EEPSEA PRACTITIONERS SERIES 2

Managing Agricultural Pollution

Insights from EEPSEA-Funded Studies

Economy and Environment Program for Southeast Asia
May 2009

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Foreword

We at the Economy and Environment Program for Southeast Asia (EEPSEA) are pleased to present to you the second monograph in the series that provides you with practical guidelines on the proper management of the environment. These guidelines were extracted from nine researches on environmental and resource economics funded by the Program.

Entitled *Managing Agricultural Pollution*, this monograph explores how to best address the four major forms of agricultural pollution in the region, namely: soil erosion, agrochemical misuse, extensive soil salinity, and the illegal dumping of agricultural wastes. Emphasized in the monograph are the economic losses suffered by the agricultural sector as a result of these phenomena and the dire need to address them so as to ensure food security in the years to come.

Like the others in this series, we have designed this monograph to be an easy-to-use reference for natural resource managers. Featured are management strategies that are general enough to transcend different socio-economic and political settings. Specific bio-physical interventions, policy reforms and institutional strengthening activities to control and minimize the environmental degradation brought about by man's agricultural activities are also recommended. However, we encourage users to build on and adapt the strategies presented here to better suit their unique situations. The studies reviewed for this monograph were conducted from 1999 to 2007, thus, their recommendations are based on the realities and experiences prevailing at the time they were conducted. The full text of each of the studies reviewed can be accessed at the EEPSEA website (www.eepsea.org) or through email (eepsea@idrc.org.sg).

The publication of this monograph is part of EEPSEA's commitment to improve natural resource management in the region through environmental economics research. We hope that this report is useful to your work.

Herminia Francisco
Director, EEPSEA

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Introduction

Climate change and the exponential population growth rate have put pressure on agricultural production in recent years having created the need to produce more at shorter intervals in limited land areas. In turn, this has triggered the misuse of agricultural production assets. The already limited agricultural land areas have been cultivated using erosive farming practices. Farmers have resorted to and abused the use of production technologies such as chemical fertilizers and pesticides to increase their yield and income. As a result, land has become degraded, waters polluted, human health impaired, and the overall environmental integrity compromised. Thus, in their desperate plight to increase production, the resulting agricultural pollution has further prevented peasant farmers from escaping the vicious cycle of low production and poverty.

Agricultural pollution in Southeast Asia takes many forms. The EEPSEA studies reviewed for this series point to four major contributors to agricultural pollution in the region: soil erosion, unregulated agrochemical use, soil salinity, and wanton dumping of agricultural wastes.

Soil erosion, one of the leading causes of agricultural pollution, is a major environment and socio-economic problem in many Southeast Asian countries. Cultivated land is easily washed away by heavy rains if soil conservation measures are not practiced. This accelerated erosion has led to reduced soil nutrient content, the development of unfavorable soil physical properties, and reduced crop yields.

Chemical pesticides, one of the most prominent solutions to eradicate insect-borne, endemic diseases, are also a source of pollution. The extensive and excessive use of many environmentally-persistent, non-patented, toxic, and cheap agrochemicals in developing Southeast Asian nations is of great concern as this can generate acute and chronic health problems as well as local and global environmental contamination.

Soil salinity is another major problem for agriculture in many parts of the world. Mostly affected by salinity problems are the semi-arid regions associated with the great river systems of Southeast Asia. The effects of salinity on agriculture can be dramatic. As salt levels build up, both wet and dry seasons are affected. Ultimately, farmers have to abandon part of their acreage, leaving landscapes which show a patchwork of productive irrigated fields and abandoned saline land.

Careless dumping of agricultural waste pollution is yet another source of agricultural pollution. In Vietnam, rice mills in the Hau Giang Province illegally dump 220,000 tons of husks into the Mekong Delta annually (VietnamNet.vn, 2008*).*

Soil erosion, environmental contamination from pesticide use, soil salinity, and the dumping of agricultural waste are just some of the agricultural pollution issues faced by the Southeast Asian agricultural sector today. The impact of these phenomena is further worsened by the farmer's continued use of incorrect agricultural practices due to the pressure to sustain high crop yields. If each form is left unabated, the regional economy will eventually suffer multimillion US$ losses because of decreasing crop yield. It will rob millions of peasant farmers of their land and lead to widespread unemployment and poverty.


Photo by NgyThanh

Farmer in Thanh Hoa, Vietnam.

Issues and Problems in Addressing Agricultural Pollution

Misuse of agricultural inputs and its on-site costs

Several prevalent land use practices have been proven to increase agricultural production costs because of their long-term effect on farmland fertility. Thus, in their effort to produce more with less, peasant farmers unwittingly cultivate their land using methods that cost them more in the long run.

The EEPSEA studies reviewed for this series highlight the economic losses experienced when facing agricultural pollution.

On-site economic costs of soil erosion

Soil erosion is the physical removal of the topsoil by various agents including falling rain, water flowing over and through the soil profile, wind, and gravitational forces (Lal, 1990 as cited by Bui Dung The, 2001). Human activities, such as crop production without appropriate conservation technology, accelerate the natural erosion process (Francisco, 1998 as cited by Bui Dung The, 2001).

Soil erosion's most notorious on-site effect is the decline in farmland fertility. Through accelerated soil erosion the soil's organic matter and nutrients are lost, its water-holding capacity is decreased, and the depth of cultivable soil is reduced (Bui Dung The, 2001). As a result, there is a decline in farm productivity leading to the loss of income, which particularly affects the marginal farmer (Barbier, 1996 as cited by Bui Dung The, 2001).

