following years. Hence, pesticide imports dropped in the two following years, that is, 2009 and 2010. The overall trend over the recent decades has been one of increased pesticide imports into Vietnam, and between 2005 and 2012 the average growth rate of pesticide imports was 18.8%/year in terms of value and 10.6%/year in terms of quantity[1] (see Figure 1).

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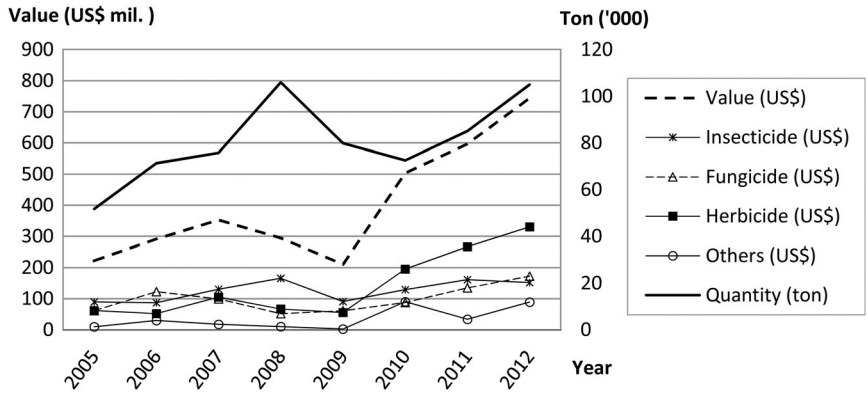

Figure 1. Vietnam's pesticide imports from 2005 to 2012 (in million US$ and million kg). Source: ILS (2013).

Increasing reliance on pesticides has resulted in high costs for Vietnam, with expenditure for imported pesticides roughly equalling its revenues from vegetable and fruit exports, that is, US$829 million in 2012 (Tan, 2013). In addition, there have been indirect costs: social and environmental costs related to pesticide use, loss of export opportunities due to high pesticide residues on products, and an unstable agricultural productivity associated with a polluted agro-ecosystem.

Over the past two decades, many developed nations have adopted strategies to cut down pesticide use and to promote a greening of agricultural production, to protect the environment and consumer health. Examples are the US 'Big Green' (Zilberman, Schmitz, Casterline, Lichtenberg, & Siebert, 1991) organic farming promotion campaign, and decreased pesticide use in countries such as Sweden, Norway, Denmark, and the Netherlands in the 1990s (Edland, 1997; Pettersson, 1997; Pimentel, 1997 cited in Wilson & Tisdell, 2001). In an effort to further reduce pesticide use, the EU issued Directive 91/414/EEC in 2010, aiming at the withdrawal of over 60% of pesticide active ingredients (AIs) from the European market. Tightened Maximum Residue Limits legislation and new Sustainable Use of Pesticides and Water Framework Directives will further limit the use of the remaining pesticides in EU countries (Birch, Begg, & Squire, 2011).

Many developing countries have also striven to reduce the reliance of their agricultural production on toxic pesticides. For instance, Nicaragua and Indonesia tried to do so in the 1980s (Matteson, 2000; Thrupp, 1988; cited in McCann, 2005) and China – the largest consumer of pesticides – more recently set a target of 20% reduction of pesticide use by 2016 (CRI, 2011). However, many developing countries have not been successful in reducing pesticide use in agriculture, largely because they have limited state capacities and capabilities for developing and enforcing adequate policies on restricting pesticide distribution and use, as well as an inadequate understanding of farming practices related to pesticide use. This has resulted in improper and ineffective government approaches to addressing pesticide use at farm level, for instance in India, Iran, and Colombia (Hashemi, Peshin, & Feola, 2014), Ethiopia (Mengistie, Mol, Oosterveer, & Simane, 2015), Thailand (Panuwet et al., 2012), Bangladesh (Rahman, 2013), Sri Lanka (Jayasinghe & Silva, 2003), and Caribbean countries (Pereira, Boysielal, & Chang, 2007).

This paper reviews Vietnam's pesticide policy to promote proper pesticide use in agriculture, as well as the impact of this policy on agricultural pesticide distribution and use in Vietnam. After introducing the methodology, the paper analyses developments in the number of pesticides (AIs and formulated pesticides) that have been registered, imported and distributed in Vietnam over the past 15 years. This is followed by a detailed analysis of developments in pesticide use at farm

level between 2002 and 2013. This paper concludes with an analysis of the successes and failures of Vietnamese pesticide policy.

