Reducing vector-borne disease by empowering farmers in integrated vector management

Henk van den Berg,[a] Alexander von Hildebrand,[b] Vaithilingam Ragunathan[c] & Pradeep K Das[d]

Problem Irrigated agriculture exposes rural people to health risks associated with vector-borne diseases and pesticides used in agriculture and for public health protection. Most developing countries lack collaboration between the agricultural and health sectors to jointly address these problems.

Approach We present an evaluation of a project that uses the "farmer field school" method to teach farmers how to manage vector-borne diseases and how to improve rice yields. Teaching farmers about these two concepts together is known as "integrated pest and vector management".

Local setting An intersectoral project targeting rice irrigation systems in Sri Lanka.

Relevant changes Project partners developed a new curriculum for the field school that included a component on vector-borne diseases. Rice farmers in intervention villages who graduated from the field school took vector-control actions as well as improving environmental sanitation and their personal protection measures against disease transmission. They also reduced their use of agricultural pesticides, especially insecticides.

Lessons learned The intervention motivated and enabled rural people to take part in vector-management activities and to reduce several environmental health risks. There is scope for expanding the curriculum to include information on the harmful effects of pesticides on human health and to address other public health concerns. Benefits of this approach for community-based health programmes have not yet been optimally assessed. Also, the institutional basis of the integrated management approach needs to be broadened so that people from a wider range of organizations take part. A monitoring and evaluation system needs to be established to measure the performance of integrated management initiatives.

Bulletin of the World Health Organization 2007;85:561–566.

Une traduction en français de ce résumé figure à la fin de l'article. Al final del artículo se facilita una traducción al español. .الترجمة العربية لهذه الخلاصة في نهاية النص الكامل لهذه المقالة

Background and context

Malaria and other vector-borne diseases are a major public health problem in WHO's South-East Asia Region.[1] In the wake of increasing resistance to both drugs and pesticides, there is a need to establish integrated vector management strategies that are less reliant on chemical methods of disease control. These strategies should involve other sectors and local communities in managing the ecosystem to reduce health risks and increase the sustainability of programmes to control vector-borne diseases.[2,3]

There is an opportunity for integrated vector management strategies to exploit tropical agriculture's rich experience in integrated pest management strategies. Briefly, integrated pest management that uses the "farmer field school" approach entails providing practical, field-based education to farmers during weekly meetings. During these sessions farmers acquire the skills needed to analyse their ecosystem and make evidence-based decisions to grow healthy crops while relying less on agrochemical inputs.[4,5] Special attention is given to developing communication skills and strengthening farmers' groups. The farmer field schools that address rice farming commonly result in immediate farm-level benefits in terms of reductions in the use of agrochemicals and in developing stable or increased yields; they are a proven entry point for farmer-driven development.[6] Farmer field schools were introduced in Sri Lanka in 1995, and were scaled up in 1999–2002, when almost 1000 field schools were held. Technical assistance was provided by the Food and Agriculture Organization (FAO) of the United Nations. An 82% reduction in frequency of insecticide applications and a 23% increase in yield have been attributed to training, and these results proved durable during a period of five years.[7,8]

A pilot project on integrated pest and vector management that started in Sri Lanka in 2002 has been unique in educating farmers about agriculture and public health by involving farmers in vector-management activities.[9] Project funds have been limited and funding sources diverse. The FAO facilitated the project and provided the initial grant of US$ 35 000, which was the only source of external funding during the first three years (Phase I). The United Nations Environment Programme provided US$ 56 500 during 2005–2007 (Phase II), and WHO supported an evaluation mission in 2006.

The project has several institutional partners. The central-level Plant

---

[a] Laboratory of Entomology, Wageningen University, PO Box 8031, 6700 EH Wageningen, the Netherlands. Correspondence to Henk van den Berg (e-mail: henk.vandenberg@wur.nl).

[b] Environmental Health, WHO Regional Office for South-East Asia, New Delhi, India.

[c] Food and Agriculture Organization, New Delhi, India.

