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Benefits of the 3R approach for agricultural waste management (AWM) in Vietnam

Under the framework of joint project on Asia Resource Circulation Research

Assoc. Prof. Huynh Trung Hai and Dr. Nguyen Thi Anh Tuyet
Institute for Environmental Science and Technology
Hanoi University of Science and Technology

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1 Introduction

1.1 The need for Preface on agricultural waste management

In recent years, Vietnam's agricultural sectors have developed rapidly. The country has become the world's second-largest rice exporter and also a key partner of many developed countries such as the USA, Japan, and countries in the EU in terms of the export of other agricultural products. According to statistical data, the output of cereals reached 43.3 million tons in 2009, including rice output of 38.9 million tons, an increase of 116,000 tons over 2008 figures. Exported rice reached a record level at 5.95 million tons. However, accompanying this development has been wastes from the irrational application of intensive farming methods and the abuse of chemicals used in cultivation, remarkably affecting rural environments in particular and the global environmental in general.

Wastes generated from agricultural sectors such as plant residues after harvesting and cattle manure include hydrocarbons, proteins, lipids, and some other organic compounds. Recently, agricultural waste management (AWM) for ecological agriculture and sustainable development has become an issue of concern for the government. For example, almost all of these agricultural "wastes" can be easily digested. The products of the decomposition process not only provide essential nutrients for plants but also make the soil porous and improve the characteristics of the soil, especially its ability to retain water, thus contributing to clean, safe, and sustainable agriculture.

1.2 Literature review for the 3R approach in AWM in Vietnam

The 3Rs (reduce, reuse, and recycle) were introduced to the Vietnamese people about 10 years ago. But even before that, some initial activities of the 3Rs were already being carried out because Vietnamese farmers are typically industrious, hard-working, and thrifty.

The project entitled "Study in using agricultural residues to produce enzymes that can be used for animals and poultry in Vietnam (VS/BT/95)," funded by the Swedish International Development Cooperation (SIDA), was carried out between 2004 and 2007 and directed attention to the large amount of cultivation waste generated annually [1]. This project was carried out with the aim of building capacity for national researchers and scientists regarding knowledge of enzymes and enzyme-proboscis production. Another successful study carried out by Nguyen Duy Hang focused on reusing agriculture wastes as nutrient mixtures for orchids and other ornamental plants in the southern province of Lam Dong. This study was recognized as meaningful because of the benefits it brought to the Vietnamese farmers and its contribution to environmental protection. Cultivation residues can be not only reused for agricultural purposes but also recycled as an energy source in industrial sectors. The project entitled "Sustainable Integration of Local Agriculture and Biomass Industries," funded by the Japan International Cooperation Agency (JICA), addresses agricultural wastes and sustains local agriculture in conjunction with biomass industries in the Mekong Delta [2].

Another purpose of the project is researching and developing technologies to contribute to climate change mitigation such as by switching away from biomass to clean fuels, such as biogas and bio-ethanol (to use as fuels for industry and for running motors). The project has been planned for implementation over five years (2009 to 2014). Focusing on recycling these waste sources, Prof. Tran Binh (since 2009) has been successful in his work to create a gas cooker which produces gas from biomass [2]. The body design of this special cooker does not permit the discharge of smoke outside the cooker itself and makes the heat and smoke return to enhance burning. In addition, a pilot-scale study by Prof. Hoang Dung was carried out to convert agricultural wastes to molasses, which is then transformed into ethanol.

In terms of livestock waste, through the use of computer programming Dr. Nguyen Quang Khai has achieved great success in manufacturing biogas facilities that are designed to ensure optimum size, structural strength, and safety while saving material. Two of his biogas facilities, called KT1 and KT2, won Vietnam's tenth national technical innovation contest [3]. The facilities are becoming popular and are being utilized in over 80,000 projects nationwide. At the end of June 2009, Dr. Khai and his colleagues designed and built an anaerobic lake covering 7000 m^3 of a Trai Lam farm. After decomposition, the resulting biogas can be used to run electric generators and the wastes can be recycled as food for fish.

Recently, a five-year project entitled "Livestock Waste Management in East Asia" underway since 2006 set a target of reducing the major negative environmental and health impacts of rapidly increasing and concentrated livestock production on water bodies and thus on the people of East Asia. Its global environmental objective is to reduce livestock-induced, land-based pollution and environmental degradation of the South China Sea, including where it impacts Thailand, China, and Vietnam [4].

1.3 Objectives and the scope of this study

Although in Vietnam there exists a certain amount of research related to 3R approaches in agricultural sectors as mentioned here, the concept of the 3Rs is not yet a familiar one for rural residents. The government and other functional organizations are paying greater attention to means of improving 3R activities. This study addresses environmental issues related to waste generation from cultivation, livestock, and agricultural service activities and evaluates potential benefits of the 3R approach in AWM in Vietnam. In addition, it also identifies the challenges and opportunities in promoting this international 3R mission while also suggesting some options for promoting effective 3R activities.

2 Overview of agricultural waste generation and environmental consequences

This study was carried out under the framework of a joint research program between the Institute for Global Environmental Strategies (IGES), which has expertise and interest in promoting policy research on sustainable resource circulation in Asia and is a contractor of the commissioned research project "Asia Resource and Circulation Policy Research" from the Ministry of the Environment of Japan (MOEJ), and the Institute for Environmental Science and Technology (INEST), which has expertise and interest in conducting policy research for sustainable resource circulation in Asia. This project was funded by MOEJ.

2.1 State of agricultural development in Vietnam

2.1.1 Cultivation activities

The economy of Vietnam is based on agriculture, with 74% of the country's population living in farming areas. Since joining the World Trade Organization (WTO), the country has continually revised its land-related policies and liberalized food material production in rural areas, with these changes resulting in not only strong growth in cultivation outputs but also profound effects on economic development processes as a whole. According to the General Statistics Office (GSO) data shown in Table 2.1, the annual yield of staple crops has not been increasing steadily. However, except for maize, production output growth rates averaged 3.2%–3.6% a year for the period 1995 – 2008.

Table 2.1 Annual production outputs of typical food crops and industrial crops

Unit: 1,000 heads

Year	Rice	*Growth rate (%)*	Maize	*Growth rate (%)*	Peanuts	*Growth rate (%)*	Sugar cane	*Growth rate (%)*
1995	24.96		1.18		0.34		10.71	
1996	26.19	*4.9*	1.54	*30.5*	0.36	*5.9*	11.43	*6.7*
1997	27.29	*4.2*	1.65	*7.1*	0.35	*-2.8*	11.92	*4.3*
1998	28.92	*6.0*	1.61	*-2.4*	0.39	*11.4*	13.84	*16.1*
1999	31.39	*8.5*	1.75	*8.7*	0.32	*-17.9*	17.76	*28.3*
2000	32.53	*3.6*	2.01	*14.9*	0.36	*12.5*	15.04	*-15.3*
2001	32.11	*-1.3*	2.16	*7.5*	0.36	*0.0*	14.66	*-2.5*
2002	34.45	*7.3*	2.51	*16.2*	0.40	*11.1*	17.12	*16.8*
2003	34.57	*0.3*	3.14	*25.1*	0.41	*2.5*	16.85	*-1.6*
2004	36.15	*4.6*	3.43	*9.2*	0.47	*14.6*	15.64	*-7.2*
2005	35.83	*-0.9*	3.78	*10.2*	0.49	*4.3*	14.95	*-4.4*

2006	35.85	*0.1*	3.85	*1.9*	0.46	*-6.1*	16.72	*11.8*
2007	35.94	*0.3*	4.30	*11.7*	0.51	*10.9*	17.40	*4.1*
2008	38.73	*7.8*	4.53	*5.3*	0.53	*3.9*	16.13	*-7.3*
Average	**30.71**	***3.2***	**2.59**	***10.4***	**0.39**	***3.6***	**14.25**	***3.6***

Source: Vietnamese Statistical Yearbook, 2008

In 2009, agricultural products accounted for about 25% of gross national product, within which the cultivation sector contributed the most. Among cultivation products, rice used more than 70% of total harvesting area and yielded about 90% of total cereal output in Vietnam. The policy orientations for the development of the cultivation sector are as follows [5, 6]:

- Maintaining a cultivation output growth rate of about 2.6%–2.7% a year for the period 2011–2020 by focusing on solutions for increasing both productivity and product quality, reducing costs, and maintaining reasonable scales for food security in the future.
- Focusing on the development of tropical plants that address future needs and have advantages in the world market such as wet rice, coffee, rubber, cashews, pepper, tea, and tropical vegetables and fruits; reducing the amount of attention given to plants having lesser market advantages and accepting imports to meet the processing/consumption demand of the country, such as in the cases of cotton, tobacco, temperate vegetables and fruits, and soya beans.

2.1.2 Cattle breeding activities

In Vietnam, there were about 18,000 breeding farms in 2008. The number of heads of breeding stock on large-scale farms ranges from hundreds to thousands, including not only cattle and poultry but also sows, boars, small pigs, and pigs for meat. Chicken breeding farms are often built using a closed-cage model and have an average scale of 5,000 chickens kept for eggs and 10,000 chickens bred for meat [7]. According to the General Statistics Office (GSO) data shown in Table 2.2, annual production of staple cattle and poultry has not increased steadily. However their average growth rates reached 3.3%–5.2% a year for the period 1995–2008.

Table 2.2 Number of heads of cattle and poutry, 1995 – 2008

Unit: 1,000 heads

	Cows		Pigs		Poultry	
Year	Number	Growth rate *(%)*	Number	Growth rate *(%)*	Number	Growth rate *(%)*
1995	3,639		16,306		142,100	
1996	3,800	*4.4*	16,922	*3.8*	151,400	*6.5*
1997	3,905	*2.8*	17,636	*4.2*	160,600	*6.1*
1998	3,987	*2.1*	18,133	*2.8*	166,400	*3.6*
1999	4,064	*1.9*	18,886	*4.2*	179,300	*7.8*
2000	4,128	*1.6*	20,194	*6.9*	196,100	*9.4*
2001	3,899	*-5.5*	21,801	*8.0*	218,100	*11.2*
2002	4,063	*4.2*	23,169	*6.3*	233,300	*7.0*
2003	4,394	*8.1*	24,885	*7.4*	254,600	*9.1*
2004	4,908	*11.7*	26,144	*5.1*	218,200	*-14.3*
2005	5,541	*12.9*	27,435	*4.9*	219,900	*0.8*
2006	6,511	*17.5*	26,855	*-2.1*	214,600	*-2.4*
2007	6,725	*3.3*	26,561	*-1.1*	226,000	*5.3*
2008	7,220	*7.4*	25,580	*-3.7*	241,000	*6.6*
Average	**4,510**	***5.2***	**21,014**	***3.3***	**191,300**	***4.0***

Source: GSO, 2009

In terms of breeding methods, there are two common types of cages for breeding pigs: 1) cages with concrete floors, which are mainly used for breeding pigs for meat, and 2) iron cages, which are used for breeding sows. Also, there are two common types of cages for breeding chickens, with one type used for meat chickens and the other for layer chickens: 1) open cages (without a closed wall around, ventilation system, or system for creating humidity); and 2) closed cages. The household scale farm in Vietnam is also very popular, with the number of pigs, poultry, buffalo, and cows ranging from 5 to 10, 5 to 15, 1 to 2, and 1 to 5, respectively. This scale requires few workers and does not need much investment relatively speaking.

Over the next five years, cattle breeding in Vietnam is poised to become a major sector expected to reach 25-30% of total agricultural output and satisfying domestic as well as export demand. The policy orientations for the development of the livestock sector are as follows [5,6]:

- Promoting the growth rate of livestock output to reach 6–7% a year for 2011–2015 and 5–6% a year for 2016–2020, satisfying domestic demand for meat, poultry, eggs, and dairy products such as fresh milk and condensed milk from cows and goats. Targets for the numbers of breeding cows, pigs, and poultry are 4 million, 34.75 million, and 400 million heads, respectively, by 2020.
- Orienting the development of cattle breeding towards concentrated industrial production in order to meet domestic demand, ensure food safety and hygiene, prevent disease, and protect the environment.
- Focusing on the development of dominant sectors in each area, specifying optimal self-sufficient capacity, and the need for imported products in cases in which products from foreign countries have dominance.

2.2 Agricultural waste generation and environmental issues

2.2.1 Wastes from cultivation activities

According to GSO data, total staple crop residues and total industrial crop residues in 2008 were estimated at around 40.2 million tons and 10.6 million tons, respectively, as shown in Table 2.3.

