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Geographical determinants and environmental implications of livestock production intensification in Asia

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Abstract

Under growing and urbanising demand, livestock production is rapidly evolving in South, East and South-east Asia, with both an increase of production and a shift to intensive production systems. These changes infer impacts on the environment, on public health and on rural development. Environmental impacts are mainly associated with a mismanagement of animal excreta, leading to pollution of surface water, ground water and soils by nutrients, organic matter, and heavy metals. In the framework of the Livestock Environment and Development Initiative, this research aims at assessing, on a regional scale, the impacts of livestock production on nutrient fluxes. Phosphate (P_2O_5) mass balances were chosen as an indicator and were calculated on the basis of spatially modelled livestock densities, estimated excretion values and crop uptake. The results show a strong West—East gradient regarding the distribution of monogastrics, with clear concentration in densely populated areas and around urban centres. P_2O_5 overloads are estimated on 23.6% of the study area's agricultural land, mainly located in eastern China, the Ganges basin and around urban centres such as Bangkok, Ho Chi Minh City and Manila. On average, livestock manure is estimated to account for 39.4% of the agricultural P_2O_5 supply (the remaining share being supplied by chemical fertilisers). Livestock is the dominant agricultural source of P_2O_5 around urban centres and in livestock specialised areas (southern and north-eastern China), while chemical fertilisers are dominant in crop (rice) intensive areas.

Keywords: Livestock production; Eutrophication; Nutrient balance; Environment indicator; Geographical Information Systems (GIS); Phosphate; Asia

1. Introduction

The term "Livestock revolution" has been used to describe the rapid expansion of livestock production in developing countries (Delgado et al., 1999). Table 1 shows similar rising trends in consumption and production across the globe, with highest rates in the developing world. If trends in production and consumption are rather parallel, it is nevertheless proposed that the growth in production is driven by demand, the latter being mainly fuelled by population growth, urbanisation and income growth in developing countries (De Haan et al., 1998).

Globally, this growth trend is not uniformly spread. As shown in Table 1, the annual growth rate for meat production between 1982 and 1994 was 5.4% for the developing world and only 1.1% in the developed world. Furthermore, among the developing countries, Asia has the fastest developing livestock sector (annual growth rate for meat production over the same period was 8.4% in China and 5.7% in Southeast Asia), as a consequence of faster growth in human population, economy and urbanisation.

Recent analysis (Delgado et al., 2002) predicts that this trend will endure over the next 20 years, although the pace of growth may dwindle. Over the 1997–2020 period, annual growth of consumption is predicted to

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Table 1
Trends in the consumption and production in meat by region, 1982–1994

Region	Annual growth rate of total meat consumption 1982–1994 (%)	Annual growth rate of total meat production 1982–1994 (%)	Total meat consumption 1993 (million metric tons)	Total meat production 1993 (million metric tons)
China	8.6	8.4	38	38
Other East Asia	5.8	5.0	3	2
India	3.6	3.7	4	4
Other South Asia	4.8	4.8	2	2
Southeast Asia	5.6	5.7	7	8
Latin America	3.3	2.9	21	23
WANA[a]	2.4	3.9	6	6
Sub-Saharan Africa	2.2	2.1	5	6
Developing world	5.4	5.4	88	88
Developed world	1.0	1.1	97	100
World	2.9	2.9	184	188

Source: compiled from Delgado et al. (1999).
Note: meat includes beef, pork, mutton and goat, poultry.
[a] West Asia and North Africa.

average 3.0% in China, 3.3% in Southeast Asia and 2.8% for the developing world.

The livestock sector is responding to this surge in demand for livestock products with some drastic transformations. These transformations basically take four different forms (De Haan et al., 1998). First, livestock production tends to concentrate in areas favoured by cheap input supplies (particularly feed), and by good market outlets for livestock products. Such conditions are found in the vicinity of large cities. Second, the proportion of livestock production met by specialised and intensive industrial systems is increasing rapidly, as those systems react faster to growing demand. The rapid growth in scale is general, and the new settlements directly compete with land-based, small-scale production, sometimes supplanting them. The industrialisation of production leads to a disconnection between livestock activities and cropping activities. This happens on a functional level (large-scale livestock production shifting to industrial type management), and on a spatial level (industrial livestock activities moving towards peri-urban areas). Third, the production is shifting from ruminants (e.g. cattle, sheep, goats), to monogastrics (e.g. pigs, laying hens, broilers, ducks), that have a better feed conversion ratio. Fourth, vertical integration along the land–livestock–food chain creates economies of scope.

2. Potential impacts of intensive livestock production

The geographical concentration of livestock in areas with little or no agricultural land leads to high impacts on the environment (water, soil, air and biodiversity), mainly related to manure and waste water mismanagement. Nutrient overloads can result from several forms of mismanagement amongst which are over-fertilisation of crops, over feeding of fish ponds, and improper waste disposal of agricultural (e.g. livestock) or industrial wastes. Nutrient overloads in the crop–livestock systems mainly occur when the nutrients present in manure are not properly removed or recycled. The major effects of animal waste mismanagement on the environment have been summarised by Menzi (2001):

- Eutrophication of surface water (deteriorating water quality, algae growth, damage to fish etc.) due to input of organic substance and nutrients if excreta or waste water from livestock production get into streams through discharged, run-off or overflow of lagoons. Surface water pollution threatens aquatic ecosystems and the quality of drinking water taken from streams. Nitrogen and Phosphorus are both nutrients often associated with accelerated eutrophication of surface water (Correll, 1999; Zhang et al., 2003). However, Phosphorus is often the limiting factor to the development of blue-green algae, which are able to utilise atmospheric N_2. Therefore, developping Phosphorus management is often identified as main strategies to limit surface water eutrophication from agricultural sources (Mainstone and Parr, 2002; Daniel et al., 1994).
- Leaching of nitrate and possible pathogens transfer to the ground water from manure storage facilities or from fields on which high doses of manure have been applied. Nitrate leaching and pathogen transfer are especially threats for drinking water quality.
- Accumulation of nutrients in the soil if high doses of manure are applied. This can threaten soil fertility.
- Natural areas such as wetlands and mangrove swamps are directly impacted by water pollution, often leading to bio-diversity losses.

As a result of economies of scale, industrial livestock production generates substantially lower income per unit of output than smallholder farms, and benefits at production level occur to fewer producers. While cheap animal protein also indirectly favours poor consumers, the poverty and equity effects, as regards industrial livestock production, are on balance largely negative (De Haan et al., 2001).