[d] Vector Control Research Centre, Pondicherry, India.

doi: 10.2471/BLT.**06.035600**

(*Submitted: 9 August 2006 – Final revised version received: 15 January 2007 – Accepted: 25 January 2007*)

Protection Service of the Department of Agriculture, part of the Ministry of Agriculture, conducts technical coordination. The Department of Agriculture Offices at the district level and the Mahaweli Authority, which governs major irrigation schemes, implement the field schools. The Department of Public Health's Anti-Malaria Campaign, part of the Ministry of Health, has assisted in curriculum development and monitors mosquito populations.

This paper is based on the findings of an evaluation mission in June 2006, commissioned by WHO's Regional Office for South-East Asia, to determine the effectiveness, sustainability and replicability of the integrated pest and vector management approach in the context of implementing WHO's integrated vector management strategy.[10] Data were obtained through field visits, discussions with farmers and other stakeholders, and unpublished records and reports.

The problems

At the field level, irrigated agriculture poses several public health risks associated with vectors of human disease and the use of pesticides for agriculture and to protect public health. Paddy fields, irrigation systems and peridomestic environments facilitate breeding of vectors of malaria, lymphatic filariasis, Japanese encephalitis and dengue.[11–15] Additionally, the use of insecticides may cause acute poisoning and leave toxic residues in food;[16,17] resistance may develop in vector populations against the insecticides used for control;[18,19] and biodiversity may be degraded, which may contribute to a resurgence of mosquitoes.[20,21] Therefore, convergence is needed between integrated pest management strategies and integrated vector management strategies to help farmers improve their agricultural practices while minimizing environmental risks to health. However, the intersectoral collaboration required to jointly address environmental health risks is lacking in most developing countries.

An international workshop facilitated by the United Nations Environment Programme provided the basis for intersectoral project development in Sri Lanka. The triggers were the Stockholm Convention on Persistent Organic Pollutants, the Bahia Declaration of the Intergovernmental Forum on Chemical Safety and World Health Assembly resolution WHA-50.13, all of which call on countries to develop viable alternative strategies for controlling vector-borne diseases, particularly malaria, and to reduce reliance on insecticides through the promotion of integrated pest-management approaches.

Box 1. **Lessons learned**

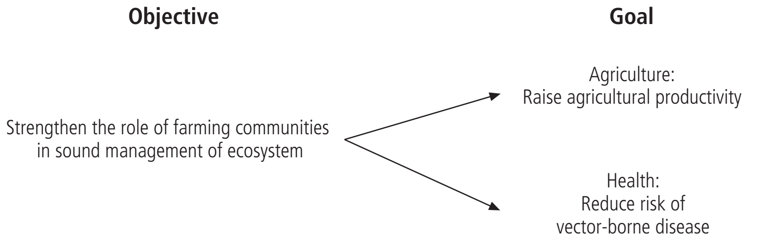
Role of farmers: The farmer field school intervention focusing on integrated pest and vector management motivates and enables rural people to take part in vector-management activities in their agricultural and peridomestic environments. It also helps reduce the agricultural use of insecticides and reliance on pesticides to protect public health.

Curriculum: There is scope to expand the curriculum to cover the health effects of pesticides.

Role for the health sector: Benefits of the intervention for other community-based health programmes that relate to vector-borne disease and the use of pesticides need to be further developed. This could be done, for example, by involving communities in the surveillance of vector populations and local health staff in farmer field school sessions.

Institutional basis: Extending the institutional basis by involving more organizations in integrated pest and vector management will be essential to allow this interdisciplinary approach to progress beyond the pilot stage. A more efficient monitoring and evaluation system needs to be integrated into the project.

Fig. 1. **How a shared objective contributes to sector-specific goals in agriculture and health**



