AMBIO 2014, 43:661–672
DOI 10.1007/s13280-013-0438-y

KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

REPORT

Managing Manure from China's Pigs and Poultry: The Influence of Ecological Rationality

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Received: 15 January 2013 / Revised: 22 March 2013 / Accepted: 23 August 2013 / Published online: 12 September 2013

Abstract We have investigated manure management practices at three farm scales in Chinese pig and poultry production. The concept of ecological rationality was employed to explore empirically how environmental concerns drive adoption of environmental-friendly manure management technologies at different farm scales. The more developed Rudong County in Jiangsu Province and the less developed Zhongjiang County in Sichuan Province were chosen as cases for study of 258 animal breeders. On the contrary to our hypothesis, medium-scale farmers were not always found to be laggards in adoption of manure management technologies. Government ecological rationality played a key role to induce environmental-friendly technology adoption on its own, but also in cooperation with ecologically rational individual or network drivers. Authorities no longer applied their efforts in a conventional command-and-control way, but more in the form of incentives, stimulation, and information to farmers. Individual farmers in general showed low environmental responsibility in relation to manure handling.

Keywords Manure management practices · Pig farmers · Poultry farmers · Nutrient emission

INTRODUCTION

A nationwide pollution source census was launched in China in 2007. It was the first time for the Chinese government to systemically assess pollution emissions in all provinces and from different human activities. The census showed that livestock production, which previously had largely been ignored in environmental management, was responsible for 38 and 56 % of total agricultural nitrogen and phosphorus non-point source pollution, respectively (MoEP 2010).

Livestock production has developed rapidly in China, especially after the economic reform program was launched in 1979 which allowed farmers to breed animals in their backyards (Li 2009). Since the mid-1990s the Chinese government further has supported the expansion of livestock husbandry production resulting in considerable intensification and diversification. Pig and poultry farming all along make up major part of livestock production, but other species expanded from 14 % of livestock value in 2001 to 27 % in 2011 (*Statistical Yearbook of Chinese livestock production*, 2000–2009). Based on the number of animals on farm, three farm scales are distinguished in Chinese official statistics, i.e., household scale, medium scale, and large scale; the latter two are defined as intensive farms. Over the past 10 years the proportion of household-scale livestock breeding has decreased by 1.4 % annually, and this trend is likely to continue in the long term (Shen and Shi 2008). Taking pig farming as example, around half of pig output comes from household-scale farms, with the other half being shared by medium- and large-scale farmers. The intensification in poultry farming is much higher. Medium-scale farmers contribute more than half of broiler output, while household-scale production reduces to 20 % of broiler output (Table 1). The proportion of intensive layer hens farming reaches 72 % of sectoral output, and large-scale farms take 48 %. Nevertheless, scholars believe that intensive livestock husbandry is not and will not be the only mode of production in China (Li et al. 2007). They

Electronic supplementary material The online version of this article (doi:10.1007/s13280-013-0438-y) contains supplementary material, which is available to authorized users.

identify the continuing coexistence of three husbandry patterns as one of the most important differences between China and many developed countries.

Did the described shift in livestock scales contribute to an increase in non-point source pollution (NSPS)? Welsh and Rivers (2011) have concluded that farm scale determines farming practices. However, the literature does not provide a clear conclusion on the relation between farm size and environmental pollution. Household-scale farms can incorporate more environmentally friendly eco-agricultural farming practices (Woodhouse 2010). In China, an increasing number of farm households follow an "eco-engineering model", where livestock feces are used for value-adding biogas production or reused as organic manure (Bluemling and Hu 2011). By the same token, sound disposal of especially intensive livestock manure has become an issue of environmental concern in many counties. This is due to increased livestock densities but still with the same limited availability of arable land for manure disposal, thus increasing the risk of nutrient losses (Kellogg et al. 2000; Giller et al. 2002; Burton and Turner 2003; Gao and Zhang 2010). To curb this behavior, seasonal and limited manure application is required in many European countries (Maguire et al. 2009). However, it was also stated that more complex and modern technologies that mitigate nutrient loads can be used more easily in industrialized production systems (Goldstein and Udry 1999). Anaerobic digesters are more easily introduced to more specialized livestock production (Zaks et al. 2011). There is hence no obvious straightforward conclusion which of three farm scales contributes most to non-point source pollution mitigation in China.

