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Réduire l'utilisation des pesticides agricoles dans les pays du Sud : verrous et leviers socio-techniques / Reducing the use of agricultural pesticides in Southern countries: socio-technical barriers and levers.
Coordonnateurs : Ludovic Temple, Nathalie Jas, Fabrice Le Bellec, Jean-Noël Aubertot, Olivier Dangles, Jean-Philippe Deguine, Catherine Abadie, Eveline Compaore Sawadogo, François-Xavier Cote

ARTICLE DE RECHERCHE / RESEARCH ARTICLE — OPEN ACCESS

Toward a comprehensive analysis of pesticide use in Cambodian rice farming and identification of levers for its reduction

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Abstract – This article reports on pesticide use in rice production by 210 farmers across seven provinces in Cambodia along a gradient of intensification defined by the number of rice crops per year. Using descriptive statistics and thematic analysis of both qualitative and quantitative data, we compare rice production systems with one, two, or three crops per year. The level of pesticide use was assessed through spraying frequency and the type of pesticide used, the pests targeted by farmers, and their active ingredients. The results indicate varying intensities of pesticide use, with the highest application rates per cycle, particularly of insecticides, in the three-crop rice system. Farmers primarily rely on advice from local pesticide sellers for their choice of product and application rate and often mix different pesticides to enhance efficacy. Through on-site visits, 68 different active ingredients were identifiedd on the labels of pesticide packages stored on farms. Farmers expressed concern about the health and environmental risks associated with pesticide use. Our study highlights the complex relationships between agricultural intensification and pesticide use, as well as the importance of tailored extension services that offer information, education, and training to help farmers mitigate the risks of intensive pesticide use. It also underscores the need for ongoing surveys to document agricultural practices in evolving systems.

Keywords: agricultural practices / pesticide application / active ingredients / human health

Résumé – Analyse détaillée de l'usage des pesticides en riziculture au Cambodge et identification des leviers pour leur réduction. Notre étude documente l'utilisation des pesticides dans les cultures de riz de 210 agriculteurs à travers sept provinces du Cambodge, selon un gradient d'intensification défini par le nombre de cycles de riz par an. Des statistiques descriptives et des analyses thématiques des données qualitatives et quantitatives ont permis de comparer des systèmes rizicoles à un, deux ou trois cycles par an. Le niveau d'usage des pesticides a été évalué selon la fréquence de traitement et les types de pesticides utilisés, les bioagresseurs ciblés par les agriculteurs ainsi que les matières actives. Les résultats indiquent différentes intensités d'usage des pesticides, les parcelles avec trois cycles de riz par an ayant les plus hautes fréquences d'application par cycle, en particulier pour les insecticides. Les agriculteurs de l'enquête sont surtout dépendants des vendeurs de pesticides locaux pour le choix des produits et des doses appliquées et ils mélangent souvent différents pesticides pour en améliorer l'efficacité. Lors des visites sur site, 68 matières actives différentes ont été identifiées sur les emballages de pesticides conservés par les agriculteurs. Les personnes interrogées ont fait part de leur inquiétude concernant les dangers pour la santé et les risques environnementaux. Cette étude met en évidence les relations complexes entre l'intensification agricole et l'usage des pesticides, ainsi que l'importance de services d'appui agricole adaptés pour l'éducation et la

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formation des agriculteurs. Elle reflète aussi la nécessité de suivis réguliers des pratiques agricoles dans des systèmes en rapide évolution.

Mots-clés : pratiques agricoles / application de pesticides / matières actives / santé humaine

1 Introduction

The agricultural sector plays a key role in Cambodia's economy: in 2021, agriculture made up 22.8% of the gross domestic product (GDP) and employed 35.7% of the labor force (MAFF, 2023a). Rice is the main driver of Cambodia's agricultural sector, contributing 15% of the GDP (FAO, 2021). Rice farming in Cambodia has changed significantly since the early 2000s. In 2010, the government launched a policy to expand rice production and export capacity, aimed to make Cambodia a major rice exporter by encouraging farmers to harvest two or three crops annually (RGC, 2010). This policy was designed to promote agricultural modernisation and intensification, focusing on increasing yields through intensive input use, improving productivity to boost food security, and raising farmers' incomes through higher yields and better market access (Takeshima and Joshi, 2019). The policy marked a shift from the traditional single rainfed crop in the rainy season to two crops that rely on mechanisation, high-yield varieties, pesticides, and chemical fertilisers (RGC, 2010). The transformation recalls the 1970s Green Revolution that transformed the Global South (Castella, 2012).

Most rice farmers grow rice for both self-consumption and sale (Chun, 2014; Cramb, 2020). Managing pests and diseases is one of the main challenges in rice production, insect pests being the leading cause of yield losses (Dunn *et al*., 2023). Pesticides are seen as essential to sustaining agricultural production, locking rice farmers in a cycle of dependency despite concerns about health risks (Brown, 2002; Pin & Mihara, 2013; Matsukawa *et al*., 2016; Schreinemachers *et al*., 2017; Castilla *et al*., 2019). Pesticide use in Cambodia has increased significantly in recent decades (FAOSTAT, 2025; Figure 1), particularly compared to other Asian countries. Studies have reported that farmers often misuse pesticides by applying them too early in the rice growth stage, using the wrong quantities, and are not necessarily aware of which pests are targeted (Jensen *et al*., 2011; Preap and Sareth, 2015). Matsukawa *et al*. (2016) specified that farmers often mix several different pesticides in one spray tank and apply them simultaneously without paying attention to the categories of the pesticides used because they believe that mixing pesticides enhances rice growth and controls pests. As a result, the rice ecosystem is being disturbed, natural enemies of the pests are being reduced while the pest population grows, enabling outbreaks of secondary pests (*e.g.* brown planthopper), and the development of pesticide resistance (Matteson, 2000), in addition to which many farmers have reported symptoms of pesticide poisoning (Jensen *et al*., 2011). Flor *et al*. (2020) described the context of pesticide dependency and its causes in rice farming in Cambodia and identified rice farmers trapped in pesticide lock-ins, where they continue using pesticides out of habit, part of their cultivation system, and due to the effective contribution of pesticides, plus promotion of pesticide use. Castilla *et al*. (2019) demonstrated that intensifying rice production leads to misuse of agricultural inputs, hindering sustainability. Thus, to avoid future pest outbreaks and to mitigate the negative impacts of the intensification of pesticide use or reliance on pesticides, it is essential to gain a better understanding of current pesticide use in rural areas of Cambodia. This understanding will help identify key levers to reduce pesticide use in rice farming and to promote sustainable pest management strategies.

2 Materials and methods

2.1 Selection of the study sites

Our sampling design was set up to reflect a gradient of rice intensification across different socio-geographic and ecological contexts in Cambodia. We selected seven provinces among those with high and diverse rice production considering access to water, border proximity, and rice value chains.

Three of the provinces selected are located in the plains: Prey Veng (PV), Takeo (TK), and Kampong Cham (KPC) provinces, three are located in the Tonle Sap area (that depends on the hydrological regime of the central lake): Battambang (BTB), Siem Reap (SR), and Kampong Thom (KPT) provinces, and one province is located in the plateau area: Kampong Speu province (KPS), see Figure 2.

2.2 Sample size

In each province, three districts were selected in consultation with the Provincial Department of Agriculture, Forestry and Fisheries (PDAFF) to represent the diversity of rice cropping practices. A village was then randomly selected in each district. Information on the village's location, access to water, and level of intensification was collected in a meeting with the village chief. In each village and in coordination with village chiefs, ten plots were selected purposively to represent the different rice farming practices. The farmers in charge of the plots were interviewed, giving a total of 210 interviews for the whole study.

