# How to Reduce Global Warming Potential of Crop Production in Northern China – a Farmer's Perspective Analysis

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**ABSTRACT**

There is an increasing need to promote more environmentally sustainable agriculture and small-scaled farm business in the NCP. This paper adopts two key environmental indicators to improve scientific understanding of environmental impact of summer maize and winter wheat production system and explain distinct performance results from farmer's management aspect. This paper highlights farm management diverseness and its impact on environmental performance of crop production. The farm households are grouped into three categories based on similarity on environmental impact results. The cluster analysis shows that input intensification often results in poor performance environmental damage. To realize shift from high input intensive agriculture to sustainable agriculture, multi-scale and system approaches with sufficient reference to local specificities needs to be implemented to achieve more environmental sustainable agriculture in the NCP.
**Keywords:** Greenhouse gas emission, farming management, diversity, China.

## 1. INTRODUCTION

As the most populous country in the world, national grain and food self-sufficiency has been a primary goal of the Chinese government since the foundation of People's Republic of China in 1949. To safeguard food demand of continuing increasing population, tremendous effort has made to increase cereal productivity in the last decades. From 1982 to 2011, a 61% increase of the grain yields of three main crops (rice, wheat and maize) had been achieved nationwide while applied synthetic fertilizer increased from 12.8 to 62.1 (a 486% increase) million ton over the same period (NBSC, 1986; NBSC, 2012a; NBSC, 2012b). All this clearly indicates a comparatively faster growth of input intensities (materials, energy, and capital) to yield level, which has huge implications on environmental performance of crop production in China.

The North China Plain (NCP), as one of the most important and at the same time most densely populated agricultural regions of China, provides about three fourth of national winter wheat (WW) and one third of national summer maize (SM) production (NBSC, 2007). The input intensification in NCP exerts a substantial effect on greenhouse gas (GHG) emission from agricultural sources (Hu, 2011). In the recent years, the international literature shows growing interest in reducing environmental contamination of current farm practices in the NCP with different methodological approaches. The literature is dominated by experiment researches and model simulations aiming to limit GHG emission by nitrogen application reduction without yield loss (Ju, 2009; Chen et al., 2006). However, diversity of farm practices is often neglected in literature and decisions on fertilizer application habit, crop residue management and agricultural machinery from small-scale households was seen homogenously. It is imperative to examine environmental impact of current farm practices in the NCP.

Therefore, this paper aims to improve the understanding of environmental impact of the SM-WW double cropping system under the current diverse crop management practice in the NCP. To achieve these goals, we employ two environmental indicators, namely GHG emission and carbon footprint (CF) on a household survey data set from the NCP. Three farm household groups -“good performance”, “fair performance” and “poor performance”- are identified based on similarity in environmental impact results, with group characteristics explained from farm management viewpoint. Finally, necessary information e.g. GHG emission mitigation potential are generated for decision maker to reduce environmental damage in Chinese agriculture.

## 2. METHODOLOGY

### 2.1 Study Area and Data Collection

Quzhou County, as a representative county of the NCP, is located in southern Hebei Province in the center of the NCP, where more than 80% cultivated land is dominated by SM and WW double cropping system.

The information necessary for this study was collected from both secondary and primary sources. Secondary information was derived from peer-reviewed literature, database from Life cycle assessment (LCA) software GaBi 5 (Eyerer, 2006), statistical yearbooks and documents provided by government agencies. Primary information was collected through a standard household survey and local expert interviews. 65 farm households were selected by a simple randomly selection process. The result of interviews was examined by communication with the enumerators and telephonic re-interview some of the households. Expert interviews were conducted with local fertilizer dealer, agricultural machinery renter and dealer, officials of extension service station and local villages for information on agricultural subsidy, lifetime and annual maintenance cost of agricultural machinery.

### 2.2 GHG Emission and Carbon Footprint (CF)

The GHG emission from SM-WW production system in the NCP was assessed in a partial life cycle perspective from raw materials extraction up to the point of grains transportation out of the farm. The system boundary of GHG emission from SM-WW production system in the NCP is shown in dashed box of Figure 1 and one unit

SM/WW grain was set as functional unit. According to guidance from IPCC (IPCC, 2007), the global warming potentials for 100-year horizon of carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$) to $CO_2$e emission are 1, 25 and 298, respectively. Total GHG emission was consist of pre-farm embedded and on-farm GHG emissions. Pre-farm embedded emission is the GHG emission embedded in the production process of key farm inputs before those were transported to the farm.