2. Methodology

This study used two main methodologies to investigate quantitative developments in pesticide use: existing longitudinal national data sets of registered pesticides approved for agricultural use, and longitudinal primary data collection of actual farm-level pesticide use in a vegetable production district (Dong Anh District, Hanoi).

Annual lists of registered (and thus approved) pesticides, provided by the Ministry of Agriculture and Rural Development (MARD) from 1999 to 2013, were obtained and analysed. Data on types of pesticides in terms of both AIs and formulated pesticides were identified, analysed, and synthesized.[2] Toxicity classes of pesticides were determined with reference to the WHO Classification of Pesticides 2009 (IPCS, 2009).[3]

The primary data collection on farm-level pesticide use was conducted in the Donganh District, Hanoi, which has long been an important vegetable producing region for the Hanoi market (see Figure 2). After having been trained to use self-recording methods for daily farming practices, 30 farmers in this district carried out self-monitoring on a daily basis during eight months between August 2013 and March 2014 regarding their pesticide use practices on vegetables. Similar monitoring data had been gathered before using a similar methodology and from largely the same group of farmers, viz. from 32 households between August 2002 and March 2003,[4] and from 32 farm households between August 2006 and March 2007.[5] These repeat assessments allow a longitudinal comparison to track changes in pesticide use over time. The monitoring campaigns from August 2002 to March 2003, August 2006 to March 2007, and August 2013 to March 2014 are referred to below as monitoring periods 1, 2, and 3, respectively (hereafter MP1, MP2, and MP3). A total of 199 primary production units[6] with a sown area of 7.55 ha were monitored in MP1, and 225 primary production units with a sown area of 8.17 ha in MP2. The corresponding figures for MP3 are 301 and 11.69 ha, respectively. To some extent, there is a tendency for farmers to diversify their vegetable crops. However, Kohlrabi, Wrapped heart mustard, and Choysum remained the major vegetable crops throughout the three monitoring periods (see Table 1).

Figure 2. Location of the research site.

3. Pesticides policies

Before the mid-1980s, Vietnam used a centralized management system for agriculture. Pesticides were imported, distributed and guided for use by state officials at different government levels. However, since Vietnam developed towards a market-based economy, starting from the Renovation Policy adopted in 1986, the pesticide sector became more privatized, especially with respect to pesticide imports, production/formulation and distribution (retail). Agricultural extension services counselling farmers on agricultural production were paralleled by pesticide production and trading companies and private retailers, who also counsel and inform smallholder farmers in their pesticide use for vegetable production

To provide a legal basis for private actors in pesticide imports, production, packaging, and distribution, MARD annually (from 1986 onwards) issues a list of pesticides approved for import, production/formulation, distribution and use in Vietnam. From 1992 onward, this list has been specified into three categories: permitted pesticides, pesticides permitted for restricted use, and banned pesticides. Pesticides of the second category can only be used at specific locations, for specific crops, with strict application methods required. The list of pesticides is annually updated with newly registered pesticides as well as those reclassified as restricted or banned. The list is of key importance for state pesticide management authorities at all levels to implement the national policy. It is also vital for private actors in the pesticide import, production and distribution sectors.

Ordinance No. 8-L/CTN (Nguyen, 2014), issued in 1993, was the first comprehensive legal document on pesticide management in Vietnam, outlining the objectives of plant protection; the requirements for pesticide production, formulation, distribution, and use; the responsibility and rights of relevant state authorities in monitoring and inspecting activities related to pesticide import, production, distribution and use; and the establishment of a plant protection system from central to district level. Ordinance No. 8-L/CTN was amended in 2001, as the use of Integrated Pest Management (IPM-)based pest and disease control in the Vietnamese agricultural sector was further emphasized (Socialist Republic of Vietnam, 2002).

Pesticide trade has been very lucrative in Vietnam, with a remarkable increase in the number of actors in this sector over the last decades, all applying different strategies to promote pesticide use at farm level (Hoi, Mol, Oosterveer, & van den Brink, 2009). In 2012, the Department of Plant Protection (part of MARD) issued Document No. 310/BVTV-TTr to tighten its control over the unbridled promotion of pesticide use by pesticide companies among farmers, which for instance claimed positive side-effects of pesticides such as stimulating crop growth and fruiting success (Plant Protection Department, 2012).