2.3 Data collection and analysis

The questionnaire was developed using KoboToolbox1, so that data could be collected via tablets during field interviews lasting one to two hours. Data were collected on sociodemographic and farm characteristics (family members, age, gender, total farm size, number of land parcels), agricultural practices used in the selected plot (number of rice crops, land preparation, crop rotation), and repeated questions for each rice crop (the variety used, estimated yield, significant constraints, fertilisation, pesticide applications) and finally details were collected on each pesticide application (application method, number of products, type of pesticide used, quantity, common and commercial name of the product used,

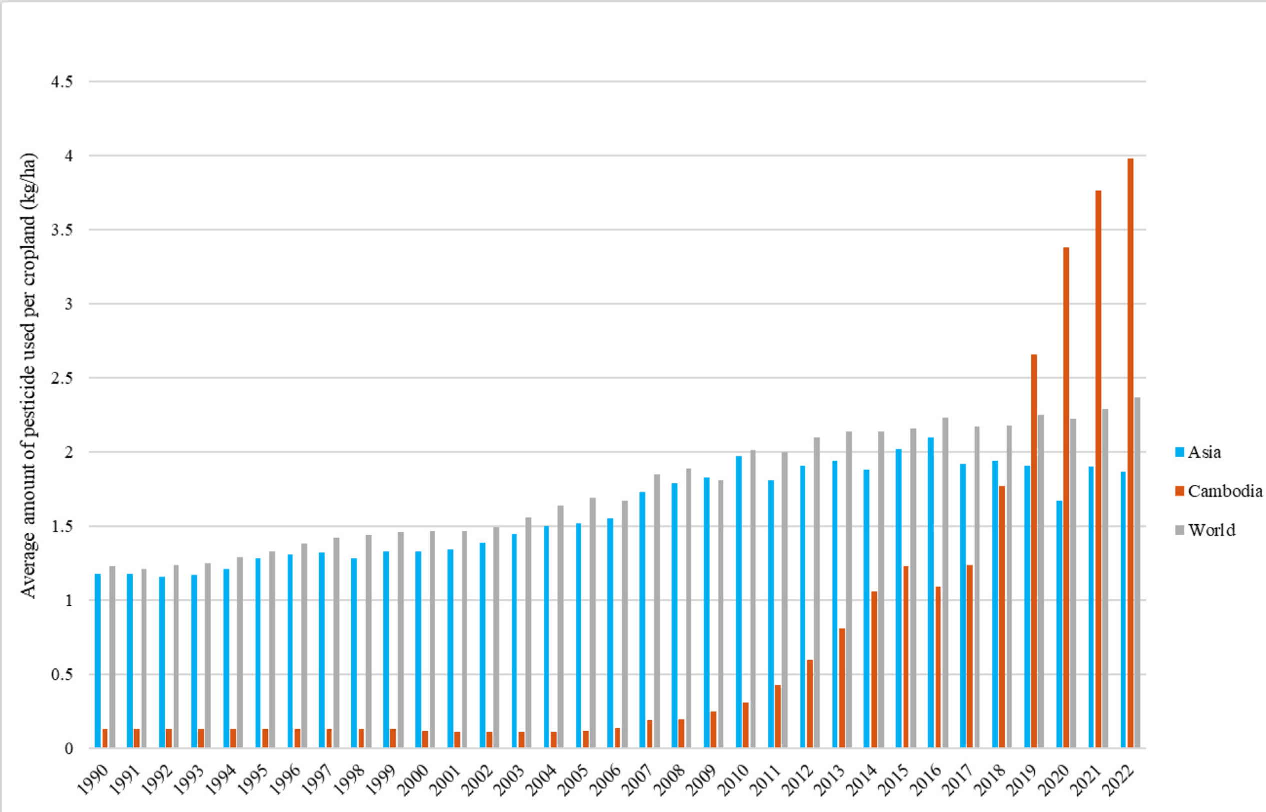

Figure 1. Pesticide use per area of cropland (source: FAOSTAT).
Figure 1. *Utilisation de pesticides par hectare de terres cultivées.*

purpose of pesticide use, etc.). If farmers had kept the product packaging, photos were taken. Otherwise, farmers identified the package in a photo gallery. If identification was still not clear, the common name in Khmer was recorded. The survey was conducted from April 2023 to January 2024. Quantitative data were analysed using descriptive statistics in R-studio version 4.4.0. Qualitative data were analysed using thematic analysis. Open-ended responses to 'Do you think this pesticide has negative effects on human health or the environment?' were also recorded.

3 Results

3.1 Socioeconomic characteristics of rice farmers

The survey showed that socioeconomic characteristics varied among households across provinces (Table 1). Gender distribution varied significantly, with a larger share of female respondents in Kampong Spue province (47%) compared to Kampong Cham province (13%). Respondents' ages also varied, with the mean age of respondents ranging from 43.6 years in Kampong Thom province to 54.4 years in Prey Veng province. Farming experience also varied considerably, with respondents in Kampong Thom reporting an average of 19 years of agricultural experience, which was compared to 31 years in Kampong Speu. However, respondents in Kampong Speu province had a smaller average landholding of 1.3 hectares, compared to 5.49 hectares in Battambang province. The annual number of rice crops also varied, with households in Takeo cultivating an average of 2.37 crops per year, in contrast to 1.30 crops per year in Kampong Speu. Literacy rates were high across all provinces, ranging from 77% in Kampong Spue to 90% in Siem Reap, while levels of formal education varied. For instance, the percentage of respondents with no school education was highest in Takeo province (20%), while university education was most prevalent in Battambang province at 6.7%. Reliance on farming as the main income source also varied considerably across provinces, with the highest proportion observed in Battambang (92%) and the lowest in Takeo (59%).

3.2 Level of intensification in the rice plots in the study

The plots were classified according to the number of rice crops cultivated per year, as a proxy for the level of rice intensification.

Classification using the number of rice crops per year combines information on water management, drainage in the rainy season or irrigation in the dry season, on short varieties that need mineral fertilisation, and the knowledge that increasing the number of crops per year also increases the risks of pests and diseases.

One cycle-system has only one rice crop per year, grown during the rainy season, known as rainy-season rice or grown in the dry season, referred to as dry-season rice, which applied

