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Managing the Livestock Revolution

Policy and Technology to Address the Negative Impacts of a Fast-Growing Sector

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PREFACE

The strong expansion of the animal products sector in the developing world can pose major threats to global water, soil, and air quality, the livelihood of smallholders, and public health, if no preventive and mitigating measures are taken. Dramatically growing demand for meat and milk, and the growing concentration of production, processing, and retailing have already led to excessive stock density in several middle-income countries, causing major imbalances between animals and their surrounding natural and human ecosystems. Without appropriate public policies, these trends are expected to continue.

This paper is aimed at informing decision makers involved in public policy in the developing world and in the international donor community with an overview of the main issues involved, and their possible solution, and trade-offs, to give this important issue a higher profile in the policy debate, and avoid some of the policy errors made in the industrialized world.

Currently this paper is most relevant to middle income countries with a rapidly growing livestock sector—such as, Brazil, China, Mexico, Thailand, and several East European countries. However, it should become increasingly relevant to the urban and peri-urban areas of the rest of the developing world, including Sub-Saharan Africa.

This document is organized as follows:

Chapter 1 describes the emerging patterns of animal product demand and supply, the underlying forces that shape these patterns, and their implications for the structure of animal agriculture.

Chapter 2 summarizes the main impact of these trends, focusing on the changing role of livestock manure from a resource to a waste material that must be managed if negative effects on water, soil, and air quality are to be avoided, and for equity and public health on the concentration of farms and animals, respectively, which can crowd out smallholders and provide a favorable environment for the emergence of diseases.

Chapter 3 describes some of the technological tools available to prevent and mitigate these negative effects, and describes the main financial, regulatory, and institutional instruments applied in Organisation for Economic Co-operation and Development and middle-income countries, and their applicability to a broader scale of developing countries.

Chapter 4 describes existing policy and institutional support mechanisms and environmental policy instruments.

Chapter 5 provides the rationale for public policy involvement and recommends public policy entry points and possible World Bank support for the main tools and instruments described above.

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ACRONYMS AND ABBREVIATIONS

BSE	Bovine Spongiform Encephalopathy
CAFO	Concentrated animal feeding operations
CDC	Center for Disease Control
CIWF	Compassion in World Farming
DIVA	Differentiating infected from vaccinated animal
EMS	Environmental management systems
EU	European Union
FAO	Food and Agriculture Organization
GT–TAD	Global Framework for the Progressive Control of FMD [foot–and– mouth disease] and other Transboundary Diseases
GEF	Global Environment Facility
GIS	Geographic information systems
ha	hectare
HPAI	Highly Pathogenic Avian Influenza
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
kg	Kilogram
km	Kilometer
LEAD	Livestock, Environment, and Development Initiative
LEI	Landbouw Economisch Instituut, Agricultural Economics Research Institute
MDA	Minnesota Department of Agriculture
MINAS	MINeral Accounting System
N	Nitrogen
NRARS	Natural Resource, Agriculture, and Engineering Service
OECD	Organisation for Economic Co-operation and Development
OIE	World Animal Health Organization
P	Phosphorous
P_2O_5	Phosphate
PCF	Prototype Carbon Fund
RIVM	Rijks Instituut voor Millieu, (State Institute for the Environment)
SARS	Severe Acute Respiratory Syndrome
SPF	Specific pathogen-free
SSA	Sub-Saharan Africa
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
VCJD	Variant Creutzfeld–Jakob disease
WANA	West Asia and North Africa
WHO	World Health Organization

EXECUTIVE SUMMARY

SETTING THE SCENE

Fueled by fast-expanding demand, the production of meat and milk in the developing world has doubled in recent decades, and this trend is expected to continue. This expanding sector can provide income, employment, and high quality nutrition for vulnerable groups, and in many areas of the world, essential soil fertility inputs.

However, as production grows, market forces, often supported by deliberate or unintended government policies, are causing, in particular in the pig and poultry sector, a spatial concentration of larger-size production units, mostly around urban areas, and an economic concentration of production, processing and retailing. This geographical and economic concentration of the livestock sector probably improves the affordability of meat and milk for the urban poor, and might create better-paid employment up- and downstream of the producer, but has significant negative effects on the environment, animal and human health, and social equity.

IMPACTS

Environment

Regarding the environment, the excessive nitrogen, phosphate, and heavy metal levels in the effluent of intensive livestock farms causes environmental pollution and loss of biodiversity. While exact data on the total global environmental impact are not available, some illustrative facts are:

More than 130,000 square kilometers of arable land in China and 30,000 square kilometers in Thailand, (together an area about four times the size of the Netherlands), have an estimated annual livestock nutrient waste production of phosphate of at least 20 kilograms per hectare per year in excess of the adsorptive capacity of the surrounding ecosystem. The extent of nitrate nutrient loading is probably even more severe.

The resulting eutrophication[1] of fresh water, with specific phenomena such as “red tide” or harmful algae blooms in East Asia, is affecting fisheries and some of the most valuable aquatic biodiversity, such as the coral reefs of the South China Sea.

The increased cereal requirements to feed the pig and poultry population to meet the increased demand would require over the next two decades an additional area of about 65 million hectares, more than the size of France.

Animal and human health

Regarding animal and human health, multiple factors, such as changes in weather and climate, land use, human behavior, and lifestyles; a growing population of more susceptible, elderly, and immuno-compromised individuals; and globalization with increased human-to-human contacts and dietary diversity, play a significant role in changing host–pathogen relationships. However, the accelerating demand for animal products has also increased the geographical density of livestock and the interface between livestock and people, and is leading to genetically uniform but highly vulnerable livestock populations. These trends are also major contributors to the emergence, or reemergence, of animal and human diseases. As in the case of environmental effects, global data are often not available or are unreliable, but some illustrative facts are:

- About every year, an emerging livestock-related disease—such as the Nipah virus, Bovine Spongiform Encephalopathy (BSE), Severe Acute Respiratory Syndrome (SARS), and Highly Pathogenic Avian Influenza (HPAI)—threatens the global human population. Together these diseases have caused over 1,000 deaths.
- Livestock-related and livestock-pollution-induced, food-borne diseases are a major source of child morbidity and mortality, and a major source of acute gastroenteritis, which, for example, has been estimated to cost Dutch society about US$27 million a year.
- Animal diseases have caused extraordinary losses. The economic losses due of BSE are estimated at roughly US$20 billion worldwide, losses due to HPAI are estimated to be at least US$1 billion worldwide, and losses to foot-and-mouth disease in the U.K. alone at US$8 billion. This is accompanied by the destruction of large numbers of animals, often belonging to smallholders, with the subsequent social hardship and animal welfare consequences.

Inadequate control and eradication policies and measures are causing these diseases to become endemic and much more costly and difficult to eradicate.

Equity

While the East Asian experience shows that smallholders using family labor are reasonably efficient, factors—such as, economies of scale in waste management, disease control and biosecurity, consumer demand for uniform products, and biased policies—lead to increasing farm sizes and the danger of smallholders being crowded out. The overall effect of this trend is unclear, although it might lead to increased employment in other parts of the supply chain.

CURRENT STATUS OF TECHNOLOGIES AND INSTITUTIONS

Environment

Countries in the Organization for Economic Co-operation and Development (OECD), particularly the United States and Western Europe, have experienced a similar expansion and concentration of the livestock sector over the last three decades. Much can be learned from their experiences, often based on trial and error. Obviously, except for very radical solutions, such as prohibiting livestock production, there is no “silver bullet” for solving these problems. Some major aspects include:

- There are many technologies available to mitigate the waste burden. A more balanced ration and better feeding technology can reduce nitrogen and phosphate production by 10-50 percent depending on the species. Separating solids from liquids, and using different aeration techniques can reduce organic and even the heavy metal content. Bio-digestion to produce energy becomes also increasingly interesting, as the prices of fossil fuels rise. Finally, GPS technology, combined with soil and crop nutrient analysis can greatly improve the accuracy of balancing crop requirements and total nutrient application, thus reducing leaching and run-off of surplus nutrients into surface water. All these technologies bring livestock waste production more in line with the absorptive capacity of the surrounding ecosystem. However, few of these technologies are "win–win," so their general adoption would need to be accompanied by an appropriate set of regulatory, financial, and communication instruments, which includes the costs and benefits of the environmental and public health externalities.

- Regulation has been the instrument of choice in most OECD and other high-density livestock countries. It covers zoning to improve the spatial distribution of intensive livestock production, and restrictions on livestock numbers and livestock waste application methods and timing. It has faced with enforcement problems. Financial instruments have mainly focused on subsidizing pollution mitigation or reduction in livestock numbers, with only limited experience with more market-based instruments such as tradable quota systems.

Animal and human health

For the main direct and indirect impacts of increasing livestock densities on animal and human health and treatment options, the "state of the art" is as follows:

- There is a wide range of treatment options available to reduce the microbial load of manure, and hence the incidence of livestock-waste food-borne diseases. Storage systems, longer-term composting, biodigestion, or aerobic treatment greatly reduce most bacteria, but more drastic and expensive treatment systems using disinfectants, such as lime, or heat, will be required for complete safety.[2]
- Tools for early diagnosis of emerging zoonoses[3] and other pathogens are available, or, with some exceptions such as BSE, can be reasonably quickly developed. The early reporting of disease outbreaks is hampered by lack of infrastructure and skilled staff in the public sector; inadequate use of the private sector (for example, para-veterinary and para-health) resources; and inadequate cooperation between animal and human health service providers, where the human health services focus on the human-to-human transmission, and the veterinary services on the animal-to-animal transmission, leaving a major gap for the animal-to-human transmission. Conflicts of interest among different sectors and services (veterinary and health services, trade, and tourism) often also delay the official declaration of an emerging disease. Finally disease surveillance systems are almost exclusively managed at the national level, whereas there are major economies of scale to work at multi-country levels.
- "Stamping out," which includes destruction of diseased and suspected animals and strict quarantine measures, has been the preferred measure for eradicating emerging animal diseases, but has major social and ethical drawbacks. Moreover, experience with the management of, for example HPAI, shows that in the absence of adequate enforcement and compensation, compliance with stamping out is very weak. A much greater use of vaccination seems to be preferable on these social, ethical and efficiency grounds, but is met with trade restrictions as the OECD countries have generally adopted a non-vaccination policy. These trade restrictions are based in part on the difficulties in distinguishing between vaccine and disease induced immunity, although modern technology is making it now possible to make this distinction.

Equity

Vertical integration, contracting producers for the supply of uniform standard products against guaranteed forward pricing, has been the main strategy for providing smallholders access to this expanded market, and surveys in East Asia show a major positive effect on producer income. However, in a situation of weak enforcement and regulation, monopolies and collusion become major dangers of farmers losing independence and income share.

AN ACTION PLAN FOR THE INTERNATIONAL COMMUNITY

The Livestock Revolution poses major environmental and public health threats, but it can also contribute to pro-poor growth and improved livelihoods for urban and rural poor. The many externalities involved provide a strong justification for public policy involvement. Key recommendations for governments, donors, including the World Bank and other international and regional institutions are described below.

At the global level

At the global level, the main need is to increase awareness for the opportunities, but also the threats that the livestock revolution entails, and find new policies, technologies, and institutional arrangements in dealing with them. This will require actions in the following areas.

Assessing the level of global externalities involved. As emerges from this paper, while there is information on the costs of the environmental and public health effects of the livestock revolution and their mitigation, there is little information on the degree of public goods involved, and even less if these concern global, national, or local public goods. Still, such information is crucial for assessing the possible incentives for private investments and the chance of scaling up, to be able to address these issues on much broader scale, than currently the case. Such greater understanding of the degree of public goods concerned would be an essential element to raise global awareness for these issues.

Innovating global disease control. The recent disease outbreaks show that current approaches are no longer effective in this era of globalization. New approaches must be developed with all stakeholders. With the many institutions and some significant vested interests involved, the World Bank could use its global convening authority to facilitate this new thinking. This report proposes establishing a global platform for emerging zoonoses[4] and other pathogens that could support ongoing activities—such as the Global Framework for the Progressive Control of foot–and–mouth disease (FMD) and other Transboundary Diseases (GT-TAD)[5]—but that would broaden its scope through private-sector partnerships with, for example, the pharmaceutical, processor, and/or retail sectors. This platform could promote innovative approaches for the control of zoonoses and advocate for increased funding by, stressing the spillover dangers from the developing to the industrialized world under the current disease situation. Some initial support from the World Bank's Development Grant Facility is being considered. Promoting innovation could consist of studies on the cost of "business as usual" in animal disease control and its implications for human health. These studies could include:

- Critically assessing current disease control strategies, particularly issues such as, the current status of veterinary services in the developing world, the effectiveness of early global alert systems, and the non-vaccination strategy, among others;
- Assessing what technology introduction and policy changes are needed and what the costs and benefits of alternative strategies might be;
- Researching and developing robust and easy-to-apply disease and immunity level diagnostics and vaccines of the so-called "orphan" diseases;
- Studying the feasibility and eventual implementation of global or regional insurance and compensation systems; and
- Developing models—that promote regional integration of services, in particular—for surveillance and early alert disease systems, for vaccination campaigns and "stamping out" diseases, and for imposing quarantine measures that include adequate compensation for producers.

Enhancing the profile and sustainability of work on livestock environment interactions at the global level. While there is a reasonable level of awareness under the livestock specialists community of the challenges of the livestock revolution, the major importance of these challenges are not yet recognized by the broader global community, and have not yet led to sustainable institutions and funding for the prevention and mitigation of the negative livestock and environment interactions. The following actions are therefore required:

- A greater effort in public awareness creation at global and "hotspot" country levels. Citizens need to realize that local actions that harm the environment can transcend national boundaries, creating negative impacts on regional and global scales.
- Sustainable, long-term integration of livestock–environment interactions work is needed at national, regional, and global institutions. Current programs of the main international organizations, such as FAO and the ILRI, have mostly a project-specific focus.
- Linking livestock waste treatment operations with global public good support initiatives, such as carbon trade in the Prototype Carbon Fund, and payment for other environmental services under the Global Environment Facility; and
- Expanding research on improved livestock waste management and health technologies, described in Chapter 3. Global public support is required for those pro-poor or "orphan" (commercial nonviable) technologies, described above, such as the increase in the efficiency of feed use, and small-scale manure crop and energy recycle systems.

At the national level

With national public goods of environmental sustainability of water, land, air, and biodiversity, poverty reduction, and public health at stake, there are major national and local public policy roles. Chapter 3 outlines a vast array of technologies, but widespread adoption of these technologies needs to be supported by an expanded menu of financial, regulatory, and institutional instruments and support actions. Following the categorization adopted in Chapter 3, the international community, including the World Bank should support:

- Creating greater awareness among decision makers and the public about the major environmental and public health implications of increased livestock density that goes beyond "nuisance" factors to less obvious aspects, such as nutrient loading and emerging zoonoses;
- Preparing national manure management plans in those countries with major current or expected problems—such as Brazil, China, Thailand, Mexico, Philippines, Vietnam, and several ECA countries;[6]
- Developing and implementing regional zonal planning capacities, including the development of GIS technology and its supporting database and the legislation and institutions to implement and enforce a better spatial distribution of livestock production;
- Strengthening the definition and implementation of market-based incentives for sustainable livestock waste management, including a tradable quota system;
- Strengthening national public animal and human health surveillance systems, particularly by promoting closer integration with private grassroots animal and human health systems, and closer collaboration between animal and human health institutions;
- Developing associative forms of livestock waste management—such as, cooperative biodigestion systems, watershed-focused manure management plans, among others; and

- Developing and testing legislation that supports supply chains that adequately protect the interest of all stakeholders, including smallholders, and prevent the monopolies or collusion of the integrators.

The Livestock Revolution will continue, and could have major global negative environmental, public health, and social externalities. As seen, there is no "silver bullet" and experience from the developed world shows that there is not even a proven package of interventions, and trial and error approaches will be needed. Still, the threats are so significant that coordination among all stakeholders involved at the global and national levels is needed.

