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# An institutional approach to manure recycling: Conduit brokerage in Sichuan Province, China

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ABSTRACT

With increases in living standards and dietary changes, the livestock sector has grown rapidly worldwide, which has led to considerable environmental pollution through livestock manure. Particularly in East Asia, meat production has increased fast. While part of the problem can be resolved by further processing manure into commercial organic fertilizer, technological solutions do face their limits in dealing with high pollution loads at farms. There is hence urgent need for policy instruments that could help mitigate environmental pollution. However, not much is known about related policy initiatives. This paper introduces a cooperative in Sichuan Province, China, which connects livestock farms to crop farms that are willing to use livestock breeders' manure on their land. As no frameworks exist which could aid the analysis of such a cooperative, we develop a framework based on the concept of "brokerage". Our analysis shows that for the case of Qionglai, structural conditions are favourable to the cooperative closing the nutrient cycle by means of brokerage. However, as our analysis shows, constraints to the cooperative's effectiveness foremost come from its daily operations. Within the given institutional structure, further qualitative improvements should be undertaken in terms of manure processing and manure management. The application of the framework to manure recycling shows that the framework and brokerage in general are useful analytical concepts for the circular economy. We conclude that the framework could also be applied to other fields of the circular economy, like food waste or bioenergy.

## 1. Introduction

For the sustainability of the global food system, improving the environmental performance of the livestock sector is essential (Herrero et al., 2013). Nitrogen losses from manure have increased over the last decades as livestock production has grown considerably, responding to a change in living standards and dietary changes together with global population increase (Lassaletta et al., 2016). In the European Union, the livestock sector significantly contributes to environmental pollution by the whole agricultural sector, e.g. it makes 73% of the agricultural sector's water pollution, both in terms of nitrogen and phosphorus (Leip et al., 2015). But also in emerging economies like China, livestock production has major impacts on the environment. In 2017, more than 150 million tons of meat and eggs were produced in China, resulting in about 3.8 billion tons of animal manure. 40% of this manure is not effectively treated and utilized, adversely affecting the environment and people's livelihoods (Ministry of Agriculture, 2017).

In the European Union, despite early policy initiatives (e.g. the 1991 Nitrate Directive), high nitrogen emissions can still be observed, particularly in areas with high livestock breeding density (Bouaroui et al., 2014). Against this background, the question arises how environmental pollution by nitrogen and phosphorous can be managed in developing countries or transition economies. Particularly in East Asia, meat production has increased rapidly (Thornton, 2010; Liu et al., 2017). For example, in the last thirty years, China's meat production increased twice as fast than the world average (Zheng et al., 2015). While a number of publications document environmental pollution from livestock production in China, less is known about initiatives that aid to overcome this problem. For example, Zheng et al. (2015) provide scenarios of different policy instruments' effectiveness in motivating farmers to deal with manure in an environmental friendly way. Ma et al. (2017) use scenarios to assess the impact of a broader range of measures, from changes in human diets to balanced fertilization of cropland. In their review of manure management practices in China, Chadwick et al. (2015) find that the transportation of manure is one of the bottlenecks for a more environmentally friendly manure management in China. The manure cooperative presented in this paper is a relevant measure in this regard.

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Environmental pollution from manure to a large extent occurs due to a disconnect between crop and livestock production (Lassaletta et al., 2016). The nitrogen cycle is not closed as manure (i.e. nitrogen surpluses) is not applied on crop land but emits into the soil and water bodies eventually. In China, particularly in the pig-farming sector, livestock production traditionally took place in smallholder structures (Zheng et al., 2014) where manure was recycled as organic fertilizer on farmers' land. The increase in demand for livestock products led to these smallholders often extending their farms in their backyard, without proper waste management facilities. As a result, manure drained into water bodies and soil (Zheng et al., 2013). Without fermentation in a biogas digester, manure contains pathogens which can lead to the spreading of pests. Furthermore, excessive disposal of manure can lead to soil pollution by heavy metals, and to nitrogen overload and eutrophication accordingly. The government responded to the uncoordinated expansion of smallholder farming with a policy of professionalization and standardization, i.e. by supporting the development of large–scale farms. Farms were required to install proper manure collection tanks, often combined with a biogas digester. However, they often do not have enough land where to eventually dispose of their manure (Bluemling, 2017).

One solution to overcome environmental pollution from livestock manure can be to bring livestock farms into contact with crop farms that are willing to use manure on their land. While in traditional agriculture, manure was often recycled on the own farm land, nowadays, the use of organic fertilizer is limited. In the United States, the United Kingdom and other Western countries, organic fertilizer accounts for 50% of the total amount of fertilizer used. In China, the use of organic fertilizer accounts for less than 20% of the total amount of fertilizer used (Fu and Shan, 2017). In this article, we hence look at how a private sector party can help to close the nitrogen cycle. The Chinese government has for some years asked private actors to contribute to environmental policy implementation, with the result that new policy arrangements emerge, bringing together the government and different kinds of private actors, from primary producers to service providers. In such a situation where a former hierarchical political system becomes more dependent on horizontal structures of interconnected private actors, the question arises how the transformation towards more horizontal structures can be brought about, - how can actors get into contact so that they create these institutional arrangements that are needed to more sustainably govern the environment?

This article introduces an institutional arrangement in which horizontal structures were created that link livestock farms and crop farms to facilitate manure recycling on agricultural land. The idea seems simple and pertinent, however, as we will show, some conditions apply under which a cooperative's involvement can be effective. Accordingly, the overall objective of this article is to find out under which conditions the nutrient cycle can be closed by means of horizontal institutional arrangements that come about within a process of "brokerage". On the one hand, the paper wants to assess how effective an institutional arrangement can be in reducing pollution loads from intensified livestock breeding. On the other hand, it wants to test a framework that is based on "brokerage". No conceptual framework exists so far by means of which we can analyze new horizontal structures for manure recycling, which is why a second aim of the paper is to devise and test a framework based on "brokerage".

The paper starts out with introducing the framework, and then applies it to a case of a cooperative of former livestock farmers in Qionglai District, Sichuan Province, China, which, responding to increased demand for manure collection services, acts as a broker for manure collection and distribution.

## 2. Material and methods

This section is divided into two parts. First, an introduction will be given to the analytical framework that was devised for the analysis of brokerage (Section 2.1). Second, methods and data are described that were used for the application of the framework to the case of a cooperative in Qionglai District, China (Section 2.2).

### 2.1. Analytical framework: brokerage

Simply speaking, brokerage can be defined as "behavior by which an actor influences, manages, or facilitates interactions between other actors" (as in Obstfeld et al., 2014, 141, who base their definition on Marsden et al., 1982). According to Fernandez and Gould (1994, 1457), brokerage is a "relation in which one actor mediates the flow of resources or information between two other actors who are not directly linked".

