Feasibility Study

Rural Household Biogas and Conservation Tillage CDM Project Development

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Rural Household Biogas & Conservation Tillage CDM Project Development

APCAEM-ESCAP

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Contents

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Executive summary

Agriculture is one of the major anthropogenic sources of greenhouse gas emissions in China particularly through CH_4 (methane) and N_2O (nitrous oxide) emissions as well as loss of soil carbon stores. However, mitigation programmes in China have not paid sufficient attention to controlling emissions from the agricultural sector through CDM (clean development mechanism) projects.

Funded by the Spanish MDG Achievement Fund, the study explored the potential of CDM projects in the agricultural sector in China in an effort to reduce the greenhouse gas emissions and promote the development of sustainable agricultural technologies. Feasibility studies and methodology guidelines for CDM projects in two areas including rural household biogas and conservation tillage were conducted and proposed.

The study thoroughly reviews the laws, regulations and policies of the Chinese government on rural renewable energy development and farmland management, and analyzes the economic benefits of various technologies to assess the additionality of CDM projects in household biogas and conservation tillage. Through study tours and surveys, the authors collected statistical data on household biogas production and distribution, fossil fuel replacement, and conservation tillage development and distribution of technologies to determine and explore the baselines. Approved CDM methodologies and their applicability were collected by the authors to develop methodology guidelines. The study also estimated the emission reduction potentials of CDM projects through case studies.

On household biogas, the study showed that the Chinese government attaches great importance to the development of rural biogas. Laws, regulations and policies issued by the central government highlight the importance of biogas development for the building of the so-called new socialist countryside. Based on the statistical data on household biogas development, livestock development, climate condition, and energy consumption, the feasibility report establishes the selection criteria for identifying the most appropriate provinces for developing CDM projects in China, and estimates that about 20 provinces have the basic conditions for developing household biogas CDM projects.

The methodologies approved by UNFCCC CDM Executive Board are listed and summarized with detailed application categories and conditions. To promote the application of the methodologies, a case study based on the data of Hunan Province was conducted to illustrate the critical issues and implementation procedures in developing CDM projects in household biogas, including the definition of baseline, CERs calculation, additionality assessment and other important issues which are critical for the development of CDM projects. It is estimated that each household would have a GHG emission reduction of 2.14 metric tons of CO_2e annually in Hunan Province.

On conservation tillage, the study outlines the development of conservation tillage in China, and policies that the Chinese government has adopted to support its development. Comparison between conservation tillage in China and countries in the world is made. According to the study, in recent years, the Chinese government has paid great attention to the adoption of conservation tillage technology. At present, China is experiencing an important transition from experiment to extension of conservation tillage. There are currently about two million hectares of cropland in China under conservation tillage. During the 11th five-year plan period for the social and economic development of China (2006-2010), the Ministry of Agriculture of China sets the target for arable land under conservation tillage at more than four million hectares nationwide.

Soil carbon sequestration in agricultural soils has huge potential. However, under the first phase of Kyoto Protocol, LULUCF (land use, land-use change and forestry) activities are not allowed.

In order to prepare a methodology for CDM projects in conservation tillage for future application, a feasibility study was conducted, which included applicability, project boundary, assessment of additionality, baseline determination, methods for estimating changes in soil organic carbon stocks and other GHG emissions, and associated monitoring plans.

The study concludes that CDM projects can be developed in conservation tillage to help increase the carbon stock, reduce fossil fuel consumption and greenhouse gas emissions, and improve sustainable natural resource management.

1. Feasibility study on rural household biogas CDM project development

In recent years, significant attention has been paid to biomass energy development in the course of promoting rural sustainable development in China. While providing renewable energy and improving the ecological environment of the rural areas, a biogas project also contributes to the reduction of greenhouse gas emissions. It is apparent that the biogas project can raise the economic returns and increase farmers' income in China if the project can be developed as a CDM project. A successful integration of the biogas project with CDM development will demonstrate the benefits of improving the rural environment, promoting renewable energy uses and sustainable development of the countryside in China.

1.1 Policies for biogas development

The Chinese government has attached great importance to the development of rural biogas. Since 2005, several laws, regulations and policies issued by the central government have highlighted the importance of biogas development for the building of the so-called new socialist countryside. Therefore, the development of household biogas CDM projects is closely in line with the relevant provisions of national strategies and policies including the specific policies regarding CDM projects development in China, i.e. *Clean Development Mechanism Project Operation and Management Methods in China.*

1.1.1 Laws and regulations on biogas development in China

A host of national laws and regulations have clear stipulations on biogas development, including *Law of Agriculture, Law of Energy Conservation, and Law of Renewable Energy.*

Article 54 in the *Agriculture Law of the People's Republic of China* stipulates that governments at different levels shall prepare the plans for agricultural resource zoning, agricultural environment protection, and renewable energy development in the rural areas (*Agriculture Law of the People's Republic of China,* 2003).

The *Law of the People's Republic of China on Energy Conservation* stipulates in Article 4 that the state encourages the development and utilization of new energy and renewable energy. (*Law of the People's Republic of China on Energy Conservation,* 2007)

The *Law of the People's Republic of China on Renewable Energy* states in Article 18 that the state encourages and supports the development and utilization of renewable energy in the rural areas. Authorities in charge of energy affairs at the county level or above shall, in collaboration with other authorities concerned, prepare the plan for renewable energy development in the rural areas in line with the actual needs of local economic and social development, ecological protection, and hygiene control, and diffuse the technologies concerning the conversion of biomass resources, such as biogas, household solar energy application, small scale wind energy, and small scale water energy (*Law of the People's Republic of China on Renewable Energy,* 2004).

1.1.2 Policies for biogas development

Biogas production in the rural areas provides a new energy for farmers' daily life. It is also one of the important approaches for improving ecological environment, developing the circular economy, and facilitating the construction of new socialist countryside.

For example, it was proposed to "accelerate the pace of energy construction in the rural areas, and continuously promote the biogas development in the rural areas" in the "Comments on the Policies Concerning Further Strengthening the Comprehensive Production Capacity of the Rural Areas" (*Zhongfa [2005] No. 1), a CPC Central Committee and State Council document.*

It was also requested to "vigorously develop biogas digesters and biogas projects at medium and large intensive animal operations, and diffuse the application of energy-efficient stoves in the rural areas" in the "circular economy on the recent major activities for building a saving-oriented society" *(Guofa, 2005, No. 21), a State Council document.*

It was pointed out that efforts shall be made "to accelerate the pace of energy construction in the rural areas and diffuse the application of biogas in desirable areas, raise the scale of the construction of biogas projects in the rural areas, and diffuse household biogas projects where appropriate, support intensive animal operations to build medium and large biogas digesters". The construction of biogas digesters shall include innovation of animal barns, toilets, and kitchens in the rural areas", as stated in the "comments on promoting development of new socialist countryside," *(Zhongfa, 2006, No. 1), a CPC Central Committee and State Council document.*

1.2 National biogas development strategies

1.2.1 Biogas development plan

In 2007, the Chinese government published a strategic plan to develop agricultural biomass energy for the period of 2007 - 2015 (Ministry of Agriculture, 2007a), and a plan to promote the application of biogas digesters in the rural areas (2006-2010) (Ministry of Agriculture, 2007b). Those plans clearly defined principles and objectives of biogas development in the rural areas. According to the plans, biogas development shall follow the principle of government guidance with farmers' willingness to participate. Rural biogas development is a public undertaking, calling for the policy, fund, and service support from the government on the one hand, and respecting farmers' wishes on the other. Farmers are to be guided and encouraged to be part of the development, along with the involvement of the industry and other stakeholders.

In the rural areas, the household biogas project follows a basic model called "one digester plus three innovations" namely building a household biogas digester, and modifying the toilet, kitchen, and animal enclosures. Under this model, a household biogas digester may have the volume of between 8 and 10 cubic meters, with a range of defined types by national technical standards.

According to those national plans, China will reach 40 million households biogas digesters by 2010, of which 18 million are new users. Household biogas digesters will reach 30 per cent of the rural population suitable for applying biogas technology. The total volume of biogas production by biogas digesters will be about 15.5 billion cubic meters of biogas per year. By 2015, the total number of household biogas digesters will reach 60 million with an annual biogas production of 23.3 billion cubic meters.

1.2.2 Biogas development supporting system

One-plus-three Innovation is a systematic project covering animal breeding, biogas tank construction, and associated daily operation and maintenance. To ensure the smooth operation of biogas digesters, technical support and trained technicians are needed. Technical standards and supporting systems will be helpful for the implementation of CDM projects, including construction, operation and monitoring.

At present, technical standards covering construction, operation and maintenance on household biogas digesters have been established, including:

- Collection of standard design drawings for household anaerobic digesters
- Specifications for checking and accepting the quality of household anaerobic digesters
- Operation rules for construction of household anaerobic digesters
- Household-scaled biogas and integrated farming system - specifications on design, construction and use for a southern model
- Household-scaled biogas and integrated farming system - specification on design, construction and use for a northern model

Biogas digesters construction and gas pipeline maintenance in the rural areas are mainly performed by biogas technicians. Biogas technicians have to be approved for qualification certificate through an official test supervised by the Ministry of Agriculture. Household biogas technician training covers basic technology of household biogas, design and construction of household biogas digesters, biogas utilization technology, pipeline design and installation of biogas, and biogas daily management and maintenance. By the end of 2007, certified technicians for rural energy biogas reached 188,000 in China. In 2009, the biogas technicians were included in the training program under “Sunshine Project” organized by Ministry of Agriculture. A broad training on the system-wide household biogas was planned in the winter of 2009 and the spring of 2010. The training program will ensure that each village has 1-2 biogas certified technicians to support the biogas construction and operation.

1.3 Current status and potentials of biogas development

1.3.1 Current status of household biogas development

Fig. 1 shows the development trends of household biogas projects in China. By the end of 2008, the number of the overall household biogas digesters had reached to 30.49 million. During the period of 1990-2008, the number of household biogas digesters had gone up 6.4 fold while household biogas digesters increased 100 per cent in total installations from 2004-2008. The major driving forces behind such rapid development are policy and technology support and financial investment. However, most farmers could not afford a biogas digester as a result of limited subsidies provided by the central government.

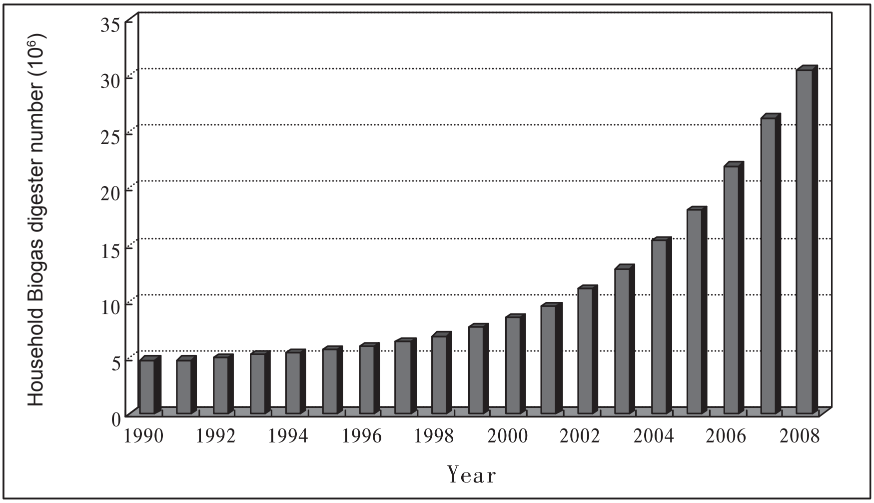

Figure 1 Development trends of household biogas projects during the period of 1990-2008 in China

1.3.2 Household biogas potentials

Household biogas potentials can be estimated based on the quantity of animal manure feedstock. Animal manure, one of the major polluted sources in the rural areas in China, contributes significant greenhouse gases emissions. Meanwhile, it is also an important material feedstock for biogas fermentation. Rational individual breeding activities are important for household biogas application in the rural areas. In 2007, China had 439.895 million pigs, 285.647 million sheep, 105.948 million heads of cattle, and 5.02 billion hens and broilers in stock. At present, China has 80.11 million farming households engaged in pig breeding activities, 2.16 million in dairy cattle breeding, 15.35 million in beef cattle, 29.14 million in hen and egg production, 28.61 million in broiler, 23.93 million in sheep, and 21.95 million in draught cattle, or 201.25 million households engaged in domestic animal breeding in total (China Livestock Husbandry Yearbook 2008).

The farming households who provide feedstock for household biogas digesters were around 201 million in 2007. For animal manure management and biogas CDM methodology development, a condition of a local annual average temperature of over 5°C is required in order to make the digester operate according to the design. Under the climatic conditions for biogas digesters, the estimated rural households which are suitable for developing biogas digesters were around 195 million in 2007. Table 1 gives the potential of number of different animals based on data provided in the 2007 year book of animal industry.

Table 1 Numbers of rural household breeding and numbers of animal in regions with an annual average temperature above 5°C in year 2007

Livestock Type	Household Breeding Level	Number of household breeding (10,000)	Number of Livestock or Poultry (10,000)
Pig	1-49 In Stock	7734.3	39817.9
Dairy Cattle	1-4 In Stock	189.7	521.8
Beef Cattle	1-9 Slaughter	1459.17	3529.6
Hen	1-499 In Stock	2824.78	64176
Broiler	1-1999 In Stock	2772.03	137109.9
Sheep	1-29 Slaughter	2344.36	20481.5
Draught cattle	1-3 In Stock	2195.17	
Total	/	19519.51	265636.7

1.4 Distribution of biogas digesters and potential provincial CDM projects

To analyze the potential for CDM project development, the following factors have been taken into account in the regional analysis of household biogas: 1) the number households engaged in livestock breeding/management activities to ensure the total scale of CDM projects; 2) existing manure management modality to determine the potential greenhouse gas emission reduction from manure management; 3) existing fossil fuel consumption and methane substitution to determine the CO_2 emission reductions; 4) number of livestock per household to determine the CH_4 emission reductions; and 5) number of existing households possessing biogas digesters as a proportion of the household population suitable for the technology (Dong Hongmin. Li Yu’e, 2009).

1.4.1 Number of households breeding/managing livestock in the target provinces

As manure from Concentrated Animal Facility Operation (CAFO) is for intensive treatment, household biogas digesters will not be constructed for CAFOs in general. This section mainly deals with the number of rural households with breeding livestock. Table 2 shows the number of household breeding various livestock in the provinces of China. The top ten provinces with the highest number of households breeding pigs are Sichuan, Yunnan, Hubei, Guizhou, Hunan, Chongqing, Henan, Guangxi, Anhui and Hebei. The top ten provinces with the highest number of households breeding dairy cattle are Xinjiang, Inner Mongolia, Hebei, Heilongjiang, Shan'xi, Shandong, Shanxi, Yunnan, Henan and Sichuan; most are in northwestern and northern China. The top ten provinces with the highest number of households breeding layers are Sichuan, Hubei, Henan, Hebei, Shandong, Hunan, Anhui, Inner Mongolia, Shan'xi and Jiangxi. Taking into account the fact that household biogas application mainly relies on pig and cattle manure as raw material, the CDM projects are mainly selected from the top ten provinces with the largest number of households breeding pigs and cattle.