Table 1 Shares of different scale production in China and cases

Animal species	Regions	Shares in total animal output (%)		
		Household scale	Medium scale	Large scale
Pigs	Average in China	51	27	22
	More developed Case	42	41	17
	Less developed Case	83	9	8
Broilers	Average in China	20	58	22
	More developed Case	5	83	12
	Less developed Case	17	77	6
Layer hens	Average in China	28	24	48
	More developed Case	3	8	89
	Less developed Case	58	6	36

Data source: Statistical Yearbook of Chinese Livestock Production; Statistic tales of local livestock and poultry production

For explaining and mitigating nutrient emissions from livestock husbandry in China, we need to understand how the manure of different scale farms is managed, as well as what factors make farmers change their practices. The innovative concept of 'Ecological Rationality' (ER) separates environmental concerns to be "relatively autonomous from ideological, political and especially economic […] rationalities" (Mol 1999, p. 170). Institutional and behavioral changes follow ER when environmental interests and logics are the main causes, reasons, and motivations for change. The movement towards distinguishing and identifying ER indicates "the growing importance of environmental interests, ideologies and logic in shaping social practices and institutions; in fact, it emphasizes the institutionalization of the environment in social practices and institutions" (Mol 1999, p. 170). Empirical studies that show how ER becomes institutionalized among different actors and institutions are still limited, and this hold also for China. Zhong and Mol (2008) illustrated how urban infrastructure management became more ecologically rational though the legalization and institutionalization of public hearings. Livestock production is a good case to search for ER in rural China, because both environmental and economic interests of manure management are obvious and can be distinguished. However, in Chinese livestock husbandry an ER is not directly obvious. Governmental policies at different levels are sometimes supporting, but in other cases obstructing environmental impacts reduction and livestock husbandry environmental reform, while farmers often are not aware of the necessity to mitigate nutrient emissions. Therefore, three ways in which ecological rationalities can be incorporated in livestock husbandry in contemporary China are distinguished (see Box 1). Analyzing the incorporation of ER through governmental institutions, farmers, and farmer networks could help to understand whether and how manure management practices change at different scales and situations of livestock husbandry. The coming together of ecological rationalities at different levels (i.e., governmental, individual, and network) could have a combined influence on changing production processes within China's livestock husbandry, which should be favorable for the environment.

Box 1: Definitions of Three Articulations of Ecological Rationality

An ecological rationality can be adopted by individual farmers, which we might label 'individual ecological rationality.' The motivation comes from environmental awareness and a normative position against negative environmental effects of livestock production. These two motivations have been proven effective for environmental technology adoption (De Souza Filho et al. 1999; Chen et al. 2013). Changing farm practices may also find their roots in a network of farmers, called 'network ecological rationality.' The more farmers are embedded in (informational) networks, the more information they will receive how to realize a change in farming. Furthermore, these networks expose farmers to group norms and peer pressure to change to environmental-friendly practices. Ecological rationality can also be advanced in farming practices through governmental policies and institutions that relate to husbandry farming, called 'governmental ecological rationality.' Governmental regulation can be supportive to a change in farm practices. Extension programs can significantly facilitate voluntary adoption of technology change (Fuglie and Kascak 2001), by supporting information, understanding, and acceptance of new technologies. It may hence exercise soft measures to push farmers towards technology adoption (De Souza Filho et al. 1999; Karahanna et al. 1999). Apart from these informational measures, coercive and incentive measures of governments could play an important role in technology adoption for more ecologically rational production (Bearden et al. 1986).

When ER leads to the adoption of environmentally friendly technologies, then other factors may be crucial for improving manure management as compared to when only economic factors are taken into account. For example, education facilitates innovation adoption significantly (Fuglie and Kascak 2001), and risk aversion levels also co-determine whether individuals are likely to adopt new practices (Rogers 2003). Three perceived technology characteristics have been proven to be important: 'relative advantage' over other technologies or the present circumstance, 'compatibility' with the circumstances into which technologies will be adopted, and 'complexity' to learn or use the technology (Rogers 2003). In many cases relative advantage is defined as higher profitability of a technology, which is positively associated with higher probability of adoption (Pitt and Sumodiningrat 1991; Le et al. 2006).

In the next section, a conceptual framework for understanding nutrient mitigation on farm level is proposed. Our research focused on two major animal species, pigs and poultry (broilers and hens) in a developed and in a less developed area. When agro-ecological household-scale farms are extended into medium-scale farms, they are expected to have neither the land, the individual environmental concerns and capacity, or the governmental attention to implement the advanced manure management technologies that large-scale farms apply. We therefore hypothesize that medium-scale farms would be the most severe polluters.

MATERIALS AND METHODS

We studied manure management practices in Chinese pig and poultry farms of three farm scales. ER is used as our base to test our assumption about medium-scale farmers, while other factors are considered as assists (Fig. 1). Individual ER