This article employs the conceptualization of brokerage as defined by Obstfeld et al. (2014) who understand brokerage as a *process* "that alters interaction between two or more parties in a wide variety of triadic structures" (Obstfeld et al., 2014, 136). Obstfeld et al. (2014) distinguish different kinds of brokerage, i.e. *conduit brokerage*, *tertius iungens* and *tertius gaudens*, and this paper focuses on *conduit brokerage* as brokers are relatively free whom to connect, and do not intend to induce collaboration between the two parties. Obstfeld et al. (2014) describe several conditions for conduit brokerage. For the framework at hand, we organize these conditions into three steps. The first step looks at conditions for brokerage on a structural level, which are important for the initialization phase: What conditions need to be given so that a cooperative can act as a broker for manure recycling? The second step looks at conditions for the institutionalization of the cooperative: Under which conditions can brokerage be maintained? And the third step looks at the conditions for the cooperative to be effective in the distribution of manure: Under which conditions will a cooperative distribute manure effectively, i.e. in how far does it help in redistributing manure so as to balance pollution loads? Fig. 1 provides an overview of these steps and their variables. In the following, the analytical steps will be further outlined.

#### 2.1.1. Structural conditions for conduit brokerage

The first structural variable for analysis is "interdependence", which is taken from Gulati (1995). Interdependence "describes a situation in which one organization has resources or capabilities beneficial to but not possessed by the other" (Gulati, 1995, 621). Interdependence describes both, the dependence of the livestock farmer on the service of the broker to collect manure, and the dependence of the arable farm on the broker in terms of providing fertilizer. Interdependence may be brought about in different ways. Large-scale livestock farms are required to look after the disposal of manure. This creates interdependence with arable farms who can apply surplus manure. Arable farms again depend on livestock farms because of the Ministry of Agriculture's plans to reduce chemical fertilizer use in the frame of the Zero Growth Policy (see Bluemling, 2017), and because they need organic fertilizer to improve soil structure, or because they grow crops according to certain standards that require the application of organic fertilizer. In the context of China, we presume that livestock farms are the driving force and assume that the stricter the regulation, the higher the interdependence between livestock farms and crop farms.

A further indicator that relates to interdependence is the dependence on the broker. Not always is a broker required to realize the exchange of resources among interdependent actors. To know about the dependence on the broker, one needs to analyze the resource that is exchanged. For example, manure needs to be transported from one place to the other, and then needs to be applied on agricultural land. Not all livestock farms or crop farms will possess suitable means of transport. A second indicator for dependence is the distance between livestock farm and crop farm, – in how far is a broker needed to bridge this distance? We presume that the more difficult it is to pass on a resource, and the larger the distance between the parties, the higher the dependence on the broker.

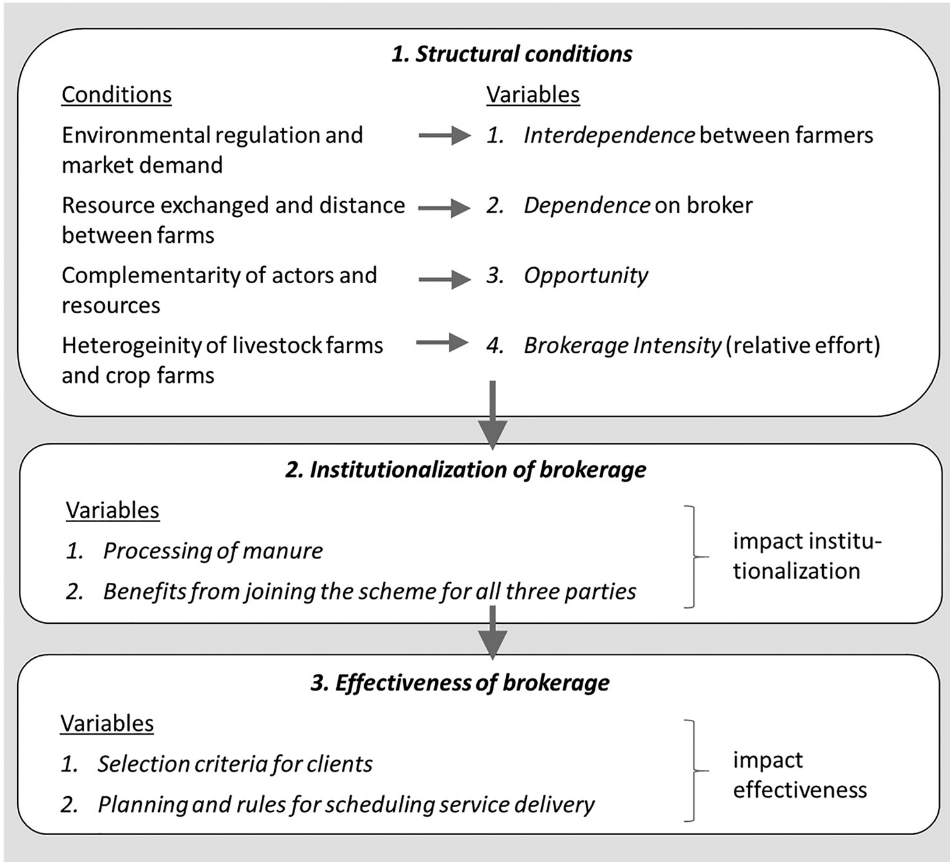


**Fig. 1.** Analytical Framework Conduit Brokerage.

Based on Obstfeld et al. (2014, 139), a further variable to analyze brokerage is "opportunity", which is the "relative availability of complementary actors and resources". An analysis of manure recycling hence has to compare in how far manure demand and manure quantity match. This will provide the general "opportunity" context. We presume that the more complementary the two parties, the better brokerage can be initiated.

"Brokerage intensity", as a further variable, is the "relative effort and range of brokerage behaviors … at the broker's disposal" (Obstfeld et al., 2014, 139). It is to some extent subject to structural preconditions. This study focuses on the "relative effort" a broker needs to spend. Following Obstfeld et al. (2014, 153) "increases in heterogeneity demand greater brokerage intensity". The conditions for "brokerage intensity" hence need to be looked at by examining heterogeneity in the livestock sector, both in terms of the kind of livestock, but also in terms of farm size, and by examining heterogeneity of arable farms (i.e. in particular their cropping patterns). Livestock farms' heterogeneity can increase brokerage intensity because the transportation of different kinds of manure requires a higher degree of coordination. For example, if crop farms demand different kinds of manure, not a livestock farm close by can be contacted, but the closest farms with the respective kinds of manure. Heterogeneity with arable farms can reduce brokerage intensity because different kinds of crops require fertilizers at different times of the year. Brokerage will be less intensive than with homogeneous cropping patterns because in the latter case, there will be times of very high manure demand and times with no manure demand. In the latter periods, the cooperative would have to spend extra effort (e.g. travel longer distances) to find farms where to dispose of manure.

### 2.1.2. *Institutionalization of brokerage*

The second analytical step looks at the conditions for the institutionalization of brokerage. Two variables are considered. The first asks in how far what is passed on is further modified by the broker (Obstfeld et al., 2014). In the case at hand, this points at the processing of manure, e.g. if processing technology is applied. Processing technology could refer to biogas digesters, where methane is emitted before the digestate is put on the field, as well as where pathogens are destroyed, improving manure quality (Bluemling et al., 2013). But processing technology can also refer to technology that helps remove heavy metals before manure is applied on the field. We presume that the more treatment, the more likely will the receiving party join the manure recycling network, given improved manure quality.