Table 2 Number of household breeding in target provinces (China Livestock Husbandry Yearbook 2008)

Provinces	Pig	Dairy cattle	Beef cattle	Sheep	Layer	Broiler
Total	80104750	2159701	15351990	23934411	29135097	28613036
Beijing	18923	2747	1847	8612	13599	1478
Tianjin	10453	672	3840	8132	19753	883
Hebei	2978815	378584	945924	1188201	2381448	239868
Shanxi	553816	61929	194259	396974	477356	45889
Inner Mongolia	1790847	435468	583383	1268215	1157452	564861
Liaoning	1346920	20534	545568	227175	873112	220191
Jilin	1739109	33661	470889	129383	318907	395564
Heilongjiang	915315	194407	212545	112074	480214	497153
Shanghai	14570			108369	111108	112556
Jiangsu	1958993	2836	87450	1703081	945669	392564
Zhejiang	991223	1763	29766	234957	252721	615729
Anhui	3915688	2768	694431	1132573	1220496	926565
Fujian	1073643	2910	96855	137225	114031	714079
Jiangxi	2564314	2589	949587	95699	1051652	127358
Shandong	1863405	73833	1146711	2377411	1731493	298002
Henan	4299611	39476	2569298	4239945	2850458	543210
Hubei	6161931	3018	229441	497299	3005124	33234
Hunan	5886761	1880	789091	899526	1401298	4033331
Guangdong	1421303	1989	407193	25195	380098	2235218
Guangxi	4280626	425	667096	167602	420324	3093498
Hainan	617366	2	160775	112899	100405	519192

Provinces	Pig	Dairy cattle	Beef cattle	Sheep	Layer	Broiler
Chongqing	4350933	3029	185710	154406	17234	19525
Sichuan	13783319	36533	848320	3993476	5200910	8512081
Guizhou	6058641	1041	1177318	734367	668249	1441335
Yunnan	7223468	47885	903594	584401	843093	1916681
Tibet	26932		154831	129686	117	8143
Shaanxi	2307542	154361	413237	913356	1079814	384785
Gansu	1466945	29244	491445	712758	969911	341696
Qinghai	107318	34675	76822	249396	88184	
Ningxia	283098	16193	49201	443848	232369	146038
Xinjiang	92922	575249	265563	948170	728498	232329

1.4.2 Manure management modalities under baseline scenario

Domestic animals raised by farming households are limited in number. In addition to a limited number of farmers using biogas digesters to treat manure, most farmers have chosen on-site storage plus farmland utilization. Animal manures, both solid and liquid, are stored and treated in an open septic tank for one or two months, or even longer. The manure can be applied directly to farmland after pollution-free treatment. This type of application enjoys numerous merits, including small investment, no operational cost, and improved soil conditions. However, it releases a huge amount of greenhouse gases in an anaerobic environment. In southern China, abundant rainfall allows a relatively higher mean temperature compared with the north. Therefore, GHG emissions from manure storage processes in southern China are much higher than in northern China.

1.4.3 Fossil fuel consumption and methane potential alternative per household

Individual household emission reduction potential is mainly explained in the context of local energy consumption, biogas as substitute energy and its equivalent for such substitution, and local climatic conditions. Figure 2 show rural household consumption of coal. For example, annual coal consumption of rural households in Shan’ xi Province (one of the provinces with the largest coal production in China) is more than 4,500 kg per household. However, in Tibet, Shanghai, Guangxi, Hainan, Guangdong, and Zhejiang, coal consumption is lower than 500 kg per household per year. Except for the provinces mentioned above, annual rural household coal consumption in most provinces is between 500 to 2,000 kg, which can be used for estimating the potential to reduce GHG emissions by using biogas to replace coal. CDM Executive Board has a strict definition on emission reduction from biomass. As a general principle, replacing straw or firewood by biogas will not be considered for contributing to GHG emission reduction.

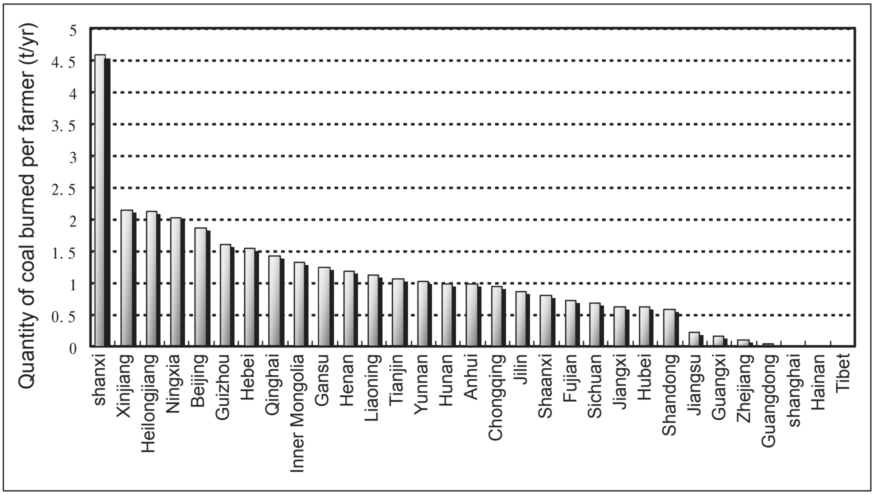

Figure 2 Coal consumption for cooking per household in different provinces in 2007

1.4.4 Individual household animal breeding volume

The potential of GHG emission reduction due to manure management of rural households is mainly related to the number of animals, species, and local climatic conditions. Figure 3 presents annual mean temperatures of selected provinces. Because the average annual temperature of Qinghai, Jilin and Heilongjiang is below 5°C, there is no emission reduction potential. Figures 4 to 7 show the provincial average number of pigs, dairy cattle, laying hens and beef cattle per household. In most provinces, the average number of pigs is more than three, except Inner Mongolia. The average number of dairy cows is more than one, except Tibet and Shanghai. Except for Shanghai, the average amount of beef cattle is more than one. Thus, these provinces can be considered as areas with the potential for GHG emission reduction through the development of biogas projects.

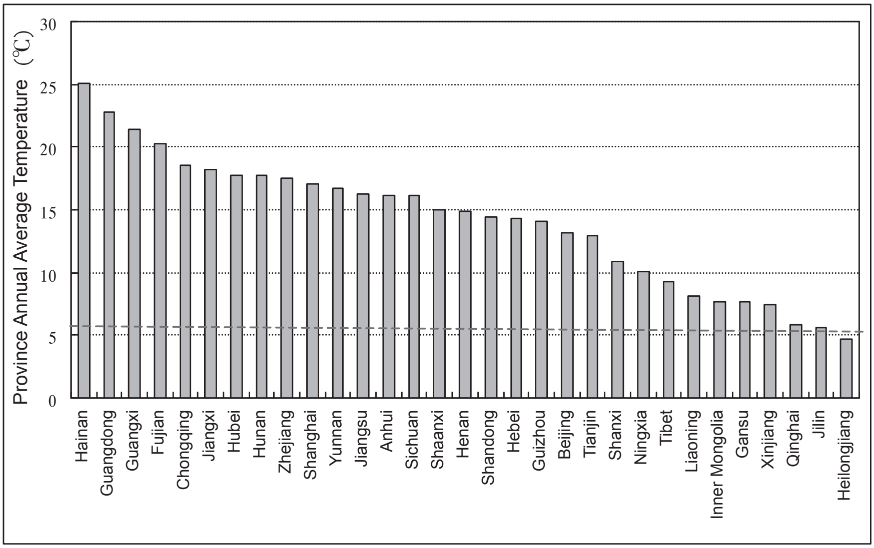

Figure 3 Annual mean temperatures of difference provinces

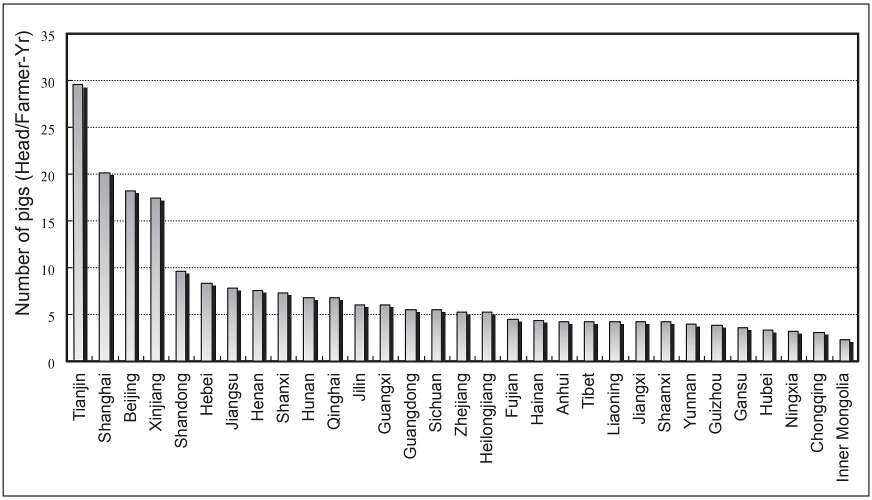

Figure 4 Average number of pigs per household of different provinces in 2007.

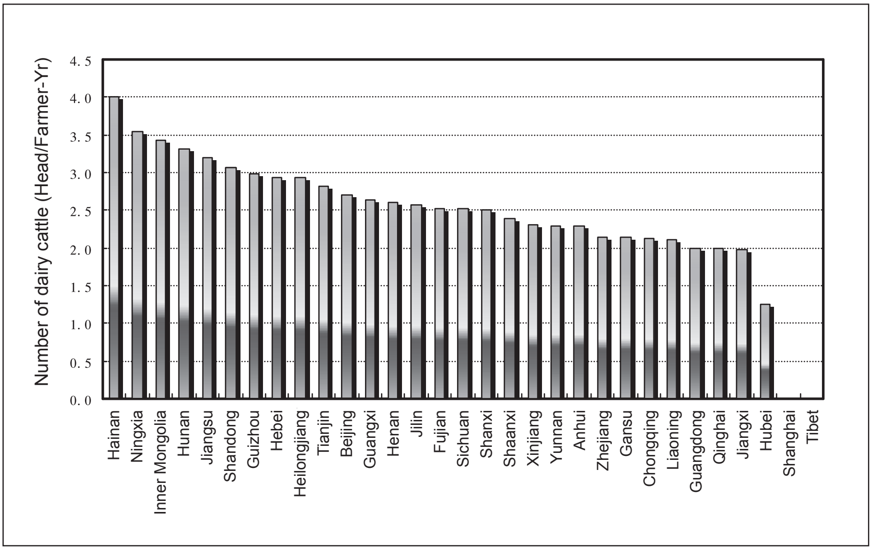

Figure 5 Average number of dairy cattle per household of different provinces in 2007

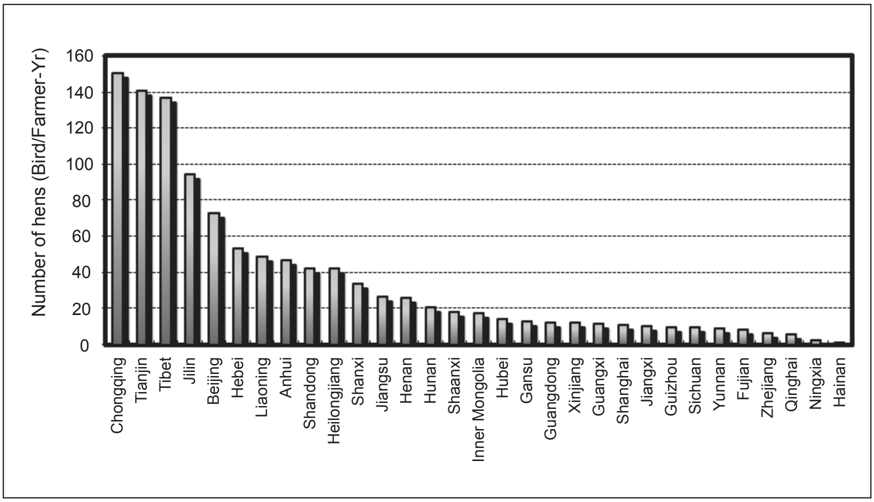

Figure 6 Average number of layer hens per household of different provinces in 2007.

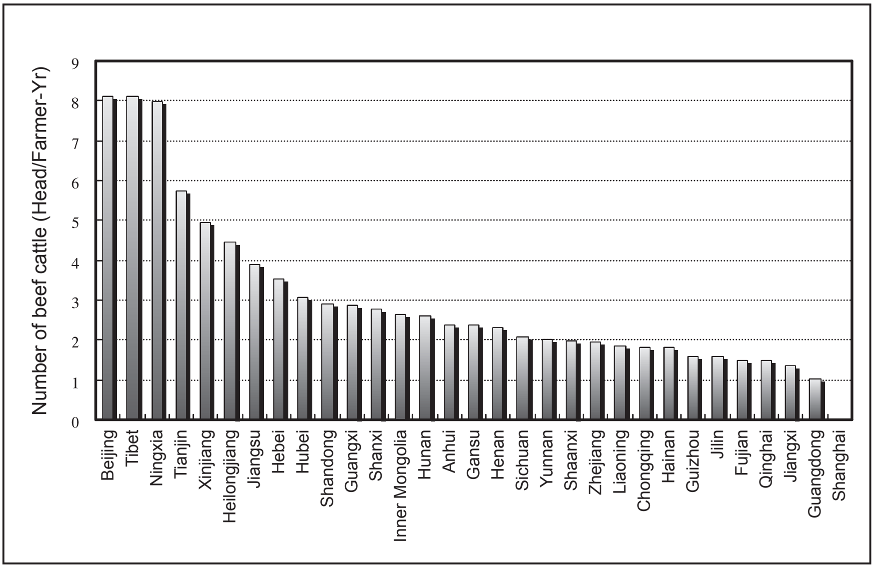

Figure 7 Average number of beef cattle per household of different provinces in 2007.

1.4.5 Status quo and potential for provincial biogas development

Table 3 shows the number of biogas households as a proportion of total farmer households in selected provinces. The provinces with a higher proportion of biogas households posses better conditions for the implementation of biogas projects due to the large number of livestock and favorable climatic conditions. More difficulties are faced for those provinces to support additionality check and investigation as required by a CDM project. The barriers for CDM implementation still exist, especially in the area of financial investment. Therefore, it is possible to justify the additionality of CDM projects in those areas. If a province with a low biogas diffusion rate is chosen, it may face obstacles of climatic conditions, fund, technology, and policies in promoting CDM projects, even though it may justify the additionality. This is because even with additional funds from a CDM project, the existence of other obstacles, or insufficient additional funds for building a biogas digester, may eventually limit the potential for diffusing household biogas application in these regions.

Table 3 Biogas households as a proportion of total farmers in the selected provinces

Provinces	Household number (10,000)	Cumulative number of 2006 (10,000)	Number of biogas households as a proportion of total farmer households (%)
Guangxi	986.1	280.5	28.4
Yunnan	877.4	171.4	19.5
Hainan	112.6	19.8	17.6
Sichuan	1979.2	339.0	17.1
Jiangxi	795.3	118.8	14.9
Hubei	1016.4	146.0	14.4
Hebei	1448.6	203.2	14.0
Guizhou	792.3	98.2	12.4
Hunan	1492.5	164.0	11.0
Ningxia	93.6	9.8	10.5
Chongqing	718.8	69.7	9.7
Henan	2025.7	183.4	9.1
Shaanxi	705.0	46.7	6.6
Liaoning	695.6	35.2	5.1
Fujian	682.3	30.8	4.5
Qinghai	77.6	3.4	4.4
Gansu	463.7	18.1	3.9
Xinjiang	223.9	7.6	3.4
Shandong	2050.4	65.6	3.2
Shanxi	638.4	20.1	3.2
Anhui	1346.1	37.6	2.8
Jiangsu	1593.2	42.7	2.7
Inner Mongolia	351.4	7.9	2.3
Tibet	40.4	0.9	2.2
Guangdong	1540.5	29.1	1.9
Heilongjiang	494.0	8.2	1.7
Jilin	383.7	4.4	1.2
Beijing	142.2	1.4	1.0
Zhejiang	1224.6	10.1	0.8
Tianjin	119.8	0.8	0.6
Shanghai	111.1	0.0	0.0

To calculate development potential and additionality of household biogas application, it is suggested that if the farmer's net income minus his expenditure of the year can't provide matching fund for building a biogas digester, then the farmer has additionality. This will serve as evidence for screening out provinces with a lower biogas diffusion rate. In terms of development potential, except Guangxi, Yunnan and Hainan, which have high proportion of household biogas application, the other provinces with a proportion of biogas households under 20 per cent would be a desirable candidate for the case study.