Table 1. General overview of vegetable production in Dong Anh, 2002–2013.

	Total sown area (in % area and ha)		
Vegetable crop	MP1 2002–2003 ($N = 32$)	MP2 2006–2007 ($N = 32$)	MP3 2013–2014 ($N = 30$)
Kohlrabi (% area)	48.4	46.2	26.2
Wrapped heart mustard (% area)	12.1	22.1	29.2
Choy sum (% area)	3.8	7.4	7.4
Cabbage (% area)	4.4	1.5	7.0
Tomato (% area)	9.1	1.6	3.4
Wax gourd (% area)	3.3	3.7	3.3
Others (%)	18.9	17.5	23.4
Total vegetable crops (in numbers)	21	19	29
Total sown area (in ha)	7.55	8.17	11.69

Over the last decade, the Vietnamese government has put considerable effort into the promotion and implementation of various pesticide reduction campaigns such as '3 Reductions, 3 Gains',[7] '1 Must, and 5 Reductions'[8] (targeting pesticides in rice production), and '4 Rights'[9] (targeting all crops). The '4 Rights' campaign was officially institutionalized in the 2013 Law on Plant Protection and Quarantine. This Law covers the same subject as the revised Ordinance No 8-L/CTN of 2002, regulating especially pesticide registration. But the emphasis on bio-efficacy as the most important criterion for pesticide registration has changed. While (negative) effects of pesticides on health and environment remain the responsibility of pesticide companies, through the technical pesticide registration documents they provide to MARD (Lan, Le, & Phong, 2014), it is expected that the Law will have a stronger administrative impact on pesticides, as more human and financial resources are allocated for the enforcement of pesticide registration policy and pesticide campaigns.

4. Pesticide use at the national level

Despite the Vietnamese pesticide policies, pesticide imports and use in Vietnam have increased in terms of quantity and types (both as formulation and AI). Between 2002 and 2013, the number of AIs increased 1.8-fold, while the number of formulated pesticides increased 5.7-fold (an annual growth rate of 17%).[10] In terms of AIs, it is especially the numbers of pesticides of toxic categories II and UK which have risen (2- and 3.4-fold, respectively). In terms of formulations, it was the number of pesticides of toxic categories II, III, and UK[11] which showed the greatest increase (7.4-, 5.9- and 9.1-fold, respectively). Pesticides of toxicity Ib seem to have been slightly reduced in terms of the number of AIs between 2002 (12 AIs) and 2013 (10 AIs), but the number of formulated pesticides of this highly toxic category has increased considerably, from 34 in 2002 to 149 in 2013 (see Figure 3).[12]

The rapid increase in types of AIs is caused by a combination of new AIs being registered and newly mixed AI compounds, with very few AIs being removed from the list of pesticides approved in Vietnam. For instance, between 2002 and 2013, pesticide AI types increased from 210 to 386, whilst only three AIs were banned in that period: deltamethrin in 2012, and dichlorvos and dicofol in 2013. No AI has been moved from the 'permitted' to the 'restricted use' category.

The increasing demand for pesticides, notably insecticides, is attributed to biological factors (such as increasing production area of vegetable and fruit crops, increased pesticide resistance of pests and diseases), as well as to incorrect pesticide use at farms. According to experts, up to 80% of pesticides (in terms of quantity) used in agriculture in Vietnam are used incorrectly (i.e. violating the '4 Rights' principles), causing poor bio-efficacy and increased production costs, and resulting in greater toxic load to the environment (Nguyen, 2014). A survey in the Thai Binh

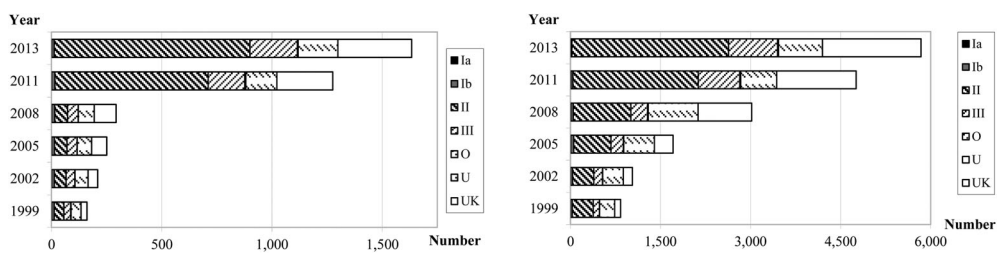

Figure 3. Number of pesticides: AI (left) and formulation (right) in Vietnam, 1999–2013.
Sources: IPCS (2009), Ministry of Agriculture and Rural Development (2002, 2005, 2008, 2013).