There are also a number of animal diseases associated with increasing intensity of production and concentration of animals on limited space, many of them pose a threat to human health (zoonotic diseases). Industrial and intensive forms of animal production may be a breeding ground for emerging diseases (Nippah, Bovine Spongiform Encephalopathy, Avian Flu), with public health consequences. Finally, animal products from intensive production systems tend to have higher residues content (Nardone and Valfrè, 1999).

3. Framework and objective of the study

The Livestock, Environment and Development (LEAD) Initiative is an inter-institutional project with the secretariat in Food and Agriculture Organisation of the United Nations (FAO). The work of the Initiative targets the protection and enhancement of natural resources as affected by livestock production and processing in the context of poverty reduction and public health enhancement, through better policy formulation for appropriate forms of livestock development. Aiming at enhanced policy making, the LEAD initiative develops decision-support tools to asses livestock–environment interactions, for early warning, activity targeting and decision making.

In this framework, the objective of the study was to asses at the regional level the contribution of livestock to nutrient fluxes, especially in the areas with nutrient overloads.

4. Methods

4.1. Study area

The study was limited to South, East and South-east Asia as defined by FAOSTAT (FAO, 2003). Asia was selected because it has (1) the highest livestock production regional growth in the world, mainly due to rapid expansion of industrial systems, (2) high use of mineral fertilisers and (3) relatively high livestock densities. Developed countries within Asia (Japan and South Korea) were not considered, neither Pakistan and Mongolia in which intensive livestock production systems are hardly represented. The countries were divided into two groups based on the size and importance of the livestock sector in terms of density. The first group comprised countries considered only at national level (Bangladesh, Bhutan, Myanmar, Cambodia, Nepal, North Korea, Philippines, Singapore, Sri Lanka, Macau, and Taiwan), while the second countries that were considered at province level (China, Indonesia, India, Laos, Malaysia, Thailand and Vietnam).

4.2. Statistical data sources

FAOSTAT (FAO, 2003) was mined to obtain comprehensive national statistics on livestock numbers by species (cattle, buffalo, sheep, goats, pigs and poultry), crop production, pastures and fertiliser consumption. Primary data on both livestock and crop production at province level were obtained from national statistical yearbooks and supplemented by web-sites. Table 2 provides a list of primary data sources on livestock and crop production at sub-national level. In the case of fertiliser consumption, the country total was obtained from FAOSTAT (FAO, 2003) and distributed to the province level using crop production figures and a yield index.

4.3. Spatial modelling

Because the spatial resolution of available statistics was coarse (single value per administrative unit), and subject to high variability within the study area (large differences in administrative units sizes), it was decided to develop spatial models in order to homogenise resolution. The common resolution was set to a 5 arc-minutes pixel grid in geographic projection.

Spatial models for cattle, buffalo and small ruminants were available at FAO (2001b), but it was necessary to develop specific models for monogastric species. Thus, livestock population data were distributed within each administrative unit on a raster basis. The procedure described below allows the estimation of the spatial distribution of monogastric species within a given administrative unit.

First, the pig and poultry populations were divided into a percentage of industrial and backyard shares, at national or province (China and India) level. These percentages were estimated on the basis of prior studies (Fang et al., 2000; Rattanarajcharkul et al., 2000; Delgado and Narrod, 2002) and statistics such as Gross Domestic Product per capita, and Gross Domestic Product per capita growth (World Bank, 2002).

The share of livestock from backyard production was spatially distributed over the rural population, assuming that rural people and livestock are linearly positively correlated. Rural population, urban population and urban centres extend were derived from Landscan 2000 (ORNL, 1998) and FAO (2003) statistics.

Suitable areas for industrial production were identified as production belts around urban centres. A buffer distance was calculated for each urban centre, considering that the area where industrial production systems

Table 2
Primary provincial level data sources on livestock and crop production

Country	Year of the data	Source
China	1998	China Agriculture Press (1999). China Agriculture Yearbook (1999)
India	1998/99	Central Statistical Organisation (2000). Statistical abstracts India (1999). Ministry of Statistics and Programme Implementation, India
Laos	1998/99	Agricultural Census Office (2000). LAO Agricultural Census (1998/99)—highlights Viantiane, Laos
Malaysia	1999	http://agrolink.moa.my/jph/dvs/statistics/statidx.html. Department of Statistics, Malaysia (Sarawak Branch) (2000). Yearbook of statistics—Sarawak 2000. Department of Statistics, Malaysia (Sabah Branch) (2000). Yearbook of statistics—Sabah 2000
Thailand	1999	National Statistical Office (1999). Statistical Yearbook—Thailand, National Statistical Office, Thailand No. 46
Vietnam	1998	General Statistical Office (2000). Statistical Yearbook 1999. Statistical Publishing House, Hanoi, VietNam
Indonesia	1999	Department of Partanian (1999). Statistical Book on Livestock. Direcktorat Jenderal Perternakan Departmen Pertanian, Indonesia. Department of Partanian (1999). Agricultural Statistics (2000). Ministry of Agriculture, Indonesia

may be located vary according to the urban population, the infrastructure conditions, and level of economic development. Weighted coefficients allowed defining the size of the production belt around cities, from a minimum of 40 km (small areas with scarce infrastructure) to 200 km (for larger cities with highest development). From these rings, a series of unsuitable pixels were removed, on the basis of information on transport infrastructure (USNIMA, 1997), protected areas (WCMC, 1998), water bodies, and closed forest (FAO, 2001a). The industrial share of the livestock was then evenly distributed on the suitable areas.

For pigs and poultry, the total distribution is finally the result of aggregating backyard and industrialised stocks. For selected administrative units in India (three northern states), Thailand (nine provinces at the east of Bangkok), China (three eastern and northern provinces), Vietnam (four provinces around Ho Chi Minh) and the Philippines (whole country), the estimated spatial distribution of livestock was compared against statistical data sets available for administrative subunits (i.e Counties within a Province). In these administrative units, representing 5% of the study area, 1120 pixel were randomly selected to calculate a Spearman's correlation coefficient between estimated and observed densities. The coefficients (0.721 and 0.766 respectively for pigs and poultry) indicated a positive correlation with 99.9% confidence.