As a second variable, pricing of the broker's service is looked at. Obstfeld et al. (2014) emphasize that a broker's expectations of rewards need to be considered. The framework additionally includes the benefits of both livestock farms and arable farms from joining the scheme. This is because in situations like the one at hand, when interdependence is created by new laws and regulations, the demand for a broker's service does not necessarily come from the farmers themselves. We presume that brokerage will more easily be institutionalized if the perceived benefits from joining the scheme outweigh the costs from the service (e.g. benefits could be increases in product quality or soil improvements for arable land farmers, lower costs than potential fines for livestock farmers).

### 2.1.3. *Effectiveness of brokerage*

The last step of the analysis assesses in how far the institutional arrangement was effective in reducing pollution loads by means of redistributing manure.

First, the cooperative can influence effectiveness through the selection of clients. A cooperative is assumed to be more effective if its selection criteria take into consideration the manure scheduling regime

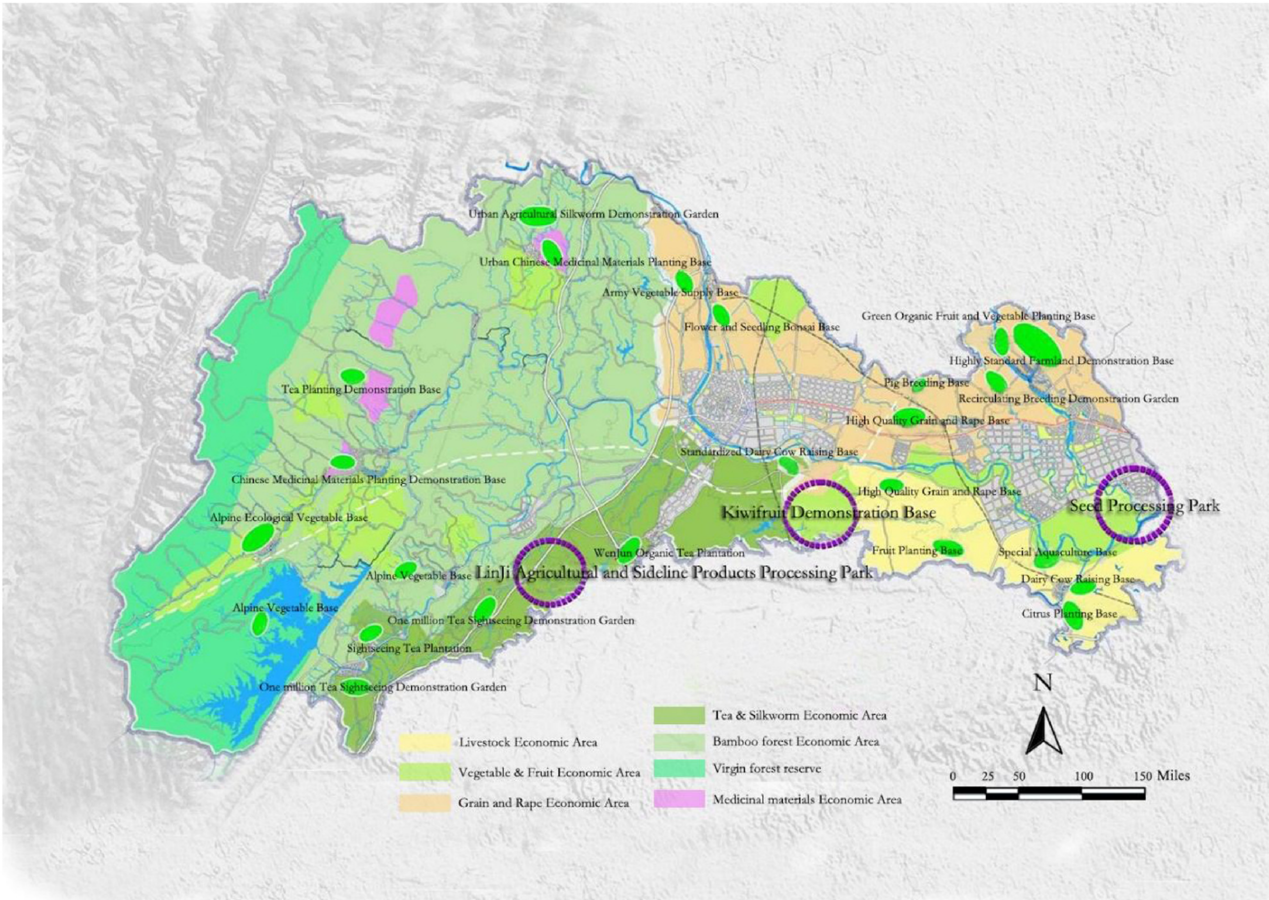


**Fig. 2.** Land Use Plan and Zoning in Qionglai District.
***Source***: Drawn based on data provided by Qionglai Agriculture and Forestry Bureau, November 2017.

of crop farms. For example, a cooperative may have a(n area) limit up to which it accepts farms of a certain cropping pattern, so as to avoid that it cannot dispose of manure at times that these farmers' crops do not require fertilizer. Otherwise, not collecting manure would have implications for manure storage facilities of livestock farms and may lead to environmental pollution eventually. The more consideration is given, in the selection of crop farms, to a distribution of fertilization over the year, the more effective a cooperative is presumed to be in distributing manure.

The second variable that is presumed to influence the effectiveness of brokerage, are the rules that determine the scheduling of the cooperative's service delivery. A more long-term planning will enable a cooperative to match manure and manure demand spatially and over the course of a year, and hence will reduce travel distances and related carbon emissions.

We use the above framework to analyze the brokerage of a manure cooperative in Qionglai District, Sichuan Province, China.

### *2.2. Methods and data*

As this research addresses a societal phenomenon that has not yet been researched (i.e. horizontal institutional arrangements for manure redistribution), an exploratory research design is deemed appropriate, i.e. case study analysis. Out of 19 cooperatives that have so far been established in Qionglai District with a focus on manure collection and distribution, the "Green Circle"-Cooperative was the first manure cooperative to be established in 2014. This article hence selected the Green Circle Cooperative for its single, in-depth case study analysis as it was the cooperative that had been established the longest and hence would allow an analysis for each of the three steps outlined above. In 2016, the 19 cooperatives together provided their service to in total 246 large-scale farms with manure collection facilities, out of which 67 were pig farms, 158 were poultry farms and 21 were cattle farms (Chengdu Agricultural Committee, 2016).

Qionglai District is located in the West of the Chengdu Plain. It is an intensive agricultural region with strong growth in the animal husbandry sector. According to the Statistical Yearbook of Qionglai's Economic and Social Development (Qionglai Bureau of Statistics, 2017), annual agricultural output value increased over the previous year by 4.4%. While the annual agricultural output value of crop farming increased by only 1.4%, animal husbandry grew by 6%. As such, the Qionglai manure cooperatives can be considered to have formed in an environment that is somewhat representative for China's strong agricultural growth with a national annual growth rate of 5.75% (Han et al., 2017).

Data was collected during site visits over the period from July 2016 to April 2018. Data was collected from all stakeholder groups related to the cooperative: The president and vice president of the cooperative, members of the cooperative (i.e. truck owners), labour of the cooperative (i.e. who are employed for manure collection, transport and application), clients of the cooperative (i.e. crop farmers and livestock farmers), as well as officials of the Qionglai District Bureau of Agriculture and Forestry.