province in 2014 found that 80% of the farmers violated the '4 Rights' principles suggested for pesticide use, and 70% did not comply with the recommended preharvest interval (PHI) (Lan et al., 2014).

Another major problem is the continued presence of low-quality and counterfeit pesticides on the market, the main cause of which is ineffective state management of pesticides. According to government statistics, these products account for about 10% of the total pesticides (in terms of quantity) distributed and used in Vietnam (ILS, 2013). In reality, these pesticides could have an even larger market share, as illegal pesticides are not included in government statistics. Wholesalers and retailers are aware of the long list of low-quality pesticides, and have questioned why many of these pesticides could be successfully registered and distributed in Vietnam (Anh, 2013).

Low-quality pesticides contribute to the overuse of pesticides or the use of pesticide cocktails by farmers (Hoi, Mol, Oosterveer, & van den Brink, 2009). In addition, there are too many pesticide names on the market, which puzzles farmers and forces them to rely on pesticide retailers for information on efficacy and utilization. Ironically, a large percentage of existing pesticide retailers are former and/or even current farmers who have insufficient technical knowledge about pesticides. In 2013, 52% of the 1324 pesticide retailers in Hanoi were reported to be doing business without having a technical certificate for pesticides (HanoiDARD, 2013). Farmers who are confused by the large numbers of pesticides have been deceived by pesticide retailers. Since advanced pesticides often have lower retail profit margins compared to cheap and low-quality or counterfeit ones[13] (Anh, 2013), retailers instruct farmers to use counterfeit pesticides, sometimes in combination with high quality ones (Hoi, Mol, Oosterveer, & van den Brink, 2009).

5. Pesticide use at farm level

At farm level, pesticide use in the Dong Anh district increased between 2002 and 2013 in all respects: frequency of use, quantity of AI and quantity of formulated pesticides. Some of these increases can be associated with a rising cropping index,[14] but most of the increase is related to pesticide market forces and the agriculture production conditions, such as more (and more pesticide-resistant) pests and diseases. This has driven farmers to more pesticide use, and towards the use of highly toxic pesticides (such as pesticides of toxicity class Ib). Over the three monitoring periods, insecticides retained the largest share of pesticide use by farmers, while the share of herbicides increased slightly (see Table 2).

Between MP1 and MP3, the total quantity of pesticides used increased 1.9- and 2.5-fold for formulated pesticides and AIs, respectively. This increase is much larger than that of the cropping index between MP1 and MP3 (1.3 times). The quantity of formulated pesticides used per ha/cropping season increased from 11.20 to 13.09 kg and 13.99 kg in MP1, MP2, and MP3, respectively.

Table 2. Trend of pesticide use in monitoring periods.

	Types	MP1 (%)	MP2 (%)	MP3 (%)
Formulation	Insecticide	55.2	69.1	54.2
	Fungicide	34.1	20.1	35.1
	Herbicide	3.0	9.6	9.1
	UK	7.7	1.2	1.6
AI	Insecticide	52.8	64.5	49.0
	Fungicide	43.6	22.1	38.0
	Herbicide	3.6	13.4	13.0

In terms of AIs (excluding some unknown AIs), pesticide quantity/ha/cropping season increased from 5.61 to 5.37 kg and 9.11 kg in MP1, MP2, and MP3, respectively.

There has thus been a strong association between the market availability of pesticides (Figure 2) and pesticide use at farms. Even though the use of pesticides of toxicity class Ib has clearly decreased, the use of pesticides of toxicity class II increased in MP2 and again increased in MP3. In addition, there is a trend for new biological insecticides (such as avermectin, abamectin, and acetamiprid) to be increasingly used, and they currently dominate the range of insecticides used by farmers. The use of chemical pesticides such as fenobucarb, indoxacarb, nereistonxin, and permethrin greatly decreased in MP3. However, the application of two chemical pesticides of toxicity class II increased, viz. chlorpyrifos and cypermethrin. Consumption of pesticides of toxicity class U has also increased, notably that of mancozeb and validamycin. Copper hydroxide was used less in MP2 and MP3, while thiophanate-methyl was increasingly used in MP3 and became one of the 10 most used pesticides in this monitoring period. Zineb use decreased in MP2 as compared to MP1, but then increased again in MP3 (see Tables 3 and 4).