This vicious cycle is clearly illustrated in a study conducted by Tran Din Thao (2001) in the mountainous regions of Northern Vietnam. Taking the annual rainfall into consideration, the study used data on soil loss and the yield of maize and cassava from 1992 to 1998. According to the study results, the treatment without soil conservation measures lost more soil on the average as compared to the treatments that employed soil conservation. Moreover, maize yield decreased slowly under the treatments with soil conservation measures (5 percent per year) as compared to the treatment without soil conservation wherein the maize yield decreased very fast (17.4 percent per year). Furthermore, after seven years, soil loss in the treatment without soil conservation reduced the yield of maize by as much as 2.2 times of that under the treatment that used soil conservation. Based on the difference in gross value of production, this means that a farmer that did not use soil conservation would have lost VND 1,832.5 thousand (US$ 108.43) per hectare in 1998. The same trend was found in cassava production.

Photo by Tran Duc Toan, National Institute for Soils and Fertilizers, Chem, Hanoi, Vietnam

Land use on sloping land in Vietnam, inevitably causing soil erosion.

This impact of soil erosion may be more dramatic in the tropics than in temperate conditions. According to Lal (1990 as cited by Bui, 2001), the soil is more fragile and climactic conditions are more extreme in the tropics. This, coupled with the fact that the cost of land degradation in developing countries may be more than 15 percent of the gross national product (Barbier and Bishop, 1995 as cited by Bui, 2001), makes land degradation due to soil erosion an important concern for policymakers.

A study on the land use systems by Central Vietnam upland farmers revealed the extent of soil erosion associated with four land use systems, namely: a) upland rice-based system, b) upland sugarcane system, c) fruit tree-based agroforestry system, and d) eucalyptus-based system. Using the value of the annualized income loss, the on-site opportunity cost of soil erosion for each land use system per hectare as compared to the fruit tree-based agroforestry system are as follows, in increasing order: VND 635,000 (US$ 37.57) for the sugarcane system; VND 1,019,000 (US$ 60.29) for the eucalyptus-based system; and VND 1,022,000 (US$ 60.47) for the upland rice-based system (Bui Dung The, 2001).

Cost of agrochemical misuse

The use of agrochemicals is one of the most prevalent practices in modern agriculture. Chemical fertilizers boost the soil's nutrient content while chemical pesticides protect against crop pests and diseases. Both enhance farm yield thereby promising the farmer a high return for his labor and investment.

Because of these, farmers — especially those from developing countries — have been observed to overuse and misuse them, relying heavily on their promised results. This does not only negatively affect the ecological environment; it can also substantially affect profit maximization. A continuous increase in agrochemical application in excess of the necessary level will negatively affect economic return, which is why farmers need to keep the amount used at the optimal level in order to maximize profit. Sadly, this is not usually the case.

In a study conducted on the pesticide use in Vietnam's Mekong Delta paddy production, it was found that on average, farmers overused pesticides by 274.4 grams of the active ingredient causing them to lose VND 105,644 (US$ 6.25) per hectare (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999). Likewise, in China's Zhejiang Province, the optimal pesticide use level is 201 yuan (US$29.38) per hectare, which is 42 percent lower than the actual expenditure on pesticide use (Jikun Huang, et al., 2001).

The same is true of chemical fertilizer use. Rice farmers in the Mekong River Delta overused nitrogen by about 27 kg per hectare and underused phosphorus and potash by 56 kg and 5 kg per hectare, respectively. This has led to a cost of VND 43,390 (US$2.56) per hectare. For the 3,190,000 hectares of paddy cultivated area in the region, this translates to a total cost of VND 141 billion (US$ 8,343,000) (Nguyen Huu Dung, et al., 1999).


Photo by Sachin Sharma

Moreover, the application of nitrogen beyond the recommended rate while there is lesser potassium and phosphorus use is ultimately detrimental. As experienced by Red River Delta rice farmers and Ho Chi Minh City vegetable farmers, too much nitrogen makes the plant more susceptible to plant pests and lowers their resistance to diseases (Nguyen Huu Dung, et al., 1999). Clearly, the overuse of agrochemicals can also lead to ecological damages that can significantly increase agricultural production cost in the future.

A high application rate of agrofilm can also adversely affect plant growth (Funing Zhong, et al., 2006). Agrofilm is a kind of plastic film that is widely used by farmers in drought and cold areas to keep the soil moisture and raise soil temperature. The film is easily broken into small pieces that are difficult to pick up; hence, a large portion of them is left to accumulate in the soil. These pieces can prevent seedlings from sprouting or the roots of the seedlings from growing deep down into the soil. A survey has shown that the average quantity of agrofilm residues remaining in the soil in Xinjiang, China is 0.26 kg per hectare after 10 years of accumulation. The resulting yield losses range from 11 to 23 percent for maize, 9 to 16 percent for wheat, 5.5 to 9 percent for soybean, and 14.6 to 59.2 percent for vegetables when agrofilm residues reach 2.5 to 3 kg per mu[1] (Agricultural Department of Xinjiang, 2004 as cited in Funing Zhong, et al., 2006).