Summary of selection of the candidate provinces was shown in Figure 8. It can be inferred that except for Qinghai, Jilin and Heilongjiang provinces, which have low air temperature; and Tibet, Shanghai, Guangxi, Hainan, Guangdong and Zhejiang, which consume a small volume of coal; and Shanghai, Guangxi and Yunnan, which have low breeding volume; the other 20 provinces meetthe basic conditions for household biogas CDM projects development. However, whether one place can be considered for development of a CDM project, in addition to the potential GHG emission reduction, the availability of suitable methodologies and additionality shall also be analyzed.

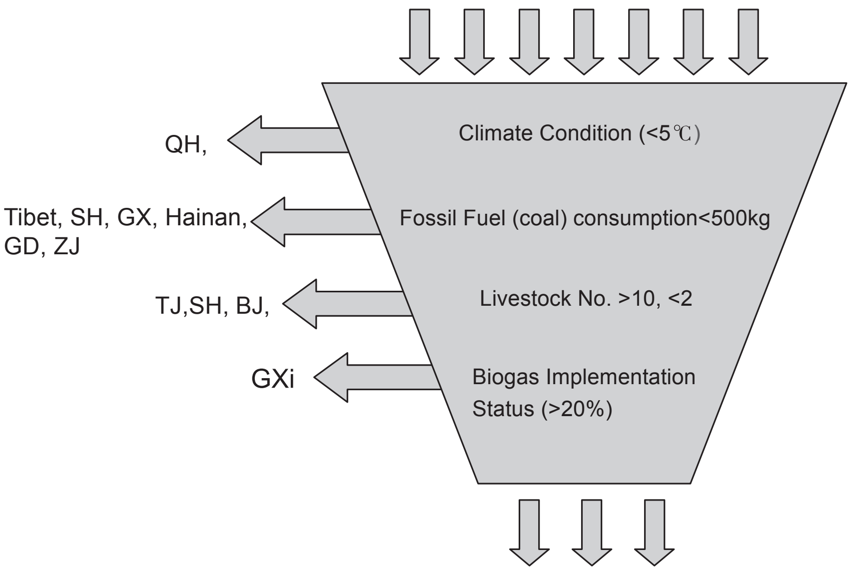

Figure 8 Selection of the candidate provinces

1.5 Methodologies analysis related to biogas digesters

CDM project development requires the baseline determination and GHG emission reduction by applying a specific CDM methodology and establishing a project's monitoring plan. The specific methodology can either be the one used in other similar CDM projects approved by the CDM Executive Board, or it could be a new methodology for the project which needs to be submitted and approved by the CDM Executive Board. CDM project developers should visit UNFCC CDM website at http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html?searchon=1&searchmode=advanced to search and analyze the approved methodologies and registered projects during the planning stage and choose the most appropriate methodology for the project to be developed.

1.5.1 Applicability analysis of existing methodologies

Today, the UNFCCC CDM Executive Board has approved five methodologies relating to animal manure management, including one general methodology, one integrated methodology and three small-scale project methodologies. Detailed information is shown in Table 4. (Dong Hongmin. Li Yu'e, 2009) Table 4 Approved CDM Methodologies (till June 30, 2009)

Table 4 Approved CDM methodologies (till June 30, 2009)

Classification of Methodology	Type of Methodology
General methodology	
AM0073 - Version 01	GHG emission reductions through multi-site manure collection and treatment in a central plant
Integrated methodology	
ACM0010 - Version 05	Consolidated baseline methodology for GHG emission reductions from manure management systems
Small-scale project Methodologies	
AMS-III D - Version 16	Methane recovery in animal manure management systems
AMS-III R - Version 01	Methane recovery in agricultural activities at household/ small farm level
AMS-III Y - Version 02	Methane avoidance through separation of solids from wastewater or manure treatment systems

(1) AM0073-Version 01-GHG emission reductions through multi-site manure collection and treatment in a central plant (UNFCCC, AM0073/Version 01, Sectoral Scope: 13 and 15, EB 44)

This methodology applies to project activities where manure is collected by digester trucks, canalized and/or pumped from multiple livestock farms and the collected material is subsequently treated in a single central treatment plant. The existing anaerobic manure treatment systems, in the multiple livestock farms within the project boundary, are replaced by a central treatment plant with one or a combination of more than one animal waste management systems (AWMSs) that result in less GHG emissions. CERs may also be claimed from biogas sourced heat/electricity exportations.

The methodology is applicable under the following conditions:

- Farms where livestock populations, comprising of cattle, buffalo, swine, sheep, goats, and/or poultry, are managed under confined conditions;
- Farms where manure is not discharged into natural water resources (e.g. rivers or estuaries);
- Farms where animal residues are treated under anaerobic conditions;
- The annual average temperature in the site where the anaerobic manure treatment facility in the baseline existed is higher than 5°C;
- In the cases where the baseline anaerobic treatment system is an open lagoon, the lagoon depth shall be greater than 1 m;
- The retention time of the organic matter in the baseline anaerobic treatment systems should be at least 30 days;
- If residues are stored in between collection activities, storage digesters shall comprise outdoor open equipments;
- If the treated residue is used as fertilizer in the baseline, project proponents must ensure that this end use remains the same throughout the project activity;
- Sludge produced during the project activity shall be stabilized through thermal drying or composting, prior to its final disposition/application;
- The AWMS/process in the project case should ensure that no leakage of manure waste into ground water takes place, e.g., the lagoon should have a non-permeable layer at the lagoon bottom;
- CERs shall be claimed by the Central Treatment Plant managing person/entity, only. Other parties involved must sign a legally binding declaration that they will not claim CERs from the improved animal waste treatment practices. Such declarations shall be verified by an appropriate authority (i.e., DOE) during the validation, and these documents shall be valid throughout the whole crediting period.

(2) ACM0010-Version 05-Consolidated baseline methodology for GHG emission reductions from manure management systems (UNFCCC, ACM0010/Version 05, Sectoral Scopes: 13 and 15, EB 42)

This methodology is generally applicable to manure management on livestock farms where the existing anaerobic manure treatment system, within the project boundary, is replaced by one or a combination of more than one animal waste management systems (AWMSs) that result in less GHG emissions.

This methodology is applicable to manure management projects with the following conditions:

- Farms where livestock populations, comprising of cattle, buffalo, swine, sheep, goats, and/or poultry, is managed under confined conditions;
- Farms where manure is not discharged into natural water resources (e.g. rivers or estuaries);
- In case of anaerobic lagoons treatments systems, the depth of the lagoons used for manure management under the baseline scenario should be at least 1m;
- The annual average temperature in the site where the anaerobic manure treatment facility in the baseline existed is higher than 5°C;
- In the baseline case, the minimum retention time of manure waste in the anaerobic treatment system is greater than 1 month;
- The AWMS/process in the project case should ensure that no leakage of manure waste into ground water takes place, e.g., the lagoon should have a non-permeable layer at the lagoon bottom.

(3) AMS-III.D-version 16-Methane recovery in animal manure management systems (UNFCCC, III.D./Version 16, Sectoral Scope: 15, EB 53)

(a) This methodology covers project activities involving the replacement or modification of existing anaerobic manure management systems in livestock farms to achieve methane recovery and destruction by flaring/combustion or gainful use of the recovered methane. The methodology is only applicable under the following conditions:

- The livestock population in the farm is managed under confined conditions;
- Manure or the streams obtained after treatment are not discharged into natural water resources (e.g., river or estuaries), otherwise AMS-III.H shall be applied;
- The annual average temperature of baseline site where anaerobic manure

treatment facility is located is higher than 5°C;

- In the baseline scenario the retention time of manure waste in the anaerobic treatment system is greater than 1 month, and in case of anaerobic lagoons in the baseline, their depths are at least 1 m;
- No methane recovery and destruction by flaring, combustion or gainful use takes place in the baseline scenario.

(b) The project activity shall satisfy the following conditions:

- The final sludge must be handled aerobically. In case of soil application of the final sludge the proper conditions and procedures (not resulting in methane emissions) must be ensured;
- Technical measures shall be used (including a flare for exigencies) to ensure that all biogas produced by the digester is used or flared.

(c) Projects that recover methane from landfills shall use AMS-III.G and projects for wastewater treatment shall use AMS-III.H.

(d) The recovered methane from the above measures may also be utilized for the following applications instead of flaring or combustion:

- Thermal or electrical energy generation directly; or
- Thermal or electrical energy generation after bottling of upgraded biogas; or
- Thermal or electrical energy generation after upgrading and distribution:
    - ♦ Upgrading and injection of biogas into a natural gas distribution grid with no significant transmission constraints; or
    - ♦ Upgrading and transportation of biogas via a dedicated piped network to a group of end users.

(e) If the recovered methane is used for project activities covered under the first point of paragraph (d), that component of the project activity shall use a corresponding category under Type I.

(f) If the recovered methane is used for project activities covered under the second point or third point of paragraph (d), the relevant provisions in AMS-III.H related to upgrading, bottling of biogas, injection of biogas into a natural gas distribution grid and transportation of biogas via a dedicated piped network shall be used.

(g) Measures are limited to those that result in aggregate emission reductions of less than or equal to 60 kt CO_2 equivalent annually from all Type III components of the project activity.

4) AMS-III R-version 01-Methane recovery in agricultural activities at household/small farm level (UNFCCC, III.R./Version 01, Sectoral Scope: 15, EB 35)

This methodology is developed for methane recovery in agricultural activities on household/small farm level. Rural household/small biogas could be applied by using this methodology.

(a) This project category comprises recovery and destruction of methane from manure and wastes from agricultural activities that would be decaying anaerobically emitting methane to the atmosphere in the absence of the project activity. Methane emissions are prevented by:

- Installing methane recovery and combustion system to an existing source of methane emissions, or
- Changing the management practice of a biogenic waste or raw material in order to achieve the controlled anaerobic digestion equipped with methane recovery and combustion system.

(b) The category is limited to measures at individual households or small farms (e.g. installation of a domestic biogas digester). Methane recovery systems that achieve an annual emission reduction of less than or equal to 5 tonnes of CO_2e per system are included in this category. Systems with annual emission reduction higher than 5 tCO_2 equivalent are eligible under AMS III.D.

(c) This project category is only applicable in combination with AMS I.C.

(d) The project activity shall satisfy the following conditions:

- The sludge must be handled aerobically. In case of soil application of the final sludge the proper conditions and procedures that ensure that there are no methane emissions must be ensured.
- Measures shall be used (e.g. combusted or burnt in a biogas burner for cooking needs) to ensure that all the methane collected by the recovery system is destroyed.

(e) Aggregated annual emission reductions of all systems included shall be less than or equal to 60 kt CO_2 equivalent.

(5)AMS-III Y-version 02-Methane avoidance through separation of solids from wastewater or manure treatment systems (UNFCCC, III.Y./ Version 02, Sectoral Scope: 13, EB 50)

(a) This methodology comprises technologies and measures that avoid or reduce methane production from anaerobic wastewater treatment systems and anaerobic manure management systems, through removal of (volatile) solids from the wastewater or manure slurry stream. The separated solids shall be further treated, used or disposed in a manner resulting in lower methane emissions.

(b) The project activity does not recover and combust biogas i.e. the baseline wastewater or manure treatment plant as well as the project system are not equipped with methane recovery. Project activities which recover and combust biogas from manure management systems shall consider AMS-III.D or AMS-III.R. Project activities, which recover and combust biogas from wastewater treatment systems, shall consider using AMS-III.H. Project activities that substitute anaerobic wastewater treatment systems with aerobic wastewater treatment system shall consider AMS-III.I.

(c) The technology for solids separation shall be one of the below or a combination thereof so as to achieve a minimum dry matter content of separated solids larger than 20 per cent:

- Mechanical solid/liquid separation technologies, operated in line with the inflowing freshly generated wastewater or slurry manure stream so as to avoid stagnation;
- Thermal treatment technologies that evaporate water content from the waste stream, either releasing vapor to the atmosphere or condensing it into a liquid fraction (condensate) containing negligible volatile solids or COD load, resulting in a solid fraction. Examples include evaporation and spray drying technologies.

(d) The dry matter content of separated solids shall remain higher than 20 per cent throughout until its final disposal, destruction or use (e.g. spreading on the soil).

(e) Separation of solids using gravity (settler digesters, ponds, or geotextile containers/bags) is not included in this methodology.

(f) In case of animal manure management systems the following conditions apply:

- Animals shall be managed in confined conditions;
- No organic bedding material is used in the animal barns or intentionally added to the manure stream;
- If the baseline manure slurry was treated in an anaerobic lagoon or another liquid treatment system, the outflow liquid from the lagoon was recycled as flush water or used to irrigate fields; however, it was not discharged into river/lake/sea. In the latter case, i.e. effluent discharge into river/lake/sea, the system is considered as a wastewater treatment system and not a manure management system;
- A minimum interval of six months was observed between each removal of the solids accumulated in the lagoon.

(g) In case of wastewater treatment systems the following conditions apply:

- The baseline treatment systems do not include a fine solids separation process (i.e. grading smaller than 10 mm aperture, primary settlers, mechanical separation, etc.);
- In case the baseline treatment system was an anaerobic lagoon or a liquid system, a minimum interval of 30 days was observed between each removal of the solids accumulated in the lagoon.

(h) This methodology is not applicable when the project treats solids removed from an existing lagoon, or sludge originated from settlers or from any other biologically active treatment device of the baseline animal manure management/ wastewater treatment system.

(i) The separated solids shall be further treated, emissions resulting from further treatment, storage, use or disposal shall be considered. If the solids are combusted for thermal or heat generation, that component of the project activity can use a corresponding methodology under type I. If the solids are mechanically/ thermally treated to produce refuse-derived fuel (RDF) or stabilized biomass (SB) the relevant provisions in AMS-III.E shall be followed. If the solids are used as animal feeds (e.g. feed to cows, pigs), any emissions from enteric fermentation and emissions from the manure, depending on the treatment system in those instances shall be considered as project emissions.

1.5.2 Application guidelines for household biogas CDM methodologies

Taking into account the fact that each farming household has a very limited emission reduction potential from the biogas digester, a project, therefore, has to be bundled with hundreds and even thousands of farming households to have a cost-effective CDM project. In this context, the baseline and monitoring plan have to be prepared using random techniques. For a project with an emission reduction less than 60,000 tonnes (about 20,000-30,000 households), both AMS-I.C and AMS-III.R can be used in a combined manner. When planning to build 100,000 or even 300,000 biogas digesters each year, a province can divide them into a number of smaller projects. This may increase the difficulties of validation and endorsement. Therefore, it is suggested to develop programme of activities (POA) household biogas CDM project while developing smaller tied-up projects.

Application of the methodology has five main aspects, including:

- Determine the project activity boundary;
- Definition of the baseline;
- Calculation of emission reduction;
- Justification of additionality; and
- Monitoring plan of the project.

Following issues should be noted when applying the methodologies combined with AMS-I.C and AMS-III.R to develop the household biogas CDM projects.

(1) Project boundaries

According to the national biogas development plan in China, household biogas digester construction uses the so called “one digester plus three innovations” model, namely building a household biogas digester, and modifying the toilet, kitchen, and animal enclosures into an integrated unit. On the one hand, biogas digesters treat the manure waste from pigs, other livestock and poultry. This will change and improve the existing waste management of open rural anaerobic pig manure and sewage. On the other hand, the new treatment by using biogas digesters will also reduce the CH_4 emissions from pig manure and sewage. Methane recovered from biogas digesters can also provide renewable energy for cooking, water boiling and other uses thus reducing GHG emissions if biogas is used for replacing the fossil fuels like coal or LPG.