Consecutive face-to-face and telephone interviews were carried out with the president and vice president of the cooperative, covering topics as they emerged in the course of this case study research, e.g. the operation of the cooperative, manure collection practices, cost effectiveness of manure application and farmers' dependency on the cooperative. During site visits to the cooperative, further material was collected, e.g. copies of the below mentioned manure accounting books. Focus groups were organized with members of the cooperative as well as with clients of the cooperative, covering topics of traditional manure application and the cooperative's manure service. To know about the cost effectiveness of the use of manure, a field experiment was carried out together with the cooperative, using different soil samples. During this experiment, further insight was gained into manure and fertilizer application practices.

Over time, we hence obtained comprehensive primary data on the operation and development of the Green Circle Cooperative.

At the same time, by means of interviews with local staff from the "Department of Animal Husbandry of the Qionglai District Bureau of Agriculture and Forestry" and the "Chengdu Agricultural Committee", we retrieved information about local government policies that support cooperatives in the agricultural sector, as well as on subsidies for farmers to use manure. We also could obtain documents like work reports on the treatment of livestock and poultry manure and related materials.

In addition, we obtained data for the period from 2014 to 2018 on the livestock industry development in Qionglai District from the Qionglai District Statistical Yearbook and Sichuan Statistical Yearbook.

As in our analysis, the "dependence" variable foresees to consider the spatial distribution between livestock farms and crop farms, we furthermore collected data from the Qionglai Agriculture and Forestry Bureau, which we mapped in Figs. 2 and 4, using ArcGIS 10.0, AutoCAD2016 and Adobe Photoshop CS6.

## 3. Results

In the following, we first provide some information about the case study context, with a focus on the livestock sector in the region, and then apply the framework as delineated above.

### 3.1. Case study context

There are in total 217,355 registered livestock farms in Sichuan Province, which include 11,048 large-scale farms, 75,866 medium-scale farms and 130,441 smallholder farms[1] (Sichuan Agricultural Letter 2017). For large-scale farms, the installation of waste disposal facilities is compulsory, however, not all of them do have a waste disposal facility, e.g. according to the Chengdu Agricultural Committee (2016), 77.8% of the local large-scale livestock farms were equipped with waste disposal facilities. Medium-scale and smallholder farms are made liable not to pollute the environment, and may expect punishment for emitting manure and urine into the environment. However, waste disposal facilities are not compulsory. Government subsidies exist for small- and medium scale operations to build waste disposal facilities on a voluntary basis (see Qionglai Agriculture and Forestry Bureau, 2017).

### 3.2. Structural conditions

This first step looks at in how far regional conditions are conducive to setting up a cooperative, based on the criteria of Interdependence, Dependence, Opportunity and Relative Effort.

[1] "Large-scale animal husbandry farms" are defined as having more than 500 animals; "medium-scale animal husbandry farms" as having less than 500 and more or equal to 50 animals; "small-scale animal husbandry farms" have less 50 animals. Sichuan Province Environmental Protection Agency's "Guidelines for Pollution Prevention and Control of Livestock and Poultry in Sichuan Province (Trial)" http://www.scagri.gov.cn/zwgk/tzjd/201707/t20170731_516793.html.

#### 3.2.1. Interdependence

We start with analyzing in how far the general institutional and political environment has brought livestock and crop farms into a relationship of Interdependence.

*3.2.1.1. Livestock farms*. A gradual separation of livestock breeding and arable farming, together with scale increases in livestock breeding operations, has left livestock farms with insufficient cultivated arable land to dispose of manure. Furthermore, in recent years, the Chinese government has issued a number of laws and regulations to enhance agricultural environmental pollution control (see Table 1).

The 2017 "Opinion on accelerating the utilization of waste from livestock and poultry farming" was the first guidance document particularly addressing the treatment and utilization of manure. Related measures are to be carried out primarily with large-scale farms in counties with a strong animal husbandry sector, which is the case for Qionglai District. The guidance document increases the pressure on livestock farms to look after manure management in that it sees enterprises as responsible for reducing the environmental footprint of their operations, controlling production processes and end-use management. The government's role is to provide support in tackling the problem, and issue related policies, as well as to look after stricter law enforcement and monitoring of law abidance. This guideline hence has increased the pressure on livestock farms to find manure disposal sites.

In addition to the guidance document, the 2015 Environmental Protection Law increased the pressure on provincial governments. In Sichuan Province, a provincial account was set up which monitors livestock and poultry production and pollution prevention. The result of the monitoring was that 63,733 farms out of in total 130,441 smallholder farms should be closed, relocated or refurbished (including 40,035 farmers, accounting for 62.82% of the total), and all of them were designated for refurbishment. By August 4, 2017, a total of 14,346 farms were completely refurbished, including 2,057 large-scale farms and 12,289 medium-scale farms, which makes 22.5% of all livestock farms in Sichuan (Sichuan Provincial Department of Agriculture, 2017).[2] This shows that pressure for livestock farmers to comply with new environmental regulation has increased.

In accordance with the government's strategy to provide supportive policies, from 2014 to 2017, Qionglai District Government launched a special management scheme to address pollution from livestock breeding. Based on a remediation plan for farms with serious environmental pollution, planning and capital investment was enhanced for rural biogas projects, for the construction of septic tanks, for manure transportation trucks and other auxiliary equipment.

*3.2.1.2. Crop farms*. Concerns around food safety have opened up opportunities for organic farming in China (Xie et al., 2015). Crop farmers have started to seize the opportunity to transform to organic farming as complying with green or organic product standards enhances market competitiveness (Reganold and Wachter, 2016). In Qionglai, at the end of 2015, 62 different "safe and high-quality agricultural products" were certified. Among them, 19 products are "pollution-free agricultural products", which are products of good quality and where pollutants are within the range of national pollution standards (Xiong et al., 2016, 2). Nine of the certified products are "green food products", where manure, but also, to some extent, chemical fertilizer is used, and where production conditions (e.g. soil pollution) are not yet up to the standard of organic production. 34 organic products so far have been certified by the provincial government. Within this overall development towards less pollutant agriculture, the demand for manure fertilizer is hence increasing. Interdependence in this case is driven by market demand.

[2] Sichuan Provincial Department of Agriculture. Report on the Work of Agricultural Ecological Environment Protection in 2017.08.09.

**Table 1**
Policies and Regulation related to environmental pollution by livestock and poultry manure.

| Year | Governmental entity | Regulation/Law |
|---|---|---|
| 2001 | Ministry of Environmental Protection | "Livestock pollution prevention and control management measures" |
| 2012 | Ministry of Environmental Protection and the Ministry of Agriculture | "12th Five-Year Plan for Pollution Prevention and Control of National Livestock and Poultry Breeding" |
| 2013 | State Council | "Arrangements on Recent Soil Environmental Protection and Comprehensive Management" |
| 2014 | State Council | "National Manure Pollution Prevention and Control Regulations for large-scale Livestock and Poultry Farms" |
| 2015 | Ministry of Environmental Protection | "New Environmental Protection Law of the People's Republic of China" |
| 2017 | State Council | "Opinions on accelerating the utilization of waste from livestock and poultry farming" |

Apart from consumers' demand, also the 2015 Ministry of Agriculture's "Action Plan for Zero Growth of Fertilizer Use" will further trigger interdependence. National, provincial, district and other local government funds have pooled considerable amount of funding for projects that support the Ministry's Action Plan.

