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Environmental potentials of policy instruments to mitigate nutrient emissions in Chinese livestock production ☆

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HIGHLIGHTS

- A framework based on an Agent Based Model is built for policy assessment.
- The effects of five policies on nutrient mitigation are simulated and compared.
- Only three policies prove to be the most effective to reduce nutrient emission.
- Medium-scale farms are more relevant for ecological reform of livestock production.
- A number of policy implications and development strategies are concluded.

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ABSTRACT

To minimize negative environmental impact of livestock production, policy-makers face a challenge to design and implement more effective policy instruments for livestock farmers at different scales. This research builds an assessment framework on the basis of an agent-based model, named ANEM, to explore nutrient mitigation potentials of five policy instruments, using pig production in Zhongjiang county, southwest China, as the empirical filling. The effects of different policy scenarios are simulated and compared using four indicators and differentiating between small, medium and large scale pig farms. Technology standards, biogas subsidies and information provisioning prove to be the most effective policies, while pollution fees and manure markets fail to environmentally improve manure management in pig livestock farming. Medium-scale farms are the more relevant scale category for a more environmentally sound development of Chinese livestock production. A number of policy recommendations are formulated as conclusion, as well as some limitations and prospects of the simulations are discussed.

1. Introduction

The negative effects of modern agricultural production, especially water eutrophication, are a world-wide environmental problem, which has been well documented in research of both developed countries and developing countries such as China (Foy et al., 2003; Ulén et al., 2007; MEP, 2010; Jarvie et al., 2013). Agricultural nutrient emissions, mainly in the form of non-point source pollution (NPSP), can be the result of runoff from either livestock farms, or from farmlands after manure or chemical fertilizer application. The need to mitigate nutrient losses has been the focus and subject of policy-making in certain countries over some decades. Some of these policies target the national or international level, e.g. the EU Water Framework Directive and the Clean Water Act in the US, whereas others work on regional or lower levels. A surplus of manure from increasing and more intensive animal production is considered a major cause of agricultural nutrient pollution (Maguire et al., 2009). Therefore, environmental management practices in these countries aim at better manure management by such means as manure recycling through anaerobic digestion, restricting animal density on agricultural land, or setting limitations on manure application (Maguire et al., 2009; Zaks et al., 2011).

China has been one of the most important producers of livestock products in the world since its economic reform (FAO, 2006). Due to the government's priority of increasing agricultural productivity and output as well as the steep rise in meat consumption, China significantly increased meat production over the past 30 years at a rate twice as fast as the world average (Li, 2009; Ortega et al., 2009). Thus, it is no surprise to find that livestock production is a major source of nutrient pollution,

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which almost equals that from crop production (MEP, 2010). As a consequence of increasing pollution, Chinese livestock policies have gradually shifted from a one-sided objective of economic development to a more integrative objective that also includes environmental considerations. This process dates back to 2001, when management measures for pollution control and standards of pollutant discharge were issued in livestock sector, although these measures and standards only attempted to govern large-scale industrialized animal producers. However, environmental policies so far have performed poorly in rural China, because of the limited voice of environmental agencies, the insufficient environmental interest of local governments, and no market demand for 'ecological' livestock products, among other issues (Swanson et al., 2001).

When confronted with the problem of how to enhance the effectiveness of environmental policies for Chinese livestock production, policy-makers face two essential questions. The first question concerns the policy instruments to implement. There are few studies that explore the effectiveness of environmental policy instruments in Chinese livestock production. However, such research is deemed crucial because theoretically optimal policy instruments, such as environmental taxes, may have quite different effects depending on the sector and issue (Mickwitz et al., 2008). A second question confronting policy-makers concerns the appropriate definition of the producer group that should be targeted by environmental policies. Actors in one economic sector can be heterogeneous; some are large-scale producers, whereas others are small or micro-producers; and some may act as promoters and supporters of strict environmental management, others may not (Oye and Maxwell, 1994). Since the mid-1980s, Chinese farmers have been permitted to keep more animals than needed for self-consumption, i.e. farmers can undertake animal production as a means of revenue generation. Consequently, livestock production in China has undergone considerable intensification and diversification. This change also implies that depending on production scale, livestock producers may have distinct environmental considerations, show distinct responses to policies and differ in their contributions to nutrient emissions (Zheng et al., 2013a). As a consequence, environmental management of rural livestock production in China has become rather complex. Chinese policy-makers need to find effective policy instruments for the different categories of livestock producers to achieve better nutrient mitigation.