The number of illegally imported formulated pesticides offering no information on AIs fell considerably between MP1 and MP3. For instance, 9.1 and 7.7% of pesticide flows and formulation quantity, respectively, were identified as pesticides of unknown AI in MP1, whilst these figures were only 2.0 and 1.6% in MP3 (cf. Table 3).

Compared to MP2, pesticide cocktailing was less prevalent in MP3,[15] as application mostly involved single pesticides (see Table 5).

With respect to the types of pesticides used, our study area shows trends similar to those in the annual registration lists (Figure 2), both showing 1.7- and 2.0-fold increases in AIs and formulated pesticides, respectively. Regarding toxicity classes, pesticides of toxicity class UK have become most prevalent, in terms of formulation, followed by those of toxicity class II and those of class III in the recent monitoring period (see Table 6).

6. Pesticide policy enforcement

In terms of the prevalence of banned pesticides (i.e. highly toxic and/or illegal ones), it is likely that state regulation has had an impact on both the pesticides available on the market and the kinds of pesticide used at farms in Dong Anh. The use of pesticides of toxicity class Ib and illegal pesticides (i.e. those with unknown AI) has consistently decreased throughout our farm monitoring periods, whilst new biological pesticides are increasingly imported, distributed and used.

Regardless of this effect of state regulation on the market availability of pesticides, farmers continue to pay attention mostly to the efficacy of available pesticides, and not so much to state pesticides policies such as the '4 Rights'. For instance, pesticides designated as restricted use by state policy have continued to be used regularly by vegetable farmers: methomyl and deltamethrin (banned in early 2013) appeared 46 times in a total of 2294 pesticide flows in MP3. In addition, a long list of pesticides used by farmers in MP3 were not registered for use on vegetables, such as Ansuco 5WG, Conphai 15WP, Goltoc 250EC, Marshal 200SC, PeRan 50 E, Regent 800 WP, Topsin M 70 WP, Vitashield 40E. Since these pesticides are registered for crops other than vegetables, the recommended PHI will not be adequate for use on vegetables. So even if farmers follow producer and state instructions for pesticide PHI (which they often do not), consumer safety of the vegetables is still questionable when these pesticides are used. This means that once farmers have access to a pesticide, they will hardly consider its legal status, let alone its toxicity. Farmers often have no knowledge about, nor access to, the annual list of approved pesticides, and will not consider the list of thousands of different formulated pesticides in selecting and using pesticides. Hence, state efforts to promote and institutionalize the '4 Rights' have largely failed.

Table 3. Quantities and toxicity of pesticides used in the three monitoring periods.

	MP1 (%) ($N = 32$)			MP2 (%) ($N = 32$)			MP3 (%) ($N = 30$)		
AI toxicity	Flows[a]	Quantity of formulation	Quantity of AI	Flows	Quantity of formulation	Quantity of AI	Flows	Quantity of formulation	Quantity of AI
Ib	1.6	2.0	1.6	0.9	1.1	1.1	0.1	0.4	0.4
II	27.1	24.6	18.4	31.8	41.0	40.6	29.6	40.9	40.4
III	4.7	11.1	8.7	3.8	3.1	3.7	7.9	8.7	12.9
U	25.6	32.4	39.9	22.8	27.6	31.3	24.2	30.4	34.4
UK (known AI)	31.9	22.3	31.4	39.6	26.0	23.3	36.3	18.0	11.9
UK (unknown AI)	9.1	7.7	–	1.1	1.2	–	2.0	1.6	–
Total (in number of flows and kg for formulation & AI)	1,697	84.8	42.5	2,209	106.7	43.8	2,294	163.6	106.5

[a]A flow means a single recorded pesticide used by farmers.

Table 4. The 10 most used pesticides in the three monitoring periods.