Impacts of soil salinity on resource use, crop productivity and profitability

Soil salinity is primarily caused by excessive irrigation and inadequate drainage. Saline soils contain soluble salts that interfere with the growth of most crops. The long-term presence of excess salts in the soil can irreversibly damage it. According to Selliah Thiruchelvam and S. Pathmarajah (1999), who studied the salinity problems in Sri Lanka's Mahaweli River System "H" Irrigation Project, salinity can lead to the following agricultural problems if left uncorrected:

1. **Reduced crop intensity.** Salts make nutrients less available to plants. Therefore, crop production possibilities are severely restricted under salinity-affected soils. In the Mahaweli Irrigation Project, it was found that with the increase in extent of salinity, the area allocated to rice increases because of its greater tolerance to salinity. Late-maturing (4 ½ months), improved varieties are planted in areas with more available water; early-maturing (3 months) varieties are planted in water-scarce areas. However, other important cash crops such as chili and big onions are planted less. These crops' relative share declines in moderate saline areas. They are not grown in high saline areas.

[1] 1 hectare = 15 mu

2. **Decreased profitability.** Salinity incidence reduces farmland productivity thereby decreasing agricultural profitability. In the Mahaweli Irrigation Project, it was noted that rice yield loss can range from 10 to 15 percent in moderately saline areas. In high and severe salinity areas, yield loss is one-third of the yield of salinity-free areas. Thus, net income from rice can fall by about 22 and 43 percent in moderate and high saline areas, respectively. Clearly, high saline areas are becoming economically non-viable to cultivate.

   Likewise, the increased cost of production leads to decreased profitability. Farmers report an increased cost of controlling salinity. Unit cost of production rises by about 25 and 32 percent in the moderate and high saline areas, respectively.

3. **Land scarcity.** Land degradation due to soil salinity aggravates land scarcity. In extreme situations, the farmland becomes so damaged that it is abandoned. About 4 percent of the total cultivable area in Nochchiyagama, Sri Lanka may be abandoned because of salinity incidence if no remedial measures will be taken.


Photo courtesy of the International Rice Research Institute

Saline soil in Pampanga, Philippines.

Health and environmental costs of agricultural pollution

Besides decreasing agricultural productivity and profitability, agricultural pollution generates additional costs because of the ecological, social and health damages that result from it. In most cases, these are the *external costs* or the losses not internalized in agricultural production but that are spillover effects of the misuse of agricultural production inputs. Like the on-site costs of agricultural pollution, these need to be addressed as they hinder long-term economic development efforts.

Impact of agrochemical misuse on human health

The improper use of pesticides and other agrochemicals causes not only yield losses but health problems as well. In Vietnam, Ho Chi Minh City farmers spray pesticides frequently without any protective clothing (Nguyen Huu Dung, et al., 1999). Mekong River Delta farmers improperly apply hazardous pesticides in combination with other chemicals (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999). As a result, there are many reported cases of acute illnesses and poisoning symptoms due to the unsafe handling of pesticides. Such cases are found to be proportional to the number of years of pesticide use (Nguyen Huu Dung, et al., 1999).

The link between farmer's health and pesticide use is also clearly illustrated in the case of China's Zhejiang Province. Health impairments like headache, nausea, and skin irritation were found to increase with pesticide use. Moreover, pesticides commonly used by rice farmers in the region belong to categories III and IV, which are known to cause more chronic diseases. A number of farmers have been found to have abnormalities in blood platelets and white blood cells that affect their liver and kidney (Jikun Huang, et al, 2001).

Based on an estimation of health costs to Vietnam's Mekong Delta farmers from pesticide exposure in the 1996-1997 winter-spring rice season, health costs per farmer can reach up to VND 46,390 (US$ 2.75) per year. This estimation reflects only those the farmer would spend in recovering at home. If opportunity costs of medical treatment for curing the poisonous symptoms were added, this estimated cost can reach as much as VND 91,390 (US$ 5.40) per farmer. This can be further aggravated if the farmer smokes and drinks (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999).

Also because farmers cannot tend to their farms due to the health effects of pesticide, the expected crop yield cannot be attained. This makes farmers' health an important concern of the policymakers in the context of economic efficiency.


Photo courtesy of the International Rice Research Institute

Farmers applying pesticides with no protective clothing is typical in the Region.

Effect of pesticide use on aquaculture

Rice production discharges pesticides into water bodies and such contamination negatively affects fish productivity. In Vietnam's Mekong Delta, much research evidence demonstrates pesticide use as the main cause of environmental water pollution and its consequent adverse effects on fish culture as well as fish capture (Nguyen, 1990; Vo, 1995; Dang, 1998 as cited in Dang Minh Phuong, 2002). In turn, these result to fish price increase, health impairments among farmers and consumers, and loss of biodiversity.

These damages are not internalized in the cost of rice production. However, by analyzing data on average fish cost, the assimilative capacity of the water environment, and water quality over time, it was computed that the total loss of fish culture as a result of pesticide misuse in the Mekong Delta is about US$ 9 billion in 2001 (Dang Minh Phuong, 2002).

External environmental costs of agricultural waste dumping

Agricultural wastes are dumped into rivers, lakes, coastal waters, and the high seas throughout the world. This creates vast dead zones — oxygen-depleted waters where little can live — in many coastal areas.

In Vietnam, there is an intensive and increasing pollution of the rivers and canals with the unused rice husk dumped and discharged by the Mekong Delta paddy milling centers (Nguyen Van Hanh and Nguyen Van Song, 2007). Mekong Delta's dumped rice husk totals to 1,400,000 tons per year and because increasing paddy production and rice export is the most important long-term economic development orientation of the area, this volume will continue to rapidly increase as more and more milling centers being established. Moreover, the local communities' change in traditional rice husk end uses — from using rice husk fuel to using commercial energy types — has decreased local rice husk consumption and increased unused rice husk dumping.