In conclusion, interdependence for crop farms is created by government regulation and market demand.

### 3.2.2. Dependence

Dependence has two dimensions, i.e. the dependence on the broker due to the characteristics of the resource that is exchanged with the broker's help, and dependence on the broker because of the distance between farms. In Qionglai District, the spatial distribution of crop farming is relatively fragmented. In the Western part, mountainous areas are suitable for orchards, tea and bamboo cultivation. The Eastern part, i.e. the plains, are appropriate for crop and vegetable production. The vast majority of livestock and poultry farming is located in the Eastern part of the plains (see Fig. 2).

Farms are hence to some extent dependent on the cooperative to bridge the spatial gap. The cooperative's service furthermore includes the emptying of the biogas digesters or manure tanks, the transportation of manure, the application of manure to crop farmers' fields. To this end, farmers depend on the cooperative's related equipment.

From this step of the analysis, we may conclude that dependence on the broker is relatively high.

### 3.2.3. Brokerage intensity

Brokerage intensity refers to the "relative effort" a broker needs to spend to mediate between livestock farms and crop farms.

According to a survey by Qionglai's Agriculture and Forestry Bureau of Rural Environmental Construction, annually, more than 1.4 million pigs, 21 million poultry, and 9500 cows are slaughtered.[3] Animal husbandry in Qionglai District produces annually 1.2 million tons of manure, i.e. 763,288 tons of pig manure, 302,055 tons of poultry manure and 104,500 tons of manure from cattle.[4] Hence, 65.2% of manure is pig manure, 25.8% comes from poultry and 8, 9% from cattle. While this heterogeneity will be conducive to serve clients' demands, it also increases brokerage intensity.

As foremost large-scale livestock farms will be equipped with biogas digesters or manure tanks, the scheme will focus on these livestock farms. Policy-makers furthermore support the collection of livestock manure from medium-scale farms which often do not have manure tanks, so that further environmental pollution can be mitigated. This is why also medium-scale farms form part of the client base.

From the demand side, we can see from Table 2 that there are more than nine different kinds of crops with varying requirements in terms of frequency of manure application and amount of manure per application. This diversity implies that there is potential to level out peaks in the supply of manure, and that less effort is required in the delivery of manure. Also for crop farms, heterogeneity in scales is likely to imply that only medium and large-scale farms are to join. As their demand for manure is low, small-scale crop farms often have their own sources of manure and would not need to join such a scheme.

**Table 2**
2016 Qionglai District – planted areas and crops.
Source: (a) Qionglai Bureau of Agriculture and Forestry; (b) local survey,[a] 2017.

| Crop | Area (ha)[(a)] | Manure application | | Total manure demand (t) |
|---|---|---|---|---|
| | | Time(s) [(b)] | Amount [(b)] (tons/a/ha) | |
| Rice | 10440 | 2 | 45 | 469,800 |
| Corn | 3129 | 2 | 75 | 234,675 |
| Wheat | 3977 | 2 | 75 | 298,275 |
| Tea | 4948 | 1–3 | 75 | 371,100 |
| Tangerine | 1926 | 1–3 | 75 | 144,450 |
| Kiwi | 4106 | 3–4 | 75 | 307,950 |
| Others fruit | 1471 | 3–4 | 90 | 132,390 |
| Rapeseed | 2238 | 2 | 75 | 167,850 |
| Vegetable | 3085 | 2 | 300 | 925,500 |
| Total | 35320 | | | 3,051,990 |

[a] Data was collected by means of face-to-face interviews. Figures refer to manure that is used complementary to chemical fertilizer.

Furthermore, as shown in Fig. 2, livestock breeding areas and horticultural land are spatially separate. While this implies a greater dependence on the service of the broker, it also means that brokerage effort will increase the farer away crop farms are located from livestock farms.

In conclusion, heterogeneity in cropping patterns among crop farms will level out peaks. Livestock heterogeneity will increase effort. Heterogeneity in scales is likely to result in the cooperatives focussing on large-scale and medium-scale operations only. The larger the distance between crop and livestock farms, the higher furthermore brokerage intensity.

### 3.2.4. Opportunity

Opportunity looks at the "relative availability of complementary actors and resources". Qionglai District has a cultivated area of 44,620 ha. In 2016, 15,700 tons of chemical fertilizer were used, i.e. 6,000 tons of nitrogen fertilizer, 3,110 tons of phosphate fertilizer, 1,700 tons of potash fertilizer and 4,900 tons of compound fertilizer (Statistical Bureau of Sichuan Province, 2017).

To know how much manure could replace the use of chemical fertilizer, we use the method of Liang (2014) to calculate the annual amount of manure from livestock and poultry. As shown in Table 2, the total amount of manure demanded by crop farming in Qionglai is 3.05 million tons annually. Based on manure production of annually 1.2 million tons (see Section 3.2.3), livestock farms in Qionglai District would be able to cover 39.3% of the total manure demand in the

[3] Source: Local survey, Agriculture and Forestry Bureau of Rural Environment Construction. 2017, Qionglai.

[4] These figures are based on the following calculation: Livestock breeding periods are 199 days for pigs, 210 days for poultry, and 365 days for cattle. Each pig annually excretes about 1 ton of manure; each poultry excretes about 0.025 tons; each cow discharges about 11 tons (see Qiao, 2016; Wang et al., 2006; Zhang et al., 2018).

district. It is likely that these 39.2% would be applied to certain crops only. Manure is less frequently applied to arable crops like corn, wheat or rapeseed. If these crops are not included, manure from Qionglai could cover 58.5% of crop manure demand.

By matching demand and supply, we see that there is ample opportunity for brokers to make the link between livestock farms and crop farms. It becomes clear that the cooperative can contribute to mitigating the manure pollution problem in Qionglai District: It can distribute manure so that more than half of regional vegetable and fruit farming's manure demand can be covered.

### 3.3. Institutionalization of brokerage

In this second part of our analysis, we look at the conditions under which brokerage can be maintained, with a focus on "Processing" and "Rewards". As this brings us closer to the cooperative itself, the Green Circle Cooperative will first be briefly introduced.

While this article provides the case of a "cooperative" acting as a broker, it would not necessarily require a cooperative for brokerage. In the context of China, an agricultural cooperative is understood as a "special market subject" whose objective is to improve the degree of organization among farmers (Xu and Wu, 2017). On paper, cooperatives are clearly defined, however, in reality, they can take shape in a variety of ways.

In the case at hand, former livestock farmers decided to set up a cooperative because it can serve as a rather loose framework within which farmers can individually provide their manure recycling service. In 2017, the cooperative consisted of 28 members and 18 manure trucks. Members hence either individually or together with another member bought a truck which they operate under the umbrella of the cooperative. Trucks have different storage capacities: 7 trucks have a capacity of 5–5.5 tons, 8 trucks a capacity of 6 tons, one truck a capacity of 16 tons, one truck is of a capacity of 22 tons, and a further truck of 30 tons.