For each pixel, the percentage of cropped area and rangeland was also estimated using Landscan (1998) Land Cover map as well as FAO and IIASA (2000) Soil constraints and Climate constraints maps. The layers were combined using the weighted linear combination technique (Eastman, 1999). Selected classes of Land Cover were defined unsuitable for agricultural land (e.g. developed, snow and ice, barren land), the others were assigned a score representing cropping (pasture) suitability. For each pixel, a percentage of cropland (rangeland) was estimated and for each country, a resulting cropland (rangeland) area calculated. In each country separately, an iterative process allowed to adjust the calculated cropland (rangeland) area in order to match FAOSTAT (FAO, 2003) figures, with a maximum error of 5%.

4.4. The nutrient balance methodology

4.4.1. Overview

Nutrient mass balance calculations compare the amount of nutrients entering the system with the nutrients leaving the system. They have been used to estimate nutrient flows at farm, regional and national level (Brouwer et al., 1995; Saleem, 1998; Scoones and Toulmin, 1998; Bindraban et al., 2000; OECD, 2001). The usefulness of this indicator with comparison to empirical approaches (e.g. soil or water sampling) is its robustness and the possibility to calculate it on the basis of statistics, and thus for large areas.

If the balance (i.e. nutrient inputs minus outputs) is positive, there is an oversupply of nutrients and environmental risks, if the balance is negative, there is a risk of nutrient depletion. In-between, a balanced situation indicates that there is a potential equilibrium in the crop–livestock and crop–fertiliser nutrient fluxes. But the balance done at a regional scale does not usually inform on actual farming practice (e.g. animal wastes can be discharged to streams, inferring severe environmental impact) thus, the estimation of nutrient balances provides only an indicator of potential depletion, overload or equilibrium.

Prior nutrient balance calculations combined with Geographical Information Systems (GIS) at local level in Jiangu Province of China (Fang et al., 2000) and eastern Thailand (Rattanarajcharkul et al., 2000), proved to be a useful decision-support tool for policy making and the identification of areas suitable for livestock production growth.

4.4.2. Selection of Phosphate as an indicator

As an indicator for the nutrient balance status, Phosphate (P_2O_5) was chosen for the following reasons: (1) it has a high environmental importance, (2) it usually is the first nutrient which constrains the livestock carrying capacity of land, and (3) the calculation is more accurate than for nitrogen, for which various losses (ammonia volatilisation, denitrification, leaching etc.) and inputs (fixation by legumes, atmospheric deposition) are difficult to quantify reliably.

4.4.3. Balance calculation

On the input side of our calculations, the components are chemical fertilisers and nutrient excretion from manure, while the outputs are the nutrient uptake (content) of the harvested crops (including grazing). The total P_2O_5 excreted in the manure for a given area was estimated as follows (Eq. (1)).

$$P_e = \sum_{i=1}^{n} \varepsilon_i N_i \qquad (1)$$

where P_e is the the total excretion for the given area; n, the total number of livestock species in the area; ε_i, the standard nutrient excretion factor for a given species of livestock with a specified yield and intensity factor in the area, estimated as described below (cf. 4.4.4); N_i, total number of livestock of each species present in the area.

The P_2O_5 uptake of crops in the area was estimated as follows (Eq. (2)).

$$P_u = \sum_{i=1}^{m} \upsilon_i Q_i f_i \qquad (2)$$

where P_u is the total uptake for a given nutrient for the area; m, the total number of crops; υ_i, the nutrient uptake coefficient for crop i expressed in elemental needs (P per unit product); Q_i, total production of crop i in the area; f_i, mass conversion factor from P to P_2O_5, equal to 2.29.

Thus the nutrient balance was calculated as the difference between total input and total output (Eq. (3)) or as the ratio between total input and total output (Eq. (4)).

$$B_d = (gP_e + P_c) - P_u \qquad (3)$$

$$B_r = \left(\frac{gP_e + P_c}{P_u}\right) \times 100 \qquad (4)$$

where B_d is the nutrient balance in the area expressed as a difference; B_r, the nutrient balance in the area expressed as a ratio; P_c, the total P_2O_5 applied from chemical fertilisers in the area; g, the availability factor of the nutrient present in manure, set to 1 for P_2O_5 in our study.

4.4.4. Estimation of standard nutrient excretion factor

The livestock weight and excretion can differ considerably depending on their genetic potential, natural and structural conditions, production intensity, etc. As differentiated information for conditions in Asia was hardly available, this information had to be derived from available statistical data on livestock production in the different countries (FAO, 2003). The chosen approach, which has been described in detailed by Menzi (2002) is summarised as follows:

First, the statistical data on animal numbers and production (carcass weight, number of animals slaughtered, milk and egg yield) was analysed for each livestock category to derive information on the intensity of production.

Then, intensity categories were defined for each livestock category, on the basis of indicators such as average carcass weight, the ratio between livestock numbers and slaughtered animals, and the milk yield per cow. All in all, for twelve livestock categories, thirty five classes were considered: dairy cows (4); young stock for dairy production (4), other cattle (4); milking buffaloes (4); other buffaloes (1); small ruminants (3); horses, mules and asses (4); pigs (3); laying hens (3); other chicken—broilers, growers, cocks—(3); turkeys (1); ducks (1).

Finally, based on the number of slaughtered animals and the carcass weight produced, the average life weight per animal was estimated for each livestock category. To distribute the number of animals slaughtered to fattened and old animals, assumptions had to be made concerning the population structure. For pigs, the average life weight was estimated individually for each country based on the carcass weight. For the highest production intensity of each livestock category, the N, P_2O_5 and K_2O excretion per animal place per year was estimated based on experience from Thailand (Rattanarajcharkul et al., 2000), China (Fang et al., 2000) and Europe (Poulsen and Kristensen, 1997; RAC and FAL, 2001). For the other intensity classes, it was estimated how much lower excretions would be as compared to the highest class, based on live weight and yield per animal per year. In this procedure, the lower feed quality in extensive production systems was also considered. Based on the relevant production data, the intensity class was individually assigned for each livestock category in each country.

Regarding nutrient uptake, values for different crops, expressed in kg of uptake per unit of crop output, were available at FAO (1995).