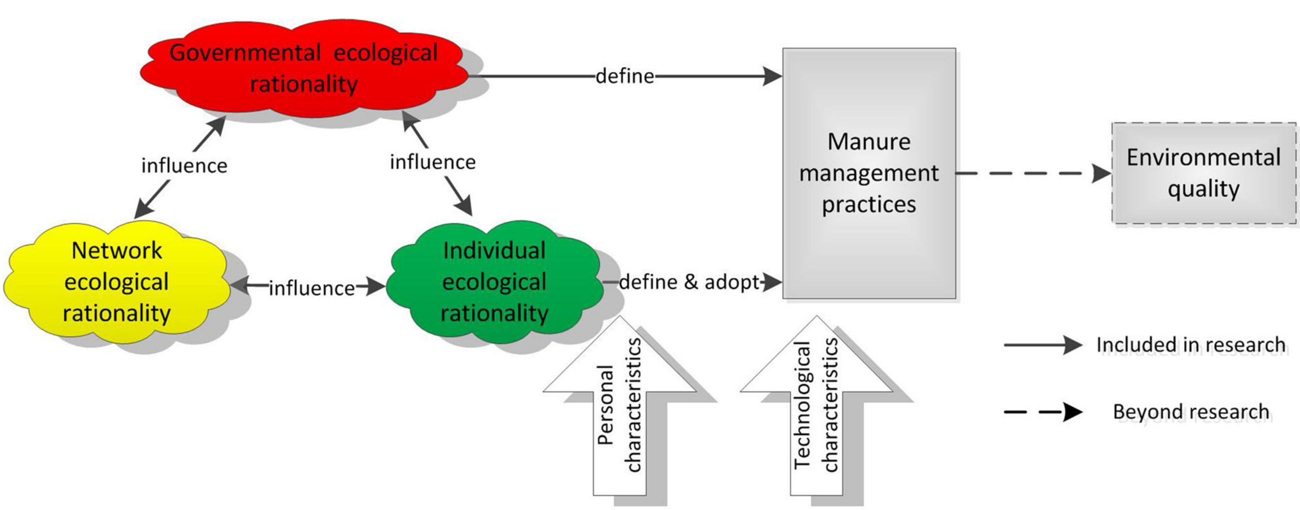

Fig. 1 Conceptual framework of this research

was evaluated by measuring the farmers' awareness of negative environmental effects of their manure operations. Such awareness is valued into four scales (see Electronic Supplementary Material, Table S1). Respondents were also asked on a number of governmental driving forces and barriers to improve manure management technologies, which together were taken as a proxy for governmental ER. In addition, questions on the extent to which interactions with colleague farmers improved manure management were used to measure network ecological rationalities among farmer groups. Advantages and disadvantages of technologies could also be driving forces and barriers for their adoption, respectively. Governmental and technological driving forces, barriers and interactions were valued as percentages of responding farmers who approved the importance of these items. The indicators of personal characteristics include education level and risk aversion, which were measured into five and three scales, respectively (see Table S1). An ANOVA method was used to explore the differences across multi-scale groups and cases.

Study Area

The research covers studies in two areas with varying socioeconomic development and represented livestock production with different degrees of intensification. The more developed area was Rudong County in Jiangsu Province in Eastern China (Case 1) where the demand for livestock products have increased with urbanization (Li 2008), population density and purchasing power (Li et al. 2008), and where there is some quite intensive livestock production (Fig. 2). The other area Zhongjiang County in Sichuan Province in Southwest China (Case 2) is a less developed region with traditional livestock production and a higher share of small-scale animal husbandry (Fig. 2). Table 1 lists the proportion of the three farm scales in China and in the two case study counties. Surveys in Cases 1 and 2 were conducted in September 2010 and July 2011, respectively. In total 258 farmers were surveyed face-to-face. The details of case introduction and data collection are shown in Appendix S1 (Electronic Supplementary Material).

Manure Management Practices

Data on manure management practices in China do not exist in official statistics, or in other regular records. The first China pollution source census (CPSC) stated that non-point source pollution of livestock production in Case 1 were around 7 times as large as that of Case 2 in 2007, when the value of livestock production of Case 1 is less then Case 2. Manure nutrient loads from an animal farm were determined from the methods farmers used to collect and handle manure (Ogink et al. 2000; Cederberg and Flysjö 2004; Petersen et al. 2007). Table 2 lists specifications and characteristics of manure management practices involved in this research. For the different manure management practices, CPSC has reported coefficients of on-site nutrient emission per animal per day (MoEP 2010). The environmental friendliness of manure management practices are qualitatively described according to these coefficients, and valued on a scale from 1 to 4 (see Table 2), where lower values mean larger emissions of nutrients into the environment. Relative economic advantages, compatibilities with farming methods and complexities of practices were analyzed qualitatively, on the basis of expert consultation.

