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Vertical and system integration instead of integrated water management? Measures for mitigating NPSP in rural China

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Introduction

To reconcile groundwater quality and local development, research and policy generally focus on water management instruments, however, in developing countries, a variety of constraints exist for their implementation. The quantitative basis for defining pollution or abstraction limits usually is weak (Steenbergen 2006). Some authors argue that for groundwater, not so much permits may be effective but self-regulation (Lopez-Gunn et al. 2006). Even though in China, sub-village institutions exist for groundwater irrigation management (see Bluemling et al. 2010), for Non-Point Source Pollution (NPSP), they may only become effective if a limit on pollution and an effective monitoring structure is experienced, either through legislation, or a stringent implementation structure. Countries in Asia often lack an administrative structure to implement policies with a multitude of dispersed groundwater users (Llamas 2006). Further considered effective are schemes of payment for environmental services since they compensate for losses through a reduction in fertilizer application. They can be applied for certain designated areas, e.g. watersheds that serve urban water supply. However, in rural areas of developing countries, central water supply systems hardly exist, households supply water through their own shallow wells; groundwater pollution hence will directly affect them.

This paper presents an approach to NPSP reduction that is not based on water management instruments, but works through a reintegration of nutrient streams within the agricultural system. By reintegrating a waste product on-farm, it facilitates capitalizing on nutrient streams and in this way becomes a means for local development and water resources protection. This system has found wide distribution in China, where it has been developed.

After a brief introduction to groundwater pollution in rural China, the main sources for NPSP, livestock raising and chemical fertilizer application, are presented. The potential of conventional policy instruments for a reduction in NPSP from fertilizer application is then discussed. In a fourth part, the approach to a reduction in nitrate from livestock manure is presented. The discussion compares the two approaches to NPSP reduction in their underlying logic and implementation effectiveness.

Key words: non-point source pollution, China, system integration, integrated water management

Groundwater pollution in China

44% of drinking water in China's rural areas fail to meet domestic water quality standards[1]. About 75% of the rural population extracts drinking water from groundwater. Fertilizer application, domestic waste water and excreta from livestock, which are often directly discharged to the environment, contribute to water pollution. Zhang and colleagues in 1996 found in more than half of their sample locations in North China, nitrate pollution exceeding concentrations of 50 mg No3/l, the allowable limit for nitrate in drinking water at that time. While in 1991, nitrate in the North China Plain mainly originated from fertilizer, by 2001, it also originated from untreated domestic wastewater and leakage from manure and urine (Chen 2010). In the North China Plain, nitrate pollution has been found at depths deeper than 100 m (Chen 2010). But also other watersheds like the Sichuan Basin suffer from considerable groundwater contamination from both fertilizer use and animal manure (Li et al. 2007). Since in the great majority of villages, no centralized water supply exists, but drinking water is supplied through wells of 2 – 20 m depth, farm households are especially prone to increased nitrate levels.

Sources of pollution: chemical fertilizers and livestock production

Sources for nitrate NPSP in China are twofold. The government's target of a grain self-sufficiency of at least 95% has resulted in augmented fertilizer use. The major grains in China, wheat and maize, have experienced an increase in production of 24.6% and 36.7% respectively from 2002 to 2008[2]. Increases are a result of gains in productivity, and related to this, increased fertilizer application. In 2008, nitrogen fertilizer use (N total nutrients) in China reached 33.5% of the world total. Of the chemical fertilizers used in China, N fertilizer makes 60 to 70 % (Li et al. 2009). Increased fertilizer application rates do not only contribute to higher grain production, they also increase linearly with farmers' income (Gao et al. 2006).