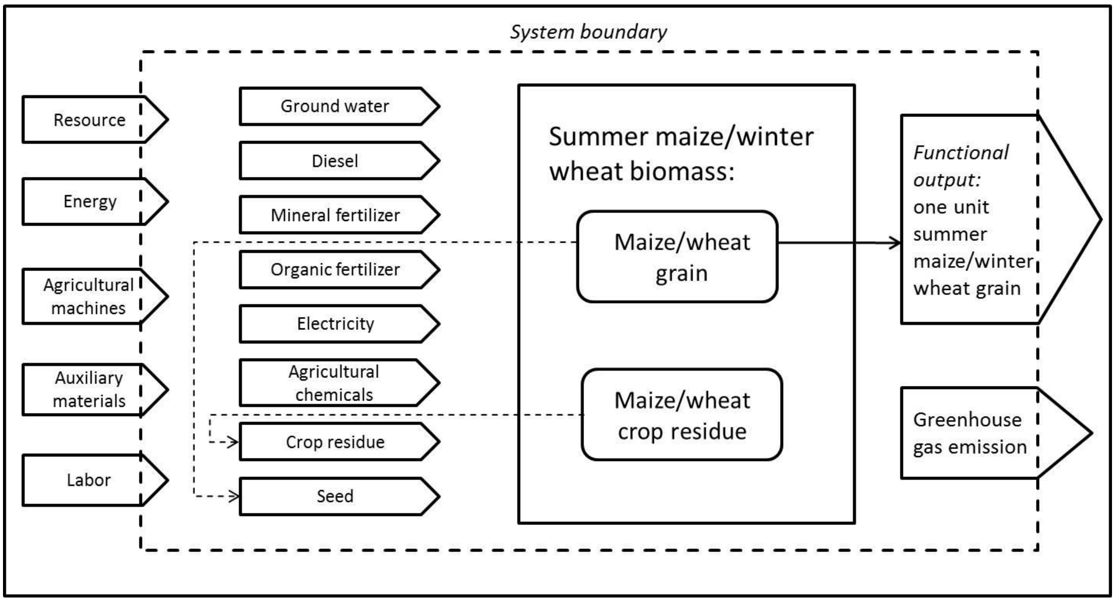


Figure.1. System boundary of SM and WW production system in the NCP.

On-farm GHG emission covered direct and indirect emissions from soil by applied mineral, organic fertilizers and crop residue in soil, diesel/electricity consumption for ground water acquisition, diesel consumption in agricultural mechanization (soil preparation, crop residue returning) and transport. GHG emission from soil consists of methane ($CH_4$), nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$). $CH_4$ and $CO_2$ emitted from soil were thought as a light sink and background emission respectively and therefore excluded from calculating GHG emission from soil. $N_2O$ emission from soil using IPCC (2006) guidelines and localized emission factor (EF) of $N_2O$ emissions from synthetic fertilizer inputs from experiment conducted in Quzhou (Hu, 2011) was calculated.

## 2.3 Cluster Analyses

65 SM-WW farm households were clustered based on their similarities on environmental effect using SPSS (SPSS, 2002). Indicator CF was chosen as cluster criterion as it expresses both environmental intensity and efficiency of input use to produce one unit product.

# 3. RESULTS and DISCUSSIONS

## 3.1 Input Flows of 65 SM-WW Farm Households

The main assumptions and environmental parameters to calculate GHG emission and CF were summarized in Table 1. The household-specific GHG emissions were individually calculated.

Table 1. Key input flow data including applied amount and EFs to estimate GHG emission of SM-WW farm households in NCP.

| Input Flows | Input Unit | SM Input Flow | WW Input Flow | EF (kg $CO_2$e/kg/MJ/ Unit/liter) |
|---|---|---|---|---|
| Ammonium bicarbonate | kg/ha | 277 (0-1500) | 661 (0-2250) | 1.73 [1] |
| Urea | kg/ha | 116 (0-700) | 145 (0-750) | 1.65 [1] |
| NPK compound | kg/ha | 586 (0-1500) | 673 (0-2250) | 1.30 [2] |
| DAP | kg/ha | 51 (0-1500) | 162 (0-1500) | 0.3 [3] |
| Ammonium sulphate | kg/ha | 29 (0-1500) | 39 (0-750) | 0.63 [2] |
| Ammonium nitrate | kg/ha | 6 (0-375) | 0 | 1.97 [2] |
| Manure | kg/ha | 173 (0-3750) | 1060 (0-7500) | 0.044 [4] |
| Seed | kg/ha | 36 (11-53) | 272 (131-375) | 0.22 [2] |
| Agricultural chemicals | Unit | 1 Unit | 1 Unit | 94.4 |
| Labor | hour/ha | 601 (245-1384) | 242 (90-833) | 0 |
| Residue management | liter/ha | 56.4 | 0 | 3.5 [2] |
| Irrigation | MJ /ha | 1262 (331-3086) | 2407 (485-4849) | 0.314 [2] |
| Threshing | MJ /ha | 22.5 | 0 | 0.314 [2] |
| Sowing seeds | liter/ha | 15 | 15 | 3.5 [2] |
| Harvest | liter/ha | 4 (0-30) | 36 | 3.5 [2] |
| Transport | liter/ha | 16 (0-30) | 17 (0-38) | 3.5 [2] |
| Fertilizer transport [5] | liter/ha | 15.3 | 4.0 | 3.5 [2] |

Data without citation is from household survey.
1. Own calculation on EF factor of Ammonium bicarbonate and urea in China based on GHG emission and consumption in fertilizer plant Zhao (2011), CMA and CCF (2006), Zhou (2010),
2. EF factors from GaBi Data bank,
3. EF for DAP from Patyk (1997),
4. EF for manure from Jia and Guo (2009),
5. Diesel consumption of fertilizer transport process from factory to field was calculated in SMP and WWP model by GaBi software.