5. Results and discussion

5.1. Nutrient content in livestock excretion

Table 3 gives an overview of the standard annual nutrient excretion factor per animal place and the average live weight for all the considered livestock categories. Differences in excretions are large between the different intensity classes, especially for dairy cows and milking buffaloes: excretions are more than 90% lower for intensity class four than for intensity class one. This

Table 3
Average live weight and annual excretion per animal place (N, nitrogen; P_2O_5, phosphate; K_2O, potash)—2000

Livestock category	Intensity class	Live weight	Excretion per animal place per year		
			N_{total} (kg)	P_2O_5 (kg)	K_2O (kg)
Dairy cows[a]	1	600	100,0	40,0	100,0
	2	500	65,0	26,0	65,0
	3	400	26,0	10,4	26,0
	4	300	6,5	2,6	6,5
Young dairy stock	1	300	40,0	16,0	40,0
	2	250	32,5	13,0	32,5
	3	200	14,3	5,7	14,3
	4	150	3,9	1,6	3,9
Other cattle	1	250	30,0	10,0	25,0
	2	200	22,5	7,5	18,7
	3	150	15,0	5,0	12,5
	4	100	12,0	4,0	10,0
Milking buffalo[b]	1	600	100,0	40,0	100,0
	2	500	65,0	26,0	65,0
	3	400	26,0	10,4	26,0
	4	300	6,5	2,6	6,5
Other buffalo		200	10,0	6,0	10,0
Small ruminants	1	45	4,0	1,5	6,0
	2	30	3,2	1,2	4,8
	3	20	2,4	0,9	3,6
Horses/mule/asses	1	500	40,0	20,0	60,0
	2	300	24,0	12,0	36,0
	3	200	16,0	8,0	24,0
	4	170	12,0	6,0	18,0
Pigs	1	31–73[c]	8,4	5,3	3,9
	2	39–61[c]	7,3	4,8	3,0
	3	26–65[c]	4,9	2,7	2,1
Laying hens (10 birds)	1	21	6,5	4,3	2,1
	2	21	5,6	3,4	1,7
	3	21	4,6	2,6	1,3
Other chicken (10 birds)	1	10	5,3	2,5	1,7
	2	10	4,6	2,1	1,4
	3	10	3,9	1,7	1,1
Turkeys		5,0	1,0	0,5	0,3
Ducks		2,0	0,6	0,3	0,18

[a] Milk yield of the classes 1, 2, 3, 4: 7000, 3500, 1700, 500 kg.
[b] Milk yield of the classes 1, 2, 3, 4: >3000, 1500–3000, 750–1500, <750 kg.
[c] Average live weight individually determined for each country.

is due to a difference of more than 90% in yield, to the weight of animals and to the quality of feed used. It is therefore important that the production intensity is considered individually for each country rather than using a standard value for the whole of Asia. Excretions differed much less for pigs and poultry than for cattle because production is more homogeneous.

Pig, dairy cattle and laying hen intensity classes are presented in Table 4, showing substantial variability across the study area. It was not possible to disaggregate the national excretion figures due to the lack of available data. It can thus be assumed that in large countries, the production intensity was underestimated or overestimated in regions with high or low production intensity respectively (e.g. eastern/western China).

5.2. Geographical trends in livestock densities and nutrient balances

To facilitate the analysis of results, the information derived from spatial analysis was summarised into tables for groups of countries. Five groups were identified, on the basis of production systems and level of economic development:

Table 4
Intensity classes for selected livestock categories in the study area—2000

	Intensity class		
	Pigs	Dairy cattle	Laying hens
Bangladesh	NA	4	3
Bhutan	3	4	3
Cambodia	3	4	3
China	2	3	2
Hong Kong	1	3	3
India	3	4	2
Indonesia	2	3	3
Korea, Dem People's Rep	3	3	2
Laos	3	4	3
Macao	1	NA	3
Malaysia	2	4	2
Myanmar	3	4	3
Nepal	3	4	3
Philippines	1	3	3
Singapore	1	NA	2
Sri Lanka	3	4	1
Taiwan	1	3	2
Thailand	2	3	2
Viet Nam	2	4	3

Group 1: China (considered alone because of its dominant size in the study area),
Group 2: India (also considered alone because of its size),
Group 3: Nepal, Bhutan, and Bangladesh (remaining southern Asia countries),
Group 4: Thailand, Vietnam, Philippines, Malaysia, and Indonesia (threshold economies in south-eastern Asia),
Group 5: Myanmar, Laos, and Cambodia (south-eastern Asia countries characterised by less developed economies than group 4).

The other countries included in the study (Sri Lanka, North Korea, Macau, Singapore, and Taiwan) are not included in the tables because of their small size and because they could hardly be assigned to one of the five groups identified above.

5.2.1. Livestock densities

The two largest countries of the study (China and India) account for 72% of the area and more than 85% of the total livestock biomass (Table 5), showing a slightly higher livestock biomass density than the average in the region. China and India are also part of two distinct sets of countries. The first set is characterised by high total biomass densities, and strong ruminant component. It embraces Groups 2, 3 and 5 (Table 5). The other set, which includes groups 1 and 4, has lower total biomass densities and a larger share of monogastric to total biomass.

Maps 1 and 2 present the results of pigs and poultry distribution models. For the two species, high concentration levels are observed around urban centres such as Hanoi, Bangkok, Manila, Guangzhou, and in highly populated areas such as the south-eastern Chinese coast or the area between Shanghai and Beijing. This observation might be biased by the fact that spatial modelling relies on the localisation of a share of the production (industrial) around urban centres. Nevertheless, verifications made in selected areas (cf. 3.3.) and the fact that peri-urbanisation is also observed in countries where detailed statistic was gathered (e.g. Thailand, Vietnam and Indonesia) give evidence that concentration of monogastrics around urban areas is not a bias.

Within this common overall pattern, some discrepancies appear between pig and poultry densities (Maps 1 and 2). Generally, poultry production concentrates more in peri-urban areas than pig production, which can be related to higher level of industrialisation of the former. In China, both populations present a strong West–East gradient, but the pig densities gradient is smoother, with densities that are still relatively important in south-eastern provinces such as Yunnan, Ghizhou and Sichuan. These observations are in coherence with prior research (Verburg and Van Keulen, 1999). Densities in India follow a quite different geographical pattern, with pigs mainly located in the Ganges basin, when poultry are observed in the whole country, mainly around cities. Finally, the two populations are clearly contrasted in the Islamic countries Bangladesh and Indonesia, where very low pig densities and strong poultry population are observed.