Table 2.3 Estimated residues of staple crops and industrial crops in 2008

Agricultural plants	Area, *1,000 ha*	Production, *1,000 tons*	Crop residue rate *(%)*	Crop residues *1,000 tons*
Staple crops				
Rice	7,414	38,725	55	21,298
Maize	1,125	4,531	250	11,328
Sweet potatoes	162	1,323	45	595
Cassava	557	9,395	75	7,046
Total				**40,269**
Industrial crops				
Sugar cane	271	16,128	65	10,483
Peanuts	256	533	20	106
Soybeans	191	268	10	26
Total				**10,616**

Sources: General Statistics Office, 2009; Hoang Huu Than, 2005

These figures indicate that the amount of waste per unit of final product is rather large. However, the wastes can be reused and/or recycled because of the high ability for their components to bio-decompose. While the material inputs of the digestion process are highly diverse, they all include carbohydrates, proteins, and lipids. The theoretical biogas yield can be calculated using equations (1) and (2) below. The results are presented in Table 2.4.

$$M_{CH4} = 0.37C + 0.49P + 1.04L \quad (1)$$

$$M_{CO2} = 0.37C + 0.49P + 0.36L \quad (2)$$

Where:

M_{CH4} and M_{CO2} – amounts of CH_4 and CO_2 generated from 1 g of raw material;
C – amount of carbohydrates in 1 g of raw material (g);
P – amount of protein in 1 g of raw material (g);
L – amount of lipids in 1 g of raw material (g);
0.37, 0.49, 1.09 in equation (1) – coefficients of the amount (in liters) of CH_4 generated from 1 g of carbohydrates, proteins, and lipids, respectively; and
0.37, 0.49, 0.36 in equation (2) – coefficients of the amount (in liters) of CO_2 generated from 1 g of carbohydrates, proteins, and lipids, respectively.

Table 2.4 Chemical components of waste materials and their theoretical biogas productivity

Yield Material	Content, *grams, dry weight*			Biogas, *liters/gram, dry weight*	
	Carbohydrate	Protein	Lipid	CH_4	CO_2
Pig manure	0.420	0.114	0.060	0.274	0.233
Poultry manure	0.470	0.088	0.045	0.264	0.233
Horse manure	0.453	0.094	0.028	0.243	0.224
Buffalo and cow manure	0.270	0.104	0.052	0.205	0.170

Source: Estimated by the authors, INEST-2009

<u>*Excess pesticides:*</u>

While Vietnam's hot and humid tropical climate is favorable for growing crops, it also supports the generation and development of insects and weeds. This situation creates a high demand for pesticides in order to kill insects and protect against the spread of epidemic diseases.

Vietnamese farmers are abusing pesticides. In 2007, the agriculture sector used 75,800 tons of pesticides, a doubling of the amount used in 2000 [8]. After using pesticides, most of the bottles and packages holding these pesticides are thrown into fields or ponds. According to an estimate made by the Plant Protection Department (PPD), about 1.8% of the chemicals remain in their packaging [9]. These wastes have the potential to cause unpredictable environmental consequences such as food poisoning, unsafe food hygiene and contaminated farmland due to their potentially lasting and toxic chemicals. At the same time, existing stagnant, unused or contraband pesticides have been increasing in both number and type. In 2007, the amount of unused pesticides and pesticide packages with residue from the original contents was up to nearly 70 tons of powder, as shown in Table 2.5. The concern is that pesticides that have been stored or buried in the wrong way may leak or enter the environment through osmosis and thereby affect the environment.

Table 2.5 Amount of unused pesticides in 2007

Type of pesticide	Powdered form *(tons)*	Liquid form *(1,000 l)*	Packages with pesticide residues *(tons)*
Amount	69.2	43.6	69.6

Source: PPD, 2009

According to the results of a survey conducted by the Ministry of Natural Resources and Environment (MONRE) over two years (from 2007 to 2009) on locations contaminated by chemicals, there are 1099 locations contaminated by pesticides spread across 37 provinces and cities of Vietnam. Among them, 53 sources were identified as sources causing serious environmental pollution. These chemical wastes are usualy difficult to handle and persist in the environment for a long time.

Excess fertilizers:

In agricultural production, fertilizers play an important role in maintaining the productivity and quality of plants. Inorganic fertilizer is inexpensive and characterized by high productivity. However, many farmers apply more fertilizer to their crops than the amount that can be absorbed by the plants. In a previous study [10], we found that the specific fertilizer consumption[1] (SFC) in Vietnam far exceeds that of other countries having similar agricultural agropedology and climatic conditions (Figure 2.1). In 1989, about 100 kg was applied per hectare of farmland in Vietnam, an amount similar to that of the Philippines, Indonesia, Bangladesh, and Pakistan. But in 1996, the reported SFC in Vietnam was 273 kg fertilizer/ha farmland, an amount 2.7 times as large. The serious consequence of such a change is that while the cultivation structure has improved, improper fertilization is affecting Vietnamese agriculture. Since there is a growing tendency towards soil degradation, fertilizer is used to the point of abuse in order to increase the annual agricultural output.

[1] Fertilizer consumption (100 grams per hectare of arable land) measures the quantity of plant nutrients used per unit of arable land. Fertilizer products cover nitrogenous, potash, and phosphate fertilizers (including ground rock phosphate). The time reference for fertilizer consumption is the crop year (July through June). Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.

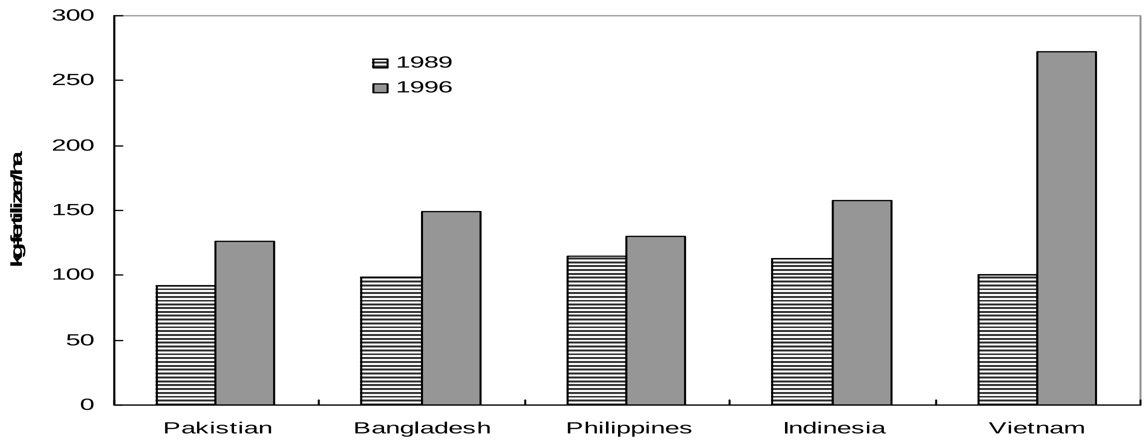

Figure 2-1 Comparison of specific fertilizer consumption among countries

Source: Estimated by the authors, 2004

At present, since nearly 100% of farmland has had inorganic fertilizers applied, the total use of nitrogenous fertilizer (N), phosphate fertilizer (P2O5), and potassium fertilizer (K2O) has increased more than five times during these 20 years, reaching over 2.4 million tons in 2007 (Figure 2.2). The largest amounts were used for rice cultivation, which accounted for 69.1% of all inorganic fertilizers consumed. The next largest uses were for perennial industrial crops (16.0%) and maize (9.5%) (Figure 2.3) [11].

Unit: Million tons

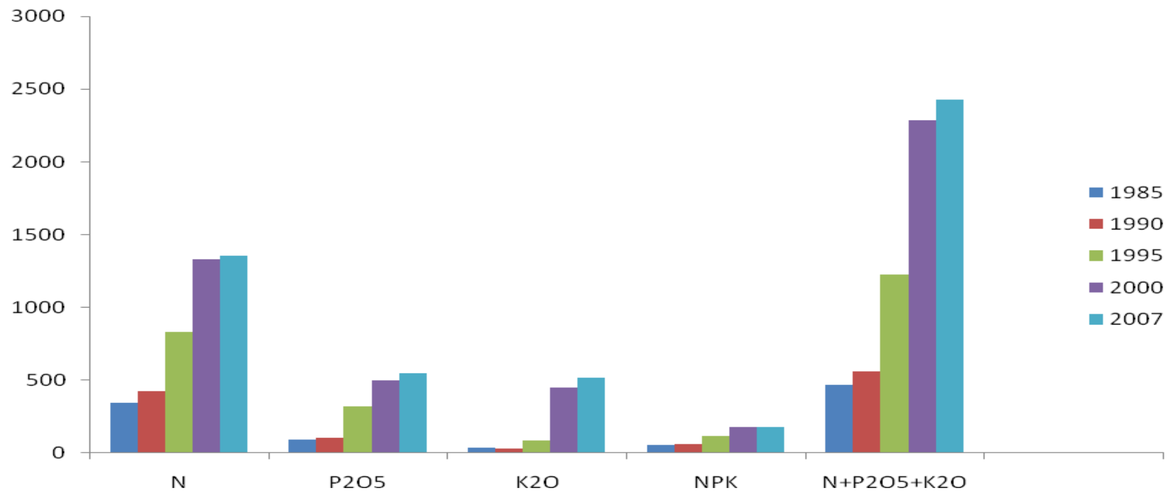

Figure 2-2 Inorganic fertilizer use in Vietnam over time

Figure 2-3 Uses for inorganic fertilizers in 2007
Source: PPD, 2008

According to agrochemical experts, the rate of absorption of nitrogenous, phosphorus, and potassium fertilizers in Vietnam are in the ranges of 30–45%, 40–45%, and 40–50%, respectively, depending on the land characteristics, plant types, and method of fertilization [12]. It has been found that those fertilizers are used for soil mulching and that 60–65% (equivalent to 1.77 million tons) of urea, 55–60% (equivalent to 2.07 million tons) of superphosphate, and 55–60% (equivalent to 344 thousand tons) of potassium chloride were in excess. Among the fertilizer excess, a portion is retained in the soil, a portion enters ponds, lakes and/or rivers as a result of either rain flows or the irrigation system, resulting in the pollution of surface water, a portion enters the ground water, and a portion evaporates or becomes denitrated, causing air pollution. In terms of ecological consequences, except for the N-fertilizers that remain in the soil colloid for subsequent crops, a large amount of those excess fertilizers negatively impact agricultural production and the environment such as by food poisoning and field pollution, respectively. That is to say failure to treat and manage those wastes effectively results in pollution of the environment and material resources. Moreover, nitrogen emissions from the soil to the environment need to be avoided in order to reduce the impacts of greenhouse gases.

2.2.2 Waste from livestock

Waste from livestock activities include solid waste such as manure and organic materials in the slaughterhouse; wastewater such as urine, cage wash water, wastewater from the bathing of animals and from maintaining sanitation in slaughterhouses; air pollutants such as H_2S and CH_4; and odors. Currently, there are about 18,000 breeding farms in the entire country, of which the proportion of industrial scale farms is just 37%. Most of the farms have developed spontaneously and have been built and planned in residential areas evenly. These farms lack proper treatment systems for manure and wastewater. The pollution caused by livestock production is therefore a serious problem.

Table 2.6 Generation rate of solid waste from breeding activities

Unit: kg/head/day

	Cow	Buffalo	Pig	Poultry	Goat, sheep	Horse	Deer
Value in range	10 – 20	15 – 25	1.2 – 4	0.01 – 0.05	-	-	-
Average value	18	15	2.0	0.2	1.5	4.0	2.5

Source: National Institute of Agricultural Planning and Projection, 2008

Based on the numbers of animals (given in Table 2.1) and average generation rates of solid wastes (given in Table 2.6), we can roughly estimate the waste amount from breeding activities in Vietnam. The results are presented in Figure 2.4. According to calculations by the Department of Animal Health (DAH), stored manure comprises about 25% of all manure, with this stored manure being collected and packaged (into sacks) for sale for use by consumers as a fertilizer source or fish food. Twenty percent of all manure is recycled for biogas, 10% is used for composting, and the remaining 45% (equivalent to 34.4 tons) is discharged directly into the environment without treatment. This untreated and non-reusable waste source can generate greenhouse gases while also having negative effects on the fertility of the soil and causing water pollution.