The problem is made more complicated by the fact that there is no region-wide cooperation in looking for an environment-friendly and effective solution. Thus, rice husk dumping has become a region-wide environmental threat to the health of the local community and their livelihood, especially to aquaculture (Nguyen Van Hanh and Nguyen Van Song, 2007).

Options for the disposal mode of these agricultural wastes must be explored. The choice should be based on economic feasibility, environment-friendliness, and local development priorities.

A rice husking plant in the An Giang province dumps its waste rice husk directly into the Mekong River.

Environmental and social costs of salinity

Aside from interfering with crop growth and aggravating land scarcity, soil salinity also causes several critical environmental and social problems (Thiruchelvam and Pathmarajah, 1999). In Nochchiyagama, Sri Lanka where salinity is severe, water is no longer fit for drinking forcing farmers to change their water source. About 30 percent of the households, mostly women, walk more than one kilometer to fetch safe drinking water. Thus, 25 percent of these women's productive time is lost to this additional chore.

Although relating health problems with salinity and waterlogging is difficult, it has been noted that malaria is most widespread in waterlogged areas. Diseases associated with poor water quality such as dysentery and amoebiasis are also common in Nochchiyagama (Thiruchelvam and Pathmarajah, 1999).

It is also difficult to identify the impact of salinity on vegetation. However, based on the observations of the Mahaweli farmers interviewed, salinity and waterlogging cause the surrounding natural vegetation to be replaced with non-productive types. They also observed that the forest and natural vegetation recover slowly, which results in the loss of shrubs and forest and has been felt through depleted fuel wood supply (Thiruchelvam and Pathmarajah, 1999).

Low adoption of recommended control measures

Despite the recognized adverse consequences of soil erosion, many farmers still refuse to practice soil conservation. Together with using the wrong land use option, farmers' non-adoption of soil conservation continues to aggravate soil erosion in the uplands.

Likewise, activities have been identified and recommended to prevent and control salinity incidence in farm plots and yet many still choose not to adopt such measures thereby further aggravating farmland salinity.

Why are there still those who choose not to follow recommended practices and participate in natural resource management? A farmer's decision on whether or not to adopt a recommended control measure is neither thoughtless nor impulsive. Certain socio-economic and bio-physical factors influence him. Several EEPSEA studies have been conducted to identify these factors and these studies have identified the following issues of concern:

Economic disincentive of applying erosion control technologies

The additional labor and cost of applying available technologies is one of the main reasons why farmers choose not to practice soil erosion control. Based on a survey of farmers in Northern Vietnam, many do not want to invest in soil conservation activities in areas far from their houses because they find it difficult to maintain hedgerow lines when the main crops are harvested (Tran Dinh

Thao, 2001). Others feel that soil conservation practices on high sloping lands require too much labor and are too expensive since they have to re-plant hedgerow lines every year.

The farming methods they use also affect the farmers' decision to adopt soil conservation measures. Those who prepare their land by clearing wild grass by burning do not want to plant hedgerows lines. Growing hedgerows would require hand-weeding and the labor requirement for this is deemed too high.

Limiting factors in adopting agroforestry

Upland farmers in Central Vietnam, especially the ethnic minority, still use erosive land use systems to meet their immediate needs (Bui Dung The, 2001). Despite efforts to introduce agroforestry as a financially profitable and less erosive land use option in the uplands, it is still not widely practiced. Bui Dung The (2001) attributes this to the complexity of designing and managing the system. The proper combination of tree and crop is not easy to establish and it requires high capital which poor upland farmers do not have.

> ***"Upland farmers still use erosive land use systems to meet their immediate needs."***

Moreover, the probability of the agroforestry system being chosen decreases if the farmer is older. This has to do with the farmer's attitude towards risk and uncertainty. Older farmers are likely to be more conservative and less open to technology. Another reason for the limited adoption of agroforestry is the fact that that past policy interventions were biased toward reforestation.

Due to these limiting factors, it is imperative that agroforestry be able to demonstrate a balance between its costs and its benefits if it is to be adopted. It is indeed a worthwhile land use option in terms of conserving the soil and in ensuring stable financial returns in the long run. Unfortunately, poor upland farmers are more concerned about short-term benefits (Bui Dung The, 2001).

Factors hindering the adoption of salinity control activities

To prevent salinization of fields, farmers in Sri Lanka's Mahawelli River System "H" irrigation project implement various strategies, such as: a) organic matter application, where farmers mainly use straw and some amount of farmyard manure and green manure; b) on-farm water management through deep and more ploughing, and land leveling and flushing; c) cleaning and deepening of drainage canal; and d) the use of chemical ameliorates, mainly gypsum, in highly affected farms. However, according to Selliah Thiruchelvam and S. Pathmarajah (1999), some problems hinder the effectiveness of these strategies.

"Certain socio-economic and bio-physical factors influence a farmer's decision on whether or not to adopt a recommended control measure."

When done excessively and improperly, irrigation causes soil salinity. For instance, in the Mahaweli River System "H" irrigation project, drainage improvements were not adequately performed due to inadequate capital and lack of cooperation among the farmers. Originally, a drainage network for the whole irrigation system was planned. However, farmers cleared only the irrigation field canal but not the drainage canals. In some places, field drainage canals were even turned into cultivated lands. These resulted to water-clogging and soil salinity.