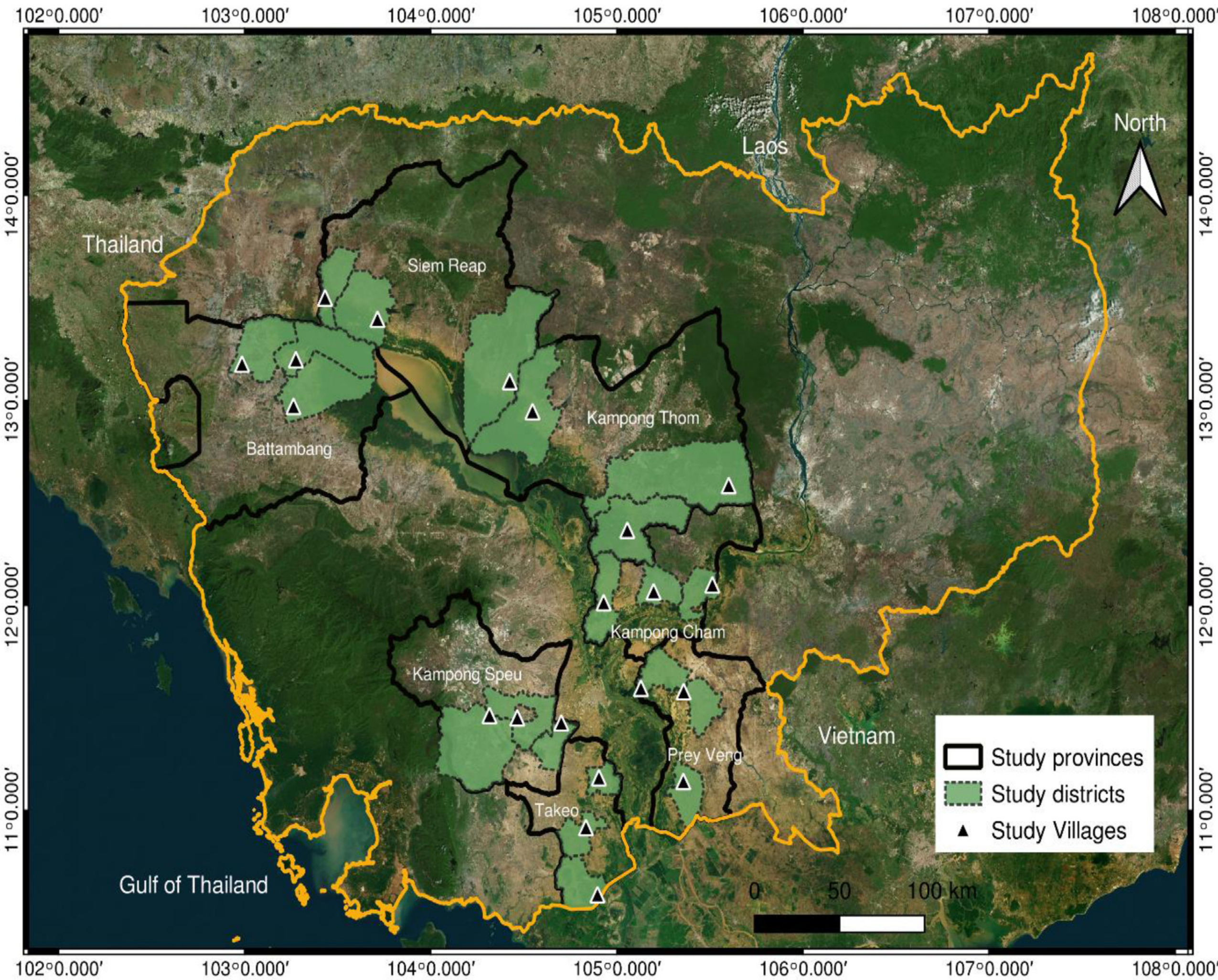

Figure 2. Map of selected provinces for the study.
Figure 2. *Carte des provinces sélectionnées pour l'étude.*

to 40% of the plots in this system. Rainy season rice is grown mostly in Kampong Speu province. The sowing starts in June and rice is frequently harvested in November, but harvest dates vary with variety. Medium- and late-maturing, photosensitive rice varieties, such as Phkar Romdoul, Phkar Khney, Phkar Malis, Neang Khun, Rang Chey, Krahorm Thngun, were reported as well as local varieties. This system can be termed 'rainfed lowland single-crop system'. 'Dry season rice' applies to plots cultivated under full or partial irrigation in areas that are flooded every year in the rainy season. Sowing begins in late October and the rice is harvested in January or February. The varieties reported in this system are early-maturing varieties, including OM5154, OM49, Sen Kra Ob, Sra Ngae Sral, and IR504. Broadcast sowing is the predominant method and was most commonly observed in Kampong Cham and Takeo provinces.

The two cycle-system involving two rice crops per year was observed in all the provinces studied. Two rice crops are grown on the same plot during the rainy season. Forty-eight percent of all the plots surveyed used this system. The first cycle starts early with broadcast sowing as soon as the rainy season starts and the crop is harvested by mid-August or September, after which there is a one-week fallow period before the second crop is sown. About 71% of farmers in the study use the same early-maturing varieties in both crop cycles of this system (OM5154, OM49, IR504, IR66, Sen Kra Ob, or Sra Ngae Sral). Alternatively, depending on water availability, they may sow early maturing varieties as the first crop and medium-duration varieties (Phkar Khney, Kngok Pong, Neang Khun) as the second. This system can be termed 'rainfed lowland favorable double-crop system'.

The three cycle-system consists of two crops during the rainy season and one during the dry season, all on the same plot and was found in 12% of the plots. This system entails using early-maturing varieties (OM5154, OM49, Sen Kra Ob, Sra Ngae Sral, and IR504) in all three crop cycles. Improved access to water and higher prices paid for rice in 2024 led some farmers to even consider four cycles yearly. In Battambang, one farmer interviewed reported growing four rice crops in the year preceding the interview; this could be a new practice that has not yet been described in the literature.

Table 1. Socioeconomic characteristics of farms involved in the survey: mean (min-max) according to the 30 interviews of each province.
Tableau 1. *Caractéristiques socioéconomiques des exploitations agricoles impliquées dans l'enquête : les chiffres indiquent les moyennes (min-max) dans les 30 enquêtes de chaque province.*

Province	BTB (n=30)	KPT (n=30)	KPC (n=30)	KPS (n=30)	PV (n=30)	SR (n=30)	TK (n=30)
Gender Distribution (%)							
Female	20	37	13	53	17	13	17
Male	80	63	87	47	83	87	83
Age (years)	49.3	43.6	50.8	54.1	54.4	54.9	48.1
Total number of household members	5.37	4.9	5	5.33	4.3	5.13	5.07
Active labor (people)	1.80	1.67	1.37	1.57	1.57	1.33	1.63
Experience (year)	26.2	19.6	26.2	31.0	30.8	30.2	23.3
Total plot size owned (ha)	5.49 (0.26-20)	3.13 (0.25-20)	1.57 (0.5-3.8)	1.30 (0.1-8)	1.91 (0.25-8)	5.36 (0.7-30)	2.39 (0.14-7)
Number of plots (units)	3.70 (1-12)	5.20 (1-20)	4.30 (1-15)	6.37 (1-30)	3.03 (1-8)	5.87 (1-25)	4.20 (1-13)
Number of rice crops per year	2.13 (2-4)	1.43 (1-2)	1.53 (1-3)	1.30 (1-2)	1.63 (1-3)	1.63 (1-3)	2.37 (1-3)
Landowner (%)	80	83	100	97	93	100	93
Literacy rate (% of able to read)	83	87	87	77	63	90	80
Educational attainment (%)							
Primary school	60	60	27	40	60	60	43
Secondary school	13	27	50	33	17	20	23
High school	13	7	10	17	10	10	10
University	7	0	0	0	0	0	3
No formal education	7	7	13	10	13	10	20
Households with farming as the primary income source (%)	92	75	76	77	65	68	59

BTB – Batambang; KPT – Kampong Thom; KPC – Kampong Cham; KPS – Kampong Speu; PV – Prey Veng; SR – Siem Reap; TK – Takeo; n – Number of respondents

As can be seen in Table 2, the three cycle-system has the most intensive use of inputs (seeds, fertilizer, and pesticides) in each crop cycle (see also Figure 3), and achieves higher yields per cycle compared to the other two systems. This indicates that increasing the number of crop cycles will increase input use, particularly fertilizers and pesticides.

3.3 Number of pesticide applications during the cropping season

Figure 3 shows the number of applications per rice crop cycle and per target pest based on farmers' responses to the question: "Why do you use this product?". Insects were mentioned as the most frequent target, especially during the second and third crop cycles in the three cycle-system. There could thus be a link between the number of rice cycles per year and pesticide applications per cycle, with farmers who use the three cycle-system applying more pesticides than those who use one- and two-cycle systems.

Figure 3 shows that in the one cycle-system, the number of pesticide applications was relatively low compared to the other two systems, with herbicides and molluscicides commonly used in Kampong Speu, insecticides in Kampong Cham, Prey Veng, and Takeo, and herbicides in Kampong Thom and Siem Reap.

The use of products targeting rodents was only observed in Siem Reap and Kampong Cham. In the two cycle-system, weed and snail treatments were primarily applied in the first month whereas insect and disease treatments were applied throughout the season, with the highest insecticide use in Kampong Thom. Molluscicide use often increased in the second cycle of this system in almost all provinces, while rodenticides were applied in Battambang, Kampong Thom and Siem Reap. In the three cycle-system, insects remained the primary target pest. Both insect and disease treatments increased in the second and third cycles, particularly in Kampong Cham and Prey Veng. In contrast, snail and weed treatments appeared to remain consistent in all the cycles of this system across provinces, except in Kampong Cham, where the highest frequency of molluscicide applications was recorded during the first crop.