## 3.2 GHG Emission and CF of SM and WW Production Systems

The yields of SM and WW of 65 households ranged from 5250 to 9375 kg $ha^{-1}$ and from 3750 to 9000 kg $ha^{-1}$, respectively. Similarly, environmental impact indicators show a great dissimilarity especially on CF (see table 2). The environmental impact of SM and WW does not appear difference either on CF or GHG emission. It indicates that environmental impact of SM and WW under current farming practices are very diverse and improvement strategy discussion can not be carried on before grouping households into cluster based on their similarities on environmental impact results.

Table 2. Output flow data of SM and WW production systems in the NCP.

| | SM | WW |
|---|---|---|
| Yield (kg/ha) | 7317 (5250-9375) | 6428 (3750-9000) |
| GHG (kg $CO_2$e/ha) | 3629 (1380-8628) | 3129 (1147-5401) |
| Carbon Footprint (kg $CO_2$e/kg) | 0.5 (0.2-1.2) | 0.5 (0.2-1.3) |

### 3.3 Cluster Analysis

The above two parts have showed diversity on both farm management option and environmental impact of SM and WW production system. Low environmental impact is not always favorable for example in low yield level. Therefore, CF was chosen as cluster criterion expressing both intensity and efficiency of farming practices to produce one unit product. The households were then divided into three categories (good, fair and poor) based on their performance on CF per unit SM and WW product respectively.

Table 3. The percentage, mean values of environmental impact indicators, nitrogen and labor input per hectare of three cluster groups.

| Environmental impact indicators | Cluster groups | | |
|---|---|---|---|
| | Poor | Fair | Good |
| SM | | | |
| Farmer household number | 11 | 37 | 17 |
| Yield (kg/ha) | 7023 | 7291 | 7566 |
| Carbon Footprint (kg $CO_2$e/kg) | 0.70 | 0.44 | 0.27 |
| Nitrogen input (kg N/ha) | 318 | 215 | 99 |
| Labor input (hour/ha) | 538 | 461 | 486 |
| WW | | | |
| Farmer household number | 8 | 21 | 36 |
| Yield (kg/ha) | 4828 | 6336 | 6837 |
| Carbon Footprint (kg $CO_2$e/kg) | 1.17 | 0.79 | 0.49 |
| Nitrogen input (kg N/ha) | 398 | 362 | 235 |
| Labor input (hour/ha) | 301 | 209 | 249 |

Table 3 presents the percentage, mean values of environmental impact indicators, nitrogen and labor input per hectare in respective cluster group. The percentage of cluster membership indicates that environmental impact of SM and WW production show a wide range in the NCP. 17 and 36 of 65 farmer household fell into the so-called "best practices" category they are satisfying performance on SM and WW farming practices, respectively. They have highest yield of three groups: 7566 kg and 6837 kg per hectare in SM and WW production respectively. Except labor input, cluster group "good" have best performance on CF, yield and nitrogen input. 11 and 8 households belong to cluster group "poor" who need to urgently take action to improve their environmental impact in SM and WW cropping system. With highest nitrogen and labor input in SM production system, cluster group "poor" has lowest yield and CF. Between group "poor" and "good" we identify a third group, the group "fair", which has medium environmental impact.

The mean yield of SM and WW from survey was 7317 and 6428 kilo $ha^{-1}$ and range from 5250 to 9375 and 3750 to 9000 kilo $ha^{-1}$, respectively. The modeled average potential yield of SM and WW are 10.3 and 8.0 t $ha^{-1}$ in the NCP, respectively (Lu, et al., 2013; Meng, et al., 2013). Farmers attained only 71% and 80% of modeled potential yield of SM and WW in the NCP and limiting factors of yield growth needs to be identified for yield improvement.

## 4. OUTLOOK FOR MORE SUSTAINABLE AGRICULTURE

The improvement suggestions for “fair” and “poor” groups are generated based on above analysis of farming practices and its impacts on environmental effect. Evidence suggested that inefficient crop management practices could be the most important reason such as poor water and fertilizer management, crop management and low efficiency of light and heat resource use (Meng, et al., 2013). Fertilization and irrigation strategy including timing, amounts/frequency, infrastructure development should address local condition and crop demand on nutrients and water. Second, overusing fertilizer is not apparent in the policies of central or local government (Norse, 2012) and not awared by extension agents and farmers in China. Third, increasing ageing population and labor shortage in the NCP due to rural labor migration make efficient use of resource and crop management even difficult to operationalize. Enhancing labor efficiency should be a promising strategy to increase productivity of crop systems and further enable household income growth in rural China. Last but not the least, farmer training program is being trailled and shows potential on increasing fertilizer use efficiency (Huang, et al., 2008). The consistent crop management advices to farmers through in-site guidance and straightforward training program should be provided by agricultural extension agent, although farmer training is not without cost. Hence, neighborhood mutual help scheme should be promoted to cover availability shortage of extension services to help “poor” and “fair” performance households follow recommended farming practices.

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