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Optimizing county-Level manure redistribution with the most cost-effective way in Handan Area: balancing economic and environmental benefits

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LIST OF FIGURES & TABLES

CONTENT

1． INTRODUCTION

1.1 BACKGROUND

In recent years, the global economy has experienced substantial growth, leading to significant development in human economies. However, this progress has come at the cost of increased greenhouse gas (GHG) emissions, posing a crucial global challenge (Xue et al., 2019). Currently, the excessive emissions of ammonia (NH3) and GHGs (including Methane, Carbon dioxide, and Nitrous oxide (N_2O)) have far-reaching effects on climate and environmental pollution, adversely impacting human health and ecosystems, with estimated total losses of anaual amounting to 2 billion dollars (Wang et al., 2021).

The North China Plain (NCP) is recognized as one of the most heavily polluted regions worldwide (Yang et al., 2018). Northern China (focusing on the Beijing-Tianjin-Hebei (BTH) region) frequently experiences heavy particulate matter pollution events (Cheng et al., 2019). Among the cities in the NCP region, Handan, a medium-sized city situated on the edge of Hebei, exhibits pollution levels almost twice as high as the average of the province (Yang et al., 2018). Livestock farming is the largest source of agricultural NH_3 emissions in the Hebei region. It shoulders a substantial burden of production tasks, and with its rapidly growing economy, there is a continuous rise in demand for products, prompting the intensification of livestock farming (Cheng et al., 2021). Consequently, the region faces the challenge of managing significant amounts of manure, urine, and sewage, generated concurrently and intensively (Shi et al., 2022).

Animals excrete most of the nitrogen and phosphorus from their diets into feces, and dumped animal manure becomes a source of nitrogen. Main sources of excess nitrogen include the inefficient application of fertilizers and improper disposal of excreta. This results in large inputs of N into the soil, atmosphere, surface water, and groundwater. Additionally, the nutrients stored in soil organic matter are easily lost through leaching (Zhang et al., 2022). As a result, they bring a series of environmental problems that require resolution, such as malodor emission, surface water eutrophication, groundwater contamination, soil acidification, etc. (Shi et al., 2022).

1.2 PROBLEM DESCRIPTION

The development context described above leads to our key issues concerning crop production and environmental sustainability.

First, the nutrient composition of manure from intensive farms often does not align with the actual nutrient demands of the local farmland, resulting in excess or wasted nutrients. Hebei Province, characterized by challenging natural conditions, faces a shortage of waste treatment facilities in most farms and has low rates of raw manure recycling (Jian & Ming, 2011). Although manure can improve various soil properties such as water retention capacity and soil fertility, the extent of its impact depends on its physicochemical properties, as well as the rate and timing of application, soil type, and climate (Mottet et al., 2017). In recent years, the intensification of agricultural and livestock practices has engendered a rise in the production of synthetic fertilizers, while farmers prefer to use chemical fertilizers rather than manure (Bodirsky et al., 2014).

In addition, there have been nutrient imbalances due to the unreasonable application of NPK in different soils. Although Hebei Province adopted an alternative approach to recycle livestock manure for synthetic nitrogen (N) fertilizer use (Zhang et al., 2020), Many farmland managers in Hebei Province lacked basic information on the characteristics of the soil, the physical properties of the manure, and the key chemicals, and also did not take into account the soil fertility utilization rate and the type of fertilizer (Zhang et al., 2020). At the same time, P and K are often overused if designed to meet the N needs of crops, leading to nutrient imbalances. Managers often focus on the value of N and neglect to consider the importance of P and K in crop nutrients (Antoniadis et al., 2015).

Furthermore, an important issue is the spatial disparity between nutrient supply and demand when implementing manure recycling measures. The potential for nutrient recycling at the county level is often subject to misestimation (Zhang et al., 2019). To control water pollution, numerous regional ranches are being relocated to northern China, with consideration given to farm reconstruction or cross-border livestock transportation to achieve spatial redistribution (Bai et al., 2019). However, these measures entail considerable time and costs. Additionally, some counties in the region also seem to suffer from nutrient oversupply due to livestock density and feeding practices (Leip et al., 2019). Previous analyses have shown that the positive correlation between nitrogen use efficiency (NUE) and crop yields is not consistently evident at the level of fertilizer replacement. Instead, the corresponding values are lower in the case of complete replacement (Zhang et al., 2020).

Finally, even though many researchers have advocated the prioritization of spatial reallocation of manure over that of livestock and poultry, the economic aspect has been overlooked in previous studies (Scarlat et al., 2018). Long-distance waste transportation involves barriers such as high transportation costs and the risk of pathogen transmission, and some remote counties are unable to obtain enough manure (Jin et al., 2020). According to a former survey of 49 livestock production areas in the north, such as Anping County, the price of manure is 40-80 yuan/ton if the nutrient content of the manure is above 8%. When the nutrient content is less than 3%, an additional fee of RMB 20 per ton is levied. The total cost is as high as RMB 696.9/ton, of which raw material purchase cost accounts for 48.54% and raw material transportation cost 14.45%. Regrettably, fertilizer distribution in this important area is virtually empty. The characteristics of manure are highly variable and can enter the environment through various loss pathways such as erosion, runoff, and leaching, posing a threat to the natural environment (Bai et al., 2018). The remediation of these further imposes a considerable economic burden.

In conclusion, the current state of technological advancements in manure recycling in Hebei Province may not fully address the challenges posed by spatial variations in nutrient supply and crop nutrient demand (Waldrip et al., 2015). There is a great deal of uncertainty about how best to balance fertilizer allocation, economic yield, nutrient use efficiency (NUE) and crop yield with environmental benefits (Dalgaard et al., 2014). Therefore, our research aims to assist relevant government agencies in adopting a cost-effective fertilizer allocation strategy that reduces reliance on chemical fertilizers, meets future agricultural nutrient demands, and mitigates ammonia and greenhouse gas emissions. To fill the gap in balancing environmental benefits and cost considerations in spatial optimization of resources.

1.3 RESEARCH OBJECTIVE

This study aims to enhance fertilizer utilization to reduce synthetic fertilizer inputs and nutrient losses through balanced fertilization and optimization of spatial distribution of fertilizers in order to make better and cost-effective management decisions. By developing a model that incorporates the economy and the environment, the results are obtained to reflect a realistic set of manure allocation and transportation investment decisions. These findings are expected to assist farm and ranch stakeholders as well as government in investing better in the future and offer valuable insights for policy design. Moreover, the results contribute to climate improvement efforts by limiting pollutant gas emissions and optimizing financial management practices in North China.

1.4 RESEARCH QUESTION

Our central research question is, “The distribution of manure at county level to optimize resource space in the most cost-effective way”. In order to answer the main research question, we proposed three sub-research questions:

- **RQ1: what is the impact of balanced NPK fertilization from manure and fertilizer through intra-county transportation without considering costs on the utilization of manure and fertilizer and the resulting NPK losses in Handan, China?**
- **RQ2: what is the impact of balanced NPK fertilization from manure and fertilizer combined with space distribution of manure through inter-county transportation without considering costs on the utilization of manure and fertilizer and the resulting NPK losses in Handan, China?**
- **RQ3: What is the impact of combining balanced NPK fertilization and manure distribution through inter-county transportation with considering costs to optimize nutrient use and reduce NPK losses in Handan, China?**

We use an optimization model to analyze the economic and environmental impacts of the above measures. Environmental costs were not specifically mentioned in the question. However, this study's focus on enhancing NPK utilization primarily involves recycling manure to mitigate nutrient runoff and enhance resource efficiency. This approach inherently diminishes the likelihood of residual nutrients being discharged into the atmosphere, sewage systems, and other environmental compartments. Furthermore, it results in a decreased reliance on chemical inputs, reduced erosion rates, and the fostering of soil health. These are all improved environmental benefits. Therefore, the balanced fertilization mentioned in the question to increase nutrient use is also a sideways way to reduce environmental costs. The model needs to strike a balance between minimizing total transport costs and maximizing environmental benefits. It is a multi-objective mathematical model that takes into account factors such as flow of manure, cost, and efficiency. The absorptive capacity of farmland, transport distance and topography are all important factors in the optimization model.

Three RQs explored the economic and environmental impacts of different levels of animal manure recycling and distribution methods. The "economic optimum" is achieved when manure application rates reach a point where the marginal cost of additional manure application is the same as the additional revenue from increased harvests (Leip et al., 2019). In counties where the demand for manure cannot be precisely met, a division between surplus and deficit counties arises. This necessitates the transportation of manure from one county to another while ensuring targeted application to specific crops, thereby minimizing nutrient wastage within each area. Merely considering the manure demand of each county overlooks important factors like distance, urgency, scarcity, and surplus between counties. These factors encompass environmental, time, and economic costs. Therefore, an optimal solution is required that considers the collective costs of both manure utilization and distribution, allowing for an efficient and optimal distribution of manure.

In RQ1, we restricted our study to the county level and assessed the maximum fertilizer utilization potential of each county under balanced fertilization conditions, i.e., the maximum amount of NKP elements required by the soil in each of the 16 counties in Handan, China. In RQ2, we explored the potential for maximizing manure utilization with balanced fertilizer application and manure allocation in counties within Handan City. In RQ3, we investigated strategies for manure distribution that would ensure that costs are kept as low as possible while simultaneously addressing the requirements of Handan's counties in balancing manure application and improving nutrient use utilization. In addition, we compare the three RQs two by two for a detailed discussion

In reality, it is difficult to change the distribution of livestock, so prioritizing changes in the distribution of livestock manure is considered to be the most appropriate measure and the most effective way (Zhu et al., 2022). Effective management strategies must take into account the diverse environmental constraints and the capacity of farmland. This study needs to reconnect livestock and farmland production, and low transportation costs will be the crucial aspect of this study.

2. STUDY REGION AND DATA SOURCES

2.1 STUDY REGION

The city of Handan is situated in the densely populated North China Plain region, with geographical coordinates of 114°28' 4" East longitude and 36°36' 2" North latitude (Yang et al., 2018). Its altitude of 66 meters (216.54 ft) above sea level, coupled with a temperate monsoon climate and open terrain, provides a favorable environment for sustained agricultural and livestock development (Yang & Liu, 2020). Handan's GDP reached US$45.6 billion in 2015, ranking fourth in Hebei Province (Yang et al., 2018). Despite its economic productivity and well-developed transportation, Handan faces challenges due to poor natural conditions caused by emissions from heavy industries. The area contends with heavy atmospheric pollution and soil contamination from heavy metals and sediment deposition (Zhang et al., 2021). This study aims to address and mitigate the environmental-economic contradiction in this region.

This study was supported by researchers from China Agricultural University. It focuses on 16 county-level jurisdictions within Handan City, Hebei Province, Northern China, namely Daming, Guangping, Chenganxian, Quzhou, Qiuxian, Jize, Linzhang, Shexian, Guantao, Cixian, Weixian, Handanxian, Yongnian, Feixiang, Fengfengkuangqu, and Wuanshi. These counties, equal in the administrative hierarchy, are collectively considered as 16 counties for uniform analysis.

This study is divided into two main parts: intra-county and inter-county. Many managers first focus on intra-county transportation. In each county, we focus on six animals on the livestock side (Dairycow, Beefcow, Pig, Sheepgoat, Broiler, Layer), and six crops on the farm side Cereals, Vegetables, Fruits, Tubers, Oilcrops, Cotton). Each county's soil system necessitates different fertilizer quantities.

Figure 1. Satellite image of Handan city captured in 2023

Source: Chinese Bigemap GIS Office

2.2 DATA SOURCES

The data are mainly derived from China Statistical Yearbook(*China Statistical Yearbook*, 2021), China Statistical Database, China Agricultural University Database, and Hebei Provincial Statistical Yearbook. The China Statistical Yearbook is an authoritative and comprehensive publication that offers statistical data on various aspects of China's economy and society. It plays a crucial role in providing accurate and up-to-date statistical information. To better fit the reality of the data, we have used 2019 statistics, which reflect the situation in Hebei Province in 2018.

We have three important components in environmental and economic assessment, i.e., crop cultivation, animal husbandry, and transportation. The first step in modeling GAMS includes creating a consistent and comprehensive database. See Appendix I for raw data details.

2.2.1 FARM DATA

1. Crop type and sowing area: the specific crops grown on the farm (Cereals, Vegetables, Fruits, etc.), and the area of land allocated for growing each crop. These data are crucial for determining the overall size of the farm.

2. Yield Targets: In this step, we gather information on the average yields, the current yields, and the potential to increase yields of different crop types. These give an estimate of the desired yield target for each crop, not only the current yield but also the desired target yield. These are the benchmarks for the later assessment of crop requirements.

3. Nutrient Requirements: Nutrient requirements for nitrogen (N), phosphorus (P), and potassium (K) for each crop at optimum growth and development. This requires coefficients for crop NPK requirements and NPK uptake coefficients for different crop types.

4. Soil fertility: Soil analysis includes soil fertility level, soil fertilizer deposition, and fertilizer input rate coefficients. Different soil fertility NPK are divided into 3 levels, the higher the fertility, the relatively low demand. Soil fertilizer deposition is the amount of NPK deposited in the soil, kg/ha, which is part of the waste and needs to be replenished. Fertilizer input rate coefficients help calculate the coefficients of SOMN (soil organic matter nitrogen) input, which are divided into low (L), medium (M), and high (H) levels (kg/ha). i.e., the ratio of the three elements of NPK being absorbed. Combining the nutrients supplied and recycled by the soil with the nutrient requirements for crop growth allows us to calculate the actual nutrient input needed.

2.2.2 LIVESTOCK DATA

For the livestock component, for providing the manure end of the spectrum. To calculate the actual amount of manure available we can obtain the following data:

1. Livestock type, number and growth period: This includes the type of livestock available (e.g. Dairycow, Beefcow, Pig) and the total number of animals in each category. Different animals have varying growth periods and growth rates, which help determine the potential amount of manure produced.

2. Manure solid-liquid ratio and excretion coefficient: The four manure types can be divided into two main types, each requiring separate consideration due to differences in solid-liquid excretion rates, even within the same animal species. Different livestock breeds have different average fecal productivity, which depends on the manured excretion rate. The fecal excretion coefficient is a parameter for the proportion of nutrients ingested by an animal that is excreted

through the feces since we know that not all nutrients ingested by an animal are excreted as manure. It helps quantify the nutrient content of manure.

3. Nutrient NPK content and extraction rate in manure: Nitrogen, phosphorus, and potassium are crucial elements in manure. Data on their percentages aid in assessing potential nutrient management and environmental concerns. We can also obtain The ratio of NPK recovery of different manure types to calculate the amount of nutrients we can recover from manure. Coefficients for calculating the availability of manure nutrients (N, P, K) are used to determine the actual usage of NPK nutrients when utilizing manure.

4. Losses in the extraction process of the system: Manure losses within the system mainly occur during the Housing, Storage, and Treatment stages. These losses are manifested in the form of gases and leaching.

2.2.3 TRANSPORTATION DATA

1. County Location and Distance: This data includes the arrangement of the 16 counties in Handan City and the distances between each pair of counties, which affects the overall transportation distance and influences fuel consumption and travel time.

2. TransCost: Transportation involves a lot of costs such as the cost of fuel, the efficiency of the vehicles or fuel consumption rate, and vehicle wear and tear rate of these factors with the change of distance, we unified it into Transport cost.

3. Manureprice: Market prices of different types of manure

For detailed data and parameter definitions, please refer to the appendix. Additionally, the definition of parameters in the GAMS (General Algebraic Modeling System) can be found in the appendix. Specific arithmetic methods and formulas used in the study are outlined in the methodology chapter.

3 . THEORETICAL BACKGROUND

3 . 1 SPECIAL PROPERTIES OF MANURE

Manures have some special properties that distinguish them from ordinary fertilizer materials. First, they are not only enriched with NPK nutrients essential for plant growth (Gong et al., 2020), but they also serve as a soil amendment (Urra et al., 2019). Organic matter (OM) in manure contributes to soil health and resilience thereby increasing crop yields (Urra et al., 2019). They increase soil OM content (thus improving porosity, aeration, water holding capacity), structural stability and nutrient utilization. At the same time, they stimulate microbial activity and biomass, enhancing soil fertility by improving soil aggregation over time.

Many feeds in modern pastures contain antibiotics that are excreted due to the malabsorption of animals. Consequently, the feces serve as carriers of antibiotic-resistant bacteria and antibiotic-resistance genes (ARGs). The diverse microbial communities such as bacteria, fungi and protozoa in manure contribute to nutrient cycling and overall ecosystem functioning in the soil (Zhu et al., 2013).

Meanwhile, manure has a porous structure, abundant surface functional groups and cation exchange capacity, which influence the migration of metal ions and organic pollutants in the environment through adsorption reactions (Sun et al., 2022). These attributes render manure suitable as a medium for pollutant removal and as an adsorbent for soil remediation, e.g. derived from cow manure can better remove heavy metals from aqueous solution simultaneously (Sun et al., 2022).

Furthermore, manures possess the valuable characteristic of slow and continuous nutrient release, making them ideal candidates for slow-release fertilizers. They can steadily supply nutrients to the soil over an extended period, thereby reducing losses caused by leaching and volatilization (Shaji et al., 2021). Additionally, they contribute to the reduction of N_2O fluxes (Ball et al., 2004).

These specific properties of manure emphasize its importance for building sustainable and resilient agricultural systems.

3.2 MANURE AS A NATURAL RESOURCE & AN ECONOMIC COMMODITY

Manure holds dual significance as both a natural resource and an economic commodity (Khoshgoftar Manesh et al., 2020). As a natural resource, it serves as a valuable source of organic matter and essential plant nutrients, effectively enhancing soil quality and nutrient balance (Kleinman et al., 2017). Manure also has ecological benefits and can provide ecosystem services. These include supporting agroecosystem biodiversity, increasing soil surface coverage, reducing ineffective nutrient runoff, optimizing atmospheric balance within farming systems, and providing biological control (Leip et al., 2019). Frequently, manure can also exhibit characteristics of a potential pollutant. But this is based on it not being fully utilized as a natural resource. So the major attribute this still belongs to its natural properties. In this study, the main consideration is to utilize more of its ecological service providing side, which will naturally mitigates its potential impact as a pollutant side by side.

Simultaneously, due to its economic value and potential uses, manure can be considered an economic commodity. To attain the status of a "commodity," it must be exchangeable and hold value. Although manure is not directly consumed by humans or used as a raw material for manufacturing goods, it serves as an input for crop production and is frequently traded at considerable prices. So it makes sense to think of manure as a by-product of pork. But as a commodity chain manure is still in the nascent stage of localization (Colson & Boutonnet, 2006).

In addition, manure can generate income in different forms: Firstly, manure holds a market value and a shadow price. Previous studies have proposed theoretical approaches to define nutrient demand based on nutrient response curves to economic and physical optima. The pricing of manure is dependent on the value they place on the nutrients needed to meet crop production. Ranchers can trade manure for profit, while farmers can use manure as a fertilizer to replace synthetic fertilizers, thereby reducing input costs (Sharara et al., 2018).

Furthermore, manure can serve as a source of bioenergy which is one of the alternative sources of "renewable energy". For example, anaerobic digestion can convert manure into biogas for electricity generation (Khoshgoftar Manesh et al., 2020).

In practice, economic revenues from manure can also be the product of regulatory policies (Leip et al., 2019). Localities that dispose of manure as waste and violate environmental regulations are subject to fines. Implementing proper manure management practices can reduce liabilities and penalties for farmers (A. Janzen et al., 1999).

However, previous literature has shown that the value generated by manure as a substitute can exceed the cost of waste management (Wilkinson, 1979). The value of animal manure per ton applied is usually inversely proportional to its water and carbon content. Its application to the field can increase crop productivity, resulting in higher-value agricultural commodities and potentially higher profits (Sharara et al., 2018). Previous studies have utilized nutrient concentrations of manure along with production costs and revenues to determine the monetary value of manure testing, revealing its economic benefits (B. Regan & S. Andersen, 2014). This is a feature of the figurative monetary valuation of manure as an economic commodity.

In summary, the treatment and regulation of manure offer promising approaches, and an important challenge is selecting the most cost-effective combination of technologies (A. Janzen et al., 1999).

3 . 3 ENTRY POINTS FOR QUANTIFYING EFFICIENCY OF MANURE

The effective management of manure nutrients requires a balance between ecological and economic factors in a homeostatic state (A. Janzen et al., 1999).To quantify and evaluate the environmental and economic benefits of manure, we need to find entry points that can be quantified as reflecting the utility function.

Manure use: Increasing manure application leads to a corresponding decrease in chemical fertilizer use, which is considered an environmental utility (De Rosa et al., 2022). This reduction in chemical fertilizers benefits soil health, agricultural efficiency, yielding cleaner and more sustainable agricultural practices (Šarauskis et al., 2021). Manure maintenance is often associated with application rates many times greater than those required to supplement synthetic fertilizers (De Rosa et al., 2022). Maximizing the rate of manure application under practical conditions can greatly benefit the environment (Šarauskis et al., 2021). Thus, the amount of manure used is a critical parameter for analysis.

Nutrient use (Nuiuse): Apart from the quantity of manure applied, the proper utilization of the nutrients in the manure is also an important part of the assessment. Ensuring healthy soil that supplies the necessary nutrients to crops is important for achieving optimal yields. Maintaining nutrient balance allows for the recycling of crop-consumed nutrients back into the soil through manure (Šarauskis et al., 2021). However, if not managed properly, this can result in nutrients not being taken up due to over-fertilization. These can lead to negative environmental impacts such as field leaching, contamination of groundwater, and more overhead costs (Fleming & Long, 2002). By combining economic and ecological analyses, the ecological benefits of nutrients in manure can be retained, their economic value captured, and ecological and economic goals achieved (A. Janzen et al., 1999). Thus, the amount of nutrient NPK used is an important point to analyze.

Cost: Recycling manure must consider the economic feasibility of an application. While manure is more expensive than synthetic fertilizers, farmers may not choose to utilize manure if the overall cost of adopting organic manure throughout the supply chain is prohibitively high. Despite its reduced environmental impact, economic support may be required to incentivize manure adoption (Šarauskis et al., 2021). So we need to keep costs as low as possible both in the price of the applied manure itself and in transportation consumption. It should be noted that sometimes the purchase and transportation of composted manure can be three times more costly and create a greater economic burden compared to just recycling within county. But given the substitution value and slow release of manure nutrients over time, the various potential benefits from a long-term application are still economically beneficial if one does not seek to close the financial gap in the short term. Therefore how the upfront policy arranges the spatial redistribution scheme of manure is very important (De Rosa et al., 2022). Thus, the total cost of manure itself and transportation is an important point to analyze.

4 . MODEL STRUCTURE AND SCENARIOS DESIGN

4 . 1 MODEL-BASED

This research will use the modeling software GAMS (General Algebraic Modeling System). This requires translation of the model into GAMS code. the GAMS software is particularly helpful because it can calculate shadow prices, build optimality problems, etc. This is useful for analyzing the impact of constraints (price, transportation, distance, production). The model aims at minimizing the cost of manure distribution through the cost of different measures in manure management. Various constraints are first established, and this study focuses on the constraints imposed on transportation. The data used in the study were obtained from the National Bureau of Statistics - China Statistical Yearbook - National County Statistical Yearbook - Local Statistical Website - Statistical Database of Handan City, Hebei Province (*China Statistical Yearbook*, 2021). The specific data types will be mentioned in the following methodology, and the specific values will be added in the appendix in the form of Excel tables.

In realistic situations, crop response curves are difficult to obtain. For manure economic optimal NUE, a pragmatic approach is to use default loss rates from the IPCC (Eggleston et al., 2006) or LEAP (Savelli et al., 2019) guidelines in combination with on-farm environmental conditions, or to use representative loss rates measured or modeled for representative conditions to obtain standard application rates manure nutrient (Leip et al., 2019). It is estimated by the difference between crop uptake and losses and plays the role of a measure.

It has been shown that moderate replacement of N fertilizer by manure can reduce N_2O emissions in paddy soils (Shang et al., 2011). In the meantime, because it improves soil structure, water-holding capacity and microbial activity, it increases the nutrient uptake capacity of the crop roots, leading to an increase in crop yield and a significant increase in the efficiency of N use (Liu et al., 2010). Secondly, the additional supply of mineral nutrients such as potassium and phosphorus is also responsible for the increase in yield with crops(Gil et al., 2008). Therefore, NPK are important elements that plays a role in the manure replacement of the fertilizer link. In this study, we then specified the upper limit of NPK required for crop production in all counties as the maximum potential for manure nutrient utilization under balanced fertilization. When the maximum utilization of manure nutrients is satisfied in all counties, the problem is to minimize the cost.

4.2 MODELING OF RQ 1

For RQ1, Maximizing manure use within county is based on balanced N, P, K fertilization, and there is no manure transportation across counties.

The answer to this research question is a fundamental premise for solving the cost problem. Balanced fertilization refers to the proper supply of all nutrients throughout the growth of a crop. Microscopically, crops require large amounts of N, P, and K. Applying plant nutrients in adequate amounts and optimal proportions is called "balanced fertilization". PK are non-renewable resource, and future production of chemical fertilizers to supplement PK is more difficult. Because they are mined from finite reserves in the earth's crust and are not easily replaced or regenerated on human timescales (Roberts & Stewart, 2002). So we should give priority to manure in the application of fertilizers to prioritize the use of PK in natural resources. Replacing PK with manure will contribute to the slow depletion of N that will be consumed in the production process, and we will supplement with chemical fertilizers for the shortage(Zhang et al., 2019). Each farm has a location of economic optimum and physical optimum, once this point is exceeded, manure becomes surplus. So, for each farm, you can't input too much manure at one time. In the actual problem, we need to find the point of balance between the nutrient supply of manure fertilizer and the nutrients required for the back-end mineral to replace the above optimal point (Leip et al., 2019)

This question involves calculating how much manure is available in each county. On the manure production side, We need to calculate the nutrients（NPK） supplied by manure in each county

$Manure_i\,supply$ = Available-Solid + Available-Liquid =Number of animals x Feces_Excretion x GrowthPeriod x Soliduse + Number of animals x Urine_Excretion x GrowthPeriod x Liquiduse

In this case, i indicate manure types (liquid, solid, compost, digestion). Available-Solid contains available solid and compost. Available-Liquid contains available liquid and digestion.

$Nutrient\,supply$ = Recovered nutrients in manure (solid, liquid, compost, digestion) = N, P, K in manure extraction - N, P, K loss in manure collection and treatments.

In this case, i indicate manure types (liquid, solid, compost, digestion)

- Because the volume of manure excretion (feces and urine) = Number of animals × Growth period × Coefficient of manure excretion (kg/head/d)
- Nutrients in manure = Volume of manure excretion × N, P, K content in manure
- N, P, K loss in manure collection and treatments = N, P, K in manure × Ratio of manure treatments (solid-liquid separation, storage, composting and anaerobic digestion) × Coefficients of N, P, K loss (NH3, N2O, NOx, N, Pleaching and Kleaching)

So: $Nutrient\, supply$ = Number of animals × Growth period × Coefficient of manure excretion (kg/head/d) × N, P, K content in manure- N, P, K in manure × Ratio of manure treatments (solid-liquid separation, storage, composting and anaerobic digestion) × Coefficients of N, P, K loss (NH_3, N_2O, NO_x, N and P leaching)

In this formula, “Coefficient of manure excretion (kg/head/d)” is Excretion for manure and urine, equivalent to the amount of manure excreted per animal per day. Number of animals is refers to the number of different species of animals in each county that are in livestock ranches in a year. Growth period is the number of days an animal can be alive in a year. When calculating the total direct output of manure, multiply the number, growth period, and coefficient corresponding to each animal, and then add up the output values corresponding to the six animals.

In this case, we selected six types of animals in each county. Our Anicategories are Dairycow, Beefcow, Pig, Sheepgoat, Broiler, and Layer.

Four types of animal manure were selected for each species: solid, liquid, compost, digestion

And the four manure types are subdivided into two major categories: solid and liquid

Soliduse: Solid, Compost；Liquiduse: Liquid, Digestion

Also we have the growth period of 6 animals and the amount of their solid-liquid excretion during the period. Then we can calculate the amount of solid-liquid all excretion during the cycle of 6 animals in each county.

There are three channels of loss of Nitrogen, Phosphorus, and Potassium (NPK) from manure during this period: Housing, Storage, Treatment

Nloss_Housing：NH_3, N_2O, N_2

Nloss_Storage：NH_3, N_2O, N_2, Nleaching

Nloss_Treatment：Compost, Digestion of NH_3, N_2O, N_2, Nleaching

Ploss_Housing：Pleaching;

Ploss_Storage：Pleaching;

Ploss_Treatment：Pleaching;

Kloss_Housing：Kleaching;

Kloss_Storage：Kleaching;

Kloss_Treatment：Kleaching;

From this, we can get Manure_availability: Also refers to " Mineralizable Factor value" (MFV). Mineralizable elements refers to the portion of elements in manure that can be converted into plant-available forms through microbial decomposition in the soil. MFV is the mineralizable proportion of the corresponding element in the manure.

At the same time, we have Content_Feces, Content_Urine: NPK nutrient content that can be supplied in manure, From this we can calculate the NPK nutrients supplied by manure at the front side of each county. Substituting the data into the above equation, we can calculate the $Manure_i\ supply,\ Nutrient\ \ supply.$

On the farm side, We need to calculate the nutrients required to produce the corresponding yield of the crop

Crop Demand= Crop yield × Uptake factors of N, P, K × Coefficients of fertilizer N, P, K uptake – (Soil N, P, K supply –SoilN, P, K deposition)

In this case, we selected six types of crops in each county: Cereals, Vegetables, Fruits, Tubers, Oilcrops, Cotton.

we have yield targets and sownarea. The total production of each plant per county can be calculated. Then we have nutrient demand (Nuidemand): The required amount of NPK for 6 types of crops. We can get the nutrient content required by the crop.

Each county has different soil nutrient contents and different atmospheric deposition. Both of them also supply the nutrients required for crop growth. So when we calculate the amount of external nutrients required for crop growth we have to subtract the soil nutrient content (excluding the deposition) because they are already present in the farm system and can be supplied directly. The difference between the nutrients required by the crop and the nutrients available in the soil is the amount of nutrients that need to be supplied by manure. The difference between the nutrients required by the crop and the nutrients available in the soil is the amount of nutrients that need to be provided by manure. Substituting the values in the database in the above formula, we can calculate Crop Demand.

This operation can also be applied to RQ2, RQ3 $\mathrm{Manure_i\ supply,\ and\ Crop\ Demand.}$

So the objective function is:

Step 1: Min z $=\sum_{i}^{n}(\text{Manure}_i\ \text{supply} - \text{Manure}_i\ \text{use})$

Constraints are:

$$\sum_{i}^{n}(\text{Manure}_i \times k_i^N \times MFV_i^N) \leq \sum_{r}^{m}(\text{Crop Demand}^N)$$

$$\sum_{i}^{n}(\text{Manure}_i \times k_i^P) \leq \sum_{r}^{m}(\text{Crop Demand}^P)$$

$$\sum_{i}^{n}(\text{Manure}_i \times k_i^K) \leq \sum_{r}^{m}(\text{Crop Demand}^K)$$

In this case, i indicates manure types (liquid, solid, compost, digestion), n indicates 4 types of manure. r indicates cropcategories, m indicates 6 types of crops. $k_i^{N, P, K}$ is the content of N, P, K in Manure_i, MFV_i^N is the Mineralizable Factor value. And"Crop demand" refers to the nutrient need at target yield in the original data. z means the differences between supply and use. Because the values of MFV_i^P and , MFV_i^K are both 1, so the above is omitted. In this case, we need to minimize the differences between supply and use.

The constraints mean: The sum of N, P, K elements in manure nutrients in each county cannot exceed the corresponding N, P, K requirements for crop growth: Volume of manure × N, P, K content of manure × N, P, K effect coefficients ≤ Crop N, P, K requirements

The specific operation is:

From this, we can calculate Manure_i use under various restrictions

And different types of manure usually face different treatment fates. Many manures are stored in local storage tanks or anaerobically digested to produce biogas for direct local reuse. This is for operational convenience, but also because the bioenergy potential in many manures is lost during the collection and transport of the material (Wang et al., 2021).

Based on the information in the database, it was possible to calculate not only the maximum use of manure nutrients to meet the needs of all counties but also the N, K, and P needed for crop production in each county. this involved having surpluses and deficits of manure in the 16 counties.

4.3 MODELING OF RQ 2

For RQ2, Maximizing the manure use by balanced fertilization and manure distribution among counties.

The potential for manure utilization varies within each county, with some counties having a surplus of manure and others having a shortage, so it needs to be distributed among the counties of Handan. Without changing the total amount of fertilizer available, fertilizer from surplus counties is delivered to crops in deficit counties. In this problem, transportation costs are not considered, and only balanced manure application needs to be satisfied in all 16 counties studied within Handan City. By calculating the manure application potential in Handan City, the cost of assuming that this ideal situation is met can be estimated.

This step also ensures that balanced fertilization is a prerequisite, so the logic used in the first step applies to this step as well. The difference is that according to the previous step, we divide the counties into surplus and deficit counties.

As in the previous step, still with six animals and six crops, we need to ensure that the overall manure nutrients remain the same for the 16 counties, only transported between the 16 counties.

For Surplus County, we named county c. When the supply county manure supplies the county's crop nutrient needs, manure available from Scounty we name $\text{Recovered manure}_c$.

The calculation method of Manure_i supply and Crop Demand refers to RQ1

So the objective function is:

Step 2: Min z =

$$\sum_{c}^{n}(\text{Manure}_c \text{ supply } - \sum_{d}^{m}\text{Manure}_{c,d} \text{ use})$$

In this case, c indicates the counties of manure supply, d indicates the counties of manure demand, n indicates 13 (number of Scunty), and m indicates 3 (number of Dcounty). $\text{Manure}_{c,d}$ is the amount of manure transported from c to d. Manure c supply is the known amount of manure that can be supplied from supply county c. Manure c,d use is the location variable that can be solved based on the constraints, i.e. the amount of manure that can be transported from supply county c to demand county d (c can be equal to d) The ultimate goal is to minimize the manure surplus in supply county c.

Constraints are:

$$\sum_{c}^{n}\sum_{d}^{m}\mathrm{Manure}_{c,d} \geq 0$$

$$\sum_{c}^{n}\left(\sum_{d}^{m}\mathrm{Manure}_{c,d}\right) \leq \sum_{c}^{n}\mathrm{Recovered\ manure}_{c}$$

$$\sum_{c}^{n}\sum_{d}^{m}\left(\mathrm{Manure}_{c,d}\times k_{c,d}^{N}\times \mathrm{MFV}_{c,d}^{N}\right) \leq \sum_{d}^{m}\mathrm{Crop\ Demand}_{d}^{N}$$

$$\sum_{c}^{n}\sum_{d}^{m}\left(\mathrm{Manure}_{c,d}\times k_{c,d}^{P}\right) \leq \sum_{d}^{m}\mathrm{Crop\ Demand}_{d}^{P}$$

$$\sum_{c}^{n}\sum_{d}^{m}\left(\mathrm{Manure}_{c,d}\times k_{c,d}^{K}\right) \leq \sum_{d}^{m}\mathrm{Crop\ Demand}_{d}^{K}$$

In this case, c indicates the counties of manure supply, d indicates the counties of manure demand, n indicates 13, and m indicates 3. $\mathrm{Manure}_{c,d}$ is the amount of manure transported from c to d. $\mathrm{Manure}_{c,d}$ here refers to sum of different types of manure. In the direct results running with GAMS, it is distinguished between manure types, but it is more convenient to aggregate across manure types in the final analysis.And"Crop demand_d" refers to the nutrient need at target yield in demand county.

The Constraints mean: Manure is distributed according to the mode of transport, and the sum of N, P, and K elements in manure nutrients in all counties in Handan cannot exceed the corresponding N, P, and K requirements for crop growth.

4.4 MODELING OF RQ 3

For RQ3, Maximize cost-effectiveness by balancing fertilizer application and manure distribution among counties.

The answer to this research question is the most important part of accomplishing the research objectives. Since the needs and distances vary from county to county, how to allocate the amount of manure transported and the corresponding delivery distances at the least cost to achieve the best overall benefit is the primary question to be considered in manure distribution. This question is intended to provide a clear answer to investors in farms and ranches as well as government management-related authorities. Analyzing and comparing cost changes, harvesting benefits, and environmental benefits with the results of the first two questions and evaluating the respective impacts can provide an integrated and cost-effective management plan.

As in the second question, we are still divided into surplus and deficit counties, involving transportation before counties. But in this step, we need to consider the cost. The calculation method of Crop Demand refers to RQ1.

So the objective function is:

Step3: Minz =

$$\sum_{c}^{n}\sum_{d}^{m} \mathrm{Manure}_{c,d} \times (\mathrm{Manure}_{c}\mathrm{price} + \mathrm{Tansportation\ Cost}_{c,d} \times \mathrm{Distance}_{c,d})$$

In this case, c indicates the counties of manure supply, d indicates the counties of manure demand, $\mathrm{Manure}_{c,d}$ is the amount of manure transported from c to d.

We have:

TransCost：Compost is suitable for transportation.

Manure_{c}price: Market price of each type of manure in Surplus County

All these costs we have to take into account.

Constraints are:

$$\sum_{c}^{n}\sum_{d}^{m} \mathrm{Manure}_{c,d} \geq 0$$

$$\sum_{c}^{n}\left(\sum_{d}^{m} \mathrm{Manure}_{c,d}\right) \leq \sum_{c}^{n} \mathrm{Recovered\ manure}_{c}$$

$$\sum_{c}^{n}\sum_{d}^{m} (\mathrm{Manure}_{c,d} \times k_{c,d}^{N} \times \mathrm{MFV}_{c,d}^{N}) \leq \sum_{d}^{m} \mathrm{Crop\ Demand}_{d}^{N}$$

$$\sum_{c}^{n}\sum_{d}^{m} (\mathrm{Manure}_{c,d} \times k_{c,d}^{P}) = \sum_{d}^{m} \mathrm{Crop\ Demand}_{d}^{P}$$

$$\sum_{c}^{n}\sum_{d}^{m} (\mathrm{Manure}_{c,d} \times k_{c,d}^{K}) \leq \sum_{d}^{m} \mathrm{Crop\ Demand}_{d}^{K}$$

16 inter-county distances are fixedly known in the database. And"Crop demand_{d}" refers to the nutrient need at target yield in demand county. Transportation Cost is also affected by distance. The functional relationship between distance and Tansportation Cost is：

$$\text{Transportation cost} = \text{Tc} = \tau + \text{pd}$$

In this case, τ is fixed cost, and p is the price of fuel consumed per unit distance transported. d is Distance. With different transportation distances, there will be different additional consumptions, such as transportation tool costs, depreciation rate costs of tools, risk costs, etc., which will have different corresponding values depending on the distance. The specific values need to be investigated in the study.

The above formula allows us to calculate $\text{Manure}_{c,d}$. When manure has been distributed at a minimal cost, counties with insufficient manure are supplemented with chemical fertilizers. From RQ1 we know the required nutrient content of each county, minus the content of each county after manure distribution, which is the amount of fertilizer supplement required. Multiplying this by the unit price of fertilizer, we can get the cost of fertilizer supplementation. Including the minimum cost of the previous manure distribution, this is the total cost considered for RQ3. But we don't need to pay much attention to the cost of supplemental fertilizer. Because the cost of fertilizer is much less than the cost of manure(Hara, 2001). RQ2 focuses only on the overall use of manure in 16 counties, while RQ3 only needs to ensure that the cost of the step of manure distribution is minimal, then the final total cost is usually less than the case of RQ2.

RQ1 and RQ2 both have to ensure the maximum potential of manure under balanced fertilization, only one is within the county and one is within all the study counties in Handan, so the formula is the same, but the constraints are different. RQ2 and RQ3 both involve the transportation of manure in sixteen counties, only one is considering the maximum potential of manure and the other is considering the comprehensive cost-effectiveness, so the constraints are the same but the formulas are different.

5. RESULTS

Utilizing the previously mentioned raw data, the important intermediate data are calculated, following which we can solve the model using GAMS. The obtained results will be thoroughly analyzed in the subsequent sections. Refer to Appendix I for details of the raw data and the meaning of the corresponding parameter. It is worth noting that all data used in this study are sourced from official literature and statistical yearbooks. However, the model employed herein simplifies the actual situation, consequently yielding relatively idealized scenarios for comparing the results in different settings.

5.1 INTERMEDIATE DATA

Table 1 shows the important data intermediate data. Avaimanure at the ranch end, i.e., available volume of solids and liquids, t. In the statistics, the total gain in manure was calculated as the total output of manure from the animals minus the total losses in the process. The total amount of manure gained by all types of manure from all animals in the 16 counties was 24970412 tons. This total gain comprised 18,501,605 tons of solids and 6,468,807tons of liquids. Notably, the total amount of solids was approximately 2.86 times higher than the total amount of liquids. This difference suggests that solids are more advantageous for later distribution, given their greater ease of transportation compared to liquid forms.

Table 1. Amount of manure available per county (t)

County	Anicategories	Manuretypes			
		Solid	Compost	Liquid	Digestion
Daming	Dairycow	16353	9604	7574	2013
Daming	Beefcow	230959	213193	185168	
Daming	Pig	334567	213903	460252	197251
Daming	Sheepgoat	632152			
Daming	Broiler	20308	30462		
Daming	Layer	148374	222561		
Guangping	Dairycow	8994	5282	4166	1107
Guangping	Beefcow	12004	11081	9624	
Guangping	Pig	51263	32775	70521	30223
Guangping	Sheepgoat	98999			
Guangping	Broiler	6506	9759		
Guangping	Layer	47108	70662		
Yongnian	Dairycow	94846	55703	43931	11678
Yongnian	Beefcow	114759	105931	92007	
Yongnian	Pig	180825	115609	248754	106609
Yongnian	Sheepgoat	342135			
Yongnian	Broiler	30726	46089		
Yongnian	Layer	433485	650228		
Chenganxian	Dairycow	31888	18728	14770	3926
Chenganxian	Beefcow	93632	86429	75068	
Chenganxian	Pig	124532	79619	171314	73420
Chenganxian	Sheepgoat	384364			
Chenganxian	Broiler	9908	14862		

Chenganxian	Layer	107229	160843		
Quzhou	Dairycow	34341	20168	15906	4228
Quzhou	Beefcow	140208	129423	112410	
Quzhou	Pig	188611	120587	259466	111200
Quzhou	Sheepgoat	335387			
Quzhou	Broiler	29200	43800		
Quzhou	Layer	252154	378231		
Handanshi	Dairycow	89940	52822	41659	11074
Handanshi	Beefcow	27849	25707	22328	
Handanshi	Pig	80958	51760	111371	47730
Handanshi	Sheepgoat	99348			
Handanshi	Broiler	6557	9836		
Handanshi	Layer	46072	69108		
Qiuxian	Dairycow	4906	2881	2272	604
Qiuxian	Beefcow	44175	40777	35417	
Qiuxian	Pig	45363	29003	62405	26745
Qiuxian	Sheepgoat	314797			
Qiuxian	Broiler	14534	21801		
Qiuxian	Layer	110205	165307		
Jize	Dairycow	23711	13926	10983	2919
Jize	Beefcow	59540	54960	47736	
Jize	Pig	96627	61778	132926	56968
Jize	Sheepgoat	233247			
Jize	Broiler	12630	18945		
Jize	Layer	99748	149622		
Wuanshi	Dairycow	11447	6723	5302	1409
Wuanshi	Beefcow	81628	75349	65444	
Wuanshi	Pig	393471	251564	541285	231979
Wuanshi	Sheepgoat	48511			
Wuanshi	Broiler	6861	10291		
Wuanshi	Layer	77267	115901		
Feixiang	Dairycow	69499	40817	32191	8557
Feixiang	Beefcow	99874	92191	80073	
Feixiang	Pig	140346	89729	193069	82744
Feixiang	Sheepgoat	393903			
Feixiang	Broiler	10976	16464		
Feixiang	Layer	91531	137296		
Linzhang	Dairycow	19623	11525	9089	2416
Linzhang	Beefcow	170458	157346	136663	
Linzhang	Pig	177294	113352	243898	104528
Linzhang	Sheepgoat	495927			
Linzhang	Broiler	22054	33081		
Linzhang	Layer	105113	157669		
Fengfengkuangqu	Dairycow	19623	11525	9089	2416
Fengfengkuangqu	Beefcow	18726	17286	15014	

Fengfengkuangqu	Pig	144166	92172	198325	84996
Fengfengkuangqu	Sheepgoat	67008			
Fengfengkuangqu	Broiler	3405	5107		
Fengfengkuangqu	Layer	20259	30388		
Shexian	Beefcow	59060	54517	47351	
Shexian	Pig	68867	44030	94738	40602
Shexian	Sheepgoat	135179			
Shexian	Broiler	8217	12326		
Shexian	Layer	65223	97835		
Guantao	Dairycow	23711	13926	10983	2919
Guantao	Beefcow	90271	83327	72374	
Guantao	Pig	170717	109147	234850	100650
Guantao	Sheepgoat	194276			
Guantao	Broiler	40100	60150		
Guantao	Layer	424012	636018		
Cixian	Dairycow	40882	24010	18936	5034
Cixian	Beefcow	49937	46096	40036	
Cixian	Pig	126805	81072	174441	74760
Cixian	Sheepgoat	170544			
Cixian	Broiler	13298	19947		
Cixian	Layer	114640	171960		
Handanxian	Dairycow	28617	16807	13255	3524
Handanxian	Beefcow	35532	32799	28487	
Handanxian	Pig	48362	30920	66530	28513
Handanxian	Sheepgoat	77827			
Handanxian	Broiler	4768	7152		
Handanxian	Layer	20251	30377		
Weixian	Dairycow	8994	5282	4166	1107
Weixian	Beefcow	41294	38118	33107	
Weixian	Pig	202636	129554	278759	119468
Weixian	Sheepgoat	384364			
Weixian	Broiler	11723	17585		
Weixian	Layer	145605	218408		

Table 2 presents the important intermediate data Nuidemand, i.e., NPK demand of different crop types per county, t. Nuidemand refers to the required NPK in specific crop-soil system, t。As soil nutrient levels vary across counties, in calculating the soil nutrient demand in addition to the nutrients needed for the expected yield crop, the soil itself should be subtracted from the nutrients, and then the amount lost to deposition should be added. See Appendix III for details of the specific operational GAMS code. The total NPK requirements of all crop species in the 16 counties, as shown in table 2, are 213,557(t), 27,146(t), and 79,464(t), respectively. This indicates that N is a nutrient element that is much more in demand than P, K in the general state. However, this does not ignore the important role of K. In the fertilization process, we should ensure that NPK is one of the elements to meet the demand for the remaining two elements with fertilizers that can meet the single-element demand to make up.