Table 5 Emission sources and gases included within the project boundary

	Sources	Gas	Included/ Excluded	Justification /Explanation
Baseline	Emissions from manure	CH_4	Included	Major source of emission in the baseline.
		N_2O	Excluded	Excluded for simplification. This is conservative.
		CO_2	Excluded	CO_2 emissions from the decomposition of organic waste are not included.
	Emissions from burning of coal	CO_2	Included	Major source of emissions in the baseline.
		N_2O	Excluded	Based on the survey, the coal consumption under baseline condition is higher than that in project condition. Therefore, N_2O emissions from burning of coal are not included. It is conservative not to consider N_2O.
		CH_4	Excluded	Based on the survey, the coal consumption under baseline condition is higher than in project condition. Therefore, CH_4 emission from burning of coal in the baseline scenario is higher than that in project condition. It is conservative not to consider CH_4 emission from burning of coal.
	Emissions from burning of biomass (firewood and crop straw)	CO_2	Excluded	Based on the survey, firewood and straw consumption under baseline condition is higher than that in project condition. Therefore, CO_2 emission from burning of firewood and straw is not included. This is conservative.
		N_2O	Excluded	Based on the survey, firewood and straw consumption under baseline condition is higher than that in project condition. Therefore, N_2O emission from burning of firewood and straw is not included. This is conservative.
		CH_4	Excluded	Based on the survey, firewood and straw consumption under baseline condition is higher than that in project condition. Therefore, CH_4 emission from burning of firewood and straw is not included. This is conservative.

	Sources	Gas	Included/ Excluded	Justification /Explanation
Project Activity	Emissions from biogas digester	CH_4	Included	Leakage from biogas digester is major emission source under project activity according to AMS III.R
		N_2O	Excluded	No N_2O formed in biogas digester
		CO_2	Excluded	CO_2 emissions from the decomposition of organic waste are not included.
	Emissions from burning of coal	CO_2	Included	Major source of emissions in the baseline
		N_2O	Excluded	Based on the survey, the coal consumption under baseline condition is higher than that in project condition. Therefore, N_2O emission from burning of coal is not included. This is conservative.
		CH_4	Excluded	Based on the survey data, the coal consumption under baseline condition is higher than that in project condition. Therefore, CH_4 emission from burning of coal is higher than in project condition. It is conservative not to consider CH_4 emission from burning of coal.
	Emissions from burning of biomass (firewood and crop straw)	CO_2	Excluded	Based on the survey, firewood and straw consumption under baseline condition is higher than that in project condition. Therefore, CO_2 emission from burning of firewood and straw is not included. This is conservative.
		N_2O	Excluded	Based on the survey, firewood and straw consumption under baseline condition is higher than that in project condition. Therefore, N_2O emission from burning of firewood and straw is not included. This is conservative.
		CH_4	Excluded	Based on the survey, firewood and straw consumption under baseline condition is higher than that in project condition. Therefore, CH_4 emission from burning of firewood and straw is not included. This is conservative.

(2) Determination of baseline

The determination of baseline is a critical step in estimating emission reductions of a CDM project. Higher baseline emission is attractive for CDM project owners and investors because it will bring more CERs and higher profit.

According to requirements of AMS-III.R, sampling methods should be used for the survey of baseline data with confidence level of 95 per cent. Survey data include:

- Animal type and number in household production system;
- Manure management usage;
- Fuel type, consumption, efficiency of fuel usage before installation of biogas digesters.

(3) Calculation of emission reduction

To calculate emission reduction, procedure and equations provided in AMS-III R and AMS- I.C should be followed strictly. Regional data have high priority when selecting parameters in the calculating process. Domestic data of the same type can be used when there are no regional data available. Default parameters recommended by IPCC guideline can be applied if both country and regional specific data are not available. It should be noted that evidence and document records from related questionnaire or officially published literature for the applied data should be available or accessed by the public.

(4) Additionality assessment

Additionality assessment is a core part of CDM methodologies. To decide the eligibility of the proposed CDM project activity, two key points are required to follow. Firstly, the baseline scenario without project activity is determined. Secondly, it shall be evidenced that emission reduction of the CDM project activities will not occur under the baseline scenario.

AMS-I.C and AMS-III.R do not require specific method for additionality assessment. The simplified modalities and procedures for small-scale CDM project activities can be applied. Project participants shall provide an explanation to show that the project activity would not have occurred anyway due to at least one of the following barriers:

- Investment barrier: Due to low economic efficiency, farmers are not willing to construct biogas digesters. If there is no CDM or governmental investment, farmers will continue to use the original approach for manure management, heating and cooking.
- Technological barrier: There is technological risk for farmers to implement biogas digester due to lack of technical assistance in constructing biogas digesters and less experiences of operation because of the low popularization rate of the technique.
- Barrier due to prevailing practice: The laws, regulations, and environmental

standards for methane recovery are not applied to farmers based on current situation of practice.

- Other barriers: Service system is inadequate and poor dissemination of information to farmers and no matching funds are available.

(5) Monitoring parameters

Because household biogas digesters implemented in the bundled projects have the similar design following the national technical standards, the same monitoring plan can be used. According to monitoring requirements of methodologies, AMS I.C and AMS III.R, the individual biogas digester systems with annual emission reduction lower than 5 tonnes of CO_2 equivalent can be monitored by the following parameters:

- Recording annually the number of systems operating;
- Estimating the average annual hours of operation of a system using survey methods;
- Because this program adopted the default VS value recommended by IPCC and the animal manure fed into the biogas digesters is verified by the number of pigs, pig number of households should be surveyed and monitored;
- Recording the information of land application of anaerobic digested effluent.

1.6 Case study

In order to demonstrate the feasibility of the development of household biogas CDM projects, Hunan province, which has the medium level of climatic conditions, income, coal consumption and the average pigs breeding volume, is chosen for a case study.

1.6.1 Emission reduction means of household biogas activities

In the case study, the model so called "one digester plus three innovations", is used, namely building a household biogas digester, and modifying the toilet, kitchen, and animal enclosures into an integrated unit. Methane recovered from biogas digesters which use pig manure as raw material feedstock, can produce clean energy, biogas, for cooking, water boiling, burning etc, thus reducing CO_2 emission from firing coal.

1.6.2 Defining the baseline

Following steps have been conducted for defining the baseline:

(1) Household animal breeding volume. According to Statistic Yearbook for Agriculture 2007, the total number of farming households in China engaging in pig breeding is 5.887 million, with 40.278 million pigs slaughtered per year; that is to say, 6.8 heads per household. If the pig slaughter rate is counted as 150 per cent, the average figure is 4.5 head in stock per household.

(2) Manure management modality. Field investigation shows that manure pits are mainly used to store animal manures in Hunan provinces. Animal manures would be applied to croplands and vegetable fields during the growing seasons.

1.6.3 Emissions reduction from household biogas application

(1) Emissions under the baseline scenario

Greenhouse gases emissions under the baseline scenario include CH_4 emissions under the manure management, and CO_2 emissions for coal combustion.

a) CH_4 emissions under the baseline scenario

CH_4 emissions under the baseline scenario can be calculated by using IPCC Tier-2 method (2006 IPCC Guideline), in line with AMS-III.R methodology.

Based on the average numbers of pigs in stock in Hunan, which is 4.5 head, and CH_4 emission factors of manure management system, calculation results show that a farmer in Hunan will produce CH_4 emissions of 0.66 t CO_2e/year per household.

b) CO_2 emissions under coal burning baseline scenario

CO_2 emissions under the coal-burning baseline scenario can be calculated by using coal CO_2 emission factor recommended by the National Development and Reform Commission (NDRC) of China for estimating China grid emissions, in line with AMS-I.C methodology. Calculation results show that CO_2 emission factor for raw coal is 1.98 t CO_2/t. According to the statistics provided by Hunan, a household consumes 983 kg of coal per year. The calculation results show that under the coal burning baseline scenario, a farmer has CO_2 emissions of 1.95 t CO_2/year per per household.

c) Per household emission inventory under the baseline scenario

Under the baseline scenario, each household in Hunan has an emission inventory at 2.61 tCO_2e/year-household.

(2) Emission inventory under the project scenario

Greenhouse gas emissions under the project scenario include the emissions from biogas digester leakage and CO_2 emissions from coal burning.

a) Emissions from biogas digester leakage

CH_4 emissions from biogas digester leakage are calculated to be 0.20 t CO_2e/year-household for Hunan in line with AMS-III.R methodology.

b) CO_2 emissions from coal burning under the project scenario

CO_2 emissions from coal burning under the project scenario are calculated using the same method as done under a baseline scenario. The annual biogas production of a household biogas digester with volume of 8 m^3 is 385 m^3, and the heating value and heating efficiency of biogas are 5000 kCal/m^3 and 55 per cent, respectively. The heating value and heating efficiency of raw coal are 5000 kCal/kg and 25 per cent, respectively (Hao Xianrong, Shen Fengju, 2006). Based on the statistics provided by the Ministry of Agriculture, the amount of biogas produced by a typical household biogas digester can substitute 845 kg of raw coal. Average consumption amount of coal for cooking, heating water, cooking pig feeder, after implementing the biogas projects is 138kg. Further calculation shows that each farmer household will have a CO_2 emission of 0.27 t CO_2/year-household in Hunan.

c) GHG emissions per household under the project scenario

Under the project scenario, a farmer in Hunan will produce an emission of 0.47 tCO_2e/year per household.

(3) GHG emission reduction per household

The GHG emission reduction per household under the project scenario is calculated by deducting the GHG emission inventory under the project scenario from the GHG emission inventory under the baseline scenario. As a result, each farmer household would have a GHG emission reduction at 2.14 tCO_2e annually in Hunan Province.

Table 6 Emission inventory per household under the baseline scenario and the project scenario respectively (tCO_2e/year/household)

	Manure management or CH_4 emissions from biogas digester leakage	CO_2 emissions from coal burning	Emissions per household
Baseline	0.66	1.95	2.61
Project	0.20	0.27	0.47
Emission Reduction			2.14

(4) GHG emission reduction potential resulting from building new household biogas digesters in 2009 for Hunan province

In accordance with the project in 2009, 81,000 new household biogas digesters will be built. Based on the GHG emission reductions per household, it can be estimated that emission reduction potential of new households biogas digesters in Hunan will be 173,300 tCO_2e/year.

It shall be noticed that emission reduction potentials are calculated only based on planned objectives. However, the realization of the planned objectives will be mainly determined by the availability of funding, including the financing from CDM projects. At present, the government is not in a position to subsidize all planned biogas activities.

1.6.4 Additionality assessment

1.6.4.1 Investment obstacles

1) Investment analysis of household biogas project

Household biogas application needs investment in two major categories: the investment for biogas digesters and associated equipment; and the investment for the other facilities in the so called “one digester plus three innovations” including the modified toilet, kitchen, and animal enclosures. To ensure the smooth operation of biogas digesters, the construction of biogas digesters shall follow the standard model. Table 7 shows the investment in one-plus-three model in Hunan. Household biogas application is mainly financed by farmers themselves, the local and central government at a ratio of 70 per cent, 5 per cent, and 25 per cent, respectively.

Table 7 Specifications of biogas digesters and associated investment in Hunan (Yuan)

	Digester Volume	$6m^3$	$8m^3$	$10m^3$	$12m^3$	$15m^3$	$20m^3$
1	Biogas Digester	2250	2700	3150	3330	3600	4050
2	Animal Enclosures	300	400	500	600	700	800
3	Toilet	300	300	300	300	300	300
4	Kitchen	800	800	800	800	800	800
Total		3650	4200	4750	5030	5400	5950

In Hunan, the proposed type of biogas digester is suspension cover model, with a size of ca $10m^3$. In some regions, a farmer may prefer building a larger biogas digester of 15 m^3.

According to Economic Assessment of Methodologies and Parameters for Construction Project which is published by China Planning Press, the benchmark IRR (Internal Rate of Returns) for husbandry project is 9 per cent. Based on the important parameters of the proposed project, the IRRs of the proposed project with CDM and without CDM are calculated. The main parameters are shown in Table 8.

Table 8 Main parameters for the calculation of financial indicators

Parameters	Value
Project Life Time	20 Years
Total Investment	4750 Yuan
Maintenance Cost	50 Yuan/yr
Biogas Revenue (coal saving)	423 Yuan/yr
Expected CERs	2.14t CO_2/yr
Expected CER Price	15 \$/tCO_2 e
Exchange Rate	\$1=6.8 RMB
CER Crediting Time	10 Year

The IRRs with and without the income from CER sales are listed in Table 9 below. From Table 9, the IRR without income from selling CERs is 5.52 per cent, which is lower than the benchmark IRR of 9 per cent for the animal husbandry, making the proposed project financially unacceptable. With the income from CERs, the IRR is increased to 9.95 per cent, which is higher than the benchmark IRR of 9 per cent for the animal husbandry and is financially acceptable. Therefore, the revenue of the proposed CDM project can ensure the project to overcome the economic barriers and verify the project's additionality.

Table 9 IRRs with and without the income from CERs sale

CERs	IRR
Without Income from Selling CERs	5.52%
With Income from Selling CERs	9.95%

2) Analysis of farmers' capability of providing proprietary investment

To understand farmers' capability of providing proprietary investment, the study team analyzed the income and expenditure data provided by National Bureau of Statistics of China. The results show that most farmers in Hunan Province cannot afford the proprietary money needed for building a biogas digester. Tables 10 and 11 show the cash flow situation of farmers in Hunan Province.

Table 10 Net income per capita of Hunan rural residents in the first half of 2007

	Cash Income (Yuan)	Proportion(%)
Total Annual Income Per Capita	5360.14	—
Cash Income during the Period	4198.2	100%
Wage Income	1740.4	41.5%
Family Income from Other Economic Activities	2011.8	47.9%
Property Income	34.8	0.8%
Transfers	411.2	9.8%

Note1: Data source: Statistical Data from the National Bureau of Statistics of China, 2009a

Table 11 Cash expenditure per capita of Hunan rural households in 2007

	Cash Expenditure (Yuan)	Proportion(%)
Cash Expenditures during the Period	4081.2	100.0%
Production Costs	937.4	23.0%
Taxes and Fees Expenditure	8.8	0.2%
Living Cash Expenditures	2699	66.1%
Property Expenditures	5.2	0.1%
Transfers Expenditures	431	10.6%

National Bureau of Statistics of China, 2009b
Data obtained based on the first half of 2007

A typical farmer in Hunan Province has an average annual income of RMB 5,360, of which RMB 4,198 is in cash and RMB 1,165 in other income. The farmer has an average annual expenditure of RMB 4,081, of which RMB 2,699 is for living expenditure, or 66.1 per cent of the total expenditure in cash; and RMB 937 for production activities, or 23.0 per cent of the total expenditure. Income and expenditure are almost balanced without much saving. In the context of current year net cash flow, the farmer cannot afford proprietary fund for one-plus-three model with the net income.

The biogas produced from the one-plus-three model will only be used by farmers themselves, without marketable products. As a result, the benefit derived from the model is the saving on expenditure, rather than cash income. Official fund raising channels do not provide loans to non-production activities. In this context, it is almost impossible for farmers to get loans for biogas activities from commercial banking institutions.

1.6.4.2 Technical obstacles (IESDA-CAAS,World Bank Consultation Report —Feasibility Study Report of Animal Waste CDM Project, 2008)

One-plus-three model is a systematically integrated project, covering animal breeding, biogas digester construction, and associated daily operation and maintenance. Smooth operation of biogas digesters means ensuring an environment desirable for microbe fermentation, with appropriate temperature, anaerobic condition, material mixture, and concentration of organic matters. Therefore, technical support and trained technical personnel are needed.