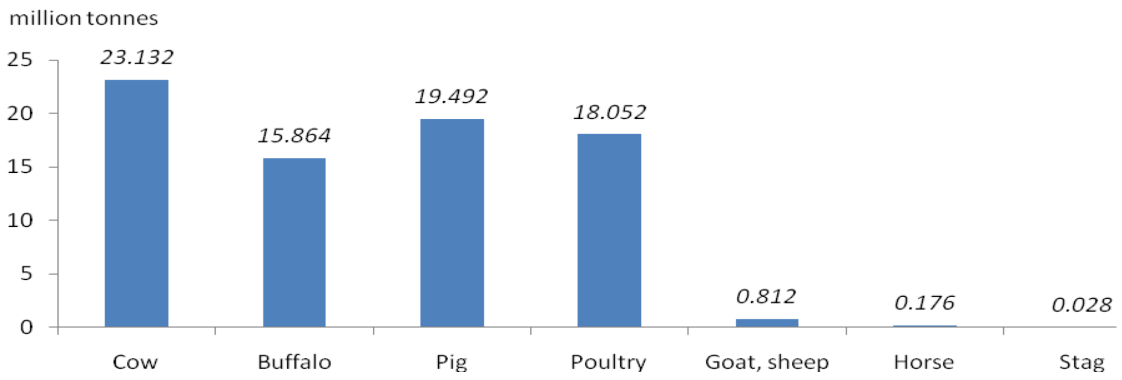

Figure 2-4 Amount of livestock waste generated in 2008

Source: Estimated by the authors, INEST 2009

Animal manure contains viruses, germs, multigerms, and parasite eggs, any of which can survive for a few days or a few months in manure or wastewater, polluting soil and water while also harming human and animal health. In addition, farm wastes include a considerable amount of different materials, redundant food residues, and corpses from cattle and poultry. The number of pathogenic microorganisms in the wastes depends in part on the food consumed by the animal, the gender, and the species as well as the way of hygiene and the method for treating waste.

Wastewater from livestock:

In livestock wastewater, water volume accounts for 75–95% of total volume, while the rest includes organic matter, inorganic matter, and many species of microorganisms and parasite eggs. Those germs and substances can spread diseases to humans and cause many negative effects on the environment. Generally speaking, large-scale pig farms are equipped with wastewater treatment systems using biogas technology.

Air pollution:

Air pollution includes odors emanating from cages resulting from the digestion process of livestock wastes, from the putrefaction process of organic matter in manure, from animal urine, and/or from redundant foods. The intensity of the smell depends on animal density, ventilation, temperature, and humidity. The proportion of NH_3, H_2S, and CH_4 varies along with the stages of the digestion process and also depends on organic materials, the components of foods, microorganisms, and the status of the animals' health.

2.2.3. GHG generation from agricultural wastes

The hot and humid tropical climate of the country provides favorable conditions for decompositing organic components, accelerating fermentation, and putrefaction. Some agricultural by-products such as straw and rice husks are used as a major source of fuel for cooking in some rural areas, while other agricultural by-products are used for growing mushrooms and making plywood. The rest is burnt directly in the field, releasing GHGs into the air. According to the initial national communications of Vietnam [13, 14], emissions from agricultural waste have always comprised the largest share of Vietnam's total GHG emissions. Agricultural waste GHG emissions were 52.4 $MtCO_2$ eq. in 1994 and 65.1 $MtCO_2$ eq. in 2000, comprising about 50% and 45% of total GHG emissions nationally in these two years, respectively (Table 2.7). Of total GHGs emitted from the agricultural sector, emissions from waste management activities such as the prescribed burning of savannas, field burning of agricultural residues, and manure management comprised nearly 9% (Figure 2.5).

Table 2.7 GHGs inventory by agricultural sector in Vietnam

Year	Sector	Energy	Agriculture	Industrial process	Land use change and forestry (*)	Waste	Total
1994	Amount(**) *$MtCO_2$ eq.*	25.6	52.4	3.8	19.4	2.6	103.8
	Percentage *(%)*	**24.6**	**50.5**	**3.7**	**18.7**	**2.5**	**100**
2000	Amount(**) *$MtCO_2$ eq.*	50.4	65.1	10	15.1	2.6	143.2
	Percentage *(%)*	**35.2**	**45.5**	**7.0**	**10.5**	**1.8**	**100**

Source: Standing Office of the Vietnam National Steering Committee for UNFCCC and KP, 2003, 2008

(*)- *Net emissions after accounting for carbon sinks*

(**)- *Estimate based on the estimated CH_4 emissions from organic waste fermentation under anaerobic landfill conditions, in accordance with IPCC guidelines*

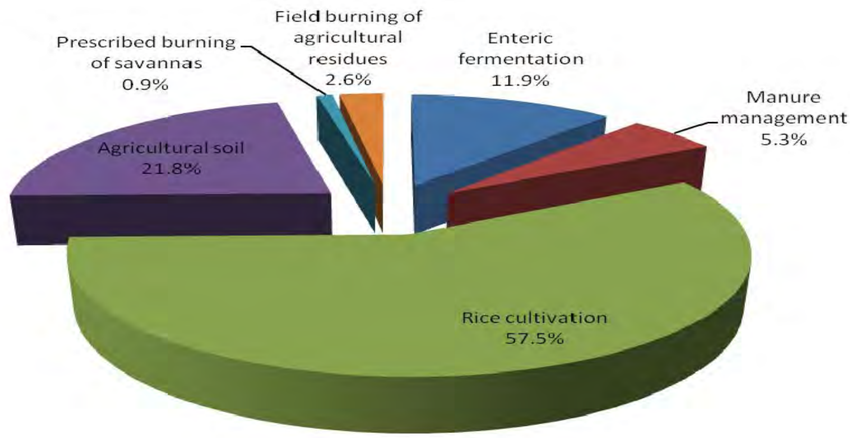

Figure 2-5 GHGs emissions from the agriculture sector in 2000

Source: Standing Office of the Vietnam National Steering Committee for UNFCCC and KP, 2008

3 Policy background and opportunities for the 3R approach in agricultural waste management

3.1 Agriculture development scenarios in Vietnam

Agricultural restructuring in recent years has taken place step by step, tapping the strengths of each region and linking more closely with markets for agricultural products. Owing to its rapid population growth (2.23% growth rate), Vietnam needs to keep rice fields for food security while applying intensive farming and improving the quality of cultivation through the use of advanced technologies. Some of Vietnam's agricultural products have held strong positions in world markets, both in quantity and quality (such as rice, coffee, cashew nuts, and pepper). Such products should get a high degree of consideration and support from the government in order to increase production.

Vietnam's policies support agricultural activities by helping to find more opportunities to improve the current status of technology as well as access to new sources of technology in the world. For long-term effective development, Vietnam needs to prepare carefully in order to handle different scenarios actively. A useful tool for this task is formulating potential development scenarios that Vietnam may face. These scenarios are necessary for policy makers to decide strategies and conduct planning. Scenarios for agriculture development in Vietnam up to 2020 are overviewed in Figure 3.1 and Box 3.1.

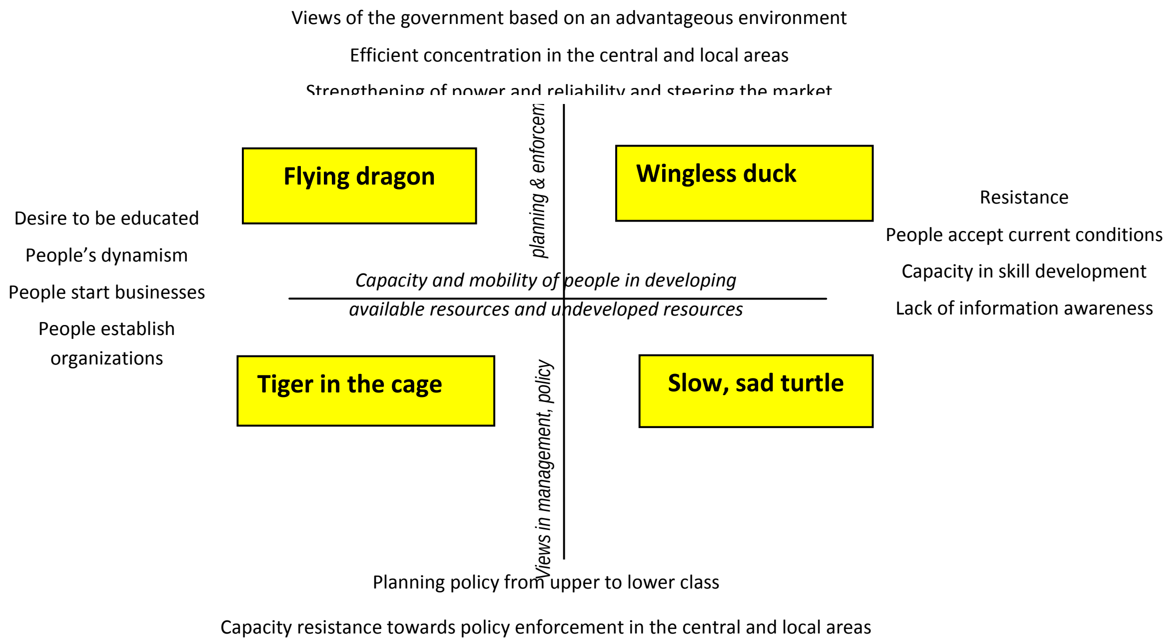

Figure 3-1 Matrix of Vietnam's agriculture development scenarios up to 2020

Source: National Institute of Agriculture and Projection, 2009

Box 3.1. Summaries of agriculture development scenarios in Vietnam

"Slow, Sad Turtle" Scenario

"Slow, sad turtle" is a scenario in which the government does not prepare carefully enough for catching opportunities in the global market. In addition, the Vietnamese people have insufficient confidence and skills to capture various opportunities. The interaction between the government (having limited capacity) and human resources (being low in quality) constrains the ability to promote the economy. As a result, economic development lags behind its potential. Poverty reduction also progresses slowly.

"Wingless Duck" Scenario

"Wingless duck" is a scenario in which the opening of markets and joining the WTO provide Vietnam a very good opportunity to develop. Three main urban centers stand out as providing the momentum for development, with fullly skilled and educated human resources to take full advantage of the opportunity. Policies issued concentrate excessively in these three centers while rural areas are neglected or receive only a small trickle of investment and the poor quality of human resources there comprises a barrier for catching up with opportunities that have become available through globalization. Large portions of both the rural and the urban population do not benefit from development.

The development strategies focus on urbanization associated with industrialization, while ignoring the demands of the rural economy. Rural areas lack investments in infrastructure, education and skill development so that the development is inhibited and opportunities are forgotten. Poverty in rural areas is not reduced and a large number of rural people are not dynamics.

In agriculture, the Government has not conducted the necessary investments for infrastructure to create better linkages between rural economy and the three dynamic economic centers. This restricts farmers and businesses organizations in rural areas to access to opportunities in domestic and international markets.

"Tiger in the Cage" Scenario

In the "tiger in the cage" scenario, both the Vietnamese government and the Vietnamese people take a development route in which the targets for growth are achieved, but both plans and human resources evolve and improve quicker than changes in regulations. Government policies are made in a perfunctory manner and are unpredictable. The high rate of economic growth becomes less sustainable as a result of environmental degradation and inequality. Vietnam subsequently fails to achieve expected development and development targets. Therefore, a substantial portion of the population seems frustrated and fails to meet their goals. Based on growth rate and achievements of socio-economic development especially after joining WTO, the Government launches oriented development strategies to make sure the stability. However, in fact, the progression is faster than the institutional capacity that the government proposed. Capabilities and expectations are not satisfied making people disappointed about the weakness of the Government. The Government has also expressed boredom with their weaknesses in the innovation process direction

"Flying Dragon" Scenario

Under the "flying dragon" scenario, reliability is developed broadly throughout the country. Innovation activities based on achievements arising through globalization and a strategic government vision for the long term create advantageous conditions for the private sector in terms of both the economy and human resource development. The growth of agriculture and other trading output in rural areas is quite high, in parallel with high rates of growth of urban development. A positive power for the development and a positive power for the people's benefit motivate development. Although certain portions of the population do not benefit in the initial stages, long-term investments by both state-owned and private sector entities along with the development of a social security system create valuable preconditions for socioeconomic development in the future.

Source: National Institute of Agriculture and Projection, 2009

3.2 Policy background and the national strategy on the 3Rs

In recent years, the 3Rs as they apply to wastes have been recognized as an important concept in terms of sustainable development and the development of national policies and stategies. The 3R approach in Vietnam has been emphasized in umbrella policies such as the Viet Nam Agenda 21, the Law on Environmental Protection (LEP) amended in 2005, the National Strategy on Environmental Protection to 2010 with a vision toward 2020, the National Strategy on 3R, and Extended Public Responsibility (EPR). For example, the National Strategy on 3R provides detailed programs up to 2015 including setting up a legal system and economic instruments in waste management, campaigns to enhance community awareness on the 3Rs and improving capacity in rural areas, and classifying wastes at their sources in five municipalities and large cities. Up to 2020, it also puts forth a framework for the development of a market for waste and recycled products as well as means for transporting waste and recycled products [15].

Legal documents related to the 3Rs in AWM:

Laws and sub-law documents on environmental protection in general and agricultural environmental protection in particular have been issued and enforced over these 20 years. Table 3.1 lists legal documents related to AWM in Vietnam.