3.4 Main active ingredients used for the treatment of rice crops

During the survey, according to the labels on the pesticide packages kept at home by 128 farmers, 68 different active ingredients were found corresponding to insecticides, herbicides, molluscicides, rodenticides, and disease control products (fungicides and antibiotics), and, according to MAFF (2022) none of these active ingredients are currently banned in Cambodia; 41% of the products found on the farms contained a mixture of 2 to 3 active ingredients. Additionally, we discovered some pesticide packages labelled in foreign languages (*e.g.*, Vietnamese) on some farms in Takeo and Kampong Thom provinces; these may be purchased directly

Table 2. Agronomic characteristics of surveyed plots by rice production system.
Tableau 2. *Caractéristiques agronomiques des parcelles par systèmes rizicoles.*

Variables	Rice production systems		
	One cycle-system	Two cycle-system	Three cycle-system
Percentage of rice plot (%)	40	48	12
Distribution by province (%)			
Battambang	0	93.10	6.90
Kampong Thom	56.67	43.33	0
Kampong Cham	56.67	33.33	10
Kampong Speu	70	30	0
Prey Veng	53.33	30	16.67
Siem Reap	36.67	63.33	0
Takeo	10	43.33	46.67
Average plot size (ha)	0.68 ± 0.71	0.89 ± 1.03	0.56 ± 0.43
Rice varieties (%)			
Early-maturing	32.94	92.50	98.61
Medium-maturing	32.94	7.50	1.39
Late-maturing	34.12	0	0
Inputs (mean ± SD)			
Seed rate per cycle (kg/ha per cycle)	194 ± 109^{a}	253 ± 90.5^{b}	369 ± 213^{c}***
Number of fertilizer applications per rice crop cycle (time/cycle)	1.76 ± 0.83^{a}	2.44 ± 0.65^{b}	2.71 ± 0.54^{c}***
Quantity of fertilizer used per rice crop cycle (kg/ha/cycle)	189 ± 150^{a}	284 ± 130^{b}	356 ± 133c***
Number of pesticide applications per rice crop cycle (time/cycle)	2.57 ± 1.63^{a}	4.19 ± 1.92^{b}	4.55 ± 1.25^{b}***
Number of products per rice crop cycle (unit/cycle)	3.77 ± 2.67^{a}	6.12 ± 3.54^{b}	7.73 ± 3.66^{c}***
Number of pesticides per application (unit/application)	1.46 ± 0.80^{a}	1.46 ± 0.86^{a}	1.70 ± 0.94^{b}***
Quantity of pesticide per rice crop cycle (kg/ha/cycle)	2.74 ± 3.06^{a}	3.75 ± 3.60^{a}	5.11 ± 3.66^{b}***
Yield per cycle (tonnes/ha)	3.76 ± 1.89^{a}	4.45 ± 1.58^{b}	5.53 ± 1.42^{c}***

Within a row, means with different superscript letters $^{(a,b,c)}$ differ significantly ($p<0.01$); *** represents $p<0.01$ significant level; t/ha – 1,000 kg per hectare

from the other country or may have been imported informally, meaning the farmer had less access to reliable recommendations on product use.

3.4.1 Advice on pesticides – Source of information

The pesticide sellers play a dominant advisory role in farmers' decisions to choose, use, and obtain information across all three systems; this includes information on the crop stage, visible pest damage, pest presence, and preventive actions. Farmers also refer to their previous experience when choosing pesticides and application rates, especially in the three cycle-system. Advice from relatives or neighbors also plays a role in information transfer and in the choice of pesticide across all the rice systems analysed in the present study. Few farmers followed label instructions concerning application rates and targets (Table 3).

3.4.2 Pesticide application practices

Farmers often state that they mixed different pesticides in one spray, creating 'pesticide mixtures' with combinations such as two types of insecticides or insecticides and herbicides, some farmers even used pesticides that already contained 2-3 active ingredients. Many farmers stated that combining different pesticides increases effectiveness and that spraying a single pesticide is less effective. Sellers also recommend mixing pesticides (*i.e.*, an insecticide with fungicide and supplement) to control insects while preventing associated diseases. Some farmers reused or rotated pesticide products during the course of the cropping season; each application was counted as separate, even if the product name was the same (*i.e.*, we counted it as 2 pesticides even if the same pesticide was used each time). Table 4 lists the number of applications and pesticides used per cycle, which varied depending on the system and region. Farmers in Prey Veng sprayed an average of 11 pesticides, with 5 applications in the three cycle-system, which was more than in the other systems and in the other regions. Kampong Thom was the scene of the largest number of applications per crop cycle (6 applications) in the two cycle-system compared to the other systems. In contrast, in Kampong Speu, pesticide use and application frequency were lower in each crop cycle across all three systems, herbicides and molluscicides being the most common products applied. Farmers in this province reported limited access to water, leading them to grow mostly late-maturing rice varieties in the rainy season, primarily for self-consumption.

3.4.3 Methods of pesticide application

Spraying methods varied by system and region, from manual spraying by farmers or hired workers, often on foot, with or without tanks, to drone spraying, which is influenced by convenience, the availability of service providers, the cost

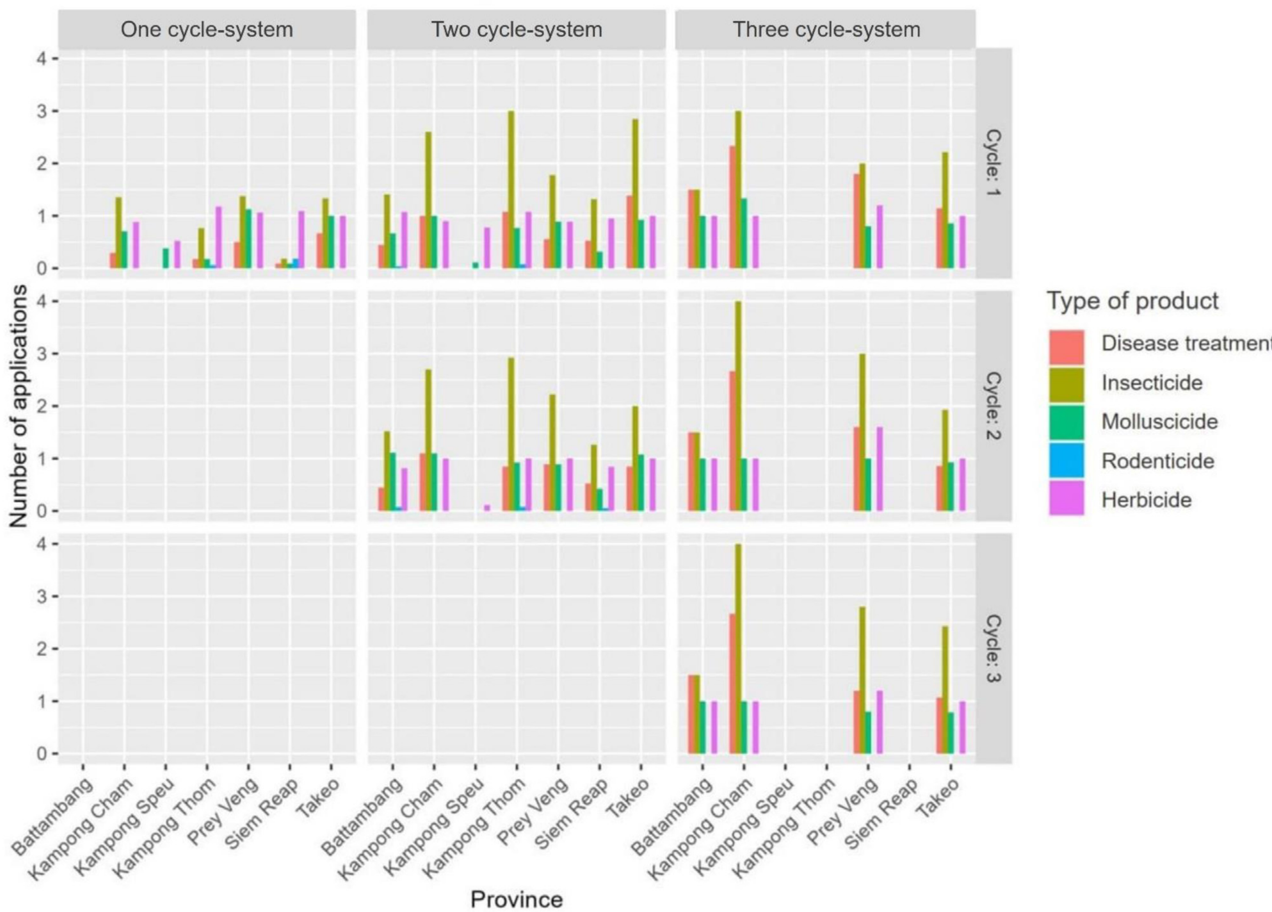

Figure 3. Number of pesticide applications per cycle according to the rice systems and the types of products used in each province. The products were classified according to the farmer's purpose.