This research takes into consideration the complexity of rural livestock production in China and explores the potential of Chinese livestock policies to mitigate nutrient emissions using an agent-based analysis. An Agent-Based Model (ABM) simulates the behavior of a system based on autonomous agents who individually but interdependently make their decisions according to a set of rules (Page, 2008; Macal and North, 2010). ABMs can thus cope with the heterogeneity of individuals and capture emergent phenomena generated by heterogeneity and interactions among agents (Grimm and Railsback, 2005; Macal and North, 2007). In this way, ABMs can incorporate the diversity of livestock producers in rural China, their different responses to policies, and the aggregate effects of their decisions, i.e., policy implementation effectiveness.

2. Methods

2.1. Research framework

The framework to assess the mitigation potentials of policies can be divided into two levels: the individual level of farmers and the system level, as shown in Fig. 1.

National policies from governmental agencies function at the system level, attempting to constrain and guide livestock producers in operating their farms. Two types of national policies exist for Chinese livestock production. Most national policies are implemented for non-environmental purposes, such as food security, livelihood improvement and poverty reduction. For instance, government-financed insurance attempts to expand overall animal production, while subsidies for constructing industrial farms aim to promote intensive livestock production (GOSC, 2011). A second type of policy aims to reduce the environmental effects of livestock production by improving manure management practices. Although there is no comprehensive policy program in China to improve manure management or control pollution from livestock production, the central government integrates environmental concerns into a number of other policies. For instance, the promotion of household biogas digesters also contributes to improving environmental management in livestock production (SCC, 2012; He et al., 2013). Policies addressing environmental concerns will be summarized under "environmental policies" in this research; the aforementioned policies will be summarized as "agricultural policies" (Fig. 1). Apart from national policies, aggregate livestock production and its associated environmental performance are also measured at the system level. At an individual level, farmers make a diversity of decisions in response to policies. An Agent-based Nutrient Emission Model (ANEM) was used to predict farmers' decision-making, as well as the economic and environmental performance of livestock production, whereas policies were considered exogenous forces (Zheng et al., 2013b).

The assessment of the effects of environmental policies is conducted as scenario analysis. The scenarios for different policy instruments are

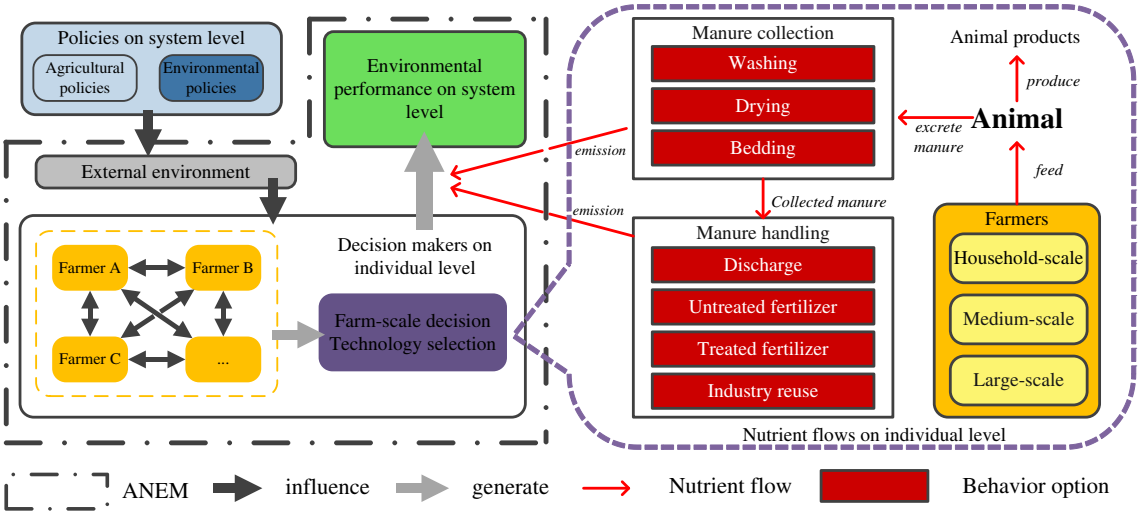

Fig. 1. Conceptual framework and model structure.