Also, the Mahaweli authority focused more on the operation and maintenance of the main and branch irrigation canals while the drainage canals were neglected. This allowed the salinity problem to continue increasing.

It was also observed that farmers have applied ameliorates without the proper technical information. This may aggravate the salinity problem in the long run.

Lack of knowledge on the control measures' profitability and necessity

Farmers' lack of knowledge on the on-site costs of soil erosion and soil salinity as well as the benefits of their control measures has contributed to their lax attitude towards natural resource management. As in the case of the farmers in the Mahawelli River System "H" irrigation project, those cultivating severely affected areas did not believe that salinity control activities were profitable. They preferred to shift to alternative crops (Thiruchelvam and Pathmarajah, 1999).

Likewise, some farmers simply do not see the need for soil erosion control. In a survey of Central Vietnam farmers, most reasoned that soil conservation measures were not necessary (Bui Dung The, 2001). The upland rice farmers explained that the land was still serving the needs of the people. Others said that they have lived for years without erosion control and that they can continue without it.

These perceptions indicate a need to inform the farmers of the on-site costs of soil erosion and soil salinity and to demonstrate to them the benefits of soil conservation and salinity control. This will help them realize how much they are losing if they continue with their erosive land use practices.

Adverse impact of crop insurance on pesticide use

Caution has been raised regarding the impact of crop insurance on the use of pesticides (Funing Zhong, 2006). Crop insurance is purchased by agricultural producers to protect themselves against either the loss of their crops due to natural disasters or the loss of revenue due to the decline in the prices of agricultural commodities. However, there are concerns that crop insurance participation may indirectly create a problem on the environment through the farmers' increased purchase and application of agrochemicals. Thus, precautions must be taken so that the provision of crop insurance as a government policy to support agricultural growth does not induce increases in agrochemical use and cost the environment in any significant way.

Recommended Strategies to Manage Agricultural Pollution

Control soil erosion.

Evaluate the economic cost of soil erosion and the benefits of soil conservation.

To offset the adverse consequences of soil erosion, the economic cost of soil erosion must be established. Likewise, it is equally important to have specific data on the economic benefits of soil conservation. Such information can be used to better convince farmers whose foremost considerations are profitability and cost-effectiveness.

For instance, a study on the on-site costs and benefits of soil conservation in the moutainous regions of Northern Vietnam was able to prove the cost-effectiveness of practicing soil conservation. The study compared the profitability of three soil conservation techniques in growing maize and cassava, namely: a) the use of tea hedgerows; b) the use of *Tephrosia candida* hedgerows on the boundaries; and c) the use of tea and grass hedgerows (Tran Dinh Thao, 2001).

Based on the results, the treatment that used *Tephrosia candida* hedgerows produced the highest maize and cassava yield. It also gave the highest net present value (NPV), an indicator of how much value an investment adds to the value of the overall project. Material and labor costs were also lowest in this treament. Although the returns from the tea hedgerows under the treatment with tea and grass hedgerows were higher than that under the treatment of *Tephrosia candida* hedgerows, material and labor costs were higher, especially in the first year. Therefore this technology is not advisable for poor farmers.

The results of this particular Vietnam case also indicate that soil conservation facilitates intensive and improved crop productivity. For maize production, a one percent increase in material and labor costs for soil conservation practices increases the yield by 0.04 percent and 0.0512 percent, respectively. For cassava production, the yield increases by 0.0035 percent and 0.0064 percent, respectively.

The study also proved that the high rate of soil loss in plots without soil conservation results in considerably lower yields. On the average, the yield of maize under the treatment without soil conservation decreased by 17.4 percent per year whereas the yield under the treatment with soil conservation decreased by only 5 percent per year. Similarly, cassava yield under the treatment without soil conservation was reduced by 11.5 percent per year while the yield under the treatment with soil conservation was reduced only by 4.2 percent annually.

Growing cassava on sloping land in Vietnam

Promote the adoption of economically worthwhile and least erosive land use systems.

A study on the land use systems of Central Vietnam upland farmers looked into the extent of soil erosion associated with four land use systems, namely: a) upland rice-based system; b) upland sugarcane

"Promoting the adoption of the agroforestry system is a promising solution in addressing soil erosion."

system; c) fruit tree-based agroforestry system; and d) eucalyptus-based system (Bui Dung The, 2001).

In terms of financial profitability, the four land use systems are deemed profitable based on their NPV. However, the fruit tree-based agroforestry system shows the highest profitability of VND 13,837,000 (US$ 818.76) per hectare at a discount rate of 10 percent. It appears to be more superior than the other systems in terms of profitability after the fifth year based on a cost-benefit analysis with a time frame of 50 years. The upland rice and eucalyptus systems are the least profitable.

On the other hand, some land use systems proved more erosive than others. Based on the results of the study, the upland rice system is the most erosive, with a soil loss of 80 tons/hectare per year. The sugarcane system was found to be less erosive than the upland rice-based system but its annual soil loss level (53 tons/ hectare per year) is still much higher than the soil loss tolerance value. The fruit tree-based agroforestry system is the least erosive, with a soil loss of 40 tons/hectare per year.

These results prove that promoting the adoption of the agroforestry system is a promising solution in addressing soil erosion. It not only minimizes soil erosion but is also profitable. However, it requires high investment and is complicated in design and management. Therefore, the provision of credit, incentives, and extension services should form part of this land use system's promotion plan.

Consider the factors associated with the adoption of soil conservation measures.