Workers are employed to help irrigate the fields, and additional workers are recruited in times of high manure demand. Under the umbrella of a cooperative, each member receives governmental subsidies for the equipment that they use. As the cooperative consists of former livestock farmers, its location is also within the livestock breeding zone, i.e. close to manure providers.

#### 3.3.1. Rewards

From Section 3.2.1.1, it became clear that livestock farmers benefit from the cooperative in that they do not have to look after the disposal of their manure and do not have to pay levies in case manure from their farm emits to the environment. The transport of manure is for free if manure is of high-quality. For manure of low quality, the cooperative charges fuel subsidies of 20–30 RMB[5] per car from livestock farmers.

For crop farmers, a major benefit is the improvement in soil quality due to the application of manure. Nutrient availability is improved, as well as water retention capacity, soil bulk density and soil temperature and a reduction in production costs is achieved (Rurangwa et al., 2017). Experiments of one of the authors showed that for kiwis, fertilizer costs decreased by 4,500 RMB/ha with the application of manure, despite the fact that crop farmers have to pay for the manure. Pricing is done based on the kind of manure, its quality and the distance between crop farm and livestock farm (Liao et al., 2017). For example, if a crop farm is located within a range of 20 km from a livestock farm, chicken manure costs 40 RMB, cow dung and pig manure cost 30 RMB. Beyond 20 km, 1 RMB/m$^3$/km have to be paid additionally. However, there is no uniform standard in fee collection: About half of the crop farmers do pay a fee, the other half does not.

This difference originates in the fact that the government provides subsidies. The cooperative itself can obtain subsidies because the government considers to have "outsourced" some of its tasks to the cooperative. The amount of subsidies is determined by the cooperative and the township government, i.e. the administration one level below the District government. For example, the subsidy provided by Guyi Township government is 10,000 RMB for every manure truck, other townships provide similar amounts of subsidy. The cooperative can use these subsidies to reduce service fees. Therefore, prices often range from 0 RMB/m$^3$, 15 RMB/m$^3$, 20 RMB/m$^3$, 30 RMB/m$^3$, to 40 RMB/m$^3$, depending on mentioned criteria and subsidies. Crop farmers additionally receive subsidies of 8 RMB/m$^3$ for the use of manure.

For members of the cooperative, manure recycling is good business. An average truck can generate 120,000 RMB of profit annually.

In conclusion, as all participants in the scheme can improve their farming conditions or are able to gain a living from it, the scheme is likely to be able to institutionalize in the long-term.

#### 3.3.2. Processing of manure

While the redistribution of manure to crop farms mitigates high nutrient and phosphorous pollution loads, manure can also contain considerable amounts of heavy metals. In China, animal manure can be an important source of heavy metals in rural environments (Zhang et al., 2012). According to Xiong et al. (2010), copper loads in animal manure may at some places not only pose a risk to soil quality, but also a health risk.

The question hence arises in how far the Green Cycle Cooperative further processes manure by e.g. taking out heavy metals. The answer is relatively straight-forward: the cooperative does not further process manure. A requirement for collecting manure is that manure has been processed for about 30 days. According to some members of the cooperative, this implies that heavy metals will have sunk to the ground of the tank and hence will not be soaked in by the truck's pump.

Some crop farms will demand a mix of different kinds of manure, others will prefer manure from a certain kind of animal only, and again others will prefer manure with little water content, or will prefer liquid manure or slurry. These differences in demand result in different ways of processing manure. Livestock breeders' feeding and management levels will also result in different nutrient compositions of manure. According to crop farmers, high quality manure sources are undersupplied, but the cooperative cannot find manure of respective quality. While there hence is demand to monitor manure contents or upgrade manure quality, the cooperative has not yet taken the opportunity to further process manure to bring it up to a certain standard. Fig. 3 summarizes the main variables that help to institutionalize the arrangement.

### 3.4. Effectiveness

The last part of the evaluation looks at the effectiveness of the cooperative in distributing manure. From above analysis, we know the structural conditions for the broker, i.e. the general interdependence and dependence of the broker's clients, as well as in how far supply and demand match. In this section, we further narrow down the analysis to look at which selection criteria, within the above structural conditions, the Green Circle Cooperative employs to look for clients. These selection criteria, as well as the cooperative's rules for scheduling the delivery of manure, will have an impact on its effectiveness to distribute manure.

#### 3.4.1. Selection of parties

A cooperative is assumed to be more effective if its selection criteria take into consideration the manure scheduling regime of crop farms.

The way the Green Circle cooperative gets into contact with its clients is based on demand and on intermediaries. The local government provides information to the Cooperative about potential manure

[5] RMB ("Renminbi")'s conversion rate is 1 RMB = 0.16 US Dollar (16 June 2018).

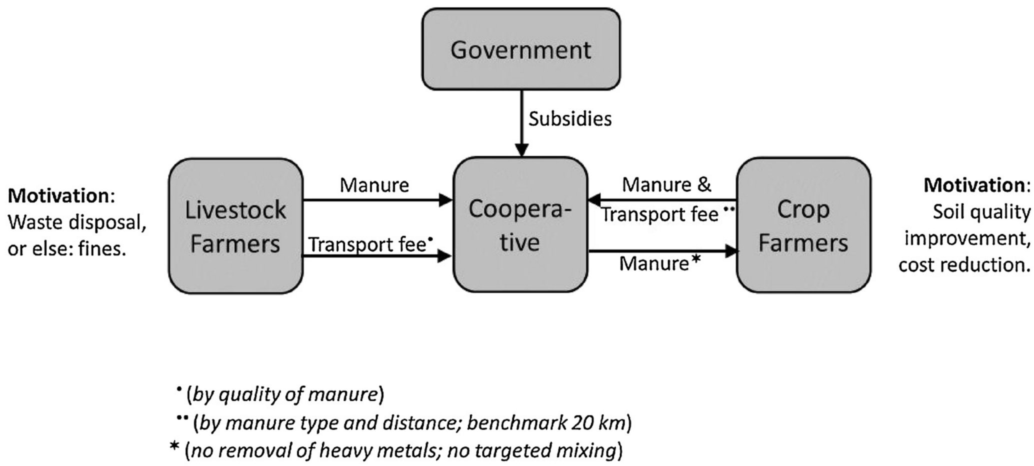


**Fig. 3.** Institutionalization of brokerage.

receiving clients, i.e. names, planting area, contact information, and their location. Members of the Green Circle Cooperative then contact them. About 10% ~ 20% of the Green Circle Cooperative's client base is recruited in this way. The Cooperative makes also use of WeChat groups which either were set up by the government or by the cooperative itself. They comprise local farmers accepting manure, livestock farmers and members of the cooperative. Livestock farmers and crop farmers can use the group to send a message that they want to have their manure collected or that they need manure respectively. From WeChat Groups, the cooperative recruits about 20% of its client base. Further 30% of clients join based on word-of-mouth recommendation.

There are hence no standardized criteria based on which new clients are selected, e.g. with a view to levelling out peaks of fertilizer provision. If the cooperative has the choice, crop farmers will be selected from whom timely payment of service fees can be expected. For livestock farmers, manure quality is an important selection criterion, and further criteria are whether supporting infrastructure (biogas digester, etc.) exists, or traffic convenience. Distance between the livestock farm and the manure receiving farms is a further criterion: the distance between the location of a member of the cooperative and the manure receiver in general shall not exceed more than 20–25 kms.