5.2.2. P_2O_5 excretion

Map 3 presents an estimated unbalanced distribution of livestock P_2O_5 excretion. Large areas of eastern China, Indonesia, Thailand, Bangladesh and India

Table 5
Estimated bio-mass weight distribution of selected livestock categories in selected regions in Asia—1998 to 2000

Region	Cattle		Buffalo		Small ruminants		Pigs		Poultry		Total	
	Bio-mass (t/km^2)	% Of study area	Bio-mass (t/km^2)	% of study area	Bio-mass (t/km^2)	% Of study area	Bio-mass (t/km^2)	% Of study area	Bio-mass (t/km^2)	% Of study area	Bio-mass (t/km^2)	% Of study area
Group 1												
China	1.5	*27.4*	0.5	*14.8*	0.9	*60.6*	2.7	*87.4*	1.1	*76.8*	**6.7**	***44.5***
Group 2												
India	9.2	*55.5*	7.7	*73.0*	1.1	*27.0*	0.1	*1.3*	0.2	*3.6*	**18.3**	***40.9***
Group 3												
Nepal Bhutan, Bangladesh	12.8	*8.1*	3.3	*3.2*	2.6	*6.5*	0.1	*0.1*	0.8	*1.9*	**19.5**	***4.6***
Group 4												
Thailand, Vietnam, Philippines, Malaysia, Indonesia	0.7	*4.7*	0.6	*5.6*	0.2	*4.7*	0.7	*7.7*	0.5	*11.7*	**2.7**	***6.2***
Group 5												
Myanmar, Laos, Cambodia	1.7	*3.6*	0.8	*2.7*	0.0	*0.3*	0.3	*1.0*	0.1	*0.7*	**3.0**	***2.3***
Total study area	**3.0**	**100.0**	**1.9**	**100.0**	**0.8**	**100.0**	**1.6**	**100.0**	**0.8**	**100.0**	**8.1**	**100.0**

present significant (more than 15 kg/km^2) loads of livestock originated P_2O_5. In India, the load is especially important in the Ganges basin, where as in China it has more of a peri-urban pattern. In the other countries, the livestock P_2O_5 excretion is generally lower, except around urban centres, such as Bangkok, Ho Chi Minh, Hanoi, Singapore or Manila, and in the Java island.

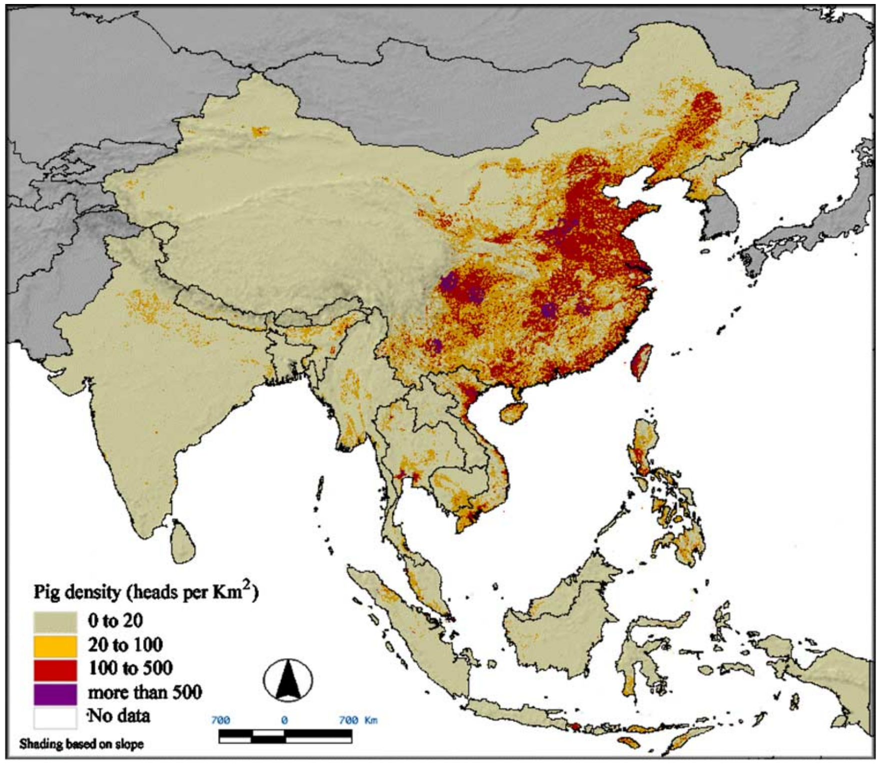
The calculated contribution of monogastrics to phosphate excretion shows a West-East gradient, as shown by Map 4. Monogastrics account for more than 75% of the excreted P_2O_5 in large parts of China, Vietnam, Malaysia, and Indonesia and around urban centres. Table 6, in which a clear difference appears between groups dominated by monogastrics (1 and 4), and groups dominated by ruminants (2, 3 and 5) supports this observation. The two extremes being China and India, in which contribution of monogastrics to total P_2O_5 in livestock excretion is of 76.0% and 5.7% respectively. It is also estimated that pigs and poultry account for very similar shares of the excretion through the study area, except for group 3, in which pig densities are low.

Cattle are estimated to contribute almost one third of P_2O_5 excretions in groups 2 and 3 (Table 6), while they contribute nearly 40% of excretions in group 5. Buffaloes are responsible for more than half of the P_2O_5 excretion in India, and about one third in groups 3 and 5, but are estimated to account for only 6.0% of the excretion in China. Small ruminants have a generally low contribution to P_2O_5 excretions (below 7%), except in countries of group 3, where they are estimated to represent 19.6% of the excretions.