Addressing the problems

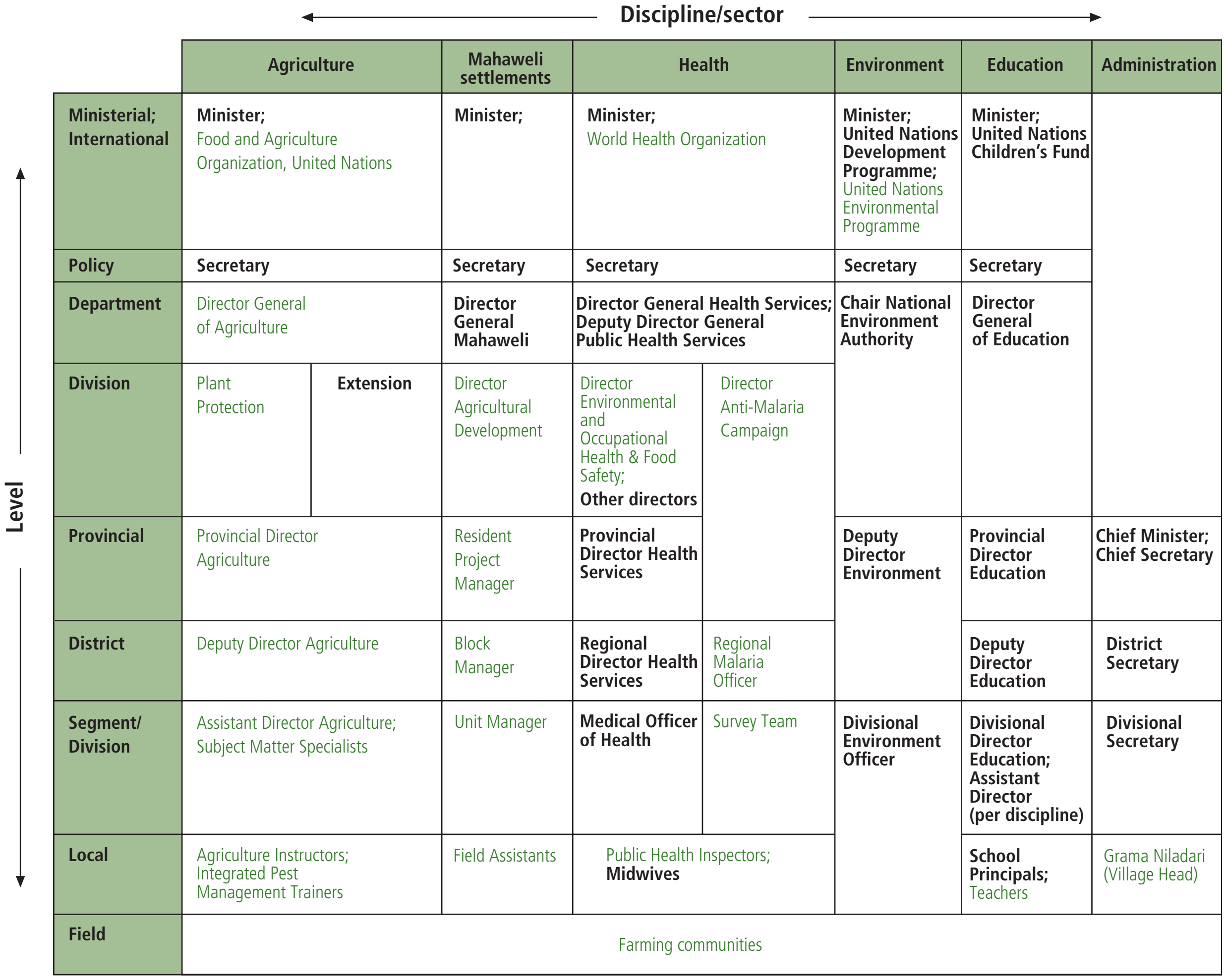
At a project-inception workshop held early in 2002, multisectoral stakeholders agreed upon objectives and a course of action. Subsequently, field-based workshops were held where trainers in integrated pest management and vector specialists learned from each other about vector ecology, agro-ecology and environmental management options. As curriculum development began, surveys on farmers' knowledge and perceptions were used to tailor the curriculum to meet local needs. Field-testing was done and improvements made to new exercises on sampling methods, identifying mosquitoes, the breeding habitat, the life-cycle of the mosquito, predators of mosquitoes and the disease cycle. The end result was a field school curriculum on integrated pest and vector management that differed from that on integrated pest management.[10] The duration of the field school was increased from 16 weeks to 20 weeks; the vector management component focused on the beginning of the season, when most vector breeding occurs.

The field schools were implemented during both the long rainy season and the short rainy season; in recognition of the flight radius of vector mosquitoes, the schools were clustered within villages to achieve area-wide effects. Alumni of the new field schools were guided in techniques of problem analysis and in planning exercises to assist them in taking action.