Figure 3. *Nombre d'applications de pesticides par cycle selon les systèmes rizicoles et les types de produits utilisés dans chaque province. Les produits ont été classés selon l'objectif poursuivi par l'agriculteur.*

of hired labor, and perceived effectiveness (Table 5). Among the farmers interviewed in Battambang, drone spraying is mainly used in the two cycle-system and the three cycle-system, while in Siem Reap, drones are frequently used in the two-cycle system. All the farmers who used drones hired the drone operator to spray, but they themselves continued to make the decision to use pesticides and which pesticide to use. Tank sprayers are widely used across all provinces and systems, particularly in the one and two cycle-systems in Kampong Cham and Kampong Thom, and in the two and three cycle-systems in Prey Veng and Takeo provinces. In Kampong Speu, farmers applied pesticides manually in both rice systems, mainly molluscicides and some herbicides (in powder form), although manual tanks are commonly used in the two cycle-system.

3.5 Farmers' perception of the health and environmental effects of pesticide use

In the provinces where an open question was asked about the farmers' use of pesticides, 87% (n=180) of surveyed farmers expressed concern about health risks linked to pesticide use, 8% mentioned environmental impacts such as water contamination and harm to wildlife, and less than 1% expressed concern about pest resistance due to prolonged use (Figure 4). On the other hand, 22% of the farmers were concerned about yield loss if they did not apply pesticides, which is the most familiar method of pest control available to them. Some farmers believed that using protective measures may reduce health risks during application. In Prey Veng, farmers showed less concern about pesticide-related health risks, consistent with previous results showing that these farmers sprayed many times and used the highest level of mixed pesticides in one spray (see Table 3). In Kampong Cham, a small but notable group (7%) of farmers expressed willingness to stop using pesticides if viable alternatives emerge. However, pesticides are considered essential for pest control and yield maximisation in all the provinces studied. Farmers in Siem Reap expressed concern about the environmental impacts of pesticides (Figure 4). Farmers prioritize rice quality and safety over yield in Kampong Speu, where rice is mainly grown for self-consumption with one rice crop per year (the one cycle-system). Farmers in this province expressed concern about pesticide residues affecting taste, texture, and food quality; they opted to avoid using pesticides.

Table 3. Sources of pesticide advice and application decisions by rice system.
Tableau 3. *Sources d'information pour le choix des pesticides et la quantité appliquée par les systèmes rizicoles.*

Variables	Reason for product choice (%)			Why did you use this product at this stage? (%)			Source of product information (%)			Basis for application rate decision (%)		
	One cycle-system	Two cycle-system	Three cycle-system	One cycle-system	Two cycle-system	Three cycle-system	One cycle-system	Two cycle-system	Three cycle-system	One cycle-system	Two cycle-system	Three cycle-system
Advice from seller	45.40	45.65	43.18	32.52	30.21	35.24	79.19	82.19	87.47	63.46	63.51	66.60
Advice from the extension agent	1.48	0.13	0.49	0.78	1.03	0.56	2.71	4.15	1.63	3.08	0.27	0.21
Advice from relative/ neighbor	13.06	7.79	9.25	5.01	3.79	3.20	17.19	13.44	9.54	6.54	3.87	0.42
Farmers' own experience	18.10	18.86	23.70	0.00	0.00	0.00	0.00	0.00	0.00	21.92	25.95	32.56
Effectiveness	21.66	27.18	22.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Affordable cost	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Accessibility	0.00	0.13	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Visible damage	0.00	0.00	0.00	7.24	7.54	5.01	0.00	0.00	0.00	0.00	0.00	0.00
Presence of the pest	0.00	0.00	0.00	22.22	17.19	13.37	0.00	0.00	0.00	0.00	0.00	0.00
Rice growth stage	0.00	0.00	0.00	16.28	17.68	11.14	0.00	0.00	0.00	0.00	0.00	0.00
Preventive	0.00	0.00	0.00	16.02	20.39	30.92	0.00	0.00	0.00	0.00	0.00	0.00
Labeling	0.00	0.00	0.00	1.03	2.17	0.56	0.00	0.00	0.00	5.00	6.40	0.21
Advertisement/ Media	0.30	0.07	0.49	0.00	0.00	0.00	0.00	0.11	0.54	0.00	0.00	0.00

Table 4. Pesticide use: number of applications and pesticides used per cycle and per application by rice system (mean ± SD).
Tableau 4. *Nombre d'applications de pesticides par cycle, nombre de pesticides utilisés par cycle et par application, par systèmes rizicoles (moyenne ± écart type).*

Province	Number of applications per cycle per system (time/cycle)			Number of pesticides per cycle per system (unit/cycle)			Number of pesticides per application per system (unit/application)		
	One cycle-system	Two cycle-system	Three cycle-system	One cycle-system	Two cycle-system	Three cycle-system	One cycle-system	Two cycle-system	Three cycle-system
Battambang	–	3.76 ± 1.45	4.00 ± 1.09	–	5.11 ± 2.49	5.50 ± 0.55	–	1.36 ± 0.83	1.38 ± 0.71
Kampong Thom	2.44 ± 1.55	6.27 ± 1.87	–	3.50 ± 2.42	8.54 ± 4.62	–	1.44 ± 0.97	1.36 ± 1.97	–
Kampong Cham	3 ± 1.50	5.00 ± 1.80	6.56 ± 0.52	4.12 ± 2.23	7.40 ± 2.68	9.22 ± 3.73	1.37 ± 0.69	1.48 ± 0.73	1.41 ± 0.77
Kampong Speu	1.37 ± 0.49	1.13 ± 0.35	–	1.43 ± 0.65	1.13 ± 0.35	–	1.05 ± 0.23	1.00 ± 0.00	–
Prey Veng	3.81 ± 1.76	4.17 ± 2.00	5.14 ± 0.86	5.38 ± 3.24	6.06 ± 3.56	11.29 ± 4.65	1.41 ± 0.64	1.45 ± 0.84	2.19 ± 1.13
Siem Reap	1.73 ± 1.27	3.14 ± 1.29	–	3.64 ± 2.20	4.78 ± 2.40	–	2.11 ± 1.10	1.52 ± 0.95	–
Takeo	3.14 ± 1.29	4.77 ± 1.31	4.00 ± 0.94	6.00 ± 3.46	8.27 ± 3.50	6.55 ± 2.52	2.00 ± 0.87	1.73 ± 0.73	1.64 ± 0.85

(–): Not practiced

Table 5. Pesticide application methods by rice system and province.
Tableau 5. *Méthodes d'application des pesticides par les systèmes rizicoles dans chaque province.*

Province	Machine sprayer with a tank (%)			Drone sprayer (%)			Manual tank sprayer (%)			Manual application (by hand) (%)		
	One cycle-system	Two cycle-system	Three cycle-system	One cycle-system	Two cycle-system	Three cycle-system	One cycle-system	Two cycle-system	Three cycle-system	One cycle-system	Two cycle-system	Three cycle-system
Battambang	0.00	32.51	37.50	0.00	49.75	45.83	0.00	9.85	16.67	0.00	7.88	0.00
Kampong Thom	87.18	93.87	0.00	0.00	0.00	0.00	7.69	1.84	0.00	5.13	4.29	0.00
Kampong Cham	86.27	95.00	100	0.00	0.00	0.00	7.84)	0.00	0.00	5.88	5.00	0.00
Kampong Speu	47.37	11.11	0.00	0.00	0.00	0.00	10.53	44.44	0.00	42.11	44.44	0.00
Prey Veng	65.57	86.67	91.67	0.00	0.00	0.00	8.20	8.00	8.33	26.23	5.33	0.00
Siem Reap	73.68	34.51	0.00	0.00	35.40	0.00	5.26	22.12	0.00	21.05	7.96	0.00
Takeo	77.78	91.13	87.50	0.00	0.00	0.00	0.00	0.00	8.93	22.22	8.87	3.58

4 Discussion

The results of this study concern 210 rice farmers in Cambodia and are therefore not representative of broader dynamics of rice cultivation in the entire country. Nevertheless, they are important first steps in observing both intensive and extensive rice farming practices across small and large farms, to highlight the variability of farming practices within the study areas and socio-economic contexts.