1. SETTING THE SCENE

DEMAND PATTERNS

In recent decades, the developing world has experienced a spectacular growth in the demand for animal products. A more affluent urban population uses a proportional or even increasing part of its growing income on animal products.[7] While per capita consumption in the developed world remained stable, with some changes in between beef and poultry, because of health concerns of the first, people in developing countries have doubled their consumption of meat (and even tripled the amount of poultry meat) over the last two decades. Per capita milk consumption increased by more than 50 percent over the same period (table 1.1). Delgado and others (1999) introduced the term "Livestock Revolution" for this phenomenal growth in supply and demand.[8]

Table 1.1. Food consumption trends of various animal products in the developing and industrial world

Region and Product	***Total Consumption***		***Share of Total 2003 (%)***	***Per Capita Consumption***	
	1983	***2002***		***1983***	***2002***
	(million metric t)			***(kg person^{-1} y^{-1})***	
Developed World					
Beef	32	29	52	27	22
Pork	34	38	45	29	29
Poultry	19	33	52	16	25
Small ruminants[9]	3	3	25	2	2
Total meat	88	103	47	74	76
Milk	233	268	56	195	195
Developing World					
Beef	16	27	47	5	6
Pork	20	46	57	6	12
Poultry	10	29	51	3	7
Small ruminants	4	9	75	1	2
Total meat	50	112	53	14	25
Milk	122	198	44	35	46

Sources: Delgado and others 2001; Delgado and others 2003b; FAOSTAT Database 2005.

These trends are expected to continue. Current per capita consumption in the developing world is only one-third to one-fourth of that in the developed world, and is likely to follow past developed-country consumption patterns, with a straight relationship between income and animal product consumption to about 70 kilograms of meat and 150 kilograms of milk per person per year. Considerable growth in demand for these products can therefore still be expected. This is also reflected in the various projections

(Food and Agriculture Organization [FAO] and International Food Policy Research Institute [IFPRI]), of which the work done by Delgado and others (1999); Delgado and others (2001); and Delgado and others (2003b) at IFPRI are the best known. Delgado and his collaborators predict a further near doubling of the demand for meat and milk in the developing world, with the result that the developing countries in 2020 would out-demand the developed world in meat, and substantially approach the total milk consumption of the developed world.

Most of the increase in demand is, and will continue to be, in East Asia and Latin America, with China in particular expected to spearhead the increased demand for meat and milk, as shown in table 1.2.

Table 1.2. Past and projected meat and milk consumption in major regions of the world

	Meat			***Milk***		
	1983	***1997***	***2020***	***1983***	***1997***	***2020***
Region	***(kg person^{-1} y^{-1})***					
China	16	43	73	3	8	16
Other East Asia	11	18	54	10	12	29
India	4	4	8	46	62	105
Other South Asia	6	9	13	47	63	82
Latin America	40	54	70	93	112	130
WANA	20	21	26	86	73	92
SSA	10	10	12	32	30	37
World	30	36	45	76	77	89

Note. Figures are given in kilograms per person per year
Source: Delgado and others 2001; Delgado and others 2003b.

This demand will be rather evenly distributed over the different types of meats. Until 2020, Delgado and others (2001) expect an annual increase in the demand for poultry meat in the developing world of 3.9 percent, and expect other important animal products to grow between 2.0 and 3.0 percent per year, as shown in table 1.3.

SUPPLY PATTERNS

This extraordinary growth in demand will be met almost exclusively by production in the developing countries, as demonstrated in table 1.3 and figure 1.1.

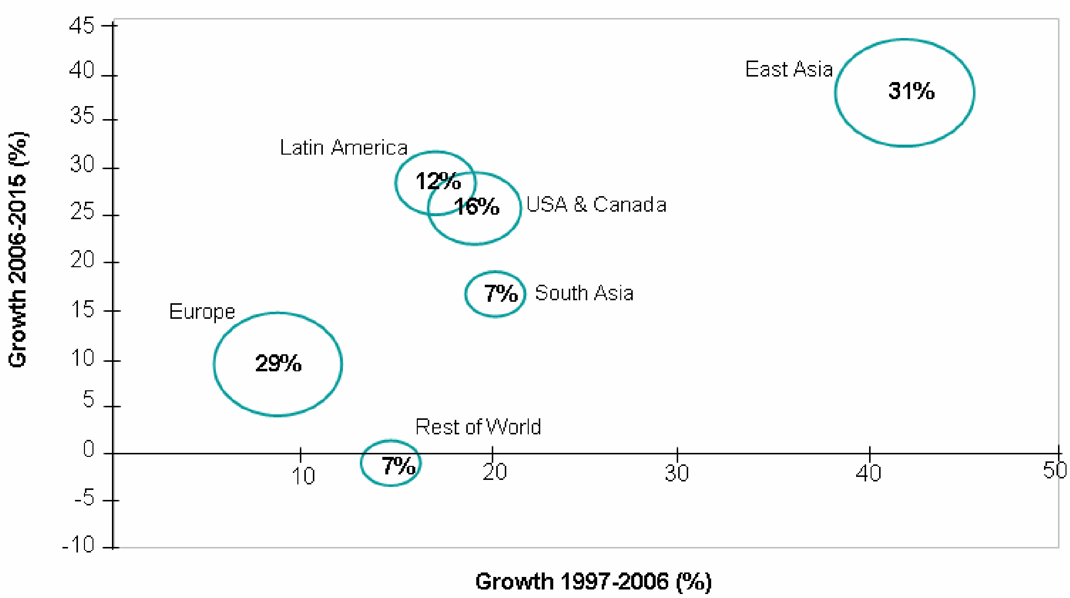
There are a number of reasons for this trend. First, the perishable character of animal products and the resulting high costs of transportation induce production to be located near the consumers, that is, around urban areas of the developing world. Second, particularly in pig and poultry production, modern technology in almost all areas (breeding, feeding, and housing) can be easily transferred from the developed world to the developing world. Large units in the developing world now demonstrate similar or even better productivity performance indicators, such as growth and carcass composition, and efficiency indicators, such as fertility and feed conversion, than those in the OECD countries. For example, feed conversion by poultry in Brazil, at 1.93 kikograms feed per kilogram growth, is lower than the 1.95 in the United States. In dairy production, with a much greater influence of physical factors such as climate and soils, and lesser economies of scale, modern technology is less transferable, and production has remained smallholder or family-farm based.

Table 1.3. Projected trends in per capita consumption of animal products in the developed and developing world

Economy and Product	*Production Growth Rate, 1997–2020 (% y^{-1})*	*Total Production (million metric t y^{-1})*		*Share of Total in 2020 (%)*
		1997	*2020*	
Developed World				
Beef	0.6	31	35	41
Pork	0.5	36	41	34
Poultry	1.6	30	42	39
Total meat	0.9	100	123	37
Milk	0.6	339	390	50
Developing World				
Beef	2.8	27	51	59
Pork	2.3	47	80	66
Poultry	3.7	29	67	61
Total meat	2.9	110	211	63
Milk	2.8	208	390	50

Source: Delgado and others 2003b.

Figure 1.1. Production growth and share in world meat production of intensive livestock



Source: Berkum and others 2003.

Third, intensive operations in the developed world face increasingly stricter environmental and animal welfare standards, and therefore find it difficult to compete with producers and processors from the developing world, with often less stringent and more loosely enforced standards.

Growth patterns within the developing world differ significantly, with an almost explosive growth for meat production in East Asia in the 1980s and 1990s. Current and projected future growth of production is still significant, although leveling somewhat. Milk production gets an increased impetus in East Asia (table 1.4). Export-led growth is still particularly strong in poultry production, as in Brazil, which still had an annual growth in poultry production of 9 percent during 2000–04.

Table 1.4. Past and projected growth (percent/year) in meat and milk production in different regions of the world

	Meat		*Milk*
Region	***1983–94***	***1994–2020***	***1994–2020***
China	8.0	2.9	3.2
Other East Asia	5.0	2.4	3.9
India	3.7	2.8	1.6
Other South Asia	4.8	2.6	3.1
Latin America	2.9	2.2	2.0
WANA	3.9	2.5	2.6
SSA	2.1	3.4	4.0
World	3.0	1.8	1.6

Source: Delgado and others 2003b.

STRUCTURAL CHANGES

These regional treads are leading (or have already led) to a number of global "hotspots" in East Asia and Latin America, where the strong growing production, in turn, has led to the following patterns of production in the developing world:

Economic concentration

The Livestock Revolution caused a major increase in pig and poultry farm size in the "hotspot" areas. Several factors, although difficult to difficult to attribute individually, contributed to this trend.

First, the level of investment for housing, feeding, breeding, and animal health technology seems to favor large scale enterprises, although field research by Delgado and others (2003a) does not give an unambiguous confirmation of this logical hypothesis.[10] Their survey on the cost of production in different size pig, poultry, and dairy farms in East Asia and India showed that, if family labor was included, large enterprises had about the same profits per kg product as small farmers, but higher than medium size farms. Total profits were, of course, much higher in the large farms. Excluding the costs of family labor and environmental externalities increased the profits per unit product for the small farms.[11]

Second, the concentration in the input and processing sector, combined with vertical integration and contract farming, also leads to increasing farm size. Those larger integrators prefer to deal with larger production units, while for the producers, at least initially, contract farming increases profitability as shown by the above mentioned survey by Delgado and others (2003a). Middle-income countries increasingly follow the developments in OECD countries. In the processing sector, for example in the United States, four companies have 60 percent of the poultry market share. The percentage of pigs produced under contract in the United States went from 10 percent in 1993 to 75 percent in 2003 (Harkin 2004). In the Philippines, six integrators cooperating in an association now have 80 percent of the broiler meat market, dictating prices and quality and food safety standards (Costales and others 2003). In Brazil, by 1994, four companies produced 40 percent of the broiler meat and the two largest had 60 percent of exports (Henry and Rothwell 1995). In 2004, five companies managed 85 percent of exports.

Third, the increasing importance of supermarkets, with their demand for uniform and safe products, has reinforced this trend. However, while the rise of the supermarkets in developing countries is impressive—from a sales volume of US$1 billion in China in 1995 to US$55 billion in 2002, for example; (Hu and others 2004)—the rise has been slower for fresh products, such as pasteurized milk and fresh meat. For meat, in East Asia the traditional fresh market will most probably remain the main outlet. Supermarkets have played a major role in the rapid expansion of further processed and longer duration products such as ultra high temperature milk in China, where supermarkets now distribute 70 to 80 percent of the milk. In Latin America and in East Asia, they often rely, at least in part, on foreign direct investment (Reardon and others 2003), and have introduced higher quality and food safety standards and more reliable supply, and are therefore also having a general pull effect on the quality of other sectors.

Finally, the policy and institutional framework favor large-scale production units. In many countries, the large-scale commercial sector, because of its political power, continues to have special privileges. This has significance for several areas:

- Large enterprises often benefit more from tariff or fiscal incentives. For example, in the Philippines the members of the main large pork producer association have preferential access to breeding animals (3 percent) and imported feed grain (35 percent compared with 60 percent for smallholders and independent producers).
- Large and influential enterprises also often have easier access to subsidized credit, which can promote inefficient, large-scale pig, milk, and poultry production in the peri-urban areas of developing countries.
- Per unit of product, large enterprises produce more waste, but, because of poor enforcement of environmental regulations, spend less on mitigating these effects.

Large-scale, intensive, meat-producing enterprises are therefore the main source of growth in meeting the increased demand for meat in the developing world. They buy a large majority of their stock feed[12] and are thus completely divorced from the surrounding land base. Some figures demonstrate these trends: During 1985–94, industrial meat production grew worldwide by about 4.3 percent per year, whereas small-scale production increased only by 2.2 percent per year (Sere and Steinfeld 1996). In fact, large-scale, industrial production accounts for roughly 80 percent of the total production increase in livestock products in Asia since 1990 (de Haan and others 2001). This is also demonstrated at the country level in East Asia and Latin America, as shown in table 1.5, although exact data on farm structure are often not available, and are not collected under uniform standards.

Table 1.5. Illustrative cases of concentration of animal production in East Asia and Latin America

Country	***Description***	***Year***	***Indicator***	***Year***	***Indicator***
Thailand	# of farms with > 5,000 birds	1993	1,104	1995	2,595
Brazil	% broilers from > 10,000 birds	1985	52	1998	73
Brazil	# of milk suppliers (000) to 10 largest milk processors	1997	175	2000	114
China	Percentage of pork from enterprises > 500 pigs per year	1985	8	1999	40
Philippines	% of pigs on farms > 80 animals	1980	18	2000	20

Source: Delgado and others 2003a.

The pork industry in the Philippines does not seem to conform to these trends, because there has been a major commercialization of the "backyard" sector into commercial, although small, production units.

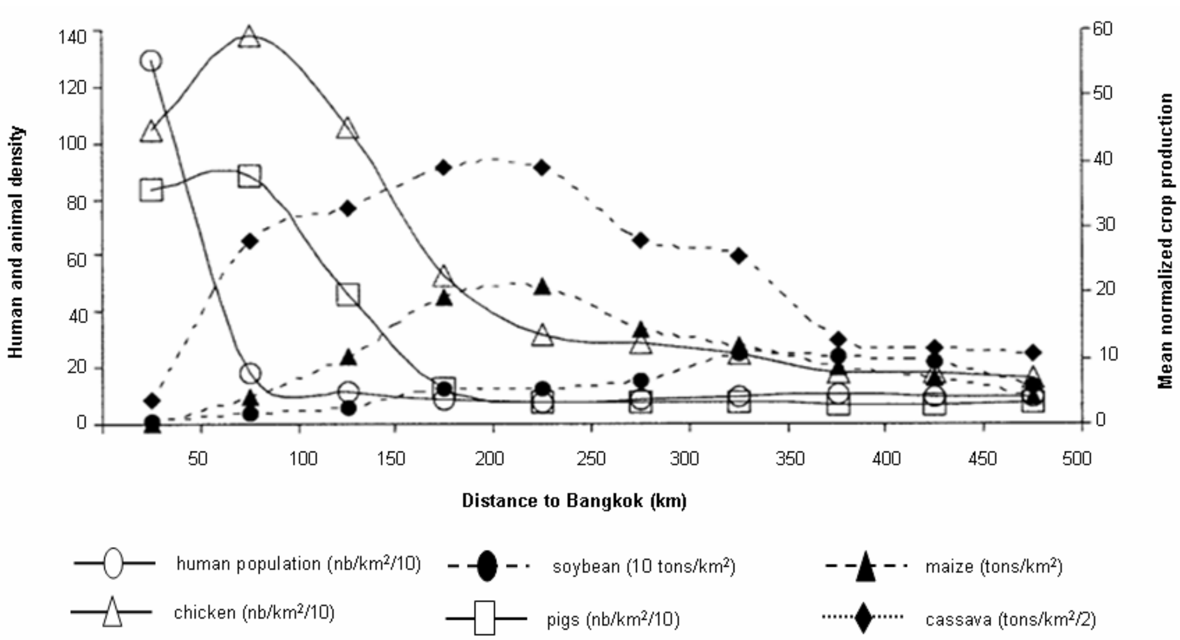
Spatial Concentration

Natural resources, such as climate and the availability of land and water, and labor, are traditionally important factors affecting business location. For perishable products, such as meat and milk, firms tend to locate near suppliers and clients to benefit from economies of scale and transport costs. For Western Europe, these forces have resulted in pig populations near port facilities (Breton, Belgium, the Netherlands), feed production (Denmark), and urban conglomerates (Catalonia, Po delta).

In the developing world, a similar picture emerges, as poor infrastructure (roads and refrigerated trucks) is causing intensive production units to locate near consumers, resulting in an excessive concentration of production along the Eastern Seaboard of China, in Thailand around Bangkok (figure 1.2), and in Brazil in the State of Sao Paolo. Some provinces on China's Eastern Seaboard, with the proximity of consumers and good port facilities, have a livestock density of over 500 livestock units per square kilometer, whereas on the basis of average crop requirements and arable land availability, a density of 100 would be in line with the absorptive capacity of the surrounding land.