By mid-2006, the project has held 67 farmer field schools on integrated pest and vector management (with 20–30% of participants being women) involving 1000 families of farmers in 11 locations. The Anti-Malaria Campaign conducted fortnightly mosquito surveys in two locations during the course of the project to monitor its impact. Each location had an intervention and comparison village separated by 2–4 km, in line with the maximum flying range of 2–3 km for *Anopheles* mosquitoes.[13,22]

Central-level workshops have been held every season since 2002 to assist in the evaluation and planning of field activities. The project has supported field

Fig. 2. **Present and potential stakeholders of the integrated pest and vector management strategy**[a]



	Agriculture		Mahaweli settlements	Health		Environment	Education	Administration
Ministerial; International	**Minister;** Food and Agriculture Organization, United Nations		**Minister;**	**Minister;** World Health Organization		**Minister; United Nations Development Programme;** United Nations Environmental Programme	**Minister; United Nations Children's Fund**	
Policy	**Secretary**		**Secretary**	**Secretary**		**Secretary**	**Secretary**	
Department	Director General of Agriculture		**Director General Mahaweli**	**Director General Health Services; Deputy Director General Public Health Services**		**Chair National Environment Authority**	**Director General of Education**	
Division	Plant Protection	**Extension**	Director Agricultural Development	Director Environmental and Occupational Health & Food Safety; **Other directors**	Director Anti-Malaria Campaign			
Provincial	Provincial Director Agriculture		Resident Project Manager	**Provincial Director Health Services**		**Deputy Director Environment**	**Provincial Director Education**	**Chief Minister; Chief Secretary**
District	Deputy Director Agriculture		Block Manager	**Regional Director Health Services**	Regional Malaria Officer		**Deputy Director Education**	**District Secretary**
Segment/ Division	Assistant Director Agriculture; Subject Matter Specialists		Unit Manager	**Medical Officer of Health**	Survey Team	**Divisional Environment Officer**	**Divisional Director Education; Assistant Director (per discipline)**	**Divisional Secretary**
Local	Agriculture Instructors; Integrated Pest Management Trainers		Field Assistants	Public Health Inspectors; **Midwives**			**School Principals;** Teachers	Grama Niladari (Village Head)
Field	Farming communities							

[a] Green type indicates that stakeholders have been exposed to the project either in the field or in meetings. Bold type indicates potential stakeholders who have not been exposed to the project.

experimentation by trainers and farmers to study interactions between agricultural practices such as the use of fertilizer and vector breeding. A part-time national expert was recruited in 2005 to assist in coordinating the project.

Field visits and group discussions in 2006 revealed that field school alumni were able to distinguish between beneficial and harmful insects, and to identify larvae and adults of three vector mosquito genera (*Anopheles*, *Culex*, *Aedes*). Alumni had acquired the skills necessary to analyse their agricultural and peridomestic environments and make locally appropriate decisions to manage vectors, pests and crops.

Alumni reported that they applied insecticide less frequently during rice production as a result of becoming more aware of adverse effects. Common vector-control actions that contributed to reducing local risk were eliminating breeding sites, rearing fish for household use, cleaning surroundings, applying mineral oil to bodies of water, covering water containers and using bednets. The field school generated visible enthusiasm and self-confidence among farmers. At one site, field school alumni had reportedly approached the Anti-Malaria Campaign office to learn about vector-borne diseases. Nevertheless, the monitoring and evaluation framework needs to be strengthened to ensure evidence-based recording of the project's performance.

A separate study by Yasuoka et al. verified an impact on knowledge, agricultural practices and vector-control actions that were attributable to the integrated pest and vector management intervention.[23] The study also reported a 60% increase in the use of bednets, also attributable to the intervention, indicating there was an increased awareness about personal protection. The same researchers suggested that the role of farmers in vector management was most important during the short rainy season, when ecosystem management is associated with reduced densities of anopheline mosquitoes, thus providing an opportunity to interrupt local transmission of malaria.[24] However, the effect of the intervention on malaria transmission in areas where *Anopheles (Cellia) culicifacies* is more common remains to be studied. This species is considered to be the major malaria vector in Sri Lanka and has a preference for breeding in temporary pools and semiprotected wells.[25,26] Measuring the impact of the intervention on disease burden was beyond the scope of the pilot project owing to the limited scale of field operations. Data on the use of insecticides for public health protection were not available.