In order to determine the appropriate policies that will help promote the adoption of soil conservation in farming, the determinants of the farmers' soil conservation expenditure and land use choices must be considered.

According to a survey of upland farmers in Northern Vietnam, farmers would be more willing to invest in soil conservation if there is an increase or improvement in available labor resource, family income, land use time, and rural transport conditions (Tran Dinh Thao, 2001). Thus, any intervention promoting the adoption of soil conservation should focus on improving the condition of these factors.

On the other hand, a survey of Central Vietnam upland farmers revealed that policy-related variables — such as the availability of land use incentives, extension services, and credit — have great impact in shaping farmers' choice of land use system (Bui Dung The, 2001). This implies that future interventions such as credit, incentives and extension services should be directed towards the promotion of a less erosive yet economically viable land use system.


Photo by NgyThanh

"Upland farmers are more willing to invest in soil conservation if there is an increase in available labor resource, family income, land use time, and rural transport conditions."

Design a master plan of land use.

Governments should design a master plan of land use in mountainous regions (Bui Dung The, 2001). Such a plan should clearly identify the borders between forestry and agricultural lands. Farmers should also be issued long-term rights to land use, taking into consideration land tax, farm size (average cultivated land per farm), and management of agricultural land resources.

Regulate the use of agrochemicals.

Impose a tax on pesticide price.

The amount of pesticide discharge depends on the level of insect attacks and the effectiveness of pesticide regulations. But mostly, it depends upon the farmers' use of pesticides, which in turn depends highly upon its price. Hence, raising the price of pesticides by means of imposing a levy is the suggested policy to reduce pesticide discharge (Dang Minh Phuong, 2002; Nguyen Huu Dung and Tran Thi Thanh Dung, 1999). This will somehow limit the dose and frequency of pesticide use.

This tax on pesticide price could be called "health tax" as it aims to reduce the cost to farmers' health. In Vietnam, given the current prices of inputs and paddy, a 33.4 percent increase may be imposed on the price of pesticides so that farmers would reduce their pesticide use to an optimum level for profit maximization (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999).

Advocate for a stricter pesticide regulatory policy.

A stricter pesticide regulatory policy must also be in place in order to regulate pesticide use. For example, Vietnam's Pesticide Control Agency and Plant Protection Department should tightly control and monitor the registration of all kinds of pesticides based on their hazardous levels (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999). The kinds of pesticides sold at retail shops should be monitored. This is especially important since insecticides already banned are still available because they are cheaper. Some pesticides such *as DDT, Lindan, Metamidophos, Methyl Parathion, Aldrin, Heptachlor, and Dieldrin* are banned from production and trading, but their residues still exist in water samples (Vo Mai, 1996 as cited in Dang, 2002). Government authorities should organize large-scale campaigns to enforce the law and seize banned or restricted pesticide types. Violators should be heavily fined (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999).

Like in Vietnam, there is a need to set-up more stringent policies in China on the use of pesticides despite several regulations and standards on the acceptable residue levels in crops. More importantly, concrete enforcement systems that will ensure the implementation and observance of these rules and regulations are required (Jikun Huang, et al., 2001).

Promote Integrated Pest Management.

Overuse of and heavy dependence on agro-chemicals can also be addressed by the promotion of Integrated Pest Management (IPM). IPM uses information on the life cycles of pests and their interaction with the environment in combination with available pest control methods to manage pest damage economically and with the least possible hazard to people and the environment. Although IPM takes advantage of all appropriate pest management options including the use of pesticides, it can significantly reduce the use of pesticides because of its environmentally sensitive approach (EPA.gov, 2008).

Vietnam is promoting this approach through its IPM training program in rice, a continuing program that hopes to provide efficient service to rice farmers and make them more informed in pest control. The training involves two courses, the training of trainers and the farmers' field school (FFS). After finishing the training for trainers, farmers serve as resource persons in the FFS. Vietnam's experience shows that farmers participating in the IPM program reduce their pesticide use by approximately 75 percent. Farmers are also able to save on the amount of fertilizers and seeds used, thus lowering production costs. More importantly, the IPM farmers gain similar or higher yields than non-IPM farmers (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999).

An IPM strategy is also helpful in changing farmers' perception of high yield losses due to pests. By educating farmers on the impact of pest problems, their attitude in applying more pesticides to avert the risk of high yield loss can be changed, eventually leading to reduced pesticide application. Alongside IPM, alternatives to agrochemical practices

"IPM can significantly reduce pesticide application because of its environmentally sensitive approach."

can also be developed. In Zheijiang, China for example, a few farmers use the host-plant resistance, a system known to reduce pesticide use without reducing crop yield. This practice can be taught to more farmers as they make decisions on pesticide use (Jikun Huang, et al., 2001).

Put in place economic incentives such as crop insurance.

Appropriate economic incentives can help control agrochemical overuse. In Xinjiang, China, a study that analyzed the impact of crop insurance on agrochemical use revealed that farmers' decisions on their fertilizer, pesticide and agrofilm applications are influenced by their crop insurance participation (Funing Zhong, et al., 2006). The findings indicate that, on average, Manasi Watershed farmers with insurance apply 20.2 percent more agrofilm, 2.9 percent more fertilizers, and 18.99 percent less pesticides than farmers who do not have crop insurance.

"Farmers' decisions on their fertilizer, pesticide and agrofilm applications are influenced by their crop insurance participation."