At present, biogas digester construction and maintenance in the rural areas are mainly conducted by biogas technicians. Biogas technicians have to pass an official examination for the certificate as an approved technician awarded by the Ministry of Agriculture. However, along with the ascending employment cost, it is becoming difficult to keep biogas technicians in the village. Biogas technicians make their money mainly from their involvement in a biogas project. According to a briefing by the rural energy offices in Hunan, it will take 7 days for a biogas technician to complete the construction of a biogas digester. A biogas technician will be paid RMB 400-500 for the package deal, or RMB 55-65 per day. In addition, the biogas technician is supposed to provide free maintenance service for one year. Most biogas technicians are craftsmen coming from the rural areas. The ascending labor cost allows them to earn some RMB 100 a day if they are engaged in other economic activities. Apparently, the payment to building a biogas digester is relatively low. Plus, because of the limited payment capability of biogas digester owner, it is difficult for a biogas technician to make money through the biogas projects. The situation has seriously affected biogas technicians' enthusiasm to build and maintain biogas digesters.

In summary, obstacles analysis shows that without the help of a CDM project, farmers will not be in a position to build biogas digesters and would rather continue to treat animal manures in an anaerobic septic digester, and cook food using coal, straw, and firewood. In addition, the biogas produced from the one-plus-three model will only be used by farmers themselves, without marketable products. As a result, the economic benefit produced from the model is the saving on expenditure, rather than cash income. No official banking institutions are willing to provide loans to non-productive activities. To facilitate the construction of biogas digesters and attract the involvement of lower and middle-income farmers in the project, additional financial support has to be secured for the farmer households who are willing to build a biogas digester. Both farmers' proprietary fund and current subsidy level cannot meet the needs. Therefore, additionality exists for a CDM project.

2. Feasibility study on CDM methodology for conservation tillage

2.1 Introduction

Conservation tillage is an integrated tillage system in which large amounts of crop straws are used to cover the soil and minimize all the possible tillage activities. Conservation tillage, which employs the technologies such as no-tillage or minimum tillage, micro-terrain rebuilding, land covering, and controlling weeds with herbicides, is aimed to reduce the disturbance and increase the straw coverage to soil (Gao HW, 2005; Gao WS, 2007; Li HW, 2008). It is composed of four essential components (Di Y, 2008):

- Planting techniques without tillage;
- Covering soil with straws or plant residues;
- Deeply loosing the soil; and
- Integrated control techniques on weeds and pests.

Comparing with the traditional tillage practice, conservation tillage can increase soil organic carbon content with the following reasons:

1) It can reduce the disturbance on soils to protect soil organic matter from oxidization and mineralization.

2) Straw coverage adds more soil organic carbon, which means conservation tillage may increase soil organic carbon in different degrees (Campbell et al., 1996).

3) Conservation tillage affects soil temperature and moisture status, which in turn affects soil carbon stock indirectly. Soil temperature affects microorganisms' activity, and determines the decomposing speed of soil organic matter (Wang SQ and Liu J Y, 2002). Fortin M.C. et al found that traditional tillage practice compared

with no-tillage practice would result in a high soil temperature that helps release more carbon dioxide in the early growing stage. Many previous studies (Liang Y L, 1997; Cai D X et al, 1995; Steiner, 1989) have shown that no-tillage practice is able to increase soil moisture, while the dry-wet cycle induced by traditional tillage practice accelerates the mineralization of soil and the decomposition of soil organic matter (Yang J C et al., 2003).

4) Different tillage practices may have different effects on microorganisms' activity, which may lead to varying accumulation of organic matter in soils. Previous studies (Staley, 2001; Wang et al., 1994) suggested that compared with traditional tillage practices, more microorganisms, wireworms, and arthropods are likely to live in the soils under no-tillage practices. The diversity of soil micro-organisms and fauna can enhance the microbial biomass carbon noticeably in soils.

Conservation tillage also enhances the soil productivity and sustainability. Meanwhile, conservation tillage can also cut down the consumption of energy, reduce environmental pollution caused by straw burning, and avoid the loss of organic matter. Due to the advantages mentioned above, conservation tillage has been widely accepted as one of the approaches for emission reduction and carbon sequestration by the international society (Di Y, 2008).

Food and Agriculture Organization (FAO) states in *"Food and Agriculture Institution Newsletter"* and *"World agriculture: towards 2015-2030"* that conservation tillage is a new revolution for tillage practice and is a win-win tillage system for agricultural production and environmental protection. In the coming 10-20 years, conservation tillage will play an increasingly active role in the sustainable development of agriculture. International Soil Tillage Research Organization believes that conservation tillage, as a successful example of soil protection, is a sustainable agricultural practice that can coordinate the development of both food production and environmental protection (Di Y, 2008).

In 1997, Kyoto Protocol was adopted at the Third Conference of the Parties (COP3) held under the United Nations Framework Convention on Climate Change (UNFCCC). Kyoto Protocol defined the legally binding greenhouse gases emission reduction targets for Annex I countries (i.e., developed countries and economy transforming countries) over the first commitment period 2008-2012. It also imposed some restrictions on Land Use, Land-Use Change and Forestry (LULUCF) activities, explicitly asking the developed countries and economy transforming countries to implement their emission reduction obligations through afforestation (Article 3.3 in Kyoto Protocol) and other activities that can increase the carbon stock of terrestrial ecosystems (Article 3.4 in Kyoto Protocol) (UNFCCC, 1997).

The Seventh Conference of the Parties (COP7) of the UNFCCC, held in 2001, adopted Marrakesh Accords, which established the modalities and procedures for Annex I Parties to account the carbon stock derived from afforestation, reforestation, deforestation, forest management, cropland management, grazing land management, and revegetation (UNFCCC, 2001). Annex I Parties are encouraged to initiate afforestation or reforestation-related Clean Development Mechanism (CDM) projects in the developing countries to fulfill their own emission reduction obligations using the carbon stock derived from such activities. However, forest management, cropland management, grassland management, and revegetation are not eligible as project activities under CDM defined in the Marrakech Agreement. As a result, UNFCCC CDM Executive Board has not yet approved any CDM methodology for increasing cropland soil carbon stock through conservation tillage practice.

At present, the international climate change agreement post-2012 is still under negotiation. It is still uncertain if cropland management, including conservation tillage practice, can become an eligible project activity under CDM post-2012. Therefore, considering the effects of conservation tillage of enhancing the soil carbon stock, incentives for farmers to take actions of enhancing carbon sequestration, as well as providing technical support for reaching an international climate change agreement and associated implementation post-2012, it is necessary to conduct a feasibility study of conservation tillage as an eligible project activity under CDM and methodology guidelines.

2.2 Conservation tillage in China and other countries

2.2.1 Conservation tillage in other countries

Conservation tillage has been steadily accepted and applied in more than 70 countries since the 1980's. According to the statistics by FAO, areas where conservation tillage is adopted have reached 169 million ha in the world, which occupied 11 per cent of the world's total cropland area. The total non-tillage cropland area of 74.76 million ha accounts for 4.9 per cent of the world's total cropland area (Table 12) (Department. of Agricultural Mechanization, Chinese Ministry of Agriculture, 2008). Conservation tillage mainly desirable for growing upland crops has been widely applied in northern and southern America. For example, some countries, including the United States, Brazil, Argentina and Paraguay, and Australia in the southern hemisphere, have registered 60 per cent or more cropland under conservation tillage practice. Compared with these regions, Asian and African regions are relatively limited in their application of conservation tillage, whose practice would become the focus of future agricultural development (Gao H W et al, 2008).

Table 12 Conservation tillage (CT) in some countries (2002)

Regions	Country	Total cropland area 10^4 ha	Conservation Tillage*		No-tillage	
			The Area of Conservation Tillage 10^4 ha	Percentage of the total area (%)	The Area of No-tillage 10^4 ha	Percentage of the total area (%)
North America	USA	11400	6769	60	2241	19.7
	Canada**	4256	1300	70	408	9
	Mexico	2520	—	—	65	2.6
South America	Brazil	5330	3990	74.8	1735	32.6
	Argentina	2500	2000	80	1450	58
	Paraguay	220	178	80.1	130	59.1
	Bolivia	187	94	50.3	42	22.5
	Uruguay	126	60.3	47.9	25	19.8
	Venezuela	264	—	—	17	6.4
	Chile	198	—	—	13	6.6
	Colombia	193	—	—	7	3.6
Europe	Belgium	76.8	14	18.2	0.92	1.2
	Republic of Ireland	134.3	1	0.7	0.01	0.3
	Slovakia	147.8	14	9.5	1	1.01
	Switzerland	42	12	28.6	0.9	3
	France	1830.5	300	16.4	15	0.82
	Germany	1183.2	237.5	20.1	35.4	2.99
	Portugal	215.3	3.9	1.8	2.5	1.16
	Denmark	236.5	23	9.7	11.8	5
	United Kingdom	538	144	26.8	2.4	1.02
	Spain	1434.4	200	13.9	30	2.09
	Hungary	482	50	10.4	0.8	0.17
	Italy	828.3	56	6.8	8	0.97
Africa	South Africa	1536	—	—	30	1.9
	Ghana	285	—	—	4.5	1.6
Australia		2000	1460	73	900	45
Asia and other countries		—	—	—	≥200	—
Total	The Total Area of Tillage in The World 150000		≥16906	≥11.3	≥7476.2	4.9

* Data on no-tillage area; some countries report no data on conservation tillage.
** Conservation tillage is mainly adopted in three agricultural provinces in Canada.
Source: Department of Agricultural Mechanization, Chinese Ministry of Agriculture, 2008.

2.2.1.1 North America

United States: United States is one of the earliest countries that started the study on conservation tillage. In the 1930s, the "Dust Bowl" that swept across the United States forced Americans to study and apply conservation tillage in the west region. In the 1930s-1940s, the straw cover approach stopped the wind erosion in the western prairies. In the 1950s-1960s, ridge tillage was introduced to reduce soil erosion and improve soil drainage. In the 1960s, no-tillage seeders and herbicides were developed to allow widespread applications of conservation tillage in the country. Minimum tillage, no-tillage, strip tillage, or ridge tillage had been applied in 27 per cent of American farms in 1998. The cropland area under conservation tillage reached 44.15 million ha in 2000 and 67.66 million ha in 2002. All the cereal production activities have employed conservation tillage technologies in USA (Gao W H et al., 2008). In 2004, the cropland area under conservation tillage accounted for 62.2 per cent of the nation's total, which was 69.69 million ha (Li Y J et al., 2008). The conservation tillage area in the United States during 1990-2004 was published by Conservation Technology Information Center (CTIC) (Table 13).

Table 13 The area of conservation tillage and its percentage of sowing area and other farming methods in the USA (1990-2004), unit Mha, %

	1990	1992	1994	1996	1998	2000	2002	2004
Different Types of Conservation Tillage (Straw Coverage Rate after Sowing>30%)								
No-tillage	6.84	11.37	15.74	17.36	19.34	21.12	22.38	25.25
	6.00%	9.90%	13.70%	14.80%	16.30%	17.50%	19.70%	22.60%
Ridge Tillage	1.21	1.38	1.46	1.38	1.42	1.34	1.13	0.89
	1.10%	1.20%	1.30%	1.20%	1.20%	1.10%	1.00%	0.80%
Straw Cover Farming	21.56	23.18	22.98	23.26	23.43	21.65	18.21	19.42
	19.00%	20.20%	20.00%	19.80%	19.70%	18.00%	16.00%	17.40%
The Total Area of Conservation Tillage	29.62	35.93	40.18	42	44.18	44.14	41.71	45.56
Other Farming Methods (Straw Coverage Rate after Sowing<30%)								
Reduced-tillage (15%-30%)	28.73	29.7	29.62	30.27	31.61	24.81	25.94	24.12
	25.30%	25.90%	25.80%	25.80%	26.20%	20.60%	22.80%	21.50%
Total of the Straw Management	58.36	65.63	69.81	72.28	75.8	68.96	67.66	69.69
	51.30%	57.30%	60.80%	61.50%	61.50%	67.20%	59.40%	62.20%
Traditional Tillage (0-15%)	55.32	48.89	45.08	45.16	42.94	51.44	46.26	42.25
	48.70%	42.70%	39.30%	38.50%	36.20%	42.70%	40.60%	37.70%
The Total Sowing Area in United States	113.68	114.49	114.89	117.44	118.73	120.39	113.88	111.94

Source: United States Conservation Tillage Information Center (CTIC) and Reports of Crop Stubble Management (2004).

Canada: Before the 1960s, moldboard plowing was popularly applied in Canadian farms. Excessive tillage and less plant residue return had made soils vulnerable to wind and water erosion. Canadians started to introduce conservation tillage and corresponding studies from the 1960s. In the 1970s-1980s, farming machines and herbicides were successfully developed to support conservation tillage practice. In 1985, conservation tillage had been widely applied in three major agricultural provinces. In 1996, Canada registered 4,955 million ha of cropland area under conservation tillage system, 12 per cent of the nation's total cropland area (Wang C S et al., 2004). At the end of 2002, 60 per cent cropland area had adopted conservation tillage and moldboard plowing was entirely disappeared in Canada (Gao H W et al., 2008).

2.2.1.2 Latin America

Latin America has practiced the fast development and application of conservation tillage practice though with a late start. It has become the region where the proportion of farms applying conservation tillage has been the highest in the world; is the second largest conservation tillage area after North America.

Brazil: Brazil introduced conservation tillage practices at the end of the 1970s, when the area was 1.3 million ha and only took up 0.3 per cent of the nation's total cropland area. A decade later, conservation tillage cropland area increased to 9 million ha, while the proportion jumped to 23 per cent of the nation's total cropland area. The development of conservation tillage practice accelerated in 1990s which reached up to 14.34 million ha at the end of the decade, equivalent to 36 per cent of the nation's total. In 2004, conservation tillage cropland area reached to 23.1 million ha, approaching 60 per cent of the nation's total cropland (Di Y, 2008).

Argentina: Argentina started to try no-tillage system in 1974. The conservation tillage area remained very limited, only 25,000 ha, until 1986. The period from the end of 1980s to the early 1990s marked the fast popularization of the practice. In 1996, Argentina placed 4.4 million ha of cropland under no-tillage system. At the end of 2002, conservation tillage area accounted for more than 20 million ha, exceeding 80 per cent of the nation's total cropland (Gao H W et al, 2008).

Other countries: Paraguay started to adopt no-tillage practice in the 1980s. With a fast popularization rate, it registered 50×104 ha of no-tillage cropland, mainly for soybean, in 1998. Meanwhile, 65 per cent of mechanized large farms in the country have adopted no-tillage practice. Bolivia introduced no-tillage practice in 1986. In 1996, it had placed 10.2 ×104 ha of cropland under the practice. No-tillage practice had been adopted at about 35 per cent of wheat growing land in Bolivia (Supply and Demand Information Center of Chinese San-nong, 2007).

2.2.1.3 Australia

Australia started to work on conservation tillage in the 1970s, with an accelerated spread in the 1980s. During the period of 1996-2002, conservation tillage cropland went from 60 per cent to 73 per cent in acreage (IGao H W et al., 2008). Ninety five per cent of summer grain crops and 60 per cent of winter crops have been grown under conservation tillage practice (Li H W and Hu L F, 2008).

2.2.1.4 Europe

The development of conservation tillage practice in Europe is fast though it started relatively late. Twelve countries have applied this practice. Total acreage sees no large difference with northern American counterpart and basically matched with South America (No-tillage Practice at Domestic and Abroad, 2008). Most areas of Europe have abundant rainfall, with light soil erosion. Simplifying agricultural production procedures and reducing the cost of production became the momentum to introduce conservation tillage system in the 1980s in some countries including Germany, France, and Switzerland. The last decade has witnessed a large increase of conservation tillage area in those countries with 16 per cent~28 per cent of the cropland adopting the practice (Conservation Tillage Practice Abroad, 2008).