Although livestock concentrations are increasing in the vicinity of urban areas, livestock expansion is also occurring in feed-producing areas, such as in the State of Mato Grosso in Brazil, where there has been a strong expansion of production and processing, based on the soybean and corn revolution. The extraordinary proximate concentration of people and livestock poses probably one of the most serious environmental and public health challenges for the coming decades. They will be discussed in Chapter 2.

Figure 1.2. Human and livestock densities, and main feed production areas as affected by the distance to Bangkok



Source*:* Gerber and others 2005.

2. EFFECTS OF THE LIVESTOCK REVOLUTION

The extraordinary increase in demand for animal products in the developing world has led to a spatial concentration of larger-size production units mostly around urban areas, and economic concentration of processing and retailing, sometimes driven by foreign direct investments. This geographic and economic concentration in the livestock sector has significant negative—although also some positive—effects on the environment, public health, and social equity, which will be discussed in this chapter.

ENVIRONMENTAL EFFECTS

Livestock produce 12 billion tons of waste each year (de Haan and others 1997), and while most is recycled for use in crop production and energy, in several countries the amount produced exceeds the adsorptive capacity of the surrounding ecosystems and leads to the degradation of air, water, and soil quality, and losses of biodiversity. The increased pollution by the leather and wool processing, although causing serious water pollution in particular with heavy metals and near urban areas, but not being directly linked to the concentration caused by the Livestock Revolution, is outside the scope of this paper.

Impact on ecosystems components

Livestock waste, through its nitrogen, phosphorus, greenhouse gas, and ammonia emissions, and heavy metals[13] can seriously affect surface and groundwater quality, soil chemical and physical characteristics, and air quality, and can contribute to global warming. These effects are detailed below.

Eutrophication of Surface Water. Livestock waste, high in phosphates, nitrates, and organic matter, when directly discharged into open water, encourages the growth of oxygen-depleting plant life such as blue algae, and increases the turbidity of water, thereby preventing the penetration of sunlight and thus harming other aquatic organisms and destroying fish habitats. Nitrogen and phosphate from livestock waste are important sources of this process, which is caused by eutrophication. For example, livestock waste caused about 28 percent of total chemical oxygen demand of the discharge of the Pearl River in Southern China in 1996, and it is seriously threatening the mangrove, sea grass, and coral reefs stands of one of the world's most diverse shallow-water marine areas in the South China Sea (World Bank 2002). This figure is expected to rise to 90 percent in 2010. Accelerated algae growth, known as "red tide", occurs with increasing frequency along the entire eastern seaboard of China.

Pollution of Groundwater and Soil. "Nutrient loading" or use of feed, manure, and fertilizer nutrients in excess of livestock and crop nutrient demands, is a direct result of increasing animal densities and poor nutrient management practices. For example, 46 percent of the cropped area of East Asia is estimated to have an annual phosphate (P_2O_5) surplus of more than 10 kilograms, and already four percent has an estimated 40 kilogram per hectare per year phosphate surplus from livestock manure. Moreover, with chemical fertilizer added, a total of about 60 percent of cropland in China has a surplus of more than 40 kilograms phosphate per hectare per year (Gerber and others 2005).

A similar picture emerges in the United States, where recoverable manure nitrogen exceeds crop system needs in 266 of 3141 counties (eight percent), and recoverable manure phosphorus exceeds crop system needs in 485, or 15 percent, of 3141 counties (USEPA 2003). These high levels of nitrates and phosphates saturate the soil, and therefore affect the quality of drinking water and soil structure and fertility, and hence the productive capacity of the land and the landscape.

Greenhouse Gas Emission. Intensive production units—such as, cattle feed lots and intensive pig and poultry systems—produce fewer greenhouse gasses per unit of product than extensive production units. However, the intensive units still produce about 15 million tons of methane and one million tons of nitrous oxide (N_2O) annually.[14] This is about five percent of total greenhouse gas emission (de Haan and others 1997). Methane emission is caused by enteric fermentation of ruminant (cattle, sheep, and goats) and anaerobic fermentation of large volumes of manure. N_2O, produced by an aerobic process, is mainly the result of improper storage and inadequate separation of the different livestock waste components. Ammonia is the main cause of acid rain, which comes, in part, from the oxidation of nitrous oxide from manure, and in part by direct volatilization from inadequate storage facilities and, in particular, from application to arable land. Ammonia affects aquatic life and forests, because it acidifies soils and water. For example, in the Netherlands, 70 percent of the country's nitrogen-related acid rain is estimated to come from livestock. Finally, ammonia is one of the main carriers of bad odors, which is one of the main friction points of intensive livestock production and society in general.

Habitat Destruction: The Feed Grain Connection. The Livestock Revolution will cause an increase in the demand for feed grains[15] from 657 million tons in 1997 to a projected 911 million tons in 2015, and 1,148 million tons in 2030 (Bruinsma 2003). Delgado and others (2001) have similar projections. This means that at an average yield of about 4 tons per hectare, about 65 million hectares of agricultural land will be required during 1997–2030, or more than the total area of France, to meet the increased cereal demand. Earlier work (de Haan and others 1997) showed, that most of these demands were met from supplies from environmentally less sensitive feed grain production areas, such as the American Midwest. However, with the increased scarcity of fishmeal for pigs and poultry production, because of the Blue Revolution, there has been a major expansion for in the demand for soybean meal, which in turn as caused a major expansion of soy bean cultivation in the humid forest areas of Brazil. Moreover, in the absence of major technological breakthroughs, which would either greatly increase feed cereal yields or the efficiency of conversion of feed into animal product, or both, the increased need for feed grains can be expected to lead to the conversion of sensitive biodiversity habitats, such as the tropical humid forest areas to arable land.

PUBLIC HEALTH EFFECTS

The *public health effects* of high livestock densities can be differentiated into direct human health effects of environmental pollution and indirect effects related to the closer interface within livestock populations and between livestock and humans.

Direct effects caused by environmental pollution

High levels of nitrates in water lead directly to Blue Baby Syndrome, with about 3,000 cases of infant mortality recorded over the last 40 years, and probably many more unreported cases in the tropics (Pretty and Conway 1988). More importantly, manure, through contaminated water or fresh produce, can carry a range of serious human pathogens, with high morbidity and mortality incidence in babies and children. These pathogens, often asymptomatic in livestock, vary from bacterial pathogens such as E. coli O157:H7, campylobacter, salmonella, and leptospira spp., and protozoan agents (cryptosporidium) to viruses, such as the hepatitis A virus. While exact figures on the mortality and morbidity from water and food-borne diseases from livestock are scarce and attribution is difficult, water-borne diarrhea causes some 6,000 deaths daily, mostly among children under five years of age.

Indirect effects

Disease transmission from animals to humans (zoonoses) has occurred throughout history. Goats transmitting tuberculosis to humans, and cattle originating major measles epidemics, were earlier manifestations of such phenomena. However, more recently, there has been a particularly strong upsurge of livestock zoonoses[16] and pathogens, which has brought this relationship to the center of public attention:

- *Nipah virus* in Malaysia in the mid-1990s caused 257 reported disease cases in humans, of which 115 were fatal, and led to the destruction of 1.2 million pigs.
- *Bovine Spongiform Encephalopathy* (BSE), indirectly linked with intensification, has been diagnosed in over 200,000 cattle in several European and North American countries, and the probable human expression in a new variant, Creutzfeld–Jakob disease (vCJD), has caused the death of 149 people in the U.K. (as of April 1, 2005) and a small number of cases in other countries. The economic losses to this disease are estimated at US$20 billion.
- *Severe Acute Respiratory Syndrome* (SARS) was diagnosed in 8,101 cases in 2003 and 2004, with 774 deaths. It led to the death or destruction of about 120 million birds.
- *Highly Pathogenic Avian Influenza* (HPAI), as of 15 March 2005, had been diagnosed in 69 humans, with a mortality rate of about 70 percent (WHO 2005). In Vietnam, for example, HPAI has resulted in an estimated drop in gross domestic product of 0.3 percent (World Bank, 2004), and some estimates of losses already experienced by the entire region go as high as US$10 billion.

There are multiple causes of the emergence of new zoonoses, and include changes in climate and weather, land use and habitats, and human behavior and lifestyles; a growing population of more susceptible, elderly, and immuno-compromised individuals; and globalization, which increases human-to-human contact and dietary diversity. However, the accelerating demand for animal products also plays an important role in the increased human health threat, because the increased geographical density of livestock and the closer interface between livestock and people greatly facilitate the jump of pathogens from one species to another, and the rapid spread within populations.

In most cases the pathogens originated in wild animals, such as the fruit bat (or flying fox) transmitting the Nipah virus, civets in the case of SARS, and probably wild birds in the case of HPAI. In Nipah and HPAI, the pathogens were first transmitted to domestic animals, that is, pigs and poultry, respectively, before they became a threat to human health. Even in the case of BSE, intensified animal production and increased interface between animal populations proved a major driving force behind the emergence of the disease. Recycling animal waste of a different species (sheep) was the main vector in the transmission of the pathogen to cattle, and the use of new slaughterhouse technologies was the main cause for the transmission of the pathogen to humans.

At the animal level, virus introduction from wild animals is most likely to occur in extensive, open, smallholder systems, and therefore areas with a high density of smallholders are more likely to contract the disease. For subsequent spread of the disease, larger units must be infected, where the considerable movement of feed, live animals, and humans in such medium-size units, and the lack of genetic diversity, make them easy targets. The highest risk of an outbreak of these emerging zoonoses is therefore in areas where smallholder and commercial systems coexist (Slingebergh and others 2004), which is confirmed by some initial explanatory analysis by Gilbert and others (in press) on the recent HPAI outbreaks.

One could argue that the significant increase in farm size in the developing world could constrain the emergence of these zoonoses, because the animal–human interface is less frequent and better controlled.

This has important implications for smallholder systems, as will be described in the section below on equity effects.

Similarly, smallholder systems and live animal markets play a key role in the transmission to humans, because they facilitate close contact between different species and between disease carriers and humans. In general, two patterns of transmission emerge:

- In the first pattern, the actual transmission of the pathogen from animals to humans is rare, but once it has occurred, human-to-human transmission maintains the infection, as shown in influenza A and SARS.
- In the second pattern, animal-to-human transmission is the usual source of human infection and human-to-human disease transmission is rare. Examples of pathogens with this pattern of transmission include the Nipah virus and, until now, HPAI, (as well as, for example, rabies, Lyme disease, and West Nile virus).

One of the greatest threats in this area is whether HPAI, until now in the second category, will mutate (eventually with other influenza virus strains) to change to the first pattern, upon which a pandemic could develop.

Transmission of Non-Zoonotic Diseases. The dominant role of supermarkets and consumers, and the strong increase in farm size described above, have resulted in an extraordinary drive toward product standardization, which, particularly in the broiler and pig industry, is leading to a major narrowing of the genetic base of these stocks, with the consequent reduction in resistance to disease outbreaks.

The increase in the size of farms has generally increased their investments in protection measures from outside infection, and, therefore decreased the number, of disease outbreaks. However, the spatial concentration together with the increased susceptibility has increased the speed of transmission and the impact of animal disease, as shown by recent outbreaks of Classical Swine Fever and foot–and–mouth disease in Europe and Latin America. Fast transmission of the virus within areas of high stock density led to large economic losses, such as the 2001 foot–and–mouth disease outbreak in the U.K. that resulted in about US$5 billion in direct and US$8 billion in indirect (mainly tourism) losses. This danger is still more acute in the developing world, where large livestock enterprises are being established where there are very weak veterinary and human health services.

Use of Antibiotics and other Feed Additives. The need to impose stricter disease control under high livestock density situations, and the additional 5 to 10 percent gain in growth and feed conversion of antibiotics, leads to the use of high levels of antibiotics. Use of antibiotics in feed leads to resistant strains of, for example the food-borne pathogenic bacteria *Salmonella* and *Campylobacter,* and results in resistance of these bacteria to classic treatment in humans.

The extent of this problem is difficult to assess, because part of the antibiotic resistance is also caused by overuse by doctors, but animal-product-induced antibiotic resistance is certainly a part of the problem. The use of antibiotics in feed is allowed in most developing countries, although the extent, level, and quality of the products are difficult to assess. Illegal use is also widespread. Although no official data are available, CDC and the Union of Concerned Scientists estimate a total of 25 million pounds to be in use, or 30 percent of total use for non-therapeutic purposes, such as increased growth (CDC 2005). The use of antibiotics as a growth promoter was recently banned in the European Union (EU) and New Zealand, although the ban has seen an upswing in the use of antibiotics for therapeutic purposes, which leads to the suspicion of leakage to non-therapeutic use.

EQUITY EFFECTS

The social and equity effects of the livestock revolution relate to the impact of changes in the structure of the production and processing, to the public health effects, and to the affordability of livestock products.

Crowding-out effect

The threat of smallholders being crowded out of livestock production by large-scale enterprises is often mentioned, in particular in pig and poultry production, where large units would significantly benefit from economies of scale, and where buyers prefer to buy larger volumes of a consistent quality, which smallholders cannot supply. However, the evidence emerging from recent studies is mixed, and other factors, such as the particular characteristics of the sector and the strength of the overall economy also seem important. For example, in Thailand, the number of small pig farms fell from 1.3 million in 1978 to 420,000 in 1998, which could be interpreted as a significant restructuring with possible important social implications. On the other hand, in the Philippines, which also witnessed a strong increase in the industrial sector, the smallholder system, with about 3 million farmers, maintains itself in parallel with the industrial sector (Delgado and others 2003a). Differences in alternative employment opportunities between the Thai and Philippine economies might explain these different trends. Such a restructuring did not take place in the Thai dairy sector, but did occur in the dairy sector in Brazil, where the number of smallholders delivering milk to the 10 largest dairy processors declined from about 175,000 to 110,000 during 1997–2000. The decline was particularly strong in the suppliers of the three largest processors, which could indicate that the crowding out of the smallest producers is led by the processors.

However, no systematic research is available on the characteristics of the out–migrating farmers, or on their future livelihood and employment. Moreover, the stronger backward and forward linkages of the industrial sector would provide alternative employment for smallholders pushed out by the larger units. Research in horticulture, for example, shows that the overall employment effect of farm size expansion on the total food chain is positive (World Bank 2005).

Vertical integration and other associative forms

Vertical integration, with one firm controlling more than one part of the supply chain, and in this case, meat or milk processors controlling, through long-term contracts, the supply of raw material from smallholder producers, has been advocated as an important tool for securing the participation of poor rural producers in the expanded market. The experience with vertical integration is mixed. On the positive side, Delgado and others (2003a) showed that contract farmers in the Philippines and Thailand received more than twice the level of profits per unit of product than independent producers, because they benefited from forward contracts in a situation of falling world market prices. However, experiences in the United States (Harkin 2004) and, for example, China (Zhang and others 2004), point to some negative sides, because farmers felt they lost independence, their margins were reduced and, in China, contracts were complied with only if independent market prices were higher than the contract price. Anecdotal evidence from China also points to weak compliance from farmers when market prices are higher than the contract price.

Cooperatives also have a mixed record in the developing world, ranging from the very positive experiences with the cooperative dairy systems in India and several OECD countries, to government-dominated, unviable systems in many African and East Asia countries.