Table 2. NPK demand of different crop types per county (t)

County	Cropcategories	Elements		
		N	P	K
Daming	Cereals	17962	1740	6658
Daming	Vegetables	3464	335	1400
Daming	Fruits	326	21	88
Daming	Tubers	4	0	2
Daming	Oilcrops	6402	482	1776
Daming	Cotton	101	8	33
Guangping	Cereals	5427	1052	2012
Guangping	Vegetables	1489	288	602
Guangping	Fruits	116	15	31
Guangping	Tubers	119	23	77
Guangping	Oilcrops	717	108	199
Guangping	Cotton	93	16	30
Yongnian	Cereals	11777	1141	4365
Yongnian	Vegetables	13743	1328	5553
Yongnian	Fruits	196	13	53
Yongnian	Tubers	49	5	32
Yongnian	Oilcrops	291	22	81
Yongnian	Cotton	48	4	16
Chenganxian	Cereals	7053	1367	2614
Chenganxian	Vegetables	3646	705	1473
Chenganxian	Fruits	338	43	91
Chenganxian	Tubers	150	29	98
Chenganxian	Oilcrops	311	47	86
Chenganxian	Cotton	877	146	283
Quzhou	Cereals	10300	998	3818
Quzhou	Vegetables	4019	388	1624
Quzhou	Fruits	215	14	58
Quzhou	Tubers	31	3	20
Quzhou	Oilcrops	281	21	78
Quzhou	Cotton	614	51	198
Handanshi	Cereals	5951	577	2206
Handanshi	Vegetables	539	52	218
Handanshi	Fruits	191	12	51
Handanshi	Tubers	17	2	11

Handanshi	Oilcrops	193	15	54
Handanshi	Cotton	33	3	11
Qiuxian	Cereals	3398	659	1260
Qiuxian	Vegetables	1792	346	724
Qiuxian	Fruits	178	23	48
Qiuxian	Tubers	36	7	23
Qiuxian	Oilcrops	94	14	26
Qiuxian	Cotton	1440	239	465
Jize	Cereals	5377	521	1993
Jize	Vegetables	4684	453	1893
Jize	Fruits	88	6	24
Jize	Tubers	14	1	9
Jize	Oilcrops	218	16	60
Jize	Cotton	126	10	41
Wuanshi	Cereals	9833	1905	3644
Wuanshi	Vegetables	1086	210	439
Wuanshi	Fruits	569	73	153
Wuanshi	Tubers	227	43	148
Wuanshi	Oilcrops	632	95	175
Wuanshi	Cotton	144	24	47
Feixiang	Cereals	8121	787	3010
Feixiang	Vegetables	5163	499	2086
Feixiang	Fruits	382	24	103
Feixiang	Tubers	67	6	43
Feixiang	Oilcrops	325	24	90
Feixiang	Cotton	537	45	173
Linzhang	Cereals	13366	1295	4954
Linzhang	Vegetables	4373	423	1767
Linzhang	Fruits	574	37	154
Linzhang	Tubers	246	23	161
Linzhang	Oilcrops	557	42	155
Linzhang	Cotton	157	13	51
Fengfengkuangqu	Cereals	1724	334	639
Fengfengkuangqu	Vegetables	172	33	70
Fengfengkuangqu	Fruits	122	16	33
Fengfengkuangqu	Tubers	28	5	18
Fengfengkuangqu	Oilcrops	16	2	4
Fengfengkuangqu	Cotton	0	0	0
Shexian	Cereals	3285	636	1217
Shexian	Vegetables	494	95	199
Shexian	Fruits	242	31	65
Shexian	Tubers	82	16	53
Shexian	Oilcrops	100	15	28
Shexian	Cotton	1	0	0
Guantao	Cereals	7517	728	2786

Guantao	Vegetables	3312	320	1338
Guantao	Fruits	233	15	63
Guantao	Tubers	43	4	28
Guantao	Oilcrops	973	73	270
Guantao	Cotton	85	7	27
Cixian	Cereals	5777	1120	2141
Cixian	Vegetables	1756	339	709
Cixian	Fruits	123	16	33
Cixian	Tubers	109	21	71
Cixian	Oilcrops	277	42	77
Cixian	Cotton	29	5	9
Handanxian	Cereals	5007	485	1856
Handanxian	Vegetables	718	69	290
Handanxian	Fruits	14	1	4
Handanxian	Tubers	105	10	69
Handanxian	Oilcrops	465	35	129
Handanxian	Cotton	44	4	14
Weixian	Cereals	15144	2935	5613
Weixian	Vegetables	2723	526	1100
Weixian	Fruits	1207	154	324
Weixian	Tubers	145	28	94
Weixian	Oilcrops	519	78	144
Weixian	Cotton	79	13	26

In Appendix II table B1 shows the data Nuicontent at the livestock end, i.e., the N, P, K content of different manure types per county, (t). It's obtained by aggregating the values from ContentSolid and ContentLiquid. ContentSolid represents the amount of nutrients available in solids relative to the total amount of solids. The specific procedure for calculating the nutrient content SolidNui is described in the methodology, and ContentLiquid provides the same information for liquids. See Appendix III for details of the specific operational GAMS code. As indicated in the table, the average values of N, P, and K content for all animals and types in the 16 counties are 0.004147705, 0.001288701, and 0.004349144, respectively. The percentage content of P is consistently lower than that of N、K in the same amount of manure. So elemental P may be the most common limiting condition when applying manure. The limiting factor for manure application is not solely based on the amount of manure itself but rather the concentration of nutrients it contains at a micro level. The Nuicontent table could not be simplified because of the excessive amount of data in the table and the need to apply the specific information of the NPK elements in it. Refer to Appendix II for the specific table.

5.2 RESULTS IN RQ 1

In RQ1, we analyzed the impact of balanced NPK fertilization on manure utilization, i.e., environmental consequences and economic costs, in the county. The results were shown as follows：

Table 3 shows the manure use, i.e., the actual manure use in each county (t). The calculation excludes transportation and aims to achieve a balanced NPK fertilizer application within each county. The total manure use across all counties was 20,625,229 t, which accounts for 82.60% of the total manure acquisition, amounting to 24,970,412 tons. The total objective function is to minimize the manure residual, which is the total residual for all counties, is 4345183 t. Although the recovery rate seems relatively high, this still results in a substantial amount of wasted resources due to the large base and the unit of measurement in tons.

Table 3. The amount of manure used per county in RQ1 (t)

county	**Manuretypes**			
	Solid	**Compost**	**Liquid**	**Digestion**
Daming	1382712	440741	652995	199264
Guangping	224875	129559	84312	31331
Yongnian	1196776	325950	384693	118287
Chenganxian	678245	360481	171314	73420
Quzhou	902386	149591	387782	115428
Qiuxian	295430	259769	62405	26745
Jize	525504	151858	191645	59888
Wuanshi	619185	459827	564671	231979
Feixiang	806129	226212	305333	91301
Linzhang	990469	337380	389650	106944
Fengfengkuangqu	173094	198325	0	84996
Shexian	201367	185373	94738	40602
Guantao	651692	97253	318206	103569
Cixian	373872	343085	174441	74760
Handanxian	215357	118054	108272	32036
Weixian	794616	408946	316032	120576
Total	10031709	4192403	4206489	1511128

Table 4 shows the actual use of the nutrient element NPK in each county area of Nuiuse, t. The total nutrient use across all counties was 169,609.87 tons, with specific usage values for N, P, and K amounting to 76,326 tons, 23,419 tons, and 69,866 tons, respectively. The realized NPK content amounts to 73.85% of the total available. The remaining nutrients are partly lost in the land along with the residual manure, and partly released into the environment after waste treatment. Another portion is subjected to solid-liquid separation and anaerobic digestion, and converted into energy gases like methane for subsequent reuse (Aguirre-Villegas et al., 2014). Although the same soil receives the same amount of manure input on the same farm, the compositional content of the nutrient elements influences the actual amount of elements absorbed. Consequently, element P exhibits the lowest actual utilization.

Table 4. The amount of NPK used per county in RQ1 (t)

county	**Elements**		
County	**N**	**P**	**K**
Daming	9831	2587	9429
Guangping	1978	658	1790
Yongnian	8430	2513	7731
Chenganxian	5238	1691	4646
Quzhou	5945	1475	5688
Qiuxian	2913	1127	2546
Jize	3705	1008	3492
Wuanshi	5740	2261	4606
Feixiang	5561	1386	5422
Linzhang	7141	1833	7016
Fengfengkuangqu	1465	751	1125
Shexian	1892	779	1563
Guantao	4321	1148	3986
Cixian	3658	1502	3041
Handanxian	1784	527	1747
Weixian	6723	2175	6037
utilization rate			Total NPK 73.85%

The following figure is a geographically graded map produced by ArcGIS, which visualizes the spatial distribution of NPK nutrient element utilization in RQ1. Nutrient use is classified into five categories, ranging from low to high, with specific thresholds shown in the list in the lower-left corner of the map. The values representing nutrient use are depicted with varying shades, progressing from lighter to darker. Beige indicates lower utilization, while light pink represents medium average values, transitioning to peach and eventually red tones, signifying higher utilization. The figure demonstrates that the overall proportion of counties falling into different utilization classes across the 16 counties is relatively balanced, that is, there exists a considerable disparity in nutrient utilization among the different counties. The distribution of color blocks in the figure appears scattered, indicating an uneven distribution of manure nutrients. Moreover, the nutrient utilization class gap is particularly evident between certain similar counties. At this time, the spatial distribution of manure exhibits irregular patterns, characterized by a sense of disorder and looseness, with distinct geographical divisions.

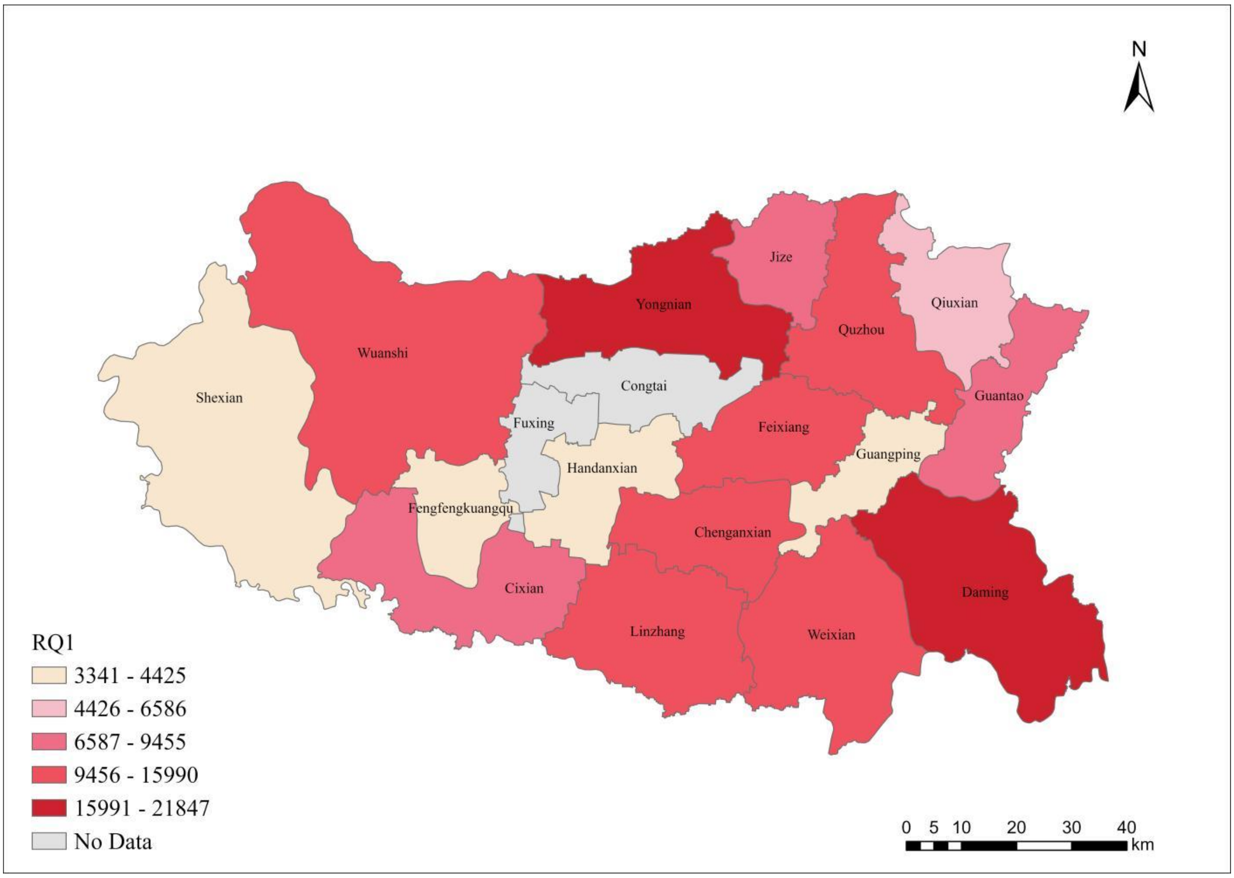

Figure 2. ArcGIS geographic classification map of NPK nutrient use (t) in Handan in RQ1

To prevent nutrient wastage, once one of nutrient element is adequately supplied through manure, further application stops to avoid surplus. This makes it possible for the manure used to be deficient or surplus in nutrients in addition to the manure that is not recycled. To address this, the distinction between supply and demand counties is based not on the remaining amount of manure but on the remaining amount of NPK nutrients in the manure. The amount of NPK remaining in the manure should be the amount of NPK supplied minus the amount of NPK actually used. Nutrient supply (Nuisupply) is shown in the Appendix.

Then subtracting the actual amount of NPK used in the 16 counties total from the amount of NPK elements for all counties in Nuisupply gives the amount of nutrient loss in RQ1. At this time, the total loss of N in 16 counties is 19718(t), P is 5987(t), K is 18525(t), and the total loss of NPK is 44230(t). It can be seen that N is the largest loss element at this time.

Table 5 below shows differences in NPK used compared to nutrient requirements, i.e., Nutrient demand minus Nutrient use. Upon satisfying crop demand for one of NPK element, manure input cessation ensues, with chemical supplementation covering residual needs. 13 counties have fulfilled singular element demand, designated as supplying counties (Scounty). Merely three counties are currently using nutrient NPKs that are not at the upper limit of growth requirements. This indicates that these three counties can still continue to apply manure, designated as demand counties (Dcounty). As seen in table 6, Daming, Yongnian, Chenganxian, Quzhou, Qiuxian, Jize, Wuanshi, Feixiang, Linzhang, Fengfengkuangqu, Shexian, Guantao, and Cixian, are designated as supply counties. On the other hand, Guangping, Handanxian, and Weixian are identified as demand counties (Dcounty). Both Guangping and Handanxian have relatively low demand, while Weixian faces an extreme nutrient deficiency and requires the most substantial amount of manure and the highest number of transportation routes during subsequent transportation.

Table 5. Differences in NPK used compared to nutrient requirements (t)

	County	Elements	
County	**N**	**P**	**K**
Daming	18428	0	528
Guangping	5983	843	1161
Yongnian	17674	0	2368
Chenganxian	7137	645	0
Quzhou	9515	0	108
Qiuxian	4025	160	0
Jize	6803	0	528
Wuanshi	6750	90	0
Feixiang	9034	0	84
Linzhang	12132	0	226
Fengfengkuangqu	597	0	190
Shexian	2311	14	0
Guantao	7843	0	527
Cixian	4413	40	0
Handanxian	4570	77	615
Weixian	13093	1559	1264

Table 6. Distinguish Supply county and Demand county

Scounty	Dcounty
Daming	Guangping
Yongnian	Handanxian
Chenganxian	Weixian
Quzhou	
Qiuxian	
Jize	
Wuanshi	
Feixiang	
Linzhang	
Fengfengkuangqu	
Shexian	
Guantao	
Cixian	

5.3 RESULTS IN RQ 2

In RQ2, we analyzed the impact of balanced NPK fertilization on manure utilization, i.e., environmental consequences and economic costs, for the 16 counties as a whole. The results were shown as follows,

Table 7 shows the manureuse, i.e., the amount of manure transported from each supply county to each supply county, irrespective of cost, (t). Note that manureuse here refers solely to the amount of manure transported from county S to county D, and not the amount of manure utilized in each county after transport as seen in RQ1. Observing table 7 below, we find that all 13 supply counties in this scenario participate in transportation, resulting in a considerable number of transportation routes. Among them, Daming, Quzhou, Qiuxian, Wuanshi, Feixiang, Linzhang, and Fengfengkuangqu are responsible for transporting manure to the three demand counties. The total amount of manure transported across all counties in this scenario amounts to 7272230 (t). Each of these transport routes involves a substantial quantity of manure, exceeding 10,000 tons, indicating the large-scale nature of this transportation program.

Table 7. Amount of manure for transportation from per Scounty to per Dcounty in RQ2 (t)

Scounty	Manureuse		
	Guangping	**Handanxian**	**Weixian**
Daming	167757	460252	597853
Yongnian	0	248754	382280
Chenganxian	0	0	276622
Quzhou	222952	259466	111200
Qiuxian	26745	62405	61906
Jize	310233	0	59540
Wuanshi	267694	541285	369203
Feixiang	209845	27762	275813
Linzhang	120736	123162	471903
Fengfengkuangqu	84996	198325	182516
Shexian	0	94738	109469
Guantao	0	0	529928
Cixian	201565	0	215323
Total			7272230

Table 8 shows Nuiuse, i.e., the actual nutrient use transported from each supply county to each demand county, t. As with Manureuse above, Nuiuse refers only to the amount of nutrients transported, not the amount used by soil in each county. The total transported nutrient use was 36,257 (t), comprising 17,804 (t) of N, 5,838 (t) of P, and 12,614 (t) of K.

However, after transportation, it is not guaranteed that the NPK elements will achieve balanced fertilization within the supply and demand counties. If the NPK elements still do not meet the nutrient content (Nuidemand) required by the growing crops in the county after transportation, additional fertilization is needed to compensate. On the other hand, if the soil nutrient content in the county meets the equilibrium state after transportation, the actual nutrient use will be equal to the demand. To calculate the number of nutrients in each county after transportation, the original number of nutrients available in the county should be used as the basis for calculating the number of nutrients to be transported, plus (in the case of demand counties) or minus (in the case of supply counties) the amount of nutrients to be transported. The actual amount of nutrient use absorbed by the soil in each county is then determined by comparing the amount of nutrients transported with the soil nutrient demand (Nuidemand) to see if the equilibrium is achieved. The smaller value between the two is defined as Nuifactuse, which is in the following table 9. After transportation, the total nutrient utilization in 16 counties is 194,792, comprising 98,593 (t) of N, 23,856 (t) of P, and 72,342 (t) of K, respectively. Then subtracting the actual amount of NPK used in the 16 counties total from the amount of NPK elements for all counties in Nuisupply gives the amount of nutrient loss in RQ2. At this time, the total loss of N in 16 counties is 3016(t), P is 9374(t), K is 22484(t), and the total loss of NPK is 34874(t). It can be seen that at this time K is the largest loss element, the loss of N element is greatly reduced, and the total loss is reduced.

Table 8. Amount of NPK used for transportation from Supply county to Dcounty in RQ2 (t)

County	**Elements**		
Scounty	**N**	**P**	**K**
Daming	3045	985	2190
Yongnian	1582	534	1105
Chenganxian	519	115	363
Quzhou	1444	490	992
Qiuxian	371	124	259
Jize	934	305	672
Wuanshi	2821	959	1918
Feixiang	1335	412	1081
Linzhang	1816	585	1326
Fengfengkuangqu	1138	382	788
Shexian	487	166	331
Guantao	1284	435	879
Cixian	1028	348	711
Dcounty	**N**	**P**	**K**
Guangping	4241	1500	2951
Handanxian	3329	604	2362
Weixian	10234	3734	7302

The following figure is a geographic transportation map created by ArcGIS that visualizes transportation between the 16 counties on the map. Transportation is categorized into 5 classes from less to more, with specific thresholds displayed in the list at the bottom left corner of the map. The direction of transportation in the map is the direction of the arrow pointing, i.e., supply county to demand county. Colors range from light to dark and cool to warm by the amount of nutrients in the manure. Blue-green tint signifies less transportation, yellow tint represents medium average values, transitioning to orange tint, and eventually, red tint, indicating the highest amount of transportation. In the figure, 8 lines are blue tones and 4 lines are red tones, which shows that the proportion of transportation lines with less transportation is larger. Specifically, Guangping and Handanxian are situated on the eastern and western sides, respectively, of the central part of the city. Both receive a similar amount of supplied NPK, 8692(t) in Guangping and 6296(t) in Handanxian. In contrast, Weixian, located on the edge of Handanxian, exhibits a high demand for nutrients. The total amount of NPK transported to Weixian is 21269(t), making it the demand county with the longest transportation route, the highest amount of transportation, and consequently, the most labor-intensive and costly process.

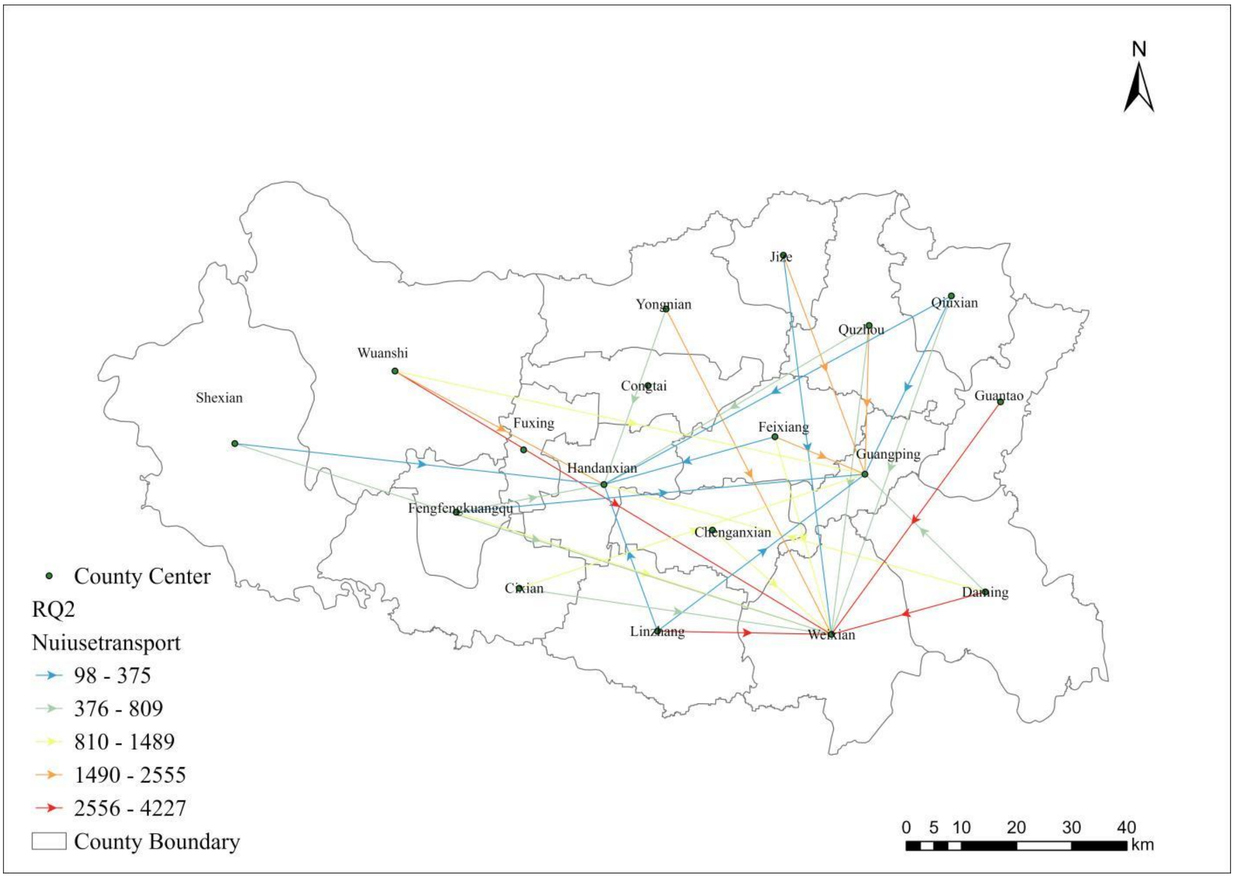

Figure 3. ArcGIS geographic transportation map of NPK nutrient use in Handan in RQ2

Table 9. Amount of actual NPK used after transport per county in RQ2 (t)

county	Elements		
ScountyFactNuiuse	**N**	**P**	**K**
Daming	8177	2308	8558
Yongnian	10474	2513	10062
Chenganxian	5538	1636	4646
Quzhou	7748	1475	5796
Qiuxian	4024	1178	2546
Jize	3592	1008	3599
Wuanshi	3127	1302	3097
Feixiang	5063	1386	5136
Linzhang	6080	1631	6407
Fengfengkuangqu	1229	391	764

Shexian	2484	779	1563
Guantao	9080	1148	4513
Cixian	3706	1264	3041

DcountyFactNuiuse	**N**	**P**	**K**
Guangping	6213	1500	2951
Handanxian	5107	604	2362
Weixian	16951	3734	7302
Utilization rate			Total NPK 84.82%

The following figure presents a geographic hierarchical map created by ArcGIS, illustrating the spatial distribution of actual NPK nutrient element utilization in RQ2 after transportation. As in the previous scenario, nutrient element utilization is categorized into five classes, with darker color in a reddish hue indicating higher utilization. However, the specific thresholds for these classes, displayed in the list at the lower left corner of the figure, are relatively higher compared to the overall RQ1 thresholds. But note that at this stage we do not focus on the different RQ Nuiuse horizontal comparison, the specific values will be compared in detail by the list below, gis grading map mainly observe the manure space optimization after different treatment options. From the figure, it can be seen that the overall proportion of counties falling into different graded categories among the 16 counties is more concentrated in RQ2, indicating a reduced nutrient utilization gap between counties. The distribution of color blocks in the map is more regular than in RQ1. Counties situated in the southeast exhibit higher overall nutrient utilization, gradually decreasing towards the west and north. The distribution of color blocks with similar colors is more concentrated at this time, showcasing a regular gradual trend from southeast to northwest. And at this point, every two similar counties have relatively similar nutrient utilization classes. That shows that the spatial distribution of manure after transportation is more balanced and regular compared to before, and the nutrient utilization of similar regions is no longer so fragmented, which will not cause too much nutrient waste, and the overall spatial optimization effect is remarkable, as the nutrient utilization becomes more efficient and well-distributed across the region.

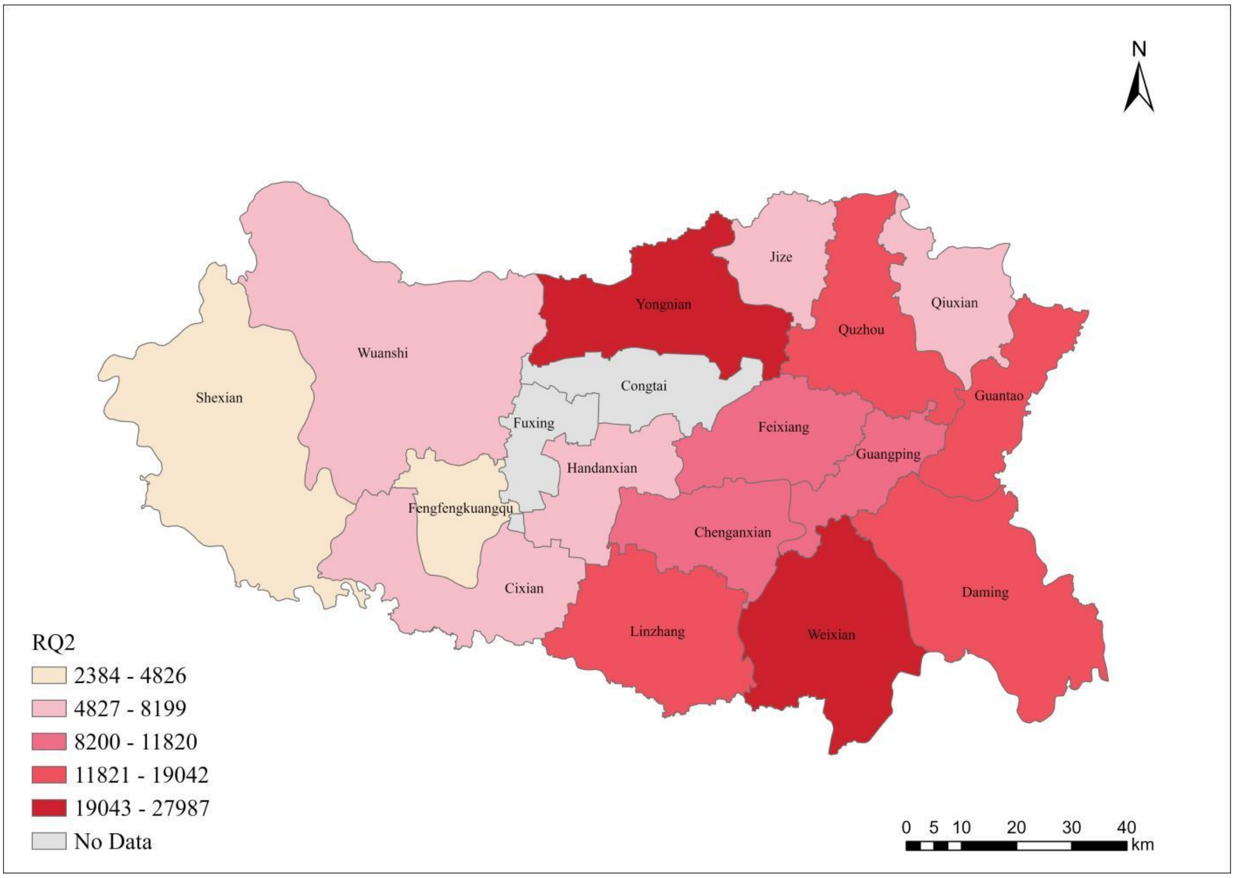

Figure 4. ArcGIS geographic classification map of NPK nutrient use (t) in Handan in RQ2

The following Table 10 presents the Nuifactuse change in RQ2 relative to RQ1, representing the change in NPK nutrient use after manure transportation between the 16 counties while keeping the total amount of manure constant. Analyzing the table, the rightmost column illustrates the change in the total amount of NPK elements used after transportation in each county. It shows that the actual NPK use decreased in 7 of the 13 supply counties and increased in 6 supply counties, but overall supply county NPK use increased by 1.28%. On the other hand, the NPK elemental use in the demand counties exhibited significant increases, with Guangping, Handanxian, and Weixian experiencing increments of 140.99%, 98.96%, and 87.38%, and the NPK elemental use in the three demand counties was raised by a total of 99.52%. At the bottom of the table is the change of total elemental amount in 16 counties, as shown in the table, the NPK use after transportation was elevated by 29.17%, 1.87%, and 3.55%, respectively. Consequently, the overall NPK total nutrient element use in the 16 counties increased by 14.85% in total.

It can be seen that the transportation of manure in this case increased the overall nutrient use, with a relatively smaller increase in the supply counties and a larger increase in the demand counties. The highest increase in N and the lowest increase in P was due to the low proportion of P in the manure.

Table 10. RQ2 Change in NPK use relative to RQ1 per county (t)

county	**Change**			
Scounty	**N**	**P**	**K**	**elements**
Daming	-16.83%	-10.78%	-9.24%	-12.84%
Yongnian	24.24%	0.00%	30.14%	23.43%
Chenganxian	5.74%	-3.24%	0.00%	2.12%
Quzhou	30.32%	0.00%	1.90%	14.57%
Qiuxian	38.16%	4.52%	0.00%	17.65%
Jize	-3.05%	0.00%	3.08%	-0.07%
Wuanshi	-45.53%	-42.41%	-32.77%	-40.31%
Feixiang	-8.96%	0.00%	-5.28%	-6.34%
Linzhang	-14.86%	-11.01%	-8.68%	-11.71%
Fengfengkuangqu	-16.11%	-47.97%	-32.04%	-28.64%
Shexian	31.29%	0.02%	0.00%	13.98%
Guantao	110.12%	0.00%	13.21%	55.90%
Cixian	1.32%	-15.82%	0.00%	-2.31%
			ScountyTotal	1.28%
Dcounty	**N**	**P**	**K**	**elements**
Guangping	214.17%	128.17%	64.85%	140.99%
Handanxian	186.32%	14.66%	35.20%	98.96%
Weixian	152.12%	71.66%	20.94%	87.38%
			DcountyTotal	99.52%
	RQ1	**RQ2**	**change**	
Total NPK	169610	194792	14.85%	
N	76326	98593	29.17%	
P	23419	23856	1.87%	
K	69866	72342	3.55%	

The above considerations in Manureuse and Nuiuse do not take into account the cost factor, but only the maximum redistribution of manure. After obtaining objective's the optimal solution, we subsequently calculated the cost. The overall cost was divided into two parts as seen in Table 11, one was the price of the manure itself which was 18558816 and the other was the transportation cost for different distances which is 118260861. The total cost for this research problem amounts to 136,819,676, where the transportation cost on the road outweighs the price of the transported manure itself by a considerable margin.

Table 11. The cost of transporting manure from per Supply county in RQ2 (Euro)

Scounty	**Cost**	
	Price	**TCost**
Daming	3433549	25943340
Yongnian	1698181	8618840
Chenganxian	379700	2334719
Quzhou	1448357	7596314
Qiuxian	389764	2690694
Jize	1070298	5221468
Wuanshi	2720530	24369183
Feixiang	1297457	4419832
Linzhang	2150461	7565925
Fengfengkuangqu	1167570	7469620
Shexian	466142	5620906
Guantao	1274093	8128502
Cixian	1062713	8281518
	18558816	118260861
Total cost		**136819676**

In conclusion, this research question will increase the use of manure itself, as well as will enhance the actual use of the nutrient element NPK within it. This suggests that spatial optimization can effectively reduce the wastage of resources, enhance soil sustainability, mitigate air pollution arising from intensive farming practices, and ultimately yield positive environmental benefits. The advantage of this research question is to minimize the manure surplus in the supplying counties, that is, to maximize spatial manure redistribution. This means that this measure allows the 16 counties to reduce manure accumulation with the original amount of manure available. However, it is essential to consider the associated high transportation costs and evaluate the economic viability of this strategy. Because large volumes of transportation do not result in large increases in nutrient utilization in supplying counties, there may be some involved transportation that is not useful or that can be considered foregone. Therefore, a comprehensive assessment is required to weigh the potential benefits against the incurred costs.

5.4 RESULTS IN RQ 3

Table 12 shows the manureuse, i.e., the amount of manure transported from each supply county to each supply county, taking into account the cost t. Consistent with RQ2, manureuse here does not refer to the amount of manure used in each county after transportation but specifically focuses on the quantity of manure transported from Scounty to Dcounty.

Compared to RQ2, it is clear that both the transportation routes and the amount of manure transported have been reduced. As shown in the left column of the table 12, only seven counties, namely Daming, Yongnian, Chenganxian, Quzhou, Feixiang, Linzhang, and Guantao, are actually participating in transportation, which is six fewer counties than in the previous problem (RQ2). The remaining counties do not partake in any transportation. The number of demand counties remains at three, and all of them receive substantial amounts of manure replenishment. The table 13 reveals that the total quantity of manure transported in RQ3 is 2,757,578 tons, indicating a decrease of 4,514,652 tons or approximately 62.08% compared to RQ2. It can be seen that except for the five routes of Daming-Guangping, Yongnian-Handanxian, Chenganxian-Weixian, Feixiang-Weixian, and Linzhang-Weixian, the amount of manure transported in the remaining transport routes are all decreasing. Overall, the transportation in RQ3 involves fewer routes but higher quantities transported in each trip, aligning with the distinctive characteristics of RQ3.

Table 12. Amount of manure for transportation from per Scounty to per Dcounty in RQ3 (t)

Scounty	Manureuse		
	Guangping	**Handanxian**	**Weixian**
Daming	314411		
Yongnian	0	310531	0
Chenganxian	0	0	417373
Quzhou	188611		
Qiuxian	0	0	0
Jize	0	0	0
Wuanshi	0	0	0
Feixiang	0	0	396614
Linzhang	0	0	495210
Fengfengkuangqu	0	0	0
Shexian	0	0	0
Guantao	315720	0	319109
Cixian	0	0	0
Total			2757578

Table 13. RQ3 Change in the amount of manure used relative to RQ2 per county (t)

Scounty	Change		
	Guangping	**Handanxian**	**Weixian**
Daming	146653	-460252	-597853
Yongnian	0	61776	-382280
Chenganxian	0	0	140751
Quzhou	-34341	-259466	-111200
Qiuxian	-26745	-62405	-61906
Jize	-310233	0	-59540
Wuanshi	-267694	-541285	-369203
Feixiang	-209845	-27762	120800
Linzhang	-120736	-123162	23306
Fengfengkuangqu	-84996	-198325	-182516
Shexian	0	-94738	-109469
Guantao	315720	0	-210819
Cixian	-201565	0	-215323
Total change			**-4514652**
	Guangping	**Handanxian**	**Weixian**
Daming	87.42%	-100.00%	-100.00%
Yongnian	0.00%	24.83%	-100.00%
Chenganxian	0.00%	0.00%	50.88%
Quzhou	-15.40%	-100.00%	-100.00%
Qiuxian	-100.00%	-100.00%	-100.00%
Jize	-100.00%	0.00%	-100.00%
Wuanshi	-100.00%	-100.00%	-100.00%
Feixiang	-100.00%	-100.00%	43.80%
Linzhang	-100.00%	-100.00%	4.94%
Fengfengkuangqu	-100.00%	-100.00%	-100.00%
Shexian	0.00%	-100.00%	-100.00%
Guantao	0.00%	0.00%	-39.78%
Cixian	-100.00%	0.00%	-100.00%
Total change (%)			**-62.08%**

Table 14 shows the Nuiuse, i.e., the amount of nutrient use actually transported from supply county to demand county, t. Similar to RQ2, Nuiuse here specifically focuses on the amount transported. The total transported nutrient use was 29,715 tons, with the breakdown being 13,454 tons for N, 5,838 tons for P, and 10,423 tons for K, respectively. In the same way as RQ2, after transportation, the nutrient element NPK will not happen to satisfy the balanced fertilization. It is necessary to again compare the size of the element NPK after transportation to the nutrient content (Nuidemand) that meets the soil requirements of the growing crops in the county to see if the equilibrium is met. The smaller of the two values represents the amount of nutrients actually taken up by the soil in each county, which is defined as Nuifactuse that getting in the following table 15. At this time the total amount of manure nutrient utilization in each county for 194983, of which the amount of N, P, K use were 98289 (t), 23594 (t), 73803 (t), respectively.

Then subtracting the actual amount of NPK used in the 16 counties total from the amount of NPK elements for all counties in Nuisupply gives the amount of nutrient loss in RQ3. At this time, the total loss of N in 16 counties is 3320(t), P is 9637(t), K is 21023(t), and the total loss of NPK is 33980(t). It can be seen that at this time K is the largest loss element, the loss of N element is greatly reduced, and the total loss is still reduced.

Table 14. The amount of NPK nutrient transported from per Supply county to per Demand county in RQ3 (t)

county	Elements		
Scounty	**N**	**P**	**K**
Daming	1171	550	796
Yongnian	1460	604	1061
Chenganxian	2160	978	1793
Quzhou	703	330	477
Qiuxian	0	0	0
Jize	0	0	0
Wuanshi	0	0	0
Feixiang	2007	911	1649
Linzhang	2502	1136	2054
Fengfengkuangqu	0	0	0
Shexian	0	0	0
Guantao	3451	1329	2592
Cixian	0	0	0
Dcounty	**N**	**P**	**K**
Guangping	3389	1500	2380
Handanxian	1460	604	1061
Weixian	8604	3734	6981

Below is a geographic transportation map created by ArcGIS that visualizes RQ3 transportation on a map. In contrast to RQ2 where all 16 counties were involved in transportation, RQ3 consists of only 10 counties and 8 transportation routes. The map shows that not only the transportation routes are greatly reduced, there is no long-distance transportation in this RQ (e.g., the diagonal distance from Wuanshi to Weixian in RQ2), but mostly short-distance transportation or a few medium-distance transportation. Transportation routes become concise and clear and adhere to the principle of neighboring county preference. Similar to RQ2, transportation in RQ3 is classified into five classes based on the number of nutrients, with class-specific thresholds displayed in the list at the lower left corner of the figure. The hue changes from blue to red, representing less to more transportation. However, note that the grading thresholds in RQ3 differ from those in RQ2, with overall larger thresholds. In RQ3, the thresholds for blue-green-tinted transport lines are similar to those for orange-tinted lines in RQ2. The proportion of transport lines with different grades in RQ3 is relatively balanced.

Regarding nutrient amounts, Guangping receives 7269(t) of NPK, which is similar to RQ2. However, Handanxian receives 3126(t), indicating a reduction compared to RQ2. Meanwhile, Weixian remains the demand county with the highest transportation volume, receiving a total of 19320(t) of NPK. Although this quantity is reduced compared to the previous RQ, it still represents the highest number of transportation routes and the highest route class in the graph.