Discussion

The integrated pest and vector management strategy has helped farmers to minimize the use of agrochemicals, particularly insecticides; to improve agronomic practices; and to reduce health risks associated with vector-borne diseases and pesticides. Alumni from the farmer field school were motivated to take part in vector-management activities (Box 1). As the local evidence base expands, the curriculum could also emphasize the use of fertilizers, crop rotation and larvivorous fish for vector management.[27–29] Moreover, there is scope for expanding the curriculum to cover the health effects of pesticides, using exercises in participatory monitoring of signs and symptoms of poisoning,[30] and by extending farmers' knowledge of rice farming to other local crops that are sprayed with insecticides.

The sectors of agriculture and health, despite their differing goals of raising agricultural productivity and reducing health risks, share the objective of enhancing the role of rural communities in providing sound management of the local ecosystem (Fig. 1). This provides a motive for collaboration. Convergence between the activities of the health and agriculture sectors during the project's first year resulted in effective cross-sector learning and a joint process of curriculum development. In the implementation phase, however, the surveillance activities by the Anti-Malaria Campaign were not integrated with the activities of the field school. Convergence was limited to holding seasonal joint workshops. A lesson learned is that field-level integration requires better synchronization of the Anti-Malaria Campaign's surveillance with weekly field school activities to allow for interaction and mutual learning; regular district-level forums for local stakeholders are also desirable. Also, finding ways to increase the participation of local health staff needs to be addressed. The Anti-Malaria Campaign plans to adopt the integrated pest and vector management strategy to prevent malaria in areas of low transmission since there is an apparent additive effect between the use of bednets and the strategy.

The health sector's current surveillance system, which is constrained by limited resources, could benefit from community participation by developing local capability in monitoring and evaluation. Benefits of community-based surveillance are twofold: it provides better coverage and intervals for data collection, allowing for the more accurate and timely targeting of interventions, and it contributes to a local feeling of project ownership, enhancing preventive community action and personal protection. Increasing the participation of the health sector in integrated pest and vector management initiatives would further improve the performance of community-based health programmes.

Another lesson learned is that potential stakeholders – at the policy level, senior level and district level – need exposure to the strategy (Fig. 1, Fig. 2). Extending the institutional basis by involving more organizations in integrated pest and vector management is essential to achieving greater acceptance of the multisectoral approach. This would allow it to progress from an externally funded pilot programme to one supported by the national budget. For example, the strategy could be used as an interdisciplinary topic for project-based education in secondary schools.

In addition to its suitability under Sri Lankan conditions, the integrated pest and vector management approach is potentially replicable in other countries and other regions. It is as an adaptive educational approach that may initially focus on situations where vector-borne diseases are associated with irrigated environments for growing rice. The integrated pest and vector management approach could play a key part in meeting the global action goals of the Strategic Approach to International Chemicals Management. ■

Funding: WHO's Regional Office for South-East Asia supported the evaluation mission in 2006 and preparation of this paper.

Competing interests: None declared.

Résumé

Responsabilisation des agriculteurs dans le cadre de la lutte intégrée contre les vecteurs pour faire reculer les maladies à transmission vectorielle

Problématique L'agriculture irriguée expose la population rurale aux risques sanitaires liés aux maladies à transmission vectorielle et aux pesticides utilisés en agriculture et en santé publique pour protéger les populations. Dans la plupart des pays en développement, la collaboration entre les secteurs agricole et sanitaire est insuffisante pour faire face à ces problèmes.

Démarche Nous présentons l'évaluation d'un projet utilisant des stages pratiques pour agriculteurs en vue d'enseigner aux exploitants agricoles comment gérer les maladies à transmission vectorielle et améliorer les rendements en riz. L'enseignement apporté aux agriculteurs sur ces deux pratiques est appelé « lutte intégrée contre les parasites et les vecteurs ».

Contexte local Un projet intersectoriel concernant les systèmes d'irrigation des rizières au Sri Lanka.