Public health effects and the poor

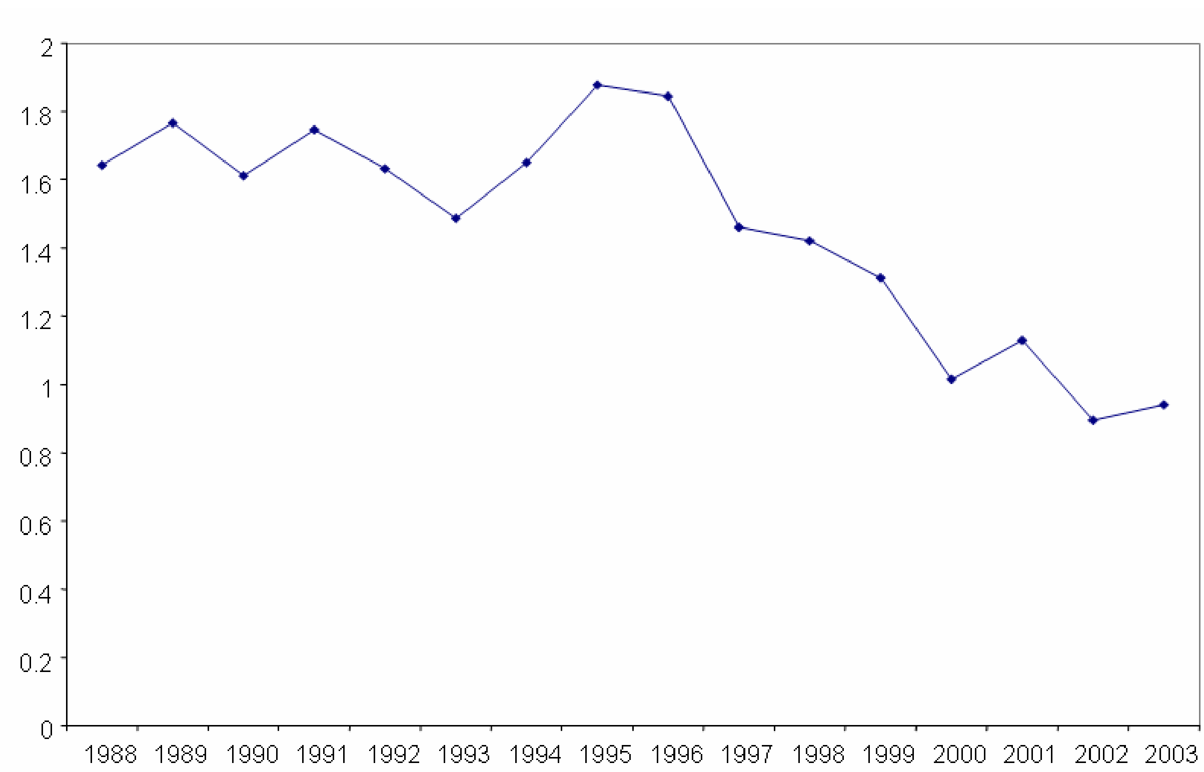
Indirectly, the public health hazards associated with pollution and animal concentration affect the urban and rural poor, particularly. With about 10 to 20 percent of the population of the key "hotspot" countries depending on surface water for their daily needs, they will be most severely affected.

Affordability of animal products

The main social benefit of the Livestock Revolution concerns the lower price of meat products from the industrial sector, because it improves the access of the urban poor to affordable sources of essential nutrients. Generally, prices of meat products, particularly of poultry products, have declined in recent decades, as shown by figure 2.1, and the projections by Delgado and others (2001) foresee a further decline of about three percent per year during 1997–2020.

At the same time, the strong expansion of the demand for animal products has caused only a minor increase in feed grain prices; maize, for example, is expected to increase by one percent per year during 1997–2020, after a fall of about 50 percent over the last two decades. Thus, the main effect of the Livestock Revolution on agricultural prices seems to be to stem the fall in feed grain prices, such that maize and soybeans will increase in value over time compared to rice and wheat. This would, however, not harm the poor, because the prices of maize and soybeans would be much lower than the prices in the 1980s (Delgado and others 2001).

Figure 2.1. Price of poultry broiler meat, Brazil (US$ 000 ton), inflation adjusted (2004 = 100)



Source: FAOSTAT Database.

ENVIRONMENT–PUBLIC HEALTH–FARM SIZE INTERACTIONS

While most interactions are direct, two specific multiple linkages need more attention. They concern the links between farm size and pollution and farm size and emerging diseases. Both have a direct effect on social welfare.

Environment and farm size

Large pig and poultry operations produce more nutrient discharge per unit product than small farm units, thus confirming the public perception of those large units as the main polluters. Moreover, there is some evidence from East Asia that small producers pay more per kilogram product to internalize the environmental costs than the large units do. Box 2.1 provides some details of the first study carried out by Delgado and others (2003a) on this subject in the developing world (the Philippines and Thailand).

Public health and farm size

The larger farms, resulting from the Livestock Revolution, have larger investments in bio-security, reducing the livestock-human interface, and therefore the chance of emerging new zoonoses. The enhance bio-security also reduces the animal-to-animal disease transmission, although the increase genetic uniformity makes these animal populations more vulnerable. Moreover, also as described above, new diseases emerged in particular, where smallholders and larger enterprises existed side by side. In areas with a disease outbreak, large enterprises, often aided by Veterinary Services, therefore seek to eliminate smallholder livestock holdings, also under the new policy of the World Animal Health Organization (OIE) which allows the status of disease freedom (and therefore access to export markets) to particular areas within a country, and even particular farms in an area.

Box 2.1. Small or large producers: which are dirtier?

Comparing large and small farms in East and South Asia, Delgado, Rosegrant, and Wada (2003) got the following results:

- 40 percent of the large swine farms in the Philippines and 90 percent of Indian poultry farms had a surplus nitrogen balance for the surrounding areas; none of the small farms had.
- Small pig and poultry farms spent between 0 and 100 percent more per kilogram product on environmental mitigation than large farms.
- However, the costs that large units would have to incur if the same standards were imposed would not be enough to tip the balance back to smallholder producers.

Source*:* Delgado and others 2003a.

Small farmers are therefore often hit the hardest when affected by an outbreak of a disease, such as the Avian flu, although smallholder livestock is, throughout the developing world, an important source of income (for example US$15 to US$20 per year in Laos, or two month's sustenance). Disease outbreaks therefore lead to the loss of animals through death and destruction of diseased or suspected animals, often a sharp drop in price and to major restrictions of a permanent nature on smallholder livestock husbandry practices. For example, in East and Southeast Asia following the HPAI crisis, the keeping of scavenging poultry and ducks (the main HPAI reservoir), and marketing of live animals were forbidden, although only unevenly implemented.

3. TECHNICAL SOLUTIONS

New technologies, financial incentives, and regulatory and administrative changes will be required to deal with increasing animal waste loads and protect the environment, human health, and equity. It is unrealistic to expect to reduce demand, as argued by some (Goodland 1997), because the strong preference for meat and milk of the population of most of the developing world, and their current level of consumption, make it politically and even morally impossible to deny them these preferred foods. While there should be some emphasis on the place of animal products in a balanced and healthy diet, continued and even growing attention to prevention and mitigation of the negative effects of the Livestock Revolution must be the main focus of public policy.

However, experience in Europe and the United States shows that no generally applicable "silver bullet" solution exists. Zoning approaches aimed at changing livestock density, such as extensification or intensification, can only be part of the solution. Extensification in areas with an already high animal population density yields little environmental profit, and, in the absence of profitable manure processing, a reduction in livestock population will be often necessary in those areas. Concentrating intensive livestock farms in industrial areas seems to be a possibility from a spatial viewpoint, but has been faced with cultural and ethical objections. Disseminating the pig population to arable farming areas is minimally profitable, because of the limited extent to which the environment can be used.

MITIGATING ENVIRONMENTAL POLLUTION

Livestock nutrient waste can be a valuable input into crop production, and in many locations of the world, crops and livestock continue to be operationally and functionally linked enterprises. However, as crop and livestock enterprises became more specialized, as livestock concentrated near the feed or the consumers, and as inorganic fertilizers and transport costs declined, the two sectors separated. As livestock production specialized, manure became an undesirable byproduct, and the notion of its intrinsic fertilizer benefit has been replaced with a "waste" cost.[17]

Overview of Technologies

The management of animal waste includes a series of fundamental activities: waste production, collection, handling, storage, treatment, and land application. The specifics of these activities differ by livestock type, operational features such as animal housing and the presence or absence of storage, and the spatial integration of livestock with crop production to enable waste nutrients to be effectively recycled and not lost to the environment.

Numerous effective technologies to reduce pollution from livestock wastes are available, and, although many have been developed for developed countries, they are mostly transferable and have been adopted successfully in middle-income countries. Farmer adoption of waste management technologies is closely linked to need, capability, and cost. Economies of scale play an important role and depend on farm size, but there are very few win–win situations, so most waste management technologies need other measures to be generally implemented.

The main technology areas are:

- Feed management practices that reduce animal waste, consisting of more closely matching livestock diets to animal nutritional needs, by increasing the digestibility and bio-availability of nutrients in feed. This maximizes feed conversion into meat and milk and minimizes nutrient loads in waste, and is scale neutral regarding farm size.
- Animal waste handling, treatment, and storage technologies are available, although these are most economical in large operations. Their main financial attraction (although generally not enough to cover all costs) lies in reducing labor requirements, and the production of energy.
- Land spreading of wastes and recycling through crops, if carried out with adequate attention to soil and weather conditions and the overall nutrient balance, can be one of the more attractive options. The recent development and use of manure management decision tools have proven effective in integrating effective waste use into soil–crop–climate–livestock systems.

FEED MANAGEMENT PRACTICES THAT REDUCE ANIMAL WASTE

Strategies to improve waste management need to start at the front end, rather than the back end, of the animal, focusing on the relationship between feed, animal performance, and nutrient excretions in waste. Two technologies have been proven to be win–win propositions in that they are both profitable and reduce negative environmental impacts of waste:

- Improved diet composition and feeding practices to reduce overall volume and nutrient concentration in the waste stream; and
- Water conservation strategies to reduce waste mass, thereby making waste more transportable.

Summaries of diet modification strategies for dairy, poultry, and swine are in table A1.1. These are farm-size-neutral strategies that could benefit a wide spectrum of small to large operations.

Feed

Depending on livestock type and associated dietary practices, significant reductions in manure volume and nitrogen (N) and phosphorous (P) loads can be obtained through improved diet composition, as shown in the big reductions in Flanders (box 3.1).

Box 3.1. Belgian experience in reducing nutrient outputs by reducing nutrient intake

The government of the Flemish part of Belgium introduced a three-track strategy to reduce excess phosphate (from 35 million kg P_2O_5 to 6 million kg P_2O_5 in 2003) discharged in its soil and water. It consisted of (a) reducing nutrient intake by providing low-protein and phosphate feeds, (b) manure processing and export, and (c) improving manure management. It was expected that the first two would reduce the surplus of 35 million kg P_2O_5 in 1998 by 25 percent, and that improved manure management by half, but by 2003, when the P_2O_5 surplus was reduced to 6 million kg, group (a) had contributed 21 million kg, whereas (b) and (c) together had contributed only 7.5 million kg, demonstrating the potential of this kind of technology.

Source: Mestbank 2004.

For poultry, assuring proper and well-balanced protein, amino acid, and total N levels in the feed can reduce manure N output by as much as 50 percent. Reductions in dairy manure N and P due to diet management are somewhat less, but are still about 15 to 20 percent for N and 20 to 30 percent for P. Pig diet modifications can reduce waste N and P loads by adjustments in protein type and level, including use of low-stachyose soy,[18] the use of enzymes, modification of feed particle size, and feeding newly developed corn hybrids, which are low in phytate.[19]

An important aspect of dietary nutrient management concerns reduction in the excretion of N and P forms that are most susceptible to environmental loss. For example, excess protein in dairy diets is excreted in urine, which can be converted rapidly and lost as ammonia gas, or transformed rapidly to nitrate, which is susceptible to leaching loss. Feeding mineral P excessively increases water-soluble P in feces, the form most susceptible to loss in surface runoff from manure-amended fields. Feeding phytase or low-phytate corn to poultry and swine increases feed P availability, which can dramatically reduce total P in manure, but cause a slight increase in water-soluble P.

Water

Although not often considered a diet component, the use of water as part of feeding and cleaning systems can impact the amount of waste produced and transported for land application. In several countries, the price relationship between water and labor has reached such levels that large farms revert to manual labor. For example, some recently built large dairy farms around Beijing have abandoned their automated barn scrape and water-based flush systems and use local labor to clean and remove manure from barns.

Animal Waste Handling and Storage Technologies

Numerous manure handling and storage systems are available and used on livestock farms, from simple ways to stack manure for short periods of time to glass-lined cement structures for long-term manure storage (table A1.3). Table A1.4 provides an overview of the impact of the different storage and treatment methods on the physical, chemical, and biological characteristics of waste and the relative removal of organics, N, P, heavy metals, and pathogens. Whereas anaerobic lagoons are the most common form of waste treatment on farms that use scrape and flush systems, aerated lagoons use oxidation to break down organic matter and separate liquids for land application and solids for composting. Although fermentation processes greatly reduce the organic content and pathogen load of the effluent, the major problem is the removal of heavy metals, for which more sophisticated equipment is required.

Most dairy and pig manure is now flushed from housing, and manure is stored in outside lagoons. The widespread expansion of flush and lagoon systems in the United States and East Asia was premised on labor efficiency and the notion that storage would facilitate calculation of manure nutrients available and allow for land application during favorable weather conditions and close to crop nutrient demands. However, anaerobic manure lagoons emit more methane than other storage systems (table A1.5). Anaerobic lagoons accounted for approximately seven percent of global methane emissions in 1991, a figure that has likely increased substantially. Also, emissions of ammonia, hydrogen sulfide, and carbon dioxide from manure storage, and carbon dioxide emissions from compost are other potential negative environmental outcomes of some waste storage systems.

Storage costs vary between US$1 and US$5.50 per 1,000 gallon storage space. The economics of waste storage and the storage period length depend on herd size, climate, and soil conditions (table 3.1). A principal rationale for encouraging the adoption of storage concerns favorable economics because of reduced labor requirements and better timing opportunities of the stored manure for land application, and hence better balancing the stored nutrients with crop nutrient needs.

Because of the economies of scale, most small-scale livestock operations will not be able to afford waste storage facilities, and therefore rely almost exclusively on family labor. The frequent removal and land spreading of manure fits their labor supply, although the semi-treated nature might have implications for human health. Small-scale operations need low-cost alternatives to current practices, such as improved ways to protect manure during the practice of short-term stacking.

Table 3.1 Conditions and characteristics associated with manure storage

Storage Period	***Conditions and Characteristics***
Short term (3 months or less)	Warm climate, no long periods of saturated soil. Pasture, grass, and hay land available for spreading. Equipment, time, and labor available as needed for frequent spreading.
Medium term (3 to 6 months)	To accommodate short periods of saturated soil. May not be adequate for some annual crop rotations. Some pasture, grass, or hay land likely needed for spreading.
Long term (6 months to 1 year)	Provides greatest flexibility for spreading. May best fit timing of cropping operations. Provides storage from one irrigation season to the next. Most flexibility for scheduling custom spreading operations.

Source: Fulhage and Hoene 2001.

Biodigestion for Energy

In addition to nutrients, manure also contains energy that can be converted into fuel. Biogas is a mixture of mainly methane and carbon dioxide produced when manure undergoes anaerobic fermentation, and contains approximately 60 percent of the energy value of natural gas. Optimum anaerobic fermentation occurs between 35 ^oC and 37 ^oC, and biodigestion does not work without outside heat sources in cold climates. In large-scale operations, manure is added at frequent intervals to the digester, biogas is removed continuously, and semi-solid effluent is removed periodically. The decision to use an aerobic digester can be based on several factors: the type and amount of manure available, alternative uses for the manure, projected use for the biogas, regulations regarding the purchase of the excess energy, odor reduction potential, and effluent use (MDA 1995).