2.2.1.5 Africa

According to the statistics by FAO in 1993, a large number of countries, including Angola, the Republic of Benin, Ghana, Sudan, Côte d'Ivoire, Kenya, Mozambique, Nigeria, South Africa, Algeria, Tanzania, Zambia, and Zimbabwe, have introduced no-tillage practice. Unfortunately, the practice has not yet been widely accepted by local farmers (Zou Y B, 2004).

2.2.2 Conservation tillage and relevant policies in China

2.2.2.1 Conservation tillage in China

Experiment on conservation tillage started in the 1960s in China. In the 1970s, efforts in introducing straw coverage, minimum tillage, and no-tillage practice yielded impressive increases in grain production. (Zhang F et al., 2004). In the 1980s, some studies on conservation tillage technologies were started such as whole stubble coverage based no-tillage (Ji Z S, 1995), stubble coverage based reduced tillage (Shi S B et al., 1990), minimum or no-tillage practice (Ma D M et al., 1998), high stubble coverage based minimum tillage (Zhao E L, 1998), and covered deep loosing and seeding practice (Li Q J, 1996). These efforts promoted the early application of conservation tillage in China with different technologies. Conservation tillage was first introduced in Hebei, Liaoning, Inner Mongolia, and Gansu on a trial basis. The Ministry of Agriculture started a pilot project for conservation tillage in 2002. In 2003 and 2004, the Ministry of Agriculture recommended an array of no-tillage seeders for wheat and corn to farmers. From 2005, demonstration areas under conservation tillage had been extended to northern China (Gao H W et al., 2008). Since 2002, China has established 173 national demonstration sites and 328 provincial demonstration sites in 15 provinces, municipalities, and autonomous regions in the north China. There are currently about 2.0 million ha of cropland in China subject to conservation tillage, 6.67 million ha of cropland with no tillage, 20.0 million ha of cropland with returning of crop straw to the field. The application of conservation tillage technologies has led to an increase of food production by more than 0.4 million tons, reduced water consumption of 1.2 billion m^3, reduced cost of 0.9 billion Yuan, decreased soil erosion by 30 to 60 million tones a year. The practice also cuts down dust production at farms by 0.6 million tons and 1.25 million tons of CO_2 emission (Zhang B W, 2008).

2.2.2.2 Policies on developing conservation tillage in China

1) Policies on developing conservation tillage

Conservation tillage has numerous benefits to agriculture as mentioned in the introduction section. The Chinese government has paid great attention to the popularization of conservation tillage practice in recent years enacting a range of documents to promote the development of conservation tillage since 2005.

"Comments on several policies concerning integrated production capacity building of the rural areas" (Zhongfa [2005] No. 1), a CPC Central Committee and State Council document, call for to "reform traditional tillage systems and develop conservation tillage practice."

"Several comments on promoting the construction of socialist new rural areas" (Zhongfa [2006] No.1), a CPC Central Committee and State Council document,

stating that efforts shall be carried on implementing more conservation tillage pilot projects and subsidizing the pilot projects aiming at raising soil organic matter.

"Several comments on developing modern agriculture and promoting the construction of socialist new rural areas in a steady manner" (Zhongfa [2007] No.1), a CPC Central Committee and State Council document, proposing to change the existing tillage and planting systems, and subsidize no-tillage popularization projects.

"Several comments on strengthening the construction of agricultural infrastructures, and raising farmers' income through promoting the development of agriculture" (Zhongfa [2008] No. 1), a CPC Central Committee and State Council document, instructing to continue the implementation of conservation tillage projects and support large farming machine facilitated farmers, and special farming machinery service companies.

To implement principles stated by the CPC Central Committee and the State Council, to introduce major modern farming initiatives, to enhance the efforts in promoting the adoption of conservation tillage and sustainable agricultural development, the Chinese Ministry of Agriculture published in 2007 the "Comments on the vigorous development of conservation tillage practice". This publication stipulated the targets for the 11^{th} five-year plan period, and proposed that the area under conservation tillage shall exceed 4 million ha, 6 per cent of the cropland area suitable for conservation tillage in northern China at the end of the 11^{th} five-year period (2006-2010). It also called for the establishment of a sound technical support system for conservation tillage practice, improve the quality of machines, and enhance the integrated ecological, economic, and social benefits of such practice in the regions where conservation tillage are adopted.

2) National development plan for conservation tillage

To promote conservation tillage, the Ministry of Agriculture and National Development and Reform Commission published *Conservation Tillage Development Plan for the Period of 2009-2015,* in which detailed targets were proposed for promoting conservation tillage. The development plan will allocate an investment of RMB 3.66 billion, of which RMB 1.87 billion will be provided by the government. Six major agricultural areas, including Northeast Plains (ridge tillage), drought and windy areas in the western part of the northeast China, Loess Plateau areas in northwest China, oasis farming areas in northwest China, Great Wall areas in northern China, and two crop rotation areas in Yellow River - Huaihe valley, will be the main areas in implementing the development plan. It is planned to establish 600 high-quality and high-yield conservation tillage sites (1.33 million ha in total) in 6 years. The efforts will place 11.33 million ha of cropland under conservation tillage through governmental support (MOA and NDRC, 2009). The targets of the *Conservation Tillage Development Plan* are listed in Table 14.

Table 14 Targets defined in the conservation tillage development plan (2009-2015)

Item	
Conservation tillage regions	600
Conservation tillage area	1.33 million ha
Accounted for total cropland	3.1%
Soil moisture increase	15%
SOC[1/] increase	0.01 - 0.06 percentage points
Reduce surface soil loss	40% - 80%
Cut down cropland dust production	50%
Diesel consumption reduced	40,000 - 50,000 tons/yr
Fertilizer application reduced	500,000 - 700,000 tons/yr
Water saving	0.3 - 0.6 billion m^3
Crop yield increase	>5%
Total grain production increase	250,000 tons
Cost decrease	225 - 450 Yuan/ha
Total lose reduced	0.3 - 0.6 billion Yuan/yr

1/ Soil Organic Carbon stock
Source: MOA and NDRC, 2009

2.2.3 Effect of conservation tillage on soil carbon stock in China

Conservation tillage also affects the vertical distribution of soil organic matter. Through their 10-year field experiments started from 1973, Blevins et al. (1983) found that soils under no-tillage practice had twice the organic carbon content than that of the tillage practice in top soils (0-5cm), which can be explained by the reduced mineralization of soil organic matter and increased organic supply from plant residues. Jin F S et al. (2000) found that organic carbon, total nitrogen, available phosphorous, and available potassium in the top 0-10cm of soil had an extremely significant linear regression with straw coverage quantity. Many previous studies (Stockfisch et al., 1999; Wright et al., 2005) indicated that conservation tillage was able to increase organic matter in the top 0-20cm of soil. The top soil layer under no-tillage practice obtained its organic carbon mainly from plant residues, leading to a noticeable increase of organic carbon compared with lower soil layers. Traditional tillage practice would turn the lower soil layer up to the top layer, allowing humus to be oxidized. The newly formed humus, on the other hand, would not be enough to compensate the humus that has been decomposed, which would result in decreased organic matter content. No-tillage practice allows plant roots to go through the humification process under the anaerobic environment, which enable the accumulation of organic matter. However, some studies (Gao X P et al., 2002) showed that straw cover may raise the organic matter content in the top 0-20cm of soil at a pear farm, with slightly reduced organic matter in the lower part of soil (20-40cm). Some other studies (Li W, 2009) suggested that soils under conservation tillage had higher organic matter than under traditional tillage practice started from the sowing period, and that soil organic matter would come down along with the increasing depth of soil profile. Under the traditional tillage practice, organic matter does not change dramatically in vertical profile (Alvarez et al., 1995).

Tillage studies have expanded from wheat and corn to other crops. For example, Tang X H et al. (2007) did the research of rice grown in the purple soil in Sichuan basin, and concluded that conservation tillage benefited the formation of large aggregates at top soil and the raise of the total soil organic carbon. Xiao J Y et al. (2002) believed that the paddy fields under long-term no-tillage practice had an enhanced soil fertility and organic matter content compared with traditional tillage practice. Hu S H (2008) studied the impacts of growing horsebean on soil moisture and nutrients, and concluded that no-tillage practice was able to remarkably increase the respective content of organic matter, alkali-hydrolized nitrogen, available phosphorous, and available potassium.

2.3 Recommendation on CDM methodology for conservation tillage

To ensure environmental benefits derived from CDM projects, a CDM project shall produce real, measurable, and long-term benefits in terms of carbon sequestration. In this context, it is necessary to establish an effective, transparent, and operational methodology. The methodology shall include applicability, project boundary, assessment on additionality, determination of baseline, method for estimating changes in soil organic carbon stocks and other GHG emissions, and associated monitoring plan.

2.3.1 Applicability

Straw in paddy soils is a major source of methane emission. Global warming effect caused by increased methane emission is larger than the sequestrated soil organic carbon in terms of CO_2 equivalent in the flooded soils. This is because methane has a higher global warming potential than CO_2. Therefore, conservation tillage project activity under CDM is only recommended to be applicable in dry land.

The conditions under which the methodology is applicable are:

- CT project activity is implemented on dry land, which is expected to remain conventional tillage in the absence of the project.
- Returning straw to the field with reduced tillage is also applicable.
- Only changes in SOC stock is eligible carbon pool.

2.3.2 Project boundary

The "project boundary" geographically delineates the CT project activity under the control of the project participants (PPs). The CT CDM project activity may contain more than one discrete area of land. Each discrete area of land shall have a unique geographical identification.

The determination of project boundary in advance is necessary for the estimation of project area. There are various methods to determine the boundary of a project. Land registration book or archives and GPS are recommended for the description of conservation tillage CDM project boundary. To ensure the precision and accuracy, the scale of the base map should be at least 1:10,000 and cannot be lower than 1:50,000.

2.3.3 Baseline scenario and additionality

Baseline for a CDM project is the scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity. One may chose one of the following methodologies to define a baseline for a CDM project:

1) Existing actual or historical emissions, as applicable;

2) Emissions from a dominant technology that represents an economically attractive action, taking into account barriers to investment;

3) Average emissions of similar project activities undertaken in the previous

five years, under similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category.

To avoid giving credits to projects that would have happened anyway ("free-riders"), rules have been specified to ensure additionality of the project, i.e., to ensure the project reduces emissions more than that would have occurred in the absence of the project. There are currently two rival interpretations of the additionality criterion:

- What is often labelled 'environmental additionality' posses that the project is additional if the emissions from the project are lower than the baseline. It is generally regarded as what would have happened without the project.
- In the other interpretation, sometimes termed 'project additionality' means that the project must not have happened without the CDM. (http://en.wikipedia.org)

UNFCCC (2008) provided Afforestation /Reforestation Methodological tool "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities". In this report, the identification of baseline scenario and demonstration of additionality in CT CDM project activities applied similar approach with A/R methodological tool mentioned above. The following steps should be applied:

- STEP 1. Identification of alternative scenarios;
- STEP 2. Barrier analysis;
- STEP 3. Investment analysis (if needed); and
- STEP 4. Common practice analysis.

STEP 1. Identification of alternative tillage scenarios to the proposed CT CDM project activity

This step serves to identify alternative tillage scenarios to the proposed CDM project activity that could be the baseline scenario, through the following sub-steps:

Sub-step 1a. Identify credible alternative tillage scenarios to the proposed CDM project activity

Identify realistic and credible tillage scenarios that would have occurred on the cropland within the proposed project boundary in the absence of the CT project activity under the CDM. Provide a list of credible alternative tillage scenarios that would have occurred on the cropland within the project boundary of the CT CDM project activity.

Sub-step 1b. Consistency of credible alternative tillage scenarios with enforced mandatory applicable laws and regulations

Review and assess compliance tillage scenarios identified in sub-step 1a with all mandatory applicable legal and regulatory requirements; remove from the tillage scenarios identified in sub-step 1a which are not in compliance with applicable mandatory laws and regulations. List of plausible alternative tillage scenarios to the CT CDM project activity that are in compliance with mandatory legislation and regulations.

If the list resulting from the Sub-step 1b contains only CT scenario, the proposed CT CDM project activity is not additional.

STEP 2. Barrier analysis

This step serves to identify barriers and to assess which of the tillage scenarios identified in sub-step 1b are not prevented by these barriers.

Sub-step 2a. Identification of barriers that would prevent the implementation of at least one alternative tillage scenario

Identify realistic and credible barriers that prevent realization of the tillage scenarios identified in Sub-step 1b. Such barriers may include, among others:

- Investment barriers, other than insufficient financial returns as analyzed in Step 3, inter alia:
    - Similar activities have only been implemented with grants or other non-commercial finance terms. In this context similar activities are defined as activities of a similar scale that take place in a comparable environment with respect to regulatory framework and are undertaken in the relevant geographical area;
    - No private capital is available from domestic or international capital markets due to real or perceived risks associated with investments in the country where the CT project activity is to be implemented, as demonstrated by the credit rating of the country or other country investment reports of reputed origin;
    - Debt funding is not available for the tillage scenarios;
    - Lack of access to credit.

- Technological barriers, inter alia:
  - Lack of access to necessary machinery;
  - Lack of infrastructure for implementation of the technology.

- Barriers related to local tradition, inter alia:
  - Traditional knowledge and practices;
  - Traditional equipment and technology.

- Barriers due to prevailing practice, inter alia:
  - The CT scenario is the "first of its kind": No activity of this type is currently operational in the host country or region.

List of barriers that may prevent one or more tillage scenarios identified in the Step 1b.

Sub-step 2b. Elimination of tillage scenarios that are prevented by the identified barriers

Determine which tillage scenarios identified in Sub-step 1b are prevented by at least one of the barriers listed in sub-step 2a. The assessment of a barrier may take into account the level of access to and availability of information, technologies and skilled labour in the region where the planned CT CDM project activity is located. Eliminate these scenarios from further consideration. Include all tillage scenarios that were identified in Sub-step 1b and were not eliminated in Sub-step 2b into the list of tillage scenarios that are not prevented by any barrier.

In applying sub-steps 2a and 2b, provide transparent and documented evidence to demonstrate the existence and significance of the identified barriers. The type of evidence to be provided may include:

Relevant legislation, regulatory information or environmental /natural resource management norms, acts or rules;

- Relevant studies or surveys (e.g. technology studies, etc);
- Relevant data from national statistics;
- Documents prepared by the project developer, contractors or partners in the context of the proposed project activity or similar previous project implementations;
- Written documentation of independent expert judgments.

STEP 3. Investment analysis

This step serves to determine which of the remaining tillage scenarios identified in Sub-step 2b is the most economically or financially attractive.

- Apply simple cost analysis, investment comparison analysis or benchmark analysis to conduct an investment comparison analysis;
- Conduct a sensitivity analysis to assess whether the initial conclusion regarding the financial attractiveness of the baseline scenario is robust to reasonable variations in the critical assumptions;
- Identification of the most economically and/or financially attractive tillage scenario within the boundary of the proposed CT CDM project area according to the most suitable financial indicator, taking into account the results of the sensitivity analysis.

STEP 4. Common practice analysis

Provide an analysis to which extent similar CT activities to the one proposed as the CT CDM project activity have been implemented previously or are currently underway. Similar CT activities are defined as that which are of similar scale, take place in a comparable environment, inter alia, with respect to the regulatory framework and are undertaken in the relevant geographical area, subject to further guidance by the underlying methodology.

If CT activities similar to the proposed CT CDM project activity are identified, compare the proposed project activity to the other similar CT activities and assess whether there are essential distinctions between them. Essential distinctions may include a fundamental and verifiable change in circumstances under which the proposed CT CDM project activity will be implemented when compared to circumstances under which similar CT were carried out. For example, barriers may exist, or promotional policies may have ended. If certain benefits rendered the similar CT activities financially attractive (e.g., subsidies or other financial flows), explain why the proposed CT CDM project activity cannot use the benefits. If applicable, explain why the similar CT activities do not face barriers to which the proposed CT CDM project activity is subject.