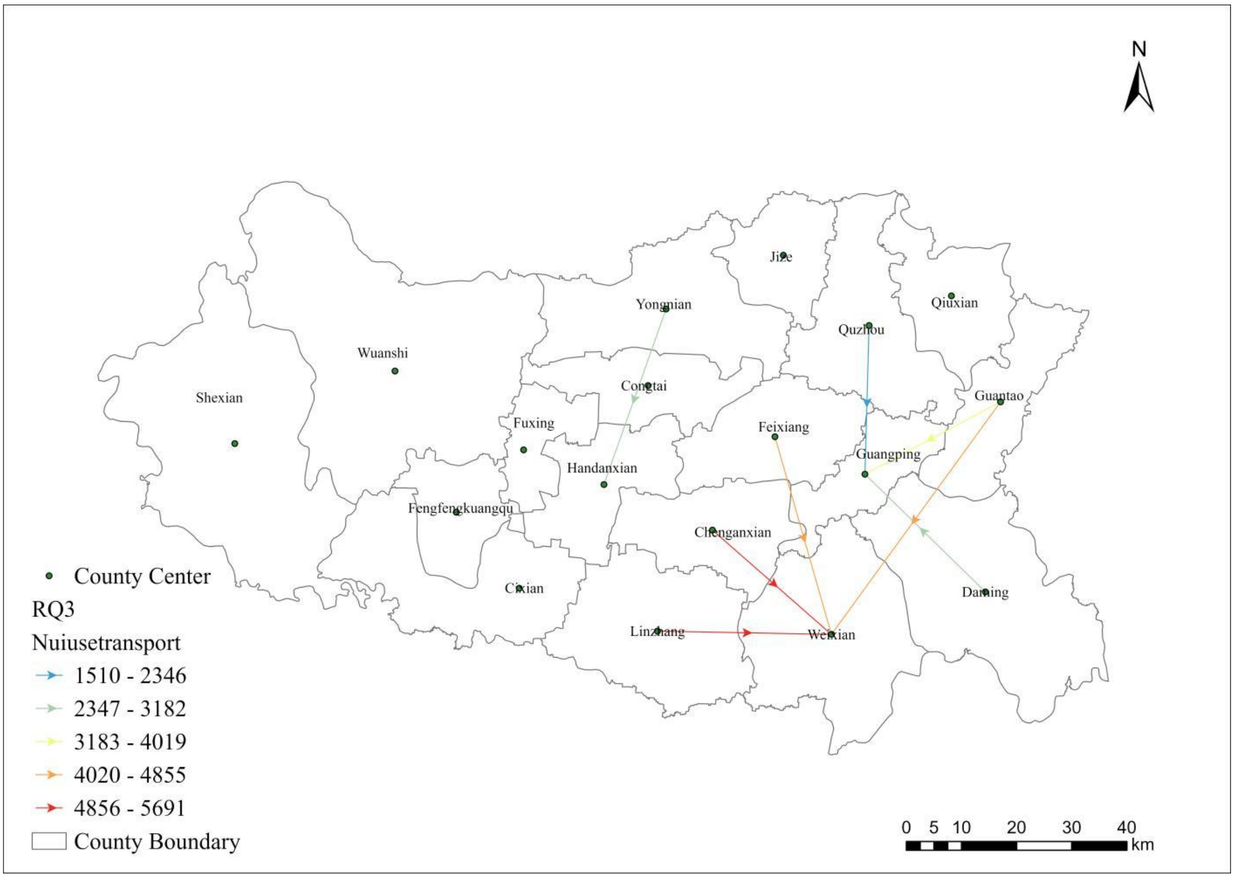

Figure 5. ArcGIS geographic transportation map of NPK nutrient use (t) in Handan in RQ3

Table 15. Amount of actual NPK used after transport per county in RQ3 (t)

county	Elements		
ScountyFactNuiuse	**N**	**P**	**K**
Daming	10051	2587	9952
Yongnian	10596	2513	10100
Chenganxian	3898	773	4040
Quzhou	8490	1475	5796
Qiuxian	4395	1288	2546
Jize	4526	1008	4020
Wuanshi	5948	2261	4606
Feixiang	4391	899	4568
Linzhang	5394	1080	5679
Fengfengkuangqu	2063	391	764
Shexian	2971	794	1563
Guantao	6912	1148	4513
Cixian	4734	1542	3041
DcountyFactNuiuse	**N**	**P**	**K**
Guangping	5361	1500	2951
Handanxian	3238	604	2362
Weixian	15322	3734	7302
Utilization rate			Total NPK 85.20%

The figure below shows a geographic hierarchical map created by ArcGIS, visualizing the spatial distribution of actual NPK nutrient element utilization in RQ3 after transport. As with the last two scenarios, nutrient element utilization is classified into five classes, with colors ranging from lighter to darker based on the values of Nuiuse. The difference is that the specific thresholds for the different classes shown in the lower left list in the figure are higher than the overall thresholds for RQ1 and lower than the overall thresholds for RQ2. From the figure, we observe that the overall proportion of counties falling into different classes among the 16 counties is more evenly distributed in RQ3, indicating a larger gap in nutrient utilization classes between different counties compared to RQ2. The distribution of color blocks in the map is relatively more spread out than in RQ2, but not as distinct as in RQ1. In the southeastern counties of the region, we notice a gradual trend in the color blocks. The supply counties appear to have darker color block classes than in RQ2, suggesting that spatial optimization is not as great as in RQ2. However, the color block grades in two-by-two counties are more similar and not as sharply segmented as in RQ1. Although the gap between different regions is still somewhat larger than in RQ2, the spatial arrangement is not excessively loose but rather characterized by small-scale regularity in different areas. It shows that this solution is not as spatially optimized as RQ2 after transportation, but overall it is a bit better than RQ1 without transportation. After the redistribution of manure, it is not as obvious as RQ2 that the regularity of rows is balanced. Instead, the general pattern of the original distribution of manure utilization slightly enhances it,

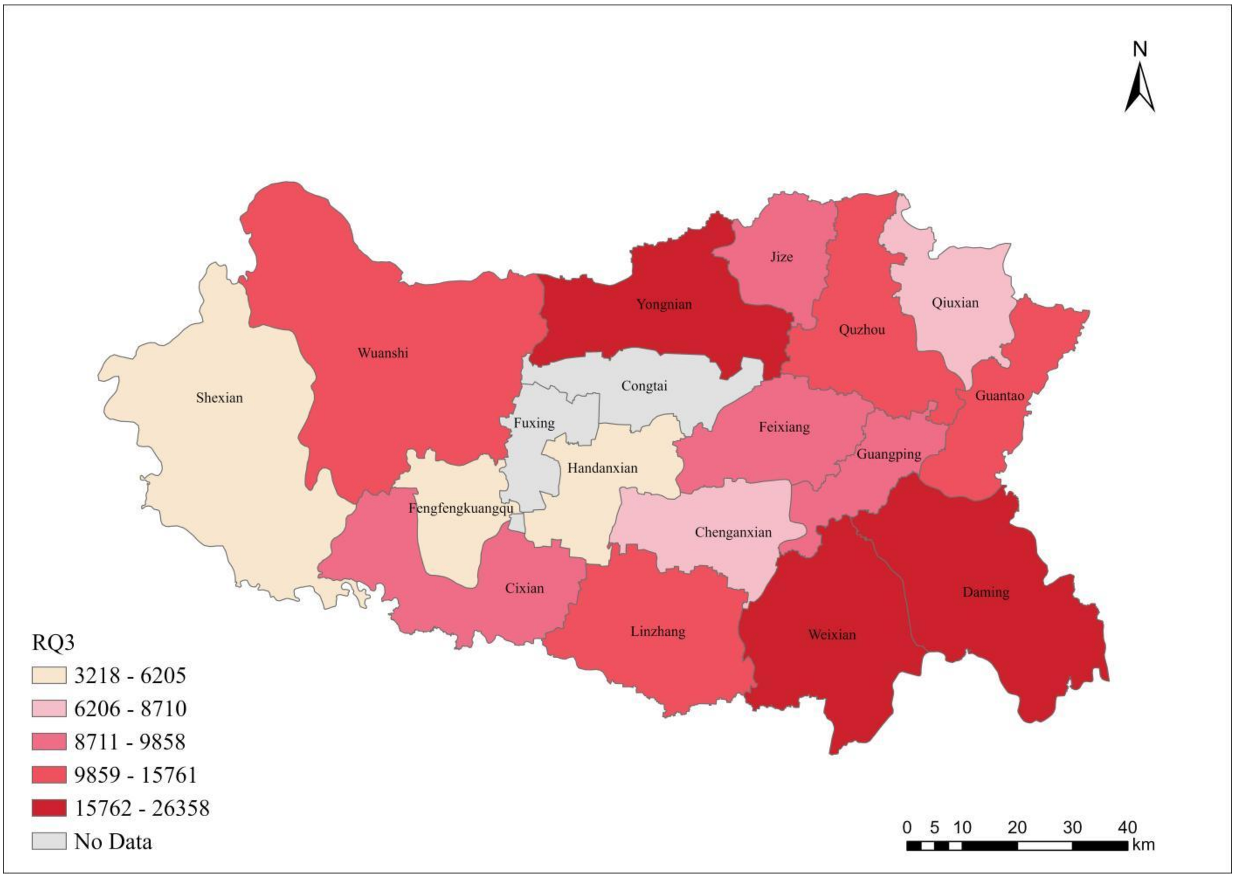

Figure 6. ArcGIS geographic classification map of NPK nutrient use (t) in Handan in RQ3

Table 16 presents the Nuiuse change in RQ3 relative to RQ1, which indicates the variation in NPK use after considering the cost of manure transportation. Under the assumption that the total amount of manure available to the 16 counties remains constant, the transportation of manure between these counties alters the actual utilization of NPK nutrients. As observed in the rightmost column of Table 16, after transportation, the NPK use decreased in 4 out of the 13 supply counties and increased in 9 supply counties. But overall supply county NPK use increased by 4.87%. Notably, the consideration of cost in RQ3 led to a higher increase in elemental use within the supply counties compared to RQ2. The demand counties continued to experience substantial increases in NPK elemental use, with rises of 121.74%, 52.91%, and

76.47% in Guangping, Handanxian, and Weixian, respectively, culminating in a total increase of 80.94% in NPK elemental use for these 3 demand counties. Compared to RQ1, the nutrient element content and total amount in each of the 3 demand counties was not elevated as much as in RQ2. At the bottom of the table are the changes in total elemental content for the 16 counties, as shown in the table, NPK use was elevated by 28.78%, 0.75%, and 5.64%, respectively. The actual use of total NPK nutrients in NPK for the 16 counties was elevated by a total of 15.37%. In comparison, the increases in NP use were not as high as in RQ2, but the elevations in K use were more pronounced, while total NPK elevations were slightly higher.

It can be concluded that even when considering the cost, the transportation of manure still increased nutrient element use, with a lesser increase in the supply counties and a greater increase in the demand counties. The increase in elemental use in the supply counties can be attributed to the blending of different types of manure application rates, where some manure ratios were adjusted to better suit the nutrient needs of the soil. Additionally, the highest increase in N and the lowest increase in P were consistently observed.

The above is the change of RQ3 to RQ1 and the comparison of this scenario with the change of RQ2 to RQ1. This is equivalent to comparing the results of the two scenarios that include transportation to the non-transportation scenario. Table 17 presents the Nuifactuse change in RQ3 relative to RQ2, i.e., RQ3 Change in NPK use relative to RQ2. This table provides a more intuitive view of the differences between the two transportation scenarios. As observed in the rightmost column of the table, nine supply counties show higher nutrient utilization when costs are considered compared to when costs are not considered, and the total amount of nutrients in all supply counties is increased by 3.54%. This suggests that accounting for costs means less export of nutrients from the supply counties and greater retention of nutrients for in-county use. On the demand county side, the three counties Guangping, Handanxian, and Weixian decreased by 7.99%, 23.15%, and 5.82% respectively, totaling a decrease of -9.31% in NPK element used in the three demand counties. Less output from the supply counties means less replenishment at the demand county end, so relatively cost-neutral transportation like this will not maximize nutrient use and spatial redistribution. However, when examining the bottom of Table 17, we find the changes in elemental totals for the 16 counties. Considering the cost, NP use decreases by 0.31% and 1.10%, respectively, while elemental K increases by 2.02%. The actual use of total NPK nutrients in the 16 counties considering cost is instead elevated by 0.46%. Despite the transportation involving smaller amounts of nutrient elements and fewer transportation routes in the cost consideration scenario, and despite the decrease in nutrient element utilization at the individual county or element level, the overall combined total NPK element use in the 16 counties experiences a slight enhancement.

Table 16. RQ3 Change in NPK use relative to RQ1 per county (t)

county	Change			
County	**N**	**P**	**K**	**elements**
Daming	2.23%	0.00%	5.55%	3.40%
Yongnian	25.69%	0.00%	30.63%	24.28%
Chenganxian	-25.59%	-54.31%	-13.04%	-24.75%
Quzhou	42.79%	0.00%	1.90%	20.23%
Qiuxian	50.89%	14.23%	0.00%	24.94%
Jize	22.15%	0.00%	15.12%	16.44%
Wuanshi	3.61%	-0.01%	0.00%	1.64%
Feixiang	-21.04%	-35.11%	-15.75%	-20.30%
Linzhang	-24.46%	-41.09%	-19.06%	-24.00%
Fengfengkuangqu	40.75%	-47.97%	-32.04%	-3.70%
Shexian	57.05%	1.86%	0.00%	25.83%
Guantao	59.96%	0.00%	13.21%	32.97%
Cixian	29.42%	2.69%	0.00%	13.62%
				4.87%
Change	**N**	**P**	**K**	**elements**
Guangping	171.09%	128.17%	64.85%	121.74%
Handanxian	81.55%	14.66%	35.20%	52.91%
Weixian	127.89%	71.66%	20.94%	76.47%
				80.94%
	RQ1	**RQ3**		
TotalNuiuse	169610	195686	15.37%	
N	76326	98289	28.78%	
P	23419	23594	0.75%	
K	69866	73803	5.64%	

Table 17. RQ3 Change in NPK use relative to RQ2 per county (t)

county	Change			
County	**N**	**P**	**K**	**elements**
Daming	22.92%	12.09%	16.29%	18.63%
Yongnian	1.16%	0.00%	0.37%	0.69%
Chenganxian	-29.63%	-52.78%	-13.04%	-26.31%
Quzhou	9.57%	0.00%	0.00%	4.94%
Qiuxian	9.21%	9.29%	0.00%	6.20%
Jize	26.00%	0.00%	11.69%	16.52%
Wuanshi	90.21%	73.62%	48.73%	70.27%

Feixiang	-13.27%	-35.11%	-11.05%	-14.90%
Linzhang	-11.28%	-33.80%	-11.36%	-13.92%
Fengfengkuangqu	67.79%	0.00%	0.00%	34.95%
Shexian	19.62%	1.84%	0.00%	10.39%
Guantao	-23.87%	0.00%	0.00%	-14.71%
Cixian	27.73%	21.98%	0.00%	16.30%
				3.54%
Change	**N**	**P**	**K**	**elements**
Guangping	-13.71%	0.00%	0.00%	-7.99%
Handanxian	-36.59%	0.00%	0.00%	-23.15%
Weixian	-9.61%	0.00%	0.00%	-5.82%
				-9.31%
	RQ2	**RQ3**		
TotalNuiuse	194792	195686	0.46%	
N	98593	98289	-0.31%	
P	23856	23594	-1.10%	
K	72342	73803	2.02%	

Table 18 shows the cost of transporting manure from per Supply county. The total cost under this research problem amounts to 52,166,782, with the manure's price accounting for 26,294,256, and the transportation cost, including fuel and other expenses, totaling 25,872,526. Unlike in RQ2, where transportation costs exceeded the price of the manure itself, in RQ3 the transportation cost on the road is even slightly higher than the price of the transported manure. This indicates a relatively balanced distribution of transportation costs and manure prices, with the manure price being $421,730 more than the transportation cost.

Table 19 displays the RQ3 Change in cost relative to RQ2 per county. Transportation cost is reduced for all counties under consideration of cost compared to RQ2. The decrease in transportation costs is generally due to a reduction in the number of transportation routes, or a re-routing of transportation tasks on routes of different distances. The price of the manure itself loaded by transportation decreases in most counties, while it increases in Yongnian, Chenganxian, Feixiang, Linzhang, and Guantao by 29.62%, 1297.98%, 270.11%, 177.76%, and 331.26%, respectively. It can be seen that except for Yongnian County, the price of loading manure in the other four counties is substantially increased. This corresponds to the aspect of transportation cost previously described, highlighting that RQ3 aims to reduce transportation routes while efficiently deploying higher volumes or manure prices to strike a balance between economic efficiency and production needs. RQ3 chose to use fewer routes, but higher volumes or manure prices. Consequently, closer transportation carries a heavier task than before. The total cost of all 16 counties in RQ3 is 61.87% less than in RQ2, achieved through a 41.68% increase in the price of the transported manure and a 78.12% reduction in transportation costs. Overall, the re-customized scenario under cost considerations proves to be more economical. The main cost control is centered around the transportation road cost, while the price of the transported manure itself experiences an increase. This means that compared to the large-scale space optimization and reallocation of manure in RQ2, the changes in RQ3 are more "extreme", involving fewer spatial allocations but with greater overall adjustments.

Table 18. The cost of transporting manure from per Supply county (Euro)

Scounty	Cost	
	Price	**TCost**
Daming	1572053	2834499
Yongnian	2201186	1984012
Chenganxian	5308126	3522674
Quzhou	943055	1577238
Qiuxian		
Jize		
Wuanshi		
Feixiang	4802011	4168707
Linzhang	5973120	4480418
Fengfengkuangqu		
Shexian		
Guantao	5494706	7304977
Cixian		

Table 19. RQ3 Change in cost relative to RQ2 per county (Euro)

Scounty	Change	
	Price	**TCost**
Daming	-1861495	-23108840
Yongnian	503005	-6634827
Chenganxian	4928426	1187955
Quzhou	-505303	-6019076
Qiuxian	-389764	-2690694
Jize	-1070298	-5221468
Wuanshi	-2720530	-24369183
Feixiang	3504554	-251125
Linzhang	3822658	-3085507
Fengfengkuangqu	-1167570	-7469620
Shexian	-466142	-5620906
Guantao	4220613	-823524

Cixian	-1062713	-8281518

	Price	TCost
Daming	-54.21%	-89.07%
Yongnian	29.62%	-76.98%
Chenganxian	1297.98%	50.88%
Quzhou	-34.89%	-79.24%
Qiuxian	-100.00%	-100.00%
Jize	-100.00%	-100.00%
Wuanshi	-100.00%	-100.00%
Feixiang	270.11%	-5.68%
Linzhang	177.76%	-40.78%
Fengfengkuangqu	-100.00%	-100.00%
Shexian	-100.00%	-100.00%
Guantao	331.26%	-10.13%
Cixian	-100.00%	-100.00%

	RQ2	RQ3	change
Totalcost	136819676	52166782	-61.87%
Price	18558816	26294256	41.68%
TCost	118260861	25872526	-78.12%

In this research question, the consideration of transportation costs reveals that the option with transportation would increase manure utilization and higher actual nutrient NPK usage within the manure compared to the non-transportation scenario in RQ1. In contrast to RQ2, RQ3 reduces the amount of manure transported and the extent of spatial redistribution. However, it also decreases transportation costs while increasing nutrient utilization. From the comparison of RQ2 and RQ3 for RQ1, one thing we can determine is that whatever route or mode of manure transportation and spatial redistribution is sure to benefit the utilization of manure and reduce the loss of NPK. This suggests that spatial redistribution of manure is conducive to reducing resource wastage. RQ1, while undoubtedly the most cost and time-efficient study scenario in terms of input costs and time, lacks awareness of spatial optimization for recyclable resources.

This deficiency negatively impacts production in regions facing resource shortages and is also detrimental to the environment in regions where resources are in excess. As a result, many recyclable resources go to waste due to inadequate resource recycling. Spatial redistribution aims to allocate resources where they are most needed. The advantage of this scenario lies in its emphasis on maximizing the utilization of NPK nutrients after transportation, rather than solely focusing on the quantity of manure transported, as in RQ2. But the essence of our recycling of manure is to absorb the NPK nutrients needed in the manure in the production of the crop, rather than simply looking at how much manure has been put in by itself. So RQ3 should be the most favorable approach to farm-end production for the 16 counties as a whole. And fewer transportation routes means less risk of corresponding lesions on the road. Additionally, RQ3 proves to be more efficient and cost-effective in transportation compared to RQ2. Overall, RQ3 stands out as the best solution for the welfare of all 16 counties, striking a balance between economic factors, growth needs, and environmental impacts. And it is the most cost-effective way to combine balanced nitrogen, phosphorus, and potassium fertilization with manure distribution.

6． CONCLUSIONS

The primary objective of this research reduce synthetic fertilizer inputs and nutrient losses through balanced fertilization and optimization of the spatial distribution of fertilizers in order to make better and cost-effective management decisions. An optimization model is utilized to strike a balance between environmental benefits and economic advantages. The environmental benefit is attained by minimizing manure surplus, equivalent to maximizing nutrient utilization. On the other hand, the economic benefit is achieved by minimizing the costs associated with spatial distribution. Three research questions were designed to compare the effects of different treatments on the results. The model has some simplifications in corresponding to the real situation and can only abstract the complex problems into formulas based on fundamental logic, but it somewhat facilitates the decision-makers to make wise choices and allocate resources efficiently. In the subsequent sections, we provide a concise summary of the primary research findings, followed by an analysis of limitations and constraints in our thinking. Then we discuss the recommendations for managers with possible improvements.

The total cost of the most cost-effective scenario obtained in this study was $52,166,782. This scenario led to a remarkable reduction of 61.87% in total cost compared to transportation without considering the cost. The total quantity of manure transported in this scenario was 2757578 tons, which is a decrease of 4514652 tons i.e. a decrease of -62.08% compared to RQ2. The total nutrient utilization of manure in the counties of the cost-effective scenario amounted to 194,983 tons, with N, P, and K utilization at 98,289 tons, 23,594 tons, and 73,803 tons. Notably, the actual NPK total nutrient use in the 16 counties of this scenario was 15.37%

higher than the no-transportation scenario, and even when considering cost, it remained 0.46% higher than the actual total nutrient use of the scenario without cost.

The most cost-effective scenario involves transportation and spatial optimization of manure. Although RQ1, which does not involve transportation, significantly reduces costs, it causes a lot of waste of resources, environmental pollution and, greenhouse gas emissions. RQ2 is the maximum transportation to reduce the surplus of manure in the supply counties, but in terms of actual, welfare it is not as good as RQ3. Because it only transports more manure in the process, but the level of nutrient utilization after transportation is not as good as that of RQ3. RQ3 is the most environmentally friendly and cost-effective method obtained, representing the highest level of comprehensive welfare. It does not maximize the spatial reallocation of resources, but it can be called the most efficient spatial reallocation of resources. Implementation of this option would require the government to establish a compensation mechanism to cover the short-term profit loss of farmers and herders. This approach would encourage stakeholders to adopt the program for the long term. Over time, the benefits from long-term crop production and the savings from environmental management will offset the initial investment, creating a virtuous economic cycle.

6.1 CONSTRAINTS

(1) Simply separating supply and demand counties

The study's complete distinction between supply and demand counties is a simplification based on surplus or deficit of manure. In practice, a county can exhibit both supply and demand characteristics, with complex nutrient inputs and outflows (Mzuku et al., 2005).so the spatial optimization model in this research may not yield a general solution that addresses the individual needs of each farm.

(2) Limited inclusion of counties in the model:

The model only considered 16 out of 18 counties under the jurisdiction of Handan City. We didn’t select Congtai and Fuxing districts due to their small size, non-agricultural nature, and administrative importance (Ma et al., 2023). While the selected 16 counties represent major agricultural and livestock sources, the omission of the other two districts may introduce bias.

(3) Representing overall efficiency using specific species:

The study selected six specific species each to represent productivity and consumptive power at the farm and ranch ends. However, this approach neglects other crops and animals. It essentially uses sampling to estimate overall efficiency, which may introduce errors in the results.

(4)Data availability challenges:

The spatial optimization model requires a substantial amount of accurate data on various aspects, such as soil available nutrients, NPK loss in acquisition, etc. Gathering and processing such complex data can be tedious, leading to potential deviations in data availability and quality.

(5) Neglecting obstacles in actual transportation:

Transportation requires professional technology, rigorous operation, and perfect infrastructure support. Otherwise, there are multiple risks in transportation. Because manure itself has the potential risk of pathogen transmission due to transportation, rainfall, irrigation, and other pathways pathogens can be transferred to water (Alegbeleye & Sant'Ana, 2020). These water sources have a substantial potential for infection and re-transmission by human contact, and transportation also increases the probability of waste spillage or leakage from storage areas. So there are many inconvenient potential risks associated with actual transportation.

(6) Inadequate consideration of stakeholders' perspectives:

The spatial optimization model gives advice more from the perspective of the government and managers, but it may not fully consider the complexities and conflicts among different stakeholders. For example, farmers are used to using synthetic fertilizers, and herders prefer to sell manure locally for higher profits. It is difficult for the model to balance the conflicts brought about by such human will.

(7) Lack of dynamics over time:

Agricultural systems are dynamic and subject to continuous changes over time. The specific spatial optimization model does not account for such dynamic changes, necessitating ongoing adjustments based on real-time management practices.

6.2 RECOMMENDATIONS

Based on the relevant literature and the findings from our study, we propose the following policy recommendations for the government, managers, and stakeholders:

(1) Incorporate nutrient budgeting and management programs:

The essence of manure recycling is the re-absorption and utilization of nutrients in manure. However, many managers do not pay attention to environmental protection, they only focus on soil fertility but do not actively implement and improve nutrient management (Ma et al., 2013). Therefore, the designation of a scientifically detailed nutrient management plan and the evaluation of the budget can greatly optimize nutrient use and reduce environmental risks. A process that includes assessment, analysis, decision-making, evaluation, and refinement (Beegle et al., 2000). By measuring and tracking nutrients rather than just manure quantity, the nutrient dynamics of each county can be carefully monitored and managed within a reasonable range.

(2) Provide economic subsidies and incentives

Many farmers favor the use of synthetic fertilizers over manure due to habitual and profit reasons, and the need for measures such as economic incentives can improve this (Jiang et al., 2022). Farmers who make increased use of manure and ranches that exhibit high degrees of recycling and reuse should be rewarded.

(3) Enforce strict waste treatment and emission measures

An agricultural policy involving rapid transformation always has a large impact on the environment. For example, when traditional production is transformed to the scale of intensive industrialized production, there are always some side effects (Qian et al., 2018). Then the transition from intra-county self-production to inter-county distribution can easily bring risks. For example, bacterial lesions in transportation, leakage of manure, failure to fully utilize it on farmland, etc. The transportation of manure requires high-density, centralized systems, and therefore, stricter waste disposal policies and emission requirements are necessary. Setting new standards for manure storage, application rates, and gas emissions, and enforcing regulations effectively, will promote responsible manure management practices.

(4) Expand the scope of flexible monitoring and evaluation

Previous monitoring tended to focus in a balanced way on important points of production activity at both ends of the farm. However, due to the occurrence of transportation, the supply county manure is reduced, naturally, the emission of harmful gases is relatively reduced in the past. Environmental monitoring should focus more on demand counties, especially in areas that receive large quantities of manure for redistribution. This includes regularly assessing sensitive areas near water bodies, air, and soil quality surrounding manure application sites.

(5) Research and development of redistribution technologies

The movement of manure between counties presents technical challenges that require innovation. The government and investors should set aside some funds for the development of better technologies. For example, using sensing, smart seeding, and crop modeling in precision agriculture technology could allow for more accurate, efficient, and targeted application of manure from different spaces (Zhang, 2016). Complete solid-liquid separation of manure for transportation may also be considered, as it can optimize the loading process due to the different nutrient contents in solids and liquids. Upgrading infrastructure, loading and storage systems, and handling technologies will ensure safe and efficient spatial distribution of manure.

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APPENDIX I

Original data on the ranch side,which used for calaulating manure NPK excretion in different animal categories

Table A1. Data used for calculating extraction of manures

Conuty	**Anicategories**					
Aninumber						Head(x10000)
County	Dairycow	Beefcow	Pig	Sheepgoat	Broiler	Layer
Daming	0.2	4.81	69.18	54.34	842.53	600.2
Guangping	0.11	0.25	10.6	8.51	269.93	190.56
Yongnian	1.16	2.39	37.39	29.41	1274.76	1753.53
Chenganxian	0.39	1.95	25.75	33.04	411.07	433.76
Quzhou	0.42	2.92	39	28.83	1211.47	1020.01
Handanshi	1.1	0.58	16.74	8.54	272.04	186.37
Qiuxian	0.06	0.92	9.38	27.06	602.99	445.8
Jize	0.29	1.24	19.98	20.05	524	403.5
Wuanshi	0.14	1.7	81.36	4.17	284.65	312.56
Feixiang	0.85	2.08	29.02	33.86	455.38	370.26
Linzhang	0.24	3.55	36.66	42.63	914.97	425.2
Fengfengkuangqu	0.24	0.39	29.81	5.76	141.25	81.95
Shexian	0	1.23	14.24	11.62	340.91	263.84
Guantao	0.29	1.88	35.3	16.7	1663.67	1715.21
Cixian	0.5	1.04	26.22	14.66	551.72	463.74
Handanxian	0.35	0.74	10	6.69	197.81	81.92
Weixian	0.11	0.86	41.9	33.04	486.38	589
GrowthPeriod						(day/year)
County	Dairycow	Beefcow	Pig	Sheepgoat	Broiler	Layer
Daming	365	365	199	365	55	365
Guangping	365	365	199	365	55	365
Yongnian	365	365	199	365	55	365
Chenganxian	365	365	199	365	55	365
Quzhou	365	365	199	365	55	365
Handanshi	365	365	199	365	55	365
Qiuxian	365	365	199	365	55	365
Jize	365	365	199	365	55	365
Wuanshi	365	365	199	365	55	365
Feixiang	365	365	199	365	55	365
Linzhang	365	365	199	365	55	365
Fengfengkuangqu	365	365	199	365	55	365
Shexian	365	365	199	365	55	365
Guantao	365	365	199	365	55	365
Cixian	365	365	199	365	55	365
Handanxian	365	365	199	365	55	365

Weixian	365	365	199	365	55	365
Feces_Excretion						(kg/head/day)
County	Dairycow	Beefcow	Pig	Sheepgoat	Broiler	Layer
Daming	35.7	25.4	4.0	3.2	0.11	0.17
Guangping	35.7	25.4	4.0	3.2	0.11	0.17
Yongnian	35.7	25.4	4.0	3.2	0.11	0.17
Chenganxian	35.7	25.4	4.0	3.2	0.11	0.17
Quzhou	35.7	25.4	4.0	3.2	0.11	0.17
Handanshi	35.7	25.4	4.0	3.2	0.11	0.17
Qiuxian	35.7	25.4	4.0	3.2	0.11	0.17
Jize	35.7	25.4	4.0	3.2	0.11	0.17
Wuanshi	35.7	25.4	4.0	3.2	0.11	0.17
Feixiang	35.7	25.4	4.0	3.2	0.11	0.17
Linzhang	35.7	25.4	4.0	3.2	0.11	0.17
Fengfengkuangqu	35.7	25.4	4.0	3.2	0.11	0.17
Shexian	35.7	25.4	4.0	3.2	0.11	0.17
Guantao	35.7	25.4	4.0	3.2	0.11	0.17
Cixian	35.7	25.4	4.0	3.2	0.11	0.17
Handanxian	35.7	25.4	4.0	3.2	0.11	0.17
Weixian	35.7	25.4	4.0	3.2	0.11	0.17
Urine_Excretion			(kg/head/day)			
County	Dairycow	Beefcow	Pig			
Daming	13.2	10.6	4.8			
Guangping	13.2	10.6	4.8			
Yongnian	13.2	10.6	4.8			
Chenganxian	13.2	10.6	4.8			
Quzhou	13.2	10.6	4.8			
Handanshi	13.2	10.6	4.8			
Qiuxian	13.2	10.6	4.8			
Jize	13.2	10.6	4.8			
Wuanshi	13.2	10.6	4.8			
Feixiang	13.2	10.6	4.8			
Linzhang	13.2	10.6	4.8			
Fengfengkuangqu	13.2	10.6	4.8			
Shexian	13.2	10.6	4.8			
Guantao	13.2	10.6	4.8			
Cixian	13.2	10.6	4.8			
Handanxian	13.2	10.6	4.8			
Weixian	13.2	10.6	4.8			

Table A2. Data used for calaulating solid and liquid ratio of different manure types

Conuty	Anicategories	Manuretype	
Soliduse			
County	Anicategories	Solid	Compost
Daming	Dairycow	0.63	0.37

Daming	Beefcow	0.52	0.48
Daming	Pig	0.61	0.39
Daming	Sheepgoat	1	
Daming	Broiler	0.4	0.6
Daming	Layer	0.4	0.6
Guangping	Dairycow	0.63	0.37
Guangping	Beefcow	0.52	0.48
Guangping	Pig	0.61	0.39
Guangping	Sheepgoat	1	
Guangping	Broiler	0.4	0.6
Guangping	Layer	0.4	0.6
Yongnian	Dairycow	0.63	0.37
Yongnian	Beefcow	0.52	0.48
Yongnian	Pig	0.61	0.39
Yongnian	Sheepgoat	1	
Yongnian	Broiler	0.4	0.6
Yongnian	Layer	0.4	0.6
Chenganxian	Dairycow	0.63	0.37
Chenganxian	Beefcow	0.52	0.48
Chenganxian	Pig	0.61	0.39
Chenganxian	Sheepgoat	1	
Chenganxian	Broiler	0.4	0.6
Chenganxian	Layer	0.4	0.6
Quzhou	Dairycow	0.63	0.37
Quzhou	Beefcow	0.52	0.48
Quzhou	Pig	0.61	0.39
Quzhou	Sheepgoat	1	
Quzhou	Broiler	0.4	0.6
Quzhou	Layer	0.4	0.6
Handanshi	Dairycow	0.63	0.37
Handanshi	Beefcow	0.52	0.48
Handanshi	Pig	0.61	0.39
Handanshi	Sheepgoat	1	
Handanshi	Broiler	0.4	0.6
Handanshi	Layer	0.4	0.6
Qiuxian	Dairycow	0.63	0.37
Qiuxian	Beefcow	0.52	0.48
Qiuxian	Pig	0.61	0.39
Qiuxian	Sheepgoat	1	
Qiuxian	Broiler	0.4	0.6
Qiuxian	Layer	0.4	0.6
Jize	Dairycow	0.63	0.37
Jize	Beefcow	0.52	0.48
Jize	Pig	0.61	0.39
Jize	Sheepgoat	1	

Jize	Broiler	0.4	0.6
Jize	Layer	0.4	0.6
Wuanshi	Dairycow	0.63	0.37
Wuanshi	Beefcow	0.52	0.48
Wuanshi	Pig	0.61	0.39
Wuanshi	Sheepgoat	1	
Wuanshi	Broiler	0.4	0.6
Wuanshi	Layer	0.4	0.6
Feixiang	Dairycow	0.63	0.37
Feixiang	Beefcow	0.52	0.48
Feixiang	Pig	0.61	0.39
Feixiang	Sheepgoat	1	
Feixiang	Broiler	0.4	0.6
Feixiang	Layer	0.4	0.6
Linzhang	Dairycow	0.63	0.37
Linzhang	Beefcow	0.52	0.48
Linzhang	Pig	0.61	0.39
Linzhang	Sheepgoat	1	
Linzhang	Broiler	0.4	0.6
Linzhang	Layer	0.4	0.6
Fengfengkuangqu	Dairycow	0.63	0.37
Fengfengkuangqu	Beefcow	0.52	0.48
Fengfengkuangqu	Pig	0.61	0.39
Fengfengkuangqu	Sheepgoat	1	
Fengfengkuangqu	Broiler	0.4	0.6
Fengfengkuangqu	Layer	0.4	0.6
Shexian	Dairycow	0.63	0.37
Shexian	Beefcow	0.52	0.48
Shexian	Pig	0.61	0.39
Shexian	Sheepgoat	1	
Shexian	Broiler	0.4	0.6
Shexian	Layer	0.4	0.6
Guantao	Dairycow	0.63	0.37
Guantao	Beefcow	0.52	0.48
Guantao	Pig	0.61	0.39
Guantao	Sheepgoat	1	
Guantao	Broiler	0.4	0.6
Guantao	Layer	0.4	0.6
Cixian	Dairycow	0.63	0.37
Cixian	Beefcow	0.52	0.48
Cixian	Pig	0.61	0.39
Cixian	Sheepgoat	1	
Cixian	Broiler	0.4	0.6
Cixian	Layer	0.4	0.6
Handanxian	Dairycow	0.63	0.37

Handanxian	Beefcow	0.52	0.48
Handanxian	Pig	0.61	0.39
Handanxian	Sheepgoat	1	
Handanxian	Broiler	0.4	0.6
Handanxian	Layer	0.4	0.6
Weixian	Dairycow	0.63	0.37
Weixian	Beefcow	0.52	0.48
Weixian	Pig	0.61	0.39
Weixian	Sheepgoat	1	
Weixian	Broiler	0.4	0.6
Weixian	Layer	0.4	0.6
Liquiduse			
County	Anicategories	Liquid	Digestion
Daming	Dairycow	0.79	0.21
Daming	Beefcow	1	
Daming	Pig	0.7	0.3
Guangping	Dairycow	0.79	0.21
Guangping	Beefcow	1	
Guangping	Pig	0.7	0.3
Yongnian	Dairycow	0.79	0.21
Yongnian	Beefcow	1	
Yongnian	Pig	0.7	0.3
Chenganxian	Dairycow	0.79	0.21
Chenganxian	Beefcow	1	
Chenganxian	Pig	0.7	0.3
Quzhou	Dairycow	0.79	0.21
Quzhou	Beefcow	1	
Quzhou	Pig	0.7	0.3
Handanshi	Dairycow	0.79	0.21
Handanshi	Beefcow	1	
Handanshi	Pig	0.7	0.3
Qiuxian	Dairycow	0.79	0.21
Qiuxian	Beefcow	1	
Qiuxian	Pig	0.7	0.3
Jize	Dairycow	0.79	0.21
Jize	Beefcow	1	
Jize	Pig	0.7	0.3
Wuanshi	Dairycow	0.79	0.21
Wuanshi	Beefcow	1	
Wuanshi	Pig	0.7	0.3
Feixiang	Dairycow	0.79	0.21
Feixiang	Beefcow	1	
Feixiang	Pig	0.7	0.3
Linzhang	Dairycow	0.79	0.21
Linzhang	Beefcow	1	

Linzhang	Pig	0.7	0.3
Fengfengkuangqu	Dairycow	0.79	0.21
Fengfengkuangqu	Beefcow	1	
Fengfengkuangqu	Pig	0.7	0.3
Shexian	Dairycow	0.79	0.21
Shexian	Beefcow	1	
Shexian	Pig	0.7	0.3
Guantao	Dairycow	0.79	0.21
Guantao	Beefcow	1	
Guantao	Pig	0.7	0.3
Cixian	Dairycow	0.79	0.21
Cixian	Beefcow	1	
Cixian	Pig	0.7	0.3
Handanxian	Dairycow	0.79	0.21
Handanxian	Beefcow	1	
Handanxian	Pig	0.7	0.3
Weixian	Dairycow	0.79	0.21
Weixian	Beefcow	1	
Weixian	Pig	0.7	0.3

Table A3. Data used for available NPK nutrients of manure

Conuty	**Elements**			
Content_Feces				
County	Anicategories	N	P	K
Daming	Dairycow	0.006	0.00155	0.0035
Daming	Beefcow	0.0055	0.0012	0.0035
Daming	Pig	0.007	0.0026	0.00355
Daming	Sheepgoat	0.0104	0.0011	0.00776
Daming	Broiler	0.0114	0.0033	0.00653
Daming	Layer	0.0114	0.0033	0.00653
Guangping	Dairycow	0.006	0.00155	0.0035
Guangping	Beefcow	0.0055	0.0012	0.0035
Guangping	Pig	0.007	0.0026	0.00355
Guangping	Sheepgoat	0.0104	0.0011	0.00776
Guangping	Broiler	0.0114	0.0033	0.00653
Guangping	Layer	0.0114	0.0033	0.00653
Yongnian	Dairycow	0.006	0.00155	0.0035
Yongnian	Beefcow	0.0055	0.0012	0.0035
Yongnian	Pig	0.007	0.0026	0.00355
Yongnian	Sheepgoat	0.0104	0.0011	0.00776
Yongnian	Broiler	0.0114	0.0033	0.00653
Yongnian	Layer	0.0114	0.0033	0.00653
Chenganxian	Dairycow	0.006	0.00155	0.0035
Chenganxian	Beefcow	0.0055	0.0012	0.0035
Chenganxian	Pig	0.007	0.0026	0.00355

Chenganxian	Sheepgoat	0.0104	0.0011	0.00776
Chenganxian	Broiler	0.0114	0.0033	0.00653
Chenganxian	Layer	0.0114	0.0033	0.00653
Quzhou	Dairycow	0.006	0.00155	0.0035
Quzhou	Beefcow	0.0055	0.0012	0.0035
Quzhou	Pig	0.007	0.0026	0.00355
Quzhou	Sheepgoat	0.0104	0.0011	0.00776
Quzhou	Broiler	0.0114	0.0033	0.00653
Quzhou	Layer	0.0114	0.0033	0.00653
Handanshi	Dairycow	0.006	0.00155	0.0035
Handanshi	Beefcow	0.0055	0.0012	0.0035
Handanshi	Pig	0.007	0.0026	0.00355
Handanshi	Sheepgoat	0.0104	0.0011	0.00776
Handanshi	Broiler	0.0114	0.0033	0.00653
Handanshi	Layer	0.0114	0.0033	0.00653
Qiuxian	Dairycow	0.006	0.00155	0.0035
Qiuxian	Beefcow	0.0055	0.0012	0.0035
Qiuxian	Pig	0.007	0.0026	0.00355
Qiuxian	Sheepgoat	0.0104	0.0011	0.00776
Qiuxian	Broiler	0.0114	0.0033	0.00653
Qiuxian	Layer	0.0114	0.0033	0.00653
Jize	Dairycow	0.006	0.00155	0.0035
Jize	Beefcow	0.0055	0.0012	0.0035
Jize	Pig	0.007	0.0026	0.00355
Jize	Sheepgoat	0.0104	0.0011	0.00776
Jize	Broiler	0.0114	0.0033	0.00653
Jize	Layer	0.0114	0.0033	0.00653
Wuanshi	Dairycow	0.006	0.00155	0.0035
Wuanshi	Beefcow	0.0055	0.0012	0.0035
Wuanshi	Pig	0.007	0.0026	0.00355
Wuanshi	Sheepgoat	0.0104	0.0011	0.00776
Wuanshi	Broiler	0.0114	0.0033	0.00653
Wuanshi	Layer	0.0114	0.0033	0.00653
Feixiang	Dairycow	0.006	0.00155	0.0035
Feixiang	Beefcow	0.0055	0.0012	0.0035
Feixiang	Pig	0.007	0.0026	0.00355
Feixiang	Sheepgoat	0.0104	0.0011	0.00776
Feixiang	Broiler	0.0114	0.0033	0.00653
Feixiang	Layer	0.0114	0.0033	0.00653
Linzhang	Dairycow	0.006	0.00155	0.0035
Linzhang	Beefcow	0.0055	0.0012	0.0035
Linzhang	Pig	0.007	0.0026	0.00355
Linzhang	Sheepgoat	0.0104	0.0011	0.00776
Linzhang	Broiler	0.0114	0.0033	0.00653
Linzhang	Layer	0.0114	0.0033	0.00653

Fengfengkuangqu	Dairycow	0.006	0.00155	0.0035
Fengfengkuangqu	Beefcow	0.0055	0.0012	0.0035
Fengfengkuangqu	Pig	0.007	0.0026	0.00355
Fengfengkuangqu	Sheepgoat	0.0104	0.0011	0.00776
Fengfengkuangqu	Broiler	0.0114	0.0033	0.00653
Fengfengkuangqu	Layer	0.0114	0.0033	0.00653
Shexian	Dairycow	0.006	0.00155	0.0035
Shexian	Beefcow	0.0055	0.0012	0.0035
Shexian	Pig	0.007	0.0026	0.00355
Shexian	Sheepgoat	0.0104	0.0011	0.00776
Shexian	Broiler	0.0114	0.0033	0.00653
Shexian	Layer	0.0114	0.0033	0.00653
Guantao	Dairycow	0.006	0.00155	0.0035
Guantao	Beefcow	0.0055	0.0012	0.0035
Guantao	Pig	0.007	0.0026	0.00355
Guantao	Sheepgoat	0.0104	0.0011	0.00776
Guantao	Broiler	0.0114	0.0033	0.00653
Guantao	Layer	0.0114	0.0033	0.00653
Cixian	Dairycow	0.006	0.00155	0.0035
Cixian	Beefcow	0.0055	0.0012	0.0035
Cixian	Pig	0.007	0.0026	0.00355
Cixian	Sheepgoat	0.0104	0.0011	0.00776
Cixian	Broiler	0.0114	0.0033	0.00653
Cixian	Layer	0.0114	0.0033	0.00653
Handanxian	Dairycow	0.006	0.00155	0.0035
Handanxian	Beefcow	0.0055	0.0012	0.0035
Handanxian	Pig	0.007	0.0026	0.00355
Handanxian	Sheepgoat	0.0104	0.0011	0.00776
Handanxian	Broiler	0.0114	0.0033	0.00653
Handanxian	Layer	0.0114	0.0033	0.00653
Weixian	Dairycow	0.006	0.00155	0.0035
Weixian	Beefcow	0.0055	0.0012	0.0035
Weixian	Pig	0.007	0.0026	0.00355
Weixian	Sheepgoat	0.0104	0.0011	0.00776
Weixian	Broiler	0.0114	0.0033	0.00653
Weixian	Layer	0.0114	0.0033	0.00653