Prevention of pests, weeds, and diseases emergence, biodiversity conservation, and soil health are the three main pillars of agroecological crop protection (Deguine *et al*., 2023). Our study shows that increasing the number of rice crops per year per plot led to more frequent pesticide applications of treatments per crop cycle. Accordingly, the three cycle-system required more pesticide applications than the one- and two-cycle systems. Similarly, Schreinemachers *et al*. (2017) showed that intense rice cultivation often involves excessive use of pesticides, while a study by Castilla *et al*. (2019) indicated that intensifying rice production poses challenges to achieving sustainability, mainly due to the improper use of agricultural inputs. Farmers interviewed in our study relied on various pesticides, particularly insecticides, which were also found by Matsukawa et al. (2016) and Dunn et al. (2023). In our study, farmers often reported mixing different products in one spray because they believed that doing so enhanced the effectiveness of treatments more than using a single product. This is similar to the results obtained by Flor *et al*. (2019), who found that farmers mixed both different types and brands of the same type of pesticide in one application. Such practices can trigger pest outbreaks and contribute to resistance (Matteson, 2000).

Our results differ from those obtained by Matsukawa *et al*. (2016) in some points: in their study, farmers interviewed in Takeo and Prey Veng applied 13.4 and 12.8 pesticides per cycle, including plant growth activators, whereas in our study, 7.15 and 7.35 pesticides were applied per cycle in the two provinces respectively, excluding growth activators across all systems. Conversely, in Siem Reap, we found an average of 4.51 pesticides in 2.81 applications per cycle across all systems, significantly higher than the 2 pesticides in 1.1 applications per cycle reported in 2016 by Matsukawa et al. This difference may reflect recent shifts in agricultural practices from 2016 to 2023 toward greater cropping intensity, particularly in Siem Reap province. These changes also reflect important transformations in the Cambodian rice sector over the last decade (Cramb, 2020). The introduction of products like antibiotics and molluscicides, which were previously not used to grow rice in Cambodia, highlights the need for long-term monitoring to track changing practices, given their use has already been reported for different crops in many countries around the world (Taylor and Reeder, 2020).

The present study identified 68 active ingredients, including 33 banned in the European Union (University of Hertfordshire, 2024). Pesticides in Cambodia are produced in China, India, or Vietnam, with labels translated before sale; only one product lacked a translated label, suggesting direct purchase in a neighboring country. Unlike Chanchao (2023), we found no highly hazardous pesticides except Abamectin, which is associated with significant health risks (Abdel Rahman, 2023; Rajaratnam *et al*., 2024) and is used in products

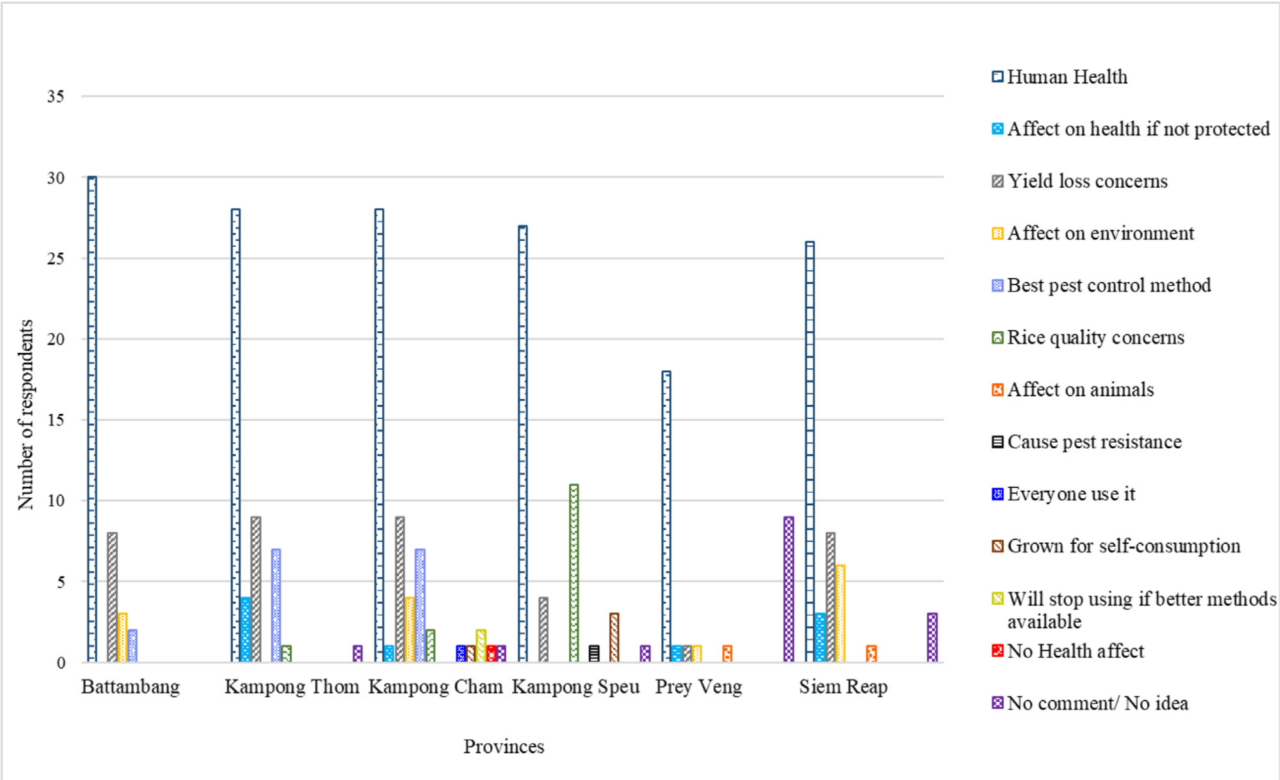

Figure 4. Farmers' perception of the consequences of pesticides.
Figure 4. *Perception des agriculteurs sur les conséquences des pesticides.*

aiming to control snails and insects. The toxicity of Abamectin is of considerable concern because this product is widely used in all the provinces we studied. In the least intensive rice system (one cycle-system) in each province, the farmers still applied one molluscicide and one herbicide, highlighting the importance of snails and weeds as biotic constraints and the need for alternative control.

Concerning the sources of information, farmers rarely adhere strictly to the recommendations and information on the product label but tend to follow the advice given by pesticide sellers when they select products and determine rates of application. This is in line with the results reported by Flor *et al*. (2019). Studies in other Asian countries have also documented pesticide sellers as the main or sole source of information and recommendations concerning pest control (Van Hoi *et al*., 2013; Heong *et al*., 2014). It is thus important to take pesticide sellers into account when providing training and raising awareness about hazardous pesticides and alternative measures, as well as to develop other sources of information like social media or local extension agents to make recommendations on pesticides.