The results also imply that if China were to give a 10 percent premium subsidy to encourage farmers to participate in the crop insurance program, the participation rate will go up to 83.24 percent (as compared to the 2003 participation rate of 44.84 percent). This will likely translate to a 2.21 percent reduction of the total pesticide application. However, agrofilm application is likely to increase by 9.15 percent. To counter this, a subsidy policy can be imposed for areas not requiring agrofilm (Funing Zhong, et al., 2006). These results indicate that a government-subsidized crop insurance program is an acceptable policy alternative.

As availability of better quality pesticides is the other important determinant of pesticide use, incentives policies (tax and price) are needed to encourage the development of new and improved pesticides both at the production/factory and marketing levels

(Jikun Huang, et al., 2001). This is a possible management strategy for farmers who have very low price responsiveness to pesticide use such as farmers in Zheijiang, China. Tax breaks can also be given to investors to encourage them to supply more phosphorus and potassium and limit the use of nitrogen (Nguyen, et. al., 1999).

Expand the rice-fish or rice-shrimp production pattern.

Raising fish or shrimp alongside rice farming has been found to lessen pesticide use. Thus a policy to expand the rice-fish or rice-shrimp production pattern further is recommended (Dang Minh Phuong, 2002).

In Vietnam's Mekong Delta, farmers who use the rice-fish or rice-shrimp production pattern limit pesticide use so that fish or shrimp survival and growth are not compromised (Dang Minh Phuong, 2002). Thus, this production pattern has reduced the pesticide pollution of the water system. Moreover, based on a cost-benefit analysis, this pattern has a high economic efficiency. Farm income can increase by as much as 1.5 to 2.5 times while the amount of pesticide use can decrease by 64 to 77 percent as compared with the rice-only production pattern.

"Raising fish and shrimp alongside rice farming can lessen pesticide use."

However, this pattern is not easy to develop due to two important conditions: 1) water sources for the rice field must be fully stabilized as the rice plant can survive more than three weeks without water but fish cannot survive after 10 minutes without it; and 2) farmers of adjacent rice fields must not apply pesticides. Imposing a tax on pesticide price can help overcome these barriers as it will reduce pesticide use. Low-interest rate loans, subsidy programs, and easy loan procedures are also necessary conditions to encourage rice farmers to develop aquaculture (Dang, 2002).

Address soil salinity.

Based on the case of Sri Lanka's Mahawelli River System "H" irrigation project, a number of interventions can be considered to help address soil salinity incidence (Thiruchelvam and Pathmarajah, 1999):

Improve irrigation water management.

Drainage improvement involves the cleaning and deepening of drainage canals to prevent their blockage at the farm level. A benefit cost analysis of drainage improvement reveals that it gives a reasonably high benefit-cost ratio.

Despite this, farmers do not adopt this control measure because of poor return from rice farming and lack of knowledge on this long-term problem. Therefore, incentives and subsidies along with training of farmers on appropriate salinity control measures are important.

Along with drainage improvement, the following are also recommended: a) prevention of excessive irrigation through institutional changes with close cooperation between the management agency and the farmers' organization; and b) agronomic practices improvement, which include field application of organic matter to prevent the capillary rise and the covering of fields with salt and drought-tolerant crops during off-season to retard salinization.

The remedy to soil salinity is mainly in the hands of the management agency rather than individual farmers because the drainage system of an entire area should be planned as a single unit rather than for a particular field. The agency can motivate farmers to act collectively to improve the drainage of an area irrespective of the salinity of individual fields.

Monitor soil and water salinity.

The continuous monitoring of soil and water salinity in the field and drainage area must also be done to prevent salinity build-up in the long run. To do so, statistical reporting and soil testing by the authorities must be strengthened.

Explore alternative uses of agricultural wastes.

***Explore the use of rice husk for biopower generation*.**

Biomass fuels, especially rice husk, can be a rich energy resource. Rice husk is being used to fuel brick-kilns and porcelain furnaces. It is also used in rural household cooking and open-air burning for fertilizing planted areas. This energy source can be further harnessed by using it to fuel biopower generation.

It has been demonstrated in Vietnam that the rice husk-fuelled biopower project is a safe and environment-friendly mode of disposing the increasing volume of agricultural wastes (Nguyen Van Hanh and Nguyen Van Song, 2007). It can minimize the dumping of a large volume of rice husk from local milling centers into the rivers and canals.

To facilitate the transfer of the rice husk bio-electricity generation technology, extension strategies must be planned and implemented. Policies on its region-wide use should be developed (Nguyen Van Hanh and Nguyen Van Song, 2007). In the case of Vietnam's Mekong Delta, it is recommended that a region-wide rice husk electricity development scheme be considered as an indispensable part of a medium-term rural electrification program for the area. Inter-provincial cooperation should be established to invest in rice husk electricity development. Detailed decrees granting subsidy to small power producers that use rice husk should also be formulated.

Put other support services in place.

Many of the EEPSEA studies reviewed for this series recognize the need for other support services to effectively address the issue of agricultural pollution. As a multifaceted problem, it requires certain enabling mechanisms for the proposed interventions to be implemented effectively. These include credit facilities, research and development, infrastructures, and capability strengthening.

Expand credit facilities in the uplands.

Credit facilities should be expanded in the upland regions (Tran Dinh Hao, 2001). Rural credit will encourage farmers to expand their economic activities in order to earn higher incomes. It will also encourage them to purchase the agricultural materials needed to practice soil conservation.

Invest in research and development.