With the general socio-economic development in the country, consumption patterns have changed, leading to a substantial increase in demand for meat. From 1990 to 2000, meat consumption almost doubled (Kanaly et al 2010). Per capita meat demand is projected to grow to 60 kg by 2020, representing an increase of 82% from 33 kg in 1993 (Kanaly et al 2010), a per capita development that should have considerable impact in a country with a population of 1.3 billion people. Livestock production has already grown at between 4.5 to 8.8% per year since 1985 (Jin et al. 2010). China's animal husbandry industry has increased from 17% of the gross agricultural product in 1978 to 34% in 2004 (Li

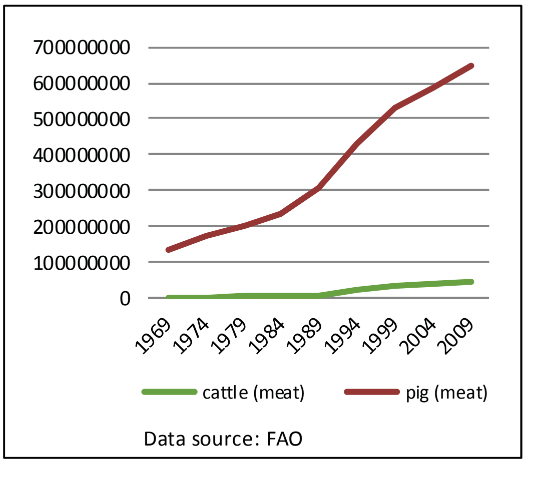


Diagram 1: Animal Production (heads

[1] Ministry of Environment, "Over 40% of Rural Areas' Drinking Water Unhealthy", 19.02.2008, http://www.mep.gov.cn/, viewed January 2011.
[2] If not else indicated, data is taken from http://faostat.fao.org/ .

2009). Pig farming, which dominates China's livestock industry, has shown an increase of 22.5% over the period 1999 to 2009, and an increase of 113.4% over the period 1989 to 2009 (see diagram 1).

According to Wang (2005), over 90% of animal farms in China do not have pollution-prevention facilities. Even though specialized livestock farming has developed rapidly, animal farming still is predominantly done by scattered individual small-scale farms. Wang (2005) estimates that about 70% of livestock farms are small and medium sized farms; according to Li (2009), by the end of 2003, 94.5% of China's pig farms were small scale operations owned by individual peasant families, raising one to nine pigs, producing about 53% of pigs slaughtered in that year. Small livestock breeders hence are important and the most difficult addressees for a mitigation of diffuse N pollution.

While excess fertilizer application for grain production hence is one part of the problem of NPSP in China, pollution from livestock production can be considered equally, if not more important, given its steep increase.

Mitigating NPSP from Chemical Fertilizer Application – an Unresolved Task

Constraining farmers' fertilizer application, strictly speaking, does not conform to the government objective of increasing agricultural productivity and maintaining grain self-sufficiency. Apart from this general context, several other factors hinder an effective implementation of measures for NPSP reduction from fertilizer application. In the following, the categorization of policy instruments by Dowd and colleagues (2008) will be used for developing this argument, by first introducing the instrument and then discussing its applicability in China.

Voluntary programs are seen as potentially effective policy instruments for NPSP mitigation, however, they require, for the case that an agreement fails, a credible enforcement threat; they further make necessary a monitoring program as well as peer-sanctions for under-performance.

In China, pollution control is the task of the Ministry of Environment (MoE). The Ministry's position in general is not very strong, in 2007 only, the State Environmental Protection Agency was upgraded to the status of a Ministry. Apart from the fact that it focuses on urban and industrial areas, it does not have the administrative structure, i.e. offices below the county level (on the township and village level), to implement policies. Environmental law is in general lacks a legal implementation structure (Orts 2003). Enforcement of environmental law is accordingly known to be weak (Shang and Liu 2009). The departments under the Ministry of Agriculture, whose offices reach down to the level of townships, promote the implementation of environmentally friendly agricultural measures. Agricultural departments include agricultural environmental protection stations which are responsible for the extension of environmentally friendly agricultural technologies. However, since the MoA follows the productivity doctrine of the central government and since the objectives for agricultural production and environmental protection are often conflicting, if not incompatible, agricultural departments are not a credible enforcement threat, rather, implementation of measures for NPSP control is likely to fall short within this structure. For the second requirement of voluntary agreements, a monitoring program, implementation costs are likely to be high. In China, per capita agricultural land is 1.4 Mu, i.e. 0.093 ha[3]. A farm household with five household members hence has 0.46 ha land, generally distributed across five parcels of land, which makes potential monitoring of farmers' individual fertilizer application costly. With a multitude of farmers and plots, the third criterion for successful voluntary agreements, i.e. peer-sanctions, also is difficult to realize. Within villages, the productivity doctrine is likely to hold; the number of small-scale holdings makes it difficult for external stakeholders to make out addressees.