If Step 4 is satisfied, i.e. similar CT activities can be observed and essential distinctions between the proposed CT CDM project activity and similar CT activities cannot be made, the proposed CT CDM project activity is not additional. Otherwise, the proposed CT CDM project activity is not the baseline scenario and, hence, it is additional.

China had a late start in working on conservation tillage. As a result, there are still many challenges ahead, though it has achieved noticeable progress in expansion of the conservation tillage practice.

- The technique system is not comprehensive. China, as a large country, has widely differing climate, soil, economy, and culture, with diversified crops and farming systems. Some experiments on the soils unsuitable for conservation tillage have resulted in the reports saying there is no difference between conservation tillage and traditional tillage practices (Zhang L S, 2007). CT techniques vary in different regions in terms of climate, soils, and crops. Apparently, one has to identify the right conservation tillage techniques under different conditions. It is still on the way to find the appropriate techniques to meet the needs of different cropping regions in China (Xie R Z et al., 2008).
- The cost of tillage machines is higher. China has achieved laudable results in introducing conservation tillage. Unfortunately, custom-built farming machines are still not available in many provinces. On the other hand, imported machines are still not affordable for most farmers. The capability of domestic machines and lower income of farmers relative to the expensive imported machines limited the widespread popularization of conservation tillage in China.
- The investment and matched technique system still needs to be improved. Many popularization procedures for conservation tillage need financial support, including the machine operation process, personnel subsidy, dissemination etc. The limited promotion funds from central and local governments have impacts on the initiative and motivation of farmers to buy the machines. The conservation tillage machines also have various problems regarding quality, such as the limited performance, frequently failure of normal function, lower efficiency, lacking technological training for the drivers, insufficient service ability, and so on.
- There are negative impacts of conservation tillage. No-tillage maintains soil water content and protects soils from erosion, and it also increases soil organic matter. However, it still has many shortcomings such as it cannot wipe out weeds and pests physically. Application of herbicides may increase the risk of pollution on the soil, and also impact the quality of grains and the biodiversity. Additionally, no-tillage may affect the quality of sowing and seedling emergence, which in turn may dampen farmers' enthusiasm for adopting conservation tillage.

In summary, China faces critical obstacles in both financial and technical aspects for extensive popularization of conservation tillage. In addition, it has to overcome other potential obstacles such as the metal and organic pollution derived from the herbicides and pesticides on the environment. Those factors may restrict the application of conservation tillage on an extensive basis. Without financial incentives of CDM projects, most area of China will continue the traditional tillage practice. Therefore, it is reasonable to use the current traditional tillage practice as the baseline scenario. CDM projects which increase the soil organic carbon stock through conservation tillage makes it have a strong additionality in China.

Table 15 Gases and emission sources within the project boundary

	Emission source	Gas	Included or excluded	Interpretation
Baseline	Cropland soil	CO_2	Included	Tillage practice affects soil CO_2 emissions, which in turn affects soil organic carbon content
		N_2O	Included	Agricultural soil is a major emission source of N_2O
		CH_4	Excluded	CH_4 is excluded due to no CH_4 emission in upland soil
	Emissions from straw burning on site	CO_2	Excluded	Omitted for simplification and conservative
		N_2O	Excluded	Omitted for simplification and conservative
		CH_4	Excluded	Omitted for simplification and conservative
	Emissions from consuming fossil fuels under tillage	CO_2	Included	Major CO_2 emission sources
		CH_4	Excluded	Omitted for simplification
		N_2O	Excluded	Omitted for simplification
Project activity	Cropland soil	CO_2	Included	Tillage practice affects soil CO_2 emissions, which in turn affects soil organic carbon content
		N_2O	Included	Agricultural soil is a major emission source of N_2O
		CH_4	Excluded	CH_4 is excluded due to no CH_4 emission in upland soil
	Emissions from straw burning on site	CO_2	Excluded	Omitted for simplification and conservative
		N_2O	Excluded	Omitted for simplification and conservative
		CH_4	Excluded	Omitted for simplification and conservative
	Emissions from consuming fossil fuels under tillage	CO_2	Included	Major CO_2 emission sources
		CH_4	Excluded	Omitted for simplification
		N_2O	Excluded	Omitted for simplification

2.3.4 Calculation of project emission reduction

2.3.4.1 Soil carbon stock

Formula (1) is applied to calculate soil organic carbon stock in the top 20 cm of soil in stratum a, sampling site i, parcel of land p, under baseline scenario.

$$C_{B,SOC_{a,i,p}} = C_{B,SOC_{sample_{a,i,p}}} \times BD_{B,a,i,p} \times Depth \times (1 - FC_{B,a,i,p}) \times F \times 44/12 \quad (1)$$

where,

$C_{B,SOC_{a,i,p}}$	Soil organic carbon stock in the top 20 cm of soil for stratum a, sampling site i, parcel of land p, under baseline scenario, in unit of $tCO_2 \cdot ha^{-1}$
$C_{B,SOC_{sample_{a,i,p}}}$	Soil organic carbon content in the top 20 cm of soil for stratum a, sampling site i, parcel of land p, under baseline scenario, in unit of g $C \cdot 100g^{-1}$ soil
$BD_{B,a,i,p}$	Soil bulk density in the top 20 cm of soil for stratum a, sampling site i, parcel of land p, under baseline scenario, in unit of $g \cdot cm^{-3}$
$Depth$	Top soil depth, 20 cm
$FC_{B,a,i,p}$	Percentage of rocks, roots, and other dead residues with a diameter larger than 2mm in the top 20 cm of soil, for stratum a, sampling site i, parcel of land p, under baseline scenario
F	Unit conversion coefficient turning soil carbon stock into t C ha^{-1}, in $10000m^2 \cdot ha^{-1}$
a	stratum
i	Sampling site
p	parcel of land
44/12	Conversion coefficient turning C into CO_2

Formula (2) is applied to calculate average organic carbon stock in parcel of land p, stratum a, under baseline scenario.

$$C_{B,SOCa,p} = (\sum_{i=1}^{n} C_{B,SOC_{a,i,p}})/n \quad (2)$$

$C_{B,SOC_{a,p}}$	Average organic carbon stock in parcel of land p, stratum a, under baseline scenario, in unit of t $CO_2 \cdot \cdot ha^{-1}$
n	Numbers of sampling sites on each parcel of land
$C_{B,SOC_{a,i,p}}$	Same as formula (1)

Formula (3) is applied to calculate average carbon stock in all selected baseline monitoring parcels of lands of stratum a.

$$C_{B,Average,a} = (\sum_{p=1}^{M} C_{B,SOC_{a,p}})/M \quad (3)$$

Where,

$C_{B,Average,a}$	Average carbon stock in all selected monitoring parcels of lands of stratum a, under baseline scenario, $tCO_2 \cdot ha^{-1}$
$C_{B,SOCa,p}$	Same as formula (2)
M	Numbers of parcels selected as monitoring plots of stratum a, under baseline scenario

Formul (4) is used to estimate soil organic carbon stock in stratum a, sampling site i, parcel of land p, under project activity.

$$C_{P,SOC_{a,i,p}} = C_{P,SOC_{sample_{a,i,p}}} \times BD_{P,a,i,p} \times Depth \times (1 - FC_{P,a,i,p}) \times F \times 44/12 \quad (4)$$

where,

$C_{P,SOC_{a,i,p}}$	Soil organic carbon stock in the top 20 cm of soil for stratum a, sampling site i, parcel of land p, under project activity, in unit of $tCO_2 \cdot ha^{-1}$
$C_{P,SOC_{sample_{a,i,p}}}$	P Soil organic carbon content in the top 20 cm of soil for stratum a, sampling site i, parcel of land p, under project activity, in unit of $g\ C \cdot 100g^{-1}$ soil
$BD_{P,a,i,p}$	Soil bulk density in the top 20 cm of soil for stratum a, sampling site i, parcel of land p, under project activity, in unit of $g \cdot cm^{-3}$
$Depth$	Top soil depth, for calculating cropland soil organic carbon stock in the top 20 cm of soil
$FC_{P,a,i,p}$	Percentage of rocks, roots, and other dead residues with a diameter larger than 2mm in the top 20 cm of soil, for stratum a, sampling site i, parcel of land p, under project activity
F	Same as formula (1)
a	stratum
i	Same as formula (1)
p	Same as formula (1)
44/12	Same as formula (1)

Formula (5) is applied to calculate average carbon stock in each parcel of land of stratum a, under project activity scenario.

$$C_{P,SOCa,p} = (\sum_{i=1}^{n} C_{P,SOC_{a,i,p}}) / n \quad (5)$$

$C_{P,SOCa,p}$	Average carbon stock under project activity in parcel of land p, stratum a, in $t\ CO_2 \cdot ha^{-1}$
n	Numbers of sampling sites on each parcel of land, stratum a
$C_{P,SOC_{a,i,p}}$	Same as formula (4)

Formula (6) is applied to calculate average carbon stock in all monitored parcels of lands of stratum a, under project activity scenario.

$$C_{P,Average,a} = (\sum_{p=1}^{N} C_{P,SOCa,p})/N \quad (6)$$

$C_{P,Average,a}$	Average carbon stock in all monitored parcels of lands, stratum a under project activity, t $CO_2 \cdot ha^{-1}$
$C_{P,SOCa,p}$	Same as formula (5)
N	Numbers of monitored parcels of lands, stratum a, under project activity

Formula (7) is applied to calculate carbon stock changes resulted from the project activity in stratum a.

$$\Delta C_{SOC,a} = \frac{C_{P,Average,a} - C_{B,Average,a}}{T} \times \sum_{p=1}^{P} A_{P,p,a} \quad (7)$$

$\Delta C_{SOC,a}$	carbon stock changes resulted from the project activity, in stratum a, $tCO_2 \cdot y^{-1}$
$C_{P,Average,a}$	Same as formula (6)
$C_{B,Average,a}$	Same as formula (3)
T	SOC monitoring frequency, 1~5 years
P	Parcel numbers involved in the project activity in stratum a,
$A_{P,p,a}$	Area of parcel of land p, in stratum a, ha

Formula (8) is applied to calculate carbon stock changes resulted from the project activity in all stratums.

$$\Delta C_{SOC} = \sum_{a=1}^{S} \Delta C_{SOC,a} \quad (8)$$

ΔC_{SOC}	carbon stock changes resulted from the project activity, $tCO_2 \cdot y^{-1}$
$\Delta C_{SOC,a}$	Same as formula (7)
S	Number of stratums

2.3.4.2 N_2O

Fertilization is a major source of cropland N_2O emissions. The methodology recommended by IPCC (2006) for calculating cropland N_2O emissions is used to estimate N_2O emissions under both baseline scenario and project activity.

Formula (9) is applied to estimate direct N_2O emissions of each parcel of land, stratum a, under baseline scenario.

$$N_2O_{B,Direct,a,p} = \frac{1}{T}\sum_{y=1}^{T}(F_{B,SN,a,p,y} + F_{B,ON,a,p,y} + F_{B,CR,a,p,y}) \div A_{B,a,p} \times EF_1 \times 44/28 \times GWP_{N2O} \quad (9)$$

where,

$N_2O_{B,Direct,a,p}$	Cropland N_2O emissions under baseline scenario in parcel of land p, stratum a, in t CO_2-e· yr^{-1} ha^{-1}
$F_{B,SN,a,p,y}$	Chemical fertilization to each parcel of land, stratum a, in year y, under baseline scenario, in t N yr^{-1}
$F_{B,ON,a,p,y}$	Organic fertilization to each parcel of land, stratum a, in year y, under baseline scenario, in t N yr^{-1}
$F_{B,CR,a,p,y}$	Returned straw to each parcel of land, stratum a, in year y, under baseline scenario, in t N yr^{-1}
EF_1	N_2O emission factors of chemical fertilizer, organic fertilizer, and straw, t N_2O-N/t N input
p	Parcel of land
$A_{B,a,p}$	Area of monitored parcel of land, stratum a, under baseline scenario, ha
T	SOC monitoring frequency, 1~5 years
44/28	Conversion coefficient turning N_2O-N into N_2O
GWP_{N_2O}	Warming potential of N_2O: 310

Formula (10) calculates the average N_2O emission in all monitored parcels of lands of stratum a, under baseline scenario.

$$N_2O_{B,Average,Direct,a} = (\sum_{p=1}^{M} N_2O_{B,Direct,a,p})/M \quad (10)$$

$N_2O_{B,Average,Direst,a}$	Average N_2O emissions in all monitored parcels of lands of stratum a, under baseline scenario, in t CO_2-e·ha^{-1}
M	Same as formula (3)

Formula (11) is applied to calculate the average annual N_2O emissions of each parcel of land, stratum a, within the monitoring period, under project activity.

$$N_2O_{P,Direct,a,p} = \frac{1}{T}\sum_{y=1}^{T}(F_{P,SN,a,p,y} + F_{P,ON,p,y} + F_{P,CR,a,p,y}) \div A_{P,a,p} \times EF_1 \times 44/28 \times GWP_{N2O} \quad (11)$$

where,

$N_2O_{P,Direct,a,p}$	Average annual N_2O emissions of each parcel of land, stratum a, within the monitoring period, under project activity, in t CO_2-e·ha^{-1}
$F_{P,SN,a,p,y}$	Chemical fertilization to each parcel of land, stratum a, in year y, under project activity, in t N yr^{-1}
$F_{P,ON,a,p,y}$	Organic fertilization to each parcel of land, stratum a, in year y, under project activity, in t N yr^{-1}
$F_{P,CR,a,p,y}$	Returned straw to each parcel of land, stratum a, in year y, under project activity, in t N yr^{-1}
EF_1	N_2O emission factors of chemical fertilizer, organic fertilizer, and straw, t N_2O-N/t N input
p	Parcel of land
$A_{P,a,p}$	Area of parcels of stratum a, involved in the project activity
T	SOC monitoring frequency, 1~5 years
44/28	Conversion coefficient turning N_2O-N into N_2O
GWP_{N_2O}	Warming potential of N_2O: 310

Formula (12) is applied to estimate changes in N_2O emission in stratum a resulted from the implementation of project activity.

$$\Delta N_2O_a = (N_2O_{P,Direct,a,p} - N_2O_{B,Average,Direct,a}) \times \sum_{p=1}^{P} A_{P,a,p} \tag{12}$$

ΔN_2O_a	Changes in N_2O emission in stratum a resulted from the implementation of project activity, tCO_2-e
$N_2O_{P,Direst,a,p}$	Same as formula (11)
$N_2O_{B,Average,Direct,a}$	Same as formula (10)
P	Parcel numbers involved in the project activity
$A_{P,a,p}$	Same as formula (11)

Formula (13) is applied to estimate changes in N_2O emission resulted from the implementation of project activity.

$$\Delta N_2O = \sum_{a=1}^{S} \Delta N_2O_a \tag{13}$$

ΔN_2O	Changes in N_2O emission resulted from the implementation of project activity, tCO_2-e
ΔN_2O_a	Same as formula (12)
S	Same as formula (8)

2.3.4.3 Calculation of CO_2 emissions from farming machines

Machine type, fuel type, and fuel consumption (per hour or per hectare fuel consumption) for each parcel of cropland, in stratum a, should be monitored, under both baseline scenario and project activity. The following formula is applied to calculate CO_2 emissions from farming machine fossil fuel consumption, for parcel of land p, in stratum a, in a year, under baseline scenario.