Table 3.1 Overview of legal documents related to AWM in Vietnam

Legal documents	Contents	Remarks
1. The Law on Environmental Protection 2005	Provides clearly for obligations and responsibilities of organizations, households and individuals for environmenal protection	This is the highest legal document in Vietnam addressing environmenal protection activities
2. Decree No. 80/2006/ND-CP by the Prime Minister, dated August 9, 2006	Provides details on and guides the implementation of a number of articles of the Law on Environmental Protection.	The Decree addresses activities related to agriculture, including environmental impact assessment, waste management, rural environmental protection
3. Decree No. 21/2008/ND-CP by the Prime Minister, dated February 28, 2008	Modifies certain articles of the Decree No. 80/2006/ND-CP dated August 9, 2006	
4. Decree No. 117/2009/ND-CP by the Prime Minister, dated December 31, 2009	Handles violations in the domain of environment protection	Business and agricultural production activities causing environmental pollution are subjects of the Decree
5. Decree No. 67/2003/ND-CP of the Government, dated June	Addresses environmental fees for	Wastewater arising through agricultural production activities is

	13, 2003	wastewater	one of subjects of the Decree
6.	Decree No. 04/2007/ND-CP dated 8 January 2007	Amends and supplements a number of articles of Decree No. 67/2003/ND-CP of the Gorvenment dated June 13, 2003	
7.	Decree No. 174/2007/ND-CP of the Government, dated November 29, 2007	Addresses environmental fees for solid waste and environmental fees for wastewater	Solid waste arising through agricultural production activities is one of subjects of the Decree
8.	Decree No. 140/2006/ND-CP of the Government, dated November 22, 2006	Promulgates environmental protection during the processes of preparation, review, approval, and organization of strategies, schemes, plans, and development projects	Rural agricultural development projects are subjects of the Decree
9.	Circular No. 116/2006/TT-BNN of MARD dated 18 Dec 2006	Guides the implementation of certain provisions of Decree No. 66/2006/ND-CP dated July 7, 2006 on the Development of Rural Trades	
10.	Circular No. 07/2007/TT-BTNMT of MONRE dated July 3, 2007	Guides the classification of polluting establishments to be addressed; guides decision-making regarding this list of polluting establishments	Agricultural production establishments causing environmental pollution are subjects of the Circular
11.	Circular No. 12/2006/TT-BTNMT of MONRE dated December 26, 2006	Provides guidance regarding professional conditions and procedures for documenting, registering, licensing, and coding in hazardous waste management	Agricultural production establishments generating hazardous waste are subjects of the Circular
12.	Decision No. 132/2000/ QD-TTg by the Prime Minister, promulgated on 24 Nov 2000	Focuses on some policies stimulating the development of rural trades	
13.	Decision No. 64/2003/ QD-TTg dated April 22, 2003	Focuses on approval of the plan for thorough handling of establishments causing serious environmental pollution	
14.	Decision No. 23/2006/QD-BTNMT of MONRE dated December 26, 2006	Focuses on the issuance of a hazardous waste list	
15.	Decision No. 42/2008/QD-BNN of MARD dated March 5, 2008	Promulgates the list of veterinary vaccines, biologicals, microorganisms and chemicals permitted for circulation in Vietnam	

16.	Decision No. 2693/QD-BNN-KHCN of MARD dated September 24, 2009	Approves the project for improving rural, agricultural environmental protection capacity for 2010-2020.

3.3 Weaknesses of existing policies and opportunities to apply the 3R approach in AWM in Vietnam

As mentioned above, Vietnam's legal documents have positively influenced the application of AWM in Vietnam and have come to be incorporated gradually into operations. Environmental protection is becoming increasingly mainstreamed in agricultural production activities. Strategies, plans, and options for development planning for agriculture and rural development must be accompanied by reports on environmental impact assessment and ultimately these projects must comply with the commitments set out in these reports. More and more, scientific research is being utilized in environmentally friendly technology projects and waste treatment technologies are becoming incorporated increasingly into agricultural activities. This represents a change from "spontaneous" AWM in which farmers handled waste in whatever way was most convenient for their daily lives and production to become AWM that meets a stricter definition of "management."

These legal documents have also contributed to rising environmental awareness among farmers and given them opportunities to master rural environmental management and protection. Most people involved in agricultural production undergo an awakening regarding their responsibilities, obligations, rights, and interests in environmental protection. They gradually get acquainted with the "polluter pays principle" and contrastingly, they become encouraged and receive preferential treatment in support of their positive activities in agricultural waste management, for example qualifying for low-interest loans to build biogas systems or flush toilets. In 2008, the Ministry of Finance (MoF) and MARD issued Circular No. 48/2008/TTLT-BTC-BNN, which amends and adds some issues on the management and use of the national budget for national programs for safe water and rural sanitation over the period 2006–2010. Within this, the government raised its level of support for certain projects as well as for households in poverty, households in communes with special difficulties, ethnic minorities, and mountainous, coastal, and island areas. It gave particular attention to encouraging farmers and households to participate in the application of models for livestock waste treatment. Therefore, these policies have served all people, including ethnic minorities.

Government efforts have been recognized as having created some initial degree of positive changes in environmental protection. However, many aspects continue to be insufficient. This following section analyzes weaknesses in current policies along with opportunities for incorporating a 3R approach into AWM in Vietnam.

3.3.1 Weaknesses of existing AWM policies

Weaknesses in legal documents, policy systems, and modes of management:

- The amended LEP (2005) sets forth clearly orientated views, decentralized management at each level, and environmental protection responsibilities in the field of agricultural production. However, there are still insufficient decrees to guide specifically the contents of the law in those areas. This leads to confusion and limited awareness of the practical aspects of implementing the law in the areas of AWM.
- Decree No. 80/2006/ND-CP and Decree No. 21/2008/ND-CP provide guidelines for the contents of strategic environmental assessments and environmental impact assessments and also state a commitment to protect the environment as regulated in the amended LEP (2005). However, the two typical characteristics of the agricultural sector are production at a small scale in most cases and the fact that most agricultural wastes can be reused. Many activities generating waste, therefore, are not subject to the obligation to comply with the provisions of these contents.
- Decree No. 66/2006/ND-CP gives directions by which the government invests in infrastructure for treating environmental pollution within the development of rural trade. However, the documents guiding its implementation such as Circular No. 116/2006/TT-BNN and Circular No. 113/TT-BTC are unrealistic in terms of application.
- Decree No. 117/2009/ND-CP stipulates penalties for administrative offences in environmental protection. In fact, in general terms, all agricultural production activities more or less pollute the environment at different levels. Were this Decree to be strictly applied, most agricultural production actives would be banned. Environmental protection offenses therefore constitute an unrealistic basis upon which to engage in environmental management or deal with small-scale manufacturing processes or agricultural production in rural areas.
- “Environmental crimes” have not been legislated and are in fact defined only within certain studies. Of ten types of environmental crimes, only two are prosecuted and brought to trial in Vietnam: forest destruction (Article 189) and violation of regulations on wild rare animal protection (Article 190).
- Authorities from both the central and local governments have been trying to overcome limitations on the environmental policies for agricultural wastes. While most localities and relevant Ministries, Departments, and sectors have established divisions of environmental management, problems have arisen from the lack of a unified approach and lack of logical assignment of responsibility among those divisions from the central to local levels. In some localities, problems of rural sanitation are managed by the Department of Natural Resources and Environment Management but in other localities, these responsibilities belong to the Department of Agriculture and Rural Development. In still other localities, these two departments overlap in their responsibilities. Human resources for environmental sanitation in rural areas are lacking

and not many employees have environmental management qualifications. Environmental police forces do not exist at the district or village level.

- In rural areas of Vietnam, legal documents do not always come fully to bear. Most people in rural areas are more acquainted with "village conventions and regulations" than legal documents or laws. However, "village conventions and regulations" in the villages are not clear enough to reduce environmental pollution. They also do not specify any penalties for polluters. Besides, village conventions and regulations have been proposed without any legal basis so they do not constitute legal sanctions to limit behaviors of polluters.
- Other constraints on AWM are its burdensome administrative procedures and its lack of efficiency among different management units. Urban and rural areas in Vietnam have their own characteristics. Each level of administration has a party committee headed by a popularly elected people's council. Each village has a leader who takes responsibility for all social and economic activities in the village. These persons play a very important role in the life in the rural villages insofar as all documents and procedures (for example, procedures for taking out loans, procedures for obtaining building permission, or permission to engage in production activities) must be confirmed by them. The relationships in the rural communities are usually relations among family, kinship, and neighbors, but even relationships among the local authorities, village leaders and the polluters exist, enabling most pollution violations to be covered up.

Insufficient public awareness and lack of environmental monitoring agencies:

- Limited awareness together with rural people's lack of concern for environmental protection are major constraints for efforts to reduce environmental pollution.
- Insufficient awareness among the people is due to financial difficulties. Poverty is concentrated in rural areas, with an estimated four-fifths of the poor working in agriculture. In many cases, people do not want to pay any amount of money for waste treatment or solid waste collection since they think that they can manage it by themselves, although in fact they pollute the environment in the process. Most farmers do not care about legal documents on environmental protection, with only large commercial farms heeding them, and even then at a limited level. The reuse and recycling of even compost agricultural waste is almost always for economic reasons rather than environmental reasons.
- No environmental monitoring agencies exist at the district level. At the provincial level, while these agencies exist, they are limited in both capacity and human resources. When environmental conflicts or serious pollution occur, these agencies often request assistance from environmental experts and central environmental monitoring stations. Therefore, in many localities, there are no data about the environmental status of the area. Pollution sometimes is evaluated on the basis of experience rather than on the basis of numerical evidence.

Lack of financial and technical support:

- A shortage of financial resources is one of the biggest barriers for reducing environmental pollution in rural areas. The environmental protection budget is very limited for local authorities. Sanitation is not maintained regularly and public awareness campaigns for environmental protection are inefficient due to lack of financial assistance.
- Most households engaged in cultivating or livestock farming at a small scale cannot afford to install pollution treatment systems. Information on financial and engineering assistance available to farmers is also limited. A lot of farmers apply a form of "integrated agriculture-aquaculture systems," but in very simple ways. For example, livestock excreta is mixed with ash and rice husks and kept in closed bags for a couple of months and then put into the soil as compost, or chicken and pig excreta are discharged directly into fishponds. Not many households have set up biogas systems even though they recognize the benefits of such systems in both economic and environmental terms, because they lack the knowledge, experience, technical tools, and budget to set them up. Borrowing money from banks or organizations such as the Women's Union, Youth Union, or the farmers' association is also not an easy option since the farmers do not have sufficient knowledge or rationale to be able to persuade these entities of the potential for success.

Figure 3.3 shows the results of a 2008 survey about barriers in livestock breeding waste management conducted by the Institute for Agricultural Planning and Design. According to that pie chart, the three main barriers mentioned by farmers who were interviewed were the lack of monitoring agencies (75.6%), large expenses for waste management (47.8%), and lack of AWM technologies and techniques (38.9%). While surveys on the management of other kind of agricultural waste yields different responses, these are the main factors cited as constraining the development of AWM.

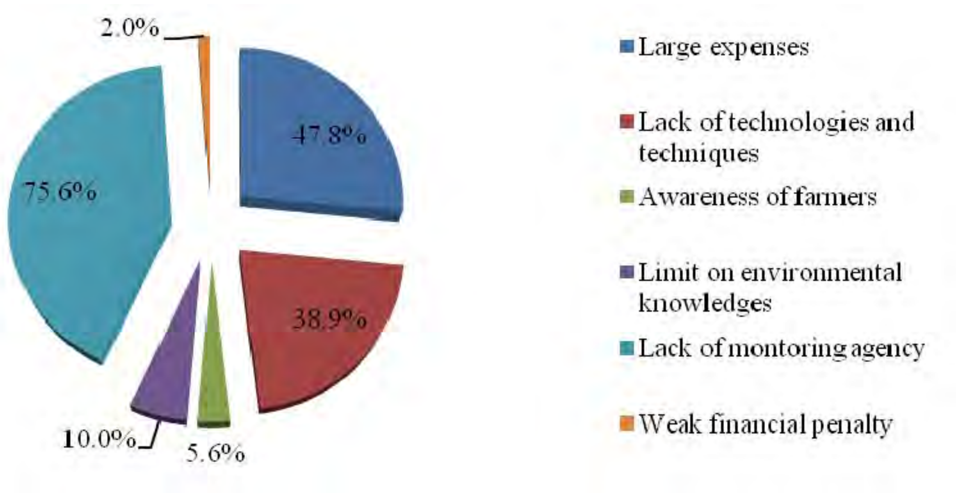

Figure 3-2 Barriers to waste management in livestock breeding

Source: Institute for Agricultural Planning and Design, 2009

3.3.2 Opportunities for a 3R approach in AWM in Vietnam

Globalization and joining the WTO have created opportunities in Vietnam for expanding the market and gaining access to necessary resources for production, such as materials, capital, and technologies. This is a good opportunity to develop production, including agricultural production. In addition, acknowledging the impacts of climate change, the government of Vietnam has been working to establish a new environmentally friendly model for economic development. MARD has established a framework of action for adapting to climate change in agriculture and rural development for the period 2008 to 2020. This section analyzes opportunities for a 3R approach in AWM in order to increase the benefits Vietnam can obtain. The different components of the 3Rs, including co-benefits with climate change reduction, will be explained.