Fig. 2 Intensive poultry farm in Case 1 and household-scale pig farm in Case 2. Photo: authors

Table 2 Specifications and characteristics of manure management practices

Technologies	Environmental friendliness	Relative economic advantage	Compatibility	Complexity
Manure collection technologies				
Washing: Animal pens are swilled down to clean mixture of feces and urine	Large pollutant leakage (valued as 1)	No investment, high water use, no energy use, labor	Tradition	Easy
Manually dry: Feces and urine are separated; solid waste is collected manually, liquid waste flows along canals or pipes	Low pollutant leakage (valued as 2)	Small investment, less water use than washing; no energy use, labor	No conflict with norms; governmental recommendation	Easy
Machine dry: Feces and urine are separated; solid waste is collected by machine, liquid waste flows along canals or pipes	Low pollutant leakage (valued as 3)	Large investment, less water use than washing, energy use, no labor	No conflict with norms; governmental recommendation; possibly bad for animal	Medium
Bedding: Organic materials on ground (e.g., straw, rice hull) fully absorb feces and urine, with micro-biological degradation	Almost zero emission (valued as 4)	Huge investment, no water use, no energy use, less labor than washing	Innovation for majority; nearly no governmental recommendation	Difficult
Manure handling technologies				
Discharge: Collected manure is discharged to rivers or non-farm land without treatment	Large pollutant leakage (valued as 1)	No investment, possible penalty	Tradition	Easy
Fertilizer: Collected manure is applied on farm land as organic fertilizer	Some pollutant leakage (plants absorb nutrients) (valued as 2)	Reduced chemical fertilizer use, requires enough farmland	Tradition	Easy
Biogas: Collected manure is stored to produce biogas; sludge is applied on farm land	Some pollutants leakage (microbes degrade and plants absorb most nutrients) (valued as 3)	Saving household energy costs, reducing chemical fertilizer use, large investments, maintenance costs	No conflict with norms; governmental recommendation in some areas	Not easy to maintain and use well by farmers
Industry: Collected manure is sold to industrial plants to produce fertilizer or aquatic fodder	Zero emission at farms (valued as 4)	Revenues from sale of manure, transport costs (sometimes)	No conflict with norms; no governmental recommendation; no mature market	Not easy to have stable buyer–supplier relationship; transport problem; difficulty to separate liquid and solid components

RESULTS

Technology Adoption and Farm Scale

The manure management practices varied according to animal species, farm scale, and development level of the areas. Manure management practices diverged between pig and poultry farms, mainly due to different characteristics of respective manure. For instance, dry collection of pig manure is not convenient due to high manure moisture, while poultry manure is drier. The latter also contains more nutrients and is thus more valuable for industrial processing. We found a general trend towards more environmental-friendly manure management with increasing farming scale (Fig. 3, also see Appendix S2 for details). Manure practices of medium-scale farms did not fall between household- and large-scale farms as might be expected from their size. Instead these farms handled manure almost equally well to large-scale farms in the same area. Medium-scale farms did thus not perform as bad as we suggested in our hypothesis. Farms in the more developed county (Case 1) did not always have the most advanced manure management practices. For instance, pig farms manure collection practices in Case 1 were hardly more environmentally friendly than in Case 2, while manure handling practices in Case 1 fell behind those of Case 2.

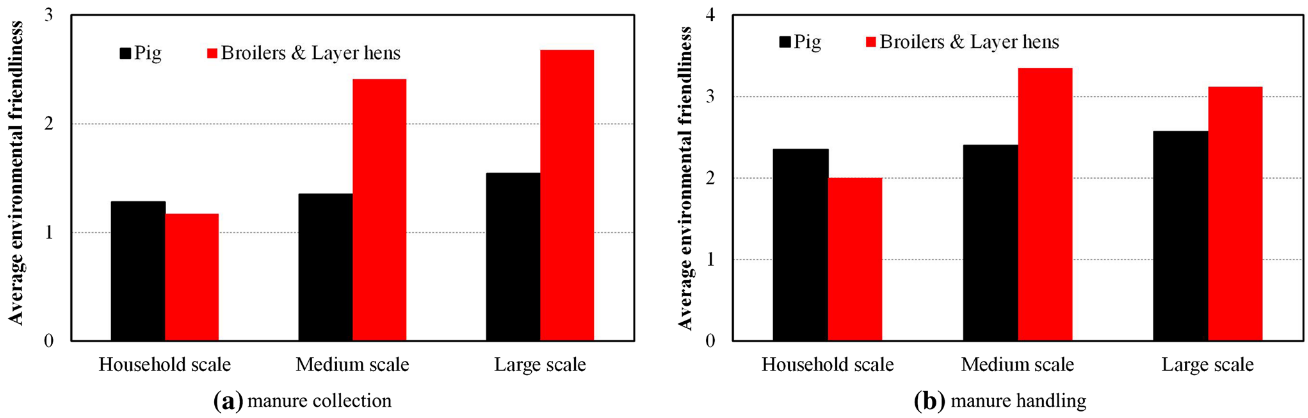

Fig. 3 Environmental friendliness of manure management practice in different farm scales. The *y*-axis relates to environmental friendliness scaled from 1 to 4 as listed in Table 2

Table 3 ANOVA analysis of ecological rationalities across scale groups and cases (pig and poultry farms)