Dowd and colleagues (2008) distinguish command and control programs as the second category of policy instruments for NPSP mitigation. Design standards require from farmers to apply certain practices (i.e. Best Management Practices) that will reduce pollution discharge. However, their implementation may not achieve desired outcomes, also because they largely depend on proper implementation which regulatory agencies need to monitor and support, and for which they lack necessary funding. Performance standards regulate dischargers based on their emissions, however, the difficulty to assess how much emission is still environmentally sound under the respective local situation, makes its implementation difficult (Dowd et al. 2008). This will especially be complicated through plot parcelling.

Empirical research in China found that pricing mechanisms, a further instrument mentioned by Dowd and colleagues (2008), reduce farm income before achieving desired reductions in nitrate leaching (Wei et al. 2009). Their implementation hence would contradict the general governmental goal to increase rural incomes. Other mechanisms, like an input tax, in China run counter to other policy mechanisms like subsidies for material inputs (among them fertilizer), and therewith would basically remain ineffective.

A higher likelihood for effective implementation is expected from the existing institutional structure of extension services, through increasing the technical level of fertilizer application. Trainings for farmers are proposed in which they learn to increase input-use efficiency and where they obtain in-depth knowledge of soil conditions, as well as start to reflect on human health and environmental protection (Wei et al. 2009). The National Program for Soil Testing and Formulated Fertilization / Fertilizer Recommendation (STaFF) which is initiated by the Ministry of Agriculture, fits in this line. Farmers get analysis results and recommendations for fertilization quantity and ratio (N,P,K), the Ministry provides subsidies for fertilizer application based on soil testing. The objective of the program is to increase fertilizer use efficiency by 3-5%, crop yield by 5% and the recycling rate of organics by 40-50%. Until now, the government spent about 1.9 billion RMB from 2005 to 2008, as a result, on 260 million mu of farmland, fertilizer has been applied based on soil sample tests.

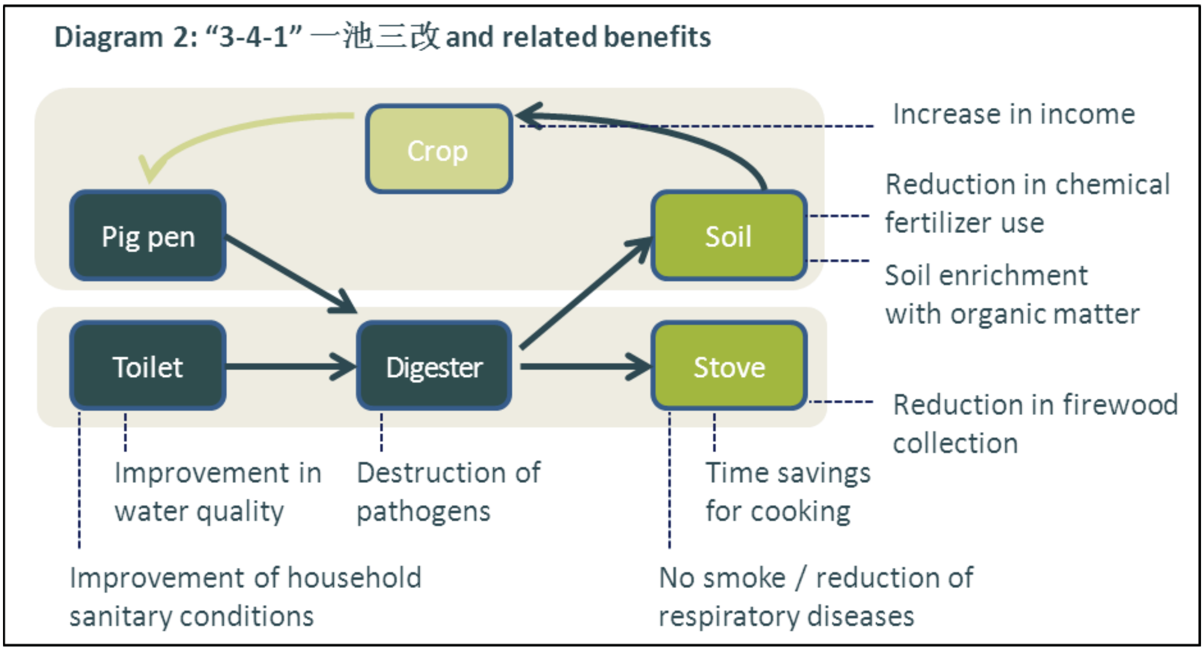
Mitigating NPSP from Livestock Production – System Integration on the Farm Level