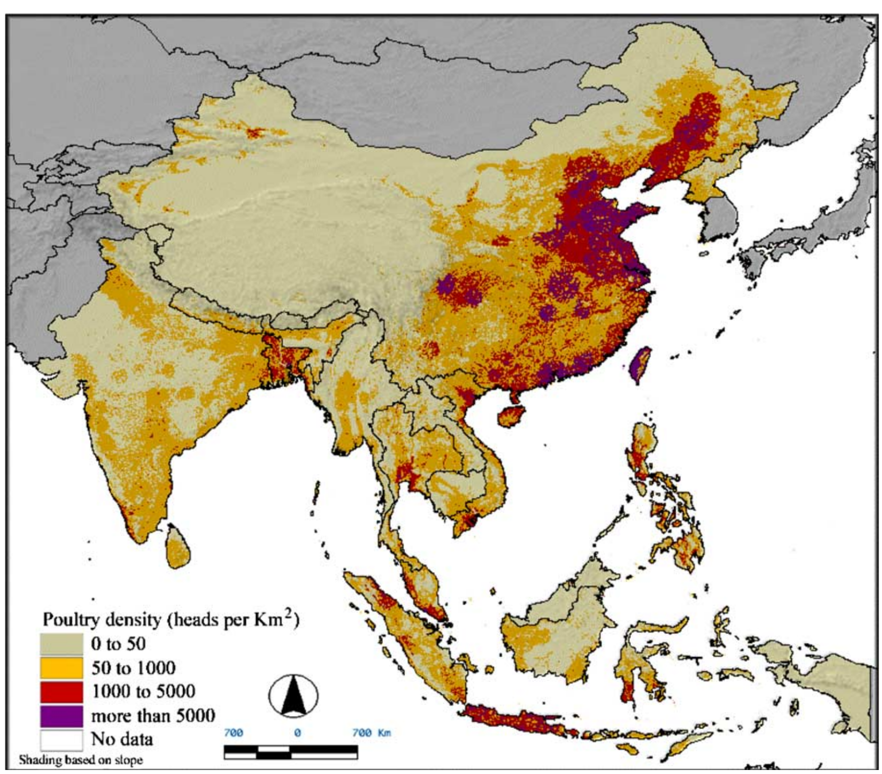
5.2.3. Nutrient balance

There is a strong heterogeneity across the study area regarding the P_2O_5 balance, from areas estimated to have a negative balance to areas with high surpluses. Considering the assumptions and estimates made, it was decided to consider that a mass balance lower than −10 kg of P_2O_5 per ha of agricultural land would characterise a phosphate deficit and, symmetrically, that a mass balance higher than +10 kg of P_2O_5 per ha of agricultural land would characterise a phosphate overload. In-between, the nutrient fluxes are said to be in equilibrium.

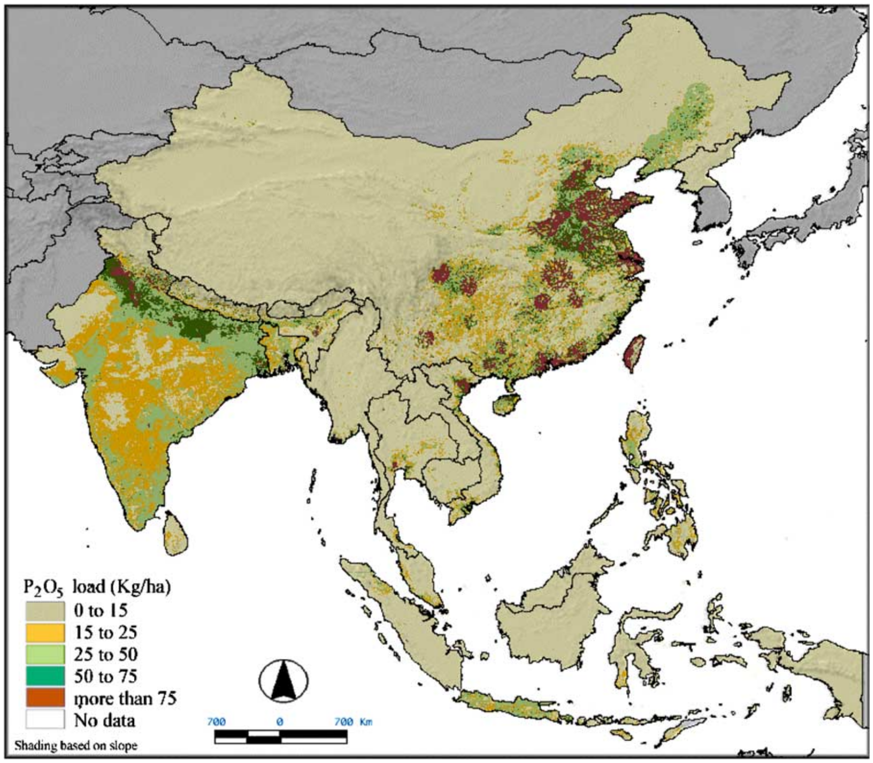
As shown on Map 5, areas having a negative P_2O_5 balance estimation are mostly located in West China and South and West India (28.9% and 69.2% respectively of the countries' cropped area—Table 7). It is also estimated that 42.6% of cropped area in the countries of group 3 have a negative balance. This is important information with regard to the potential P_2O_5 depletion of soils. In India, this situation could be related to scarce use of chemical fertilisers and relatively high yields.



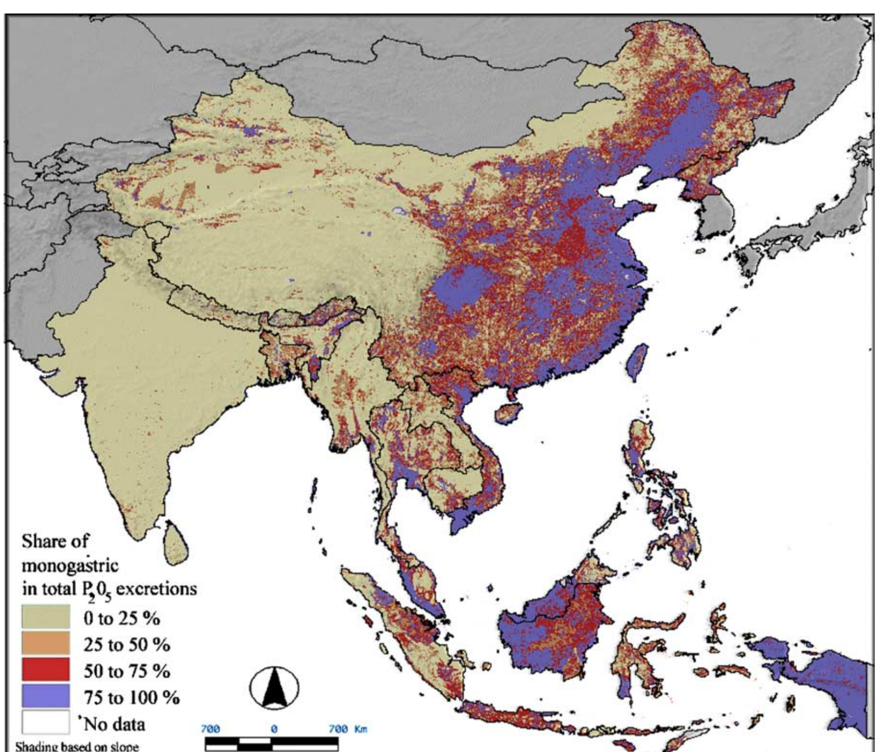
Map 1. Estimated pig densities in selected Asian countries—1998 to 2000.