Active ingredients	WHO classification	MP1 ($N = 32$)		MP2 ($N = 32$)		MP3 ($N = 30$)	
		Quantity of formulation (kg)	AI quantity (kg)	Quantity of formulation (kg)	AI quantity (kg)	Quantity of formulation (kg)	AI quantity (kg)
Insecticides							
Avermectin	UK	–	–	–	–	20.58	10.27
Abamectin	UK	4.42	0.11	4.26	0.05	7.58	0.04
Acetamiprid	UK		–	1.43	0.29	6.35	1.26
Chlorpyrifos (-Ethyl)	II	–	–	5.4	2.09	22.39	13.09
(Alpha-) Cypermethrin	II	5.83	1.22	3.65	0.23	15.26	11.35
Endosulfan	II	5.68	1.99	–	–	–	–
Fenobucarb	II	2.1	0.96	24.89	9.12	–	–
Indoxacarb	II	–	–	1.66	0.25	–	–
Nereistoxin	UK	9.77	9.14	15.09	8.11	–	–
Permethrin	II	–	–	1.81	0.91	–	–
Fungicides							
Copper hydroxide	III	4.37	2.19	–	–	–	–
Mancozeb	U	4.33	3.11	–	–	8.46	5.41
Validamycin	U	3.13	0.15	8.39	0.4	9.29	3.25
Zineb	U	13.97	11.14	–	–	11.26	8.96
Thiophanate-methyl	U	–	–	–	–	11.52	10.34
Herbicides							
Butachlor	III	2.2	1.32	7.81	4.68	10.72	9.97

Table 5. Pesticide application: cocktailing practices.

Pesticide application practices	MP2	MP3
Single pesticide application	43.6	72.7
2 pesticides-mixed application	41.0	19.2
3 pesticides-mixed application	13.2	7.5
4 pesticides-mixed application	2.1	0.5
5 pesticides-mixed application	0.2	0.1
Total application (in numbers)	1267	2294

Table 6. Number of pesticide types used in monitoring periods.

Toxicity	MP1		MP2		MP3	
	AI	Formulation	AI	Formulation	AI	Formulation
Ib	2	2	2	4	1	1
II	18	31	26	47	28	69
III	7	11	8	14	12	16
U	13	34	10	21	15	38
UK	6	28	10	28	22	92
Total	46	106	56	114	78	216

There are about 24 million farmers (with on average less than 1.0 ha/household) working in the Vietnamese agricultural sector (GSO, 2014), so monitoring and controlling pesticide use practices at farm level is of course impossible for the state sector by itself. Even though there have been some forms of contract vegetable farming in which pesticide selection and use is to some extent controlled by private contractors (Hoi, Mol, & Oosterveer, 2009a; Hoi, Mol, & Oosterveer, 2009b), this accounts for a very small segment of the farmer population. Hence, successful pesticide policy very much relies on state control of the pesticides market and improving knowledge about, and raising awareness of, pesticides among farmers and vegetable consumers in the (domestic and international) value chains.

7. Conclusions

Despite the expansion of government regulations on pesticide management over the past decade, pesticide use in the Vietnamese agricultural sector is still increasing. At macro-level, increasing numbers of pesticide types (both in terms of AIs and formulated pesticides) are being registered and distributed. At farm level, achievements in terms of reducing high-toxicity pesticides (Ib), unknown AI pesticides and cocktail applications have been offset by increasing pesticide use (both in terms of types and quantities of AIs and formulations) per production unit/cropping season, especially as regards pesticides of toxicity class II. It is particularly with respect to the latter that Vietnamese pesticides policy is failing. Although there have been successful efforts to ban some toxic pesticides and support the import and use of biological pesticides, there is no clear plan and strategy to cut pesticide dependence in vegetable farming. Policies on the proper use of pesticides (such as the '4 Rights' principles) have had very limited success. Despite increasing consumer demand and willingness to pay for safe vegetables (Hanh, 2014), and ongoing environment pollution and degradation (Hoai, Sebesvari, Minh, Viet, & Renaud, 2011; Lamers, Anyusheva, La, Nguyen, & Streck, 2011; Vietnam Environment Administration,

2013), limited successes have been achieved in 20 years of state promotion of safe vegetable production and marketing in Vietnam.