The ***reduction*** concept refers to reducing the amount of unnecessary wastes by careful preparation of raw agricultural materials. Though reduction efforts, GHG emissions can be avoided or reduced in a number of sectors related to agricultural waste, including fertilizer and pesticide production, land use change and forestry (deforestation for agriculture), and energy (harvesting).

Reuse here refers to activities in which something that cannot function in its original purposes comes to serve as a new type of product with little or no processing. Wastes from the farming process, animal husbandry, and agricultural services should be reused to the greatest possible extent, the using time of products should be extended, and energy efficiency and waste generation reduction should be given appropriate attention.

- Cultivation residues such as rice husks can be applied directly for soil mulching. This practice requires low labor input and low investment. In terms of climate change reduction, this reuse of plant residues can also avoid a certain amount of GHG emissions from the burning and composting processes.
- Livestock waste contains necessary nutrients for plants in full, including such basic substances as N, P, and K and other substances including B, Mn, Mo, and Cu. The nutrients are mainly in the form of complex organic compounds that are indigestible. These wastes, therefore, require pre-treatment before using as an organic fertilizer for the soil and plants. For example, after anaerobic digestion, organic fertilizer (incubating manure) not only destroys weeds, insects, and plant diseases (because the temperature during the incubation process is rather high due to the decomposition of organic substances), but also can promote the decomposition of organic substances and support mineralization of the soil.
- Livestock waste can also be used as a food source for fish after anaerobic digesting. When this nutrient waste discharges into a pond, a portion is used directly (for example, carp, drifting, tilapia, catfish, and white bird fish can eat this nutrient waste), while the rest is transformed to non-nutrient matter by microorganisms. Algae and aquatic plants in the pond can absorb these

inorganic substances and transform them into nutrients for the environment. And in the food chain, these algae and aquatic plants are food for phytoplankton and other aquatic animals in the pond.

Recycle involves a complex set of activities in a process to recover resources from waste. Current technologies can metabolize farming by-products such as straw, leaves, fibers, and so on. Vietnam also has great potential in recycling agricultural residues for biogas production. Compared to the reduce and reuse approaches, recycling requires greater inputs of time and labor for collecting waste materials and greater investment for processing them. The recycling process may also produce more GHG emissions. But in general, these GHG emissions are often less than the amount that would occur as a result of landfill disposal.

As with other recycling of organic waste, the objectives here are to recover valuable nutrients and energy by means of composting and anaerobic digestion.

- *Composting* is a traditional practice for agricultural waste and suitable for Vietnam, where labor costs are low. However, since the quality of composting products is usually too low to be accepted by farmers, production is limited.
  In terms of environmental benefits, a recycling approach can contribute to sustainable agriculture by reducing the use of agrochemicals. But since composting releases CH_4 and NO_x (with NO_x being a more potent GHG than CH_4), dried plant residues such as sawdust and rice husks can therefore be added to increase the dry ratio of the pile, thereby helping to maintain the aerobic conditions of the pile.
- *Anaerobic digestion* is a typical practice in Vietnam in that cow and pig manures are used to produce biogas. The main components of product gases (biogas) are CH_4 (accounting for 56–65%) and CO_2 (accounting for 35–44%). CH_4 is a flammable gas that can provide approximately 9000 kcal/m^3. This recycling approach has some advantages over composting such as requiring a shorter time and a smaller area for operation and also producing organic fertilizer that contains low quantities of heavy metals. The biogas can then be used for cooking and/or electricity generation.
- Recently, biogas technologies have become better developed in Vietnam under a budget allocation from national programs on hygienic agriculture and/or climate change. In order to maximize the effectiveness of this multipurpose technology, researchers are focusing on low cost technology solutions and comprehensive applications. The typical types of household biogas equipment (BE) being used in Vietnam can be classified as follows:

  – <u>BE with Floating Cover:</u> This biogas equipment consists of two main parts: a cylindrical body built with bricks and a floating steel cover sealed by a water joint. This type was popular before 1988. This type has been modified since then and central excrement treatment is now possible. Although this type offers such advantages as easy installation and sealing, constant pressure, and ease of observation of the biogas thanks to the floating cover, this modified type also has such disadvantages as high cost (including the cost of transportation).

– BE with Fixed Cover: This biogas equipment features a single part built with bricks for holding the digested excrement and containing the biogas, in addition to one pressure stabilization tank.

– BE made of Plastic Bags: While this biogas equipment offers such advantages as low cost, easy transport, and easy installation, it has a short lifespan, requires a substantial amount of land, and is unable to maintain its temperature in the winter. The volume of bags depends on gas demand but are usually in range of 5–10 m^3.

In addition, several projects for biogas development have been carried out. For example, there has been a program conducted in cooperation with the Netherlands that proposes building 140,000 biogas works by 2011. The VACVINA program has been studied and, being both successful and operated in many locations, it has been proposed that the program build 20,000 biogas works in Vietnam by 2014. Technology transfer activities also have been supported by international organizations such as the Institute of Biochemical Physiology Microbiology of the former Soviet Union, OXFAM of the United Kingdom, UNICEF, FAO, ACCT (the Agency for the French-speaking Community), and SIDA of Sweden.

Clean development mechanism (CDM) opportunities: As with other developing countries, the government of Vietnam has placed priority on the CDM. In light of the share of GHG emissions from agricultural waste (as shown in Table 2.7), very high CDM potential can be seen in generating heat (waste-to-energy) and in composting.

- *Generating heat*: Sugarcane bagasse, cane trash, and rice husks can be used to generate electricity. The rapid expansion of sugar mills in recent years provides an opportunity as only some of the above facilities sell electricity to Vietnam Electricity (EVN). Production of electricity from rice husks is a potential but untapped source. This biomass source is instead now mainly used in brick and ceramic furnaces as a heating material. Table 3.2 shows the final energy use of biomass types in 2000.
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Table 3.2 Biomass types and their final energy use in 2000

End use		Biomass type					Total
		Wood	Rice husks	Rice straw	Bagasse	Other biomass	
Heat, *ktoe*	Stoves (for household cooking)	6997	665	1950	165	890	10,667
	Kilns (to create construction materials)	663	140	-	-	100	903

	Ovens (for agricultural and food processing)	1,145	110	-	100	698	2,053
Electricity, *ktoe*	Energy cogeneration in the sugar industry	-	-	-	377	-	377
Total		**8,805**	**915**	**1950**	**642**	**1,688**	**1,4000**

Source: Data provided by IE (research theme on the use of RE at an industrial scale, 2001–2003)

As mentioned, recycling processes can cause GHG emissions, although in most cases these are lower than those that would be generated by the use of virgin materials and/or by landfilling. Based on the 2006 IPCC guidelines on calculating GHG emissions, Table 3.3 shows net GHG reductions from the composting process and anaerobic digestion.

Table 3.3 Potential net GHG reductions from applying the 3Rs to organic waste

Organic waste	Potential net GHGs reduction compared to landfill, *kg CO_2 equivalent/kg of organic waste*		
	Waste reduction	Composting	Anaerobic digestion
Grass[(*)]	0.48 – 1.19	- 0.44[(**)] – 1.13	0.06 – 1.19

[(*)] – Net GHG reductions of some cultivation residues such as rice husks can be estimated based on data for grass
[(**)] – The high amount of emissions in CO_2 equivalent from grass composting results from the high global warming potential of NO_x emitted through the composting process, particularly vermin composting.

This indicates that anaerobic digestion is more attractive than composting in terms of climate change mitigation. Moreover anaerobic digestion could also provide the co-benefits of energy and nutrient recovery.

4 Benefits assessment in terms of a 3R approach

As mentioned earlier, agricultural waste will increase dramatically if ways are not found to minimize it. The opportunities and benefits of a 3R approach in AWM have also been clearly laid out in previous chapters. The 3R approach is based essentially on the idea of using resources efficiently before their final disposal. Appropriate waste management by means of the 3Rs can reduce GHG emissions throughout the entire lifecycle of resources, as shown in Figure 4.1. This chapter seeks to estimate the potential of the waste that can be reduced, reused, or recycled in the areas of cultivation and livestock activities, and then evaluate their environmental, energy, and social benefits.

4.1 Benefits assessment of the 3R approach on cultivation waste potentials

4.1.1 Estimation of biomass potential from cultivation activities

As estimated in Table 2.3, residues from Vietnam's staple crops of rice, maize, sweet potatoes and cassava amount to about 40 million tons. Some by-products such as dry straw and dry stalks are used by burying or composting them as organic fertilizer for cultivation separately and on a small scale. The unused amount of these waste sources was about 17 to 19 million tons [16]. After harvesting, straws or stalks are treated very simply. Farmers just collect them and then either heap them on the field or burn them directly (Table 4.1). These ways do not require any investment, being in-situ treatment, and in the case of burning farmers can use the resulting ash as a mixed ground layer in order to increase the porosity of the soil. However, the burning of straw and dry stems emits GHGs and also causes smoke and environmental pollution.

Table 4.1 Current status of using crop residues

Type of plants	Crop residues	Current status of use	Unused residues, *ton/ha*
Maize	Dry stalks, leaves	Burning, animal fodder	15.0
Peanuts	Dry stalks	Dumping, burning, animal fodder	8.5
Seasonal rice	Dry straw, husks, bran	Burning, animal fodder	5.5
Spring rice	Dry straw, husks, bran	Burning, animal fodder	4.8
Cassava	Dry stalks	Burning, animal fodder	3.0
Sugar cane	Dry stalks, leaves	Burning, activated charcoal	-(*)
Soybeans	Dry stalks	Dumping, animal fodder	-

(*) – Almost all is reused or recycled for heating purposes.

Crop residues are characterized by seasonal availability, high levels of moisture and nutrients, and ease of decomposition. They may play a major role in sustainable energy if farmers know how to utilize them effectively. Crop residues can also be used as either fuel or fertilizers. However, the traditional use of crop residues and a lack of information on modern technologies limit the development of the large-scale use of waste biomass, leading to increases in the value of agriculture output.

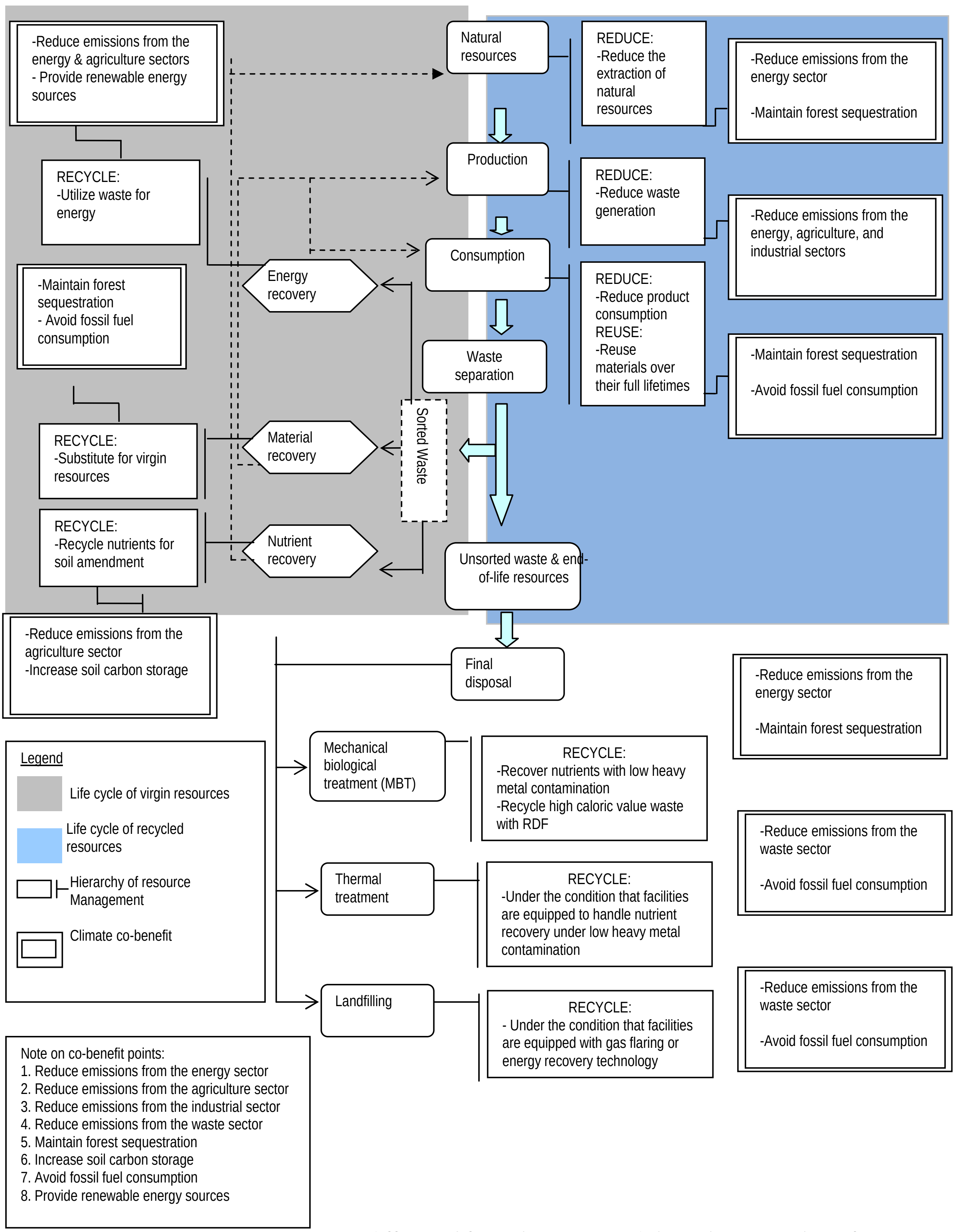

Figure 4-1 3R practices at different life-cycle stages and their climate co-benefits