$$ET_{B,FC,a,p,y} = \sum_{k=1}^{K}\sum_{j=1}^{J} FC_{B,a,p,j,k,y} \times EF_{CO2,k} \times NCV_k \div A_{B,a,p} \qquad (14)$$

where,

$ET_{B,FC,a,p,y}$	CO_2 emissions from farming machine fossil fuel consumption, in stratum a, under baseline scenario, $tCO_2\,yr^{-1}\cdot ha^{-1}$
$FC_{B,a,p,j,k,y}$	Fuel consumption by type k, machine type j, in stratum a, in year y, t yr^{-1}
$EF_{CO_2,k}$	CO_2 emission factor by fuel type k ($tCO_2\,GJ^{-1}$)
NCV_k	Thermal value of fuel type k (GJ t^{-1})
k	Fuel type
K	Numbers of fuel type
j	Machine type
J	Numbers of machine type
$A_{B,a,p}$	Area of monitored parcel of land, in stratum a, under baseline scenario, ha

Formula (15) is applied to calculate average CO_2 emissions from farming machine fossil fuel consumption, for all parcels of lands, in stratum a, during the monitoring period, under baseline scenario.

$$ET_{B,Averrage,FC,a} = \frac{1}{T}\sum_{y=1}^{T}\sum_{p=1}^{M} ET_{B,FC,a,p,y} \qquad (15)$$

$ET_{B,Averrage,FC,a}$	Average CO_2 emissions from farming machine fossil fuel consumption, for all parcels, in stratum a, during the monitoring period, $tCO_2\,yr^{-1}\cdot ha^{-1}$
T	SOC monitoring frequency, 1~5 years
M	Same as (3)
$ET_{B,FC,a,p,y}$	Same as (14)

Formula (16) is applied to calculate CO_2 emissions from farming machine fossil fuel consumption, for parcel of land p, in stratum a, in a year, under project activity.

$$ET_{P,FC,a,p,y} = \sum_{k=1}^{K}\sum_{j=1}^{J} FC_{P,a,p,j,k,y} \times EF_{CO_2,k} \times NCV_k \div A_{P,a,p} \quad (16)$$

where,

$ET_{P,FC,a,p,y}$	CO_2 emissions from farming machine fossil fuel consumption, under project activity, in stratum a, $tCO_2\ yr^{-1}\cdot ha^{-1}$
$FC_{P,a,p,j,k,y}$	Fuel consumption by type k, machine type j in year y, in stratum a, under project activity, $t\ yr^{-1}$
$EF_{CO_2,k}$	CO_2 emission factor by fuel type k ($tCO_2\ GJ^{-1}$)
NCV_k	Thermal value of fuel type k ($GJ\ t^{-1}$)
k	Fuel type
K	Numbers of fuel type
j	Machine type
J	Numbers of machine type
$A_{P,a,p}$	Area of parcel of land p, in stratum a, under project activity

Formula (17) is applied to calculate average CO_2 emissions from farming machine fossil fuel consumption, for all parcels, in stratum a, during the monitoring period, under project activity.

$$ET_{P,Averrage,FC,a} = \frac{1}{T}\sum_{y=1}^{T}\sum_{p=1}^{P} ET_{P,FC,a,p,y} \quad (17)$$

$ET_{P,Averrage,FC,a}$	Average CO_2 emissions from farming machine fossil fuel consumption, for all parcels, in stratum a, during the monitoring period, during the monitoring period, $tCO_2\ yr^{-1}\cdot ha^{-1}$
T	SOC monitoring frequency, 1~5 years
P	Parcel numbers in stratum a, involved in the project activity
$ET_{P,FC,a,p,y}$	Same as formula (16)

Formula (18) is used to calculate total changes of CO_2 emission from fossil fuel consumption in stratum a, by farming machine within the monitoring period.

$$\Delta CO_{2FC,a} = (ET_{P,Averrage,FC,a} - ET_{B,Averrage,FC,a}) \times \sum_{p=1}^{P} A_{P,a,p} \quad (18)$$

ΔCO_{2FC}	Total changes of CO_2 emission from fossil fuel consumption, in stratum a, by farming machine within the monitoring period, tCO_2yr^{-1}
$ET_{P,Averrage,FC}$	Same as formula (17)
$ET_{B,Averrage,FC}$	Same as formula (15)

Formula (19) is used to calculate total changes of CO_2 emission from fossil fuel consumption by farming machine within the monitoring period.

$$\Delta CO_{2FC} = \sum_{a=1}^{S} \Delta CO_{2FC,a} \quad (19)$$

ΔCO_{2FC}	Total changes of CO_2 emission from fossil fuel consumption by farming machine within the monitoring period, tCO_2yr^{-1}
$\Delta CO_{2FC,a}$	Same as formula (18)
S	Same as formula (8)

2.3.4.4 Calculation of GHGs leakage

According to CDM methodology, leakage by definition is the net change of anthropogenic emissions by sources of greenhouse gases which occurs outside the CDM project boundary, and that is measurable and attributable to the CDM project activity. Normally, conservation tillage practice may result in the increase of fossil fuel consumption for farmers' daily life. In this case, leakage can be calculated according to the changes in fossil fuel consumption.

- For increase in electricity consumption, the leakage shall be calculated as the amount of electricity consumption increased multiplied by the CO_2 emission factor of that grid;
- For increase in fossil fuels consumption, the leakage shall be calculated as the quantity of fossil fuels consumption increased multiplied by the CO_2 emission factor of the fossil fuels.

2.3.4.5 Project emission reduction

Project emission reduction equals baseline net emissions subtracted by project net emissions and leakage. Formula (17) can be applied to estimate the total net emissions by project activity.

$$ER = \Delta C_{SOC} - \Delta N_2O - \Delta CO_{2FC} - \textit{LEAKAGE} \quad (20)$$

2.3.5 Monitoring methodology

1) Determination of total sample size for stratum i

The number of sampling plots for measurements content of soil organic carbon both under baseline scenario and project activity were calculated based on the A/R methodological tool "Calculation of the number of sample plots for measurements within A/R CDM project Activities" (UNFCCC, 2009) with some modification.

2) Determination of sample plot size

The plots size for measurements of soil organic carbon content both under baseline scenario and project activity is determined to be 10 m×10 m.

3) Determination of plot location

a) It is recommended that permanent sample plots shall be located using the approach of aligned systematic sampling. In this approach a grid is laid over the entire project area, and the centre points of a permanent sample plots are taken as those grid intersection points that fall within a stratum. The grid shall have a random origin (i.e. the origin is a randomly selected set of map coordinates), and optionally a random orientation (a randomly selected compass orientation);

(b) To obtain the correct number of permanent sample plots in each stratum, the spacing of the grid (the distance between grid intersections) shall be varied until the necessary number of grid intersections in a stratum is obtained. It is not necessary to retain the same grid spacing for each stratum; however the same origin and orientation should be retained for the grid;

(c) Having assigned the centre points of the permanent sample plots using the above procedure, it is possible that due to inherent and unavoidable uncertainty in mapping and/or sample plot location, during sample plot installation part of a sample plot may be found to fall outside of the CT area. In this case, move the plot centre towards the centre of the parcel of land such that the outer edge of the plot coincides with the estimated position of the outer edge of the CT area. The direction of movement of the plot centre shall be at right-angles to the edge of the parcel of land;

(d) Sufficient sample plots should always be allocated to a stratum so that it is possible to omit any sample plots that prove to be inaccessible, while still maintaining the minimum number of sample plots calculated.

CDM methodology for conservation tillage shall monitor the following elements under both baseline and project scenarios: 1) organic carbon content in the top 20 cm of soil, once of 5 years; 2) fertilization, including organic manure and inorganic fertilizers, and nitrogen content in each fertilization process; 3) associated nitrogen content and straw reclaiming rate occurred each time; 4) crop types; 5) duration of farming machine operation, unit time fuel consumption, and fuel type of each operation; 6) land area and location under project activity. Methods for monitoring of these elements are described in detail as below.

4) Monitor the content of soil organic carbon

Soil samples are collected to the top 20cm soil at the end of each year. It is essential to thoroughly mix the collected soil by layer for each site before turning them into soil samples weighing 200-300g using the crossing method. Then pick out rocks, stones, roots, and other dead organic residues that are larger than 2 mm using a 2 mm mesh screen. Soil samples should be air-dried and grounded in a laboratory environment. The measurement of soil organic carbon content may be conducted with C/N analyzer or other published methods which are accepted in scientific aspects. The assaying method or equipment employed need be consistent in analyzing soil organic carbon.

Meanwhile, original soil samples from different soil layers at each sampling site are collected using a circular knife. Then, measurement shall be conducted on the wet weight of original soil and estimating the volume percentage of rocks, stones, roots, and other dead organic residues that are larger than 2mm will be conducted. Mixed soil samples collected from each layer at each sampling site need to be dried at a temperature of 105°C for weight and moisture measurement indoor. The equipment for measuring the soil moisture, such as TDR, can also be used to determine soil moisture content of each soil layer. One should calculate the dry weight of soil samples in the circular knife and average soil density of each soil layer. Unit area soil organic carbon stock can be calculated using the following formula:

$$SOC=[SOC]\times \text{bulk density}\times \text{depth}\times \text{roughness}\times 10 \quad (31)$$

where,

SOC = soil organic carbon stock, Mg C ha^{-1}

[SOC] = soil organic carbon content of a given soil weight, obtained from lab analysis, g C (kg soil dm)$^{-1}$

Bulk density = soil weight in unit volume, Mg dm m^{-3}

Depth = Depth and soil thickness where samples are collected, m

Roughness = 1-(%, volume of rough debris/100)

Multiplied by 10 to convert the unit into Mg C ha^{-1}

5) Monitor the emission of soil N_2O

It is costly and technically difficult to measure soil N_2O emissions directly. Most developing countries have no long-term automatic sampling and monitoring systems to monitor the N_2O emissions on a consecutive basis. Whereas, the methodology proposed here only asks for monitoring nitrogen input in soils under both baseline and project scenarios. The observational data shall be turned into cropland N_2O emissions through the formula recommended by IPCC. The following elements shall be monitored for the purpose: fertilizer type and associated unit area application, and nitrogen content of each parcel of land in year y under project activity; the amount of organic manure, in unit area, and nitrogen content of each parcel of land in year y under project activity; amount of returned straw in unit area; crop type, such as nitrogen fixation crop, each parcel of land in year y. Unit area nitrogen fixation rate shall be calculated based on IPCC inventory guideline proposed in 2006, and growing area etc. Also, all the elements mentioned above under baseline scenario should be monitored.

6) Monitor the fuel consumption of farming machines

Some of the data about farming machines should be monitored and recorded in both project and baseline parcel of lands, for instance, the farming machine type, the time and operation duration, fuel consumption in unit working time, and fuel type etc.

7) Land area and location under project activity

Numbers, area and location (GPS) of each parcel of land involved in the project activity shall be recorded annually.

2.4 Case Study

In order to demonstrate the feasibility of the development of conservation tillage CDM projects, a study conducted in Shandong Province was chosen for a case study.

2.4.1 Description of research

A 7-year (2003–2009) field experiment was conducted near in Shandong province. Soil at the site was a loam soil, 1.345 per cent organic matter and pH of 7.1. Mean annual air temperature and precipitation in the area is 13.0°C and 621 mm, respectively. The cropping system is winter wheat-maize rotation. All straw of wheat and maize was returned to the soil after harvest. The amount of straw returned to the soil, the content of nitrogen in the straw, nitrogen fertilizer applied, is listed in table 16.

Table 16 Information on application amount of straw amendment and nitrogen fertilizer, nitrogen in the straw

	Wheat straw amount ($t\ ha^{-1}$)	Maize straw amount ($t\ ha^{-1}$)	Nitrogen in wheat straw ($kg\ ha^{-1}$)	Nitrogen in maize straw ($kg\ ha^{-1}$)	Nitrogen fertilizer ($kg\ ha^{-1}$)
2003	6.9	7.0	16.4	44.0	500.0
2004	6.9	6.8	16.5	43.2	475.0
2005	7.1	6.6	16.8	41.8	460.0
2006	7.3	7.3	17.4	46.4	480.0
2007	7.3	8.0	17.3	50.3	460.0
2008	7.7	8.9	18.3	56.0	430.0
2009	8.0	9.5	18.9	60.1	420.0

2.4.2 Emission reduction

1) changes in Soil carbon content and N_2O emission under baseline

Traditional tillage could decrease soil carbon content. The changes of carbon content and nitrogen fertilizer application under baseline are listed in table 17. The carbon losses, the N_2O emissions in each year during the experiment period are also listed in table 17. Traditional tillage oil consumption was 27.9 l ha^{-1}. The total emission of GHG was from 2.0~2.9 t $CO_2\ ha^{-1}yr^{-1}$.

Table 17 Total GHG emission under baseline

Year	Soil organic carbon content (%)	Inorganic nitrogen fertilizer (kg N ha^{-1})	Oil consumption (l ha^{-1})	Carbon increase (t CO_2 $ha^{-1}yr^{-1}$)	N_2O emission (t CO_2 $ha^{-1}yr^{-1}$)	CO_2 emission from oil (t CO_2 $ha^{-1}yr^{-1}$)	Total Emission (t CO_2 $ha^{-1}yr^{-1}$)
2003	1.352	550	27.9				
2004	1.35	550	27.9	0.1	2.1	0.08	2.3
2005	1.351	550	27.9	0.0	2.1	0.08	2.2
2006	1.345	550	27.9	0.3	2.1	0.08	2.5
2007	1.33	550	27.9	0.6	2.1	0.08	2.9
2008	1.335	550	27.9	-0.2	2.1	0.08	2.0
2009	1.332	550	27.9	0.1	2.1	0.08	2.3

2) Changes in soil conbon content and N_2O emission under project activity

The changes of carbon content and nitrogen fertilizer application, including inorganic and organic nitrogen, under project activity are listed in table 18. The carbon increase, the N_2O emissions in each year during the experiment period are also listed in table 18. The total emission of GHG was from 0.7~1.1 tCO_2 $ha^{-1}yr^{-1}$

Table 18 Total GHG emission under project activity

Year	Soil organic carbon content (%)	Total nitrogen fertilizer (kg N ha^{-1})	Oil consumption (l ha^{-1})	Carbon increase (t CO_2 $ha^{-1}yr^{-1}$)	N_2O emission (t CO_2 $ha^{-1}yr^{-1}$)	CO_2 emission from oil (t CO_2 $ha^{-1}yr^{-1}$)	Total Emission (t CO_2 $ha^{-1}yr^{-1}$)
2003	1.352	500	32.7			0.10	
2004	1.35	475	32.7	1.2	2.1	0.10	1.0
2005	1.351	460	32.7	0.9	2.0	0.10	1.2
2006	1.345	480	32.7	1.4	2.1	0.10	0.8
2007	1.33	460	32.7	1.0	2.0	0.10	1.1
2008	1.335	430	32.7	1.1	2.0	0.10	1.0
2009	1.332	420	32.7	0.9	1.9	0.10	1.1

3) Emission reduction

Emission reduction by conservation tillage is listed in table 19. The emission reduction was from 1.0 to 1.7 t CO_2 $ha^{-1}yr^{-1}$. If the carbon price is \$15 (t CO_2)$^{-1}$, the emission reduction benefit could reach \$15~25.5 $ha^{-1}yr^{-1}$. The accumulated emission reduction during 2004 and 2009 was 7.9 t CO_2 ha^{-1}.

Table 19 Total GHG emission under project activity

Year	Net GHG emission under Baseline (t CO_2 $ha^{-1}yr^{-1}$)	Net GHG emission under project activity (t CO_2 $ha^{-1}yr^{-1}$)	Emission reduction by CT (t CO_2 $ha^{-1}yr^{-1}$)
2004	2.3	1.0	1.3
2005	2.2	1.2	1.0
2006	2.5	0.8	1.6
2007	2.9	1.1	1.7
2008	2.0	1.0	1.0
2009	2.3	1.1	1.2

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