Modifications pertinentes Les partenaires au projet ont mis au point un nouveau programme d'enseignement pour la formation pratique des agriculteurs, qui intègre une composante sur les maladies à transmission vectorielle. Des cultivateurs de riz habitant des villages concernés par l'intervention et ayant suivi avec succès cette formation ont pris des actions pour lutter contre les vecteurs, ainsi que des mesures d'assainissement et de protection individuelle pour empêcher la transmission des maladies. Ils ont aussi réduit leur consommation de pesticides agricoles, en particulier d'insecticides.

Enseignements tirés L'intervention a incité des ruraux à prendre part aux activités de gestion vectorielle et à réduire plusieurs risques menaçant l'hygiène de l'environnement. Elle leur a également apporté les moyens de le faire. Il est possible d'élargir le programme d'enseignement pour y introduire des informations sur les effets préjudiciables des pesticides sur la santé humaine et pour répondre aux préoccupations de santé publique. Les bénéfices de cette approche pour les programmes sanitaires communautaires n'ont pas été évalués au mieux. Il convient aussi d'élargir la base institutionnelle de la démarche de gestion intégrée afin qu'une gamme plus étendue d'organisations puissent y prendre part. Il faut également mettre en place un système de surveillance et d'évaluation pour mesurer les résultats des initiatives relevant de la gestion intégrée.

Resumen

Reducir las enfermedades transmitidas por vectores empoderando a los agricultores en la lucha antivectorial integrada

Problema La agricultura de regadío expone a la población rural a riesgos sanitarios asociados a las enfermedades de transmisión vectorial y a los plaguicidas utilizados en la agricultura y para proteger la salud pública. En la mayoría de los países en desarrollo se da una falta de colaboración entre los sectores agrícola y sanitario para abordar conjuntamente estos problemas.

Métodos Presentamos una evaluación de un proyecto que utiliza el método de la «escuela de campo para agricultores» para enseñar a los campesinos la manera de controlar las enfermedades de transmisión vectorial y mejorar la producción de arroz. El adiestramiento simultáneo de los agricultores en esos dos ámbitos es lo que se conoce como «control integrado de plagas y vectores».

Contexto local Un proyecto intersectorial centrado en los sistemas de riego de plantaciones de arroz en Sri Lanka.

Cambios destacables Los asociados del proyecto desarrollaron un nuevo programa de estudios para la escuela de campo que incluía un componente de control de las enfermedades de transmisión vectorial. Los cultivadores de arroz de las aldeas de intervención salidos de la escuela de campo tomaron medidas de lucha antivectorial y de mejora tanto del saneamiento ambiental como de su protección personal contra la transmisión de enfermedades. Además redujeron su utilización de plaguicidas agrícolas, especialmente de insecticidas.

Enseñanzas extraídas La intervención motivó a la población rural y le permitió participar en las actividades de control de los vectores y reducir varios riesgos para la salud ambiental. Es posible ampliar el programa de estudios para incluir información sobre los efectos perjudiciales de los plaguicidas en la salud humana y abordar otros aspectos preocupantes para la salud pública. Los beneficios de este enfoque para los programas de salud comunitarios todavía no se han evaluado de manera óptima. Además, es necesario ampliar la base institucional del control integrado para que puedan participar personas de una más amplia variedad de organizaciones, y hay que establecer un sistema de seguimiento y evaluación para medir el desempeño de las iniciativas de control integrado.

ملخص

إنقاص الأمراض المنقولة بالنواقل بتقوية قدرات المزارعين في مجال الإدارة المتكاملة لمكافحة النواقل

المشكلة: تُعَرِّض الزراعة المرويَّة السكان الريفيين لاختطار مرتفع مصاحبٍ للإصابة بالأمراض المنقولة بالنواقل وللتعرُّض لمبيدات الحشرات التي تستخدم في الزراعة وفي حماية صحة السكان. وتفتقر معظم البلدان النامية إلى التعاون بين القطاعات الصحية والزراعية لمواجهة هذه المشكلات معاً.

الأسلوب: نقدِّم تقييماً لأحد المشاريع التي تستخدمها ((المدرسة الميدانية للمزارعين)) كطريقة لتعليم المزارعين كيفية إدارة الأمراض المنقولة بالنواقل وكيفية زيادة محصول الرز. ويطلق على تعليم الفلاحين حول هذيْن المفهومَيْن معاً ((الإدارة المتكاملة لمكافحة النواقل والهوام)).