Source: IGES-WMR Working Paper 2009 – 001 on Improved Organic Waste Management

Focusing on typical crops that have a large production capacity and high rate of not being utilized, and selecting an average value for the growth rate (based on the development orientation of each agricultural subsector), we can preliminarily estimate the crop residue potential for the years 2015 and 2020. The results are presented in Table 4.2. Unused residues of rice and maize have the greatest volume and are expected to reach around 40 million tons and 20 million tons in 2020, respectively. As a consequence of development, the agricultural environment is seriously affected by the increasing amount of wastes.

Table 4.2 Unused biomass potential from selected cultivation activities

Unit: *1,000 tons*

Agricultural plant	Year 2008	Year 2015(*)	Year 2020(*)
Rice	38,182	39,137	40,115
Maize	16,875	18,563	20,419
Peanuts	2,176	2,230	2,286
Cassava	813	833	854

Source: Estimated by the authors, INEST-2009

(*) *– Assumes a 10%/year rate of increase in maize output and a 2.5%/year rate of increase in output of other crops (based on the growth rate trend shown in Table 2.1 and the development orientation of the cultivation sector).*

4.1.2 Environmental and energy assessments

In terms of 3R approaches, certain treatment methods should be applied such as technical dumping of straw or stalks in order to maintain the C/N ratio in the soil or recycling biomass as food for breeding cattle in winter or fuel for cooking or as growing media for orchids or mushrooms.

Energy benefits:

According to an estimate produced by the Center for Electric Consultancy Development, the heat-based recycling ratio of crop residues is around only 2% [13]. This figure is inferior to its potential. The potential energy benefits from unused crop residues in 2008, 2015, and 2020 can be estimated based on correlative calorific values. These are shown in Table 4.3. Rice residues have the highest biomass potential in terms of heat productivity (nearly 13,000 Mtoe) and maize residues rank second (nearly 6,800 Mtoe).

Table 4.3 Energy benefits from typical crop residues

Agricultural plant	Calorific value, *kcal/kg*	Heat productivity, *Mtoe*		
		2008	2015	2020
Rice	3450	12,310	12,618	12,933
Maize	3500	5,519	6,071	6,678
Peanuts	4249	864	886	908
Cassava	3500	266	273	279
Total		**18,959**	**19,847**	**20,799**

Source: Estimated by the authors, INEST-2009

Environmental pollution reduction and agricultural benefits:

Some crop residues such as rice husks can be reused directly for soil mulching. The components of crop residues are mainly organic. For example dry straw and stalks have an organic component percentage of 40–50% with decomposability varying from 30–80%. With about 20 million tons of unused crop residues, the potential amounts of N, P_2O_5, and K_2O in these waste sources can be roughly estimated for the years 2015 and 2020. The results are shown in Table 4.4. These cultivation residues can also provide potential materials and substances essential as nutrients for plants if used effectively. In addition, soil mulching requires low labor input and low investment. In terms of climate change reduction, this reuse of plant residues can also avoid the GHG emissions that would otherwise result from the burning and composting process.

Table 4.4 Potential N, P, and K amounts for a soil mulching and/or composting option

	Organic components	N	P_2O_5	K_2O
Percentage, *%*	*34.13*	*0.21*	*0.18*	*1.55*
Potential amount, *thousand tons*	682$^{(*)}$	143	123	106

Source: Estimated by the authors, INEST-2009
(*) – Assumes a 10% composting rate of unused crop residues.

Cultivation residues can also be recycled for organic fertilizer. In this case, pig manure is best used when mixed and composted with large quantities of plant wastes. The organic fertilizer can also promote microbial activities that keep fertilizers in the soil and make the soil foam.

4.2 Benefits assessment of the 3R approach on livestock waste potentials

4.2.1 Estimations of biogas potential from cattle breeding activities

As analyzed in chapter III, if biogas generated from livestock waste is recovered, it will reduce the use of other energy sources and bring benefits for the economy and society. In fact, the biogas productivity of biogas equipment is normally lower than the theoretical level of productivity because the actual conditions of anaerobic digestion processes cannot reach optimal levels in terms of anaerobic conditions, the C/N ratio, dry weight content, storage time, pH, temperature, etc. (cf. Table 4.5).

Table 4.5 Optimal conditions for fermentation to generate biogas

Impacting factors	Temperature *(^0C)*	pH	Storage time *(days)*		Dry weight content *(%)*		Ratio C/N
			Manure	Plants	Manure	Plants	
Optimal value	30 – 40	6.5 – 7.5	30 – 50	100	7 – 9	4 – 8	30/1

Among the aforementioned typical types of household biogas equipment in Vietnam, the biogas equipment with fixed cover that has become widespread in China and India is often considered for solid waste and wastewater treatment on breeding farms. According to the experimental results of IE, the characteristics of common waste materials and their biogas productivity when using this equipment are shown in Table 4.6.

Table 4.6 Characteristics of common materials and their biogas productivity

Material	Waste generated a day, *kg/animal*	Dry weight content, *%*	C/N ratio	Biogas production rate, *l/kg fresh material*
Animal wastes				
Cow manure	15 – 20	18 – 20 (19$^{(*)}$)	24 – 25	16 – 32
Buffalo manure	18 – 25	16 – 18 (17$^{(*)}$)	24 – 25	15 – 30
Pig manure	1.2 – 4	24 – 33 (28$^{(*)}$)	12 – 13	40 – 60
Plant wastes				
Fresh water fern		4 – 6	12 – 25	0.3 – 0.5
Dry straw		80 – 85	48 – 117	1.5 – 2.0

Source: Institute of Energy, 2008

$^{(*)}$ *– Average value of dry weight content*

Focusing on cow and pig waste on large-scale breeding farms and selecting the average values for the waste generation rate (shown in Table 2.6) and biogas production rate, we can estimate the daily amount of biogas yield in 2008, 2015, and 2020. The results are presented in Table 4.7.

Table 4.7 Potential biogas generated in BE with fixed covers

Waste materials	Number of cattle, *1,000 heads*	Manure a day, *tons*	Biogas a day, m^3		
			2008	2015(***)	2020(***)
Cow manure	2,166(*)	25,342(**)	421,070	442,124	464,230
Pig manure	7,674(*)	9,976(**)	345,330	362,597	380,726
Total			**766,400**	**804,720**	**844,956**

(*) – Assumes 30% of the total number of animals are being bred on large-scale farms, a proportion derived from the status assessment of cattle breeding activities (part II.1.2, chapter II).
(**) – Assumes that all unused manure can be used to generate biogas. Unused manure is estimated at about 45% of the total amount of manure, based on the status assessment of livestock wastes (part II.2.2, chapter II).
(***) – Assumes a 5%/year rate of growth in the number of cattle (based on the growth rate trend shown in Table 2.2 and the development orientation of the livestock sector).

Thus, the brief estimates above indicate that the amount of biogas generated from livestock waste has potential that would help serve in place of some exhausted energy sources such as coal or oil while also bringing other environmental and social benefits.

4.2.2 Assessment of environmental, energy, and social benefits

Energy benefits:

As mentioned above, biogas brings energy benefits. One unit volume of biogas is normally two-thirds CH_4 and one-third CO_2. One m^3 of biogas can provide about 6000 calories, which is equivalent to 1.0 liter of alcohol, 0.8 liters of gasoline, or 0.6 liters of crude oil. Table 4.8 shows the energy that would result from potential biogas in 2015 and 2020. The energy demand for rural cooking is roughly $0.25m^3$/person, according to the Ministry of Public Security [8]. The amount of rural cooking demand that could be met through this amount of biogas being generated is also estimated and shown in the table.

Table 4.8 Energy benefits from potential biogas in 2015 and 2020

Year	Biogas production, m^3	Gasoline, *liters*	Availability for cooking demand in rural areas, *thousand persons*	
2008	766,400	613,120	3,065,602	Occupied ~ 5.1%
2015	804,720	643,776	3,218,882	-
2020	844,956	675,965	3,379,826	-

Source: Estimated by the authors, INEST-2009

It can be seen that this amount of biogas would potentially provide enough energy to meet about 5% of the energy needs for the cooking demand of the rural population. Moreover, this energy source also provides economic benefits for rural communities.

At present, the energy converted from biogas still contributes a low portion of national energy demand. However, this is a renewable energy source and it should be developed on a larger scale over time.

Greenhouse gas emission reductions:

One kilowatt of electricity generated from biogas generates up to 1 kg less CO_2 emissions than a kilowatt generated from diesel fuel or gasoline sources [12]. On average, 0.7 m^3 of biogas can generate 1 kW of electricity power, so 804,720 m^3 of biogas (as estimated in 2015) could generate 1,149,599 kW daily while also reducing CO_2 emissions by some 1,145 tons a day.

As mentioned earlier, CH_4 has greater global warming potential than CO_2, with 1 ton of CH_4 being equivalent to 21 tons of CO_2 in terms of GHG effects. When burning CH_4 collected through the biogas equipment, CH_4 is metabolized to CO_2. Theoretically, the burning of 1 ton of CH_4 generates 2.75 tons of CO_2. Thus through burning, the GHG effects will be reduced from 21 times that of CO_2 to 7.6 times (i.e., reduced by a factor of 2.75), giving biogas a great amount of potential for CDM projects.

Agricultural benefits:

After waste materials are digested, part of the waste is converted to biogas, while another part (called organic residue) remains in the biogas equipment. This organic residue includes two phases: suspended solid and liquid. The nutrient content in suspended solid waste is higher than normal compost and can be used as fertilizer for cultivating (Table 4.9). Countries such as China, India and the Philippines have experiences in studying this organic residue. In the biogas equipment, the nutrients are metabolized partially from solids to liquids because organic compounds are digested rather slowly. The nutrients, therefore, can be stored in simple protein forms. Also the organic residue's rate of loss of P and K is much lower than that of normal compost. For example, P and K occupy from 0.6 to 1.5% and 0.05 to 1%, respectively, of the total amount of organic residue in the equipment, according to the experiment results of IE. In addition, this organic residue has important micro-demand elements such as Cu, Fe, Zn, Mn, humic acids, cellulose, and lignin, which are essential for plants.

Table 4.9 Total content of N, P_2O_5, and K_2O in some organic fertilizers

Type of manure	N *(%)*	P_2O_5 *(%)*	K_2O *(%)*
Waste of solid biogas	1.45	1.10	1.10
Dry waste residues of biogas	1.60	1.40	1.20
Incubated manure	1.30	1.00	1.00

Source: Institute of Energy, 2009

In addition, spraying the liquid by-product onto leaves can directly increase crop yields by up to 10% compared to introducing fertilizers directly into the soil, according to some research [19]. Results from the Research Institute of Chengdu (China) also indicate that a combination of organic and inorganic fertilizers increase crop yield up to 7–9% and 12.1%–14.5% compared to using only one or the other and cases in which no fertilizer is used, respectively.

5 Policies proposed for AWM in Vietnam

Treatment and reuse of organic waste generated in the breeding and cultivation processes play an important role in reducing environmental pollution and improving public health. This is also an important solution contributing to sustainable agriculture development. In terms of societal and economic aspects, a 3R approach also creates job opportunities, increased income, enhanced fairness in society, and cost reductions in waste management. Based on the benefits resulting from the opportunities overviewed in chapter III, the following are a recommended 3R hierarchy and a proposal for policy improvements to achieve better management of agricultural waste in Vietnam.