Map 2. Estimated poultry densities in selected Asian countries—1998 to 2000.



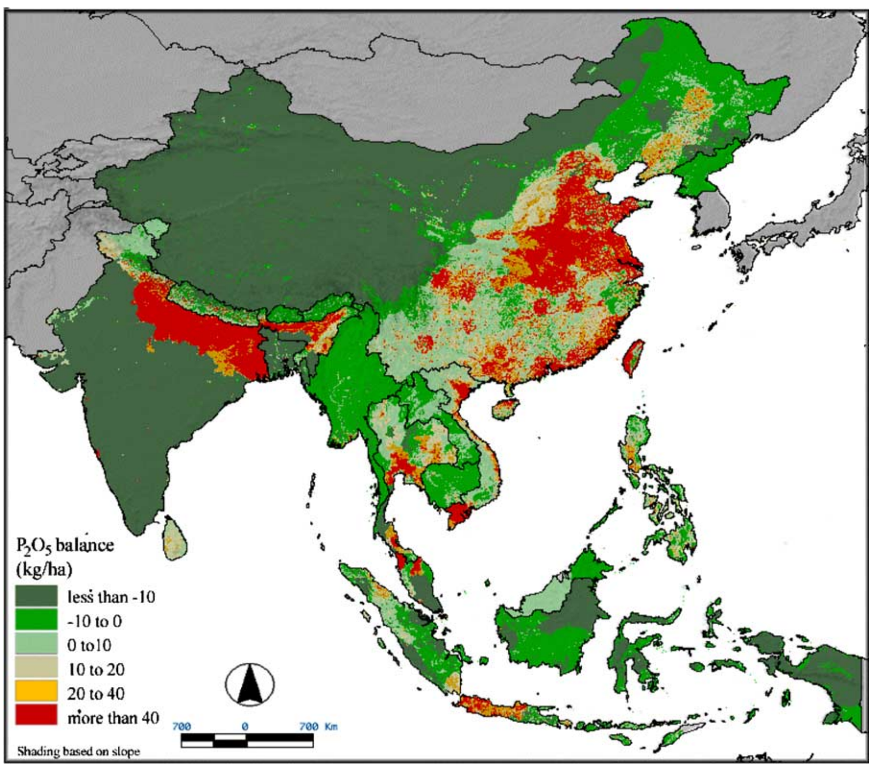
Map 3. Estimated P_2O_5 content of livestock excretion in selected Asian countries—1998 to 2000.



Map 4. Estimated contribution of monogastric species to total P_2O_5 content in livestock excretion for selected Asian countries—1998 to 2000.

Table 6
Estimated contribution of selected livestock categories to the total amount of P_2O_5 in livestock manure for selected regions in Asia—1998 to 2000

Country groups (%)	Cattle (%)	Buffalo (%)	Small ruminants (%)	Pigs (%)	Poultry (%)	Ruminants (%)	Monogastrics (%)
Group 1							
China	11.5	6.0	6.5	39.7	36.3	*24.0*	*76.0*
Group 2							
India	32.0	56.4	5.8	2.1	3.6	*94.3*	*5.7*
Group 3							
Nepal Bhutan, Bangladesh	29.6	30.1	19.6	1.4	19.2	*79.3*	*20.7*
Group 4							
Thailand, Vietnam, Philippines, Malaysia, Indonesia	12.7	16.0	3.7	31.3	36.3	*32.4*	*67.6*
Group 5							
Myanmar, Laos, Cambodia	37.2	36.4	1.5	13.7	11.2	*75.1*	*24.9*
Total study area	**18.5**	**23.4**	**6.2**	**25.9**	**26.0**	***48.1***	***51.9***



Map 5. Estimated P_2O_5 mass balance in selected Asian countries—1998 to 2000.

For the whole study area, 39.1% of the agricultural land are estimated to be in a balanced situation with regard to P_2O_5 (Table 7). In all groups, balanced fluxes are calculated on more than 45% of the agricultural land, except for India where it is calculated on 5.2% only. Most of the crops and pastures in countries such as Laos, Cambodia and Philippines are estimated to have balanced P_2O_5 fluxes (Map 5). The same holds for the Chinese provinces located in the Northeast, and the South (except the coast).

Nutrient overloads are identified in North East India, East China, Coast of Vietnam, Java Island, Central and North Thailand, with especially high surpluses at the periphery of urban centres (Map 5). For the whole study area, it is estimated that 23.6% of the agricultural land is subject to P_2O_5 surpluses (Table 7). High (more than 20 kg of P_2O_5 per ha of agricultural land) and very high (more than 40 kg of P_2O_5 per ha of agricultural land) surpluses being expected on 15.4% and 4.0% respectively of the study area. Groups 1, 2 and 4 appear to be the most concerned with high and very high overloads. On the contrary, groups 3 and 5 are generally characterised by limited geographical spread of P_2O_5 surpluses.

Table 7
Estimated nutrient balances on cropland in selected regions in Asia—1998 to 2000

Country groups	Estimated percentage of the cropped area characterised by a P_2O_5 underload	Estimated percentage of the cropped area characterised by a P_2O_5 balance	Estimated percentage of the cropped area characterised by a P_2O_5 overload		
	<−10 kg/ha	−10 to 10 kg/ha	>10 kg/ha	>20 kg/ha	>40 kg/ha
Group 1					
China	28.9	47.6	23.5	14.0	4.2
Group 2					
India	69.2	5.2	25.6	21.4	2.4
Group 3					
Nepal Bhutan, Bangladesh	42.6	47.3	10.1	5.9	1.9
Group 4					
Thailand, Vietnam, Philippines, Malaysia, Indonesia	22.1	52.6	25.3	14.5	6.1
Group 5					
Myanmar, Laos, Cambodia	23.7	73.2	3.1	1.2	0.3
Total study area	**37.3**	**39.1**	**23.6**	**15.4**	**4.0**