Given the wide misuse of pesticides on farms, a more effective pesticide market control will not be sufficient to solve all pesticide problems in Vietnam. Nevertheless, this is a first, effective and cheap strategy for Vietnamese government to start dealing with these problems. MARD now annually issues a long list of pesticides, which however puzzles local state officials involved in pesticide monitoring and regulation enforcement, as well as enabling retailers to cheat confused farmers by selling counterfeit/low-quality pesticides at higher profit rates, and making farmers dependent on retailers for pesticide selection and use. A much shorter list of pesticides, with which cheap but poor-quality pesticides are banned from the market and the remaining pesticides are carefully selected and tested under Vietnamese agricultural conditions, would reduce the confusion among state officials and farmers. A shorter list of pesticides approved for distribution and use would help local state officials improve their monitoring of the pesticide trade and local retailers to abide by state regulations, and would facilitate farmers in deciding on pesticide uses. But even with a shorter list of approved pesticides, additional government efforts remain essential, regarding more effective control of pesticide trade and retail, better monitoring of residues on vegetables, and creating a larger certified market for safe vegetables. These efforts will assist Vietnam's progress towards agricultural production schemes involving 'fewer pesticide types' and/or 'produced with less pesticides'.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. Among pesticides categories, herbicides showed the greatest increase in this period. Given the increased off-farm job opportunities and labour cost, farmers have increasingly relied on herbicides for controlling weeds instead of on manual weeding as was done in the past.
2. For types of formulated pesticides, there is a difference between the list compiled by MARD and the calculation provided in this paper. For instance, MARD calculates 'Ababetter 1.8 EC, 3.6EC, 5EC' as one formulated pesticide, while in this paper this category is regarded as consisting of three different formulations. Hence, the number of formulated pesticides presented in this paper is larger than the number indicated by MARD.
3. Only three major types of pesticides are included in the analysis in this paper: insecticides, fungicides, and herbicides. Toxicity of chlorpyrifos ethyl was obtained from http://www.insecticidechina.com/1-3-chlorpyrifos-ethyl.html.
4. Sustainable technologies for pest and disease management and soil fertility management in smallholder vegetable production in Sichuan, China and Red River Delta, Vietnam. Europe Commission ICA4-CT-2001-10054.
5. The 32 farmers monitored in MP2 were randomly taken from the list of 63 farmers monitored in MP1. Only these 32 farmers are included in the reporting on MP1 in this paper. However, for MP3, only 26 of the 32 farmers monitored in MP1 and MP2 were still farming (the others had retired from farming, or moved to other jobs due to urbanization processes, especially in Tang My village). We decided to include six new farmers in the monitoring list. Two of them ceased farm pesticides recording after the

first month of monitoring. The other 30 farmers successfully completed the 8 months of recording and monitoring pesticides.

6. A primary production unit is a full cycle of a particular crop grown on a specific land plot by one farmer.
7. Three reductions: seed quantity, nitrogen inputs, and pesticides; three gains: rice yield, rice quality, and economic return.
8. Must: use of certified varieties; five reductions: seed quantity, nitrogen inputs, pesticides, irrigation water, and post-harvest loss.
9. Four rights: use of right pesticides, right application time, right application dosage, and right application method.
10. These AIs and formulations include insecticides, fungicides and herbicides 'permitted' and with 'restricted use'.
11. Ia = extreme hazardous; Ib = highly hazardous; II = moderately hazardous; III = slightly hazardous; U = unlikely to present an acute hazard in normal use; and O = obsolete as pesticide, not classified. Pesticides not found in these data sources are defined as unknown (UK) pesticides.
12. In the annual list of MARD pesticides, types of active ingredients are counted in both single and combined use. However, for the purpose of this paper, with its focus on pesticide effects on human health and the environment, only single AIs are considered and counted. In pesticides with combined AIs, the toxicity is determined by the most toxic AI presented in the formulation. In the figure, 'type' of formulated pesticides means a combination of specific pesticide trade name, concentration and formulation. Hence the number of types of formulated pesticides in the figure is much larger than number of pesticide trade names in the MARD pesticide list.
13. Since these pesticides are very cheap, retailers can easily achieve higher profit margins for them, while in the end they are still much cheaper than the advanced pesticides, so farmers can more easily afford them.
14. The cropping index was 1.41 in MP1, 1.74 in MP2, and 1.85 in MP3.
15. A number of pesticide flows in MP1 were identified for application month, but not application date, so we could not identify whether they were mixed or used singly.

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