5.1 Recommendation for a 3R hierarchy in AWM

The 3R approach is conventionally expressed through a pyramid hierarchy, in which increases in environmental benefits are placed in order from bottom to top. In our recommendation, proposed options for AWM are also displayed through pyramid hierarchies (Figure 5.1) in which the recycling, reuse, and reduce options are placed in order from bottom to top. To prioritize sub-options within these hierarchies, the most important criteria, such as their application capacity and benefits (including both environmental benefits and economic benefits), are compared and presented in Tables 5.1 and 5.2. Co-benefits with climate change are a key element of the analysis.

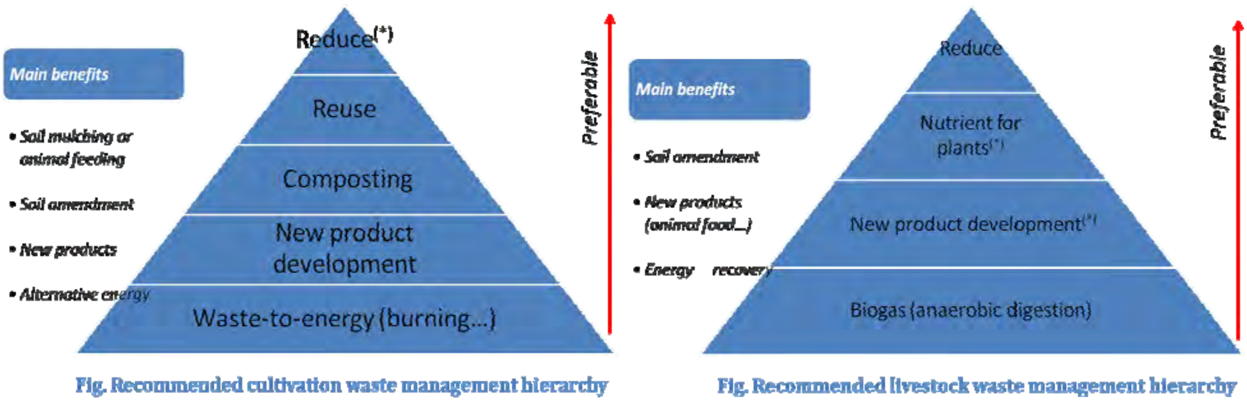

Figure 5-1 Recommended agricultural waste management hierarchy

Source: Developed by the authors, INEST-2009

As it is proposed that cultivation and livestock residues be fully taken advantage of, on-site burning or dumping options do not appear in the figure. As mentioned in chapters 2 and 3, reuse and/or simple recycling activities are already being undertaken spontaneously by Vietnamese farmers.

However, about 50% of total agricultural waste generation is still unused, and this amount has great energy supply potential through recycling (via biomass and biogas production). In terms of environmental burdens, even placed at the bottoms of the pyramids, the environmental pollution and GHG emissions from recycling processes are generally smaller than the levels that would occur as a result of landfill disposal. Hence, methodical recycling activities need to be developed.

Table 5.1 Analysis of the recommended cultivation waste management hierarchy

Options		Reduce	Reuse for soil mulching or animal feeding	Composting	New product development	Waste to energy
Benefits	*Environmental benefits*	▪ Reduces pollution and disease	▪ Reuses cultivation residues ▪ Improves soil quality ▪ Protects soil from erosion and heavy rains	▪ Recycles cultivation waste ▪ Replaces inorganic fertilizers to a degree	▪ Recycles cultivation waste ▪ New products such as ethanol are considered as a renewable energy source, which can help to reduce GHGs	▪ Recycles cultivation waste
	Economic benefits	▪ High degree of economic efficiency	▪ Numerous benefits	▪ Reduces chemical fertilizer expenses ▪ Reduces food expenses for livestock	▪ New products can be made by the farmers themselves and come onto the market	▪ Takes advantage of heat and ash ▪ Developing at an industrial scale would generate even greater benefits
Applications	*Sample applications*	▪ Reduce fertilizer and pesticide use to a reasonable amount ▪ Expand safe vegetable areas ▪ Avoid use of fresh night-soil ▪ Select good varieties/seeds (disease resistant, high yielding strains, etc.)	▪ Organic residues (such as grass clippings, straw, bark chips, and similar materials) can be used for mulching ▪ Organic content of residues is collected as animal fodder	▪ Provides compost for cultivation, replacing chemical fertilizers	▪ Straw and rice stubble can be used as media for growing orchids ▪ Ethanol can be produced from husks and straw(*) ▪ Can produce breeding fodder (fresh or dried fodder)	▪ Burned as fuel for cooking and heating ▪ Burned for ash that can be used as a material for composting or mulching
	Application capacity	▪ Investment needed (both financial and technical investment)	▪ Easy to carry out and can be applied at any scale ▪ Almost all cultivation residue can be mulched	▪ Can be applied to almost all residues ▪ Small-scale composting plants are sustainable	▪ Limited application (households have secondary jobs) ▪ Requires skill, technical knowledge, and equipment	▪ Simple and easy to carry out ▪ Applied at a small scale by almost all farmers

Options	Reduce	Reuse for soil mulching or animal feeding	Composting	New product development	Waste to energy
Disadvantages		▪ CH_4, H_2S, etc. can arise (in warm temperatures and high humidity) ▪ Diseases and germs are not treated thoroughly	▪ GHG emissions still arise ▪ Diseases and germs are not treated thoroughly	▪ Solid waste, air pollution arise during production processes	▪ Biomass combustion ▪ GHG emissions

(*) – Via hydrothermal and hydrolytic enzyme reactions. This technology is under research and development but a high degree of feasibility is expected in the future.

Table 5.2 Analysis of the recommended livestock waste management hierarchy

<table>
<tr><th colspan="2">Options</th><th>Reduce</th><th>Nutrient for plants
(after pre-treatment)</th><th>New product development</th><th>Biogas (anaerobic digestion)</th></tr>
<tr><td rowspan="2">Benefits</td><td>Environmental benefits</td><td>▪ Reduces pollution and disease</td><td>▪ Reuses livestock waste (manure)
▪ Reduces environmental pollution
▪ Replaces inorganic fertilizers to a degree</td><td>▪ Reuses/recycles livestock waste
▪ Reduces odors, flies, disease, and GHGs</td><td>▪ Recycles livestock waste
▪ Enhances energy security (by replacing a part of fossil fuels)
▪ Using biogas can reduce GHGs emissions in total(*)</td></tr>
<tr><td>Economic benefits</td><td>▪ Reduces cost for feeding materials and environmental treatment
▪ High breeding efficiency</td><td>▪ Reduces chemical fertilizer expenses
▪ Increases nutrients for soil
▪ Increases breeding productivity</td><td>▪ Reduces food expenses for livestock</td><td>▪ Reduces expenses for power (electricity) or fossil fuels</td></tr>
<tr><td rowspan="2">Applications</td><td>Sample applications</td><td>▪ Raise breeding efficiency
▪ Apply cleaner production
▪ Select fine breeds</td><td>▪ Excreta is mixed with ash, powdered lime, rice husks, etc. and food residues are composted for an appropriate period of time</td><td>▪ Chicken's excreta (with a high content of protein, ash, Ca, P) can be reused as food for cattle, pigs, fish, etc. after being treated with EM</td><td>▪ Biogas tanks with air collection system for cooking, heating and generating power
▪ Waste water from biogas tanks for irrigation(**)
▪ Sludge from biogas tanks for soil mulching</td></tr>
<tr><td>Application capacity</td><td>▪ Investment needed (both financial and technical investment)</td><td>▪ Currently applied widely in Vietnam in rural areas</td><td>▪ Apply to large scale farms
▪ Investment needed (both financial and technical investment)</td><td>▪ More popular in the rural areas of Vietnam
▪ Investment needed (both financial and technical investment)</td></tr>
<tr><td colspan="2">Disadvantages</td><td></td><td>▪ GHG may be emitted
▪ Diseases and germs are not treated thoroughly</td><td>▪ Air pollutants (such as NH_3) and GHGs (such as CH_4) still arise during production processes</td><td>▪ CH_4 is explosive
▪ CO_2 is emitted when using (burning) biogas
▪ Good quality biogas equipment that operates stably is still expensive for farmers</td></tr>
</table>

(*) – Compared to the case of not recycling - this manure amount can be naturally anaerobically digested and emit CH_4.

(**) - This wastewater source should be treated due to high BOD and germs.

5.2 Policy proposed for the improvement of AWM

Recently the agricultural economy and rural life are experiencing remarkable improvements in Vietnam. A substantial amount of scientific and technological knowledge has been applied to agricultural development. While these applications certainly have positive aspects they also lead to environmental consequences, especially when farmers lack sufficient technical skills to master the scientific and technical achievements. Moreover, a market economy characterized by weaknesses in management leads to an overwhelming of the market by products, chemicals, and materials which may be poor quality, have no origin certificate, or have other such problems. In order to promote AWM towards sustainable development in accordance with the above recommendations, there are a number of areas in policies, management tools, public awareness, and financial support that need improvement.

5.2.1 Legal document and management system

The legal system is ineffective in terms of waste management. According to statistics of the Ministry of Justice (MoJ), currently there are about 300 legal documents on environmental protection in Vietnam. However the system of these documents is not comprehensive insofar as it lacks detail and lacks obligatory regulations, for example. Therefore it affects the behavior of individuals and organizations regarding environmental protection only to a limited degree. It is necessary to have obligatory regulations on infrastructure development, such as a requirement that relevant sewage systems and centralized wastewater treatment systems be completed before operations commence at an entity, or a regulatory obligation for entities to report regularly on wastewater and solid waste treatment activities.

In addition, the administrative procedure is burdensome and the management system overlaps. A centrally coordinated system of environmental management for the agricultural sector should be created according to international standards in general, with an organization and a system of careful monitoring that ensure a good, human-friendly environment. For example, while investigating biogas development in Vietnam, the authors found that a model has been developed mainly in non-remote rural areas but not in remote or difficult areas. Steps to be taken in the future are shown in Figure 5.2. In this figure, the dark blue areas on the left indicate proposed strategies for improvement and the light blue areas on the right list proposed methods for achieving the improvement.

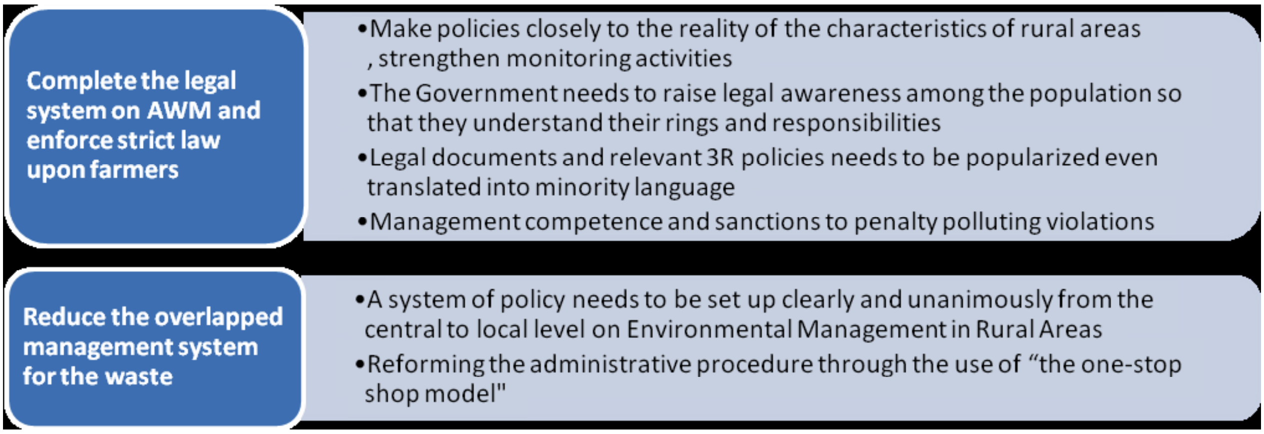

Figure 5-2 Vertical block list of proposed policies for integrated agricultural waste management
(The dark blue areas on the left indicate proposed strategies;
the light blue areas on the right list proposed methods to bring about the improvement.)

5.2.2 Building strategies and development plans

Until now, AWM has been treated as a low priority in Vietnam. Attention needs to paid to AWM during development planning in every kind of agricultural production area, such as centralized breeding farms and intensive cultivation areas. These strategies must be scientific and take development trends into account carefully so that appropriate solutions are derived. In the field of biogas generation, experiences in India and China show that after establishing governmental organizations on biogas, the use of biogas has developed strongly both quantitatively and qualitatively.