الموقع الحالي: مشروع متعدِّد القطاعات يستهدف نظم ري الرز في سري لانكا.

التغييرات الملائمة: أَعَدَّ الشركاء المساهمون في المشروع مقرَّراً دراسياً جديداً للمدارس الميدانية التي أُدْخِلَتْ باعتبارها أحد مكونات مكافحة الأمراض المنقولة بالنواقل. ويدرس الفَلاحون الذين يزرعون الرز في القرى التي طُبِّق فيها هذا المشروع، والذين تخرجوا من المدارس الميدانية، الأنشطة التي تُتَّخَذ لمكافحة النواقل، إلى جانب تحسين إصحاح البيئة، وسُبُل حمايتهم الشخصية من سراية الأمراض إليهم. كما أنقصوا من استخدامهم للمبيدات الزراعية ولاسيَّما مبيدات الحشرات.

الدروس المستفادة: أدى هذا التدخُّل إلى ترغيب القرويين وتمكينهم من أداء دورهم في أنشطة إدارة مكافحة النواقل لإنقاص عوامل الاختطار الصحية البيئية المختلفة. وهناك مجال لتوسيع المقرَّر الدراسي ليشمل معلومات حول التأثيرات الضائرة لمبيدات الهوام على صحة الناس ولمجابهة ما يعتري الصحة العمومية من قلق. ولم تُقَيَّم حتى الآن المنافع التي نتجت عن اتِّباع هذا الأسلوب في البرامج الصحية المجتمعية على أفضل وجه. ولابد من توسيع مدى الأسس المؤسسية لأسلوب الإدارة المتكاملة ليساهم فيها إناس من قطاعات أوسع من المنظمات. ولابد من إرساء نظام للتقييم والرصد لقياس آراء المبادرات في الإدارة المتكاملة.

References

1. *The World Health Report 2005: make every mother and child count.* Geneva: WHO; 2005.
2. *Global strategic framework for integrated vector management.* Geneva: WHO; 2004 (WHO/CDS/CPE/PVC/2004.10).
3. Townson H, Nathan MB, Zaim M, Guillet P, Manga L, Bos R, et al. Exploiting the potential of vector control for disease prevention. *Bull World Health Organ* 2005;83:942-7.
4. Kenmore PE. Integrated pest management in rice. In: Persley GJ., ed. *Biotechnology and integrated pest management.* Wallingford: CAB International; 1996:76-97.
5. Pontius JC, Dilts DR, Bartlett A. Ten years of IPM training in Asia: from farmer field school to community IPM. Bangkok: Food and Agricultural Organization; 2002.
6. van den Berg H, Jiggins J. Investing in farmers: the impacts of farmer field schools in relation to integrated pest management. *World Dev* 2007; 35:663-86.
7. van den Berg H, Senerath H, Amarasinghe L. Farmer field schools in Sri Lanka: assessing the impact. *Pesticides News* 2003;61:14-6. Available at: http://www.pan-uk.org/pestnews/Contents/pn61.htm
8. Tripp R, Wijeratne M, Piyadasa VH. What should we expect from farmer field schools: a Sri Lanka case study. *World Development* 2005;33:1705-20.
9. van den Berg H, Knols BGJ. The farmer field school: a method for enhancing the role of rural communities in malaria control? *Malar J* 2006;5:3.
10. van den Berg H, Das PK, von Hildebrand A, Ragunathan V. *Evaluation of the integrated pest and vector management (IPVM) project in Sri Lanka: mission report, July 2006.* New Delhi: WHO Regional Office for South-East Asia; 2006. Available at: http://www.searo.who.int/EN/Section23/Section1001/Section1110_12796.htm
11. Amerasinghe PH, Amerasinghe FP, Konradsen F, Fonseka KT, Wirtz RA. Malaria vectors in a traditional dry zone village in Sri Lanka. *Am J Trop Med Hyg* 1999;60:421-9.