Disadvantages of biogas include its explosive nature (although no more so than natural gas or liquid propane) and its hydrogen sulfide content, which can be very corrosive to electrical wiring and toxic to humans if inhaled excessively. In countries where energy is relatively inexpensive, the costs of building and maintaining anaerobic digesters for the purpose of biogas production are high relative to the replacement value of the energy produced. Over the past 10 to 15 years, many digesters have been installed and used successfully on small dairy farms in Southeast China. In these and similar areas, biogas is used by farmers for lighting, cooking, and heating. Additional advantages of biogas include odor reduction and a reduction in manure mass without nutrient loss. The effluent after fermentation contains all of the nitrogen, phosphorus, and potassium of the original manure and is a good source of fertilizer. The cost-effectiveness of methane recovery and energy conversion is still modest, although it maybe becoming increasingly attractive in areas were livestock concentration, and therefore the supply of manure, is high enough, and alternative sources of energy sources are high. Because of their energy generation and methane emission reduction potential, biodigestion might be of interest for carbon trade, for example, under the Prototype Carbon Fund, as currently explored under the World-Bank- funded National Environment Project in Brazil. Appendix 2 provides an overview of the different treatment methods and their relative costs.

TECHNOLOGIES THAT ENHANCE WASTE RECYCLING

Effective recycling of manure nutrients through crops is the linchpin of proper manure management. The use of manure as a source of fertilizer N for crop production may become more attractive as energy costs increase. Natural gas is used to produce a large percentage of inorganic fertilizer N, and natural gas accounts for 75 to 90 percent of the cost of making anhydrous ammonia. Furthermore, a reduction in the use of inorganic fertilizer N will reduce carbon dioxide (greenhouse gas) generation during its manufacturing. However, inorganic fertilizer is much easier to apply, and can be much more easily adapted to specific plant N requirements.

Decisions on the amount, form, timing, and methods of waste application focus on using waste nutrients optimally, reducing the movement of nutrients offsite, and preventing the delivery of polluted runoff to surface or groundwater to arrest the buildup of soil P and nitrate (the latter in particular in the EU, see box 3.2) and the pollution of lakes, streams, and other surface water bodies. Emerging environmental policy in the United States is aimed at abating the emission of air pollutants from animal agriculture, which is also one of the main driving forces in the developing world.

Manure benefits crop production through its fertilizer value and enhancement of soil physical properties and overall soil quality. Two factors define a large part of its value:

- The conservation of urine N. Approximately 25 to 35 percent of the N contained in manure of ruminant livestock (for example, beef and dairy cattle) is available to the plant the season following application compared with 50 to 60 percent for poultry and swine.
- The difference in the N:P ratio of manure compared to the N:P requirements of crops. Applying sufficient manure to meet crop N requirements usually results in excessive P application, which can increase the hazard of soil P buildup and loss in runoff. The N:P ratio of manure can be aligned to the N:P requirements of crops by removing unnecessary mineral P supplements from animals' diets (table A1.1), through the conservation of manure N in storage (table A1.4), and during land application (table A1.5).

Costs of livestock waste management

Waste collection, treatment, and storage technologies are expensive and require cost sharing if farmers, especially small to medium-size farms, are to adopt them (table 3.2). The economics of livestock waste management are discussed in Chapter 4.

Controlling and Eradicating Intensive Livestock Production-related Diseases

Livestock intensification has a direct public health effect through water and air pollution, and an indirect effect through the emergence of zoonoses, as described in Chapter 2. Technologies to address these effects are described below.

Box 3.2. Management practices for manure application

While spreading manure on arable land seems quite easy and straightforward, the danger of leakage into surface water resulted in the development of a set of best practices and regulations. The process is to, first, define the main pollutant (for example, sediment, nutrients, heavy metals, or pathogens) and their impact area (surface water, groundwater, air) and way of delivery, and second, adapt the following 10 best practices:

1. Prepare a manure use plan that balances manure application with crop nutrient demands.
2. Test manure's nutrient content and fertilizer value.
3. Test soil for the right amount of lime, manure, and fertilizer needed.
4. Calibrate equipment for desired application rate, and apply only when weather and soil conditions permit (an EU regulation).
5. Install buffers/field borders to serve as setbacks and natural treatment areas to protect wells, streams, and wetlands during land application.
6. Plant scavenger crops to protect soils during non-crop periods and use residual waste nutrients in soil.
7. Use manure injection/incorporation equipment.
8. Keep records of total and individual field nutrient applications (an EU regulation).
9. Inspect manure storage facilities.
10. Prepare emergency action plans for waste spills, discharges, and other potential problems.

Source: Sheffield 2001.

Table 3.2. Potential investments and inducements for waste management technologies

		Investments		***Inducements***	
Technology Domain	***Key Players in Technology Implementation (in order of importance)***	***Capital***	***Supplies and Services***	***Incentives***[a]	***Disincentives***[b]
Feeding strategies	Producer, feed industry, research, extension/outreach	1	4	2	1
Waste collection, treatment, and storage	Producer, research, policy, extension/outreach	5	3	5	1
Waste land application	Producer, policy, customized manure haulers, extension/outreach	3	5	3	3

Note: Relative opportunity for investment and use of subsidies in scored from 1 to 5, 1 = low and 5 = high. a. an example of an incentive is cost sharing; b. and example of a disincentive is taxes or fines.

Source: Authors.

Reducing livestock-waste-related food-borne diseases

There is a wide range of treatment options available to reduce the microbial load. Storage systems using higher temperatures, and longer storage periods, reduce the disease threat of most pathogens, because they do not multiply outside their normal host. However, with survival times of more than one month for most pathogens, short-term storage alone is often not enough. Longer-term composting (at 55 ^{o}C to 60 ^{o}C), biodigestion, or aerobic treatment will significantly reduce most bacteria, but more drastic and expensive treatment systems using disinfectants, such as lime, or heat, will be required for complete safety.

Managing emerging zoonoses

Recent advances in human and animal immunology are enabling the development of diagnostic tools within a rather short time after a disease emerges, with the possible exception of Bovine Spongiform Encephalopathy (BSE), where only ex post diagnosis is possible. For example, several diagnostic tools for Highly Pathogenic Avian Influenza (HPAI) in humans, based on the detection of the virus by measuring the antibody response, were available in mid-2004, about six months after the outbreak of the disease in humans. Similar molecular diagnostics are available for animals, besides the normal microbial techniques. However, the molecular techniques require high-level laboratory facilities, whereas the normal microbial techniques are time consuming. There is thus a need for a rapid but simple (pen-side) diagnostic test that grass-root-level animal and human health staff can apply.

The control strategy for the animal vector of the most recently emerging zoonoses has been based on so-called "stamping out," where all diseased animals and those within a certain radius of the outbreak (normally 1 to 5 kilometers) are destroyed. Stamping out is often combined with a transport and live market ban. This has been the basic approach of the developed world, combining disease eradication with non-vaccination and strong import restrictions and quarantine. Experience with this approach in developed countries has been mixed, as shown by the spread of the FMD and Classical Swine Fever outbreaks in Europe, which led to massive numbers of animals being culled, and massive losses, as described above. Experience with this approach in developing countries, where enforcement is weak and compensation inadequate, has been poor as well, particularly with smallholders. As rethinking of the non-vaccination strategy is therefore recommended, as will be discussed in Chapter 4 and 5.

Vaccine technology is less well developed and does not exist for, for example, the Nipah virus or BSE, or for its human variant, variant Creutzfeld–Jakob disease (vCJD). For HPAI, the fast-mutating characteristics of the virus complicate vaccine development, and only partial immunity is achieved with current available vaccines. A major issue (as with many other diseases) is the ability to differentiate between immunity induced by outside pathogens and by vaccination. If these effects cannot be differentiated, countries free of the disease do not allow export. Indonesia, with limited exports is therefore using vaccination, whereas Thailand has opted for continued stamping out. Differentiating infected from vaccinated animal (DIVA) vaccines are now being developed (Capua and Maragon 2004),

Similarly for FMD, although complicated also be the occurrence of several different strains, so-called "a marker vaccine", which would make it possible to differentiate vaccinated from pathogen induced antibodies, is practically available. Disease prevention, with strict biosecurity enforcement, often using special disease control systems (such as specific pathogen-free technology [SPF]) is now the most used alternative, particularly for large enterprises, but this approach is highly capital intensive, and anti-poor.

ENVIRONMENT, PUBLIC HEALTH TECHNOLOGY, AND EQUITY

Most technologies described above depend on economies of scale, as shown in table 3.3.

Public pro-poor technology development policies will therefore have to focus on research and disseminating those options that are scale neutral or have only a slight large-scale bias, such as feeding efficiency and vaccination, and leave the less-attractive technology approaches to the private sector, except those where there is a clear public good, such as greenhouse gas reduction.

Table 3.3. Economies of scale of selected groups of livestock/environment and livestock/public health technologies

Technology	*Scale*	*Comment*
Balancing feed requirements and feed composition/feeding management	Neutral	Most attractive option for smallholders
Manure storage and treatment	Large-scale bias	
Land application	Large-scale bias	Direct application, without storage, possible smallholder option
Vaccination	Slight large-scale bias	Greatly preferred for ethical reasons, and more effective at smallholder level than stamping out
Increased biosecurity	Strong large-scale bias	

Source: Authors.

4. POLICY AND INSTITUTIONAL SUPPORT MECHANISMS

EXPERIENCES WITH ENVIRONMENTAL POLICY INSTRUMENTS

With few "win–win" technologies available and significant levels of externalities, public policy interventions are essential. However, public policy interventions are often focused on the easily observable effects, rather than on the most important environmental losses. For example, the links between pig production and air pollution are much more certain and direct than the impact of the land application of pig manure on water pollution. In particular, fewer policy options exist for controlling the impact of diffuse, non-point source pollution from agricultural production. Non-point discharges are difficult to monitor because they occur over wide areas and vary from day to day depending on weather conditions and the frequency and timing of application of potential pollutants, such as fertilizers and pesticides.

Moreover, there is still a lack of understanding of the relationships between "type of policy instrument—behavior of farmers—agronomical and environmental effects." The response of farmers to the implementation of manure policy and measures appeared to be more varied and complex than expected, as shown by the experiences in the Netherlands, where policy has gone through considerable trial and error (Oenema 2004; Appendix 2).

Agricultural and environmental policy instruments can generally be divided into three main categories (Verbruggen 1994):

- Direct regulation or command-and-control instruments
- Economic or market-based instruments
- Communication or persuasive instruments.

Table 4.1 lists some examples of the three types of policy instruments affecting agricultural land use.

Table 4.1. Types of policy instruments

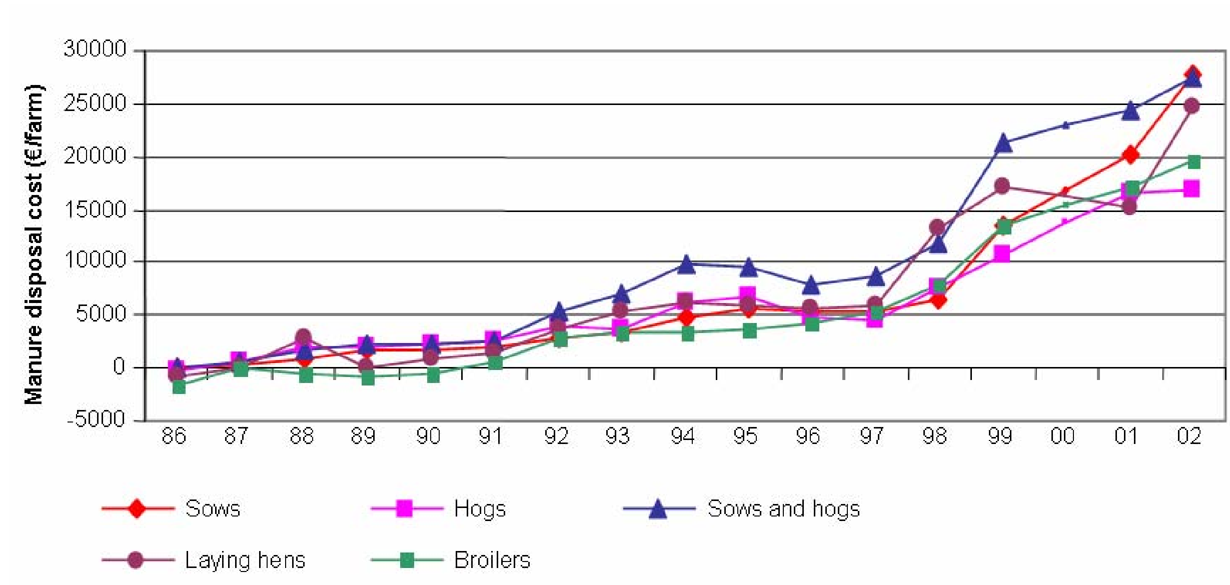
Regulatory Measures	***Economic Instruments***	***Communication Instruments***
Public-land-use planning (zoning/spatial planning)	Taxes	Agricultural extension service
	Subsidies	Education and persuasion
Pollution standards	Price support	Cooperative approaches
Prohibition of particular agricultural production methods	Import/export tariffs	
	Tradable rights and quotas	

Source: Authors.

Policy measures in the Organisation for Economic Co-operation and Development (OECD) countries have, in the past, focused on means (for example, a ban on manure application during certain time periods) rather than ends. The advantages are that such measures are relatively simple to develop, that the worst excesses can be dealt with, and a great deal can be seen to happen. It is probably also the most appropriate strategy in many developing countries.

A move to a more targeted policy approach (for example, where farmers are obliged to achieve certain targets) has a number of benefits, because it gives farmers the freedom to select the most cost-effective approach to achieve the target practices and outcomes on their farms. However, on the enforcement side, the major disadvantage is the difficulty in measuring the target. If a target cannot be measured practicably, (such as emissions to groundwater), a target derived from the original aim needs to be selected (such as mineral surplus). This is still only a proxy for the environmental damage that actually occurs. There can also be spillover environmental effects arising from agro-environmental policy measures (OECD 2003). For example, policies that place a limit on the amount of manure that can be spread can increase the quantity and distance over which manure is transported, and thereby the costs of manure disposal (see figure 4.1). Also, banning manure spreading during one season may cause excessive applications during another season and exacerbate pollution.

Figure 4.1. Manure disposal costs in the Netherlands



Source: Information provided by Dr. Gé Backus, LEI, The Hague, 2004.

REGULATORY MEASURES

Regulations are compulsory measures imposing requirements on producers to achieve specific levels of environmental quality, through environmental restrictions, bans, permit requirements, maximum rights, or minimum obligations. They leave no choice but to comply with specific rules or face penalties. They are the most common policy measure used in OECD countries to limit the environmental impact of livestock production.

Zoning is the most commonly used regulatory instrument. This can include the designation of nitrate-sensitive areas, restrictions on livestock numbers in certain areas, and the preparation and implementation of regional balances for nitrogen and phosphorus.

Approaches in the United States, European Union, and other regions

In the *United States*, concern has grown in recent years about the potential soil buildup and loss of manure nutrients to groundwater, lakes, and streams (USEPA 2003). These water quality issues have recently been joined by heightened awareness of the potential for livestock operations to emit pollutants into the atmosphere, which can adversely affect air quality and enhance nutrient enrichment and acidification of land and surface water resources (NRC 2003). To respond to these concerns, federal and state agencies have increasingly focused regulations on the amount and timing of manure application to cropland. Farms designated as concentrated animal feeding operations (CAFOs) must now obtain permits for land spreading manure.[20] The current regulatory focus is on these large CAFOs under the assumption that they produce the most manure, and therefore pose the greatest environmental risk. However, it is becoming increasingly evident that farms of all sizes can generate negative environmental impacts, and that farm production components, such as barnyards and feedlots, may pose high environmental risk.

In the *EU*, the regulatory framework has sought a reduction of overall manure production, rather than arriving at a better spatial distribution, because total livestock densities are so high that a better spatial distribution would provide relatively few environmental benefits (box 4.1). There are three types of regulations placed on livestock producers that directly affect the level of manure production.

Limiting livestock density. Norway was the first to introduce legislation in 1975 to limit the size of livestock operations. While not introduced for environmental reasons, they do reduce the environmental risks of intensive operations. Under these regulations, the maximum number of pigs for slaughter that can be kept is 1,400. In Germany, the number of animals that a livestock farmer is able to have is regulated by a maximum allowance of between two and three manure units per hectare.