From the above, we can conclude that the Green Circle Cooperative does not use selection criteria that would help to level out peaks in manure demand and hence would render manure distribution more effective. However, it needs to be said that the client base is still evolving as the cooperative is in its first years of establishment.

### 3.4.2. Scheduling of service provision

Long-term planning will enable a cooperative to match manure and manure demand spatially and over the course of a year, and hence reduce travel distances and related carbon emissions. This is why the scheduling of manure delivery needs to be looked at to determine the cooperative's effectiveness.

In an annual contract, the cooperative agrees with crop farmers upon the general amount of manure and the frequency with which it has to be provided. When crop farmers want the manure to be delivered, they need to make an appointment with the cooperative 2–3 days in advance.

Different arrangements exist with livestock farms depending on their scale. With large-scale farms, the cooperative signs a contract that stipulates the number of trucks the cooperative sends per day. A frequent number is two trucks per day. However, livestock farms at times do not provide manure in strict accordance with the contract. Manure collection based on contracts makes about 50% of the cooperative's business.

Small- and medium scale livestock breeders do not have a contract with the cooperative. They collect manure in pits, and when these manure pits fill up, livestock farms call the cooperative about three days in advance so that the cooperative can arrange a truck to collect manure. As the cooperative carries out a public task, the government subsidizes the cooperative for this service, and the cooperative only charges a small fee from livestock farmers. The provision of this service to small- and medium-scale livestock breeders, together with government subsidies, nevertheless accounts for about 50% of the cooperative's revenues.

For large-scale livestock farms, i.e. 50% of the cooperative's business, as well as for crop farms, the amount of manure is hence stipulated in long-term contracts. This would allow for an efficient delivery of manure, i.e. the regular supply by livestock farms could be matched with crop farms' stipulated demand for manure over the year.

### 3.4.3. Assessment

In the end, the question remains whether the cooperative is effective? The account of the Green Circle Cooperative shows that in 2015, it provided its service to 114 livestock farms and 178 arable farms covering 14 villages. Furthermore, based on our interviews, the cooperative has signed new transport service contracts with over 100 farms in 2017 (Table 3).

From above analysis, it became clear that the cooperative does not apply selection criteria to its clients, but rather works on demand. As we can see from Fig. 4, clients considerably vary across the years 2015 and 2016. The map shows involved villages as the unit of analysis to indicate manure import into and export from farms of a village.

A closer look at Table 4 then shows that indeed, eight villages quit the scheme in 2016, while five villages joined the scheme in 2016. The

**Table 3**
Scope of the Green Circle Cooperative's manure collection and recycling.

| Livestock Manure (tons) | 2015[1] | 2016 | 2017 | 2018 (contracted) |
|---|---|---|---|---|
| Pig | 14,355 | 24,000 | 40,000 | 15 farms |
| Cattle | – | 3000 | 2000 | 1 farm[2] |
| Chicken | – | – | 3000 | 2 farms |
| Duck | 2145 | 3000 | 5000 | 1 company[3] |

Figures for 2018 are contracts as of February 2018.
[1] Figures were calculated from the cooperative's accounting books, i.e. the total amount of manure was 16–17,000 tons. Pig manure and duck manure accounted for 87% and 13%, respectively.
[2] Oral agreement.
[3] Signed in October 2017 with a duck company which comprises more than 100 duck farms.

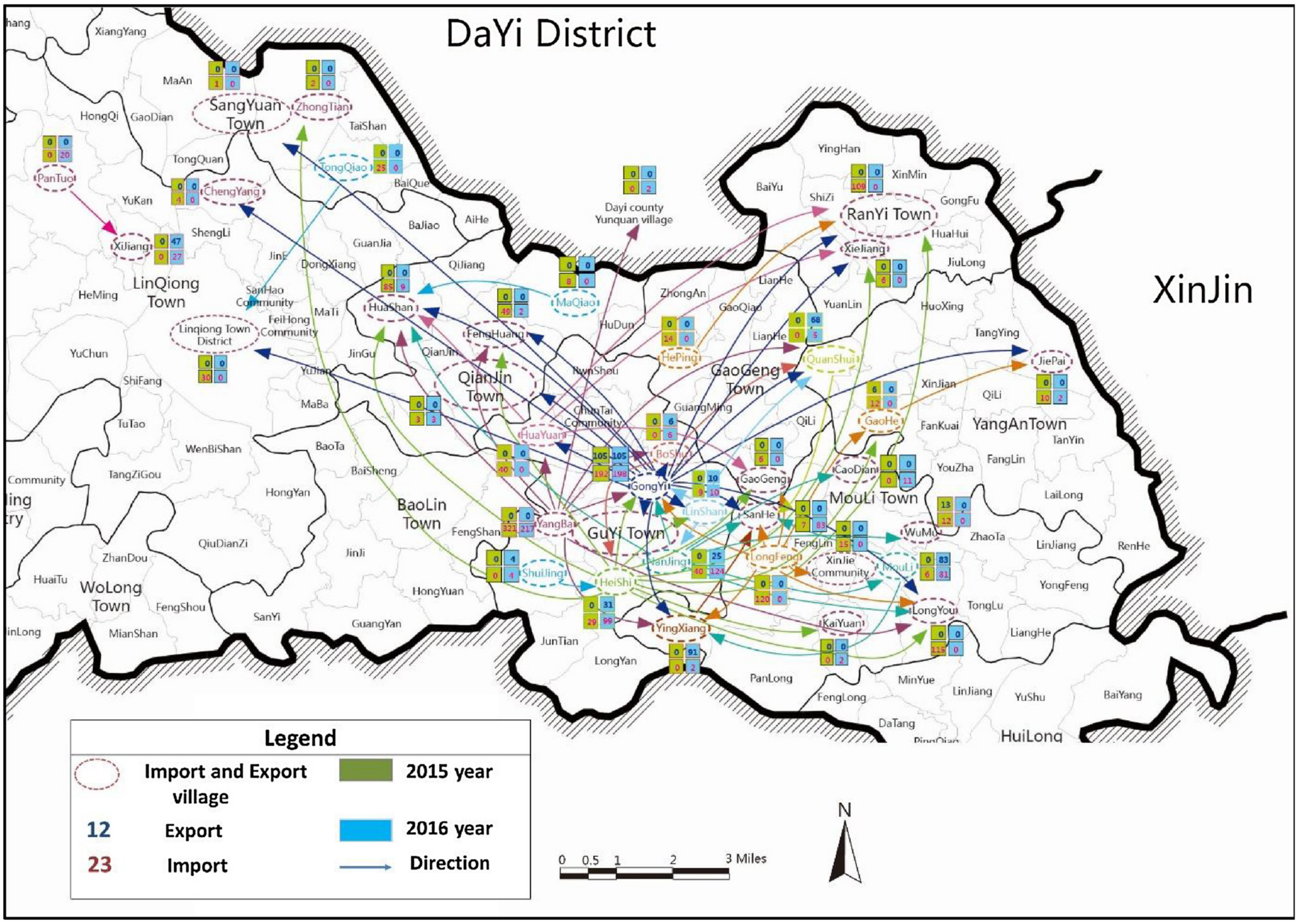


Fig. 4. Distribution of the Green Circle Cooperative's clients.
*Note*: Every village is colored differently, and manure outgoing from this village is indicated with arrows in that respective color.