Content_Urine

County	Anicategories	N	P	K
Daming	Dairycow	0.00917	0.0004	0.0108
Daming	Beefcow	0.00812	0.00009	0.0118
Daming	Pig	0.00303	0.00045	0.0015
Guangping	Dairycow	0.00917	0.0004	0.0108
Guangping	Beefcow	0.00812	0.00009	0.0118
Guangping	Pig	0.00303	0.00045	0.0015
Yongnian	Dairycow	0.00917	0.0004	0.0108

Yongnian	Beefcow	0.00812	0.00009	0.0118
Yongnian	Pig	0.00303	0.00045	0.0015
Chenganxian	Dairycow	0.00917	0.0004	0.0108
Chenganxian	Beefcow	0.00812	0.00009	0.0118
Chenganxian	Pig	0.00303	0.00045	0.0015
Quzhou	Dairycow	0.00917	0.0004	0.0108
Quzhou	Beefcow	0.00812	0.00009	0.0118
Quzhou	Pig	0.00303	0.00045	0.0015
Handanshi	Dairycow	0.00917	0.0004	0.0108
Handanshi	Beefcow	0.00812	0.00009	0.0118
Handanshi	Pig	0.00303	0.00045	0.0015
Qiuxian	Dairycow	0.00917	0.0004	0.0108
Qiuxian	Beefcow	0.00812	0.00009	0.0118
Qiuxian	Pig	0.00303	0.00045	0.0015
Jize	Dairycow	0.00917	0.0004	0.0108
Jize	Beefcow	0.00812	0.00009	0.0118
Jize	Pig	0.00303	0.00045	0.0015
Wuanshi	Dairycow	0.00917	0.0004	0.0108
Wuanshi	Beefcow	0.00812	0.00009	0.0118
Wuanshi	Pig	0.00303	0.00045	0.0015
Feixiang	Dairycow	0.00917	0.0004	0.0108
Feixiang	Beefcow	0.00812	0.00009	0.0118
Feixiang	Pig	0.00303	0.00045	0.0015
Linzhang	Dairycow	0.00917	0.0004	0.0108
Linzhang	Beefcow	0.00812	0.00009	0.0118
Linzhang	Pig	0.00303	0.00045	0.0015
Fengfengkuangqu	Dairycow	0.00917	0.0004	0.0108
Fengfengkuangqu	Beefcow	0.00812	0.00009	0.0118
Fengfengkuangqu	Pig	0.00303	0.00045	0.0015
Shexian	Dairycow	0.00917	0.0004	0.0108
Shexian	Beefcow	0.00812	0.00009	0.0118
Shexian	Pig	0.00303	0.00045	0.0015
Guantao	Dairycow	0.00917	0.0004	0.0108
Guantao	Beefcow	0.00812	0.00009	0.0118
Guantao	Pig	0.00303	0.00045	0.0015
Cixian	Dairycow	0.00917	0.0004	0.0108
Cixian	Beefcow	0.00812	0.00009	0.0118
Cixian	Pig	0.00303	0.00045	0.0015
Handanxian	Dairycow	0.00917	0.0004	0.0108
Handanxian	Beefcow	0.00812	0.00009	0.0118
Handanxian	Pig	0.00303	0.00045	0.0015
Weixian	Dairycow	0.00917	0.0004	0.0108
Weixian	Beefcow	0.00812	0.00009	0.0118
Weixian	Pig	0.00303	0.00045	0.0015

Manure_Recovery

County	Anicategories	Manuretypes	N	P	K
Daming	Dairycow	Solid	0.53	0.67	0.71
Daming	Dairycow	Compost	0.49	0.86	0.81
Daming	Dairycow	Liquid	0.53	0.67	0.71
Daming	Dairycow	Digestion	0.63	0.90	0.90
Daming	Beefcow	Solid	0.53	0.67	0.71
Daming	Beefcow	Compost	0.49	0.86	0.81
Daming	Beefcow	Liquid	0.53	0.67	0.71
Daming	Pig	Solid	0.53	0.67	0.71
Daming	Pig	Compost	0.49	0.86	0.81
Daming	Pig	Liquid	0.53	0.67	0.71
Daming	Pig	Digestion	0.63	0.90	0.90
Daming	Sheepgoat	Solid	0.53	0.67	0.71
Daming	Broiler	Solid	0.53	0.67	0.71
Daming	Broiler	Compost	0.49	0.86	0.81
Daming	Layer	Solid	0.53	0.67	0.71
Daming	Layer	Compost	0.49	0.86	0.81
Guangping	Dairycow	Solid	0.53	0.67	0.71
Guangping	Dairycow	Compost	0.49	0.86	0.81
Guangping	Dairycow	Liquid	0.53	0.67	0.71
Guangping	Dairycow	Digestion	0.63	0.90	0.90
Guangping	Beefcow	Solid	0.53	0.67	0.71
Guangping	Beefcow	Compost	0.49	0.86	0.81
Guangping	Beefcow	Liquid	0.53	0.67	0.71
Guangping	Pig	Solid	0.53	0.67	0.71
Guangping	Pig	Compost	0.49	0.86	0.81
Guangping	Pig	Liquid	0.53	0.67	0.71
Guangping	Pig	Digestion	0.63	0.90	0.90
Guangping	Sheepgoat	Solid	0.53	0.67	0.71
Guangping	Broiler	Solid	0.53	0.67	0.71
Guangping	Broiler	Compost	0.49	0.86	0.81
Guangping	Layer	Solid	0.53	0.67	0.71
Guangping	Layer	Compost	0.49	0.86	0.81
Yongnian	Dairycow	Solid	0.53	0.67	0.71
Yongnian	Dairycow	Compost	0.49	0.86	0.81
Yongnian	Dairycow	Liquid	0.53	0.67	0.71
Yongnian	Dairycow	Digestion	0.63	0.90	0.90
Yongnian	Beefcow	Solid	0.53	0.67	0.71
Yongnian	Beefcow	Compost	0.49	0.86	0.81
Yongnian	Beefcow	Liquid	0.53	0.67	0.71
Yongnian	Pig	Solid	0.53	0.67	0.71
Yongnian	Pig	Compost	0.49	0.86	0.81
Yongnian	Pig	Liquid	0.53	0.67	0.71
Yongnian	Pig	Digestion	0.63	0.90	0.90
Yongnian	Sheepgoat	Solid	0.53	0.67	0.71

Yongnian	Broiler	Solid	0.53	0.67	0.71
Yongnian	Broiler	Compost	0.49	0.86	0.81
Yongnian	Layer	Solid	0.53	0.67	0.71
Yongnian	Layer	Compost	0.49	0.86	0.81
Chenganxian	Dairycow	Solid	0.53	0.67	0.71
Chenganxian	Dairycow	Compost	0.49	0.86	0.81
Chenganxian	Dairycow	Liquid	0.53	0.67	0.71
Chenganxian	Dairycow	Digestion	0.63	0.90	0.90
Chenganxian	Beefcow	Solid	0.53	0.67	0.71
Chenganxian	Beefcow	Compost	0.49	0.86	0.81
Chenganxian	Beefcow	Liquid	0.53	0.67	0.71
Chenganxian	Pig	Solid	0.53	0.67	0.71
Chenganxian	Pig	Compost	0.49	0.86	0.81
Chenganxian	Pig	Liquid	0.53	0.67	0.71
Chenganxian	Pig	Digestion	0.63	0.90	0.90
Chenganxian	Sheepgoat	Solid	0.53	0.67	0.71
Chenganxian	Broiler	Solid	0.53	0.67	0.71
Chenganxian	Broiler	Compost	0.49	0.86	0.81
Chenganxian	Layer	Solid	0.53	0.67	0.71
Chenganxian	Layer	Compost	0.49	0.86	0.81
Quzhou	Dairycow	Solid	0.53	0.67	0.71
Quzhou	Dairycow	Compost	0.49	0.86	0.81
Quzhou	Dairycow	Liquid	0.53	0.67	0.71
Quzhou	Dairycow	Digestion	0.63	0.90	0.90
Quzhou	Beefcow	Solid	0.53	0.67	0.71
Quzhou	Beefcow	Compost	0.49	0.86	0.81
Quzhou	Beefcow	Liquid	0.53	0.67	0.71
Quzhou	Pig	Solid	0.53	0.67	0.71
Quzhou	Pig	Compost	0.49	0.86	0.81
Quzhou	Pig	Liquid	0.53	0.67	0.71
Quzhou	Pig	Digestion	0.63	0.90	0.90
Quzhou	Sheepgoat	Solid	0.53	0.67	0.71
Quzhou	Broiler	Solid	0.53	0.67	0.71
Quzhou	Broiler	Compost	0.49	0.86	0.81
Quzhou	Layer	Solid	0.53	0.67	0.71
Quzhou	Layer	Compost	0.49	0.86	0.81
Handanshi	Dairycow	Solid	0.53	0.67	0.71
Handanshi	Dairycow	Compost	0.49	0.86	0.81
Handanshi	Dairycow	Liquid	0.53	0.67	0.71
Handanshi	Dairycow	Digestion	0.63	0.90	0.90
Handanshi	Beefcow	Solid	0.53	0.67	0.71
Handanshi	Beefcow	Compost	0.49	0.86	0.81
Handanshi	Beefcow	Liquid	0.53	0.67	0.71
Handanshi	Pig	Solid	0.53	0.67	0.71
Handanshi	Pig	Compost	0.49	0.86	0.81

Handanshi	Pig	Liquid	0.53	0.67	0.71
Handanshi	Pig	Digestion	0.63	0.90	0.90
Handanshi	Sheepgoat	Solid	0.53	0.67	0.71
Handanshi	Broiler	Solid	0.53	0.67	0.71
Handanshi	Broiler	Compost	0.49	0.86	0.81
Handanshi	Layer	Solid	0.53	0.67	0.71
Handanshi	Layer	Compost	0.49	0.86	0.81
Qiuxian	Dairycow	Solid	0.53	0.67	0.71
Qiuxian	Dairycow	Compost	0.49	0.86	0.81
Qiuxian	Dairycow	Liquid	0.53	0.67	0.71
Qiuxian	Dairycow	Digestion	0.63	0.90	0.90
Qiuxian	Beefcow	Solid	0.53	0.67	0.71
Qiuxian	Beefcow	Compost	0.49	0.86	0.81
Qiuxian	Beefcow	Liquid	0.53	0.67	0.71
Qiuxian	Pig	Solid	0.53	0.67	0.71
Qiuxian	Pig	Compost	0.49	0.86	0.81
Qiuxian	Pig	Liquid	0.53	0.67	0.71
Qiuxian	Pig	Digestion	0.63	0.90	0.90
Qiuxian	Sheepgoat	Solid	0.53	0.67	0.71
Qiuxian	Broiler	Solid	0.53	0.67	0.71
Qiuxian	Broiler	Compost	0.49	0.86	0.81
Qiuxian	Layer	Solid	0.53	0.67	0.71
Qiuxian	Layer	Compost	0.49	0.86	0.81
Jize	Dairycow	Solid	0.53	0.67	0.71
Jize	Dairycow	Compost	0.49	0.86	0.81
Jize	Dairycow	Liquid	0.53	0.67	0.71
Jize	Dairycow	Digestion	0.63	0.90	0.90
Jize	Beefcow	Solid	0.53	0.67	0.71
Jize	Beefcow	Compost	0.49	0.86	0.81
Jize	Beefcow	Liquid	0.53	0.67	0.71
Jize	Pig	Solid	0.53	0.67	0.71
Jize	Pig	Compost	0.49	0.86	0.81
Jize	Pig	Liquid	0.53	0.67	0.71
Jize	Pig	Digestion	0.63	0.90	0.90
Jize	Sheepgoat	Solid	0.53	0.67	0.71
Jize	Broiler	Solid	0.53	0.67	0.71
Jize	Broiler	Compost	0.49	0.86	0.81
Jize	Layer	Solid	0.53	0.67	0.71
Jize	Layer	Compost	0.49	0.86	0.81
Wuanshi	Dairycow	Solid	0.53	0.67	0.71
Wuanshi	Dairycow	Compost	0.49	0.86	0.81
Wuanshi	Dairycow	Liquid	0.53	0.67	0.71
Wuanshi	Dairycow	Digestion	0.63	0.90	0.90
Wuanshi	Beefcow	Solid	0.53	0.67	0.71
Wuanshi	Beefcow	Compost	0.49	0.86	0.81

Wuanshi	Beefcow	Liquid	0.53	0.67	0.71
Wuanshi	Pig	Solid	0.53	0.67	0.71
Wuanshi	Pig	Compost	0.49	0.86	0.81
Wuanshi	Pig	Liquid	0.53	0.67	0.71
Wuanshi	Pig	Digestion	0.63	0.90	0.90
Wuanshi	Sheepgoat	Solid	0.53	0.67	0.71
Wuanshi	Broiler	Solid	0.53	0.67	0.71
Wuanshi	Broiler	Compost	0.49	0.86	0.81
Wuanshi	Layer	Solid	0.53	0.67	0.71
Wuanshi	Layer	Compost	0.49	0.86	0.81
Feixiang	Dairycow	Solid	0.53	0.67	0.71
Feixiang	Dairycow	Compost	0.49	0.86	0.81
Feixiang	Dairycow	Liquid	0.53	0.67	0.71
Feixiang	Dairycow	Digestion	0.63	0.90	0.90
Feixiang	Beefcow	Solid	0.53	0.67	0.71
Feixiang	Beefcow	Compost	0.49	0.86	0.81
Feixiang	Beefcow	Liquid	0.53	0.67	0.71
Feixiang	Pig	Solid	0.53	0.67	0.71
Feixiang	Pig	Compost	0.49	0.86	0.81
Feixiang	Pig	Liquid	0.53	0.67	0.71
Feixiang	Pig	Digestion	0.63	0.90	0.90
Feixiang	Sheepgoat	Solid	0.53	0.67	0.71
Feixiang	Broiler	Solid	0.53	0.67	0.71
Feixiang	Broiler	Compost	0.49	0.86	0.81
Feixiang	Layer	Solid	0.53	0.67	0.71
Feixiang	Layer	Compost	0.49	0.86	0.81
Linzhang	Dairycow	Solid	0.53	0.67	0.71
Linzhang	Dairycow	Compost	0.49	0.86	0.81
Linzhang	Dairycow	Liquid	0.53	0.67	0.71
Linzhang	Dairycow	Digestion	0.63	0.90	0.90
Linzhang	Beefcow	Solid	0.53	0.67	0.71
Linzhang	Beefcow	Compost	0.49	0.86	0.81
Linzhang	Beefcow	Liquid	0.53	0.67	0.71
Linzhang	Pig	Solid	0.53	0.67	0.71
Linzhang	Pig	Compost	0.49	0.86	0.81
Linzhang	Pig	Liquid	0.53	0.67	0.71
Linzhang	Pig	Digestion	0.63	0.90	0.90
Linzhang	Sheepgoat	Solid	0.53	0.67	0.71
Linzhang	Broiler	Solid	0.53	0.67	0.71
Linzhang	Broiler	Compost	0.49	0.86	0.81
Linzhang	Layer	Solid	0.53	0.67	0.71
Linzhang	Layer	Compost	0.49	0.86	0.81
Fengfengkuangqu	Dairycow	Solid	0.53	0.67	0.71
Fengfengkuangqu	Dairycow	Compost	0.49	0.86	0.81
Fengfengkuangqu	Dairycow	Liquid	0.53	0.67	0.71

Fengfengkuangqu	Dairycow	Digestion	0.63	0.90	0.90
Fengfengkuangqu	Beefcow	Solid	0.53	0.67	0.71
Fengfengkuangqu	Beefcow	Compost	0.49	0.86	0.81
Fengfengkuangqu	Beefcow	Liquid	0.53	0.67	0.71
Fengfengkuangqu	Pig	Solid	0.53	0.67	0.71
Fengfengkuangqu	Pig	Compost	0.49	0.86	0.81
Fengfengkuangqu	Pig	Liquid	0.53	0.67	0.71
Fengfengkuangqu	Pig	Digestion	0.63	0.90	0.90
Fengfengkuangqu	Sheepgoat	Solid	0.53	0.67	0.71
Fengfengkuangqu	Broiler	Solid	0.53	0.67	0.71
Fengfengkuangqu	Broiler	Compost	0.49	0.86	0.81
Fengfengkuangqu	Layer	Solid	0.53	0.67	0.71
Fengfengkuangqu	Layer	Compost	0.49	0.86	0.81
Shexian	Dairycow	Solid	0.53	0.67	0.71
Shexian	Dairycow	Compost	0.49	0.86	0.81
Shexian	Dairycow	Liquid	0.53	0.67	0.71
Shexian	Dairycow	Digestion	0.63	0.90	0.90
Shexian	Beefcow	Solid	0.53	0.67	0.71
Shexian	Beefcow	Compost	0.49	0.86	0.81
Shexian	Beefcow	Liquid	0.53	0.67	0.71
Shexian	Pig	Solid	0.53	0.67	0.71
Shexian	Pig	Compost	0.49	0.86	0.81
Shexian	Pig	Liquid	0.53	0.67	0.71
Shexian	Pig	Digestion	0.63	0.90	0.90
Shexian	Sheepgoat	Solid	0.53	0.67	0.71
Shexian	Broiler	Solid	0.53	0.67	0.71
Shexian	Broiler	Compost	0.49	0.86	0.81
Shexian	Layer	Solid	0.53	0.67	0.71
Shexian	Layer	Compost	0.49	0.86	0.81
Guantao	Dairycow	Solid	0.53	0.67	0.71
Guantao	Dairycow	Compost	0.49	0.86	0.81
Guantao	Dairycow	Liquid	0.53	0.67	0.71
Guantao	Dairycow	Digestion	0.63	0.90	0.90
Guantao	Beefcow	Solid	0.53	0.67	0.71
Guantao	Beefcow	Compost	0.49	0.86	0.81
Guantao	Beefcow	Liquid	0.53	0.67	0.71
Guantao	Pig	Solid	0.53	0.67	0.71
Guantao	Pig	Compost	0.49	0.86	0.81
Guantao	Pig	Liquid	0.53	0.67	0.71
Guantao	Pig	Digestion	0.63	0.90	0.90
Guantao	Sheepgoat	Solid	0.53	0.67	0.71
Guantao	Broiler	Solid	0.53	0.67	0.71
Guantao	Broiler	Compost	0.49	0.86	0.81
Guantao	Layer	Solid	0.53	0.67	0.71
Guantao	Layer	Compost	0.49	0.86	0.81

Cixian	Dairycow	Solid	0.53	0.67	0.71
Cixian	Dairycow	Compost	0.49	0.86	0.81
Cixian	Dairycow	Liquid	0.53	0.67	0.71
Cixian	Dairycow	Digestion	0.63	0.90	0.90
Cixian	Beefcow	Solid	0.53	0.67	0.71
Cixian	Beefcow	Compost	0.49	0.86	0.81
Cixian	Beefcow	Liquid	0.53	0.67	0.71
Cixian	Pig	Solid	0.53	0.67	0.71
Cixian	Pig	Compost	0.49	0.86	0.81
Cixian	Pig	Liquid	0.53	0.67	0.71
Cixian	Pig	Digestion	0.63	0.90	0.90
Cixian	Sheepgoat	Solid	0.53	0.67	0.71
Cixian	Broiler	Solid	0.53	0.67	0.71
Cixian	Broiler	Compost	0.49	0.86	0.81
Cixian	Layer	Solid	0.53	0.67	0.71
Cixian	Layer	Compost	0.49	0.86	0.81
Handanxian	Dairycow	Solid	0.53	0.67	0.71
Handanxian	Dairycow	Compost	0.49	0.86	0.81
Handanxian	Dairycow	Liquid	0.53	0.67	0.71
Handanxian	Dairycow	Digestion	0.63	0.90	0.90
Handanxian	Beefcow	Solid	0.53	0.67	0.71
Handanxian	Beefcow	Compost	0.49	0.86	0.81
Handanxian	Beefcow	Liquid	0.53	0.67	0.71
Handanxian	Pig	Solid	0.53	0.67	0.71
Handanxian	Pig	Compost	0.49	0.86	0.81
Handanxian	Pig	Liquid	0.53	0.67	0.71
Handanxian	Pig	Digestion	0.63	0.90	0.90
Handanxian	Sheepgoat	Solid	0.53	0.67	0.71
Handanxian	Broiler	Solid	0.53	0.67	0.71
Handanxian	Broiler	Compost	0.49	0.86	0.81
Handanxian	Layer	Solid	0.53	0.67	0.71
Handanxian	Layer	Compost	0.49	0.86	0.81
Weixian	Dairycow	Solid	0.53	0.67	0.71
Weixian	Dairycow	Compost	0.49	0.86	0.81
Weixian	Dairycow	Liquid	0.53	0.67	0.71
Weixian	Dairycow	Digestion	0.63	0.90	0.90
Weixian	Beefcow	Solid	0.53	0.67	0.71
Weixian	Beefcow	Compost	0.49	0.86	0.81
Weixian	Beefcow	Liquid	0.53	0.67	0.71
Weixian	Pig	Solid	0.53	0.67	0.71
Weixian	Pig	Compost	0.49	0.86	0.81
Weixian	Pig	Liquid	0.53	0.67	0.71
Weixian	Pig	Digestion	0.63	0.90	0.90
Weixian	Sheepgoat	Solid	0.53	0.67	0.71
Weixian	Broiler	Solid	0.53	0.67	0.71

Weixian	Broiler	Compost	0.49	0.86	0.81
Weixian	Layer	Solid	0.53	0.67	0.71
Weixian	Layer	Compost	0.49	0.86	0.81

Table A4. Data used for calculating loss of N throughout the process(t)

Conuty	Pathway

Nloss_Housing

County	Anicategories	NH3	N2O	N2
Daming	Dairycow	0.245	0.005	0.05
Daming	Beefcow	0.245	0.005	0.05
Daming	Pig	0.245	0.005	0.05
Daming	Sheepgoat	0.245	0.005	0.05
Daming	Broiler	0.245	0.005	0.05
Daming	Layer	0.245	0.005	0.05
Guangping	Dairycow	0.245	0.005	0.05
Guangping	Beefcow	0.245	0.005	0.05
Guangping	Pig	0.245	0.005	0.05
Guangping	Sheepgoat	0.245	0.005	0.05
Guangping	Broiler	0.245	0.005	0.05
Guangping	Layer	0.245	0.005	0.05
Yongnian	Dairycow	0.245	0.005	0.05
Yongnian	Beefcow	0.245	0.005	0.05
Yongnian	Pig	0.245	0.005	0.05
Yongnian	Sheepgoat	0.245	0.005	0.05
Yongnian	Broiler	0.245	0.005	0.05
Yongnian	Layer	0.245	0.005	0.05
Chenganxian	Dairycow	0.245	0.005	0.05
Chenganxian	Beefcow	0.245	0.005	0.05
Chenganxian	Pig	0.245	0.005	0.05
Chenganxian	Sheepgoat	0.245	0.005	0.05
Chenganxian	Broiler	0.245	0.005	0.05
Chenganxian	Layer	0.245	0.005	0.05
Quzhou	Dairycow	0.245	0.005	0.05
Quzhou	Beefcow	0.245	0.005	0.05
Quzhou	Pig	0.245	0.005	0.05
Quzhou	Sheepgoat	0.245	0.005	0.05
Quzhou	Broiler	0.245	0.005	0.05
Quzhou	Layer	0.245	0.005	0.05
Handanshi	Dairycow	0.245	0.005	0.05
Handanshi	Beefcow	0.245	0.005	0.05
Handanshi	Pig	0.245	0.005	0.05
Handanshi	Sheepgoat	0.245	0.005	0.05
Handanshi	Broiler	0.245	0.005	0.05
Handanshi	Layer	0.245	0.005	0.05

Qiuxian	Dairycow	0.245	0.005	0.05
Qiuxian	Beefcow	0.245	0.005	0.05
Qiuxian	Pig	0.245	0.005	0.05
Qiuxian	Sheepgoat	0.245	0.005	0.05
Qiuxian	Broiler	0.245	0.005	0.05
Qiuxian	Layer	0.245	0.005	0.05
Jize	Dairycow	0.245	0.005	0.05
Jize	Beefcow	0.245	0.005	0.05
Jize	Pig	0.245	0.005	0.05
Jize	Sheepgoat	0.245	0.005	0.05
Jize	Broiler	0.245	0.005	0.05
Jize	Layer	0.245	0.005	0.05
Wuanshi	Dairycow	0.245	0.005	0.05
Wuanshi	Beefcow	0.245	0.005	0.05
Wuanshi	Pig	0.245	0.005	0.05
Wuanshi	Sheepgoat	0.245	0.005	0.05
Wuanshi	Broiler	0.245	0.005	0.05
Wuanshi	Layer	0.245	0.005	0.05
Feixiang	Dairycow	0.245	0.005	0.05
Feixiang	Beefcow	0.245	0.005	0.05
Feixiang	Pig	0.245	0.005	0.05
Feixiang	Sheepgoat	0.245	0.005	0.05
Feixiang	Broiler	0.245	0.005	0.05
Feixiang	Layer	0.245	0.005	0.05
Linzhang	Dairycow	0.245	0.005	0.05
Linzhang	Beefcow	0.245	0.005	0.05
Linzhang	Pig	0.245	0.005	0.05
Linzhang	Sheepgoat	0.245	0.005	0.05
Linzhang	Broiler	0.245	0.005	0.05
Linzhang	Layer	0.245	0.005	0.05
Fengfengkuangqu	Dairycow	0.245	0.005	0.05
Fengfengkuangqu	Beefcow	0.245	0.005	0.05
Fengfengkuangqu	Pig	0.245	0.005	0.05
Fengfengkuangqu	Sheepgoat	0.245	0.005	0.05
Fengfengkuangqu	Broiler	0.245	0.005	0.05
Fengfengkuangqu	Layer	0.245	0.005	0.05
Shexian	Dairycow	0.245	0.005	0.05
Shexian	Beefcow	0.245	0.005	0.05
Shexian	Pig	0.245	0.005	0.05
Shexian	Sheepgoat	0.245	0.005	0.05
Shexian	Broiler	0.245	0.005	0.05
Shexian	Layer	0.245	0.005	0.05
Guantao	Dairycow	0.245	0.005	0.05
Guantao	Beefcow	0.245	0.005	0.05
Guantao	Pig	0.245	0.005	0.05

Guantao	Sheepgoat	0.245	0.005	0.05
Guantao	Broiler	0.245	0.005	0.05
Guantao	Layer	0.245	0.005	0.05
Cixian	Dairycow	0.245	0.005	0.05
Cixian	Beefcow	0.245	0.005	0.05
Cixian	Pig	0.245	0.005	0.05
Cixian	Sheepgoat	0.245	0.005	0.05
Cixian	Broiler	0.245	0.005	0.05
Cixian	Layer	0.245	0.005	0.05
Handanxian	Dairycow	0.245	0.005	0.05
Handanxian	Beefcow	0.245	0.005	0.05
Handanxian	Pig	0.245	0.005	0.05
Handanxian	Sheepgoat	0.245	0.005	0.05
Handanxian	Broiler	0.245	0.005	0.05
Handanxian	Layer	0.245	0.005	0.05
Weixian	Dairycow	0.245	0.005	0.05
Weixian	Beefcow	0.245	0.005	0.05
Weixian	Pig	0.245	0.005	0.05
Weixian	Sheepgoat	0.245	0.005	0.05
Weixian	Broiler	0.245	0.005	0.05
Weixian	Layer	0.245	0.005	0.05

Nloss_Storage

County	Anicategories	Manuretypes	NH3	N2O	N2	Nleaching
Daming	Dairycow	Solid	0.185	0.005	0.05	0.01
Daming	Dairycow	Liquid	0.185	0.005	0.05	0.01
Daming	Beefcow	Solid	0.185	0.005	0.05	0.01
Daming	Beefcow	Liquid	0.185	0.005	0.05	0.01
Daming	Pig	Solid	0.185	0.005	0.05	0.01
Daming	Pig	Liquid	0.185	0.005	0.05	0.01
Daming	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Daming	Broiler	Solid	0.185	0.005	0.05	0.01
Daming	Layer	Solid	0.185	0.005	0.05	0.01
Guangping	Dairycow	Solid	0.185	0.005	0.05	0.01
Guangping	Dairycow	Liquid	0.185	0.005	0.05	0.01
Guangping	Beefcow	Solid	0.185	0.005	0.05	0.01
Guangping	Beefcow	Liquid	0.185	0.005	0.05	0.01
Guangping	Pig	Solid	0.185	0.005	0.05	0.01
Guangping	Pig	Liquid	0.185	0.005	0.05	0.01
Guangping	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Guangping	Broiler	Solid	0.185	0.005	0.05	0.01
Guangping	Layer	Solid	0.185	0.005	0.05	0.01
Yongnian	Dairycow	Solid	0.185	0.005	0.05	0.01
Yongnian	Dairycow	Liquid	0.185	0.005	0.05	0.01
Yongnian	Beefcow	Solid	0.185	0.005	0.05	0.01
Yongnian	Beefcow	Liquid	0.185	0.005	0.05	0.01

Yongnian	Pig	Solid	0.185	0.005	0.05	0.01
Yongnian	Pig	Liquid	0.185	0.005	0.05	0.01
Yongnian	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Yongnian	Broiler	Solid	0.185	0.005	0.05	0.01
Yongnian	Layer	Solid	0.185	0.005	0.05	0.01
Chenganxian	Dairycow	Solid	0.185	0.005	0.05	0.01
Chenganxian	Dairycow	Liquid	0.185	0.005	0.05	0.01
Chenganxian	Beefcow	Solid	0.185	0.005	0.05	0.01
Chenganxian	Beefcow	Liquid	0.185	0.005	0.05	0.01
Chenganxian	Pig	Solid	0.185	0.005	0.05	0.01
Chenganxian	Pig	Liquid	0.185	0.005	0.05	0.01
Chenganxian	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Chenganxian	Broiler	Solid	0.185	0.005	0.05	0.01
Chenganxian	Layer	Solid	0.185	0.005	0.05	0.01
Quzhou	Dairycow	Solid	0.185	0.005	0.05	0.01
Quzhou	Dairycow	Liquid	0.185	0.005	0.05	0.01
Quzhou	Beefcow	Solid	0.185	0.005	0.05	0.01
Quzhou	Beefcow	Liquid	0.185	0.005	0.05	0.01
Quzhou	Pig	Solid	0.185	0.005	0.05	0.01
Quzhou	Pig	Liquid	0.185	0.005	0.05	0.01
Quzhou	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Quzhou	Broiler	Solid	0.185	0.005	0.05	0.01
Quzhou	Layer	Solid	0.185	0.005	0.05	0.01
Handanshi	Dairycow	Solid	0.185	0.005	0.05	0.01
Handanshi	Dairycow	Liquid	0.185	0.005	0.05	0.01
Handanshi	Beefcow	Solid	0.185	0.005	0.05	0.01
Handanshi	Beefcow	Liquid	0.185	0.005	0.05	0.01
Handanshi	Pig	Solid	0.185	0.005	0.05	0.01
Handanshi	Pig	Liquid	0.185	0.005	0.05	0.01
Handanshi	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Handanshi	Broiler	Solid	0.185	0.005	0.05	0.01
Handanshi	Layer	Solid	0.185	0.005	0.05	0.01
Qiuxian	Dairycow	Solid	0.185	0.005	0.05	0.01
Qiuxian	Dairycow	Liquid	0.185	0.005	0.05	0.01
Qiuxian	Beefcow	Solid	0.185	0.005	0.05	0.01
Qiuxian	Beefcow	Liquid	0.185	0.005	0.05	0.01
Qiuxian	Pig	Solid	0.185	0.005	0.05	0.01
Qiuxian	Pig	Liquid	0.185	0.005	0.05	0.01
Qiuxian	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Qiuxian	Broiler	Solid	0.185	0.005	0.05	0.01
Qiuxian	Layer	Solid	0.185	0.005	0.05	0.01
Jize	Dairycow	Solid	0.185	0.005	0.05	0.01
Jize	Dairycow	Liquid	0.185	0.005	0.05	0.01
Jize	Beefcow	Solid	0.185	0.005	0.05	0.01
Jize	Beefcow	Liquid	0.185	0.005	0.05	0.01

Jize	Pig	Solid	0.185	0.005	0.05	0.01
Jize	Pig	Liquid	0.185	0.005	0.05	0.01
Jize	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Jize	Broiler	Solid	0.185	0.005	0.05	0.01
Jize	Layer	Solid	0.185	0.005	0.05	0.01
Wuanshi	Dairycow	Solid	0.185	0.005	0.05	0.01
Wuanshi	Dairycow	Liquid	0.185	0.005	0.05	0.01
Wuanshi	Beefcow	Solid	0.185	0.005	0.05	0.01
Wuanshi	Beefcow	Liquid	0.185	0.005	0.05	0.01
Wuanshi	Pig	Solid	0.185	0.005	0.05	0.01
Wuanshi	Pig	Liquid	0.185	0.005	0.05	0.01
Wuanshi	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Wuanshi	Broiler	Solid	0.185	0.005	0.05	0.01
Wuanshi	Layer	Solid	0.185	0.005	0.05	0.01
Feixiang	Dairycow	Solid	0.185	0.005	0.05	0.01
Feixiang	Dairycow	Liquid	0.185	0.005	0.05	0.01
Feixiang	Beefcow	Solid	0.185	0.005	0.05	0.01
Feixiang	Beefcow	Liquid	0.185	0.005	0.05	0.01
Feixiang	Pig	Solid	0.185	0.005	0.05	0.01
Feixiang	Pig	Liquid	0.185	0.005	0.05	0.01
Feixiang	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Feixiang	Broiler	Solid	0.185	0.005	0.05	0.01
Feixiang	Layer	Solid	0.185	0.005	0.05	0.01
Linzhang	Dairycow	Solid	0.185	0.005	0.05	0.01
Linzhang	Dairycow	Liquid	0.185	0.005	0.05	0.01
Linzhang	Beefcow	Solid	0.185	0.005	0.05	0.01
Linzhang	Beefcow	Liquid	0.185	0.005	0.05	0.01
Linzhang	Pig	Solid	0.185	0.005	0.05	0.01
Linzhang	Pig	Liquid	0.185	0.005	0.05	0.01
Linzhang	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Linzhang	Broiler	Solid	0.185	0.005	0.05	0.01
Linzhang	Layer	Solid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Dairycow	Solid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Dairycow	Liquid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Beefcow	Solid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Beefcow	Liquid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Pig	Solid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Pig	Liquid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Broiler	Solid	0.185	0.005	0.05	0.01
Fengfengkuangqu	Layer	Solid	0.185	0.005	0.05	0.01
Shexian	Dairycow	Solid	0.185	0.005	0.05	0.01
Shexian	Dairycow	Liquid	0.185	0.005	0.05	0.01
Shexian	Beefcow	Solid	0.185	0.005	0.05	0.01
Shexian	Beefcow	Liquid	0.185	0.005	0.05	0.01

Shexian	Pig	Solid	0.185	0.005	0.05	0.01
Shexian	Pig	Liquid	0.185	0.005	0.05	0.01
Shexian	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Shexian	Broiler	Solid	0.185	0.005	0.05	0.01
Shexian	Layer	Solid	0.185	0.005	0.05	0.01
Guantao	Dairycow	Solid	0.185	0.005	0.05	0.01
Guantao	Dairycow	Liquid	0.185	0.005	0.05	0.01
Guantao	Beefcow	Solid	0.185	0.005	0.05	0.01
Guantao	Beefcow	Liquid	0.185	0.005	0.05	0.01
Guantao	Pig	Solid	0.185	0.005	0.05	0.01
Guantao	Pig	Liquid	0.185	0.005	0.05	0.01
Guantao	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Guantao	Broiler	Solid	0.185	0.005	0.05	0.01
Guantao	Layer	Solid	0.185	0.005	0.05	0.01
Cixian	Dairycow	Solid	0.185	0.005	0.05	0.01
Cixian	Dairycow	Liquid	0.185	0.005	0.05	0.01
Cixian	Beefcow	Solid	0.185	0.005	0.05	0.01
Cixian	Beefcow	Liquid	0.185	0.005	0.05	0.01
Cixian	Pig	Solid	0.185	0.005	0.05	0.01
Cixian	Pig	Liquid	0.185	0.005	0.05	0.01
Cixian	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Cixian	Broiler	Solid	0.185	0.005	0.05	0.01
Cixian	Layer	Solid	0.185	0.005	0.05	0.01
Handanxian	Dairycow	Solid	0.185	0.005	0.05	0.01
Handanxian	Dairycow	Liquid	0.185	0.005	0.05	0.01
Handanxian	Beefcow	Solid	0.185	0.005	0.05	0.01
Handanxian	Beefcow	Liquid	0.185	0.005	0.05	0.01
Handanxian	Pig	Solid	0.185	0.005	0.05	0.01
Handanxian	Pig	Liquid	0.185	0.005	0.05	0.01
Handanxian	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Handanxian	Broiler	Solid	0.185	0.005	0.05	0.01
Handanxian	Layer	Solid	0.185	0.005	0.05	0.01
Weixian	Dairycow	Solid	0.185	0.005	0.05	0.01
Weixian	Dairycow	Liquid	0.185	0.005	0.05	0.01
Weixian	Beefcow	Solid	0.185	0.005	0.05	0.01
Weixian	Beefcow	Liquid	0.185	0.005	0.05	0.01
Weixian	Pig	Solid	0.185	0.005	0.05	0.01
Weixian	Pig	Liquid	0.185	0.005	0.05	0.01
Weixian	Sheepgoat	Solid	0.185	0.005	0.05	0.01
Weixian	Broiler	Solid	0.185	0.005	0.05	0.01
Weixian	Layer	Solid	0.185	0.005	0.05	0.01

County	Anicategories	Manuretypes	NH3	N2O	N2	Nleaching
Daming	Dairycow	Compost	0.235	0.005	0.05	0.01
Daming	Dairycow	Digestion	0.045	0.005	0.05	0

Daming	Beefcow	Compost	0.235	0.005	0.05	0.01
Daming	Pig	Compost	0.235	0.005	0.05	0.01
Daming	Pig	Digestion	0.045	0.005	0.05	0
Daming	Broiler	Compost	0.235	0.005	0.05	0.01
Daming	Layer	Compost	0.235	0.005	0.05	0.01
Guangping	Dairycow	Compost	0.235	0.005	0.05	0.01
Guangping	Dairycow	Digestion	0.045	0.005	0.05	0
Guangping	Beefcow	Compost	0.235	0.005	0.05	0.01
Guangping	Pig	Compost	0.235	0.005	0.05	0.01
Guangping	Pig	Digestion	0.045	0.005	0.05	0
Guangping	Broiler	Compost	0.235	0.005	0.05	0.01
Guangping	Layer	Compost	0.235	0.005	0.05	0.01
Yongnian	Dairycow	Compost	0.235	0.005	0.05	0.01
Yongnian	Dairycow	Digestion	0.045	0.005	0.05	0
Yongnian	Beefcow	Compost	0.235	0.005	0.05	0.01
Yongnian	Pig	Compost	0.235	0.005	0.05	0.01
Yongnian	Pig	Digestion	0.045	0.005	0.05	0
Yongnian	Broiler	Compost	0.235	0.005	0.05	0.01
Yongnian	Layer	Compost	0.235	0.005	0.05	0.01
Chenganxian	Dairycow	Compost	0.235	0.005	0.05	0.01
Chenganxian	Dairycow	Digestion	0.045	0.005	0.05	0
Chenganxian	Beefcow	Compost	0.235	0.005	0.05	0.01
Chenganxian	Pig	Compost	0.235	0.005	0.05	0.01
Chenganxian	Pig	Digestion	0.045	0.005	0.05	0
Chenganxian	Broiler	Compost	0.235	0.005	0.05	0.01
Chenganxian	Layer	Compost	0.235	0.005	0.05	0.01
Quzhou	Dairycow	Compost	0.235	0.005	0.05	0.01
Quzhou	Dairycow	Digestion	0.045	0.005	0.05	0
Quzhou	Beefcow	Compost	0.235	0.005	0.05	0.01
Quzhou	Pig	Compost	0.235	0.005	0.05	0.01
Quzhou	Pig	Digestion	0.045	0.005	0.05	0
Quzhou	Broiler	Compost	0.235	0.005	0.05	0.01
Quzhou	Layer	Compost	0.235	0.005	0.05	0.01
Handanshi	Dairycow	Compost	0.235	0.005	0.05	0.01
Handanshi	Dairycow	Digestion	0.045	0.005	0.05	0
Handanshi	Beefcow	Compost	0.235	0.005	0.05	0.01
Handanshi	Pig	Compost	0.235	0.005	0.05	0.01
Handanshi	Pig	Digestion	0.045	0.005	0.05	0
Handanshi	Broiler	Compost	0.235	0.005	0.05	0.01
Handanshi	Layer	Compost	0.235	0.005	0.05	0.01
Qiuxian	Dairycow	Compost	0.235	0.005	0.05	0.01
Qiuxian	Dairycow	Digestion	0.045	0.005	0.05	0
Qiuxian	Beefcow	Compost	0.235	0.005	0.05	0.01
Qiuxian	Pig	Compost	0.235	0.005	0.05	0.01
Qiuxian	Pig	Digestion	0.045	0.005	0.05	0

Qiuxian	Broiler	Compost	0.235	0.005	0.05	0.01
Qiuxian	Layer	Compost	0.235	0.005	0.05	0.01
Jize	Dairycow	Compost	0.235	0.005	0.05	0.01
Jize	Dairycow	Digestion	0.045	0.005	0.05	0
Jize	Beefcow	Compost	0.235	0.005	0.05	0.01
Jize	Pig	Compost	0.235	0.005	0.05	0.01
Jize	Pig	Digestion	0.045	0.005	0.05	0
Jize	Broiler	Compost	0.235	0.005	0.05	0.01
Jize	Layer	Compost	0.235	0.005	0.05	0.01
Wuanshi	Dairycow	Compost	0.235	0.005	0.05	0.01
Wuanshi	Dairycow	Digestion	0.045	0.005	0.05	0
Wuanshi	Beefcow	Compost	0.235	0.005	0.05	0.01
Wuanshi	Pig	Compost	0.235	0.005	0.05	0.01
Wuanshi	Pig	Digestion	0.045	0.005	0.05	0
Wuanshi	Broiler	Compost	0.235	0.005	0.05	0.01
Wuanshi	Layer	Compost	0.235	0.005	0.05	0.01
Feixiang	Dairycow	Compost	0.235	0.005	0.05	0.01
Feixiang	Dairycow	Digestion	0.045	0.005	0.05	0
Feixiang	Beefcow	Compost	0.235	0.005	0.05	0.01
Feixiang	Pig	Compost	0.235	0.005	0.05	0.01
Feixiang	Pig	Digestion	0.045	0.005	0.05	0
Feixiang	Broiler	Compost	0.235	0.005	0.05	0.01
Feixiang	Layer	Compost	0.235	0.005	0.05	0.01
Linzhang	Dairycow	Compost	0.235	0.005	0.05	0.01
Linzhang	Dairycow	Digestion	0.045	0.005	0.05	0
Linzhang	Beefcow	Compost	0.235	0.005	0.05	0.01
Linzhang	Pig	Compost	0.235	0.005	0.05	0.01
Linzhang	Pig	Digestion	0.045	0.005	0.05	0
Linzhang	Broiler	Compost	0.235	0.005	0.05	0.01
Linzhang	Layer	Compost	0.235	0.005	0.05	0.01
Fengfengkuangqu	Dairycow	Compost	0.235	0.005	0.05	0.01
Fengfengkuangqu	Dairycow	Digestion	0.045	0.005	0.05	0
Fengfengkuangqu	Beefcow	Compost	0.235	0.005	0.05	0.01
Fengfengkuangqu	Pig	Compost	0.235	0.005	0.05	0.01
Fengfengkuangqu	Pig	Digestion	0.045	0.005	0.05	0
Fengfengkuangqu	Broiler	Compost	0.235	0.005	0.05	0.01
Fengfengkuangqu	Layer	Compost	0.235	0.005	0.05	0.01
Shexian	Dairycow	Compost	0.235	0.005	0.05	0.01
Shexian	Dairycow	Digestion	0.045	0.005	0.05	0
Shexian	Beefcow	Compost	0.235	0.005	0.05	0.01
Shexian	Pig	Compost	0.235	0.005	0.05	0.01
Shexian	Pig	Digestion	0.045	0.005	0.05	0
Shexian	Broiler	Compost	0.235	0.005	0.05	0.01
Shexian	Layer	Compost	0.235	0.005	0.05	0.01
Guantao	Dairycow	Compost	0.235	0.005	0.05	0.01