Limiting the expansion of livestock operations. These regulations are in place at both the country level and in specific regions within countries. In Flanders, Belgium, the first Manure Action Plan banned new livestock farms. In Spain, the Restructuring Act stipulates minimum distances between farms and an upper limit on the size of new farms, making it difficult to set up a new farm of any size in areas that already have high pig populations, such as Catalonia (Bondt and others 2000).

Box 4.1. Main livestock-related regulatory framework in the EU

Agro-environmental policies are broadly set at the Union level, through broadly focused Directives, and the setting of specific standards and their implementation are left to the individual member states, or sometimes region within the country (such as those of nitrate-vulnerable zones in France, Italy, and Sweden). Broad regulations linked to livestock and the environment are:

- The Nitrate Directive (91/676/EEC) seeking to reduce nitrate levels in surface and ground water to less than 50 mg/l nitrate;
- The Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC), requiring member states to issue best available technology for all farms exceeding certain numbers of stock; and

The Water Framework Directive (2000/60/EC), which establishes (at the watershed basis) regulations to ensure better water quality, and the Drinking Water Directive (98/83/EC), which establishes water quality standards.

Source: World Bank 2005

Restricting the amount and way of land application of manure. These are in effect in many countries, primarily for the purpose of limiting water pollution. These restrictions vary from a set standard quantity across the whole country, to maximum levels established at each individual farm level, taking into account a range of input and output factors. Most of the regulations relate to nitrogen, but some countries also impose restrictions on phosphates. To further limit water pollution, restrictions are often also placed on when manure can be spread and how close to waterways, ditches, wetlands, and so forth, to restrict nutrient runoff nutrients. These timing restrictions are generally stricter in countries with colder climates. Additional restrictions have been established in some countries to reduce ammonia emissions, involving the need to incorporate manure into the soil or restricting the manner in which manure is spread. Regulations regarding the spreading of manure are also used to reduce the impact of odor air pollution.

Decision tools for regulatory policies

Advancements in geographic information systems (GIS) are rapidly increasing the understanding of the spatial and temporal relations among landscapes, weather, waste management, and environmental outcomes, and have become a critical decision tool for regulatory instruments.

Environmental management systems (EMS) developed in the United States focus on the farm level, enabling livestock producers of all sizes and locations to integrate information on environmental risks into existing farm management practices. The EMS framework helps producers evaluate existing facilities and management systems, and then identifies opportunities to take voluntary actions that reduce environmental risks, and ensure compliance with local standards (University of Wisconsin 2001). The EMS has been tested widely on dairy, beef, and poultry farms in the United States.

For the *developing world* the Livestock, Environment, and Development/Food and Agriculture Organization Initiative has developed a GIS-based approach, which overlays soil physical characteristics such as soil classification, groundwater levels, slope, flooding risk, and arable land areas, with other environmental parameters, such as biodiversity-sensitive areas (like wetlands), and commercial characteristics such as markets and transport infrastructure, with current livestock densities to define areas of surplus stock and areas with a potential for expansion. These technologies are now well developed (Gerber and others 2005), and have been applied, for example, in Thailand.

Institutional arrangements

Three important issues relating to the effectiveness of regulations emerge from experience. First, there is the level and sector, in which the regulations are set and implemented. In the developing and developed world alike, there is a continuous struggle at the national level between Ministries of Agriculture, Environment, and Health (when public health issues are involved), on which institution sets the standards. The outcome of such a turf battle often determines the pro-production or pro-environment/health bias of the regulation. Moreover, there is the issue of central vs. local level, in both setting and implementation of the standards. Experience demonstrates the need for coordination between the ministries, with, in most cases, the environment institution, leading the standard setting, but coordinated at the cabinet-level. Standards can best be set at the national level, allowing for special standards for specific vulnerable of valuable areas, and the enforcement to be left at the local level.

Second there is the extent to which compliance with regulations is measured and assessed. Zoning and other regulations work best in the case of point source pollution (where the polluter can be unmistakably identified), where government has the financial resources to establish the infrastructure, and where there are reliable institutions to enforce environmental regulations. It will be more difficult to enforce, where institutions are weak, and where the polluter is difficult to identify (non-point source pollution), as in many countries in the developing world. More reliance has to be placed in those countries on market instruments (de Haan and others 1997). They are discussed in the next section.

Finally, there is the issue of rent seeking resulting from overly ambitious or unclear regulations, coming from the national level. Close involvement of local level, in particular in the implementation would therefore be needed.

FINANCIAL INSTRUMENTS

Because the livestock sector is an integral part of national economies, the macroeconomic policy framework in which the sector operates clearly affects its environmental impact. The European Union (EU) policy of preferential tariffs for cereal substitutes, such as cassava meal, clearly was one of the main drivers of the strong increase in livestock density in Western Europe (de Haan and others 1997). The liberalization of the economy in New Zealand in the mid-1980s, reduced the total nitrate emission between 1985 and 1995 by about 150,000 tons per year (Rae 1999), although because the liberalization caused a switch from sheep to cattle, it exacerbated nitrate surpluses in some regions. Under increased global trade liberalization, the same author predicted a reduction of nitrate overloads in the EU and Japan, and an increase in South America and Oceania, with an overall reduction at the global level.

Specific economic instruments to mitigate environmental effects have not been widely used. In particular, environmental taxes and charges and tradable rights/quotas have been implemented in only a few countries. Payments, particularly those relating to farm fixed assets, such as assistance in the construction of manure storage facilities, and on resource retirement have been increasingly used as a policy instrument (OECD 2003). This has also been the approach in the few operations the World Bank has funded so far (see pages 46–47).

Payments based on farm fixed assets subsidize farmers to offset the investment cost of adjusting farm structure or equipment to adopt more environmentally friendly farming practices. Support has often been provided to livestock farmers to meet the requirements of regulations, particularly for costly manure storage facilities. The provision of this subsidy often varies over time, depending on when the regulations were introduced, and is often provided for only a limited period of time. For example, most of the support has already been provided in countries like Denmark, Norway, and Sweden, which have had more stringent storage requirements for a number of years. In addition to support for manure storage, some governments have provided financial assistance for on-farm capital investment in manure processing facilities (OECD 2003).

Payments based on resource retirement subsidize farmers for retiring or removing resources from production, in particular from environmentally fragile land. Financing the exit of pig farmers was recently implemented in Belgium and the Netherlands. In 2000, the Netherlands introduced a package of measures involving the purchase by the government of manure production rights and pig quotas, farm audit arrangements, assistance to individual farmers, and demolition of farm buildings. In 2001–02, the government bought out animal production rights and thereby decreased the number of pigs by about 10 percent, at the cost of about US$300 million. By 2002, the scheme had been instrumental in reducing the amount of phosphate in manure by seven percent and methane emissions by 6 percent (RIVM 2004). In Flanders, Belgium, a scheme was introduced in 2001 with the aim of reducing pig numbers by 50 percent. Farmers received a premium of almost EUR400 for every sow and EUR118 for every fattening pig they sold to the State. The government budgeted a total of EUR75 million for the scheme.

Environmental taxes and charges are sometimes levied on farm inputs or outputs that are a potential source of environmental damage, and have been levied on pig farmers in Belgium, Denmark,[21] and the Netherlands, with the purpose of discouraging the excess production of nutrients in manure. These are sectorwide taxes often covering all nutrient inputs (including inorganic fertilizer), rather than those specifically from animal manure. While limited to just three countries, there has been an increase in the severity of these measures over time, in terms of both a reduction in the minimum threshold and/or an increase in the tax rate.

Assigning quotas implies that the government administers and controls a set of production rights. Tradability of these rights promotes improvement of the structure and maintains the competitive power of the entire sector. Under tradable quota systems, the state assigns to farmers producer discharge quotas, permits, restrictions and bans, and maximum rights or minimum obligations, which are transferable or tradable. In terms of livestock producers, such measures have been used only in the Netherlands, where the manure production rights of livestock producers, which were established in 1986, were made tradable in 1994. In order to reduce production levels, the government took (until 2002) 25 percent of the quota involved in each transaction. The system of tradable quotas (manure production rights) continued with the establishment of a MINeral Accounting System (MINAS) in 1998. That same year, farm manure production quotas for pig producers were transferred into a tradable system of pig production quotas, based on the number of animals (van der Bijl and others 1999).

COMMUNICATION INSTRUMENTS

Communication instruments include collective projects to address environmental issues and measures to improve information flows to promote environmental objectives. This information can be provided to both producers, in the form of technical assistance and extension, and to consumers, via labeling.

Most OECD and middle-income countries provide advisory services specifically targeted at improving the environmental performance of pig producers. This assistance can take a variety of forms, including technical advice regarding the construction of manure storage facilities, practical advice on the spreading of manure, the development of nutrient management plans, and the monitoring of environmental impacts. In the European Union, technical assistance has been provided to assist the implementation of the voluntary codes of good practice required by the Nitrates Directive. These inform farmers about practices to reduce the risk of nutrient pollution.

Community-based measures are those supporting public agencies or community-based associations (environmental cooperatives) in implementing collective projects to improve environmental quality in agriculture. Some governments have supported the development of alternative uses of manure to reduce environmental pressure and alleviate some of the constraints placed on farmers by restrictions imposed on the land application of manure (box 4.2).

There are a number of examples of voluntary environmental agreements between the agricultural sector and governments. Voluntary agreements between the agricultural sector and another private sector, such as the drinking water industry, are, however, rare. They can mainly be found in Germany and the Netherlands and to a lesser extent in France. Germany, with over 400, has the largest number of agreements. This is more than 80 percent of the total number of agreements in the EU. However, in Germany, the regional distribution of cooperative agreements is unbalanced (Heinz and others 2001).

Apparently, a number of factors can promote or hamper the establishment of cooperative agreements between water supply companies and farmers in the EU. An important promoting factor is that drinking water stems from well-contained and compact groundwater resources, such as well-determined groundwater protection zones. This limits the spatial dispersion of pollution such that the cause of the pollution can be determined unambiguously. Furthermore, the water supply companies' ability to finance the cooperative agreements, the willingness of the farmers to adopt pollution-reducing practices, and public preferences for pure and untreated water are supporting factors for the establishment of cooperative agreements. Important hampering factors are a reliance on command-and-control measures in some countries and a lack of enforcement of environmental legislation in others. Moreover, the existence of other local, regional, or national agro-environmental programs in some parts of the EU may crowd out local initiatives from water supply companies (Heinz and others 2001).

Box 4.2. Environmental cooperatives

Since 1987, the government of Denmark has developed a series of action plans for developing centralized biogas plants, to which manure is transported from nearby farms. After an initial development and demonstration program, 20 large community-sized biogas plants have been established, using both pig and dairy manure (Hjort-Gregersen 1999).

The government of the Netherlands has taken a particularly active stance in supporting, producer-led environmental cooperatives in recent years across a broad range of issues. Environmental cooperatives are local farmer associations that promote (with government support) activities related to sustainable agriculture and rural development and claim to be actively involved in effecting rural policies in their locale. Since the foundation of the first cooperative in 1992, numbers have rapidly grown to over 100. Their greatest importance is their role as valuable "field laboratories" for building stimulating and supportive institutional contexts for remodeling Dutch farming along the lines of environmental and economic sustainability (Brouwer and others 2002).

In Brazil, the World Bank's Prototype Carbon Fund is considering the payment of carbon credits to a biodigestion operation, which would be supplied by groups of farmers, and vertically integrated with a meatpacker.

Source: Authors.

MEASURING THE IMPACT OF WASTE MANAGEMENT TECHNOLOGIES

The complicated and long-term measurement requirements to ascertain cause–effect relationships between practices and water quality improvement may not be attainable during the relatively short term (five years). Water quality measurements are needed as baselines to assess long-term impacts. Environmental water sampling needs to be thought out in terms of what to measure where, when, and how often, to have the highest probability of associating measured water quality improvement to changes in farmer behavior (simple modifications of current practices, such as feed, manure handling, storage, land application, and marketing strategies).

Modest and, perhaps, more measurable shorter-term "proxy" indicators of environmental change should be considered. For example, if a project can show substantive gains in reducing manure nutrient loads through diet manipulation—and it has tested uncomplicated ways to track more equal distribution of livestock and manure nutrients and can shown the impact of storage on manure management—then the project will have much to say about adoption of management practices that will yield water quality improvements over the longer term.

The economics of livestock nutrient waste management

Little regional, or national, cost–benefit analyses of livestock waste management are available. Generally, they show that reducing nutrient loading and water pollution is more cost effective, than reducing those nutrients from surface water. For in example, figures from the Netherlands for 1998–2002 show that net loading of the soil decreased by about 0.2 kilograms P and 0.8 kilograms N per Euro spent (RIVM 2004). The cost of removal of N and P from surface waters is much higher (Chardon and others 1996).

More information is available on the costs and benefits of specific waste treatment technologies, such as bio-digesters, and manure as a substitute for inorganic fertilizer. Their cost effectiveness depends largely on the prevailing price of energy. In areas with low energy prices, such as in the US and in most developing countries, both bio-digestion and organic fertilizer have a doubtful financial profitability, and become only financially viable, when the environmental costs and benefits are included.

Within these costs-benefit analyses, however, there is little information on the degree of public goods involved, and even less if these concern global, national, or local public goods. Still, such information is crucial for assessing the possible incentives for private investments and the chance of scaling up, to be able to address these issues on much broader scale, than currently the case.

Finally, internalizing the environmental costs can also lead to major changes in the industry, for example, it has led to the complete phasing out of the pig industry in Singapore, and to major reallocation of intensive pig and beef operations from the Mid Western States to the South in the US.

INSTITUTIONS AND REGULATIONS TO MITIGATE PUBLIC HEALTH RISKS

Animal and public health regulations are set at the national level, by national authorities. In the area of control of zoonoses, the collaboration between animal and public health services is weak. Classically, the animal health services focus on animal-to-animal transmission, and the human health services on the human-to-human transmission, but there is a clear gap in animal-to-human transmission.

The World Health Organization (WHO) and the World Animal Health Organization (OIE) are responsible for facilitating the setting of health and food safety standards at the global level, in particular regarding cross-border trade, informing their members on scientific development and disease situations, and supporting national government services in disease control and eradication in the human and animal health sector, respectively. The recent outbreaks of animal-host-related diseases, such as the HPAI, have greatly strengthened the previous weak cooperation, as still exists at the national level.

Standard setting has been heavily dominated by the developed countries, which, in the animal sector, has led to the adoption of above described non-vaccination policies, seeking through strong import restrictions and quarantine to keep their own livestock populations free of disease. As experience has shown, in particular in Europe with FMD and Classical Swine Fever, but also in the Americas with BSE, this policy has not been successful, and a major rethink is required.

Weakening of the services has also affected their effectiveness. In real terms, budgets of veterinary services have generally declined, while staff numbers have increased, cutting substantially into the operating efficiency of the services (de Haan 2004). Moreover, the decentralization policy implemented in many developing countries, including in the "hotspot" countries, such as Brazil, while certainly positive concerning decision making on local public goods, has weakened the capacity for fast, coordinated efforts to address issues related to national or international public goods, such as the control of emerging diseases. Delays in declarations of disease outbreaks and weak enforcement of quarantine and other measures are the result, as shown in the delayed reporting and slow start and unsatisfactory progress during the recent HPAI outbreak.

The ambiguous attitude of public services toward engaging private service providers in the early alert systems and early control is also one of the causes of the inadequate response capacity of public services. Privately operating service providers and grass-root para-health or veterinary agents are rarely used in early alert and subsequent control systems, and a coordinated approach between human and animal health providers is even more exceptional.

As a result, the management of emergency disease outbreaks is poor in many developing countries, as shown by the survey of five countries on the experiences with the recent HPAI outbreak (Dolberg 2005):

- *Disease surveillance and early alert systems.* The Avian flu was unofficially detected in Indonesia in August 2003, whereas the official declaration took place on January 25, 2004. This delay in officially notifying the World Animal Health Organization (OIE) was likely common in most countries, as also shown by the proximity of the dates of declaration of the outbreak in the different countries (Vietnam, January 8, 2004, Lao PDR

January 14, Thailand and Cambodia January 23, and Indonesia January 25), which is epidemiologically highly unlikely. This is partially due to inadequate diagnostic facilities and skilled staff, and partly of political pressure on the public health services to suppress this information, because of the economic consequences in lost domestic and export markets for their poultry products and tourism.