Articulations of Ecological Rationality (ER)	Indicators	Difference between scale groups				Difference between cases		
		Household scale	Medium scale	Large scale	Diff. sig.	Case 1	Case 2	Diff. sig.
Individual ER (mean)[a]	Awareness of negative effect on environment	2.33	2.02	1.89	0.055*	1.94	2.14	0.077*
Governmental ER (%)[b]	Cost saving	31	14	10	0.105*	20	13	0.726
	Income increasing (subsidies)	15	19	10	0.983	13	18	0.408
	Regulatory requirement	38	42	30	0.762	43	36	0.980
	Limited persuasion	0	9	11	0.087*	2	13	0.001**
Network ER (%)[b]	Peers persuasion	15	14	20	0.018**	4	40	0.002**
	No awareness of alternative	40	26	27	0.080*	25	35	0.081*
	Information lack	19	15	14	0.580	16	22	0.207
	No social perceived preference	6	13	16	0.362	21	9	0.009**

* Different between cases at 10 % significance level, ** different between cases at 5 % significance level

[a] Individual ER is valued on a scale 1–4. 1 means no negative environmental effect of livestock production is aware of, while 4 means serious negative effect is agreed

[b] Governmental and network ER are valued as percentages of responding farmers who approved the importance of these items

Ecological Rationalities

The following analysis aimed at understanding differences in manure management from a perspective of ecological rationalities instead of a socioeconomic perspective. Table 3 presents differences in the variables constituting these ecological rationalities across the three farm scales and across the two case study areas, which will be explained in detail in the following three sections.

Individual Ecological Rationality

Around 70 % of respondents perceived "nearly no" or "little" negative environmental effects from their activities, mostly limiting these effects to smell and dust. Respondents from household-scale farms were more aware of the negative environmental effects of livestock production, especially compared to large-scale intensive farms. One possible explanation for this difference is that household-scale respondents usually show environmentally friendly performance of manure handling by adopting an 'eco-agriculture' or 'eco-engineering' model. They may be more sensitive towards environmental pollution when being exposed to pollutant emissions from their neighbors. On the other hand, large-scale intensive farmers are likely to downplay the negative environmental effects from their farms in order to ensure economic profits. Medium-scale farmers seem to be in-between. Respondents of Case 2 expressed more environmental concern than those of Case 1. Thus, individual ER may explain that Case 2 farmers have equal adoption of environmentally friendly manure management technologies as Case 1 farmers, despite of the former's lower socioeconomic development.

Governmental Ecological Rationality

In both areas ER played a clear role at governmental level to improve manure management practices. It was found to be of the same importance for all farm categories. Governmental policies played a role in changing manure management practices by altering costs and savings for different options. Progressive pricing[1] of electricity and water is a governmental ecological rational measure that 'uses' economic motives to protect environment. In Case 1, farmers adopted dry collection to reduce water costs, but due to common use of free well water this was not relevant in Case 2. Biogas production, which was believed to save household energy costs, was more common in Case 2. In both examples ER goes together with economic rationality. Cost saving was especially important for household-scale respondents. Probably due to the small proportion of manure management costs in their total production costs, the effect of cost saving on electricity and water was weaker among intensive farmers.

The question of income increase was related to governmental subsidies, and not to income from manure selling. In contrast to our assumption, manure selling did not increase income in most cases, because medium- and large-scale farmers had to pay for transporting manure and could hardly cover transport costs by the price they received for manure. Biogas production is widely promoted by the Chinese government (He et al. 2013), mostly at farm household level in rural areas. Subsidy for biogas production is mainly provided to household- and medium-scale farms. According to government interviews, this subsidy seems to be a more powerful driver in the poorer Case 2 area. Government in Case 2 considered saving energy costs by biogas valuable to improve farmer's livelihood, and applied more biogas subsidies than in Case 1. This also explains the much higher penetration rate of biogas production among household- and medium-scale farms in Case 2, but refutes the assumption of individual ER. Large-scale farms could obtain special funds for clean technology diffusion by central- and provincial-level governments. For example, the national government subsidizes large-scale livestock husbandry within its "Building the Socialist Countryside Program".

Regulatory requirements from governmental authorities and governmental persuasion may be directed towards some manure management technologies, but levels of governmental involvement differ between livestock husbandry scales. National technology and pollution emission standards aim mainly at large-scale farms, and are directly implemented by local government at these farms. Indeed, large-scale farms were required to pre-assess environmental impacts before investing in intensive livestock constructions, mandatorily taking environmental concern into consideration. According to interviews with local governmental officials, large-scale farms are usually considered key enterprises with a demonstration character at township level (but also at county or municipal level). Hence they are strongly supported, also financially, at national, provincial, or county level. Governmental support could weaken strict environmental policy implementation on livestock production, resulting in less strict monitoring and enforcement of penalties. At the same time local governments have responsibility for the "Development Plan for Modern Agriculture." This plan specifically requires distribution of manure reutilization technology, and 'circular agriculture' (Qi et al. 2008). The latter requires farm households to undertake waste recycling following an 'eco-engineering model.' Medium-scale farms did not encounter such favorable governmental attitudes and measures.