For pollution from livestock production, in China, measures addressing the pollution pathway have been designed. "Ecological Agriculture" (生态农业) is the underlying concept which understands agriculture as an integrated system consisting of agricultural production, rural economic development, and environmental improvement and protection. An integrated agricultural system shall optimize its components by strengthening their link and

[3] Ministry of Land Resources, PRC, http://www.mlr.gov.cn/wskt/glkx/tdgl/201007/t20100711_724239.htm

combining them within a circular system. Ecological Agriculture aims at recycling and reuse within a system and therewith at saving input material, at a reduction of pollution since outflows are reused as inputs, and at capitalizing the combination of these inputs, and therewith revenue generation. This makes it different from organic agriculture which rather works through the stipulation of benchmarks, i.e. abandoning synthetic chemical fertilizers and pesticides as well as feed additives in the production system.

"Ecological Agriculture" can be seen as rooting in a traditional system of nutrient cycling in Chinese agriculture, within which various sources of organic manure, e.g. animal and human excreta, cooking ash, organic waste, sediments from canals and lakes, are made use of to apply them to the land (Gao et al. 2006). At the core of Ecological Agriculture are "eco-engineering models" through which the different input and output streams are technically processed. For the case of livestock breeding, a model for the household level exists that has received considerable financial and programmatic support from the national government. The model combines a biogas digester for processing manure, a toilet for collecting and processing human excreta, a pig pen for collecting pig excreta, and a kitchen for the use of biogas in cooking, as the core components. The waste is used as inputs for the generation of biogas and organic fertilizer (see Diagram 2). The model is the basic unit that can be extended through further elements depending on local requirements. This basic unit here is called "3-4-1" (Chinese: 一池三改), in this English translation standing for the three components that are changed for one biogas digester and the total of components that are integrated. Extensions of this basic unit are done according to the climatic and agricultural conditions within the different regions in China. The "Four in one System" (四位一体) adds a solar greenhouse to increase temperature and vegetable productivity under the conditions of the colder North China climate in order to make optimal use of the organic fertilizer. "Five matches" (五配套) combines the biogas digester with a solar-powered shed, a toilet, a water tank, water saving irrigation system and an orchard. It is designed for the water scarce North West of China and works through efficiency increases for water (water tank for irrigation scheduling, irrigation technology) and increasing the income per crop (through orchards).