**Table 4**
Manure import and export for the Green Circle's client villages.
Source: Annual accounting books of the Green Circle Cooperative, Qionglai District, Sichuan Province.

| | Location of manure village | Manure Quantity (2015) (Unit: car(s)) | | | | | Manure Quantity (2016) (Unit: car(s)) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Import | | | Export | Ba-lance | Import | | | Export | Ba-lance |
| | | Total | From own village | Impor-ted | | | Total | From own village | Imported | | |
| 1 | GongYi 公议 | **105** | 46 | 59 | 192 | 87 | **156** | 75 | 81 | 198 | 42 |
| 2 | HeiShi 黑石 | **0** | 0 | 0 | 29 | 29 | **31** | 27 | 4 | 99 | 68 |
| 3 | LongFeng 龙凤 | **0** | 0 | 0 | 120 | 120 | **0** | 0 | 0 | 0 | 0 |
| 4 | NanJing 南京 | **0** | 6 | 0 | 40 | 34 | **25** | 23 | 2 | 124 | 99 |
| 5 | YangBa 杨坝 | **0** | 0 | 0 | 321 | 321 | **140** | 101 | 39 | 217 | 77 |
| 6 | HuaYuan 花园 | **0** | 0 | 0 | 40 | 40 | **0** | 0 | 0 | 0 | 0 |
| 7 | GaoHe 高河 | **6** | 2 | 4 | 12 | 6 | **0** | 0 | 0 | 0 | 0 |
| 8 | HePing 和平 | **0** | 0 | 0 | 14 | 14 | **0** | 0 | 0 | 0 | 0 |
| 9 | LinShan 临山 | **0** | 0 | 0 | 9 | 9 | **10** | 0 | 0 | 10 | 0 |
| 10 | MaQiao 马桥 | **0** | 0 | 0 | 8 | 8 | **0** | 0 | 0 | 0 | 0 |
| 11 | ShengYang 胜阳 | **0** | 0 | 0 | 4 | 4 | **0** | 0 | 0 | 0 | 0 |
| 12 | TongQiao 童桥 | **0** | 0 | 0 | 25 | 25 | **0** | 0 | 0 | 0 | 0 |
| 13 | WuMu 乌木 | **13** | 9 | 4 | 12 | −1 | **0** | 0 | 0 | 0 | 0 |
| 14 | XiaoTang 小塘 | **16** | 13 | 3 | 13 | −3 | **0** | 0 | 0 | 0 | 0 |
| 15 | BoLin 柏林 | **0** | 0 | 0 | 0 | 0 | **6** | 0 | 0 | 6 | 0 |
| 16 | PanTuo 盘陀 | **0** | 0 | 0 | 0 | 0 | **0** | 0 | 0 | 20 | 20 |
| 17 | QuanShui 泉水 | **0** | 0 | 0 | 0 | 0 | **68** | 2 | 66 | 5 | −63 |
| 18 | XiJiang 西江 | **0** | 0 | 0 | 0 | 0 | **47** | 27 | 20 | 27 | −20 |
| 19 | YinXiang 迎祥 | **0** | 0 | 0 | 0 | 0 | **91** | 1 | 90 | 2 | −89 |

*Note*: 4–5 $m^3$/car. Information from the Green Circle Cooperative's accounting books.

cooperative hence is still developing its client base. However, what also can be observed is that the amount of manure collected increased rapidly, i.e. from 134 cars in 2015 to 574 cars in 2016. According to a focus group interview, farms who received manure on average reduce their chemical fertilizer use by 40%. What is furthermore important with regard to effectiveness are the villages' balances in Table 4. A balance equals the total export subtracted by the total import to the village. If the balance and the import value are both larger than zero, the manure supply service in this village is inefficient because the manure imported to the village could (partly) be provided from farmers of the own village. This condition applies to two out of 14 villages in 2015, and 4 out of ten villages in 2016. While we have seen in section 3.4.2 that the cooperative's contracts do allow longer term planning, spatially explicit plans could render brokerage more effective, e.g. by means of annual manure balances for each village.

## 4. Discussion and conclusions

The main objective of this article was to find out under which conditions the nutrient cycle can be closed by means of horizontal institutional arrangements that come about within a process of "brokerage". The paper wanted to assess how effective institutional arrangements can be in reducing pollution loads from intensified livestock breeding by distributing manure to crop farms. Based on the application of the framework that we developed in Section 2, we analyzed, in consecutive analytical steps, the conditions that determine a broker's effectiveness. We find that structural conditions are conducive for the Green Circle cooperative in Sichuan Province, China. Environmental regulation asks livestock farms to better manage their manure, while at the same time, market demand for organic agricultural products is increasing. In Qionglai District, manure cooperatives could redistribute manure from livestock farms to cover 58.5% of vegetable and fruit farming's organic fertilizer demand. Furthermore, as livestock farms and crop farms can improve their farming by using the cooperative's service, and as the cooperative provides a source of livelihood for its members, the cooperative can be assumed to institutionalize well. The characteristics of the case study area also point at conditions where brokerage is likely to be effective, i.e. the area is characterized both by a high livestock density and a not yet highly industrialized livestock sector.

Constraints to the cooperative's effectiveness foremost come from its daily operations. While there are long-term contracts that would allow to effectively plan and accordingly allocate manure to crop farms, in two out of 14 villages (2015), and four out of ten villages (2016), manure demand could have (partly) been covered by livestock farms of the related village. Manure is hence transported from a village's livestock farms to crop farms in different parts of Qionglai, while crop farms of the village are supplied with manure from livestock farms of other villages. Improving manure redistribution rules would hence considerably improve the cooperative's effectiveness.

The cooperative would not only benefit from some training to manage manure balances. It would also benefit from improved knowledge of more environmentally sound application of manure. Our above calculations are based on manure demand values that were provided by farmers. These values are likely to exceed crop fertilizer demand, and a more efficient application of fertilizer is deemed appropriate. Members of the cooperative could take the role of informing or even training farmers in manure management. However, one could argue that within the current institutional arrangement, incentive structures run counter such a role: the more manure the cooperative distributes, the higher its revenues. As we have shown, livestock manure in Qionglai District only covers 58.5% of manure demand from vegetable and fruit farming. As the full market potential is not yet exhausted, the cooperative can still increase its client base while at the same time support a qualitative improvement in manure management by efficiency increases in manure application, but also by further processing manure.

The article showed that brokerage is a useful concept to analyze institutional arrangements that involve manure recycling. So far, no analytical framework exists by means of which one could analyze institutional arrangements that aid the realization of a circular economy. If we conceptualize agents as brokers that mediate between actors who have "waste" at their disposal and actors who can use this waste as a "resource", applying this framework will show in how far conditions are favourable for the respective broker, and in how far the broker is effective. The framework hence could also be applied to brokerage and institutional arrangements in other fields of the circular economy, like food waste or bioenergy.

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