It is recommended that governments invest in research and development concerning the appropriate protection gear to wear during pesticide use. Pesticide companies should be encouraged to distribute this protection gear to farmers instead of giving promotional items such as caps and handbags that do nothing to protect farmers from pesticide exposure during spraying (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999).

In the case of agrofilm use in the Manasi Watershed, Xinjiang, China, to prevent accumulation, an easy pick-up agrofilm can be developed or a special machine can be designed to make the clearing up of agrofilm pieces after harvest easier (Funing Zhong, et al., 2006).

Provide capability building programs.

The importance of capability development cannot be underscored enough. People cannot be expected to adopt a desired behavior if they do not appreciate its importance or understand its benefits. Thus, education, training and public awareness activities must be implemented to complement the other initiatives in managing agricultlural pollution.

For instance, farmers should be educated to improve their knowledge of soil conservation practices. They should be trained on the technology of soil erosion control, crop management on slope lands, and sustainable development of agriculture (Tran Dinh Hao, 2001).

Education and training will also encourage farmer participation in salinity control activities. This is important as the farmers' full participation is needed to manage drainage and to make decisions on canal development. Farmers should agree with land losses and share in the construction labor and the operations and management of the irrigation canals (Thiruchelvam and Pathmarajah, 1998).

To transfer the rice husk combustion and rice husk power generation technologies, it is also recommended that the staff be trained on job-specific topics. This is necessary for project designing, operation and management (Nguyen Van Hanh and Nguyen Van Song, 2007).

Agrochemical users must also be educated on the impacts of fertilizers and pesticides. It was found that educated farmers use less pesticide and that the overuse of pesticide can be attributed to having inadequate information (Jikun Huang, et al., 2001). Providing farmers with information on proper agrochemical use would make them more informed of the possible solutions and actions in solving their farming problems.

Likewise, farmers must be introduced to the optimal mix of fertilizers that will promote a more sustainable yield and lessen environmental damages. Increasing farmers' awareness on the hazardous effects of pesticide use on the environment and human health must be included in the local extension activities for them to internalize the extent of the effects of pesticide use (Nguyen Huu Dung, et al., 1999).

Photo courtesy of the International Fund for Agricultural Development

Farmers participate in a Farmer Field School session in Indonesia.

For instance, in Vietnam, village leaders have been encouraged to advise farmers on the mix of inorganic fertilizers that they will use and to promote the use of animal manure. Also, pesticide companies conduct workshops for farmers to provide them with more information on the new pesticides in the market, especially on how to safely and efficiently use them (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999). Pesticide retailers should also be informed of the hazards of new pesticides in rice farming so that they may convey this to their clients (Nguyen Huu Dung and Tran Thi Thanh Dung, 1999).

In China, local extension activities focus on changing the farmers' perception that reduced pesticide use will lead to high crop yield losses. Farmers must be made aware that the use of quality pesticides in smaller amounts does not reduce crop yield and that it is more environmentally-healthy. This can pave the way to lesser pesticide application (Jikun Huang, et al., 2001).

Provide better transportation and marketing infrastructures.

To encourage desirable changes in the farmers' use of the uplands, the government must invest in rural infrastructures and enforce policies to develop an efficient marketing system. Poor infrastructures, such as farm-to-market roads, isolate upland farmers making it difficult for them to sell their agricultural produce and buy production inputs (i.e., fertiliser, seeds). The shift to less erosive and more remunerative land use systems, such as the agroforestry system, and the adoption of profitable soil conservation would effectively benefit farmers if they have access to improved technologies and better transportation and marketing infrastructures (Bui Dung The, 2001).

Conclusion

While agricultural development has indeed brought about progress in terms of increased production, it has also unintentionally created some adverse consequences on the ecological environment and human health. Interventions both at the policy and technological levels have led to agricultural pollution, which now affects land and water resources. If left unabated, agricultural pollution will steadily weaken agricultural production itself. The irony is that while many agricultural problems have been solved, another set of problems that need another set of solutions have emerged.

The EEPSEA studies reviewed highlight workable solutions in terms of economic costs and benefits, policy recommendations, and practical actions. When applied, these would eventually reduce, if not totally end, the menace of agricultural pollution in Southeast Asia. It is believed that much of the farmers' behavior towards soil erosion, agrochemicals, soil salinity and agricultural wastes are the result of their lack of knowledge on how much they can lose in the long run if they do not adopt the recommended control measures. Hence, evidenced-based solutions have been presented in this series. These are what these studies can best offer in contributing to the growth of the agricultural sector in the Region.


Photo courtesy of the International Rice Research Institute

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PRODUCTION TEAM

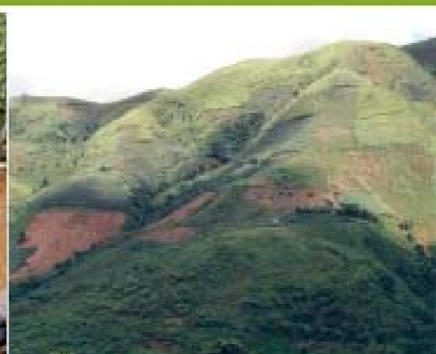
College of Development Communication, UP Los Baños

Julienne V. Bariuan, Former Assistant Professor | writer, editor, layout designer
Cleofe S. Torres, Associate Professor | co-writer, co-editor

contributors:
Joclarisse E. Albia, Instructor
Ma. Ciejay J. Calara, University Extension Specialist
Juvy N. Gopela, University Research Associate
Marifi T. Magsino, University Research Associate
Ma. Teresita B. Osalla, Assistant Professor







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