In addition, the authorities need to work in cooperation with the mass media in order to raise the public's awareness and knowledge. The government needs to consider support to improve people's lives in local communities, eliminate the gaps between urban and rural areas, and reduce medical expenses by improving people's health and fostering a cleaner environment. Beyond this, co-operation between scientific institutions and farmer associations needs to be encouraged in order to spread recycling technology (such as for biogas) and thereby generate both national and community-level benefits.

Steps towards such goals are shown in Figure 5.3.

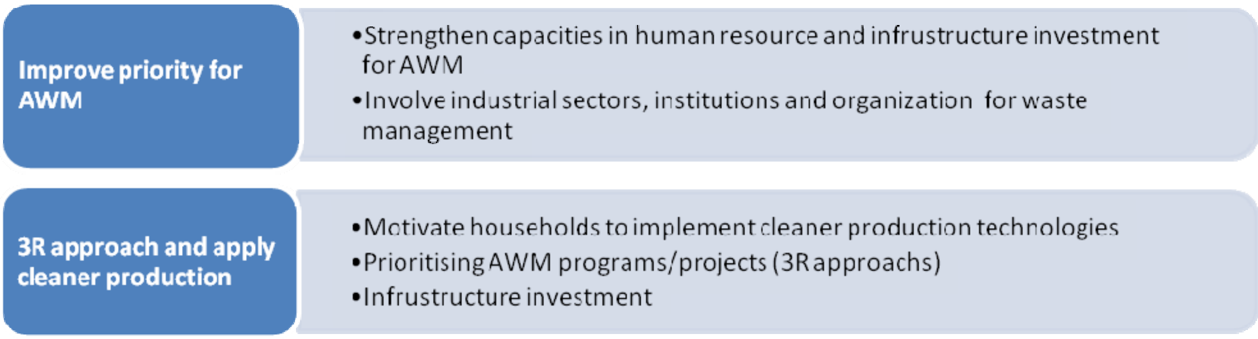

Figure 5-3 Vertical block list of proposed policies for development planning
(The dark blue areas on the left indicate proposed strategies;
the light blue areas on the right list proposed methods to bring about the improvement)

In addition, Vietnam has already suffered from natural disasters induced by climate change. Therefore, the country has been developing national action plans on climate change which cover both mitigation and adaptation strategies. The country should clearly mention GHG emission reductions in the agricultural sector and promote the 3Rs to facilitate climate change mitigation. Projects concerning agricultural waste such as waste biomass to energy and anaerobic digestion can be registered to the CDM. The CDM is an international carbon trading mechanism under which industrialized countries can purchase certified emission reduction (CER) credits from emission reductions (or emission removal) projects implemented in developing countries. Each CER is equivalent to one ton of CO_2. CERs that are purchased and can be counted as reductions by the purchasing country and contribute to that country's efforts to meet its emissions reduction targets under the Kyoto Protocol.

5.2.3 Infrastructure investment

Most farming areas are characterized by insufficient financial and technical support. Policies need to be developed on financial and technical assistance in order to control and address rural environment pollution in general and AWM in particular.

Besides the development of rural infrastructure, agricultural cooperatives should also invest in treatment systems for wastes generated through breeding and cultivation. Agricultural cooperatives would collect from the waste sources the wastes to be treated, leading to increased revenue for cooperative members and other positive results. This would raise awareness of environmental protection among participants from the agricultural field in particular and for whole community in general. Currently, treatment of wastes to produce energy also faces barriers because it requires investment in equipment as well as compliance with technical processes. While this method generates significant benefits whenever it is applied on a large scale at livestock farms, application of waste-to-energy is still limited in rural in Vietnam.

Steps towards such goals are shown in Figure 5.4.

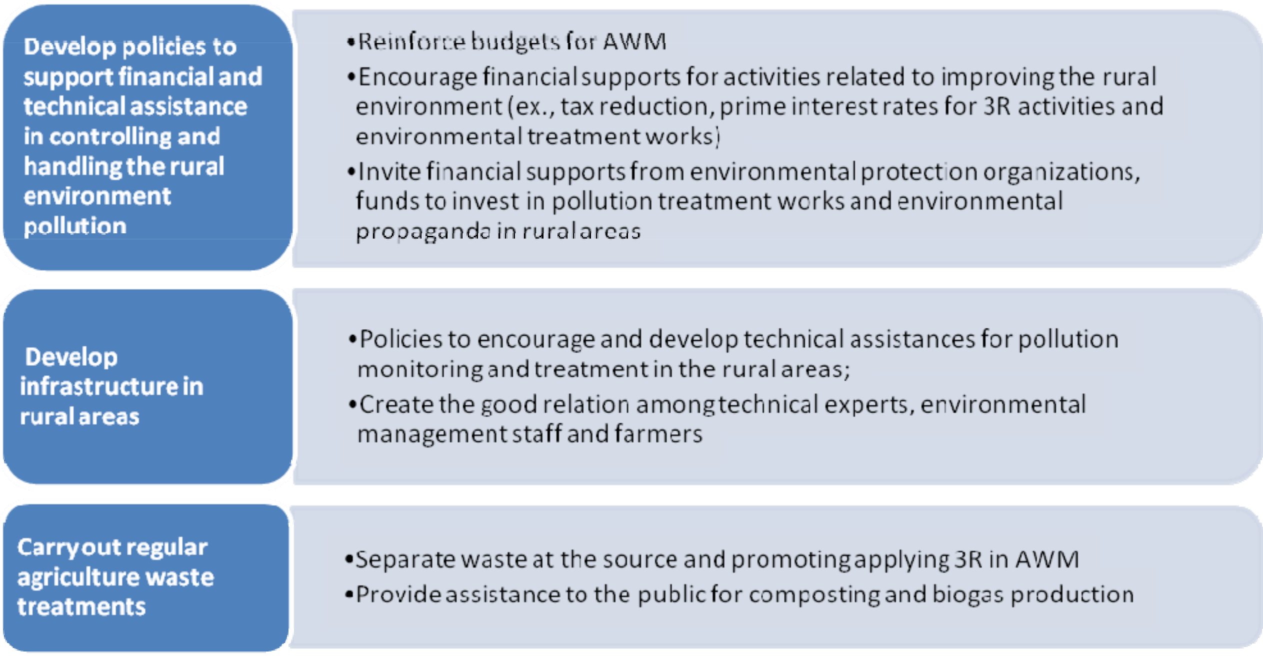

Figure 5-4 Vertical block list of proposed policies for infrastructure investment

(The dark blue areas on the left indicate proposed strategies;

the light blue areas on the right list proposed methods to bring about the improvement)

5.2.4 Public awareness of 3R approach

Currently, education on agricultural/rural environmental protection is still limited. As a result, the responsibilities of organizations, individuals, and communities in environmental protection have not been promoted yet. Public awareness campaigns foster awareness of the relationship between agricultural production and ecology and help people to recognize clearly the close relationship among nature, humans, and society.

For example, in order to *reduce the amount of unnecessary inorganic fertilizers applied, there need to be careful preparation of raw agricultural materials and the proper use of fertilizer*. As another example, in order to generate biogas with high output, a large source of raw materials appropriate for the equipment is necessary, as is a means of collection and biogas tanks. To do this, first of all, people have to be shown the benefits of biogas, namely, the energy benefits, economic benefits, and benefits in terms of reduced environmental pollution and lessened impacts on climate change. In addition, people's living conditions will be improved through improvements to their kitchens and bathrooms, through the use of closed toilets, and so on. Women and children will be liberated from cooking with straw or wood.

Steps towards such goals are shown in Figure 5.5.

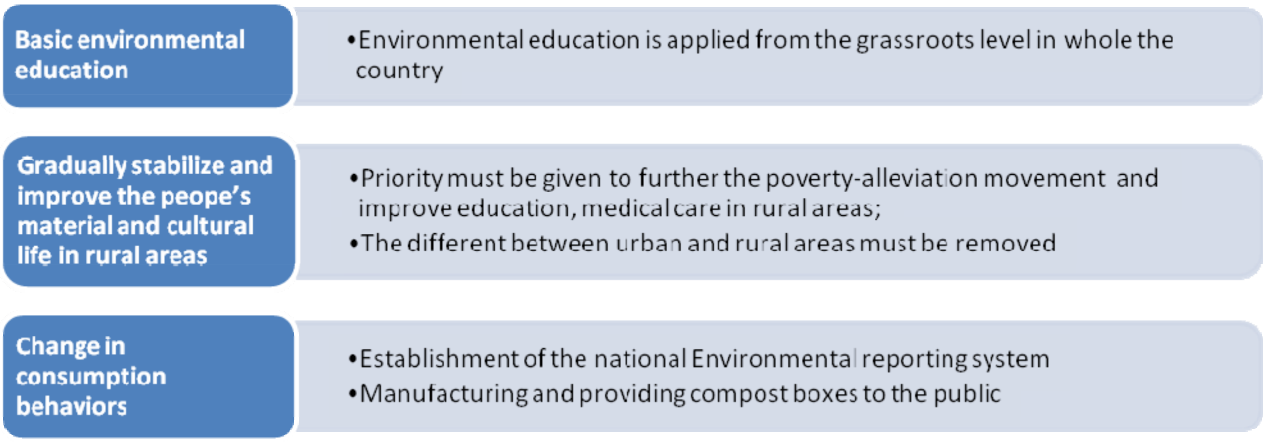

Figure 5-5 Vertical block list of proposed policies for raising public awareness

(The dark blue areas on the left indicate proposed strategies;

the light blue areas on the right list proposed methods to bring about the improvement)

6 Conclusion

As a consequence of development, the agricultural environment in Vietnam has been seriously impacted by the increasing amount of wastes. The related problem of unused pesticides being stored or disposed of improperly, leading to osmosis and leaks also affects the environment. Excessive use of fertilizers also negatively impacts agricultural production, including through food poisoning and field pollution (except for the N-fertilizers, which are retained in the soil colloid for subsequent crops). Meanwhile, regarding livestock waste, 45% of total cattle manures are discharged directly into the environment without treatment of any kind. The hot and humid tropical climate in Vietnam creates favorable conditions for the decomposition of organic components, accelerated fermentation, and putrefaction, resulting in the generation of GHGs. Moreover, increasing agricultural wastes negatively impacts soil fertility and causes water pollution. Reducing, reusing, and recycling agricultural waste, therefore, are strategic solutions contributing to the beneficial integraged management of agricultural waste. Some methods meriting application include the technical dumping of straw or stalks in order to maintain a proper C/N ratio in the soil and recycling biomass as food for breeding cattle in the winter or as fuel for cooking.

In this study, in order to demonstrate that unused agricultural waste has great recycling potential for supplying energy (biomass and biogas production), a benefits assessment was carried out. The energy benefits that can be generated from unused typical crop residues in 2008, 2015, and 2020 were estimated based on their correlative calorific values. Among food plants, rice residue has the highest biomass potential in terms of heat productivity (~ 13,000 Mtoe) and maize residue ranks second (~ 6,800 Mtoe). For livestock wastes, the amount of biogas produced from cow and pig manure at large-scale breeding farms would potentially provide enough biogas to meet about 5% of total cooking demand of the rural population. This energy source would also contribute economic benefits to rural communities. In terms of GHG emission reductions, CO_2 could be reduced by some 1,145 tons a day.

The study also proposed AWM options by indicating a hierarchy in which increasing environmental benefits (including climate change co-benefits) are distributed in order from bottom to top in a pyramid shape. In order to promote AWM that fosters sustainable development in accordance with the recommended hierarchy, improvements must be carried out to address a number of issues in policies, management tools, public awareness, financial support, and so on. It is necessary to have obligatory regulations on infrastructure development, build a centralized system of environmental management for the agricultural sector according to international standards in general, and utilize means of organization that are closely monitored for their ability to foster a positive environment for humans. Attention also needs to be paid to AWM during development planning for centralized breeding farms, intensive cultivation areas, and other agricultural production entities. Moreover, the government needs to consider support towards improving communities, eliminating gaps between urban and rural areas, and reducing medical expenses by improving people's health and creating a cleaner environment. In addition, co-operation between scientific institutions and farmers' associations needs to be encouraged in order to spread recycling technology to benefit both the nation and individual communities. Finally, public awareness raising regarding the impact of agricultural production on the ecology will help people to recognize clearly the close relationship among nature, humans, and society.

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Institute for Environment Science and Technology (INEST)

Room 301, C10 Building, Hanoi University of Technology

1 Dai Co Viet Road, Hanoi, Viet Nam

Institute for Global Environmental Strategies (IGES)

2108-11 Kamiyamaguchi, Hayama, Kanagawa, 240-0115 Japan

E-mail: iges@iges.or.jp

http://www.iges.or.jp