Persuasion can be understood as voluntary 'regulation' by government and other actors. Some farmers were persuaded to change manure management by hearsay of economic and/or environmental benefits. Others were persuaded to conform manure management practices with other farmers, or governmental preferences. However, in our research governmental persuasion was limited and only felt by intensive farms. Limited governmental persuasion worked two ways. In some cases government advised farmers to change conventional manure management technologies into more environmental-friendly ones. However, at other times governmental requests prevented demonstration farms to adopt other, even more advanced, manure management technologies. Especially large-scale farms were likely to fall victim to the latter situation. In general, governmental persuasion was more effective in Case 2 than Case 1.

Network Ecological Rationality

Persuasion towards adoption of better manure management technologies also came from peers. Regarding adoption of technology for biogas production at household-scale farms, interviewed respondents stated strong influence from neighboring farmers who already had adopted biogas technology. Some respondents were willing to adopt biogas production even without counting energy saving and governmental subsidy. This is a clear case of network ER. Medium-scale respondents were less driven by persuasion from other farmers. They claimed that they had less money

[1] Progressive pricing: the more electricity or water is used, the higher the price will be per unit.

for innovative manure investments, resources and information than large-scale ones, but confronted higher risks than household-scale farms.

Network ER can also emerge in a different way. An interview with the local governmental livestock bureau in Case 2 illustrated how the government by use of preferential policies facilitated the transfer of big livestock companies from a more developed neighboring province to the less developed Case 2 area. This resulted in another kind of network namely a primary manure market, in turn leading to more environmentally friendly manure application. This farmer network formation explains the high level of manure selling in that Case 2 area. Low awareness of existing alternatives, a lack of information of alternatives and no social perceived preference, were all barriers for technology adoption felt by husbandry farmers of all scales, which point at a lack of network ER. Household-scale farmers perceived especially strong absence of awareness of alternatives.

Other Factors

Other factors were also examined and compared between farm scales and cases as indicated in our research framework (Table 4).

Regarding education level, most respondents had 6–9 years education. We found that larger-scale farmers had received significantly more education and that, on average, farmers in Case 1 received more education than those in Case 2, possibly due to the better socioeconomic development. The latter helps to explain why Case 1 farmers generally performed better in manure management practices than Case 2, as well as why more environmental-friendly collection technologies did not reach high penetration rates among medium-scale farmers. Compared to the other two scales, medium-scale farmers considered ease of use as a relatively important driver, which might explain their rejection of new but difficult to use manure collection technologies (i.e., bedding). Still, lower education levels did not prevent medium-scale poultry farms in Case 2 to practice more biogas production than other farms, though biogas production is seen as the most difficult manure technology to construct, operate, and maintain among the four handling technologies. In this case, governmental ER rather than education level or ease of use determined biogas technology adoption.

For medium-scale farmers the main barriers for technology adoption focused on economic disadvantages. Large financial investments and high operational costs were perceived as important reasons that led to rejection of manure management improvement. Financial investment, and to a lesser extent high operational costs, were hardly seen as barriers by large-scale farms. This confirms findings of earlier studies that critical success factors for adoption of environmental technologies are less of a technical, but more of an economic nature (Engle 1995; Goldstein and Udry 1999). In addition, large-scale farms can apply for governmental subsidy to improve farm infrastructure. Land limitation was a technology adoption barrier for all scales. In the past few years, the activities of new rural reconstruction have banned livestock production from living areas, and it is expected to be further restricted within assigned areas. Especially in the more developed Case 1 area this was felt as a constraint. Labor requirements were hardly a barrier for technology adoption in general, but cannot be ignored within the more developed Case 1 area. Here industrial development in rural areas may explain increasing constraints of land and labor. Interviews revealed the difficulty of medium-scale farms: they have insufficient capability for investing, hardly any governmental support, and too little land to apply manure directly.

Table 4 ANOVA analysis of other factors across scale groups and cases (pig and poultry farms)

Category	Indicators	Difference between scale groups				Difference between cases		
		Household scale	Medium scale	Large scale	Diff. sig.	Case 1	Case 2	Diff. sig.
Individual attributes (mean)	Education level[b]	2.75	3.05	3.49	0.000**	3.34	2.80	0.000**
	Risk aversion[c]	2.25	2.31	2.32	0.775	2.28	2.33	0.561
Driving forces (%)[a]	Ease of use	7.69	25.58	5	0.090*	26.67	11.11	0.224
Barriers (%)[a]	Large investment	22.64	25.84	5.41	0.012**	31.25	18.44	0.032**
	High operational cost	26.42	21.91	13.51	0.092*	21.43	24.11	0.459
	Land limitation	20.75	26.17	24.32	0.390	32.14	7.09	0.000**
	Labor requirement	3.77	6.74	2.70	0.454	13.39	1.42	0.000**