12. Ijumba JN, Lindsay SW. Impact of irrigation on malaria in Africa: paddies paradox. *Med Vet Entomol* 2001;15:1-11.
13. Keiser J, Castro MC, Maltese MF, Bos R, Tanner M, Singer BH, et al. Effect of irrigation and large dams on the burden of malaria on a global and regional scale. *Am J Trop Med Hyg* 2005;72:392-406.
14. Erlanger TE, Keiser J, Castro MC, Bos R, Singer BH, Tanner M, et al. Effect of water resource development and management on lymphatic filariasis and estimates of populations at risk. *Am J Trop Med Hyg* 2005;73:523-33.
15. Keiser J, Maltese MF, Erlanger TE, Bos R, Tanner M, Singer BH, et al. Effect of irrigated rice agriculture on Japanese encephalitis, including challenges and opportunities for integrated vector management. *Acta Trop* 2005;95:40-57.
16. Kishi M. The health impacts of pesticides: what do we now know? In: Pretty J, ed. *The pesticide detox*. London: Earthscan; 2005:23-38.
17. Konradsen F, van der Hoek W, Cole DC, Hutchinson G, Daisley H, Singh S, et al. Reducing acute poisoning in developing countries: options for restricting the availability of pesticides. *Toxicology* 2003;192:249-61.
18. Diabate A, Baldet T, Chandre F, Akogbeto M, Guiguemde TR, Darriet F, et al. The role of agricultural use of insecticides in resistance to pyrethroids in *Anopheles gambiae s.l.* in Burkina Faso. *Am J Trop Med Hyg* 2002;67:617-22.
19. Overgaard HJ, Sandve SR, Suwonkerd W. Evidence of anopheline mosquito resistance to agrochemicals in northern Thailand. *Southeast Asian J Trop Med Public Health* 2005;36 Suppl 4:S152-7.
20. Service MW. Mortalities of the immature stages of species B of the *Anopheles gambiae* complex in Kenya: comparison between rice fields and temporary pools, identication of predators, and effects of insecticidal spraying. *J Med Entomol* 1977;13:535-45.
21. Settle WH, Ariawan H, Astuti ET, Cahyana W, Hakim AL, Hindayana D, et al. Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. *Ecology* 1996;77:1975-88.
22. Gilles HM, Warrell DA. *Bruce-Chwatt's essential malariology*. Oxford: Oxford University Press; 1993.
23. Yasuoka J, Mangione TW, Spielman A, Levins R. Impact of education on knowledge, agricultural practices, and community actions for mosquito control and mosquito-borne disease prevention in rice ecosystems in Sri Lanka. *Am J Trop Med Hyg* 2006;74:1034-42.
24. Yasuoka J, Levins R, Mangione TW, Spielman A. Community-based rice ecosystem management for suppressing vector anophelines in Sri Lanka. *Trans R Soc Trop Med Hyg* 2006;100:995-1006.
25. Amerasinghe FP, Konradsen F, Fonseka K, Amerasinghe PH. Anopheline (Diptera: Culicidae) breeding in a traditional tank-based village ecosystem in north central Sri Lanka. *J Med Entomol* 1997;34:290-7.
26. Premasiri DAR, Wickremasinghe AR, Premasiri DS, Karunaweera N. Malarial vectors in an irrigated rice cultivation area in southern Sri Lanka. *Trans R Soc Trop Med Hyg* 2005;99:106-14.
27. Ghosh SK, Tiwari SN, Sathyanarayan TS, Sampath TRR, Sharma VP, Nanda N, et al. Larvivorous fish in wells target the malaria vector sibling species of the *Anopheles culicifacies* complex in villages in Karnataka, India. *Trans R Soc Trop Med Hyg* 2005;99:101-5.
28. Victor TJ, Reuben R. Effects of organic and inorganic fertilizers on mosquito populations in rice fields of southern India. *Med Vet Entomol* 2000;14:361-8.
29. Qunhua L, Xin K, Changzhi C, Shengzheng F, Yan L, Rongzhi H, et al. New irrigation methods sustain malaria control in Sichuan Province, China. *Acta Trop* 2004;89:241-7.
30. Murphy HH, Hoan NP, Matteson P, Abubakar AL. Farmers' self-surveillance of pesticide poisoning: a 12-month pilot in northern Vietnam. *Int J Occup Environ Health* 2002;8:201-11.