- *Stamping out.* Following the outbreaks, all governments adopted a stamping out policy, seeking to cull all birds in a 1-kilometer (Indonesia) to 3-kilometer radius (Lao PDR). However, implementation is deficient. In Vietnam the survey found that only 80 percent in the affected areas culled all their stock. Similar flaws were reported in the other affected countries. This was partly the result of inadequate (or totally absent) compensation. For example, Thailand, with the highest level of compensation, still paid only 70 percent of the value of the culled birds. Lack of awareness and poor enforcement are other reasons.
- *Movement restrictions.* Outside the stamping out area strict movement controls were established. However, even there, implementation was poor. In general it was found that 10 to 12 percent of the population did not follow the movement restrictions. For example, 8 of the 21 traders interviewed in Cambodia reported continuing trading, even experiencing a higher mortality, indicating the likelihood of diseased animals being traded.
- *Vaccination.* Because of international market access restrictions, (see Chapter 3), only Indonesia decided to adopt a vaccination strategy. However, vaccination coverage was low, because of the difficulty of vaccinating free roaming animals and mistrust of the farmers of the quality of the vaccine. Vaccination coverage was therefore deficient.

These experiences show the inadequacy of the current system, and the need for innovation and action to be better equipped to handle either a likely resurgence of the current HPAI virus, or the emergence of new pathogens. They include:

- Making sure animal and human health agencies are independent to insulate them from political pressure to underreport disease outbreaks, which result from the current conflict-of-interest situations between veterinary and commercial interests, in particular at Ministries of Agriculture.
- Strengthening public capacities in disease surveillance and early alert systems, and enhancing publicly funded[22] research on simple (pen-side) diagnostic tools and vaccines.
- Greater reliance on the use of vaccination, in combination with "stamping out". Ring vaccinations, (vaccinating the entire stock in a radius of up to 20-40 km around the disease outbreak) in combination with disease eradication, or regular vaccination strategies. There is a need to reassess the validity of current non-vaccination strategies of the OECD countries, in view of their trade, equity and ethical effects;
- Greater integration of private veterinary and human health operators in the surveillance and early alert systems.
- Regional quarantine (disease exclusion) schemes, thus rationalizing the currently fragmented efforts along national borders, which are very difficult to control, and harmonizing standards and procedures. The generally acknowledged principles in favor of a strong national disease management capacity also justify regional centralization.

- Insurance schemes, at the regional or even global level, which would be able to pay acceptable compensation levels. Support for such a fund should be of interest to OECD countries, because it would directly protect their animal and human populations against diseases from developing countries spilling over into their territory.

ADDRESSING THE EQUITY ISSUE

The expansion of the demand for animal products offers potential opportunities for smallholders, but the economic concentration of the sector poses the danger that smallholders are crowded out. The overall equity effects of the Livestock Revolution on rural poverty are not clear, and need more study. Associative forms, including vertical integration and cooperatives, can provide some of the economies of scale, enabling smallholders to compete with large enterprises, but need to be built on solid legislation, which avoids monopolies and collusion of the integrators, and enforces compliance of both producers and integrators.

5. CURRENT ACTIVITIES, RATIONALE FOR INTERNATIONAL INVOLVEMENT AND THE WAY FORWARD

Although the focus is often more on the "nuisance" factors (odor, flies) of intensive livestock production, concern about these negative effects is some middle-income countries. Several recently introduced stricter regulations regarding zoning and "end of the pipe" water quality standards, but the implementation and enforcement are weak. There is a genuine concern in several high-livestock countries regarding the need to strengthen surveillance systems, and to take early action. However, on the environment, whatever enforcement takes place is largely addressing these nuisance factors near urban areas and their effect on public health. Serious attempts to arrive at a better spatial distribution of livestock, and to address the less visible and more long-term effects of high amounts of nitrate and phosphorous discharge, are still rare. Similarly, on the health side, the increased political attention to emerging diseases and animal and human health services has not yet been translated into increased budgets.

WORLD BANK INVOLVEMENT

The World Bank's support for better management of the environmental, public health, and social effects of the "Livestock Revolution" is still limited. On livestock waste management, the Bank has supported a number of initiatives.

The Livestock, Environment, and Development Initiative (LEAD), a multi-donor Trust Fund implemented by the Food and Agriculture Organization (FAO), with active participation of the Bank. In livestock waste management, LEAD has developed and piloted in East Asia the tools for zonal planning and improved spatial distribution of livestock using geographic information systems (GIS) methodology and the calculation of national or regional nutrient balances. In addition, through its Virtual Center, it has focused global attention on this issue.

A World Bank loan and a Global Environment Facility (GEF) credit has funded the implementation of a livestock pollution mitigation project in Poland. The project seeks to help farmers in four counties meet the requirements spelled out in the European Union (EU) Nitrates Directive and in the Polish Law on Fertilization. It provides a subsidy of up to US$10,000 per farm for the preparation of environmentally responsible farm management plans and the construction of tanks for storing liquid manure. Farmers contribute the remaining 50 percent. Performance in terms of tanks financed and nutrient management plans has been satisfactory.

Under GEF–World Bank funding the Danube Nutrient Reduction Plan in Serbia and Montenegro was launched, and under GEF funding, with FAO/LEAD, the East Asia Livestock Waste Management Project was launched, covering China (Guangdong Province), Thailand, and Vietnam. The emphasis in these projects is on mitigating nutrient loading, through the promotion of improved manure collection, storage, and application technology in selected watersheds, using matching grants as the most common incentive system. Policy and/or institutional needs are addressed in these projects through support for improving the regulatory framework and raising public awareness. The proposed East Asia Livestock Waste

Management Project also seeks to develop the tools and incentives to promote a better spatial distribution of intensive livestock production.

The National Environment Project in Brazil has given considerable attention to water quality as affected by intensive livestock production in the three southern states. Matching grants for livestock waste treatment (lagoons and so forth) were introduced, jointly, with a water quality monitoring system. A decision model to guide decision makers for licensing has been developed and the experiences are now being picked up by the private meatpacking industry. Finally, the project is supporting the construction of collective biodigestion installations for smallholders. An additional interesting aspect of this project is its current negotiations with the World Bank's Prototype Carbon Fund to sell the N_2O reduction of biodigestion as carbon credits, in view of the greenhouse gas reduction of biodigestion.

These interventions are introducing stricter regulations and subsidizing technological improvements in manure management, and some introduce more innovative approaches. However, the more difficult areas of implementation and enforcement of these regulations receive less attention. With a weak public enforcement capacity in many of the middle-income countries, and the prospects of large-scale subsidization of manure management infrastructure rather remote, other mechanisms, focusing on market forces and "win–win" technologies and alternative enforcement methods on the basis of peer pressure need to be explored, assessing in particular experiences in these areas in OECD countries.

In the area of animal health, there has been some international support for the strengthening of public services, and the establishment of private–public partnerships, often as part of agricultural service support projects. However, the total amount from the developed world to the developing world amounts to around US$10-15 million per year, which is certainly not in relationship with the needs. In the specific area of funding the control of emerging zoonoses, the World Bank has supported the Government of Vietnam with an Avian Flu Emergency Recovery Project, a US$5 million credit for strengthening surveillance systems and rehabilitation of the sector, poultry sector infrastructure, and public awareness activities.

THE ROLE OF PUBLIC POLICY AND THE WORLD BANK

Public policy needs to play an important role because of the global and national public goods involved with the environmental, poverty reduction, and public health aspects. The World Bank, with its convening power at the global level, its capacity to combine national policy dialogues with the levels of investments required, and its cross-sectoral expertise covering, among others things, agriculture, environment, health, and infrastructure, can support these public policies. More details and the key entry points are provided below.

GLOBAL PUBLIC GOODS

As described above, several of the environmental and public health effects transcend national boundaries, as the environmental impacts affect global climate change, open waters, and biodiversity, and the emerging diseases, such as the Avian flu, have global significance. There is a direct interest of the developed world to assist developing countries in animal disease control, as their susceptible, high value livestock population, would suffer directly from any likely spill-over of these diseases from the developing world into their territory. While the adoption of the concept of animal diseases as a global public good, does not absolve the developing countries own responsibility, it would justify also more support from the North.

However, until recently, the global institutions concerned with research—such as the United Nations Environment Programmed (UNEP), the Food and Agriculture Organization (FAO), the Global Environment Facility (GEF) and the Prototype Carbon Fund (PCF), the International Livestock Research

Institute (ILRI)—and the main environmental nongovernmental organizations paid little attention to the role of intensive livestock in affecting these global public goods. Land-based production, integrating crops and livestock in smallholder systems, and pristine environments attracted more attention than the highly visible, ill-kept large facilities around urban areas. Groups from civil society that did focus on intensive livestock production were mostly linked to animal welfare agendas, such as was done by Compassion in World Farming (CIWF).

More recently, with the establishment of the Livestock and Environment Initiative in 1997 and the work of Delgado and others (1999) on the Livestock Revolution, there has been a greater appreciation of the challenges brought about by the global intensification of livestock production and processing. However, more needs to be done on global awareness, innovation, and sustainable institution development. This would include support for the following areas.

Innovation in global disease control

As has been shown by the many disease outbreaks, in this era of globalization, current approaches are not effective. New approaches must be developed with all stakeholders. Given the vested interests in this area, the involvement of an external, global institution—such as the World Bank—would be helpful to stimulate new thinking. As a first step, it is therefore proposed to establish a global platform for emerging zoonoses and other pathogens, supporting ongoing activities such as the World Animal Health Organization (OIE) and FAO's Global Framework for the Progressive Control of FMD [foot–and–mouth disease] and other Transboundary Diseases (GT-TAD), but seeking to broaden it with private partnerships, from, for example, the pharmaceutical or processor and retailer sectors, and act as a think tank to promote innovative approaches for the control of these diseases. A proposal is being considered under the World Bank's Development Grant Facility to finance OIE for initial global awareness raising activities and additional studies in this area. These could include:

- Studies on the cost of "business as usual" in animal disease control, its implication for human health. Business as usual would imply maintaining veterinary services in the developing world at their current, under-funded and ineffective status, continuing current disease control strategies.
- Linked to the above study, a critical assessment of current disease control strategies, in particular the non-vaccination strategy, and an assessment of technology needs and costs and benefits of alternative strategies.
- Studies on the feasibility and eventual implementation of global or regional insurance and compensation systems.
- Support for development of models, in particular promoting regional integration of services, for the monitoring, surveillance, and early alert disease systems, for vaccination campaigns and for "stamping out" diseases, and imposition of quarantine measures, including adequate compensation of producers.

This platform would also serve as an advocacy instrument for increased funding, stressing the spillover dangers from the developing to the developed world under the current disease situation.

Enhancing the profile and sustainability of work on livestock environment interactions

While there is a reasonable level of awareness under the livestock specialists community of the challenges of the livestock revolution, the major importance of these challenges are not yet recognized by the broader global community, and have not yet led to sustainable institutions and funding for the prevention and mitigation of the negative livestock and environment interactions. The following action are therefore required:

- A greater effort in public awareness creation at global and "hotspot" country levels. Citizens need to realize that local actions that harm the environment can transcend national boundaries, creating negative impacts on regional and global scales.
- Sustainable, long-term integration of livestock–environment interactions is needed at national, regional, and global institutions. Current programs of the main international organizations, such as FAO and the ILRI, have mostly a project-specific focus.
- The expansion of research on improved livestock waste management and health technologies, described in Chapter 3. Global public support is required for those pro-poor or "orphan" (commercially nonviable) technologies, described above, such as the increase in the efficiency of feed use, small-scale manure crop and energy recycle systems, robust and easy-to-apply disease and immunity level diagnostics and vaccines. The current level of funding for these areas is minimal.
- Linking livestock waste treatment operations with global public good support initiatives, such as carbon trade, and the Global Environment Facility.

NATIONAL PUBLIC POLICY

With national public goods of environmental sustainability of water, land, air, and biodiversity, poverty reduction, and public health at stake, there are major national and local public policy roles. There is a vast array of technologies, which for widespread adoption need to be supported by a similar expanded menu of financial, regulatory, and institutional instruments and support actions. The international community, including the World Bank should support:

- Greater awareness creation at the decision maker and general public level, on the major environmental and public health implications of increased livestock density, going beyond the "nuisance" factors, into the less obvious aspects, such as nutrient loading and emerging zoonoses;
- The preparation of national manure management plans in those countries with major current or expected problems, such as Brazil, China, Thailand, Mexico, Philippines, Vietnam, and several ECA countries. The preparation of such a plan would consist of major public awareness raising activities in the form of workshops and round tables, and a review of current and projected livestock population densities, their implications for the environment and public health, current experiences, for example within the framework of LEAD and GEF funded project, current legislation and policies, and their effect on livestock induced pollution. This would lead to the preparation of master plans for scaling up mitigation and prevention efforts of these effects. Scaling up should be gradual focusing on the sensitive areas, but start without delay;
- The development and implementation of regional zonal planning capacities, including the development of GIS technology, its supporting database, and the legislation and institutions to implement and enforce a better spatial distribution of livestock production;
- Strengthening the definition and implementation of market-based incentives for sustainable livestock waste management, including tradable quota systems;
- Strengthening national public animal and human health surveillance systems, in surveillance, early alert, and disease management capabilities, in particular through the

promotion of a closer integration with private grass-roots animal and human health systems, and a closer collaboration between animal and human health institutions;

- Developing associative forms of livestock waste management, such as cooperative bio-digestion systems, watershed focused manure management plans, and so forth; and
- Developing and testing legislation supporting the development of supply chains, which adequately protect the interest of all stakeholders, including smallholders, and prevent the monopolies or collusion of the integrators.

The Livestock Revolution will continue, and could have major global negative environmental, public health, and social externalities. As seen, there is no "silver bullet" and experience from the developed world shows that there is not even a proven package of interventions, and trial and error approaches will be needed. Still, the threats are so significant that coordination among all stakeholders involved at the global and national levels is needed.

APPENDIX 1

Table A1.1. Dietary Strategies that Reduce the Mass and Nitrogen (N) and Phosphorus (P) Content of Dairy, Poultry, and Swine Waste

Animal Type	***Feed Management Strategy***	***Principal Effect on Manure***
Dairy	Feed protein in relation to milk production	Reduces total N, urine N, and ammonia production
	Refine mineral supplementation	Reduces total and water-soluble P
	Increase feed intake and improve forage quality	Reduces mass and N content
Poultry	Formulate diets based on amino acids rather that crude protein	Reduces total N
	Optimize amino acid profile to feed "ideal proteins"	Reduces total N
	Phase feed to match rates of growth and production	Reduces total N and P
	Formulate diets based on "true amino acid digestibility"	Reduces total N
	Select feeds with low nutrient variability	Increases feed use efficiency and reduces manure N and P
	Use enzymes (photoset) and other feed additives (vitamin D)	Reduces total P but may increase water-soluble P
	Feed readily available P (e.g., low-hydrate grains) to meet, but not exceed, requirements	Reduces total P but may increase water-soluble P
	Implement proper watering management	Reduces manure water content and ammonia production
Swine	Refine protein and amino acid supplementation	Reduces total and urine N
	Feed low-hydrate corn	Reduces total P but may increase water-soluble P
	Precision feeding	Reduces mass, N, and P
	Minimize feed waste and water use	Reduces mass
	Feed pH-altering feeds	Decreases urine pH and ammonia production
	Increase diet digestibility	Reduces N and P

Source: Authors.

Table A1.2. Relative cost of different liquid manure storage systems

Storage Type	***Relative Cost (USD per 3,785 liters)***
Naturally lined earthen pit	1.0
Clay-lined earthen basin using clay on-site	1.9
Clay-lined earthen basin using off-farm clay (varies with distance)	2.4
Earthen basin with plastic liner	2.1
Earthen basin with concrete liner	2.8
Aboveground recast concrete tank	3.9
Circular aboveground concrete tank poured in place	4.5
Aboveground glass-lined steel tank	5.5

Source: Fulhage and others 2001.