Guantao	Dairycow	Digestion	0.045	0.005	0.05	0
Guantao	Beefcow	Compost	0.235	0.005	0.05	0.01
Guantao	Pig	Compost	0.235	0.005	0.05	0.01
Guantao	Pig	Digestion	0.045	0.005	0.05	0
Guantao	Broiler	Compost	0.235	0.005	0.05	0.01
Guantao	Layer	Compost	0.235	0.005	0.05	0.01
Cixian	Dairycow	Compost	0.235	0.005	0.05	0.01
Cixian	Dairycow	Digestion	0.045	0.005	0.05	0
Cixian	Beefcow	Compost	0.235	0.005	0.05	0.01
Cixian	Pig	Compost	0.235	0.005	0.05	0.01
Cixian	Pig	Digestion	0.045	0.005	0.05	0
Cixian	Broiler	Compost	0.235	0.005	0.05	0.01
Cixian	Layer	Compost	0.235	0.005	0.05	0.01
Handanxian	Dairycow	Compost	0.235	0.005	0.05	0.01
Handanxian	Dairycow	Digestion	0.045	0.005	0.05	0
Handanxian	Beefcow	Compost	0.235	0.005	0.05	0.01
Handanxian	Pig	Compost	0.235	0.005	0.05	0.01
Handanxian	Pig	Digestion	0.045	0.005	0.05	0
Handanxian	Broiler	Compost	0.235	0.005	0.05	0.01
Handanxian	Layer	Compost	0.235	0.005	0.05	0.01
Weixian	Dairycow	Compost	0.235	0.005	0.05	0.01
Weixian	Dairycow	Digestion	0.045	0.005	0.05	0
Weixian	Beefcow	Compost	0.235	0.005	0.05	0.01
Weixian	Pig	Compost	0.235	0.005	0.05	0.01
Weixian	Pig	Digestion	0.045	0.005	0.05	0
Weixian	Broiler	Compost	0.235	0.005	0.05	0.01
Weixian	Layer	Compost	0.235	0.005	0.05	0.01

Table A5. Data used for calculating loss of P throughout the process(t)

Conuty	**Pathway**	
Ploss_Housing		
County	Anicategories	Pleaching
Daming	Dairycow	0.05
Daming	Beefcow	0.05
Daming	Pig	0.05
Daming	Sheepgoat	0.05
Daming	Broiler	0.05
Daming	Layer	0.05
Guangping	Dairycow	0.05
Guangping	Beefcow	0.05
Guangping	Pig	0.05
Guangping	Sheepgoat	0.05
Guangping	Broiler	0.05
Guangping	Layer	0.05

Yongnian	Dairycow	0.05
Yongnian	Beefcow	0.05
Yongnian	Pig	0.05
Yongnian	Sheepgoat	0.05
Yongnian	Broiler	0.05
Yongnian	Layer	0.05
Chenganxian	Dairycow	0.05
Chenganxian	Beefcow	0.05
Chenganxian	Pig	0.05
Chenganxian	Sheepgoat	0.05
Chenganxian	Broiler	0.05
Chenganxian	Layer	0.05
Quzhou	Dairycow	0.05
Quzhou	Beefcow	0.05
Quzhou	Pig	0.05
Quzhou	Sheepgoat	0.05
Quzhou	Broiler	0.05
Quzhou	Layer	0.05
Handanshi	Dairycow	0.05
Handanshi	Beefcow	0.05
Handanshi	Pig	0.05
Handanshi	Sheepgoat	0.05
Handanshi	Broiler	0.05
Handanshi	Layer	0.05
Qiuxian	Dairycow	0.05
Qiuxian	Beefcow	0.05
Qiuxian	Pig	0.05
Qiuxian	Sheepgoat	0.05
Qiuxian	Broiler	0.05
Qiuxian	Layer	0.05
Jize	Dairycow	0.05
Jize	Beefcow	0.05
Jize	Pig	0.05
Jize	Sheepgoat	0.05
Jize	Broiler	0.05
Jize	Layer	0.05
Wuanshi	Dairycow	0.05
Wuanshi	Beefcow	0.05
Wuanshi	Pig	0.05
Wuanshi	Sheepgoat	0.05
Wuanshi	Broiler	0.05
Wuanshi	Layer	0.05
Feixiang	Dairycow	0.05
Feixiang	Beefcow	0.05
Feixiang	Pig	0.05

Feixiang	Sheepgoat	0.05
Feixiang	Broiler	0.05
Feixiang	Layer	0.05
Linzhang	Dairycow	0.05
Linzhang	Beefcow	0.05
Linzhang	Pig	0.05
Linzhang	Sheepgoat	0.05
Linzhang	Broiler	0.05
Linzhang	Layer	0.05
Fengfengkuangqu	Dairycow	0.05
Fengfengkuangqu	Beefcow	0.05
Fengfengkuangqu	Pig	0.05
Fengfengkuangqu	Sheepgoat	0.05
Fengfengkuangqu	Broiler	0.05
Fengfengkuangqu	Layer	0.05
Shexian	Dairycow	0.05
Shexian	Beefcow	0.05
Shexian	Pig	0.05
Shexian	Sheepgoat	0.05
Shexian	Broiler	0.05
Shexian	Layer	0.05
Guantao	Dairycow	0.05
Guantao	Beefcow	0.05
Guantao	Pig	0.05
Guantao	Sheepgoat	0.05
Guantao	Broiler	0.05
Guantao	Layer	0.05
Cixian	Dairycow	0.05
Cixian	Beefcow	0.05
Cixian	Pig	0.05
Cixian	Sheepgoat	0.05
Cixian	Broiler	0.05
Cixian	Layer	0.05
Handanxian	Dairycow	0.05
Handanxian	Beefcow	0.05
Handanxian	Pig	0.05
Handanxian	Sheepgoat	0.05
Handanxian	Broiler	0.05
Handanxian	Layer	0.05
Weixian	Dairycow	0.05
Weixian	Beefcow	0.05
Weixian	Pig	0.05
Weixian	Sheepgoat	0.05
Weixian	Broiler	0.05
Weixian	Layer	0.05

Ploss_Storage

County	Anicategories	Manuretypes	Pleaching
Daming	Dairycow	Solid	0.3
Daming	Dairycow	Liquid	0.3
Daming	Beefcow	Solid	0.3
Daming	Beefcow	Liquid	0.3
Daming	Pig	Solid	0.3
Daming	Pig	Liquid	0.3
Daming	Sheepgoat	Solid	0.3
Daming	Broiler	Solid	0.3
Daming	Layer	Solid	0.3
Guangping	Dairycow	Solid	0.3
Guangping	Dairycow	Liquid	0.3
Guangping	Beefcow	Solid	0.3
Guangping	Beefcow	Liquid	0.3
Guangping	Pig	Solid	0.3
Guangping	Pig	Liquid	0.3
Guangping	Sheepgoat	Solid	0.3
Guangping	Broiler	Solid	0.3
Guangping	Layer	Solid	0.3
Yongnian	Dairycow	Solid	0.3
Yongnian	Dairycow	Liquid	0.3
Yongnian	Beefcow	Solid	0.3
Yongnian	Beefcow	Liquid	0.3
Yongnian	Pig	Solid	0.3
Yongnian	Pig	Liquid	0.3
Yongnian	Sheepgoat	Solid	0.3
Yongnian	Broiler	Solid	0.3
Yongnian	Layer	Solid	0.3
Chenganxian	Dairycow	Solid	0.3
Chenganxian	Dairycow	Liquid	0.3
Chenganxian	Beefcow	Solid	0.3
Chenganxian	Beefcow	Liquid	0.3
Chenganxian	Pig	Solid	0.3
Chenganxian	Pig	Liquid	0.3
Chenganxian	Sheepgoat	Solid	0.3
Chenganxian	Broiler	Solid	0.3
Chenganxian	Layer	Solid	0.3
Quzhou	Dairycow	Solid	0.3
Quzhou	Dairycow	Liquid	0.3
Quzhou	Beefcow	Solid	0.3
Quzhou	Beefcow	Liquid	0.3
Quzhou	Pig	Solid	0.3
Quzhou	Pig	Liquid	0.3
Quzhou	Sheepgoat	Solid	0.3

Quzhou	Broiler	Solid	0.3
Quzhou	Layer	Solid	0.3
Handanshi	Dairycow	Solid	0.3
Handanshi	Dairycow	Liquid	0.3
Handanshi	Beefcow	Solid	0.3
Handanshi	Beefcow	Liquid	0.3
Handanshi	Pig	Solid	0.3
Handanshi	Pig	Liquid	0.3
Handanshi	Sheepgoat	Solid	0.3
Handanshi	Broiler	Solid	0.3
Handanshi	Layer	Solid	0.3
Qiuxian	Dairycow	Solid	0.3
Qiuxian	Dairycow	Liquid	0.3
Qiuxian	Beefcow	Solid	0.3
Qiuxian	Beefcow	Liquid	0.3
Qiuxian	Pig	Solid	0.3
Qiuxian	Pig	Liquid	0.3
Qiuxian	Sheepgoat	Solid	0.3
Qiuxian	Broiler	Solid	0.3
Qiuxian	Layer	Solid	0.3
Jize	Dairycow	Solid	0.3
Jize	Dairycow	Liquid	0.3
Jize	Beefcow	Solid	0.3
Jize	Beefcow	Liquid	0.3
Jize	Pig	Solid	0.3
Jize	Pig	Liquid	0.3
Jize	Sheepgoat	Solid	0.3
Jize	Broiler	Solid	0.3
Jize	Layer	Solid	0.3
Wuanshi	Dairycow	Solid	0.3
Wuanshi	Dairycow	Liquid	0.3
Wuanshi	Beefcow	Solid	0.3
Wuanshi	Beefcow	Liquid	0.3
Wuanshi	Pig	Solid	0.3
Wuanshi	Pig	Liquid	0.3
Wuanshi	Sheepgoat	Solid	0.3
Wuanshi	Broiler	Solid	0.3
Wuanshi	Layer	Solid	0.3
Feixiang	Dairycow	Solid	0.3
Feixiang	Dairycow	Liquid	0.3
Feixiang	Beefcow	Solid	0.3
Feixiang	Beefcow	Liquid	0.3
Feixiang	Pig	Solid	0.3
Feixiang	Pig	Liquid	0.3
Feixiang	Sheepgoat	Solid	0.3

Feixiang	Broiler	Solid	0.3
Feixiang	Layer	Solid	0.3
Linzhang	Dairycow	Solid	0.3
Linzhang	Dairycow	Liquid	0.3
Linzhang	Beefcow	Solid	0.3
Linzhang	Beefcow	Liquid	0.3
Linzhang	Pig	Solid	0.3
Linzhang	Pig	Liquid	0.3
Linzhang	Sheepgoat	Solid	0.3
Linzhang	Broiler	Solid	0.3
Linzhang	Layer	Solid	0.3
Fengfengkuangqu	Dairycow	Solid	0.3
Fengfengkuangqu	Dairycow	Liquid	0.3
Fengfengkuangqu	Beefcow	Solid	0.3
Fengfengkuangqu	Beefcow	Liquid	0.3
Fengfengkuangqu	Pig	Solid	0.3
Fengfengkuangqu	Pig	Liquid	0.3
Fengfengkuangqu	Sheepgoat	Solid	0.3
Fengfengkuangqu	Broiler	Solid	0.3
Fengfengkuangqu	Layer	Solid	0.3
Shexian	Dairycow	Solid	0.3
Shexian	Dairycow	Liquid	0.3
Shexian	Beefcow	Solid	0.3
Shexian	Beefcow	Liquid	0.3
Shexian	Pig	Solid	0.3
Shexian	Pig	Liquid	0.3
Shexian	Sheepgoat	Solid	0.3
Shexian	Broiler	Solid	0.3
Shexian	Layer	Solid	0.3
Guantao	Dairycow	Solid	0.3
Guantao	Dairycow	Liquid	0.3
Guantao	Beefcow	Solid	0.3
Guantao	Beefcow	Liquid	0.3
Guantao	Pig	Solid	0.3
Guantao	Pig	Liquid	0.3
Guantao	Sheepgoat	Solid	0.3
Guantao	Broiler	Solid	0.3
Guantao	Layer	Solid	0.3
Cixian	Dairycow	Solid	0.3
Cixian	Dairycow	Liquid	0.3
Cixian	Beefcow	Solid	0.3
Cixian	Beefcow	Liquid	0.3
Cixian	Pig	Solid	0.3
Cixian	Pig	Liquid	0.3
Cixian	Sheepgoat	Solid	0.3

Cixian	Broiler	Solid	0.3
Cixian	Layer	Solid	0.3
Handanxian	Dairycow	Solid	0.3
Handanxian	Dairycow	Liquid	0.3
Handanxian	Beefcow	Solid	0.3
Handanxian	Beefcow	Liquid	0.3
Handanxian	Pig	Solid	0.3
Handanxian	Pig	Liquid	0.3
Handanxian	Sheepgoat	Solid	0.3
Handanxian	Broiler	Solid	0.3
Handanxian	Layer	Solid	0.3
Weixian	Dairycow	Solid	0.3
Weixian	Dairycow	Liquid	0.3
Weixian	Beefcow	Solid	0.3
Weixian	Beefcow	Liquid	0.3
Weixian	Pig	Solid	0.3
Weixian	Pig	Liquid	0.3
Weixian	Sheepgoat	Solid	0.3
Weixian	Broiler	Solid	0.3
Weixian	Layer	Solid	0.3

Ploss_Treatment

County	Anicategories	Manuretypes	Pleaching
Daming	Dairycow	Compost	0.1
Daming	Dairycow	Digestion	0.05
Daming	Beefcow	Compost	0.1
Daming	Pig	Compost	0.1
Daming	Pig	Digestion	0.05
Daming	Broiler	Compost	0.1
Daming	Layer	Compost	0.1
Guangping	Dairycow	Compost	0.1
Guangping	Dairycow	Digestion	0.05
Guangping	Beefcow	Compost	0.1
Guangping	Pig	Compost	0.1
Guangping	Pig	Digestion	0.05
Guangping	Broiler	Compost	0.1
Guangping	Layer	Compost	0.1
Yongnian	Dairycow	Compost	0.1
Yongnian	Dairycow	Digestion	0.05
Yongnian	Beefcow	Compost	0.1
Yongnian	Pig	Compost	0.1
Yongnian	Pig	Digestion	0.05
Yongnian	Broiler	Compost	0.1
Yongnian	Layer	Compost	0.1
Chenganxian	Dairycow	Compost	0.1
Chenganxian	Dairycow	Digestion	0.05

Chenganxian	Beefcow	Compost	0.1
Chenganxian	Pig	Compost	0.1
Chenganxian	Pig	Digestion	0.05
Chenganxian	Broiler	Compost	0.1
Chenganxian	Layer	Compost	0.1
Quzhou	Dairycow	Compost	0.1
Quzhou	Dairycow	Digestion	0.05
Quzhou	Beefcow	Compost	0.1
Quzhou	Pig	Compost	0.1
Quzhou	Pig	Digestion	0.05
Quzhou	Broiler	Compost	0.1
Quzhou	Layer	Compost	0.1
Handanshi	Dairycow	Compost	0.1
Handanshi	Dairycow	Digestion	0.05
Handanshi	Beefcow	Compost	0.1
Handanshi	Pig	Compost	0.1
Handanshi	Pig	Digestion	0.05
Handanshi	Broiler	Compost	0.1
Handanshi	Layer	Compost	0.1
Qiuxian	Dairycow	Compost	0.1
Qiuxian	Dairycow	Digestion	0.05
Qiuxian	Beefcow	Compost	0.1
Qiuxian	Pig	Compost	0.1
Qiuxian	Pig	Digestion	0.05
Qiuxian	Broiler	Compost	0.1
Qiuxian	Layer	Compost	0.1
Jize	Dairycow	Compost	0.1
Jize	Dairycow	Digestion	0.05
Jize	Beefcow	Compost	0.1
Jize	Pig	Compost	0.1
Jize	Pig	Digestion	0.05
Jize	Broiler	Compost	0.1
Jize	Layer	Compost	0.1
Wuanshi	Dairycow	Compost	0.1
Wuanshi	Dairycow	Digestion	0.05
Wuanshi	Beefcow	Compost	0.1
Wuanshi	Pig	Compost	0.1
Wuanshi	Pig	Digestion	0.05
Wuanshi	Broiler	Compost	0.1
Wuanshi	Layer	Compost	0.1
Feixiang	Dairycow	Compost	0.1
Feixiang	Dairycow	Digestion	0.05
Feixiang	Beefcow	Compost	0.1
Feixiang	Pig	Compost	0.1
Feixiang	Pig	Digestion	0.05

Feixiang	Broiler	Compost	0.1
Feixiang	Layer	Compost	0.1
Linzhang	Dairycow	Compost	0.1
Linzhang	Dairycow	Digestion	0.05
Linzhang	Beefcow	Compost	0.1
Linzhang	Pig	Compost	0.1
Linzhang	Pig	Digestion	0.05
Linzhang	Broiler	Compost	0.1
Linzhang	Layer	Compost	0.1
Fengfengkuangqu	Dairycow	Compost	0.1
Fengfengkuangqu	Dairycow	Digestion	0.05
Fengfengkuangqu	Beefcow	Compost	0.1
Fengfengkuangqu	Pig	Compost	0.1
Fengfengkuangqu	Pig	Digestion	0.05
Fengfengkuangqu	Broiler	Compost	0.1
Fengfengkuangqu	Layer	Compost	0.1
Shexian	Dairycow	Compost	0.1
Shexian	Dairycow	Digestion	0.05
Shexian	Beefcow	Compost	0.1
Shexian	Pig	Compost	0.1
Shexian	Pig	Digestion	0.05
Shexian	Broiler	Compost	0.1
Shexian	Layer	Compost	0.1
Guantao	Dairycow	Compost	0.1
Guantao	Dairycow	Digestion	0.05
Guantao	Beefcow	Compost	0.1
Guantao	Pig	Compost	0.1
Guantao	Pig	Digestion	0.05
Guantao	Broiler	Compost	0.1
Guantao	Layer	Compost	0.1
Cixian	Dairycow	Compost	0.1
Cixian	Dairycow	Digestion	0.05
Cixian	Beefcow	Compost	0.1
Cixian	Pig	Compost	0.1
Cixian	Pig	Digestion	0.05
Cixian	Broiler	Compost	0.1
Cixian	Layer	Compost	0.1
Handanxian	Dairycow	Compost	0.1
Handanxian	Dairycow	Digestion	0.05
Handanxian	Beefcow	Compost	0.1
Handanxian	Pig	Compost	0.1
Handanxian	Pig	Digestion	0.05
Handanxian	Broiler	Compost	0.1
Handanxian	Layer	Compost	0.1
Weixian	Dairycow	Compost	0.1

Weixian	Dairycow	Digestion	0.05
Weixian	Beefcow	Compost	0.1
Weixian	Pig	Compost	0.1
Weixian	Pig	Digestion	0.05
Weixian	Broiler	Compost	0.1
Weixian	Layer	Compost	0.1

Table A6. Data used for calculating loss of K throughout the process(t)

Conuty	**Pathway**	
Kloss_Housing		
County	Anicategories	Kleaching
Daming	Dairycow	0.05
Daming	Beefcow	0.05
Daming	Pig	0.05
Daming	Sheepgoat	0.05
Daming	Broiler	0.05
Daming	Layer	0.05
Guangping	Dairycow	0.05
Guangping	Beefcow	0.05
Guangping	Pig	0.05
Guangping	Sheepgoat	0.05
Guangping	Broiler	0.05
Guangping	Layer	0.05
Yongnian	Dairycow	0.05
Yongnian	Beefcow	0.05
Yongnian	Pig	0.05
Yongnian	Sheepgoat	0.05
Yongnian	Broiler	0.05
Yongnian	Layer	0.05
Chenganxian	Dairycow	0.05
Chenganxian	Beefcow	0.05
Chenganxian	Pig	0.05
Chenganxian	Sheepgoat	0.05
Chenganxian	Broiler	0.05
Chenganxian	Layer	0.05
Quzhou	Dairycow	0.05
Quzhou	Beefcow	0.05
Quzhou	Pig	0.05
Quzhou	Sheepgoat	0.05
Quzhou	Broiler	0.05
Quzhou	Layer	0.05
Handanshi	Dairycow	0.05
Handanshi	Beefcow	0.05
Handanshi	Pig	0.05
Handanshi	Sheepgoat	0.05

Handanshi	Broiler	0.05
Handanshi	Layer	0.05
Qiuxian	Dairycow	0.05
Qiuxian	Beefcow	0.05
Qiuxian	Pig	0.05
Qiuxian	Sheepgoat	0.05
Qiuxian	Broiler	0.05
Qiuxian	Layer	0.05
Jize	Dairycow	0.05
Jize	Beefcow	0.05
Jize	Pig	0.05
Jize	Sheepgoat	0.05
Jize	Broiler	0.05
Jize	Layer	0.05
Wuanshi	Dairycow	0.05
Wuanshi	Beefcow	0.05
Wuanshi	Pig	0.05
Wuanshi	Sheepgoat	0.05
Wuanshi	Broiler	0.05
Wuanshi	Layer	0.05
Feixiang	Dairycow	0.05
Feixiang	Beefcow	0.05
Feixiang	Pig	0.05
Feixiang	Sheepgoat	0.05
Feixiang	Broiler	0.05
Feixiang	Layer	0.05
Linzhang	Dairycow	0.05
Linzhang	Beefcow	0.05
Linzhang	Pig	0.05
Linzhang	Sheepgoat	0.05
Linzhang	Broiler	0.05
Linzhang	Layer	0.05
Fengfengkuangqu	Dairycow	0.05
Fengfengkuangqu	Beefcow	0.05
Fengfengkuangqu	Pig	0.05
Fengfengkuangqu	Sheepgoat	0.05
Fengfengkuangqu	Broiler	0.05
Fengfengkuangqu	Layer	0.05
Shexian	Dairycow	0.05
Shexian	Beefcow	0.05
Shexian	Pig	0.05
Shexian	Sheepgoat	0.05
Shexian	Broiler	0.05
Shexian	Layer	0.05
Guantao	Dairycow	0.05

Guantao	Beefcow	0.05
Guantao	Pig	0.05
Guantao	Sheepgoat	0.05
Guantao	Broiler	0.05
Guantao	Layer	0.05
Cixian	Dairycow	0.05
Cixian	Beefcow	0.05
Cixian	Pig	0.05
Cixian	Sheepgoat	0.05
Cixian	Broiler	0.05
Cixian	Layer	0.05
Handanxian	Dairycow	0.05
Handanxian	Beefcow	0.05
Handanxian	Pig	0.05
Handanxian	Sheepgoat	0.05
Handanxian	Broiler	0.05
Handanxian	Layer	0.05
Weixian	Dairycow	0.05
Weixian	Beefcow	0.05
Weixian	Pig	0.05
Weixian	Sheepgoat	0.05
Weixian	Broiler	0.05
Weixian	Layer	0.05

Kloss_Storage

County	Anicategories	Manuretypes	Kleaching
Daming	Dairycow	Solid	0.25
Daming	Dairycow	Liquid	0.25
Daming	Beefcow	Solid	0.25
Daming	Beefcow	Liquid	0.25
Daming	Pig	Solid	0.25
Daming	Pig	Liquid	0.25
Daming	Sheepgoat	Solid	0.25
Daming	Broiler	Solid	0.25
Daming	Layer	Solid	0.25
Guangping	Dairycow	Solid	0.25
Guangping	Dairycow	Liquid	0.25
Guangping	Beefcow	Solid	0.25
Guangping	Beefcow	Liquid	0.25
Guangping	Pig	Solid	0.25
Guangping	Pig	Liquid	0.25
Guangping	Sheepgoat	Solid	0.25
Guangping	Broiler	Solid	0.25
Guangping	Layer	Solid	0.25
Yongnian	Dairycow	Solid	0.25
Yongnian	Dairycow	Liquid	0.25

Yongnian	Beefcow	Solid	0.25
Yongnian	Beefcow	Liquid	0.25
Yongnian	Pig	Solid	0.25
Yongnian	Pig	Liquid	0.25
Yongnian	Sheepgoat	Solid	0.25
Yongnian	Broiler	Solid	0.25
Yongnian	Layer	Solid	0.25
Chenganxian	Dairycow	Solid	0.25
Chenganxian	Dairycow	Liquid	0.25
Chenganxian	Beefcow	Solid	0.25
Chenganxian	Beefcow	Liquid	0.25
Chenganxian	Pig	Solid	0.25
Chenganxian	Pig	Liquid	0.25
Chenganxian	Sheepgoat	Solid	0.25
Chenganxian	Broiler	Solid	0.25
Chenganxian	Layer	Solid	0.25
Quzhou	Dairycow	Solid	0.25
Quzhou	Dairycow	Liquid	0.25
Quzhou	Beefcow	Solid	0.25
Quzhou	Beefcow	Liquid	0.25
Quzhou	Pig	Solid	0.25
Quzhou	Pig	Liquid	0.25
Quzhou	Sheepgoat	Solid	0.25
Quzhou	Broiler	Solid	0.25
Quzhou	Layer	Solid	0.25
Handanshi	Dairycow	Solid	0.25
Handanshi	Dairycow	Liquid	0.25
Handanshi	Beefcow	Solid	0.25
Handanshi	Beefcow	Liquid	0.25
Handanshi	Pig	Solid	0.25
Handanshi	Pig	Liquid	0.25
Handanshi	Sheepgoat	Solid	0.25
Handanshi	Broiler	Solid	0.25
Handanshi	Layer	Solid	0.25
Qiuxian	Dairycow	Solid	0.25
Qiuxian	Dairycow	Liquid	0.25
Qiuxian	Beefcow	Solid	0.25
Qiuxian	Beefcow	Liquid	0.25
Qiuxian	Pig	Solid	0.25
Qiuxian	Pig	Liquid	0.25
Qiuxian	Sheepgoat	Solid	0.25
Qiuxian	Broiler	Solid	0.25
Qiuxian	Layer	Solid	0.25
Jize	Dairycow	Solid	0.25
Jize	Dairycow	Liquid	0.25

Jize	Beefcow	Solid	0.25
Jize	Beefcow	Liquid	0.25
Jize	Pig	Solid	0.25
Jize	Pig	Liquid	0.25
Jize	Sheepgoat	Solid	0.25
Jize	Broiler	Solid	0.25
Jize	Layer	Solid	0.25
Wuanshi	Dairycow	Solid	0.25
Wuanshi	Dairycow	Liquid	0.25
Wuanshi	Beefcow	Solid	0.25
Wuanshi	Beefcow	Liquid	0.25
Wuanshi	Pig	Solid	0.25
Wuanshi	Pig	Liquid	0.25
Wuanshi	Sheepgoat	Solid	0.25
Wuanshi	Broiler	Solid	0.25
Wuanshi	Layer	Solid	0.25
Feixiang	Dairycow	Solid	0.25
Feixiang	Dairycow	Liquid	0.25
Feixiang	Beefcow	Solid	0.25
Feixiang	Beefcow	Liquid	0.25
Feixiang	Pig	Solid	0.25
Feixiang	Pig	Liquid	0.25
Feixiang	Sheepgoat	Solid	0.25
Feixiang	Broiler	Solid	0.25
Feixiang	Layer	Solid	0.25
Linzhang	Dairycow	Solid	0.25
Linzhang	Dairycow	Liquid	0.25
Linzhang	Beefcow	Solid	0.25
Linzhang	Beefcow	Liquid	0.25
Linzhang	Pig	Solid	0.25
Linzhang	Pig	Liquid	0.25
Linzhang	Sheepgoat	Solid	0.25
Linzhang	Broiler	Solid	0.25
Linzhang	Layer	Solid	0.25
Fengfengkuangqu	Dairycow	Solid	0.25
Fengfengkuangqu	Dairycow	Liquid	0.25
Fengfengkuangqu	Beefcow	Solid	0.25
Fengfengkuangqu	Beefcow	Liquid	0.25
Fengfengkuangqu	Pig	Solid	0.25
Fengfengkuangqu	Pig	Liquid	0.25
Fengfengkuangqu	Sheepgoat	Solid	0.25
Fengfengkuangqu	Broiler	Solid	0.25
Fengfengkuangqu	Layer	Solid	0.25
Shexian	Dairycow	Solid	0.25
Shexian	Dairycow	Liquid	0.25

Shexian	Beefcow	Solid	0.25
Shexian	Beefcow	Liquid	0.25
Shexian	Pig	Solid	0.25
Shexian	Pig	Liquid	0.25
Shexian	Sheepgoat	Solid	0.25
Shexian	Broiler	Solid	0.25
Shexian	Layer	Solid	0.25
Guantao	Dairycow	Solid	0.25
Guantao	Dairycow	Liquid	0.25
Guantao	Beefcow	Solid	0.25
Guantao	Beefcow	Liquid	0.25
Guantao	Pig	Solid	0.25
Guantao	Pig	Liquid	0.25
Guantao	Sheepgoat	Solid	0.25
Guantao	Broiler	Solid	0.25
Guantao	Layer	Solid	0.25
Cixian	Dairycow	Solid	0.25
Cixian	Dairycow	Liquid	0.25
Cixian	Beefcow	Solid	0.25
Cixian	Beefcow	Liquid	0.25
Cixian	Pig	Solid	0.25
Cixian	Pig	Liquid	0.25
Cixian	Sheepgoat	Solid	0.25
Cixian	Broiler	Solid	0.25
Cixian	Layer	Solid	0.25
Handanxian	Dairycow	Solid	0.25
Handanxian	Dairycow	Liquid	0.25
Handanxian	Beefcow	Solid	0.25
Handanxian	Beefcow	Liquid	0.25
Handanxian	Pig	Solid	0.25
Handanxian	Pig	Liquid	0.25
Handanxian	Sheepgoat	Solid	0.25
Handanxian	Broiler	Solid	0.25
Handanxian	Layer	Solid	0.25
Weixian	Dairycow	Solid	0.25
Weixian	Dairycow	Liquid	0.25
Weixian	Beefcow	Solid	0.25
Weixian	Beefcow	Liquid	0.25
Weixian	Pig	Solid	0.25
Weixian	Pig	Liquid	0.25
Weixian	Sheepgoat	Solid	0.25
Weixian	Broiler	Solid	0.25
Weixian	Layer	Solid	0.25

Kloss_Treatment

County	Anicategories	Manuretypes	Kleaching

Daming	Dairycow	Compost	0.15
Daming	Dairycow	Digestion	0.05
Daming	Beefcow	Compost	0.15
Daming	Pig	Compost	0.15
Daming	Pig	Digestion	0.05
Daming	Broiler	Compost	0.15
Daming	Layer	Compost	0.15
Guangping	Dairycow	Compost	0.15
Guangping	Dairycow	Digestion	0.05
Guangping	Beefcow	Compost	0.15
Guangping	Pig	Compost	0.15
Guangping	Pig	Digestion	0.05
Guangping	Broiler	Compost	0.15
Guangping	Layer	Compost	0.15
Yongnian	Dairycow	Compost	0.15
Yongnian	Dairycow	Digestion	0.05
Yongnian	Beefcow	Compost	0.15
Yongnian	Pig	Compost	0.15
Yongnian	Pig	Digestion	0.05
Yongnian	Broiler	Compost	0.15
Yongnian	Layer	Compost	0.15
Chenganxian	Dairycow	Compost	0.15
Chenganxian	Dairycow	Digestion	0.05
Chenganxian	Beefcow	Compost	0.15
Chenganxian	Pig	Compost	0.15
Chenganxian	Pig	Digestion	0.05
Chenganxian	Broiler	Compost	0.15
Chenganxian	Layer	Compost	0.15
Quzhou	Dairycow	Compost	0.15
Quzhou	Dairycow	Digestion	0.05
Quzhou	Beefcow	Compost	0.15
Quzhou	Pig	Compost	0.15
Quzhou	Pig	Digestion	0.05
Quzhou	Broiler	Compost	0.15
Quzhou	Layer	Compost	0.15
Handanshi	Dairycow	Compost	0.15
Handanshi	Dairycow	Digestion	0.05
Handanshi	Beefcow	Compost	0.15
Handanshi	Pig	Compost	0.15
Handanshi	Pig	Digestion	0.05
Handanshi	Broiler	Compost	0.15
Handanshi	Layer	Compost	0.15
Qiuxian	Dairycow	Compost	0.15
Qiuxian	Dairycow	Digestion	0.05
Qiuxian	Beefcow	Compost	0.15

Qiuxian	Pig	Compost	0.15
Qiuxian	Pig	Digestion	0.05
Qiuxian	Broiler	Compost	0.15
Qiuxian	Layer	Compost	0.15
Jize	Dairycow	Compost	0.15
Jize	Dairycow	Digestion	0.05
Jize	Beefcow	Compost	0.15
Jize	Pig	Compost	0.15
Jize	Pig	Digestion	0.05
Jize	Broiler	Compost	0.15
Jize	Layer	Compost	0.15
Wuanshi	Dairycow	Compost	0.15
Wuanshi	Dairycow	Digestion	0.05
Wuanshi	Beefcow	Compost	0.15
Wuanshi	Pig	Compost	0.15
Wuanshi	Pig	Digestion	0.05
Wuanshi	Broiler	Compost	0.15
Wuanshi	Layer	Compost	0.15
Feixiang	Dairycow	Compost	0.15
Feixiang	Dairycow	Digestion	0.05
Feixiang	Beefcow	Compost	0.15
Feixiang	Pig	Compost	0.15
Feixiang	Pig	Digestion	0.05
Feixiang	Broiler	Compost	0.15
Feixiang	Layer	Compost	0.15
Linzhang	Dairycow	Compost	0.15
Linzhang	Dairycow	Digestion	0.05
Linzhang	Beefcow	Compost	0.15
Linzhang	Pig	Compost	0.15
Linzhang	Pig	Digestion	0.05
Linzhang	Broiler	Compost	0.15
Linzhang	Layer	Compost	0.15
Fengfengkuangqu	Dairycow	Compost	0.15
Fengfengkuangqu	Dairycow	Digestion	0.05
Fengfengkuangqu	Beefcow	Compost	0.15
Fengfengkuangqu	Pig	Compost	0.15
Fengfengkuangqu	Pig	Digestion	0.05
Fengfengkuangqu	Broiler	Compost	0.15
Fengfengkuangqu	Layer	Compost	0.15
Shexian	Dairycow	Compost	0.15
Shexian	Dairycow	Digestion	0.05
Shexian	Beefcow	Compost	0.15
Shexian	Pig	Compost	0.15
Shexian	Pig	Digestion	0.05
Shexian	Broiler	Compost	0.15

Shexian	Layer	Compost	0.15
Guantao	Dairycow	Compost	0.15
Guantao	Dairycow	Digestion	0.05
Guantao	Beefcow	Compost	0.15
Guantao	Pig	Compost	0.15
Guantao	Pig	Digestion	0.05
Guantao	Broiler	Compost	0.15
Guantao	Layer	Compost	0.15
Cixian	Dairycow	Compost	0.15
Cixian	Dairycow	Digestion	0.05
Cixian	Beefcow	Compost	0.15
Cixian	Pig	Compost	0.15
Cixian	Pig	Digestion	0.05
Cixian	Broiler	Compost	0.15
Cixian	Layer	Compost	0.15
Handanxian	Dairycow	Compost	0.15
Handanxian	Dairycow	Digestion	0.05
Handanxian	Beefcow	Compost	0.15
Handanxian	Pig	Compost	0.15
Handanxian	Pig	Digestion	0.05
Handanxian	Broiler	Compost	0.15
Handanxian	Layer	Compost	0.15
Weixian	Dairycow	Compost	0.15
Weixian	Dairycow	Digestion	0.05
Weixian	Beefcow	Compost	0.15
Weixian	Pig	Compost	0.15
Weixian	Pig	Digestion	0.05
Weixian	Broiler	Compost	0.15
Weixian	Layer	Compost	0.15

Original data on the farm side, which used for calaulating NPK demands for different crop types.

Table A7. Data used for calculating the yields of different crop types

Conuty			**Cropcategories**			
Yields						**(t/ha)**
County	Cereals	Vegetables	Fruits	Tubers	Oilcrops	Cotton
Daming	6.1	60.1	12	29.7	3.8	1.1
Guangping	6.1	60.1	12	29.7	3.8	1.1
Yongnian	6.1	60.1	12	29.7	3.8	1.1
Chenganxian	6.1	60.1	12	29.7	3.8	1.1
Quzhou	6.1	60.1	12	29.7	3.8	1.1
Handanshi	6.1	60.1	12	29.7	3.8	1.1
Qiuxian	6.1	60.1	12	29.7	3.8	1.1
Jize	6.1	60.1	12	29.7	3.8	1.1
Wuanshi	6.1	60.1	12	29.7	3.8	1.1

Feixiang	6.1	60.1	12	29.7	3.8	1.1
Linzhang	6.1	60.1	12	29.7	3.8	1.1
Fengfengkuangqu	6.1	60.1	12	29.7	3.8	1.1
Shexian	6.1	60.1	12	29.7	3.8	1.1
Guantao	6.1	60.1	12	29.7	3.8	1.1
Cixian	6.1	60.1	12	29.7	3.8	1.1
Handanxian	6.1	60.1	12	29.7	3.8	1.1
Weixian	6.1	60.1	12	29.7	3.8	1.1
Sownarea						**(ha)**
County	Cereals	Vegetables	Fruits	Tubers	Oilcrops	Cotton
Daming	98580	8982	2816	20	21552	1414
Guangping	29785	3860	998	643	2413	1307
Yongnian	64636	35631	1693	268	978	674
Chenganxian	38709	9453	2915	812	1048	12259
Quzhou	56530	10420	1860	170	945	8582
Handanshi	32661	1397	1653	91	651	465
Qiuxian	18650	4645	1539	195	315	20134
Jize	29510	12144	758	77	734	1768
Wuanshi	53963	2817	4917	1228	2126	2015
Feixiang	44569	13387	3300	361	1093	7511
Linzhang	73353	11339	4954	1335	1875	2201
Fengfengkuangqu	9463	446	1053	153	54	1
Shexian	18026	1280	2089	444	335	17
Guantao	41257	8586	2016	234	3277	1185
Cixian	31707	4552	1061	591	932	401
Handanxian	27481	1862	120	571	1566	620
Weixian	83115	7059	10426	784	1746	1104

Table A8. The potential of different crop yield increase

Conuty	**Yieldpotential**		
County	Cropcategories	Yield current	Yield potential
Daming	Cereals	1	1.10
Daming	Vegetables	1	1.15
Daming	Fruits	1	1.15
Daming	Tubers	1	1.10
Daming	Oilcrops	1	1.13
Daming	Cotton	1	1.15
Guangping	Cereals	1	1.10
Guangping	Vegetables	1	1.15
Guangping	Fruits	1	1.15
Guangping	Tubers	1	1.10
Guangping	Oilcrops	1	1.13
Guangping	Cotton	1	1.15
Yongnian	Cereals	1	1.10

Yongnian	Vegetables	1	1.15
Yongnian	Fruits	1	1.15
Yongnian	Tubers	1	1.10
Yongnian	Oilcrops	1	1.13
Yongnian	Cotton	1	1.15
Chenganxian	Cereals	1	1.10
Chenganxian	Vegetables	1	1.15
Chenganxian	Fruits	1	1.15
Chenganxian	Tubers	1	1.10
Chenganxian	Oilcrops	1	1.13
Chenganxian	Cotton	1	1.15
Quzhou	Cereals	1	1.10
Quzhou	Vegetables	1	1.15
Quzhou	Fruits	1	1.15
Quzhou	Tubers	1	1.10
Quzhou	Oilcrops	1	1.13
Quzhou	Cotton	1	1.15
Handanshi	Cereals	1	1.10
Handanshi	Vegetables	1	1.15
Handanshi	Fruits	1	1.15
Handanshi	Tubers	1	1.10
Handanshi	Oilcrops	1	1.13
Handanshi	Cotton	1	1.15
Qiuxian	Cereals	1	1.10
Qiuxian	Vegetables	1	1.15
Qiuxian	Fruits	1	1.15
Qiuxian	Tubers	1	1.10
Qiuxian	Oilcrops	1	1.13
Qiuxian	Cotton	1	1.15
Jize	Cereals	1	1.10
Jize	Vegetables	1	1.15
Jize	Fruits	1	1.15
Jize	Tubers	1	1.10
Jize	Oilcrops	1	1.13
Jize	Cotton	1	1.15
Wuanshi	Cereals	1	1.10
Wuanshi	Vegetables	1	1.15
Wuanshi	Fruits	1	1.15
Wuanshi	Tubers	1	1.10
Wuanshi	Oilcrops	1	1.13
Wuanshi	Cotton	1	1.15
Feixiang	Cereals	1	1.10
Feixiang	Vegetables	1	1.15
Feixiang	Fruits	1	1.15
Feixiang	Tubers	1	1.10

Feixiang	Oilcrops	1	1.13
Feixiang	Cotton	1	1.15
Linzhang	Cereals	1	1.10
Linzhang	Vegetables	1	1.15
Linzhang	Fruits	1	1.15
Linzhang	Tubers	1	1.10
Linzhang	Oilcrops	1	1.13
Linzhang	Cotton	1	1.15
Fengfengkuangqu	Cereals	1	1.10
Fengfengkuangqu	Vegetables	1	1.15
Fengfengkuangqu	Fruits	1	1.15
Fengfengkuangqu	Tubers	1	1.10
Fengfengkuangqu	Oilcrops	1	1.13
Fengfengkuangqu	Cotton	1	1.15
Shexian	Cereals	1	1.10
Shexian	Vegetables	1	1.15
Shexian	Fruits	1	1.15
Shexian	Tubers	1	1.10
Shexian	Oilcrops	1	1.13
Shexian	Cotton	1	1.15
Guantao	Cereals	1	1.10
Guantao	Vegetables	1	1.15
Guantao	Fruits	1	1.15
Guantao	Tubers	1	1.10
Guantao	Oilcrops	1	1.13
Guantao	Cotton	1	1.15
Cixian	Cereals	1	1.10
Cixian	Vegetables	1	1.15
Cixian	Fruits	1	1.15
Cixian	Tubers	1	1.10
Cixian	Oilcrops	1	1.13
Cixian	Cotton	1	1.15
Handanxian	Cereals	1	1.10
Handanxian	Vegetables	1	1.15
Handanxian	Fruits	1	1.15
Handanxian	Tubers	1	1.10
Handanxian	Oilcrops	1	1.13
Handanxian	Cotton	1	1.15
Weixian	Cereals	1	1.10
Weixian	Vegetables	1	1.15
Weixian	Fruits	1	1.15
Weixian	Tubers	1	1.10
Weixian	Oilcrops	1	1.13
Weixian	Cotton	1	1.15

Table A9. Data used for calculating Uptake of NPK

Conuty		Elements		
Nui_Demand				
County	Cropcategories	N	P	K
Daming	Cereals	2.7	0.5	1.8
Daming	Vegetables	0.4	0.1	0.4
Daming	Fruits	0.6	0.1	0.4
Daming	Tubers	0.5	0.1	0.7
Daming	Oilcrops	5.5	0.9	3.5
Daming	Cotton	5.0	0.8	3.3
Guangping	Cereals	2.7	0.5	1.8
Guangping	Vegetables	0.4	0.1	0.4
Guangping	Fruits	0.6	0.1	0.4
Guangping	Tubers	0.5	0.1	0.7
Guangping	Oilcrops	5.5	0.9	3.5
Guangping	Cotton	5.0	0.8	3.3
Yongnian	Cereals	2.7	0.5	1.8
Yongnian	Vegetables	0.4	0.1	0.4
Yongnian	Fruits	0.6	0.1	0.4
Yongnian	Tubers	0.5	0.1	0.7
Yongnian	Oilcrops	5.5	0.9	3.5
Yongnian	Cotton	5.0	0.8	3.3
Chenganxian	Cereals	2.7	0.5	1.8
Chenganxian	Vegetables	0.4	0.1	0.4
Chenganxian	Fruits	0.6	0.1	0.4
Chenganxian	Tubers	0.5	0.1	0.7
Chenganxian	Oilcrops	5.5	0.9	3.5
Chenganxian	Cotton	5.0	0.8	3.3
Quzhou	Cereals	2.7	0.5	1.8
Quzhou	Vegetables	0.4	0.1	0.4
Quzhou	Fruits	0.6	0.1	0.4
Quzhou	Tubers	0.5	0.1	0.7
Quzhou	Oilcrops	5.5	0.9	3.5
Quzhou	Cotton	5.0	0.8	3.3
Handanshi	Cereals	2.7	0.5	1.8
Handanshi	Vegetables	0.4	0.1	0.4
Handanshi	Fruits	0.6	0.1	0.4
Handanshi	Tubers	0.5	0.1	0.7
Handanshi	Oilcrops	5.5	0.9	3.5
Handanshi	Cotton	5.0	0.8	3.3
Qiuxian	Cereals	2.7	0.5	1.8
Qiuxian	Vegetables	0.4	0.1	0.4
Qiuxian	Fruits	0.6	0.1	0.4
Qiuxian	Tubers	0.5	0.1	0.7