The underlying principle of these eco-engineering models is that they fulfil multiple goals so that farmers obtain a broad range of benefits. Through these multiple benefits, it becomes less likely to stop the operation of the system in comparison to an instrument which only works through a single benefit. One may distinguish three broad categories of benefits. First, biogas use improves hygiene, health and environmental conditions. Organic waste material and excreta are collected and do not drain into and pollute the environment. Processing in the digester destroys pathogens and therewith can reduce the spreading of diseases. Cooking with biogas eliminates smoke in the kitchen, which improves indoor air quality and prevents respiratory diseases. Since it makes the collection of firewood unnecessary, biogas can further contribute to a reduction in the depletion of forests. Second, the output of the biogas digestion process, the slurry and composted manure, can be used as fertilizer and irrigation water for agriculture and in this way improve soil conditions and enrich soil with organic matter and nitrogen. This can increase agricultural production and prevent soil erosion losses, while decreasing the use of chemical fertilizers. In this way, excess chemical fertilizer use cannot result into a reduction of soil organic matter and a decline in soil fertility, so that the vicious cycle can be prevented in which soil structure declines and chemical fertilizer application is further increased for its compensation. The use of fertilizer from biogas digestion can also lead to a decrease in the use of pesticides (Zhang et al. 2009). And lastly, with these benefits, farm households gain. Household members do not have to spend time, or spend less time, for the collection of firewood, as well as spend less time for cooking. Farm households can save money which they had spent for coal and fertilizer. This all then finally may contribute to an improvement in living standards in rural areas.

Nowadays, about 35 million of the 140 million rural households in China use biogas digesters[4], most of them in the frame of one of the mentioned eco-engineering models.

Discussion

[4] Ministry of Environment, "Animal Waste A Threat to Clean Water Supply", 15.07.2010, http://www.mep.gov.cn

While water policy instruments optimize in terms of singular input-output efficiency, Ecological Agriculture optimizes through a combination of different streams, which here is referred to as system integration. Since the benefits to the farmers are at times secondary under water policy instruments, they require institutional structures in which environmental implementation is reliable, the environmental administration reaches down to the village level, or where farmers are environmentally aware and incorporate public and environmental goals in their agricultural agenda. This however is not yet so much the case in China. “System integration” works through setting positive incentives by providing multiple and interlinked benefits, in this way, practices relating to this system are likely to be sustained. System integration can hence motivate to pursue environmental protection through reintegrating previous effluents which then are capitalized to the benefit of farmers.

Given its multiple benefits, it is difficult to say to which ends the system is integrated, - is it e.g. for increasing hygiene standards in households and villages, improving farmers' livelihood or reducing NPSP by reintegrating nutrients in the system and in this way reducing chemical fertilizer application? Integration makes it difficult to distinguish this approach as part of “water policy instruments”. However, it is used in this way by the MoE which in 2008 allocated 500 million RMB for 700 villages facing problems of clean water supply due to pollution from animal waste. Depending on local conditions, these funds either are used for centralized sewage treatment plants or the before described household based eco-engineering models.

This approach to NPSP reduction from livestock manure hence starts out from the technical infrastructure for redicrecting nutrient streams on the farm household level. Since farmers' motivation to further increase its benefit to the environment may be limited, further actors should add to gaining environmental improvement out of the approach. To take out the sludge from biogas digesters, a certain manure vehicle is required that can transport the sludge to the farm plots. In China, private companies or technicians from agricultural stations provide this service against a small fee. They could furnish the vehicles with manure application equipment which improves application efficiency. This would make available a technology that farmers hardy can afford, and not only add to agricultural productivity, but also reduce diffuse pollution. The service providers could furthermore function as a knowledge distributer on improved fertilization application. They could, depending on the respective local economic conditions, with the equipment ask for higher service fees. This additional source of income would be beneficial to the development of a service sector for biogas facility maintenance. Currently, service providers can hardly live on occasional maintenance services and in future may face difficulties to survive economically.

To further increase the value of Ecological Agriculture, vertical integration, i.e. integration into the agricultural sector, could furthermore be beneficial. However, Ecological Agriculture focuses on the combination and optimization of processes, the components of these processes are flexible. For increasing the economic value of an agricultural product, labels are often used to certify a product's compliance with quality standards, and with a certification of quality, the price for the product can be increased. Given the variance in components and in-and outputs within the system, benchmarks for a label would be difficult to define, but not an unresolvable task. Further research should be done by monitoring the reduction in soil nitrate contents after the implementation of eco-engineering models.

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