Technical aspects related to manure storage often overlooked are: (a) roofing over manure storage; (b) storage capacity, or how many days storage is required; (c) whether storage structures are supposed to be emptied monthly, quarterly, or annually; (d) will the required periodic, timely emptying of storage cause labor problems? Many engineering manuals have been developed to guide the sizing, siting, design, construction, and operation and management of manure storage structures (Foliage and Boehner 2001). Particular attention may be needed in monitoring the design, construction and, perhaps most important, the maintenance of manure storage structures. This is perhaps especially important in tropical monsoon conditions. Ill-designed storage, neglected upkeep, and storage not emptied on schedule have created environmental catastrophes in temperate locations where sophisticated management is supposed to be in place. Given the importance of technologies that include manure storage, potential contingencies should be drawn up that have strict guidelines that assure contractor adherence to construction specifications, contingency plans for storage overflows, breaches, and so forth.

Table A1.3. Constituent removal from liquid stream by various manure treatment units

Treatment Unit	*Organic Material*	*N*	*P*	*Heavy Metals*	*Pathogens*
High-rate aeration	M+	M-	M-	No	M+
Low-rate aeration	M-	M-	M-	M-	M+
Lagoon with high-rate aeration	M+	M-	M-		M+
Lagoon with low-rate aeration, aerobic/anaerobic zones	M-	M-	M-	M-	M+
Solids removal, mechanical	M+	M-	M-	M-	M-
Solids removal, gravity	M+	M-	M-	M-	M-
Chemical precipitation	M+	M-	M+	M+	M-
Lagoon	M+	M+	M+	M+	M+
Lagoon with impermeable cover	M+	No	M+	M+	M+
Lagoon with permeable cover	M+	M-	M+	M+	M+
Anaerobic digester with gas collection	M+	No	No	No	M+
Aerobic boiler	M+	M-	M-	M-	M+
Constructed wetland	M+	M+	M-	M+	M+
Sequencing batch reactor	M+	M+	M+	M+	M+

M+ = Major removal; M- = Minor removal; No = little or no removal.
Source: Humenik 2001.

Table A1.4. Gaseous effluent from manure treatment units and relative costs

Treatment Unit	*Effluent Gas*			*Odor*	*Cost*	
	CH_4	*NH_3*	*H_2S*		*Initial*	*Operating*
High-rate aeration	M-	M-	M-	M-	H	H
Low-rate aeration	S-	S-	S-	S-	I	I
Lagoon with high-rate aeration	M-	M-	M-	M-	H	H
Lagoon with low-rate aeration, aerobic/anaerobic zones	S-	S-	S-	S-	I	I
Solids removal, mechanical	M-	M-	M-	M-	H	I
Solids removal, gravity	M-	M-	M-	M-	I	L
Chemical precipitation	N	N	N	N	H	H
Lagoon	M+	M+	M+	S+	L	L
Lagoon with impermeable cover	M-	M-	M-	M-	I	L
Lagoon with permeable cover	M-	M-	M-	M-	H	L
Anaerobic digester with gas utilization	M-	M-	M-	M-	H	H
Aerobic boiler	M-	M-	M-	M-	H	H
Constructed wetland	M-	M-	M-	M-	I	L
Sequencing batch reactor	M-	M-	M-	M-	H	H
Composted, aerated	M-	M-	M-	M-	I	I
Composting un-aerated	M-	M-	M-	M-	L	L
Vermin-composting	M-	M-	M-	M-	I	I

Gas: M+ = Major increase; M- = Major decrease; N = No effect; S+ = Minor increase; S- = Minor decrease; Cost: H = High; I = Intermediate; L = Low.

Source: Humenik 2001.

Table A1.5. Qualitative comparisons of major nitrate loss pathways for manure application under various management regimes and environmental conditions

Manure Management		***Soil Drainage***	***Nitrogen Loss Processes***		
Rate	***Placement***		***Ammonia***	***Gentrification***	***Leaching***
Placement Comparisons					
Med.	Surface	Well	High	Low	Medium
Med.	Incorporated	Well	Low	Medium	Medium
Med.	Injected	Well	Low	Medium	Medium
Soil Drainage Comparisons					
Med.	Incorporated	Excess	Low	Low	High
Med.	Incorporated	Poor	Low	High	Med.
Application Rate Comparisons					
Low	Incorporated	Poor	Low	Low	Low
Med.	Incorporated	Poor	Low	Medium	Medium
High	Incorporated	Poor	Low	Medium	High

Source: Meisinger and Thompson 1996.

Emission mitigation technologies are usually aimed at a particular production system component. They do not address the fact that emissions reduced in one component (for example, confinement) may be emitted later at another component (for example, manure storage), or that methods to control one pollutant may increase emissions of others. For example, the highly interactive nature of manure N transformations and pathways of N loss necessitate that manure management be based on an understanding of the tradeoffs involved in conservation of one N form and concomitant increases in other N losses (table A1.5). Major pathways of manure N losses are emissions of the gasses NH_3, N_2O, and N_2, and the leaching of NO_3. Ammonia loss ranges from 30 to 40 percent of total N excreted. Nitrate losses typically range from 10 to 30 percent, and denitrification from 2 to 5 percent of total N applied. High nitrate leaching contaminates groundwater and increases losses of N via denitrification. Although denitrification may constitute only a small percentage of applied manure N, N_2O contributes to global warming and ozone depletion. Manure injection into soil to reduce ammonia loss (and improve air quality) may increase nitrate leaching (and reduce groundwater quality) and increase denitrification (greenhouse gas formation).

APPENDIX 2. HISTORY OF THE DUTCH MANURE POLICY AND THE ROLE OF THE GOVERNMENT

The Dutch manure policy has a history of 20 years of changes, successes, and failures. The Dutch governmental bodies have changed their roles and views on policy as to intensive livestock farming more than once the past few decades, due to changing external conditions and opposing views internally. During this process a range of policy instruments were used to address the problems, particularly environmental ones, which come from an intensive farming system. These were not always successful.

In practice, the instruments of a manure policy have to realize three common aims simultaneously:

- On intensive livestock farming systems, the surplus amount of animal manure has to be transferred to farms that can accommodate this manure.
- On farms that accept animal manure from other farms, nitrate (N) and phosphorous (P) losses may not increase above environmentally acceptable losses, even when it is financially attractive to buy animal manure from other farms.
- On all farms, the N and P losses have to be decreased to environmentally acceptable levels, through drastic improvement of N and P use efficiency.

It took quit some time to realize the implications of these three common aims and to learn how to translate them into effective policy instruments. There was and still is a lack of understanding of the relationships between "type of policy instrument—behaviour of farmers—agronomical and environmental effects." The response of farmers to the implementation of manure policy and measures was more varied and complex than expected.

RECONSTRUCTION AND STIMULATING (1945–68)

Agricultural policy was given an important position in reconstructing the Netherlands, and has been the foundation in European policy since the mid-1950s. Self-sufficiency and cheap food were the most important objectives. The signal to the farmer was clear: increase production and rationalize production methods. Support came via (European) subsidies and (particularly in the Netherlands) via a smoothly run troika: education, extension, and research. This policy was successful. By the end of the 1960s the objectives had mostly been attained. From that moment onward policymakers had to deal with an "affluence problem": surpluses. There was a growing, although careful, awareness of the other side of the policy: the ongoing intensification had led to an attack on nature and landscape and to a heavy burden on the environment.

STIMULATING AND DEFENDING (1968–84)

It was for the first time in a note of *Intensive Livestock Farming* (1974) that a number of (environmental) problems were pointed out clearly and officially, but without resulting in a change in policy. Both the Ministry of Health and Environment and the sector were convinced that the problems could be solved (technically), and until 1984 policymakers continued to stimulate growth in the pig (and poultry) sector. It was during this period that the government started to send a different message. While the Ministry and nature conservation organizations drew more explicit attention to environmental problems, agricultural policy was still aimed at expansion and increase in scale, with investment subsidies, and the problems trivialized by the agrarian side. In formulating rules on manure and the environment, the opposing views became visible in, among other things, competence conflicts between the two responsible departments. The Ministry of Agriculture, Nature Management and Fisheries and the pig sector were very much of the same opinion: together they made agreements and together they brushed aside the problems.

DEFENDING AND INTERVENTION (1984–96)

In the 1980s the Ministry of Agriculture, Nature Management and Fisheries could no longer deny the environmental problems. At the policy level this was translated into the intention of stabilizing intensive farming. On 2 November 1984 an Interim Law was promulgated, but it did not achieve this goal: before implementing this law, there were enough applications for building and Nuisance Act permits to allow the pig herd to increase by 30 percent.

The first phases of the Dutch manure policy were characterized by the belief that the manure surplus could be solved by technological innovations. Various pilot plants were set up to explore the possibilities for manure processing, and initiatives were undertaken for marketing processed manure abroad. Most of these initiatives failed, except for those concerning drying and pelletizing manure for export to surrounding countries. Manure distribution was successful. The stepwise lowering of the application standards led to increasing pressure on the "manure market" and increasing costs for manure disposal.

Tradable production rights were established. Municipalities could draw up ammonia reduction plans to allow farm expansion at one location, and exchange this with termination of a business elsewhere. With this, the environmental permit had become de facto a tradable emission right.

Also, due to the compromising character of the legislation and interventions by the Parliament, one "adjustment" followed the other. The result was ever more complex, often extremely detailed, legislation, which only partly worked. With, for example, the Ecological Directive, the Pig Act, and the Identification and Recording system, the impression of accumulation and refinement of policy was reinforced. This complexity of legislation resulted in conflicts between parties: between the Ministries of Agriculture, Nature Management and Fisheries and Health and Welfare, within the Ministry of Agriculture, between government and the pig sector, between arable farmers and livestock farmers, and between North and South. The greatest pain was felt at the farm level.

INTERVENTION AND MANDATING (1997–2003)

In 1998 there an outbreak of Classical Swine Fever. The Minister of Agriculture, Nature Management and Fisheries used this to gain political momentum. The accumulation of policy instruments—pig rights, reduction and skimming of pig herds, accentuating the Pig Act, and maintaining the MINeral Accounting System (MINAS)—comes down to a generic policy that interferes with economic processes and does not affect specific farm processes that are harmful to the environment.

RULING OF THE EUROPEAN COURT AS OF 2003

In response to the decisions of the European Court and the European Commission, the Dutch government determined in the third Action Plan (2003) that crop-and soil-specific fertilization standards will be implemented by January 2006. At the same time, MINAS will be abandoned. Further, Manure Transfer Agreements will be abandoned by January 2005, because these have become redundant with the implementation of crop- and soil-specific fertilization standards. Other reasons for dismissing manure transfer agreements are their administrative burden, high costs for intensive livestock farms, and its low effectiveness. Moreover, production rights for pigs and poultry per farm, implemented earlier and still in practice, already limit the amount of animal manure produced per farm (RIVM 2004).

REFLECTIONS AND RECOMMENDATIONS

This institutional history of the European—and especially the Dutch—manure policy shows that institutional development lagged behind the increasingly intensified use of the natural environment. Control and enforcement turned out to be very difficult, and additional rules had to be introduced, which farmers time and again proved capable of circumventing. It appeared to be very difficult to downsize the intensive livestock industry. Effective environmental policies are always a mix of regulatory measures, economic incentives, and communication instruments.

It is not so easy to characterize manure policies in terms of state-centred, market-based, and communicative. Such characterizations tend to ignore the essentially hybrid character of policy measures and the public–private interaction between instruments in a regulation complex. Quotas are perhaps best described as bureaucratically allocated production restrictions. In this sense they are state centred, rather than market based. A failure to introduce and/or enforce a quota system may thus serve as an example of bureaucratic failure, rather than market failure.

Agro-environmental policy instruments have both "command and control" and "market-based" characteristics. Depending on the development phase, different elements of the policy mix have a different priority. A logical development always seems to occur over time. Initially, there is not enough sense of urgency to fully comply with the precautionary principle. In the second phase, when legislators try to enforce regulations, strategic behavior of farmers can be observed (farmers expand their activity to preempt pending new regulation). In the third phase, path dependencies make it difficult to change policies (farmers have already invested in quotas). It can be concluded that public–private interaction has a huge impact on the effectiveness of institutional development, whereby "the devil is in the details."

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Notes

[1] Eutrophication is the process by which dissolved nutrients enrich a body of water, stimulating the growth of aquatic plant life (usually resulting in the depletion of dissolved oxygen).

[2] Biodigestion is a process of degradation, transformation, or decomposition of vegetable and animal substances (organic matter) carried out by microorganisms and bacteria.

[3] Zoonoses are diseases that are communicable from animals to humans.

[4] Zoonoses are diseases that are communicable from animals to humans under natural conditions (Merriam Webster online dictionary, www.m-w.com).

[5] The framework is sponsored by the World Animal Health Organization (OIE) and the Food and Agriculture Organization of the United Nations (FAO).

[6] Preparation for these plans would include activities to raise public awareness. It would also involve a review of current and projected livestock population densities; their implications for the environment and public health; current experiences—for example within the framework of LEAD and GEF funded project; and current legislation and policies. This would lead to the preparation and adoption of a master plan for scaling up mitigation and prevention efforts of these effects. Scaling up should gradually focus on sensitive areas, but agencies need to start without delay.

[7] For example, income elasticity for meat in China is practically 1, and for milk about 1.2, which implies that for every percent increase in income, expenditure on meat and milk will rise by 1 or 1.2 percent, respectively

[8] A similar "Blue Revolution" is taking place in the aquaculture sector, and will be the subject of a follow–up study

[9] Sheep and Goats

[10] In this assertion, regarding housing, this is particularly pertinent in the use of climate control; for feeding, it regards the micro-mixing of trace elements and other feed additives in particular; breeding deals particularly with artificial insemination; and animal health technology addresses vaccination costs and applying special disease-control measures, such as specific pathogen-free technology (SPF) in particular.

[11] Although this seems a less appropriate assumption in the fast growing economies of the countries concerned.

[12] In the original definition of Sere and Steinfeld (1996) the definition was 90 percent of the feed purchased.

[13] Heavy metals such as copper and zinc are essential trace minerals and can have a positive influence on animal growth and reproduction. However, they can also be used as growth promoters at levels much higher than required for normal growth, and are major component of the pollution caused by the leather and wool industry.

[14] Nitrous oxide is four times more aggressive than methane.

[15] This includes all grains, such as corn, wheat, barley, sorghum, and rye, but does not include other feed components that have a strong environmental effect, such as soybeans and fishmeal.

[16] Other diseases, not directly related to intensive livestock production, although of recent emergence, are Rift Valley Fever and West Nile virus, which fall outside the scope of this paper.

[17] Calling it "waste" might be dangerous, however, because it might encourage too narrow a focus on treatment and neglect recycling opportunities.

[18] A genetically modified soy where the indigestible carbohydrate stachyose is replaced with the easily digested sugar sucrose.

[19] An organic form of phosphate, which pigs and poultry cannot absorb directly.

[20] A large CAFO is a farm that has more than 1,000 beef cattle, dairy heifers, cow/calf pairs, or veal calves; more than 700 mature dairy cows; more than 2,500 swine weighing 25 kilograms or more or 10,000 swine weighing less than 25 kilograms; more than 30,000 chickens with a liquid manure handling system; more than 82,000 laying hens without a liquid manure handling system; or more than 125,000 chickens other than laying hens without a liquid manure handling systems.

[21] In order to improve production conditions in Denmark, the Danish Parliament is now proposing a more liberal manure control system, which might allow larger pig production quotas to farmers who invest in advanced manure-handling technologies, but taxes on phosphorus in feed have been increased. (European Commission press release, "The Commission approves Danish introduction of a new tax on phosphorous in feed," 1 January 2005.)

[22] Because these tools have a limited market potential, public sector funding would probably be required.