Qiuxian	Oilcrops	5.5	0.9	3.5
Qiuxian	Cotton	5.0	0.8	3.3
Jize	Cereals	2.7	0.5	1.8
Jize	Vegetables	0.4	0.1	0.4
Jize	Fruits	0.6	0.1	0.4
Jize	Tubers	0.5	0.1	0.7
Jize	Oilcrops	5.5	0.9	3.5
Jize	Cotton	5.0	0.8	3.3
Wuanshi	Cereals	2.7	0.5	1.8
Wuanshi	Vegetables	0.4	0.1	0.4
Wuanshi	Fruits	0.6	0.1	0.4
Wuanshi	Tubers	0.5	0.1	0.7
Wuanshi	Oilcrops	5.5	0.9	3.5
Wuanshi	Cotton	5.0	0.8	3.3
Feixiang	Cereals	2.7	0.5	1.8
Feixiang	Vegetables	0.4	0.1	0.4
Feixiang	Fruits	0.6	0.1	0.4
Feixiang	Tubers	0.5	0.1	0.7
Feixiang	Oilcrops	5.5	0.9	3.5
Feixiang	Cotton	5.0	0.8	3.3
Linzhang	Cereals	2.7	0.5	1.8
Linzhang	Vegetables	0.4	0.1	0.4
Linzhang	Fruits	0.6	0.1	0.4
Linzhang	Tubers	0.5	0.1	0.7
Linzhang	Oilcrops	5.5	0.9	3.5
Linzhang	Cotton	5.0	0.8	3.3
Fengfengkuangqu	Cereals	2.7	0.5	1.8
Fengfengkuangqu	Vegetables	0.4	0.1	0.4
Fengfengkuangqu	Fruits	0.6	0.1	0.4
Fengfengkuangqu	Tubers	0.5	0.1	0.7
Fengfengkuangqu	Oilcrops	5.5	0.9	3.5
Fengfengkuangqu	Cotton	5.0	0.8	3.3
Shexian	Cereals	2.7	0.5	1.8
Shexian	Vegetables	0.4	0.1	0.4
Shexian	Fruits	0.6	0.1	0.4
Shexian	Tubers	0.5	0.1	0.7
Shexian	Oilcrops	5.5	0.9	3.5
Shexian	Cotton	5.0	0.8	3.3
Guantao	Cereals	2.7	0.5	1.8
Guantao	Vegetables	0.4	0.1	0.4
Guantao	Fruits	0.6	0.1	0.4
Guantao	Tubers	0.5	0.1	0.7
Guantao	Oilcrops	5.5	0.9	3.5
Guantao	Cotton	5.0	0.8	3.3
Cixian	Cereals	2.7	0.5	1.8

Cixian	Vegetables	0.4	0.1	0.4
Cixian	Fruits	0.6	0.1	0.4
Cixian	Tubers	0.5	0.1	0.7
Cixian	Oilcrops	5.5	0.9	3.5
Cixian	Cotton	5.0	0.8	3.3
Handanxian	Cereals	2.7	0.5	1.8
Handanxian	Vegetables	0.4	0.1	0.4
Handanxian	Fruits	0.6	0.1	0.4
Handanxian	Tubers	0.5	0.1	0.7
Handanxian	Oilcrops	5.5	0.9	3.5
Handanxian	Cotton	5.0	0.8	3.3
Weixian	Cereals	2.7	0.5	1.8
Weixian	Vegetables	0.4	0.1	0.4
Weixian	Fruits	0.6	0.1	0.4
Weixian	Tubers	0.5	0.1	0.7
Weixian	Oilcrops	5.5	0.9	3.5
Weixian	Cotton	5.0	0.8	3.3

Nui_factor

County	Cropcategories	N	P	K
Daming	Cereals	1.20	1.1	1.1
Daming	Vegetables	1.50	1.2	1.1
Daming	Fruits	2.00	1.2	1.1
Daming	Tubers	1.50	1.2	1.1
Daming	Oilcrops	1.40	1.2	1.1
Daming	Cotton	1.70	1.2	1.1
Guangping	Cereals	1.20	1.1	1.1
Guangping	Vegetables	1.50	1.2	1.1
Guangping	Fruits	2.00	1.2	1.1
Guangping	Tubers	1.50	1.2	1.1
Guangping	Oilcrops	1.40	1.2	1.1
Guangping	Cotton	1.70	1.2	1.1
Yongnian	Cereals	1.20	1.1	1.1
Yongnian	Vegetables	1.50	1.2	1.1
Yongnian	Fruits	2.00	1.2	1.1
Yongnian	Tubers	1.50	1.2	1.1
Yongnian	Oilcrops	1.40	1.2	1.1
Yongnian	Cotton	1.70	1.2	1.1
Chenganxian	Cereals	1.20	1.1	1.1
Chenganxian	Vegetables	1.50	1.2	1.1
Chenganxian	Fruits	2.00	1.2	1.1
Chenganxian	Tubers	1.50	1.2	1.1
Chenganxian	Oilcrops	1.40	1.2	1.1
Chenganxian	Cotton	1.70	1.2	1.1
Quzhou	Cereals	1.20	1.1	1.1
Quzhou	Vegetables	1.50	1.2	1.1

Quzhou	Fruits	2.00	1.2	1.1
Quzhou	Tubers	1.50	1.2	1.1
Quzhou	Oilcrops	1.40	1.2	1.1
Quzhou	Cotton	1.70	1.2	1.1
Handanshi	Cereals	1.20	1.1	1.1
Handanshi	Vegetables	1.50	1.2	1.1
Handanshi	Fruits	2.00	1.2	1.1
Handanshi	Tubers	1.50	1.2	1.1
Handanshi	Oilcrops	1.40	1.2	1.1
Handanshi	Cotton	1.70	1.2	1.1
Qiuxian	Cereals	1.20	1.1	1.1
Qiuxian	Vegetables	1.50	1.2	1.1
Qiuxian	Fruits	2.00	1.2	1.1
Qiuxian	Tubers	1.50	1.2	1.1
Qiuxian	Oilcrops	1.40	1.2	1.1
Qiuxian	Cotton	1.70	1.2	1.1
Jize	Cereals	1.20	1.1	1.1
Jize	Vegetables	1.50	1.2	1.1
Jize	Fruits	2.00	1.2	1.1
Jize	Tubers	1.50	1.2	1.1
Jize	Oilcrops	1.40	1.2	1.1
Jize	Cotton	1.70	1.2	1.1
Wuanshi	Cereals	1.20	1.1	1.1
Wuanshi	Vegetables	1.50	1.2	1.1
Wuanshi	Fruits	2.00	1.2	1.1
Wuanshi	Tubers	1.50	1.2	1.1
Wuanshi	Oilcrops	1.40	1.2	1.1
Wuanshi	Cotton	1.70	1.2	1.1
Feixiang	Cereals	1.20	1.1	1.1
Feixiang	Vegetables	1.50	1.2	1.1
Feixiang	Fruits	2.00	1.2	1.1
Feixiang	Tubers	1.50	1.2	1.1
Feixiang	Oilcrops	1.40	1.2	1.1
Feixiang	Cotton	1.70	1.2	1.1
Linzhang	Cereals	1.20	1.1	1.1
Linzhang	Vegetables	1.50	1.2	1.1
Linzhang	Fruits	2.00	1.2	1.1
Linzhang	Tubers	1.50	1.2	1.1
Linzhang	Oilcrops	1.40	1.2	1.1
Linzhang	Cotton	1.70	1.2	1.1
Fengfengkuangqu	Cereals	1.20	1.1	1.1
Fengfengkuangqu	Vegetables	1.50	1.2	1.1
Fengfengkuangqu	Fruits	2.00	1.2	1.1
Fengfengkuangqu	Tubers	1.50	1.2	1.1
Fengfengkuangqu	Oilcrops	1.40	1.2	1.1

Fengfengkuangqu	Cotton	1.70	1.2	1.1
Shexian	Cereals	1.20	1.1	1.1
Shexian	Vegetables	1.50	1.2	1.1
Shexian	Fruits	2.00	1.2	1.1
Shexian	Tubers	1.50	1.2	1.1
Shexian	Oilcrops	1.40	1.2	1.1
Shexian	Cotton	1.70	1.2	1.1
Guantao	Cereals	1.20	1.1	1.1
Guantao	Vegetables	1.50	1.2	1.1
Guantao	Fruits	2.00	1.2	1.1
Guantao	Tubers	1.50	1.2	1.1
Guantao	Oilcrops	1.40	1.2	1.1
Guantao	Cotton	1.70	1.2	1.1
Cixian	Cereals	1.20	1.1	1.1
Cixian	Vegetables	1.50	1.2	1.1
Cixian	Fruits	2.00	1.2	1.1
Cixian	Tubers	1.50	1.2	1.1
Cixian	Oilcrops	1.40	1.2	1.1
Cixian	Cotton	1.70	1.2	1.1
Handanxian	Cereals	1.20	1.1	1.1
Handanxian	Vegetables	1.50	1.2	1.1
Handanxian	Fruits	2.00	1.2	1.1
Handanxian	Tubers	1.50	1.2	1.1
Handanxian	Oilcrops	1.40	1.2	1.1
Handanxian	Cotton	1.70	1.2	1.1
Weixian	Cereals	1.20	1.1	1.1
Weixian	Vegetables	1.50	1.2	1.1
Weixian	Fruits	2.00	1.2	1.1
Weixian	Tubers	1.50	1.2	1.1
Weixian	Oilcrops	1.40	1.2	1.1
Weixian	Cotton	1.70	1.2	1.1

Table A10. Data used for calculating solid and liquid ratio of different manure types

Conuty	Cropcategories	Grade	
County	Cropcategories	N1P2K3	N1P3K3
Daming	Cereals		1
Daming	Vegetables		1
Daming	Fruits		1
Daming	Tubers		1
Daming	Oilcrops		1
Daming	Cotton		1
Guangping	Cereals	1	
Guangping	Vegetables	1	
Guangping	Fruits	1	

Guangping	Tubers	1	
Guangping	Oilcrops	1	
Guangping	Cotton	1	
Yongnian	Cereals		1
Yongnian	Vegetables		1
Yongnian	Fruits		1
Yongnian	Tubers		1
Yongnian	Oilcrops		1
Yongnian	Cotton		1
Chenganxian	Cereals	1	
Chenganxian	Vegetables	1	
Chenganxian	Fruits	1	
Chenganxian	Tubers	1	
Chenganxian	Oilcrops	1	
Chenganxian	Cotton	1	
Quzhou	Cereals		1
Quzhou	Vegetables		1
Quzhou	Fruits		1
Quzhou	Tubers		1
Quzhou	Oilcrops		1
Quzhou	Cotton		1
Handanshi	Cereals		1
Handanshi	Vegetables		1
Handanshi	Fruits		1
Handanshi	Tubers		1
Handanshi	Oilcrops		1
Handanshi	Cotton		1
Qiuxian	Cereals	1	
Qiuxian	Vegetables	1	
Qiuxian	Fruits	1	
Qiuxian	Tubers	1	
Qiuxian	Oilcrops	1	
Qiuxian	Cotton	1	
Jize	Cereals		1
Jize	Vegetables		1
Jize	Fruits		1
Jize	Tubers		1
Jize	Oilcrops		1
Jize	Cotton		1
Wuanshi	Cereals	1	
Wuanshi	Vegetables	1	
Wuanshi	Fruits	1	
Wuanshi	Tubers	1	
Wuanshi	Oilcrops	1	
Wuanshi	Cotton	1	

Feixiang	Cereals		1
Feixiang	Vegetables		1
Feixiang	Fruits		1
Feixiang	Tubers		1
Feixiang	Oilcrops		1
Feixiang	Cotton		1
Linzhang	Cereals		1
Linzhang	Vegetables		1
Linzhang	Fruits		1
Linzhang	Tubers		1
Linzhang	Oilcrops		1
Linzhang	Cotton		1
Fengfengkuangqu	Cereals	1	
Fengfengkuangqu	Vegetables	1	
Fengfengkuangqu	Fruits	1	
Fengfengkuangqu	Tubers	1	
Fengfengkuangqu	Oilcrops	1	
Fengfengkuangqu	Cotton	1	
Shexian	Cereals	1	
Shexian	Vegetables	1	
Shexian	Fruits	1	
Shexian	Tubers	1	
Shexian	Oilcrops	1	
Shexian	Cotton	1	
Guantao	Cereals		1
Guantao	Vegetables		1
Guantao	Fruits		1
Guantao	Tubers		1
Guantao	Oilcrops		1
Guantao	Cotton		1
Cixian	Cereals	1	
Cixian	Vegetables	1	
Cixian	Fruits	1	
Cixian	Tubers	1	
Cixian	Oilcrops	1	
Cixian	Cotton	1	
Handanxian	Cereals		1
Handanxian	Vegetables		1
Handanxian	Fruits		1
Handanxian	Tubers		1
Handanxian	Oilcrops		1
Handanxian	Cotton		1
Weixian	Cereals	1	
Weixian	Vegetables	1	
Weixian	Fruits	1	

Weixian	Tubers	1
Weixian	Oilcrops	1
Weixian	Cotton	1

Table A11. Coefficients for calculating fertilizer NPK supply, low, meidum, high(kg/ha)

Conuty		**Grade**		
N_input				
		N1P1K2	N2P1K2	N3P1K2
		N1P1K3	N2P1K3	N3P1K3
		N1P2K1	N2P2K1	N3P2K1
		N1P2K2	N2P2K2	N3P2K2
		N1P2K3	N2P2K3	N3P2K3
		N1P3K1	N2P3K1	N3P3K1
		N1P3K2	N2P3K2	N3P3K2
		N1P3K3	N2P3K3	N3P3K3
County	Cropcategories	N1P1K1	N2P1K1	N3P1K1
Daming	Cereals	15	30	45
Daming	Vegetables	15	30	45
Daming	Fruits	15	30	45
Daming	Tubers	15	30	45
Daming	Oilcrops	15	30	45
Daming	Cotton	15	30	45
Guangping	Cereals	15	30	45
Guangping	Vegetables	15	30	45
Guangping	Fruits	15	30	45
Guangping	Tubers	15	30	45
Guangping	Oilcrops	15	30	45
Guangping	Cotton	15	30	45
Yongnian	Cereals	15	30	45
Yongnian	Vegetables	15	30	45
Yongnian	Fruits	15	30	45
Yongnian	Tubers	15	30	45
Yongnian	Oilcrops	15	30	45
Yongnian	Cotton	15	30	45
Chenganxian	Cereals	15	30	45
Chenganxian	Vegetables	15	30	45
Chenganxian	Fruits	15	30	45
Chenganxian	Tubers	15	30	45
Chenganxian	Oilcrops	15	30	45
Chenganxian	Cotton	15	30	45
Quzhou	Cereals	15	30	45
Quzhou	Vegetables	15	30	45
Quzhou	Fruits	15	30	45
Quzhou	Tubers	15	30	45
Quzhou	Oilcrops	15	30	45

Quzhou	Cotton	15	30	45
Handanshi	Cereals	15	30	45
Handanshi	Vegetables	15	30	45
Handanshi	Fruits	15	30	45
Handanshi	Tubers	15	30	45
Handanshi	Oilcrops	15	30	45
Handanshi	Cotton	15	30	45
Qiuxian	Cereals	15	30	45
Qiuxian	Vegetables	15	30	45
Qiuxian	Fruits	15	30	45
Qiuxian	Tubers	15	30	45
Qiuxian	Oilcrops	15	30	45
Qiuxian	Cotton	15	30	45
Jize	Cereals	15	30	45
Jize	Vegetables	15	30	45
Jize	Fruits	15	30	45
Jize	Tubers	15	30	45
Jize	Oilcrops	15	30	45
Jize	Cotton	15	30	45
Wuanshi	Cereals	15	30	45
Wuanshi	Vegetables	15	30	45
Wuanshi	Fruits	15	30	45
Wuanshi	Tubers	15	30	45
Wuanshi	Oilcrops	15	30	45
Wuanshi	Cotton	15	30	45
Feixiang	Cereals	15	30	45
Feixiang	Vegetables	15	30	45
Feixiang	Fruits	15	30	45
Feixiang	Tubers	15	30	45
Feixiang	Oilcrops	15	30	45
Feixiang	Cotton	15	30	45
Linzhang	Cereals	15	30	45
Linzhang	Vegetables	15	30	45
Linzhang	Fruits	15	30	45
Linzhang	Tubers	15	30	45
Linzhang	Oilcrops	15	30	45
Linzhang	Cotton	15	30	45
Fengfengkuangqu	Cereals	15	30	45
Fengfengkuangqu	Vegetables	15	30	45
Fengfengkuangqu	Fruits	15	30	45
Fengfengkuangqu	Tubers	15	30	45
Fengfengkuangqu	Oilcrops	15	30	45
Fengfengkuangqu	Cotton	15	30	45
Shexian	Cereals	15	30	45
Shexian	Vegetables	15	30	45

Shexian	Fruits	15	30	45
Shexian	Tubers	15	30	45
Shexian	Oilcrops	15	30	45
Shexian	Cotton	15	30	45
Guantao	Cereals	15	30	45
Guantao	Vegetables	15	30	45
Guantao	Fruits	15	30	45
Guantao	Tubers	15	30	45
Guantao	Oilcrops	15	30	45
Guantao	Cotton	15	30	45
Cixian	Cereals	15	30	45
Cixian	Vegetables	15	30	45
Cixian	Fruits	15	30	45
Cixian	Tubers	15	30	45
Cixian	Oilcrops	15	30	45
Cixian	Cotton	15	30	45
Handanxian	Cereals	15	30	45
Handanxian	Vegetables	15	30	45
Handanxian	Fruits	15	30	45
Handanxian	Tubers	15	30	45
Handanxian	Oilcrops	15	30	45
Handanxian	Cotton	15	30	45
Weixian	Cereals	15	30	45
Weixian	Vegetables	15	30	45
Weixian	Fruits	15	30	45
Weixian	Tubers	15	30	45
Weixian	Oilcrops	15	30	45
Weixian	Cotton	15	30	45

P_input		N3P1K1	N3P2K1	N1P3K2
		N3P1K2	N3P2K2	N1P3K3
		N3P1K3	N3P2K3	N2P3K1
		N2P1K1	N2P2K1	N2P3K2
		N2P1K2	N2P2K2	N2P3K3
		N2P1K3	N2P2K3	N3P3K1
		N1P1K2	N1P2K2	N3P3K2
		N1P1K3	N1P2K3	N3P3K3
County	Cropcategories	N1P1K1	N1P2K1	N1P3K1
Daming	Cereals	2	1	0.5
Daming	Vegetables	2	1	0.5
Daming	Fruits	2	1	0.5
Daming	Tubers	2	1	0.5
Daming	Oilcrops	2	1	0.5
Daming	Cotton	2	1	0.5
Guangping	Cereals	2	1	0.5
Guangping	Vegetables	2	1	0.5

Guangping	Fruits	2	1	0.5
Guangping	Tubers	2	1	0.5
Guangping	Oilcrops	2	1	0.5
Guangping	Cotton	2	1	0.5
Yongnian	Cereals	2	1	0.5
Yongnian	Vegetables	2	1	0.5
Yongnian	Fruits	2	1	0.5
Yongnian	Tubers	2	1	0.5
Yongnian	Oilcrops	2	1	0.5
Yongnian	Cotton	2	1	0.5
Chenganxian	Cereals	2	1	0.5
Chenganxian	Vegetables	2	1	0.5
Chenganxian	Fruits	2	1	0.5
Chenganxian	Tubers	2	1	0.5
Chenganxian	Oilcrops	2	1	0.5
Chenganxian	Cotton	2	1	0.5
Quzhou	Cereals	2	1	0.5
Quzhou	Vegetables	2	1	0.5
Quzhou	Fruits	2	1	0.5
Quzhou	Tubers	2	1	0.5
Quzhou	Oilcrops	2	1	0.5
Quzhou	Cotton	2	1	0.5
Handanshi	Cereals	2	1	0.5
Handanshi	Vegetables	2	1	0.5
Handanshi	Fruits	2	1	0.5
Handanshi	Tubers	2	1	0.5
Handanshi	Oilcrops	2	1	0.5
Handanshi	Cotton	2	1	0.5
Qiuxian	Cereals	2	1	0.5
Qiuxian	Vegetables	2	1	0.5
Qiuxian	Fruits	2	1	0.5
Qiuxian	Tubers	2	1	0.5
Qiuxian	Oilcrops	2	1	0.5
Qiuxian	Cotton	2	1	0.5
Jize	Cereals	2	1	0.5
Jize	Vegetables	2	1	0.5
Jize	Fruits	2	1	0.5
Jize	Tubers	2	1	0.5
Jize	Oilcrops	2	1	0.5
Jize	Cotton	2	1	0.5
Wuanshi	Cereals	2	1	0.5
Wuanshi	Vegetables	2	1	0.5
Wuanshi	Fruits	2	1	0.5
Wuanshi	Tubers	2	1	0.5
Wuanshi	Oilcrops	2	1	0.5

Wuanshi	Cotton	2	1	0.5
Feixiang	Cereals	2	1	0.5
Feixiang	Vegetables	2	1	0.5
Feixiang	Fruits	2	1	0.5
Feixiang	Tubers	2	1	0.5
Feixiang	Oilcrops	2	1	0.5
Feixiang	Cotton	2	1	0.5
Linzhang	Cereals	2	1	0.5
Linzhang	Vegetables	2	1	0.5
Linzhang	Fruits	2	1	0.5
Linzhang	Tubers	2	1	0.5
Linzhang	Oilcrops	2	1	0.5
Linzhang	Cotton	2	1	0.5
Fengfengkuangqu	Cereals	2	1	0.5
Fengfengkuangqu	Vegetables	2	1	0.5
Fengfengkuangqu	Fruits	2	1	0.5
Fengfengkuangqu	Tubers	2	1	0.5
Fengfengkuangqu	Oilcrops	2	1	0.5
Fengfengkuangqu	Cotton	2	1	0.5
Shexian	Cereals	2	1	0.5
Shexian	Vegetables	2	1	0.5
Shexian	Fruits	2	1	0.5
Shexian	Tubers	2	1	0.5
Shexian	Oilcrops	2	1	0.5
Shexian	Cotton	2	1	0.5
Guantao	Cereals	2	1	0.5
Guantao	Vegetables	2	1	0.5
Guantao	Fruits	2	1	0.5
Guantao	Tubers	2	1	0.5
Guantao	Oilcrops	2	1	0.5
Guantao	Cotton	2	1	0.5
Cixian	Cereals	2	1	0.5
Cixian	Vegetables	2	1	0.5
Cixian	Fruits	2	1	0.5
Cixian	Tubers	2	1	0.5
Cixian	Oilcrops	2	1	0.5
Cixian	Cotton	2	1	0.5
Handanxian	Cereals	2	1	0.5
Handanxian	Vegetables	2	1	0.5
Handanxian	Fruits	2	1	0.5
Handanxian	Tubers	2	1	0.5
Handanxian	Oilcrops	2	1	0.5
Handanxian	Cotton	2	1	0.5
Weixian	Cereals	2	1	0.5
Weixian	Vegetables	2	1	0.5

Weixian	Fruits	2	1	0.5
Weixian	Tubers	2	1	0.5
Weixian	Oilcrops	2	1	0.5
Weixian	Cotton	2	1	0.5

K_input

County	Cropcategories	N3P3K1 N3P2K1 N3P1K1 N2P3K1 N2P2K1 N2P1K1 N1P3K1 N1P2K1 N1P1K1	N3P3K2 N3P2K2 N3P1K2 N2P3K2 N2P2K2 N2P1K2 N1P3K2 N1P2K2 N1P1K2	N3P3K3 N3P2K3 N3P1K3 N2P3K3 N2P2K3 N2P1K3 N1P3K3 N1P2K3 N1P1K3
Daming	Cereals	2	1	0.5
Daming	Vegetables	2	1	0.5
Daming	Fruits	2	1	0.5
Daming	Tubers	2	1	0.5
Daming	Oilcrops	2	1	0.5
Daming	Cotton	2	1	0.5
Guangping	Cereals	2	1	0.5
Guangping	Vegetables	2	1	0.5
Guangping	Fruits	2	1	0.5
Guangping	Tubers	2	1	0.5
Guangping	Oilcrops	2	1	0.5
Guangping	Cotton	2	1	0.5
Yongnian	Cereals	2	1	0.5
Yongnian	Vegetables	2	1	0.5
Yongnian	Fruits	2	1	0.5
Yongnian	Tubers	2	1	0.5
Yongnian	Oilcrops	2	1	0.5
Yongnian	Cotton	2	1	0.5
Chenganxian	Cereals	2	1	0.5
Chenganxian	Vegetables	2	1	0.5
Chenganxian	Fruits	2	1	0.5
Chenganxian	Tubers	2	1	0.5
Chenganxian	Oilcrops	2	1	0.5
Chenganxian	Cotton	2	1	0.5
Quzhou	Cereals	2	1	0.5
Quzhou	Vegetables	2	1	0.5
Quzhou	Fruits	2	1	0.5
Quzhou	Tubers	2	1	0.5
Quzhou	Oilcrops	2	1	0.5
Quzhou	Cotton	2	1	0.5
Handanshi	Cereals	2	1	0.5

Handanshi	Vegetables	2	1	0.5
Handanshi	Fruits	2	1	0.5
Handanshi	Tubers	2	1	0.5
Handanshi	Oilcrops	2	1	0.5
Handanshi	Cotton	2	1	0.5
Qiuxian	Cereals	2	1	0.5
Qiuxian	Vegetables	2	1	0.5
Qiuxian	Fruits	2	1	0.5
Qiuxian	Tubers	2	1	0.5
Qiuxian	Oilcrops	2	1	0.5
Qiuxian	Cotton	2	1	0.5
Jize	Cereals	2	1	0.5
Jize	Vegetables	2	1	0.5
Jize	Fruits	2	1	0.5
Jize	Tubers	2	1	0.5
Jize	Oilcrops	2	1	0.5
Jize	Cotton	2	1	0.5
Wuanshi	Cereals	2	1	0.5
Wuanshi	Vegetables	2	1	0.5
Wuanshi	Fruits	2	1	0.5
Wuanshi	Tubers	2	1	0.5
Wuanshi	Oilcrops	2	1	0.5
Wuanshi	Cotton	2	1	0.5
Feixiang	Cereals	2	1	0.5
Feixiang	Vegetables	2	1	0.5
Feixiang	Fruits	2	1	0.5
Feixiang	Tubers	2	1	0.5
Feixiang	Oilcrops	2	1	0.5
Feixiang	Cotton	2	1	0.5
Linzhang	Cereals	2	1	0.5
Linzhang	Vegetables	2	1	0.5
Linzhang	Fruits	2	1	0.5
Linzhang	Tubers	2	1	0.5
Linzhang	Oilcrops	2	1	0.5
Linzhang	Cotton	2	1	0.5
Fengfengkuangqu	Cereals	2	1	0.5
Fengfengkuangqu	Vegetables	2	1	0.5
Fengfengkuangqu	Fruits	2	1	0.5
Fengfengkuangqu	Tubers	2	1	0.5
Fengfengkuangqu	Oilcrops	2	1	0.5
Fengfengkuangqu	Cotton	2	1	0.5
Shexian	Cereals	2	1	0.5
Shexian	Vegetables	2	1	0.5
Shexian	Fruits	2	1	0.5
Shexian	Tubers	2	1	0.5

Shexian	Oilcrops	2	1	0.5
Shexian	Cotton	2	1	0.5
Guantao	Cereals	2	1	0.5
Guantao	Vegetables	2	1	0.5
Guantao	Fruits	2	1	0.5
Guantao	Tubers	2	1	0.5
Guantao	Oilcrops	2	1	0.5
Guantao	Cotton	2	1	0.5
Cixian	Cereals	2	1	0.5
Cixian	Vegetables	2	1	0.5
Cixian	Fruits	2	1	0.5
Cixian	Tubers	2	1	0.5
Cixian	Oilcrops	2	1	0.5
Cixian	Cotton	2	1	0.5
Handanxian	Cereals	2	1	0.5
Handanxian	Vegetables	2	1	0.5
Handanxian	Fruits	2	1	0.5
Handanxian	Tubers	2	1	0.5
Handanxian	Oilcrops	2	1	0.5
Handanxian	Cotton	2	1	0.5
Weixian	Cereals	2	1	0.5
Weixian	Vegetables	2	1	0.5
Weixian	Fruits	2	1	0.5
Weixian	Tubers	2	1	0.5
Weixian	Oilcrops	2	1	0.5
Weixian	Cotton	2	1	0.5

Table A12. Data for N, P deposition in soil, kg/ha

Conuty		**Elements**	
County	Cropcategories	N	P
Daming	Cereals	21.00	0.12
Daming	Vegetables	14.00	0.08
Daming	Fruits	21.00	0.12
Daming	Tubers	21.00	0.12
Daming	Oilcrops	21.00	0.12
Daming	Cotton	21.00	0.12
Guangping	Cereals	21.00	0.12
Guangping	Vegetables	14.00	0.08
Guangping	Fruits	21.00	0.12
Guangping	Tubers	21.00	0.12
Guangping	Oilcrops	21.00	0.12
Guangping	Cotton	21.00	0.12
Yongnian	Cereals	21.00	0.12
Yongnian	Vegetables	14.00	0.08
Yongnian	Fruits	21.00	0.12

Yongnian	Tubers	21.00	0.12
Yongnian	Oilcrops	21.00	0.12
Yongnian	Cotton	21.00	0.12
Chenganxian	Cereals	21.00	0.12
Chenganxian	Vegetables	14.00	0.08
Chenganxian	Fruits	21.00	0.12
Chenganxian	Tubers	21.00	0.12
Chenganxian	Oilcrops	21.00	0.12
Chenganxian	Cotton	21.00	0.12
Quzhou	Cereals	21.00	0.12
Quzhou	Vegetables	14.00	0.08
Quzhou	Fruits	21.00	0.12
Quzhou	Tubers	21.00	0.12
Quzhou	Oilcrops	21.00	0.12
Quzhou	Cotton	21.00	0.12
Handanshi	Cereals	21.00	0.12
Handanshi	Vegetables	14.00	0.08
Handanshi	Fruits	21.00	0.12
Handanshi	Tubers	21.00	0.12
Handanshi	Oilcrops	21.00	0.12
Handanshi	Cotton	21.00	0.12
Qiuxian	Cereals	21.00	0.12
Qiuxian	Vegetables	14.00	0.08
Qiuxian	Fruits	21.00	0.12
Qiuxian	Tubers	21.00	0.12
Qiuxian	Oilcrops	21.00	0.12
Qiuxian	Cotton	21.00	0.12
Jize	Cereals	21.00	0.12
Jize	Vegetables	14.00	0.08
Jize	Fruits	21.00	0.12
Jize	Tubers	21.00	0.12
Jize	Oilcrops	21.00	0.12
Jize	Cotton	21.00	0.12
Wuanshi	Cereals	21.00	0.12
Wuanshi	Vegetables	14.00	0.08
Wuanshi	Fruits	21.00	0.12
Wuanshi	Tubers	21.00	0.12
Wuanshi	Oilcrops	21.00	0.12
Wuanshi	Cotton	21.00	0.12
Feixiang	Cereals	21.00	0.12
Feixiang	Vegetables	14.00	0.08
Feixiang	Fruits	21.00	0.12
Feixiang	Tubers	21.00	0.12
Feixiang	Oilcrops	21.00	0.12
Feixiang	Cotton	21.00	0.12

Linzhang	Cereals	21.00	0.12
Linzhang	Vegetables	14.00	0.08
Linzhang	Fruits	21.00	0.12
Linzhang	Tubers	21.00	0.12
Linzhang	Oilcrops	21.00	0.12
Linzhang	Cotton	21.00	0.12
Fengfengkuangqu	Cereals	21.00	0.12
Fengfengkuangqu	Vegetables	14.00	0.08
Fengfengkuangqu	Fruits	21.00	0.12
Fengfengkuangqu	Tubers	21.00	0.12
Fengfengkuangqu	Oilcrops	21.00	0.12
Fengfengkuangqu	Cotton	21.00	0.12
Shexian	Cereals	21.00	0.12
Shexian	Vegetables	14.00	0.08
Shexian	Fruits	21.00	0.12
Shexian	Tubers	21.00	0.12
Shexian	Oilcrops	21.00	0.12
Shexian	Cotton	21.00	0.12
Guantao	Cereals	21.00	0.12
Guantao	Vegetables	14.00	0.08
Guantao	Fruits	21.00	0.12
Guantao	Tubers	21.00	0.12
Guantao	Oilcrops	21.00	0.12
Guantao	Cotton	21.00	0.12
Cixian	Cereals	21.00	0.12
Cixian	Vegetables	14.00	0.08
Cixian	Fruits	21.00	0.12
Cixian	Tubers	21.00	0.12
Cixian	Oilcrops	21.00	0.12
Cixian	Cotton	21.00	0.12
Handanxian	Cereals	21.00	0.12
Handanxian	Vegetables	14.00	0.08
Handanxian	Fruits	21.00	0.12
Handanxian	Tubers	21.00	0.12
Handanxian	Oilcrops	21.00	0.12
Handanxian	Cotton	21.00	0.12
Weixian	Cereals	21.00	0.12
Weixian	Vegetables	14.00	0.08
Weixian	Fruits	21.00	0.12
Weixian	Tubers	21.00	0.12
Weixian	Oilcrops	21.00	0.12
Weixian	Cotton	21.00	0.12

Data on transportation segments, which used for calculating the transportation distance and total cost.

Table A13. Data used for calculating cost of transportation (Euro per ton)

Conuty			**cost**	
Scounty	Anicategories	Manuretypes	Price	Transcost
Daming	Dairycow	Solid	5	0.3
Daming	Dairycow	Compost	20	0.3
Daming	Dairycow	Liquid	0	0.3
Daming	Dairycow	Digestion	3	0.3
Daming	Beefcow	Solid	5	0.3
Daming	Beefcow	Compost	20	0.3
Daming	Beefcow	Liquid	0	0.3
Daming	Pig	Solid	5	0.3
Daming	Pig	Compost	20	0.3
Daming	Pig	Liquid	0	0.3
Daming	Pig	Digestion	3	0.3
Daming	Sheepgoat	Solid	5	0.3
Daming	Broiler	Solid	10	0.3
Daming	Broiler	Compost	20	0.3
Daming	Layer	Solid	10	0.3
Daming	Layer	Compost	20	0.3
Guangping	Dairycow	Solid	5	0.3
Guangping	Dairycow	Compost	20	0.3
Guangping	Dairycow	Liquid	0	0.3
Guangping	Dairycow	Digestion	3	0.3
Guangping	Beefcow	Solid	5	0.3
Guangping	Beefcow	Compost	20	0.3
Guangping	Beefcow	Liquid	0	0.3
Guangping	Pig	Solid	5	0.3
Guangping	Pig	Compost	20	0.3
Guangping	Pig	Liquid	0	0.3
Guangping	Pig	Digestion	3	0.3
Guangping	Sheepgoat	Solid	5	0.3
Guangping	Broiler	Solid	10	0.3
Guangping	Broiler	Compost	20	0.3
Guangping	Layer	Solid	10	0.3
Guangping	Layer	Compost	20	0.3
Yongnian	Dairycow	Solid	5	0.3
Yongnian	Dairycow	Compost	20	0.3
Yongnian	Dairycow	Liquid	0	0.3
Yongnian	Dairycow	Digestion	3	0.3
Yongnian	Beefcow	Solid	5	0.3
Yongnian	Beefcow	Compost	20	0.3
Yongnian	Beefcow	Liquid	0	0.3
Yongnian	Pig	Solid	5	0.3
Yongnian	Pig	Compost	20	0.3

Yongnian	Pig	Liquid	0	0.3
Yongnian	Pig	Digestion	3	0.3
Yongnian	Sheepgoat	Solid	5	0.3
Yongnian	Broiler	Solid	10	0.3
Yongnian	Broiler	Compost	20	0.3
Yongnian	Layer	Solid	10	0.3
Yongnian	Layer	Compost	20	0.3

Table A14. Distance between each of the 16 counties (km)

Conuty	**county**															
County	Daming	Guangping	Yongnian	Chenganxian	Quzhou	Qiuxian	Jize	Wuanshi	Feixiang	Linzhang	Fengfengkuangqu	Shexian	Guantao	Cixian	Handanxian	Weixian
Daming	0	30.05093	73.92488684	51.89473642	54.84264253	54.03445367	72.31094824	117.1568642	48.21768969	58.6657741	95.46888646	138.9704233	36.35770878	89.33813159	76.9644926	28.6804561
Guangping		0	44.13812293	32.48755265	27.87462895	34.40084568	43.08331523	90.7120186	20.16149921	48.04415792	73.95614769	116.0178767	25.44665271	70.3582806	50.35411685	29.04653568
Yongnian			0	38.5477066	32.56828727	49.00374554	20.64244639	52.82928004	26.81527648	56.5651588	50.70277838	83.73352393	57.50422465	53.85758313	21.2969898	61.29476042
Chenganxian				0	48.12407024	61.60628128	51.83442033	66.8953639	19.66165881	19.66881557	43.65169667	87.07970868	57.53867355	38.47028818	29.15514329	28.13368046
Quzhou					0	16.65618744	19.42767393	85.37864412	28.48097732	67.41094375	78.80548372	115.6603209	27.15076369	78.9324061	49.62989279	56.01721655
Qiuxian						0	32.93629131	101.8255061	42.59401532	80.00581488	95.14933284	132.3092835	18.76650052	94.76504398	66.19912314	63.2862396
Jize							0	71.19176242	34.04688582	71.34279191	71.30474088	103.2712379	46.52709329	73.96953404	41.69270859	67.83682098
Wuanshi								0	70.55147959	72.61018399	32.2097553	33.40053072	109.1603778	42.73678576	40.44312662	94.9510143
Feixiang									0	39.13264944	55.25988988	96.36247168	41.66842461	53.12730341	30.20796948	35.03584831
Linzhang										0	43.04062086	85.49723625	73.44978138	34.11008383	42.1173439	30.15838425
Fengfengkuan											0	43.61335	96.91983	10.53564	29.77708	69.62226

gqu	234	364	763	956	172
Shexian	0	137.2831541	51.3970277 1	66.99469349	113.1768964
Guantao		0	94.48191159	70.31396225	51.12957422
Cixian			0	32.60438653	62.34036962
Handanxian				0	56.87045999
Weixian					0

APPENDIX II

Intermediate data about the N,P,K content of different manure types per county in table B1.