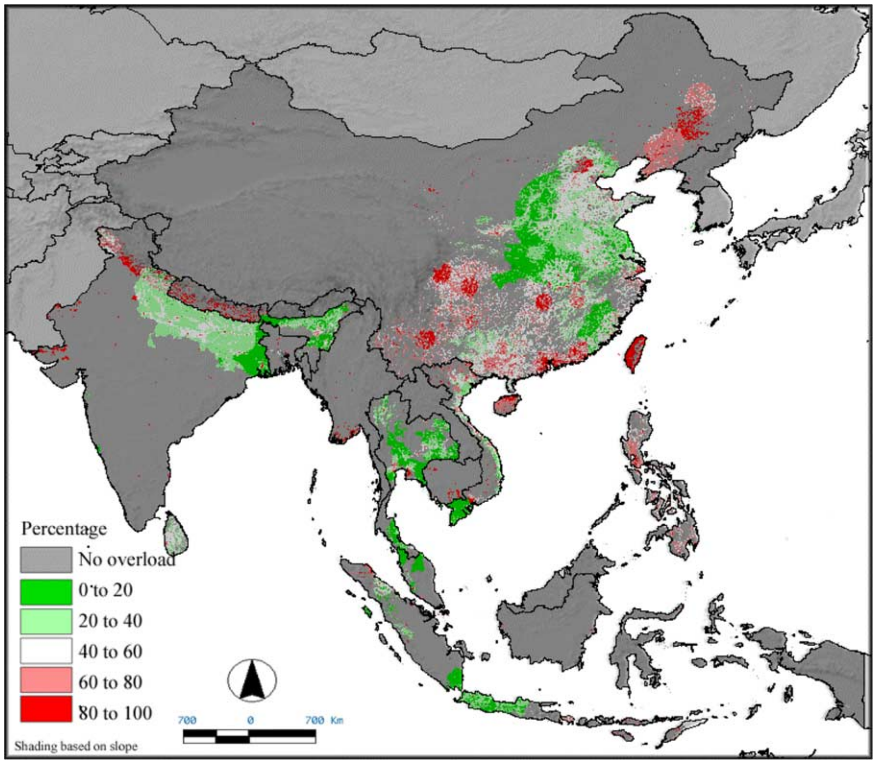
Table 8
Estimated livestock excreted P_2O_5 as a percentage of total P_2O_5 agricultural supply (excretion plus chemical fertilisers), for selected regions in Asia—1998 to 2000

Country groups	Total area	Areas characterised by an estimated overload		
		>10 kg/ha of cropland	>20 kg/ha of cropland	>40 kg/ha of cropland
Group 1				
China	41.9	46.1	47.9	61.9
Group 2				
India	36.7	30.0	30.6	41.9
Group 3				
Nepal Bhutan, Bangladesh	49.3	64.2	64.4	93.6
Group 4				
Thailand, Vietnam, Philippines, Malaysia, Indonesia	28.2	25.9	24.6	22.5
Group 5				
Myanmar, Laos, Cambodia	79.3	85.9	82.9	74.6
Total study area	39.4	40.0	40.4	51.1

Finally, the comparative analysis of phosphate excreted by livestock and phosphate from chemical fertiliser gives an indication of the actual impact livestock may have on nutrient fluxes. Both for the whole study area, and for territories characterised by an overload of more than 10 kg of P_2O_5 per ha of agricultural land, livestock excretion accounts for around 40% of the P_2O_5 load (Table 8). Nevertheless, Map 6 shows a contrasted pattern. Chemical fertilisers represent the bulk of the P_2O_5 load in lowlands where rice is the dominant crop (FAO and World Bank, 2001): Ganges basin, eastern and southern Thailand, Mekong delta, and eastern China (Jiangsu, Anhui and Henan provinces). On the other hand, manure represents more than half of the phosphate surplus in north-eastern China (Liaoning and Jilin provinces), south-eastern China (Sichuan, Hubei, Fujian and Guangdong provinces), Taiwan, and at the periphery of urban centres such as Hanoi, Ho Chi Minh, Bangkok, and Manila. As shown above, monogastrics are generally dominant in these areas.

6. Conclusion

Livestock distributions show two different patterns in the study area. On one hand the ruminant dominated areas, mostly in the North and West, in which biomass densities can reach high levels. Production systems are mixed or extensive, mostly traditional, and the livestock densities follow agro-ecological patterns. On the other hand, the south-eastern part of the study area is dominated by monogastric species. There, under market pressure, and in a framework of weak regulations, traditional mixed livestock/crops farming systems have progressively split into specialised crop and livestock activities, the location of livestock production being driven by transport costs minimization as well as labour



Map 6. Estimated contribution of livestock to total P_2O_5 supply on agricultural land, in area presenting a P_2O_5 mass balance of more than 10 kg per hectare. Selected Asian countries—1998 to 2000.

and services availability. While there are differences between pigs and poultry, the overall trend of production points towards greater production and processing concentration around urban centres.

If similar loads of P_2O_5 are reached in areas dominated either by ruminants or monogastrics, it is mainly in the later that nutrient overloads are observed. This can be related to (1) the nearly inevitable land-livestock link for ruminants (roughage) versus the trend to landless monogastrics production with exogenous feed sources, (2) the high densities of monogastric in peri-urban areas (where crop uptake is low), and (3) the higher economic development of areas where monogastric species are dominant, allowing for high chemical fertiliser application rates.

P_2O_5 overload is a concern in almost a quarter of cropland in the study area. If P_2O_5 originating in livestock is offset by chemical fertiliser sources in crop intensive lowlands, it nevertheless represents 40% of the total P_2O_5 load in the study area, with peaks around urban centres and in livestock specialised areas.

These observations suggest that there is high potential for better integration of crop and livestock activities. In overloaded areas, part of the chemical fertilisers could in fact be substituted by manure, thus substantially decreasing the environmental impacts on land and waters. If the potential substitution seams obvious, its implementation on the ground, i.e. provincial and farm level, raises a series of issues and constraints. Adequate action, including policy formulation, and development of technological packages is therefore required. In this respect, the LEAD initiative contributes through local and regional projects to the design and testing of various policy options, including command and control instruments (e.g. spatial planning; land/livestock balances; environmental authorisation), economic instruments (e.g. market based quota systems; subsidies for investment in manure management equipment), information (e.g. awareness building, capacity building), and the integration of environmental objectives in livestock and agricultural sectorial policies. The initiative also develops decision-support tools for the selection of best manure management practices according to local objectives and constraints.

In this perspective, the results of this study represent useful decision-support information for policy making and targeted interventions. Similar analyses are in progress for Latin America.

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