* Different between cases at 10 % significance level, ** different between cases at 5 % significance level

[a] Driving forces and barriers are valued as percentages of responding farmers who approved the importance of these items

[b] Education level is valued on a scale 1–5, respectively, meaning 'uneducated,' '1–6 years educated,' '6–9 years educated,' '9–12 years educated,' and '>12 years educated'

[c] Risk aversion is valued on a scale 1–3, representing 'risk averse,' 'natural,' and 'risk taking,' respectively

DISCUSSION

A reform in Chinese agricultural production is put on the agenda by policy-makers, where more environmentally sound manure collection and handling practices have to be introduced to diminish land and water pollution. In Chinese livestock husbandry one can witness tendencies of ecological modernization as "both the fundamental counter-positioning of economic and environmental interests as well as a complete neglect of the importance of environmental considerations, are no longer accepted as legitimate positions" (Mol and Spaargaren 2000, p. 46). Our hypothesis was that, compared to household and large-scale farmers, medium-scale farmers are potentially the slowest in adopting environmentally friendly manure management practices. If this was true, then environmental management improvement efforts should concentrate on farms of that size. This was based on the facts that conventional manure management of household-scale farmers is already quite environmentally sound, while large-scale farmers are more protected by government, have more investment capital and more human capacity to adopt environmentally friendly technologies. However, our empirical research found that medium-scale farmers sometime perform much better than expected, and sometimes not. With assistance of personal and technological characteristics, the various combinations of ER (governmental, network, and individual ER) seem to explain the failure of our hypothesis.

In Case 2, governmental policies institutionalize an ER through biogas subsidies, which increases the economic advantages of biogas production. At the same time information is given to influence farmers' perceptions of biogas production. As such, Case 2 medium-scale farmers are confronted with more governmental measures for biogas adoption than their equivalents in Case 1. Although individual ecological awareness seems to be less important and effective than economic reasons for biogas adoption in this case, the latter may promote medium-scale farmers to start information exchange and set good examples of environmental protection in their peer network, thus continuing the cooperation which started with biogas production. The combination of governmental, individual, and farmer network drivers enhances the adoption of environmental-friendly technologies and practices (Fig. 4a). However, more environmentally friendly manure *collection* technologies in Case 2 were driven by isolated individual ER, with little final spreading effect (Fig. 4b). Neither informational, nor incentive, nor command-and-control governmental measures were reported by the interviewees regarding manure collection technology adoption. Also farmer networks were absent for learning and dissemination of such collection technologies. Farmers with environmental awareness regarding manure still could reject adoption of more environmental-friendly collection technologies, because of difficulties in learning how to use them and because they felt no governmental drive.

Manure collection practices of medium-scale farms in Case 1 exemplify the effectiveness of isolated governmental ER (Fig. 4c), where a policy of progressive pricing of water and energy was initiated by governmental authorities (above county level). In order to reduce water costs, medium-scale