Table B1. Proportion of the N, P, K content of different manure types per county

Conuty	**Anicategories**	**Manuretypes**	**Elements**		
County	Anicategories	Manuretypes	N	P	K
Daming	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Daming	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Daming	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Daming	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Daming	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Daming	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Daming	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Daming	Pig	Solid	0.0037249	0.001748996	0.002530622
Daming	Pig	Compost	0.003443775	0.00224498	0.002887048
Daming	Pig	Liquid	0.00161397	0.000303015	0.001070352
Daming	Pig	Digestion	0.001918492	0.000407035	0.001356784
Daming	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Daming	Broiler	Solid	0.006066265	0.00221988	0.00465492
Daming	Broiler	Compost	0.005608434	0.002849398	0.005310542
Daming	Layer	Solid	0.006066265	0.00221988	0.00465492
Daming	Layer	Compost	0.005608434	0.002849398	0.005310542
Guangping	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Guangping	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Guangping	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Guangping	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Guangping	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Guangping	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Guangping	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Guangping	Pig	Solid	0.0037249	0.001748996	0.002530622
Guangping	Pig	Compost	0.003443775	0.00224498	0.002887048
Guangping	Pig	Liquid	0.00161397	0.000303015	0.001070352
Guangping	Pig	Digestion	0.001918492	0.000407035	0.001356784
Guangping	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Guangping	Broiler	Solid	0.006066265	0.00221988	0.00465492
Guangping	Broiler	Compost	0.005608434	0.002849398	0.005310542
Guangping	Layer	Solid	0.006066265	0.00221988	0.00465492
Guangping	Layer	Compost	0.005608434	0.002849398	0.005310542
Yongnian	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Yongnian	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Yongnian	Dairycow	Liquid	0.004884523	0.000269347	0.007706533

Yongnian	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Yongnian	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Yongnian	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Yongnian	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Yongnian	Pig	Solid	0.0037249	0.001748996	0.002530622
Yongnian	Pig	Compost	0.003443775	0.00224498	0.002887048
Yongnian	Pig	Liquid	0.00161397	0.000303015	0.001070352
Yongnian	Pig	Digestion	0.001918492	0.000407035	0.001356784
Yongnian	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Yongnian	Broiler	Solid	0.006066265	0.00221988	0.00465492
Yongnian	Broiler	Compost	0.005608434	0.002849398	0.005310542
Yongnian	Layer	Solid	0.006066265	0.00221988	0.00465492
Yongnian	Layer	Compost	0.005608434	0.002849398	0.005310542
Chenganxian	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Chenganxian	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Chenganxian	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Chenganxian	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Chenganxian	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Chenganxian	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Chenganxian	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Chenganxian	Pig	Solid	0.0037249	0.001748996	0.002530622
Chenganxian	Pig	Compost	0.003443775	0.00224498	0.002887048
Chenganxian	Pig	Liquid	0.00161397	0.000303015	0.001070352
Chenganxian	Pig	Digestion	0.001918492	0.000407035	0.001356784
Chenganxian	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Chenganxian	Broiler	Solid	0.006066265	0.00221988	0.00465492
Chenganxian	Broiler	Compost	0.005608434	0.002849398	0.005310542
Chenganxian	Layer	Solid	0.006066265	0.00221988	0.00465492
Chenganxian	Layer	Compost	0.005608434	0.002849398	0.005310542
Quzhou	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Quzhou	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Quzhou	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Quzhou	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Quzhou	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Quzhou	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Quzhou	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Quzhou	Pig	Solid	0.0037249	0.001748996	0.002530622
Quzhou	Pig	Compost	0.003443775	0.00224498	0.002887048
Quzhou	Pig	Liquid	0.00161397	0.000303015	0.001070352
Quzhou	Pig	Digestion	0.001918492	0.000407035	0.001356784
Quzhou	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Quzhou	Broiler	Solid	0.006066265	0.00221988	0.00465492
Quzhou	Broiler	Compost	0.005608434	0.002849398	0.005310542
Quzhou	Layer	Solid	0.006066265	0.00221988	0.00465492
Quzhou	Layer	Compost	0.005608434	0.002849398	0.005310542

Handanshi	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Handanshi	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Handanshi	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Handanshi	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Handanshi	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Handanshi	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Handanshi	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Handanshi	Pig	Solid	0.0037249	0.001748996	0.002530622
Handanshi	Pig	Compost	0.003443775	0.00224498	0.002887048
Handanshi	Pig	Liquid	0.00161397	0.000303015	0.001070352
Handanshi	Pig	Digestion	0.001918492	0.000407035	0.001356784
Handanshi	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Handanshi	Broiler	Solid	0.006066265	0.00221988	0.00465492
Handanshi	Broiler	Compost	0.005608434	0.002849398	0.005310542
Handanshi	Layer	Solid	0.006066265	0.00221988	0.00465492
Handanshi	Layer	Compost	0.005608434	0.002849398	0.005310542
Qiuxian	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Qiuxian	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Qiuxian	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Qiuxian	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Qiuxian	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Qiuxian	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Qiuxian	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Qiuxian	Pig	Solid	0.0037249	0.001748996	0.002530622
Qiuxian	Pig	Compost	0.003443775	0.00224498	0.002887048
Qiuxian	Pig	Liquid	0.00161397	0.000303015	0.001070352
Qiuxian	Pig	Digestion	0.001918492	0.000407035	0.001356784
Qiuxian	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Qiuxian	Broiler	Solid	0.006066265	0.00221988	0.00465492
Qiuxian	Broiler	Compost	0.005608434	0.002849398	0.005310542
Qiuxian	Layer	Solid	0.006066265	0.00221988	0.00465492
Qiuxian	Layer	Compost	0.005608434	0.002849398	0.005310542
Jize	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Jize	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Jize	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Jize	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Jize	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Jize	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Jize	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Jize	Pig	Solid	0.0037249	0.001748996	0.002530622
Jize	Pig	Compost	0.003443775	0.00224498	0.002887048
Jize	Pig	Liquid	0.00161397	0.000303015	0.001070352
Jize	Pig	Digestion	0.001918492	0.000407035	0.001356784
Jize	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Jize	Broiler	Solid	0.006066265	0.00221988	0.00465492

Jize	Broiler	Compost	0.005608434	0.002849398	0.005310542
Jize	Layer	Solid	0.006066265	0.00221988	0.00465492
Jize	Layer	Compost	0.005608434	0.002849398	0.005310542
Wuanshi	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Wuanshi	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Wuanshi	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Wuanshi	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Wuanshi	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Wuanshi	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Wuanshi	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Wuanshi	Pig	Solid	0.0037249	0.001748996	0.002530622
Wuanshi	Pig	Compost	0.003443775	0.00224498	0.002887048
Wuanshi	Pig	Liquid	0.00161397	0.000303015	0.001070352
Wuanshi	Pig	Digestion	0.001918492	0.000407035	0.001356784
Wuanshi	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Wuanshi	Broiler	Solid	0.006066265	0.00221988	0.00465492
Wuanshi	Broiler	Compost	0.005608434	0.002849398	0.005310542
Wuanshi	Layer	Solid	0.006066265	0.00221988	0.00465492
Wuanshi	Layer	Compost	0.005608434	0.002849398	0.005310542
Feixiang	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Feixiang	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Feixiang	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Feixiang	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Feixiang	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Feixiang	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Feixiang	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Feixiang	Pig	Solid	0.0037249	0.001748996	0.002530622
Feixiang	Pig	Compost	0.003443775	0.00224498	0.002887048
Feixiang	Pig	Liquid	0.00161397	0.000303015	0.001070352
Feixiang	Pig	Digestion	0.001918492	0.000407035	0.001356784
Feixiang	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Feixiang	Broiler	Solid	0.006066265	0.00221988	0.00465492
Feixiang	Broiler	Compost	0.005608434	0.002849398	0.005310542
Feixiang	Layer	Solid	0.006066265	0.00221988	0.00465492
Feixiang	Layer	Compost	0.005608434	0.002849398	0.005310542
Linzhang	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Linzhang	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Linzhang	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Linzhang	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Linzhang	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Linzhang	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Linzhang	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Linzhang	Pig	Solid	0.0037249	0.001748996	0.002530622
Linzhang	Pig	Compost	0.003443775	0.00224498	0.002887048
Linzhang	Pig	Liquid	0.00161397	0.000303015	0.001070352

Linzhang	Pig	Digestion	0.001918492	0.000407035	0.001356784
Linzhang	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Linzhang	Broiler	Solid	0.006066265	0.00221988	0.00465492
Linzhang	Broiler	Compost	0.005608434	0.002849398	0.005310542
Linzhang	Layer	Solid	0.006066265	0.00221988	0.00465492
Linzhang	Layer	Compost	0.005608434	0.002849398	0.005310542
Fengfengkuangqu	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Fengfengkuangqu	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Fengfengkuangqu	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Fengfengkuangqu	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Fengfengkuangqu	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Fengfengkuangqu	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Fengfengkuangqu	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Fengfengkuangqu	Pig	Solid	0.0037249	0.001748996	0.002530622
Fengfengkuangqu	Pig	Compost	0.003443775	0.00224498	0.002887048
Fengfengkuangqu	Pig	Liquid	0.00161397	0.000303015	0.001070352
Fengfengkuangqu	Pig	Digestion	0.001918492	0.000407035	0.001356784
Fengfengkuangqu	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Fengfengkuangqu	Broiler	Solid	0.006066265	0.00221988	0.00465492
Fengfengkuangqu	Broiler	Compost	0.005608434	0.002849398	0.005310542
Fengfengkuangqu	Layer	Solid	0.006066265	0.00221988	0.00465492
Fengfengkuangqu	Layer	Compost	0.005608434	0.002849398	0.005310542
Shexian	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Shexian	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Shexian	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Shexian	Pig	Solid	0.0037249	0.001748996	0.002530622
Shexian	Pig	Compost	0.003443775	0.00224498	0.002887048
Shexian	Pig	Liquid	0.00161397	0.000303015	0.001070352
Shexian	Pig	Digestion	0.001918492	0.000407035	0.001356784
Shexian	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Shexian	Broiler	Solid	0.006066265	0.00221988	0.00465492
Shexian	Broiler	Compost	0.005608434	0.002849398	0.005310542
Shexian	Layer	Solid	0.006066265	0.00221988	0.00465492
Shexian	Layer	Compost	0.005608434	0.002849398	0.005310542
Guantao	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Guantao	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Guantao	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Guantao	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Guantao	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Guantao	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Guantao	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Guantao	Pig	Solid	0.0037249	0.001748996	0.002530622
Guantao	Pig	Compost	0.003443775	0.00224498	0.002887048
Guantao	Pig	Liquid	0.00161397	0.000303015	0.001070352
Guantao	Pig	Digestion	0.001918492	0.000407035	0.001356784

Guantao	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Guantao	Broiler	Solid	0.006066265	0.00221988	0.00465492
Guantao	Broiler	Compost	0.005608434	0.002849398	0.005310542
Guantao	Layer	Solid	0.006066265	0.00221988	0.00465492
Guantao	Layer	Compost	0.005608434	0.002849398	0.005310542
Cixian	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Cixian	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Cixian	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Cixian	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Cixian	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Cixian	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Cixian	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Cixian	Pig	Solid	0.0037249	0.001748996	0.002530622
Cixian	Pig	Compost	0.003443775	0.00224498	0.002887048
Cixian	Pig	Liquid	0.00161397	0.000303015	0.001070352
Cixian	Pig	Digestion	0.001918492	0.000407035	0.001356784
Cixian	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Cixian	Broiler	Solid	0.006066265	0.00221988	0.00465492
Cixian	Broiler	Compost	0.005608434	0.002849398	0.005310542
Cixian	Layer	Solid	0.006066265	0.00221988	0.00465492
Cixian	Layer	Compost	0.005608434	0.002849398	0.005310542
Handanxian	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Handanxian	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Handanxian	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Handanxian	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Handanxian	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Handanxian	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Handanxian	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Handanxian	Pig	Solid	0.0037249	0.001748996	0.002530622
Handanxian	Pig	Compost	0.003443775	0.00224498	0.002887048
Handanxian	Pig	Liquid	0.00161397	0.000303015	0.001070352
Handanxian	Pig	Digestion	0.001918492	0.000407035	0.001356784
Handanxian	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Handanxian	Broiler	Solid	0.006066265	0.00221988	0.00465492
Handanxian	Broiler	Compost	0.005608434	0.002849398	0.005310542
Handanxian	Layer	Solid	0.006066265	0.00221988	0.00465492
Handanxian	Layer	Compost	0.005608434	0.002849398	0.005310542
Weixian	Dairycow	Solid	0.003192771	0.001042671	0.00249498
Weixian	Dairycow	Compost	0.002951807	0.001338353	0.002846386
Weixian	Dairycow	Liquid	0.004884523	0.000269347	0.007706533
Weixian	Dairycow	Digestion	0.005806131	0.000361809	0.009768844
Weixian	Beefcow	Solid	0.002926707	0.000807229	0.00249498
Weixian	Beefcow	Compost	0.002705823	0.001036145	0.002846386
Weixian	Beefcow	Liquid	0.004325226	6.0603E-05	0.008420101
Weixian	Pig	Solid	0.0037249	0.001748996	0.002530622

Weixian	Pig	Compost	0.003443775	0.00224498	0.002887048
Weixian	Pig	Liquid	0.00161397	0.000303015	0.001070352
Weixian	Pig	Digestion	0.001918492	0.000407035	0.001356784
Weixian	Sheepgoat	Solid	0.005534137	0.000734438	0.005551205
Weixian	Broiler	Solid	0.006066265	0.00221988	0.00465492
Weixian	Broiler	Compost	0.005608434	0.002849398	0.005310542
Weixian	Layer	Solid	0.006066265	0.00221988	0.00465492
Weixian	Layer	Compost	0.005608434	0.002849398	0.005310542

In RQ1, detailed table of the amount of manure and NPK nutrients actually applied in different counties (multiple levels). And the amount of NPK nutrients that each county can provide on its own before transportation.

Table B2. Amount of manure used per county in RQ1 (t)

Conuty	Cropcategories	grade	Anicategories	Manuretypes			
				Solid	**Compost**	**Liquid**	**Digestion**
Daming	Cereals	N1P1K1	Dairycow	16353			
Daming	Cereals	N1P1K1	Pig	334567			
Daming	Vegetables	N1P3K3	Pig				197251
Daming	Oilcrops	N3P1K2	Dairycow		9604	7574	2013
Daming	Oilcrops	N3P1K2	Beefcow	230959	213193	185168	
Daming	Oilcrops	N3P1K2	Pig		213903	460252	
Daming	Oilcrops	N3P1K2	Sheepgoat	632152			
Daming	Oilcrops	N3P1K2	Broiler	20308	4041		
Daming	Oilcrops	N3P1K2	Layer	148374			
Guangping	Fruits	N1P2K2	Dairycow				1107
Guangping	Tubers	N2P2K1	Dairycow	8994	5282	4166	
Guangping	Tubers	N2P2K1	Beefcow	12004	11081	9624	
Guangping	Tubers	N2P2K1	Pig	51263	32775	70521	30223
Guangping	Tubers	N2P2K1	Sheepgoat	98999			
Guangping	Tubers	N2P2K1	Broiler	6506	9759		
Guangping	Tubers	N2P2K1	Layer	47108	70662		
Yongnian	Cereals	N2P2K3	Dairycow			43931	
Yongnian	Vegetables	N1P3K3	Layer		2617		
Yongnian	Fruits	N3P1K2	Dairycow		55703		
Yongnian	Tubers	N1P1K2	Pig				106609
Yongnian	Tubers	N2P3K3	Beefcow			92007	
Yongnian	Oilcrops	N2P1K1	Dairycow				11678
Yongnian	Oilcrops	N3P3K1	Dairycow	94846			
Yongnian	Cotton	N1P1K3	Pig			248754	
Yongnian	Cotton	N1P3K1	Pig		115609		
Yongnian	Cotton	N2P2K1	Beefcow		105931		
Yongnian	Cotton	N2P2K3	Broiler	30726			
Yongnian	Cotton	N2P3K3	Beefcow	114759			

Yongnian	Cotton	N3P1K2	Broiler		46089		
Yongnian	Cotton	N3P2K1	Sheepgoat	342135			
Yongnian	Cotton	N3P2K1	Layer	433485			
Yongnian	Cotton	N3P3K1	Pig	180825			
Chenganxian	Vegetables	N1P3K1	Layer		160843		
Chenganxian	Vegetables	N1P3K2	Sheepgoat	311057			
Chenganxian	Fruits	N1P3K1	Pig	124532			
Chenganxian	Fruits	N2P2K1	Beefcow		86429		
Chenganxian	Fruits	N2P2K1	Pig			171314	
Chenganxian	Fruits	N3P1K3	Pig				73420
Chenganxian	Fruits	N3P2K3	Dairycow	31888			
Chenganxian	Tubers	N3P2K2	Broiler	9908			
Chenganxian	Oilcrops	N2P2K1	Pig		79619		
Chenganxian	Oilcrops	N2P2K3	Dairycow		18728		
Chenganxian	Cotton	N2P3K1	Beefcow	93632			
Chenganxian	Cotton	N3P1K3	Broiler		14862		
Chenganxian	Cotton	N3P3K2	Layer	107229			
Quzhou	Cereals	N1P2K1	Dairycow			15906	
Quzhou	Cereals	N1P3K3	Beefcow			112410	
Quzhou	Cereals	N3P1K1	Pig	188611			
Quzhou	Cereals	N3P3K3	Pig				111200
Quzhou	Vegetables	N2P1K3	Dairycow	34341	20168		
Quzhou	Fruits	N2P2K3	Pig			259466	
Quzhou	Fruits	N2P3K2	Broiler	29200			
Quzhou	Tubers	N1P3K2	Dairycow				4228
Quzhou	Tubers	N1P3K2	Beefcow	140208			
Quzhou	Cotton	N1P2K1	Layer	174639			
Quzhou	Cotton	N1P2K3	Sheepgoat	335387			
Quzhou	Cotton	N2P2K2	Beefcow		129423		
Handanshi	Cereals	N1P1K2	Dairycow			41659	
Handanshi	Cereals	N1P3K1	Pig		20085		
Handanshi	Vegetables	N3P1K1	Pig	80958			
Handanshi	Fruits	N2P3K2	Broiler	6557			
Handanshi	Fruits	N3P2K3	Dairycow				11074
Handanshi	Tubers	N2P2K3	Dairycow	89940			
Handanshi	Oilcrops	N1P2K3	Layer	46072			
Handanshi	Oilcrops	N1P3K1	Dairycow		52822		
Handanshi	Oilcrops	N2P1K1	Beefcow	27849			
Handanshi	Oilcrops	N3P1K1	Beefcow			22328	
Handanshi	Oilcrops	N3P2K3	Pig			111371	
Handanshi	Oilcrops	N3P3K1	Pig				47730
Handanshi	Oilcrops	N3P3K1	Sheepgoat	99348			
Handanshi	Cotton	N1P3K1	Beefcow		25707		
Qiuxian	Cereals	N1P2K2	Dairycow	4906			
Qiuxian	Cereals	N3P2K3	Pig				26745

Qiuxian	Vegetables	N1P1K2	Broiler	14534			
Qiuxian	Vegetables	N1P3K3	Pig	45363			
Qiuxian	Vegetables	N2P3K2	Broiler		21801		
Qiuxian	Vegetables	N3P1K3	Sheepgoat	76247			
Qiuxian	Vegetables	N3P2K3	Layer	110205			
Qiuxian	Fruits	N1P1K2	Dairycow		2881		
Qiuxian	Fruits	N1P1K3	Pig			62405	
Qiuxian	Fruits	N2P3K2	Pig		29003		
Qiuxian	Fruits	N3P2K1	Layer		165307		
Qiuxian	Oilcrops	N2P2K3	Beefcow		40777		
Qiuxian	Cotton	N3P2K2	Beefcow	44175			
Jize	Cereals	N2P1K1	Pig			132926	
Jize	Cereals	N2P1K1	Layer	99748	21194		
Jize	Cereals	N2P3K3	Pig	96627			
Jize	Vegetables	N1P3K2	Broiler	12630			
Jize	Vegetables	N1P3K3	Beefcow			47736	
Jize	Fruits	N1P1K2	Pig		61778		
Jize	Fruits	N3P2K3	Dairycow			10983	
Jize	Tubers	N2P1K1	Sheepgoat	233247			
Jize	Tubers	N2P2K3	Beefcow	59540			
Jize	Oilcrops	N3P2K3	Dairycow	23711	13926		2919
Jize	Cotton	N1P1K2	Pig				56968
Jize	Cotton	N3P2K2	Beefcow		54960		
Wuanshi	Cereals	N2P1K2	Dairycow	11447			
Wuanshi	Cereals	N2P2K3	Pig				231979
Wuanshi	Cereals	N2P2K3	Broiler		10291		
Wuanshi	Cereals	N3P1K2	Broiler	6861			
Wuanshi	Cereals	N3P1K3	Dairycow			5302	
Wuanshi	Vegetables	N1P1K3	Layer	77267			
Wuanshi	Vegetables	N1P2K1	Beefcow	81628		18084	
Wuanshi	Vegetables	N1P3K2	Pig		251564		
Wuanshi	Vegetables	N1P3K3	Dairycow		6723		
Wuanshi	Vegetables	N1P3K3	Beefcow		75349		
Wuanshi	Vegetables	N2P1K3	Pig			541285	
Wuanshi	Cotton	N3P3K3	Pig	393471			
Wuanshi	Cotton	N3P3K3	Sheepgoat	48511			
Wuanshi	Cotton	N3P3K3	Layer		115901		
Feixiang	Oilcrops	N1P3K3	Broiler		3475		
Feixiang	Oilcrops	N2P2K2	Dairycow				8557
Feixiang	Oilcrops	N2P2K2	Pig			193069	
Feixiang	Oilcrops	N2P2K3	Beefcow		92191		
Feixiang	Cotton	N3P3K3	Dairycow	69499	40817	32191	
Feixiang	Cotton	N3P3K3	Beefcow	99874		80073	
Feixiang	Cotton	N3P3K3	Pig	140346	89729		82744
Feixiang	Cotton	N3P3K3	Sheepgoat	393903			

Feixiang	Cotton	N3P3K3	Broiler	10976			
Feixiang	Cotton	N3P3K3	Layer	91531			
Linzhang	Cereals	N3P1K2	Dairycow	19623			
Linzhang	Tubers	N2P1K2	Beefcow	170458			
Linzhang	Oilcrops	N1P1K3	Broiler	22054			
Linzhang	Oilcrops	N1P2K1	Pig		113352		
Linzhang	Cotton	N3P3K3	Dairycow		11525	9089	2416
Linzhang	Cotton	N3P3K3	Beefcow		157346	136663	
Linzhang	Cotton	N3P3K3	Pig	177294		243898	104528
Linzhang	Cotton	N3P3K3	Sheepgoat	495927			
Linzhang	Cotton	N3P3K3	Broiler		33081		
Linzhang	Cotton	N3P3K3	Layer	105113	22076		
Fengfengkuangqu	Oilcrops	N1P2K1	Beefcow	18726			
Fengfengkuangqu	Oilcrops	N1P2K3	Dairycow	19623			
Fengfengkuangqu	Cotton	N3P3K3	Pig	134744	198325		84996
Shexian	Vegetables	N2P2K2	Beefcow	59060			
Shexian	Tubers	N2P2K2	Pig		44030		
Shexian	Cotton	N1P1K3	Broiler	8217	12326		
Shexian	Cotton	N1P1K3	Layer	65223	74500		
Shexian	Cotton	N1P2K1	Beefcow		54517		
Shexian	Cotton	N1P2K1	Pig	68867		94738	40602
Guantao	Vegetables	N1P2K1	Dairycow	23711			
Guantao	Oilcrops	N1P2K1	Beefcow	90271			
Guantao	Cotton	N3P3K3	Dairycow		13926	10983	2919
Guantao	Cotton	N3P3K3	Beefcow		83327	72374	
Guantao	Cotton	N3P3K3	Pig	170717		234850	100650
Guantao	Cotton	N3P3K3	Sheepgoat	194276			
Guantao	Cotton	N3P3K3	Layer	172717			
Cixian	Fruits	N1P2K3	Dairycow	40882			
Cixian	Tubers	N3P3K3	Pig		81072		
Cixian	Oilcrops	N1P2K1	Beefcow	49937			
Cixian	Cotton	N3P3K3	Dairycow		24010		
Cixian	Cotton	N3P3K3	Beefcow		46096		
Cixian	Cotton	N3P3K3	Pig	126805		174441	74760
Cixian	Cotton	N3P3K3	Sheepgoat	28310			
Cixian	Cotton	N3P3K3	Broiler	13298	19947		
Cixian	Cotton	N3P3K3	Layer	114640	171960		
Handanxian	Fruits	N1P2K2	Beefcow	35532			
Handanxian	Fruits	N1P3K1	Pig		30920		
Handanxian	Tubers	N3P1K3	Dairycow	28617			
Handanxian	Cotton	N3P3K3	Dairycow		16807	13255	3524
Handanxian	Cotton	N3P3K3	Beefcow		32799	28487	

Handanxian	Cotton	N3P3K3	Pig	48362		66530	28513
Handanxian	Cotton	N3P3K3	Sheepgoat	77827			
Handanxian	Cotton	N3P3K3	Broiler	4768	7152		
Handanxian	Cotton	N3P3K3	Layer	20251	30377		
Weixian	Tubers	N3P1K3	Beefcow	41294			
Weixian	Tubers	N3P3K3	Pig		129554		
Weixian	Cotton	N2P3K1	Dairycow	8994			
Weixian	Cotton	N3P3K3	Dairycow		5282	4166	1107
Weixian	Cotton	N3P3K3	Beefcow		38118	33107	
Weixian	Cotton	N3P3K3	Pig	202636		278759	119468
Weixian	Cotton	N3P3K3	Sheepgoat	384364			
Weixian	Cotton	N3P3K3	Broiler	11723	17585		
Weixian	Cotton	N3P3K3	Layer	145605	218408		

Table B3. NPK use of different manure types per county in RQ1 (t)

Conuty	**Anicategories**	**Manuretypes**	**Elements**		
County	Anicategories	Manuretypes	N	P	K
Daming	Dairycow	Solid	52	17	41
Daming	Dairycow	Compost	28	13	27
Daming	Dairycow	Liquid	37	2	58
Daming	Dairycow	Digestion	12	1	20
Daming	Beefcow	Solid	676	186	576
Daming	Beefcow	Compost	577	221	607
Daming	Beefcow	Liquid	801	11	1559
Daming	Pig	Solid	1246	585	847
Daming	Pig	Compost	737	480	618
Daming	Pig	Liquid	743	139	493
Daming	Pig	Digestion	378	80	268
Daming	Sheepgoat	Solid	3498	464	3509
Daming	Broiler	Solid	123	45	95
Daming	Broiler	Compost	23	12	21
Daming	Layer	Solid	900	329	691
Guangping	Dairycow	Solid	29	9	22
Guangping	Dairycow	Compost	16	7	15
Guangping	Dairycow	Liquid	20	1	32
Guangping	Dairycow	Digestion	6	0	11
Guangping	Beefcow	Solid	35	10	30
Guangping	Beefcow	Compost	30	11	32
Guangping	Beefcow	Liquid	42	1	81
Guangping	Pig	Solid	191	90	130
Guangping	Pig	Compost	113	74	95
Guangping	Pig	Liquid	114	21	75
Guangping	Pig	Digestion	58	12	41
Guangping	Sheepgoat	Solid	548	73	550

Guangping	Broiler	Solid	39	14	30
Guangping	Broiler	Compost	55	28	52
Guangping	Layer	Solid	286	105	219
Guangping	Layer	Compost	396	201	375
Yongnian	Dairycow	Solid	303	99	237
Yongnian	Dairycow	Compost	164	75	159
Yongnian	Dairycow	Liquid	215	12	339
Yongnian	Dairycow	Digestion	68	4	114
Yongnian	Beefcow	Solid	336	93	286
Yongnian	Beefcow	Compost	287	110	302
Yongnian	Beefcow	Liquid	398	6	775
Yongnian	Pig	Solid	674	316	458
Yongnian	Pig	Compost	398	260	334
Yongnian	Pig	Liquid	401	75	266
Yongnian	Pig	Digestion	205	43	145
Yongnian	Sheepgoat	Solid	1893	251	1899
Yongnian	Broiler	Solid	186	68	143
Yongnian	Broiler	Compost	258	131	245
Yongnian	Layer	Solid	2630	962	2018
Yongnian	Layer	Compost	15	7	14
Chenganxian	Dairycow	Solid	102	33	80
Chenganxian	Dairycow	Compost	55	25	53
Chenganxian	Beefcow	Solid	274	76	234
Chenganxian	Beefcow	Compost	234	90	246
Chenganxian	Pig	Solid	464	218	315
Chenganxian	Pig	Compost	274	179	230
Chenganxian	Pig	Liquid	276	52	183
Chenganxian	Pig	Digestion	141	30	100
Chenganxian	Sheepgoat	Solid	1721	228	1727
Chenganxian	Broiler	Solid	60	22	46
Chenganxian	Broiler	Compost	83	42	79
Chenganxian	Layer	Solid	650	238	499
Chenganxian	Layer	Compost	902	458	854
Quzhou	Dairycow	Solid	110	36	86
Quzhou	Dairycow	Compost	60	27	57
Quzhou	Dairycow	Liquid	78	4	123
Quzhou	Dairycow	Digestion	25	2	41
Quzhou	Beefcow	Solid	410	113	350
Quzhou	Beefcow	Compost	350	134	368
Quzhou	Beefcow	Liquid	486	7	947
Quzhou	Pig	Solid	703	330	477
Quzhou	Pig	Liquid	419	79	278
Quzhou	Pig	Digestion	213	45	151
Quzhou	Sheepgoat	Solid	1856	246	1862
Quzhou	Broiler	Solid	177	65	136

Quzhou	Layer	Solid	1059	388	813
Handanshi	Dairycow	Solid	287	94	224
Handanshi	Dairycow	Compost	156	71	150
Handanshi	Dairycow	Liquid	203	11	321
Handanshi	Dairycow	Digestion	64	4	108
Handanshi	Beefcow	Solid	82	22	69
Handanshi	Beefcow	Compost	70	27	73
Handanshi	Beefcow	Liquid	97	1	188
Handanshi	Pig	Solid	302	142	205
Handanshi	Pig	Compost	69	45	58
Handanshi	Pig	Liquid	180	34	119
Handanshi	Pig	Digestion	92	19	65
Handanshi	Sheepgoat	Solid	550	73	552
Handanshi	Broiler	Solid	40	15	31
Handanshi	Layer	Solid	279	102	214
Qiuxian	Dairycow	Solid	16	5	12
Qiuxian	Dairycow	Compost	9	4	8
Qiuxian	Beefcow	Solid	129	36	110
Qiuxian	Beefcow	Compost	110	42	116
Qiuxian	Pig	Solid	169	79	115
Qiuxian	Pig	Compost	100	65	84
Qiuxian	Pig	Liquid	101	19	67
Qiuxian	Pig	Digestion	51	11	36
Qiuxian	Sheepgoat	Solid	422	56	423
Qiuxian	Broiler	Solid	88	32	68
Qiuxian	Broiler	Compost	122	62	116
Qiuxian	Layer	Solid	669	245	513
Qiuxian	Layer	Compost	927	471	878
Jize	Dairycow	Solid	76	25	59
Jize	Dairycow	Compost	41	19	40
Jize	Dairycow	Liquid	54	3	85
Jize	Dairycow	Digestion	17	1	29
Jize	Beefcow	Solid	174	48	149
Jize	Beefcow	Compost	149	57	156
Jize	Beefcow	Liquid	206	3	402
Jize	Pig	Solid	360	169	245
Jize	Pig	Compost	213	139	178
Jize	Pig	Liquid	215	40	142
Jize	Pig	Digestion	109	23	77
Jize	Sheepgoat	Solid	1291	171	1295
Jize	Broiler	Solid	77	28	59
Jize	Layer	Solid	605	221	464
Jize	Layer	Compost	119	60	113
Wuanshi	Dairycow	Solid	37	12	29
Wuanshi	Dairycow	Compost	20	9	19

Wuanshi	Dairycow	Liquid	26	1	41
Wuanshi	Beefcow	Solid	239	66	204
Wuanshi	Beefcow	Compost	204	78	214
Wuanshi	Beefcow	Liquid	78	1	152
Wuanshi	Pig	Solid	1466	688	996
Wuanshi	Pig	Compost	866	565	726
Wuanshi	Pig	Liquid	874	164	579
Wuanshi	Pig	Digestion	445	94	315
Wuanshi	Sheepgoat	Solid	268	36	269
Wuanshi	Broiler	Solid	42	15	32
Wuanshi	Broiler	Compost	58	29	55
Wuanshi	Layer	Solid	469	172	360
Wuanshi	Layer	Compost	650	330	615
Feixiang	Dairycow	Solid	222	72	173
Feixiang	Dairycow	Compost	120	55	116
Feixiang	Dairycow	Liquid	157	9	248
Feixiang	Dairycow	Digestion	50	3	84
Feixiang	Beefcow	Solid	292	81	249
Feixiang	Beefcow	Compost	249	96	262
Feixiang	Beefcow	Liquid	346	5	674
Feixiang	Pig	Solid	523	245	355
Feixiang	Pig	Compost	309	201	259
Feixiang	Pig	Liquid	312	59	207
Feixiang	Pig	Digestion	159	34	112
Feixiang	Sheepgoat	Solid	2180	289	2187
Feixiang	Broiler	Solid	67	24	51
Feixiang	Broiler	Compost	19	10	18
Feixiang	Layer	Solid	555	203	426
Linzhang	Dairycow	Solid	63	20	49
Linzhang	Dairycow	Compost	34	15	33
Linzhang	Dairycow	Liquid	44	2	70
Linzhang	Dairycow	Digestion	14	1	24
Linzhang	Beefcow	Solid	499	138	425
Linzhang	Beefcow	Compost	426	163	448
Linzhang	Beefcow	Liquid	591	8	1151
Linzhang	Pig	Solid	660	310	449
Linzhang	Pig	Compost	390	254	327
Linzhang	Pig	Liquid	394	74	261
Linzhang	Pig	Digestion	201	43	142
Linzhang	Sheepgoat	Solid	2745	364	2753
Linzhang	Broiler	Solid	134	49	103
Linzhang	Broiler	Compost	186	94	176
Linzhang	Layer	Solid	638	233	489
Linzhang	Layer	Compost	124	63	117
Fengfengkuangqu	Dairycow	Solid	63	20	49

Fengfengkuangqu	Beefcow	Solid	55	15	47
Fengfengkuangqu	Pig	Solid	502	236	341
Fengfengkuangqu	Pig	Compost	683	445	573
Fengfengkuangqu	Pig	Digestion	163	35	115
Shexian	Beefcow	lid	173	48	147
Shexian	Beefcow	Compost	148	56	155
Shexian	Pig	Solid	257	120	174
Shexian	Pig	Compost	152	99	127
Shexian	Pig	Liquid	153	29	101
Shexian	Pig	Digestion	78	17	55
Shexian	Broiler	Solid	50	18	38
Shexian	Broiler	Compost	69	35	65
Shexian	Layer	Solid	396	145	304
Shexian	Layer	Compost	418	212	396
Guantao	Dairycow	Solid	76	25	59
Guantao	Dairycow	Compost	41	19	40
Guantao	Dairycow	Liquid	54	3	85
Guantao	Dairycow	Digestion	17	1	29
Guantao	Beefcow	Solid	264	73	225
Guantao	Beefcow	Compost	225	86	237
Guantao	Beefcow	Liquid	313	4	609
Guantao	Pig	Solid	636	299	432
Guantao	Pig	Liquid	379	71	251
Guantao	Pig	Digestion	193	41	137
Guantao	Sheepgoat	Solid	1075	143	1078
Guantao	Layer	Solid	1048	383	804
Cixian	Dairycow	Solid	131	43	102
Cixian	Dairycow	Compost	71	32	68
Cixian	Beefcow	Solid	146	40	125
Cixian	Beefcow	Compost	125	48	131
Cixian	Pig	Solid	472	222	321
Cixian	Pig	Compost	279	182	234
Cixian	Pig	Liquid	282	53	187
Cixian	Pig	Digestion	143	30	101
Cixian	Sheepgoat	Solid	157	21	157
Cixian	Broiler	Solid	81	30	62
Cixian	Broiler	Compost	112	57	106
Cixian	Layer	Solid	695	254	534
Cixian	Layer	Compost	964	490	913
Handanxian	Dairycow	Solid	91	30	71
Handanxian	Dairycow	Compost	50	22	48
Handanxian	Dairycow	Liquid	65	4	102
Handanxian	Dairycow	Digestion	20	1	34
Handanxian	Beefcow	Solid	104	29	89
Handanxian	Beefcow	Compost	89	34	93

Handanxian	Beefcow	Liquid	123	2	240
Handanxian	Pig	Solid	180	85	122
Handanxian	Pig	Compost	106	69	89
Handanxian	Pig	Liquid	107	20	71
Handanxian	Pig	Digestion	55	12	39
Handanxian	Sheepgoat	Solid	431	57	432
Handanxian	Broiler	Solid	29	11	22
Handanxian	Broiler	Compost	40	20	38
Handanxian	Layer	Solid	123	45	94
Handanxian	Layer	Compost	170	87	161
Weixian	Dairycow	Solid	29	9	22
Weixian	Dairycow	Compost	16	7	15
Weixian	Dairycow	Liquid	20	1	32
Weixian	Dairycow	Digestion	6	0	11
Weixian	Beefcow	Solid	121	33	103
Weixian	Beefcow	Compost	103	39	108
Weixian	Beefcow	Liquid	143	2	279
Weixian	Pig	Solid	755	354	513
Weixian	Pig	Compost	446	291	374
Weixian	Pig	Liquid	450	84	298
Weixian	Pig	Digestion	229	49	162
Weixian	Sheepgoat	Solid	2127	282	2134
Weixian	Broiler	Solid	71	26	55
Weixian	Broiler	Compost	99	50	93
Weixian	Layer	Solid	883	323	678
Weixian	Layer	Compost	1225	622	1160

Table B4. Amount of NPK supply within county before transport (t)

Sconuty	**Anicategories**	**Elements**		
County	Anicategories	N	P	K
Daming	Dairycow	128	32	145
Daming	Beefcow	2053	418	2742
Daming	Pig	3103	1284	2224
Daming	Sheepgoat	3498	464	3509
Daming	Broiler	293	131	256
Daming	Layer	2147	963	1872
Guangping	Dairycow	70	17	80
Guangping	Beefcow	106	21	142
Guangping	Pig	474	196	340
Guangping	Sheepgoat	547	72	549
Guangping	Broiler	93	42	82
Guangping	Layer	681	305	594
Yongnian	Dairycow	748	189	847
Yongnian	Beefcow	1019	207	1362

Yongnian	Pig	1676	694	1202
Yongnian	Sheepgoat	1893	251	1899
Yongnian	Broiler	444	199	387
Yongnian	Layer	6276	2815	5470
Chenganxian	Dairycow	251	63	285
Chenganxian	Beefcow	831	169	1111
Chenganxian	Pig	1154	478	827
Chenganxian	Sheepgoat	2127	282	2133
Chenganxian	Broiler	143	64	124
Chenganxian	Layer	1552	696	1353
Quzhou	Dairycow	270	68	306
Quzhou	Beefcow	1246	253	1664
Quzhou	Pig	1749	724	1254
Quzhou	Sheepgoat	1856	246	1862
Quzhou	Broiler	422	189	368
Quzhou	Layer	3650	1637	3182
Handanshi	Dairycow	710	179	803
Handanshi	Beefcow	247	50	330
Handanshi	Pig	750	310	538
Handanshi	Sheepgoat	549	73	551
Handanshi	Broiler	94	42	82
Handanshi	Layer	666	299	581
Qiuxian	Dairycow	38	9	43
Qiuxian	Beefcow	392	79	524
Qiuxian	Pig	420	173	301
Qiuxian	Sheepgoat	1742	231	1747
Qiuxian	Broiler	210	94	183
Qiuxian	Layer	1595	715	1390
Jize	Dairycow	186	47	211
Jize	Beefcow	528	107	706
Jize	Pig	895	370	642
Jize	Sheepgoat	1290	171	1295
Jize	Broiler	182	82	159
Jize	Layer	1443	647	1258
Wuanshi	Dairycow	89	22	102
Wuanshi	Beefcow	725	147	968
Wuanshi	Pig	3649	1511	2615
Wuanshi	Sheepgoat	268	35	269
Wuanshi	Broiler	98	44	86
Wuanshi	Layer	1118	501	975
Feixiang	Dairycow	548	138	621
Feixiang	Beefcow	887	180	1185
Feixiang	Pig	1301	538	932
Feixiang	Sheepgoat	2179	289	2186
Feixiang	Broiler	158	71	138

Feixiang	Layer	1324	594	1155
Linzhang	Dairycow	154	38	175
Linzhang	Beefcow	1515	308	2023
Linzhang	Pig	1644	680	1178
Linzhang	Sheepgoat	2744	364	2752
Linzhang	Broiler	318	143	278
Linzhang	Layer	1521	682	1326
Fengfengkuangqu	Dairycow	154	38	175
Fengfengkuangqu	Beefcow	165	33	222
Fengfengkuangqu	Pig	1336	553	958
Fengfengkuangqu	Sheepgoat	370	49	372
Fengfengkuangqu	Broiler	48	22	42
Fengfengkuangqu	Layer	292	131	255
Shexian	Dairycow	0	0	0
Shexian	Beefcow	524	106	701
Shexian	Pig	638	264	457
Shexian	Sheepgoat	748	99	750
Shexian	Broiler	118	53	103
Shexian	Layer	944	423	822
Guantao	Dairycow	186	47	211
Guantao	Beefcow	802	163	1071
Guantao	Pig	1583	655	1135
Guantao	Sheepgoat	1075	142	1078
Guantao	Broiler	580	260	506
Guantao	Layer	6138	2753	5351
Cixian	Dairycow	322	81	365
Cixian	Beefcow	443	90	592
Cixian	Pig	1175	486	842
Cixian	Sheepgoat	943	125	946
Cixian	Broiler	192	86	167
Cixian	Layer	1659	744	1446
Handanxian	Dairycow	225	56	255
Handanxian	Beefcow	315	64	421
Handanxian	Pig	448	185	321
Handanxian	Sheepgoat	430	57	431
Handanxian	Broiler	68	31	60
Handanxian	Layer	292	131	255
Weixian	Dairycow	70	17	80
Weixian	Beefcow	366	74	490
Weixian	Pig	1879	778	1347
Weixian	Sheepgoat	2127	282	2133
Weixian	Broiler	169	76	147
Weixian	Layer	2107	945	1837

In RQ2, detailed table of the amount of manure and NPK nutrients transported from per Supply county to per Demand county (multiple levels). Intermediate data tables for calculating actual NPK nutrient use after transportation are also provided. As well as specific breakdown tables of what the program cost is below.

Table B5. Amount of manure transported from per Supply county to per Demand county in RQ2 (t)

Sconuty	Anicategories	Manuretypes	Dcounty		
			Guangping	Handanxian	Weixian
Daming	Dairycow	Solid			16353
Daming	Beefcow	Solid			230959
Daming	Pig	Solid			321048
Daming	Pig	Liquid		460252	
Daming	Pig	Digestion	167757		29494
Yongnian	Dairycow	Solid			94846
Yongnian	Pig	Solid			180825
Yongnian	Pig	Liquid		248754	
Yongnian	Pig	Digestion			106609
Chenganxian	Dairycow	Solid			31888
Chenganxian	Pig	Liquid			171314
Chenganxian	Pig	Digestion			73420
Quzhou	Dairycow	Solid	34341		
Quzhou	Pig	Solid	188611		
Quzhou	Pig	Liquid		259466	
Quzhou	Pig	Digestion			111200
Qiuxian	Dairycow	Solid			4906
Qiuxian	Beefcow	Solid			11637
Qiuxian	Pig	Solid			45363
Qiuxian	Pig	Liquid		62405	
Qiuxian	Pig	Digestion	26745		
Jize	Dairycow	Solid	23711		
Jize	Beefcow	Solid			59540
Jize	Pig	Solid	96627		
Jize	Pig	Liquid	132926		
Jize	Pig	Digestion	56968		
Wuanshi	Dairycow	Solid			11447
Wuanshi	Pig	Solid	35715		357756
Wuanshi	Pig	Liquid		541285	
Wuanshi	Pig	Digestion	231979		
Feixiang	Dairycow	Solid	69499		
Feixiang	Beefcow	Solid		27762	
Feixiang	Pig	Solid	140346		
Feixiang	Pig	Liquid			193069
Feixiang	Pig	Digestion			82744
Linzhang	Dairycow	Solid			19623

Linzhang	Beefcow	Solid			170458
Linzhang	Pig	Solid			177294
Linzhang	Pig	Liquid	120736	123162	
Linzhang	Pig	Digestion			104528
Fengfengkuangqu	Dairycow	Solid			19623
Fengfengkuangqu	Beefcow	Solid			18726
Fengfengkuangqu	Pig	Solid			144166
Fengfengkuangqu	Pig	Liquid		198325	
Fengfengkuangqu	Pig	Digestion	84996		
Shexian	Pig	Solid			68867
Shexian	Pig	Liquid		94738	
Shexian	Pig	Digestion			40602
Guantao	Dairycow	Solid			23711
Guantao	Pig	Solid			170717
Guantao	Pig	Liquid			234850
Guantao	Pig	Digestion			100650
Cixian	Dairycow	Solid			40882
Cixian	Pig	Solid	126805		
Cixian	Pig	Liquid			174441
Cixian	Pig	Digestion	74760		

Table B6. Amount of NPK nutrient transported from per Supply county to per Demand county in RQ2 (t)

Sconuty	Anicategories	Manuretypes		Elements		
				N	P	K
Daming	Dairycow	Solid	Weixian	52	17	41
Daming	Beefcow	Solid	Weixian	676	186	576
Daming	Pig	Solid	Weixian	1196	562	812
Daming	Pig	Liquid	Handanxian	743	139	493
Daming	Pig	Digestion	Guangping	322	68	228
Daming	Pig	Digestion	Weixian	57	12	40
Yongnian	Dairycow	Solid	Weixian	303	99	237
Yongnian	Pig	Solid	Weixian	674	316	458
Yongnian	Pig	Liquid	Handanxian	401	75	266
Yongnian	Pig	Digestion	Weixian	205	43	145
Chenganxian	Dairycow	Solid	Weixian	102	33	80
Chenganxian	Pig	Liquid	Weixian	276	52	183
Chenganxian	Pig	Digestion	Weixian	141	30	100
Quzhou	Dairycow	Solid	Guangping	110	36	86
Quzhou	Pig	Solid	Guangping	703	330	477
Quzhou	Pig	Liquid	Handanxian	419	79	278
Quzhou	Pig	Digestion	Weixian	213	45	151
Qiuxian	Dairycow	Solid	Weixian	16	5	12
Qiuxian	Beefcow	Solid	Weixian	34	9	29

Qiuxian	Pig	Solid	Weixian	169	79	115
Qiuxian	Pig	Liquid	Handanxian	101	19	67
Qiuxian	Pig	Digestion	Guangping	51	11	36
Jize	Dairycow	Solid	Guangping	76	25	59
Jize	Beefcow	Solid	Weixian	174	48	149
Jize	Pig	Solid	Guangping	360	169	245
Jize	Pig	Liquid	Guangping	215	40	142
Jize	Pig	Digestion	Guangping	109	23	77
Wuanshi	Dairycow	Solid	Weixian	37	12	29
Wuanshi	Pig	Solid	Guangping	133	62	90
Wuanshi	Pig	Solid	Weixian	1333	626	905
Wuanshi	Pig	Liquid	Handanxian	874	164	579
Wuanshi	Pig	Digestion	Guangping	445	94	315
Feixiang	Dairycow	Solid	Guangping	222	72	173
Feixiang	Beefcow	Liquid	Handanxian	120	2	234
Feixiang	Pig	Solid	Guangping	523	245	355
Feixiang	Pig	Liquid	Weixian	312	59	207
Feixiang	Pig	Digestion	Weixian	159	34	112
Linzhang	Dairycow	Solid	Weixian	63	20	49
Linzhang	Beefcow	Solid	Weixian	499	138	425
Linzhang	Pig	Solid	Weixian	660	310	449
Linzhang	Pig	Liquid	Guangping	195	37	129
Linzhang	Pig	Liquid	Handanxian	199	37	132
Linzhang	Pig	Digestion	Weixian	201	43	142
Fengfengkuangqu	Dairycow	Solid	Weixian	63	20	49
Fengfengkuangqu	Beefcow	Solid	Weixian	55	15	47
Fengfengkuangqu	Pig	Solid	Weixian	537	252	365
Fengfengkuangqu	Pig	Liquid	Handanxian	320	60	212
Fengfengkuangqu	Pig	Digestion	Guangping	163	35	115
Shexian	Pig	Solid	Weixian	257	120	174
Shexian	Pig	Liquid	Handanxian	153	29	101
Shexian	Pig	Digestion	Weixian	78	17	55
Guantao	Dairycow	Solid	Weixian	76	25	59
Guantao	Pig	Solid	Weixian	636	299	432
Guantao	Pig	Liquid	Weixian	379	71	251
Guantao	Pig	Digestion	Weixian	193	41	137
Cixian	Dairycow	Solid	Weixian	131	43	102
Cixian	Pig	Solid	Guangping	472	222	321
Cixian	Pig	Liquid	Weixian	282	53	187
Cixian	Pig	Digestion	Guangping	143	30	101

Table B7. Intermediate data for calculating actual Nuiuse in RQ2 (t)

Sconuty	**Elements**		
ScountyNuisurplus	N	P	K

Daming	8177	2308	8558
Yongnian	10474	3820	10062
Chenganxian	5538	1636	5471
Quzhou	7748	2627	7644
Qiuxian	4024	1178	3929
Jize	3592	1119	3599
Wuanshi	3127	1302	3097
Feixiang	5063	1399	5136
Linzhang	6080	1631	6407
Fengfengkuangqu	1229	444	1236
Shexian	2484	779	2503
Guantao	9080	3584	8472
Cixian	3706	1264	3648
DcountyNuisurplus	N	P	K
Guangping	6213	2154	4737
Handanxian	5107	1128	4106
Weixian	16951	5905	13336
Compare:Nuisurplus-Nuidemand			
Scounty	N	P	K
Daming	-20082	-279	-1399
Yongnian	-15630	1308	-38
Chenganxian	-6836	-700	825
Quzhou	-7713	1152	1847
Qiuxian	-2913	-109	1384
Jize	-6915	111	-421
Wuanshi	-9364	-1048	-1509
Feixiang	-9532	13	-370
Linzhang	-13194	-202	-835
Fengfengkuangqu	-833	53	471
Shexian	-1719	-14	940
Guantao	-3084	2437	3960
Cixian	-4364	-278	607
Dcounty	N	P	K
Guangping	-1747	654	1787
Handanxian	-1247	523	1744
Weixian	-2865	2172	6034

Table B8. The cost for manure price and transportation in RQ2 (t)

Sconuty			Dcounty		
				Price	TCost
Daming	Dairycow	Solid	Weixian	81764	377574
Daming	Beefcow	Solid	Weixian	1154794	5332686
Daming	Pig	Solid	Weixian	1605238	7412781

Daming	Pig	Liquid	Handanxian		10600000
Daming	Pig	Digestion	Guangping	503272	1512379
Daming	Pig	Digestion	Weixian	88481	680989
Yongnian	Dairycow	Solid	Weixian	474230	1744069
Yongnian	Pig	Solid	Weixian	904123	3325082
Yongnian	Pig	Liquid	Handanxian		1589316
Yongnian	Pig	Digestion	Weixian	319827	1960373
Chenganxian	Dairycow	Solid	Weixian	159439	269137
Chenganxian	Pig	Liquid	Weixian		1445907
Chenganxian	Pig	Digestion	Weixian	220261	619675
Quzhou	Dairycow	Solid	Guangping	171704	287171
Quzhou	Pig	Solid	Guangping	943055	1577238
Quzhou	Pig	Liquid	Handanxian		3863177
Quzhou	Pig	Digestion	Weixian	333599	1868728
Qiuxian	Dairycow	Solid	Weixian	24529	93141
Qiuxian	Beefcow	Solid	Weixian	58183	220932
Qiuxian	Pig	Solid	Weixian	226817	861263
Qiuxian	Pig	Liquid	Handanxian		1239344
Qiuxian	Pig	Digestion	Guangping	80235	276014
Jize	Dairycow	Solid	Guangping	118557	306471
Jize	Beefcow	Solid	Weixian	297701	1211707
Jize	Pig	Solid	Guangping	483134	1248901
Jize	Pig	Liquid	Guangping		1718072
Jize	Pig	Digestion	Guangping	170905	736316
Wuanshi	Dairycow	Solid	Weixian	57235	326069
Wuanshi	Pig	Solid	Guangping	178575	971932
Wuanshi	Pig	Solid	Weixian	1788782	10200000
Wuanshi	Pig	Liquid	Handanxian		6567383
Wuanshi	Pig	Digestion	Guangping	695938	6312998
Feixiang	Dairycow	Solid	Guangping	347496	420363
Feixiang	Beefcow	Liquid	Handanxian		251591
Feixiang	Pig	Solid	Guangping	701729	848875
Feixiang	Pig	Liquid	Weixian		2029302
Feixiang	Pig	Digestion	Weixian	248232	869701
Linzhang	Dairycow	Solid	Weixian	98117	177542
Linzhang	Beefcow	Solid	Weixian	852290	1542222
Linzhang	Pig	Solid	Weixian	886471	1604073
Linzhang	Pig	Liquid	Guangping		1740202
Linzhang	Pig	Liquid	Handanxian		1556171
Linzhang	Pig	Digestion	Weixian	313583	945715
Fengfengkuangqu	Dairycow	Solid	Weixian	98117	409866
Fengfengkuangqu	Beefcow	Solid	Weixian	93632	391132
Fengfengkuangqu	Pig	Solid	Weixian	720832	3011158
Fengfengkuangqu	Pig	Liquid	Handanxian		1771662
Fengfengkuangqu	Pig	Digestion	Guangping	254989	1885802

Shexian	Pig	Solid	Weixian	344336	2338252
Shexian	Pig	Liquid	Handanxian		1904088
Shexian	Pig	Digestion	Weixian	121806	1378566
Guantao	Dairycow	Solid	Weixian	118557	363708
Guantao	Pig	Solid	Weixian	853585	2618607
Guantao	Pig	Liquid	Weixian		3602331
Guantao	Pig	Digestion	Weixian	301950	1543856
Cixian	Dairycow	Solid	Weixian	204409	764578
Cixian	Pig	Solid	Guangping	634023	2676526
Cixian	Pig	Liquid	Weixian		3262412
Cixian	Pig	Digestion	Guangping	224281	1578003

In RQ3, detailed table of the amount of manure and NPK nutrients transported from per Supply county to per Demand county (multiple levels). Intermediate data tables for calculating actual NPK nutrient use after transportation are also provided. As well as specific breakdown tables of what the program cost is below.