Pesticide application methods varied across rice systems and study areas, influenced by convenience, availability, cost, perceptions, and perceived effectiveness. Drone spraying, a recent method not previously documented, is now widely used in Battambang and is emerging in Siem Reap province. As farmers in these two provinces have average plot sizes of 5.49 ha and 5.36 ha, respectively on average, drones may be the most practical method for pesticide application, in line with the results of Ganesh *et al*. (2022), who noted that farmers who used drones considered that the method reduces effort and direct exposure and is efficient for large farms facing labor shortages. Drone services are accessible in these locations and farmers opt to use drones when service providers are available, as also reported by Maikaensarn and Chantharat (2020). When using drones for pesticide applications, the farmers in our survey continued to purchase the products they used previously as they are hesitant to use products selected by drone operators. Drone spraying was not observed in any system in Takeo, Kampong Thom, Kampong Cham, Kampong Speu, and Prey Veng, certainly because of the absence of service providers in these areas. But according to the fast changes in Cambodia, future surveys will be necessary to see if these services become popular in the whole country. At the same time, farmers are concerned about this method limited flexibility and uncertain effectiveness compared to mechanized or hand spraying that can be controlled directly, as described in a report by Maikaensarn and Chantharat (2020). Nevertheless, the environmental impact of drones raises serious concerns as there is reduced precision in spray targeting, particularly in rice-growing landscapes.

Most of the farmers interviewed expressed concern about the health risks of pesticides, but continued use was motivated by fear of yield loss if they stopped. The group of farmers interviewed in Prey Veng province appeared to be less concerned. This may be linked to lower literacy and education levels, so they may thus be less informed about health risks. Pesticide use has been associated with significant environmental problems across many regions in Asia, Africa, Latin America, the Middle East, and Eastern Europe (Elibariki and Maguta, 2017). In our study, 8% of farmers are concerned about the environmental impact of pesticides, and fewer than 1% of farmers were willing to stop using pesticides if viable alternatives emerge. According to Bakker *et al.* (2021a), individual farmers often perceive limited agency in reducing pesticide use, indicating the potential need for collective action to overcome these barriers.

According to FAO (2018), to mitigate the adverse effects of high-intensity rice farming among local farmers, and there is a need for targeted agricultural extension that promotes alternatives such as agroecological approaches that account for regional conditions, soil health, and the socioeconomic contexts of local farmers. Practices like crop diversification, bio-inputs, and IPM could improve soil fertility, enhance biodiversity, and reduce pest pressure, which, in turn, would help reduce pesticide use (Pretty and Bharucha, 2015; Chhay *et al*., 2017; Flor *et al*., 2018; Deguine *et al*., 2023; Vikas and Ranjan, 2024). Recently, the Ministry of Agriculture, Forestry and Fisheries of Cambodia recruited 1600 Commune agricultural officers (CAOs) to work closely with local farmers, to provide them with adequate support to adopt innovative practices, enhance productivity, and improve livelihoods and achieve economic benefits (MAFF, 2023b). In addition, agricultural cooperatives help promoting sustainable practices by working closely with local farmers. Both CAOs and agricultural cooperatives are well-positioned to educate farmers on the human and environmental risks of pesticide use and to provide essential training in agroecological practices, improving productivity and market access (Elbarazi *et al*., 2022; MAFF, 2023b; Kalogiannidis *et al*., 2024). Several countries have successfully built agricultural extension services to promote sustainable farming by transferring technology, sharing knowledge, and building farmer capacity. These services aim to improve the productivity and efficiency of agricultural production and agribusiness, support environmental protection, and contribute to rural development. For instance, in Vietnam, a study in Quang Binh province assessed farmers' satisfaction with agricultural extension services, revealing a positive relationship between service quality and farmer satisfaction, particularly in areas like assurance, reliability, and empathy (Truong, 2022). Similarly, farmer field schools and peer learning initiatives have been identified as effective mechanisms for building trust and motivating farmers to adopt agroecological practices (Murthy *et al*., 2019; Bakker *et al*., 2021b). Peer learning is central to agroecological transitions. In Mexico, case studies reveal that farmer-to-farmer learning has enabled small-scale producers to minimize reliance on external inputs and navigate challenges posed by climate change and market volatility. This approach contributed to increased resilience through locally adapted, knowledge-based solutions (Varghese and Van, 2017; Gliessman *et al*., 2018).

5 Conclusion

The present study highlights the links between agricultural intensification and pesticide use in rice production in Cambodia. The high frequency of pesticide treatments in intensive rice farming systems, the widespread mixing of different pesticides, the wide range of active ingredients, and the emerging adoption of drone spraying, reflect evolving agricultural practices in Cambodia. Despite known human and environmental health risks, most farmers interviewed continue using pesticides due to concerns over yield loss. However, some expressed willingness to adopt alternative practices. The results of this study could be used to develop projects and policies to reduce pesticide exposure and protect farmers' health.

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References

Abdel Rahman KM. 2023. Effects of abamectin and fipronil insecticides on the brain and compound eyes of the embryo of *Heteracris littoralis* (Rambur) (Orthoptera: Acrididae). *International Journal of Tropical Insect Science* 43 (4): 1237–1241. https://doi.org/10.1007/s42690-023-00989-6.

Brown D. 2002. A report by the Environmental Justice Foundation, "Death in Small Doses": Cambodia's pesticide problems and solutions, 40 p. www.ejfoundation.org.

Bakker L, Sok J, van der Werf W, Bianchi FJJA. 2021a. Kicking the habit: what makes and breaks farmers' intentions to reduce pesticide use? *Ecological Economics* 180. https://doi.org/10.1016/j.ecolecon.2020.106868.

Bakker T, Dugué P, de Tourdonnet S. 2021b. Assessing the effects of farmer field schools on farmers' trajectories of change in practices. *Agronomy for Sustainable Development* 41 (2). https://doi.org/10.1007/s13593-021-00667-2.

Castella JC. 2012. Agrarian transition and farming system dynamics in the uplands of South-East Asia. In: *The 3rd International Conference on Conservation Agriculture in Southeast Asia*. Hanoi, Vietnam: Institut de Recherche pour le Développement, p. 245. https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers13-06/010058352.pdf

Castilla NP, Stuart AM, Makara O, Sathya K, Somany S, Kumar V, *et al.* 2019. Characterisation of cropping practices, pest constraints, and yield variation in irrigated lowland rice of Cambodia. *Crop Protection* 135: 1687–8191. https://doi.org/10.1016/j.cropro.2019.104906.

Chanchao C. 2023. Current status of pesticide practices and management approaches toward the safety and health of Cambodia: A review. Insight: *Cambodia Journal of Basic and Applied Research*. 5 (2): 9–21. https://doi.org/10.61945/cjbar.2023.5.2.03

Chhay N, Seng S, Tanaka T, Yamauchi A, Cedicol EC, Kawakita K, *et al.* 2017. Rice productivity improvement in Cambodia through the application of technical recommendation in a farmer field school. *International Journal of Agricultural Sustainability* 15 (1): 54–69. https://doi.org/10.1080/14735903.2016.1174811.

Chun N. 2014. Improving rice production and commercialisation in cambodia: findings from the farm investment climate assessment. Manila (Philippines): Asian Development Bank, 60 p. www.adb.org.

Cramb R. 2020. *White gold: The commercialisation of rice farming in the lower Mekong basin*. Singapore: Springer Nature, 456 p. https://doi.org/10.1007/978-981-15-0998-8.

Deguine JP, Aubertot JN, Bellon S, Côte F, Lauri PE, Lescourret F, *et al.* 2023. Agroecological crop protection for sustainable agriculture. *Advances in Agronomy* 178: 1–59. https://doi.org/10.1016/bs.agron.2022.11.002.

Dunn L, Latty T, Van Ogtrop FF, Tan DKY. 2023. Cambodian rice farmers' knowledge, attitudes, and practices (KAPs) regarding insect pest management and pesticide use. *International Journal of Agricultural Sustainability* 21 (1). https://doi.org/10.1080/14735903.2023.2178804.

Elibariki R, Maguta MM. 2017. Status of pesticide pollution in Tanzania – A review. *Chemosphere*, 178: 154–164. https://doi.org/10.1016/j.chemosphere.2017.03.036.

Elbarazi I, Chibueze S, Yazdanpanah M, Jiang H, Ren Z. 2022. Risk cognition, agricultural cooperatives training, and farmers' pesticide overuse: Evidence from Shandong Province, China. *Frontiers Public Health* 10: 1032862. https://doi.org/10.3389/fpubh.2022.1032862.