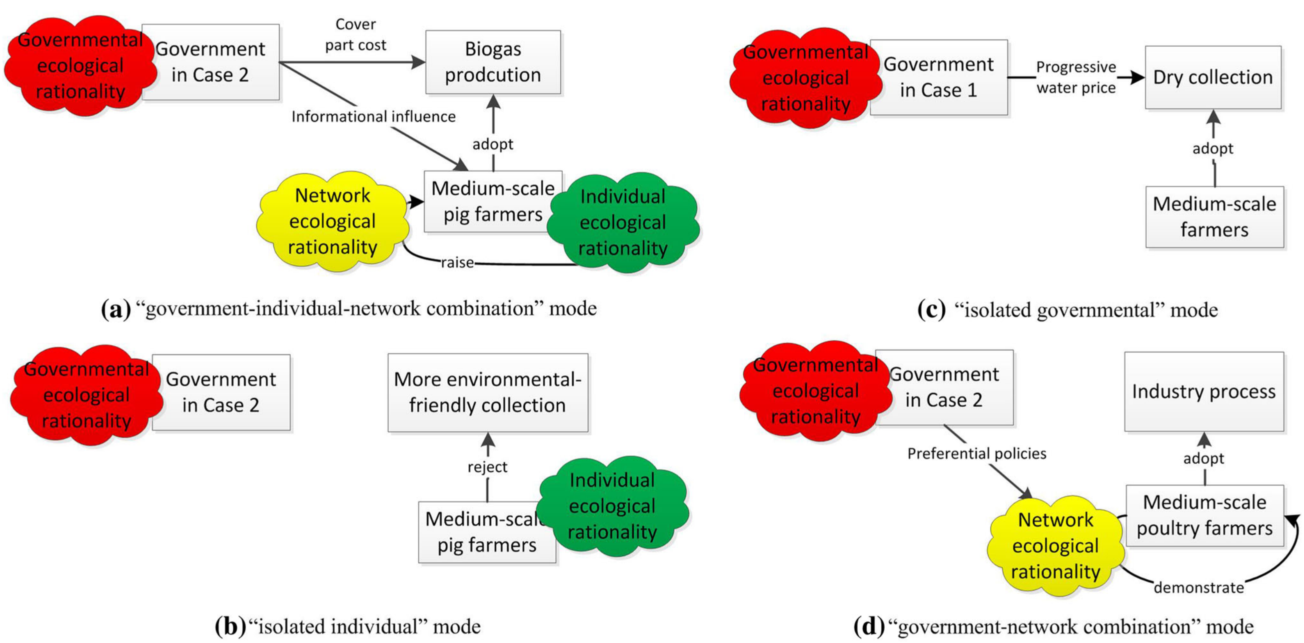

Fig. 4 Four modes of ER combinations

farmers preferred dry collection to washing, although there is little sign of an individual ER that enhanced the adoption of this technology. Another alternative way for government to activate environmentally friendly practices is to stimulate network collaboration (Fig. 4d). When non-governmental actors, such as companies in Case 2, are welcomed by preferential policies to participate in solving manure problems, economic benefits and environmental benefits come together, and are strengthened by convenience of use for farmers. This government–network combination explains the high rate of selling manure among medium-scale famers in Case 2. However, if these government–network-driven benefits cease to exist, medium-scale farms are unlikely to be able to continue these practices.

Hence, more environmental-friendly manure management does not always have to include full ER from farmers, farmer networks, and governmental authorities. In contemporary Chinese livestock husbandry governmental policy and measures seem to be a precondition for any successful mode of ER. Governmental authorities are able to induce environmentally friendly technology adoption on their own, or work together with individual or network drivers. Individual preferences and awareness did not have a strong influence on driving changes in manure management. Networks of farmers and other economic actors only drove more environmentally sound manure management practices in combination with governmental measures.

Still, this does not mean that environmental transformations are just “enforced” through conventional government steering. First, conventional command-and-control regulations have shifted to incentivizing, stimulating and informing farms to improve environmentally (e.g., progressive water pricing, providing information). Taking isolated governmental ER mode as an example, the government can create economic incentives to ensure that farmers that are not ecologically motivated still manage manure in a more environmental-friendly way. Second, non-governmental private actors can take over part of the ‘responsibility’ for environmental management from the government through their networks. Such transformations, which are part of a wider change in China’s environmental management, are often referred to as political modernization (Liang and Mol 2013).

Though governmental policy and measures are generally the same between the two areas investigated, the four modes also revealed that they differ between the two with respect to specific technologies. The less developed and more strongly government-directed Zhongjiang case was able to compete with the more developed and market-oriented Rudong case. A regional socioeconomic development is likely to promote more intensive livestock production, but this does not automatically parallel manure management improvement. This should balance the idea of a market-driven environmental change among livestock farmers in contemporary rural China: adequate government intervention remains necessary for direct environmental improvement and for facilitating the introduction and functioning of market instruments. Different ways of local policy implementation are due to different weighing of the value of livestock production in the local economy, which varies with overall socioeconomic development. In turn this aspect directs priorities set by local governments for implementation and enforcement of environmental management. The leading cadres of each government level prefer to support major economic sectors, in order to get more revenues and a better personal performance evaluation (Edin 2003; He et al. 2012). Livestock production in the less developed area (Case 2) counts for nearly half of the agricultural output. Therefore, county- and lower-level governmental officials pay more attention to livestock production in that county and, following central and provincial policies, make their policies and measures more environmentally sound than those of Case 1.

It is should be emphasized, though, that these modes are empirically found among medium-scale farms, and hence do not have to be the only modes when investigating other agricultural sectors in other counties. For instance, agricultural product labeling and voluntary standards (pollution-free, green, and organic product) are measures that could be classified as a kind of market-based ER. Although livestock farms in our case studies were not involved in product labeling and market-based environmental standards, farmers do realize the future importance of these labels. In addition, environmental preferences are emerging and articulated, not only or primarily among agricultural producers and governmental authorities, but also increasingly among citizen-consumers and other civil society communities (Wang et al. 2011). This might result in a kind of civil society ER. It can be expected that in a future market-based civil society ecological rationalities will play a more important role in China, next to the ecological rationalities revealed in this research.

Acknowledgments This research was carried out with the support of the research project SURE (SUstainable Natural REsource Use in Rural China, http://sure.ernasia.org/), which is funded by the Royal Netherlands Academy of Arts and Sciences (KNAW), Grant 08-PSA-E-02, as well as the Chinese Ministry of Science and Technology (MST), Grant 2009BAC62B01. The authors also thank for Dai Weiwei from Rudong County, Deyang Environmental Protection Bureau, and Zhongjiang County Environmental Protection Bureau for the support on farm household interviews and data collection. The authors would like to thank the anonymous reviewers for their valuable comments.

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