Table B9. Amount of manure transported from per Supply county to per Demand county in RQ3 (t)

Sconuty	**Anicategories**	**Manuretypes**	**Dcounty**		
			Guangping	Handanxian	Weixian
Daming	Pig	Solid	314411		
Yongnian	Pig	Solid		180825	
Yongnian	Broiler	Solid		30726	
Yongnian	Layer	Solid		98980	
Chenganxian	Pig	Solid			124532
Chenganxian	Broiler	Solid			9908
Chenganxian	Broiler	Compost			14862
Chenganxian	Layer	Solid			107229
Chenganxian	Layer	Compost			160843
Quzhou	Pig	Solid	188611		
Feixiang	Pig	Solid			140346
Feixiang	Broiler	Solid			10976
Feixiang	Broiler	Compost			16464
Feixiang	Layer	Solid			91531
Feixiang	Layer	Compost			137296
Linzhang	Pig	Solid			177294
Linzhang	Broiler	Solid			22054
Linzhang	Broiler	Compost			33081
Linzhang	Layer	Solid			105113
Linzhang	Layer	Compost			157669
Guantao	Pig	Solid	170717		
Guantao	Broiler	Solid			40100
Guantao	Layer	Solid	145003		279009

Table B10. Amount of NPK nutrient transported from per Supply county to per Demand county in RQ3 (t)

Sconuty	Anicategories	Manuretypes		Elements		
				N	P	K
Daming	Pig	Solid	Guangping	1171	550	796
Yongnian	Pig	Solid	Handanxian	674	316	458
Yongnian	Broiler	Solid	Handanxian	186	68	143
Yongnian	Layer	Solid	Handanxian	600	220	461
Chenganxian	Pig	Solid	Weixian	464	218	315
Chenganxian	Broiler	Solid	Weixian	60	22	46
Chenganxian	Broiler	Compost	Weixian	83	42	79
Chenganxian	Layer	Solid	Weixian	650	238	499
Chenganxian	Layer	Compost	Weixian	902	458	854
Quzhou	Pig	Solid	Guangping	703	330	477
Feixiang	Pig	Solid	Weixian	523	245	355
Feixiang	Broiler	Solid	Weixian	67	24	51
Feixiang	Broiler	Compost	Weixian	92	47	87
Feixiang	Layer	Solid	Weixian	555	203	426
Feixiang	Layer	Compost	Weixian	770	391	729
Linzhang	Pig	Solid	Weixian	660	310	449
Linzhang	Broiler	Solid	Weixian	134	49	103
Linzhang	Broiler	Compost	Weixian	186	94	176
Linzhang	Layer	Solid	Weixian	638	233	489
Linzhang	Layer	Compost	Weixian	884	449	837
Guantao	Pig	Solid	Guangping	636	299	432
Guantao	Broiler	Solid	Weixian	243	89	187
Guantao	Layer	Solid	Guangping	880	322	675
Guantao	Layer	Solid	Weixian	1693	619	1299

Table B11. Intermediate data for calculating actual Nuiuse in RQ3 (t)

Sconuty	Elements		
ScountyNuisurplus	N	P	K
Daming	10051	2743	9952
Yongnian	10596	3750	10106
Chenganxian	3898	773	4040
Quzhou	8490	2787	8158
Qiuxian	4395	1302	4189
Jize	4526	1424	4271
Wuanshi	5948	2261	5015
Feixiang	4391	899	4568
Linzhang	5394	1080	5679
Fengfengkuangqu	2367	826	2024

Shexian	2971	945	2834
Guantao	6912	2691	6759
Cixian	4734	1612	4359
DcountyNuisurplus	N	P	K
Guangping	5361	2154	4167
Handanxian	3238	1128	2805
Weixian	15322	5905	13015
Compare:Nuisurplus-Nuidemand			
Scounty	N	P	K
Daming	-18208	156	-5
Yongnian	-15508	1238	6
Chenganxian	-8477	-1563	-606
Quzhou	-6971	1312	2362
Qiuxian	-2543	14	1643
Jize	-5982	416	251
Wuanshi	-6543	-90	409
Feixiang	-10204	-487	-938
Linzhang	-13879	-753	-1562
Fengfengkuangqu	304	435	1259
Shexian	-1232	151	1271
Guantao	-5252	1543	2246
Cixian	-3336	70	1318
Dcounty	N	P	K
Guangping	304	435	1259
Handanxian	-1232	151	1271
Weixian	-5252	1543	2246

Table B12. The cost for manure price and transportation in RQ3 (Euro)

Sconuty			**Dcounty**		
				Price	TCost
Daming	Pig	Solid	Guangping	1572053	2834499
Yongnian	Pig	Solid	Handanxian	904123	1155306
Yongnian	Broiler	Solid	Handanxian	307258	196310
Yongnian	Layer	Solid	Handanxian	989805	632396
Chenganxian	Pig	Solid	Weixian	622658	1051059
Chenganxian	Broiler	Solid	Weixian	99081	83625
Chenganxian	Broiler	Compost	Weixian	297243	125438
Chenganxian	Layer	Solid	Weixian	1072286	905021
Chenganxian	Layer	Compost	Weixian	3216858	1357531
Quzhou	Pig	Solid	Guangping	943055	1577238
Feixiang	Pig	Solid	Weixian	701729	1475141
Feixiang	Broiler	Solid	Weixian	109761	115367
Feixiang	Broiler	Compost	Weixian	329283	173051
Feixiang	Layer	Solid	Weixian	915309	962059

Feixiang	Layer	Compost	Weixian	2745928	1443089
Linzhang	Pig	Solid	Weixian	886471	1604073
Linzhang	Broiler	Solid	Weixian	220537	199531
Linzhang	Broiler	Compost	Weixian	661611	299297
Linzhang	Layer	Solid	Weixian	1051125	951007
Linzhang	Layer	Compost	Weixian	3153375	1426510
Guantao	Pig	Solid	Guangping	853585	1303253
Guantao	Broiler	Solid	Weixian	400998	615085
Guantao	Layer	Solid	Guangping	1450032	1106954
Guantao	Layer	Solid	Weixian	2790091	4279685

APPENDIX III

GAMS code for getting intermediate data. Note that this step belongs to the intermediate data in the calculation of RQ1, and the part of reading data is the same as that of RQ1, so it will not be repeated. This part is only written to calculate the required parameter and the corresponding logic equation.

```
Set
County
/
Daming
Guangping
Yongnian
Chenganxian
Quzhou
Handanshi
Qiuxian
Jize
Wuanshi
Feixiang
Linzhang
Fengfengkuangqu
Shexian
Guantao
Cixian
Handanxian
Weixian
/
;

set
Anicategories
/
Dairycow
Beefcow
Pig
Sheepgoat
Broiler
Layer
/;

set
Manuretypes
/
Solid
Compost
Liquid
Digestion
/
;

Set
Cropcategories
/
Cereals
Vegetables
Fruits
Tubers
Oilcrops
Cotton
/;

set
grade
/
N1P1K1
N1P1K2
N1P1K3
N1P2K1
N1P2K2
N1P2K3
N1P3K1
N1P3K2
N1P3K3
N2P1K1
N2P1K2
N2P1K3
N2P2K1
N2P2K2
N2P2K3
N2P3K1
N2P3K2
N2P3K3
N3P1K1
N3P1K2
N3P1K3
N3P2K1
N3P2K2
N3P2K3
N3P3K1
N3P3K2
N3P3K3
/;

set
pollutant
/
NH3
N2O
N2
Nleaching
Pleaching
Kleaching
/;
set
elements
/
N
P
K
/;

set
Nsupply
/
SOML
SOMM
SOMH
/;

set YieldPot
/
Yieldpotential
/;

set NPKratio
/
PN
KN
/;

set
Chemical
/
FN
FP
FK
/;
```

For Nuidemand

```
Parameter Yields(County,Cropcategories) "The average yields of different crop types"
parameter Sownarea(County,Cropcategories) "The sownarea of different crop types"
parameter Graderatio(County,Cropcategories,grade) "The ratio of different soil fertility grade or level"
parameter Yield_current(County,Cropcategories,YieldPot) "The current yield of different crop types"
parameter Yield_increase(County,Cropcategories,YieldPot) "The potential of different crop yield increase"
Parameter Nui_Demand(County,Cropcategories,elements) "Coefficients for calaulating crop N,P,K demand"
Parameter Nui_factor(County,Cropcategories,elements) "NPK uptake factors of different crop types"


** Parameters used for calaulating soil NPK supply
Parameter SOM N_input(County,Cropcategories,grade) "The coefficients for calculating soil organic matter N supply, L, M, H kg/ha"
Parameter Deposition(County,Cropcategories,elements) "N, P, K deposition in soil, kg/ha"
Parameter P_input(County,Cropcategories,grade) "Coefficients for calculating fertilizer P supply, low, meidum, high"
Parameter K_input(County,Cropcategories,grade) "Coefficients for calculating fertilizer K supply, low, meidum, high"

parameter Cropyields2(County,Cropcategories,YieldPot) "the crop target yield t/ha";
parameter Ndemand2(County,Cropcategories,YieldPot) "the N demand under crop target yield , kg/ha";
parameter Pdemand2(County,Cropcategories,YieldPot) "the P demand under crop target yield , kg/ha";
parameter Kdemand2(County,Cropcategories,YieldPot) "the K demand under crop target yield , kg/ha";

Cropyields2(County,Cropcategories,YieldPot)=Yields(County,Cropcategories)*Yield_increase(County,Cropcategories,YieldPot);

Ndemand2(County,Cropcategories,YieldPot)=Cropyields2(County,Cropcategories,YieldPot)*Nui_Demand(County,Cropcategories,'N')*Nui_factor(County,Cropcategories,'N')*10;

Pdemand2(County,Cropcategories,YieldPot)=Cropyields2(County,Cropcategories,YieldPot)*Nui_Demand(County,Cropcategories,'P')*Nui_factor(County,Cropcategories,'P')*10;

Kdemand2(County,Cropcategories,YieldPot)=Cropyields2(County,Cropcategories,YieldPot)*Nui_Demand(County,Cropcategories,'K')*Nui_factor(County,Cropcategories,'K')*10;

parameter NRecom2(County,Cropcategories,YieldPot,grade) "the total required N in specific crop-soil system, t";
parameter PRecom2(County,Cropcategories,YieldPot,grade) "the required P n specific crop-soil system, t";
parameter KRecom2(County,Cropcategories,YieldPot,grade) "the required K n specific crop-soil system, t";
NRecom2(County,Cropcategories,YieldPot,grade)=(Ndemand2(County,Cropcategories,YieldPot)-SOMN_input(County,Cropcategories,grade)+
Deposition(County,Cropcategories,'N'))*Sownarea(County,Cropcategories)*Graderatio(County,Cropcategories,grade)/1000;

PRecom2(County,Cropcategories,YieldPot,grade)=(Pdemand2(County,Cropcategories,YieldPot)-SOMN_input(County,Cropcategories,grade)+
Deposition(County,Cropcategories,'P'))*Sownarea(County,Cropcategories)*Graderatio(County,Cropcategories,grade)/1000;
```

```
KRecom2(County,Cropcategories,YieldPot,grade)=(Kdemand2(County,Cropcategories,YieldPot)-SOMN_input(County,Cropcategories,grade)+
Deposition(County,Cropcategories,'K'))*Sownarea(County,Cropcategories)*Graderatio(County,Cropcategories,grade)/1000;
```

NPKRecom2 is NPK Nuidemand.

For Nuicotent

```
Parameter Aninumber(County,Anicategories) "The number of animal, *10000"
Parameter Soliduse(County,Anicategories,Manuretypes) "The ratio of different manure types, %"
Parameter Liquiduse(County,Anicategories,Manuretypes) "The ratio of different manure types, %"
Parameter Feces_Excretion(County,Anicategories) "The coefficient of feces excretion"
Parameter Urine_Excretion(County,Anicategories) "The coefficient of urine excretion"
Parameter GrowthPeriod(County,Anicategories) "The period of animal growth"
Parameter Content_Feces(County,Anicategories,elements) "The nutrients content of feces"
Parameter Content_Urine(County,Anicategories,elements) "The nutrients content of urine"
Parameter Manure_Recovery(County,Anicategories,Manuretypes,elements) "The ratio of NPK recovery of different manure types"
*Calaulating manure NPK excretion and the NPK ratio of available manure
Parameter Fecesvolume(County,Anicategories) "the volume of excreted feces, t";
Parameter Urinevolume(County,Anicategories) "the volume of excreted urine, t";
Parameter FecesNui(County,Anicategories,elements) "the amount of nutrients in excreted feces, t";
Parameter UrineNui(County,Anicategories,elements) "the amount of nutrients in excreted urine, t";
Parameter SolidNui(County,Anicategories,Manuretypes,elements) "the available NPK in excreted Feces, t";
Parameter LiquidNui(County,Anicategories,Manuretypes,elements) "the available NPK in excreted urine, t";
Parameter AvaiSolid(County,Anicategories,Manuretypes) "the available volume of solid, t";
Parameter AvaiLiquid(County,Anicategories,Manuretypes) "the available volume of liquid, t";
Parameter ContentSolid(County,Anicategories,Manuretypes,elements) "the NPK ratio in solid, t/t";
Parameter ContentLiquid(County,Anicategories,Manuretypes,elements) "the NPK ratio in liquid, t/t";

Fecesvolume(County,Anicategories)=Aninumber(County,Anicategories)*Feces_Excretion(County,Anicategories)*GrowthPeriod(County,Anicategories)*10;

Urinevolume(County,Anicategories)=Aninumber(County,Anicategories)*Urine_Excretion(County,Anicategories)*GrowthPeriod(County,Anicategories)*10;

FecesNui(County,Anicategories,elements)=Fecesvolume(County,Anicategories)*Content_Feces(County,Anicategories,elements);

UrineNui(County,Anicategories,elements)=Urinevolume(County,Anicategories)*Content_Urine(County,Anicategories,elements);
```

```
SolidNui(County,Anicategories,Manuretypes,elements)=Fecesvolume(County,Anicategories)*Soliduse(County,Anicategories,Manuretypes)*Content_Feces(County,Anicategories,elements)*Manure_Recovery(County,Anicategories,Manuretypes,elements);
LiquidNui(County,Anicategories,Manuretypes,elements)=Urinevolume(County,Anicategories)*Liquiduse(County,Anicategories,Manuretypes)*Content_Urine(County,Anicategories,elements)*Manure_Recovery(County,Anicategories,Manuretypes,elements);

AvaiSolid(County,Anicategories,Manuretypes)=Fecesvolume(County,Anicategories)*Soliduse(County,Anicategories,Manuretypes)*0.996;

AvaiLiquid(County,Anicategories,Manuretypes)=Urinevolume(County,Anicategories)*Liquiduse(County,Anicategories,Manuretypes)*0.995;

ContentSolid(County,Anicategories,Manuretypes,elements)$(AvaiSolid(County,Anicategories,Manuretypes)>0)=SolidNui(County,Anicategories,Manuretypes,elements)/AvaiSolid(County,Anicategories,Manuretypes);

ContentLiquid(County,Anicategories,Manuretypes,elements)$(AvaiLiquid(County,Anicategories,Manuretypes)>0)=LiquidNui(County,Anicategories,Manuretypes,elements)/AvaiLiquid(County,Anicategories,Manuretypes);
```

Nuicotent consists of ContentSolid and ContentLiquid.

GAMs code for RQ1

```
Set
County
/
Daming
Guangping
Yongnian
Chenganxian
Quzhou
Handanshi
Qiuxian
Jize
Wuanshi
Feixiang
Linzhang
Fengfengkuangqu
Shexian
Guantao
Cixian
Handanxian
Weixian
/
;

set
Anicategories
/
Dairycow
Beefcow
Pig
Sheepgoat
Broiler
Layer
/;

set
Manuretypes
/
Solid
Compost
Liquid
Digestion
/
;

Set
Cropcategories
/
Cereals
Vegetables
Fruits
Tubers
Oilcrops
Cotton
/;

set
grade
/
N1P1K1
N1P1K2
N1P1K3
N1P2K1
N1P2K2
N1P2K3
N1P3K1
N1P3K2
N1P3K3
N2P1K1
N2P1K2
N2P1K3
N2P2K1
N2P2K2
N2P2K3
N2P3K1
N2P3K2
N2P3K3
N3P1K1
N3P1K2

set
pollutant
/
NH3
N2O
N2
Nleaching
Pleaching
Kleaching
/;

set
elements
/
N
P
K
/;

set
Nsupply
/
SOML
SOMM
SOMH
/;

set YieldPot
/
Yieldpotential
/;

set NPKratio
/
PN
KN
/;

set
Chemical
/
FN
```

```
                                   N3P1K3          FP
                                   N3P2K1          FK
                                   N3P2K2          /;
                                   N3P2K3
                                   N3P3K1
                                   N3P3K2
                                   N3P3K3
                                   /;


** Parameters used for calaulating manure NPK excretion in different animal categories

Parameter Aninumber(County,Anicategories) "The number of animal, *10000"
Parameter Soliduse(County,Anicategories,Manuretypes) "The ratio of different manure types, %"
Parameter Liquiduse(County,Anicategories,Manuretypes) "The ratio of different manure types, %"
Parameter Feces_Excretion(County,Anicategories) "The coefficient of feces excretion"
Parameter Urine_Excretion(County,Anicategories) "The coefficient of urine excretion"
Parameter GrowthPeriod(County,Anicategories) "The period of animal growth"
Parameter Content_Feces(County,Anicategories,elements) "The nutrients content of feces"
Parameter Content_Urine(County,Anicategories,elements) "The nutrients content of urine"
Parameter Manure_Recovery(County,Anicategories,Manuretypes,elements) "The ratio of NPK recovery of different manure
types"
Parameter Nloss_Housing(County,Anicategories,pollutant) "The Nloss of manure in housing"
Parameter Nloss_Storage(County,Anicategories,Manuretypes,pollutant) "The N loss of manure in storage"
Parameter Nloss_Treatment(County,Anicategories,Manuretypes,pollutant) "The N loss of manure in treatment"
Parameter Ploss_Housing(County,Anicategories,pollutant) "The P loss of manure in housing"
Parameter Ploss_Storage(County,Anicategories,Manuretypes,pollutant) "The P loss of manure in storage"
Parameter Ploss_Treatment(County,Anicategories,Manuretypes,pollutant) "The P loss of manure in treatment"
Parameter Kloss_Housing(County,Anicategories,pollutant) "The K loss of manure in housing"
Parameter Kloss_Storage(County,Anicategories,Manuretypes,pollutant) "The K loss of manure in storage"
Parameter Kloss_Treatment(County,Anicategories,Manuretypes,pollutant) "The K loss of manure in treatment"

* Parameters used for calaulating NPK demands for different crop types

Parameter Yields(County,Cropcategories) "The average yields of different crop types"
parameter Sownarea(County,Cropcategories) "The sownarea of different crop types"
parameter Graderatio(County,Cropcategories,grade) "The ratio of different soil fertility grade or level"
parameter Yield_current(County,Cropcategories,YieldPot) "The current yield of different crop types"
parameter Yield_increase(County,Cropcategories,YieldPot) "The potential of different crop yield increase"
Parameter Nui_Demand(County,Cropcategories,elements) "Coefficients for calaulating crop N,P,K demand, *0.01"
Parameter Nui_factor(County,Cropcategories,elements) "NPK uptake factors of different crop types"


** Parameters used for calaulating soil N supply and fertilizer PK input rates
```

```
Parameter SOM N_input(County,Cropcategories,grade) "The coefficients for calculating soil organic matter N supply, L, M, H kg/ha"
Parameter Deposition(County,Cropcategories,elements) "N, P, K deposition in soil, kg/ha"
Parameter P_input(County,Cropcategories,grade) "Coefficients for calculating fertilizer P supply, low, meidum, high"
Parameter K_input(County,Cropcategories,grade) "Coefficients for calculating fertilizer K supply, low, meidum, high"

$libinclude xlimport Aninumber XlsData\LCS.xlsx Aninumber!A1:G18
$libinclude xlimport Soliduse XlsData\LCS.xlsx Soliduse!A1:D103
$libinclude xlimport Liquiduse XlsData\LCS.xlsx Liquiduse!A1:D52
$libinclude xlimport Feces_Excretion XlsData\Paradata.xlsx Feces_Excretion!A1:G18
$libinclude xlimport Urine_Excretion XlsData\Paradata.xlsx Urine_Excretion!A1:D18
$libinclude xlimport GrowthPeriod XlsData\Paradata.xlsx GrowthPeriod!A1:G18
$libinclude xlimport Content_Feces XlsData\Paradata.xlsx Content_Feces!A1:E103
$libinclude xlimport Content_Urine XlsData\Paradata.xlsx Content_Urine!A1:E52
$libinclude xlimport Manure_Recovery XlsData\Paradata.xlsx Manure_Recovery!A1:F273
$libinclude xlimport Nloss_Housing XlsData\Paradata.xlsx Nloss_Housing!A1:E103
$libinclude xlimport Nloss_Storage XlsData\Paradata.xlsx Nloss_Storage!A1:G154
$libinclude xlimport Nloss_Treatment XlsData\Paradata.xlsx Nloss_Treatment!A1:G120
$libinclude xlimport Ploss_Housing XlsData\Paradata.xlsx Ploss_Housing!A1:C103
$libinclude xlimport Ploss_Storage XlsData\Paradata.xlsx Ploss_Storage!A1:D154
$libinclude xlimport Ploss_Treatment XlsData\Paradata.xlsx Ploss_Treatment!A1:D120
$libinclude xlimport Kloss_Housing XlsData\Paradata.xlsx Kloss_Housing!A1:C103
$libinclude xlimport Kloss_Storage XlsData\Paradata.xlsx Kloss_Storage!A1:D154
$libinclude xlimport Kloss_Treatment XlsData\Paradata.xlsx Kloss_Treatment!A1:D120

$libinclude xlimport Nuitotalloss XlsData\middleresult.xlsx Nuitotalloss!A1:E103


* read data related to crop nutrients demand
$libinclude xlimport Yields XlsData\LCS.xlsx Yields!A1:G18
$libinclude xlimport Sownarea XlsData\LCS.xlsx Sownarea!A1:G18
$libinclude xlimport Yield_current XlsData\Paradata.xlsx Yield_current!A1:C103
$libinclude xlimport Yield_increase XlsData\Paradata.xlsx Yield_increase!A1:C103
$libinclude xlimport Nui_Demand XlsData\Paradata.xlsx Nui_Demand!A1:E103
$libinclude xlimport Nui_factor XlsData\Paradata.xlsx Nui_factor!A1:E103

* read data related to soil nutreints supply
$libinclude xlimport Graderatio XlsData\LCS.xlsx Graderatio!A1:AD103
$libinclude xlimport SOMN_input XlsData\Paradata.xlsx SOMN_input!A1:AC103
$libinclude xlimport Deposition XlsData\Paradata.xlsx Deposition!A1:D103
$libinclude xlimport P_input XlsData\Paradata.xlsx P_input!A1:AC103
$libinclude xlimport K_input XlsData\Paradata.xlsx K_input!A1:AC103

$libinclude xlimport Manure_availability XlsData\Paradata.xlsx Manure_availability!A1:F273
```

```
* read data related to ManureRes
$libinclude xlimport Fecesvolume Output\Manureuse.xlsx Fecesvolume!A1:G18
$libinclude xlimport Urinevolume Output\Manureuse.xlsx Urinevolume!A1:D18
$libinclude xlimport FecesNui Output\Manureuse.xlsx FecesNui!A1:E102
$libinclude xlimport UrineNui Output\Manureuse.xlsx UrineNui!A1:E51
$libinclude xlimport SolidNui Output\Manureuse.xlsx SolidNui!A1:F186
$libinclude xlimport LiquidNui Output\Manureuse.xlsx LiquidNui!A1:F84
$libinclude xlimport ContentSolid Output\Manureuse.xlsx ContentSolid!A1:F186
$libinclude xlimport ContentLiquid Output\Manureuse.xlsx ContentLiquid!A1:F84

$libinclude xlimport NlossHousing Output\Nutrientsloss.xlsx NlossHousing!A1:E102
$libinclude xlimport NlossStorage Output\Nutrientsloss.xlsx NlossStorage!A1:G152
$libinclude xlimport NlossTreatment Output\Nutrientsloss.xlsx NlossTreatment!A1:G118
$libinclude xlimport PlossHousing Output\Nutrientsloss.xlsx PlossHousing!A1:C102
$libinclude xlimport PlossStorage Output\Nutrientsloss.xlsx PlossStorage!A1:D152
$libinclude xlimport PlossTreatment Output\Nutrientsloss.xlsx PlossTreatment!A1:D118
$libinclude xlimport KlossHousing Output\Nutrientsloss.xlsx KlossHousing!A1:C102
$libinclude xlimport KlossStorage Output\Nutrientsloss.xlsx KlossStorage!A1:D152
$libinclude xlimport KlossTreatment Output\Nutrientsloss.xlsx KlossTreatment!A1:D118

*$libinclude xlimport Manureuse Output\Manureuse.xlsx Manureuse!A1:H247


execute_unload "..\Parameterinput.gdx",
Aninumber
Soliduse
Liquiduse
Feces_Excretion
Urine_Excretion
GrowthPeriod
Content_Feces
Content_Urine
Manure_Recovery
Nloss_Housing
Nloss_Storage
Nloss_Treatment
Ploss_Housing
Ploss_Storage
Ploss_Treatment
Kloss_Housing
Kloss_Storage
Kloss_Treatment
Yields
Sownarea
Yield_current
```

```
Yield_increase
Nui_demand
Nui_factor
Graderatio
SOMN_input
Deposition
P_input
K_input
Avaimanure
Nuidemand
Nuicontent
Nuitotalloss
;


$else.readdata
$gdxin "..\Parameterinput.gdx"

$load Aninumber
$load Soliduse
$load Liquiduse
$load Feces_Excretion
$load Urine_Excretion
$load GrowthPeriod
$load Content_Feces
$load Content_Urine
$load Manure_Recovery
$load Nloss_Housing
$load Nloss_Storage
$load Nloss_Treatment
$load Ploss_Housing
$load Ploss_Storage
$load Ploss_Treatment
$load Kloss_Housing
$load Kloss_Storage
$load Kloss_Treatment
$load Yields
$load Sownarea
$load Yield_current
$load Yield_increase
$load Nui_demand
$load Nui_factor
$load Graderatio
$load SOMN_input
$load Deposition
```

```
$load P_input
$load K_input
$load Nuidemand
$load Nuicontent
$load Nuitotalloss



$gdxin

$endif.readdata
variables

totalz
;
Positive variable
z(county,Manuretypes)
Manureuse(County,Cropcategories,grade,Anicategories,Manuretypes)
Nuisupply(county,Anicategories,elements)
*Manuresupply(county,Anicategories,Manuretypes)


equations
*APPsupply(county,Anicategories,Manuretypes)

Manuresurplus(county,Manuretypes)
APPsupply(county,Anicategories,elements)
ObjectiveFunction
Constraint01(County,Cropcategories,grade,Anicategories,Manuretypes)
Constraint02(County,Anicategories,Manuretypes)
Constraint03(County)
Constraint04(County)
Constraint05(County)
;


Manuresurplus(county,Manuretypes)..
z(county,Manuretypes)=e=sum (Anicategories,Avaimanure(county,Anicategories,Manuretypes))-sum
((Cropcategories,grade,Anicategories),Manureuse(County,Cropcategories,grade,Anicategories,Manuretypes));

APPsupply(county,Anicategories,elements)..
Nuisupply(county,Anicategories,elements)=e=sum
(Manuretypes,SolidNui(County,Anicategories,Manuretypes,elements))+sum
(Manuretypes,LiquidNui(County,Anicategories,Manuretypes,elements))-Nuitotalloss(County,Anicategories,elements);
```

```
ObjectiveFunction..
totalz=e=sum((county,Manuretypes),z(county,Manuretypes));

Constraint01(County,Cropcategories,grade,Anicategories,Manuretypes)..
Manureuse(County,Cropcategories,grade,Anicategories,Manuretypes)=g=0;

Constraint02(County,Anicategories,Manuretypes)..
sum
((Cropcategories,grade),Manureuse(County,Cropcategories,grade,Anicategories,Manuretypes))=l=Avaimanure(county,Anicate
gories,Manuretypes);

Constraint03(county)..
sum
((Cropcategories,grade,Anicategories,Manuretypes),Manureuse(County,Cropcategories,grade,Anicategories,Manuretypes)*Nui
content(county,Anicategories,Manuretypes,'N')*Manure_availability(County,Anicategories,Manuretypes,'N'))=l=sum
(Cropcategories,Nuidemand(county,Cropcategories,'N'));

Constraint04(county)..
sum
((Cropcategories,grade,Anicategories,Manuretypes),Manureuse(County,Cropcategories,grade,Anicategories,Manuretypes)*Nui
content(county,Anicategories,Manuretypes,'P'))=l=sum (Cropcategories,Nuidemand(county,Cropcategories,'P'));

Constraint05(county)..
sum
((Cropcategories,grade,Anicategories,Manuretypes),Manureuse(county,cropcategories,grade,Anicategories,Manuretypes)*Nuic
ontent(county,Anicategories,Manuretypes,'K'))=l=sum (Cropcategories,Nuidemand(county,Cropcategories,'K'));




Model transport /ALL/;
Solve transport using lp Minimizing totalz

DISPLAY z.l, manureuse.l, Nuisupply.l,Nuiuse,Nuisupply;

Execute_Unload 'outputmanuresurplus.gdx', z

Execute 'Gdxxrw outputmanuresurplus.gdx O = outputmanuresurplus.xls var = z R';

Execute_Unload 'outputmanureuse.gdx', manureuse

Execute 'Gdxxrw outputmanureuse.gdx O = outputmanureuse.xls var = manureuse R';
```

GAMs code for RQ2

```
set
Scounty
/
Daming
Yongnian
Chenganxian
Quzhou
Qiuxian
Jize
Wuanshi
Feixiang
Linzhang
Fengfengkuangqu
Shexian
Guantao
Cixian
/
;

set
Dcounty
/
Guangping
Handanxian
Weixian
/
;

set
Anicategories
/
Dairycow
Beefcow
Pig
Sheepgoat
Broiler
Layer
/;

set
Manuretypes
/
Solid
Compost
Liquid
Digestion
/
;

Set
Cropcategories
/
Cereals
Vegetables
Fruits
Tubers
Oilcrops
Cotton
/
;

set
grade
/
N1P1K1
N1P1K2
N1P1K3
N1P2K1
N1P2K2
N1P2K3
N1P3K1
N1P3K2
N1P3K3
N2P1K1
N2P1K2
N2P1K3
N2P2K1
N2P2K2
N2P2K3
N2P3K1
N2P3K2
N2P3K3
N3P1K1
N3P1K2
N3P1K3
N3P2K1
N3P2K2
N3P2K3
N3P3K1
N3P3K2
N3P3K3
/;

Set
elements
/
N
P
K
/;

set
Nsupply
/
SOML
SOMM
SOMH
/;

set
YieldPot
/
Yieldpotential
/;

set
NPKratio
/
PN
KN
/;

set
Cost
/
Price
FCost
TCost
/;

set
Chemical
/
FN
FP
FK
/;

Parameter Avaimanure(Scounty,Anicategories,manuretypes) "The amount of animal manures, t"
Parameter ManurePrice(Scounty,Anicategories,Manuretypes,Cost) "The price of different manure types, Euro per ton"
Parameter TransCost(Scounty,Anicategories,Manuretypes,Cost) "The transportation cost between counties"
Parameter Distance(Scounty,Anicategories,Manuretypes,Dcounty) "The distance between counties"
Parameter Manure_availability(Scounty,Anicategories,Manuretypes,elements) "Coefficients for calaulating manure nutrients availability, N, P,K"
Parameter Nuicontent(Scounty,Anicategories,Manuretypes,elements) "The N,P,K content of different manure types"
Parameter Nuidemand(Dcounty,Cropcategories,elements) "NPK demand of different crop types"

$iftheni.readdata "%UseExcelParameter%"=="yes"
* read data related to excretion of different manure types
```

```
$libinclude xlimport ManurePrice RightXlsdata\RightXlsdata.xlsx ManurePrice!A1:D209
$libinclude xlimport TransCost RightXlsdata\RightXlsdata.xlsx TransCost!A1:D209

$libinclude xlimport Nuicontent RightXlsdata\RightXlsdata.xlsx Nuicontent!A1:F205
$libinclude xlimport Manure_availability RightXlsdata\RightXlsdata.xlsx Manure_availability!A1:F209
$libinclude xlimport Nuidemand RightXlsdata\RightXlsdata.xlsx Nuidemand!A1:E19
$libinclude xlimport Avaimanure RightXlsdata\RightXlsdata.xlsx Avaimanure!A1:F78
$libinclude xlimport Distance RightXlsdata\RightXlsdata.xlsx Distance!A1:L209


* read data related to manure application


execute_unload "..\Parameterinput.gdx",
Avaimanure
ManurePrice
TransCost
Distance
Nuicontent
Manure_availability
Nuidemand
;


$else.readdata
$gdxin "..\Parameterinput.gdx"

$load Avaimanure
$load ManurePrice
$load TransCost
$load Distance
$load Nuicontent
$load Manure_availability
$load Nuidemand

$gdxin

$endif.readdata

DISPLAY z.l, manureuse.l,Nuiuse.l,Manurecost.l;

Execute_Unload 'outputmanureuseRQ2.gdx', manureuse.l;

Execute 'Gdxxrw outputmanureuseRQ2.gdx O = outputmanureuseRQ2.xls var = manureuse rdim=3 cdim=2,rng=Sheet1!A1';
```

GAMs code for RQ3

```
set
Scounty
/
Daming
Yongnian
Chenganxian
Quzhou
Qiuxian
Jize
Wuanshi
Feixiang
Linzhang
Fengfengkuangqu
Shexian
Guantao
Cixian
/
;

set
Dcounty
/
Guangping
Handanxian
Weixian
/
;

set
Anicategories
/
Dairycow
Beefcow
Pig
Sheepgoat
Broiler
Layer
/;

set
Manuretypes
/
Solid
Compost
Liquid
Digestion
/
;

Set
Cropcategories
/
Cereals
Vegetables
Fruits
Tubers
Oilcrops
Cotton
/
;

set
grade
/
N1P1K1
N1P1K2
N1P1K3
N1P2K1
N1P2K2
N1P2K3
N1P3K1
N1P3K2
N1P3K3
N2P1K1
N2P1K2
N2P1K3
N2P2K1
N2P2K2
N2P2K3
N2P3K1
N2P3K2
N2P3K3
N3P1K1
N3P1K2
N3P1K3
N3P2K1
N3P2K2
N3P2K3
N3P3K1
N3P3K2
N3P3K3
/;

Set
elements
/
N
P
K
/;

set
Nsupply
/
SOML
SOMM
SOMH
/;

set
YieldPot
/
Yieldpotential
/;

set
NPKratio
/
PN
KN
/;

set
Cost
/
Price
FCost
TCost
/;

set
Chemical
/
FN
FP
FK
/;

Parameter Avaimanure(Scounty,Anicategories,Manuretypes) "The amount of animal manures, t"
Parameter ManurePrice(Scounty,Anicategories,Manuretypes,Cost) "The price of different manure types, Euro per ton"
Parameter TransCost(Scounty,Anicategories,Manuretypes,Cost) "The transportation cost between counties"
Parameter Distance(Scounty,Anicategories,Manuretypes,Dcounty) "The distance between counties"
Parameter Manure_availability(Scounty,Anicategories,Manuretypes,elements) "Coefficients for calaulating manure nutrients availability, N, P,K"
Parameter Nuicontent(Scounty,Anicategories,Manuretypes,elements) "The N,P,K content of different manure types"
Parameter Nuidemand(Dcounty,Cropcategories,elements) "NPK demand of different crop types"
$iftheni.readdata "%UseExcelParameter%"=="yes"
* read data related to excretion of different manure types
```

```
$libinclude xlimport ManurePrice RightXlsdata\RightXlsdata.xlsx ManurePrice!A1:D209
$libinclude xlimport TransCost RightXlsdata\RightXlsdata.xlsx TransCost!A1:D209

$libinclude xlimport Nuicontent RightXlsdata\RightXlsdata.xlsx Nuicontent!A1:F205
$libinclude xlimport Manure_availability RightXlsdata\RightXlsdata.xlsx Manure_availability!A1:F209
$libinclude xlimport Nuidemand RightXlsdata\RightXlsdata.xlsx Nuidemand!A1:E19
$libinclude xlimport Avaimanure RightXlsdata\RightXlsdata.xlsx Avaimanure!A1:F78
$libinclude xlimport Distance RightXlsdata\RightXlsdata.xlsx Distance!A1:L209



* read data related to manure application


execute_unload "..\Parameterinput.gdx",
Avaimanure
ManurePrice
TransCost
Distance
Nuicontent
Manure_availability
Nuidemand
;


$else.readdata
$gdxin "..\Parameterinput.gdx"

$load Avaimanure
$load ManurePrice
$load TransCost
$load Distance
$load Nuicontent
$load Manure_availability
$load Nuidemand


$gdxin

$endif.readdata
variables

totalz
;
Positive variable
```

```
z(Scounty,Dcounty)
Manureuse(Scounty,Anicategories,Manuretypes,Dcounty)
Nuiuse(Scounty,Anicategories,Manuretypes,Dcounty,elements)
Manurecost(Scounty,Anicategories,Manuretypes,Dcounty,Cost)


equations
APPCost(Scounty,Anicategories,Manuretypes,Dcounty,Cost)
MNuiuse(Scounty,Anicategories,Manuretypes,Dcounty,elements)
DistributingCost(Scounty,Dcounty)
ObjectiveFunction

Constraint01(Scounty,Anicategories,Manuretypes,Dcounty)
Constraint02(Scounty,Anicategories,Manuretypes)
Constraint03(Dcounty)
Constraint04(Dcounty)
Constraint05(Dcounty)
;

APPCost(Scounty,Anicategories,Manuretypes,Dcounty,Cost)..
Manurecost(Scounty,Anicategories,Manuretypes,Dcounty,Cost)=e=Manureuse(Scounty,Anicategories,Manuretypes,Dcounty)*
(ManurePrice(Scounty,Anicategories,Manuretypes,Cost)+TransCost(Scounty,Anicategories,Manuretypes,Cost)*Distance(Scou
nty,Anicategories,Manuretypes,Dcounty));

MNuiuse(Scounty,Anicategories,Manuretypes,Dcounty,elements)..
Nuiuse(Scounty,Anicategories,Manuretypes,Dcounty,elements)=e=Manureuse(Scounty,Anicategories,Manuretypes,Dcounty)*
Nuicontent(Scounty,Anicategories,Manuretypes,elements);

DistributingCost(Scounty,Dcounty)..
z(Scounty,Dcounty)=e=sum
((Anicategories,Manuretypes,Cost),Manurecost(Scounty,Anicategories,Manuretypes,Dcounty,Cost));

ObjectiveFunction..
totalz=e=sum((Scounty,Dcounty),z(Scounty,Dcounty));

Constraint01(Scounty,Anicategories,Manuretypes,Dcounty)..

Manureuse(Scounty,Anicategories,Manuretypes,Dcounty)=g=0;

Constraint02(Scounty,Anicategories,Manuretypes)..

sum
(Dcounty,Manureuse(Scounty,Anicategories,Manuretypes,Dcounty))=l=Avaimanure(Scounty,Anicategories,Manuretypes);

Constraint03(Dcounty)..
```

```
sum
((Scounty,Anicategories,Manuretypes),Manureuse(Scounty,Anicategories,Manuretypes,Dcounty)*Nuicontent(Scounty,Anicate
gories,Manuretypes,'N')*Manure_availability(Scounty,Anicategories,Manuretypes,'N'))=l=sum
(Cropcategories,Nuidemand(Dcounty,Cropcategories,'N'));

Constraint04(Dcounty)..

sum
((Scounty,Anicategories,Manuretypes),Manureuse(Scounty,Anicategories,Manuretypes,Dcounty)*Nuicontent(Scounty,Anicate
gories,Manuretypes,'P'))=e=sum (Cropcategories,Nuidemand(Dcounty,Cropcategories,'P'));

Constraint05(Dcounty)..

sum
((Scounty,Anicategories,Manuretypes),Manureuse(Scounty,Anicategories,Manuretypes,Dcounty)*Nuicontent(Scounty,Anicate
gories,Manuretypes,'K'))=l=sum (Cropcategories,Nuidemand(Dcounty,Cropcategories,'K'));


Model transport /ALL/;
Solve transport using lp Minimizing totalz;

$include ManureParamenteroutput.gms
DISPLAY z.l, manureuse.l,Nuiuse.l,Manurecost.l;
```