FAO. 2018. The 10 elements of agroecology guiding the transition to sustainable food and agricultural systems. Rome (Italy): FAO, 15 p. https://openknowledge.fao.org/handle/20.500.14283/i9037en

FAO. 2021. *National agricultural innovation system assessment in Cambodia consolidated report*. Rome (Italy): FAO, 48 p. https://openknowledge.fao.org/handle/20.500.14283/cb5159en

FAOSTAT. [2025 JT /10/25]. Pesticides use. https://www.fao.org/statistics/highlights-archive/highlights-detail/pesticides-use-and-trade−1990-2022/en

Flor RJ, Chhay K, Sorn V, Maat H, Hadi BAR. 2018. The technological trajectory of integrated pest management for rice in Cambodia. *Sustainability* 10 (6). https://doi.org/10.3390/su10061732.

Flor RJ, Maat H, Hadi BAR, Kumar V, Castilla N. 2019. Do field-level practices of Cambodian farmers prompt a pesticide lock-in? *Field Crops Research*. 235: 68–78. https://doi.org/10.1016/j.fcr.2019.02.019.

Flor RJ, Maat H, Hadi BAR, Then R, Kraus E, Chhay K. 2020. How do stakeholder interactions in Cambodian rice farming villages contribute to a pesticide lock-in? *Crop Protection.* 135. https://doi.org/10.1016/j.cropro.2019.04.023.

Ganesh PB, Chaitanya G, Sachin RD. 2022. Application of drone systems for spraying pesticides in advanced agriculture: A review. *International Conference on Advances in Mechanical Engineering. IOP Conf. Series: Materials Science and Engineering*. https://iopscience.iop.org/article/10.1088/1757-899X/1259/1/012015

Gliessman S, Jacobs N, Clément C, Grabs J, Agarwal B, Anderson M, *et al*. 2018. Case studies 02 breaking away from industrial food and farming systems. Seven case studies of agroecological transition. www.ipes-food.org.

Heong KL, Wong L, Delos Reyes JH. 2014. Addressing planthopper threats to Asian rice farming and food security: fixing insecticide misuse. In: Heong KL, Cheng J, Escalada M. (Eds.), Rice Planthoppers: Ecology, Management, Socioeconomics, and Policy. Dordrecht (NL): Springer. https://doi.org/10.1007/978-94-017-9535-7_3.

Jensen HK, Konradsen F, Jørs E, Petersen JH, Dalsgaard A. 2011. Pesticide Use and Self-Reported Symptoms of Acute Pesticide Poisoning among Aquatic Farmers in Phnom Penh, Cambodia. *Journal of Toxicology* 2011, 639814. https://doi.org/10.1155/2011/639814

Kalogiannidis S, Karafolas S, Chatzitheodoridis F. 2024. the key role of cooperatives in sustainable agriculture and agrifood security: Evidence from Greece. *Sustainability* 16 (16). https://doi.org/10.3390/su16167202.

Maikaensarn V, Chantharat M. 2020. Effectiveness analysis of drone use for rice production in central Thailand. Sakata, Shozo ed. 2020. *Structural Changes of Agriculture in the CLMTV Countries and their Socio-Economic Impacts,* BRC Research Report. Bangkok Research Center, JETRO Bangkok/ IDE-JETRO, 8 p. https://www.ide.go.jp/library/English/Publish/Reports/Brc/pdf/27_05.pdf.

Matsukawa M, Ito K, Kawakita K, Tanaka T. 2016. Current status of pesticide use among rice farmers in Cambodia. *Applied Entomology and Zoology* 51 (4): 571–579. https://doi.org/10.1007/s13355-016-0432-5.

Matteson PC. 2000. Insect pest management in tropical Asian irrigated rice. *Annual Review of Entomology* 45 (1): 549–574. https://doi.org/10.1146/annurev.ento.45.1.549.

Ministry of Agriculture, Forestry and Fisheries (MAFF). 2022 *List of pesticides in Cambodia*, Prakas No. 252. Ministerial Proclamation No. 252 MAFF dated 20 April 2022, updating the pesticide list including banned, restricted and permitted products, (Khmer version).

Ministry of Agriculture, Forestry and Fisheries (MAFF). 2023a. *Summary report on agricultural, forestry, and fishery work for 2022 and implementation direction for 2023*. Ministry of Agriculture, Forestry and Fisheries, Phnom Penh, Cambodia. pp. 4–7. (Khmer version)

Ministry of Agriculture, Forestry and Fisheries (MAFF). 2023b. The 5th and 6th priority policy program of the royal government, 7th legislature of the national assembly. Chapter 2: Policy Program for Deployment of Commune / Sangkat Officials. pp. 8–13. (Khmer version)

Murthy L, Raj S, Kallur M. 2019. *Inspiring stories from innovative farmers*. National Institute of Agricultural Extension Management (MANAGE). Rajendranagar, Hyderabad, India. https://www.researchgate.net/publication/333238362.

Pin S, Mihara M. 2013. The Study on Conventional Farming Practice-A Case Study of Farmers' Practice in Samroung Village, Cambodia. *International Journal of Environmental and Rural Development* 4 (1): 202–208. https://www.jstage.jst.go.jp/article/ijerd/4/1/4_202/_article/-char/en

Preap V, Sareth K. 2015. Current use of pesticides in the agricultural products of Cambodia. FFTC Agricultural policy platform/fftc-ku international workshop on risk management on agrochemicals through novel technologies for food safety in Asia. https://ap.fftc.org.tw/article/98.

Pretty J, Bharucha ZP. 2015. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. Insects 6 (1): 152–182. https://doi.org/10.3390/insects6010152.

Rajaratnam A, Kularatne WKS., Bowattage S. 2024. Abamectin poisoning: a case report and review of literature. *Asian Journal of Internal Medicine* 3 (1): 49–53. https://doi.org/10.4038/ajim.v3i1.95.

Royal Royal Government of Cambodia (RGC). 2010. *The promotion of paddy production and rice export approved by the council of ministers*, 45 p. https://faolex.fao.org/docs/pdf/cam189808.pdf.

Schreinemachers P, Chen H, Pu Nguyen TTL, Buntong B, Bouapao L, Gautam S, *et al.* 2017. Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia. *Science of the Total Environment* 593-594: 470–477. https://doi.org/10.1016/j.scitotenv.2017.03.181.

Takeshima H, Joshi PK. 2019. Overview of the agricultural modernisation in Southeast Asia. *International Food Policy Research Institute (IFPRI)*, Discussion Paper No 1819. https://doi.org/10.2499/9780896293830_04

Taylor P, Reeder R. 2020. Antibiotic use on crops in low- and middle-income countries is based on recommendations made by agricultural advisors. *CABI Agriculture and Bioscience* 1: 1. https://doi.org/10.1186/s43170-020-00001-y.

Truong DD. 2022. Farming Households' Satisfaction with Quality of Agricultural Extension Services: A Case Study of Quang Binh Province, Vietnam. *Frontiers in Sustainable Food Systems* 5. https://doi.org/10.3389/fsufs.2021.779477.

University of Hertfordshire. [2024/05/03]. A to Z list of pesticide properties database (PPDB), http://sitem.herts.ac.uk/aeru/ppdb/en/atoz.htm

Van Hoi P, Mol A, Oosterveer P. 2013. State governance of pesticide use and trade in Vietnam. *NJAS – Wageningen Journal of Life Sciences*. 67 (1): 19–26. https://doi.org/10.1016/j.njas.2013.09.001.

Varghese S, Van GZ. 2017. *Agroecological Transition in Mexico: ANEC's Journey to a Better Farm and Food System*. Rome (Italy): Food and Agriculture Organisation of the United Nations (FAO). http://www.fao.org/3/a-bt410e.pdf

Vikas, Ranjan R. 2024. Agroecological approaches to sustainable development. In *Frontiers in Sustainable Food Systems* (Vol. 8) *Frontiers in Sustainable Food Systems* 8. https://doi.org/10.3389/fsufs.2024.1405409

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