The Factors Influencing the Emission of Greenhouse Gases from Tibet’s Crop Farming

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Abstract. The output of greenhouse gases resulting from Tibet’s crop farming over the years 1991 to 2015 has been estimated, and the Logarithmic Mean Divisia Index model was used to deduce the influence of the various factors underlying these greenhouse gas emissions. From 1991 to 2015, the overall carbon emissions of the Tibetan plantation industry showed a “U”-shaped change trend. Carbon emissions from plantation mainly include nitrogenous oxide and rice field methane. The LMDI decomposition results showed the economic factor (SI) and the efficiency factor (CI) determined the development trend of the total effect. The CI is an important contributor to the reduction of carbon emissions, whereas SI is important inhibiting carbon emissions. Labor factors (AL) contribute to agricultural carbon emissions. SI and AL have an upward trend in promoting agricultural carbon emissions.

1. Introduction
With the increasingly serious global climate anomalies, global warming caused by the increase of CO\textsubscript{2} and other greenhouse gas emissions caused by human activities has become one of the most serious challenges facing mankind in the 21st century [1]. Among all sectors, the agricultural sector emits approximately one third of the world’s CO\textsubscript{2} emissions, thereby playing an important role in achieving energy consumption reductions and carbon emissions mitigation. China, as a traditional agricultural country, which needs more concern on the contribution made by agricultural carbon emissions to climate, has been shown that the rapidly developing agriculture sends [2]. Although energy and carbon emissions in many sectors have been widely analyzed in China, few studies have focused on the agricultural sector, especially in farming industry, which accounted for 48.41\% of agricultural carbon emissions [3, 4]. Therefore, exploring the decoupling between farming industry and carbon emissions, analyzing the drivers of China's agricultural carbon emissions, which can provide important theoretical insights for the development of low carbon agriculture [5]. Tibet is a region where agriculture and animal husbandry are mainly developed. Promoting carbon emission reduction in the plantation industry is an important measure to reduce greenhouse gas emissions, and it is also a basic prerequisite for sustainable agricultural development in Tibet. The goal of the present research was to apply the LMDI methods to identify which factors drove these emissions over the period 1991-2015, the research described here sought to quantify greenhouse gas emissions from Tibet’s crop farming, specifically addressing the current lack of relevant information regarding emissions from this area of...
the country peopled by minority ethnic groups. Its intention was to provide a sound basis for formulating strategies designed to allow the industry to meet national emission reduction targets. More generally, the outcomes of the research should be relevant in the context of modernizing developing country agricultural sectors.

2. Methodology and Data Source

2.1. Carbon Emission Calculation from Planting Industry
Carbon emissions from agricultural production include the methane (CH$_4$) emissions and nitrous oxide (N$_2$O) emissions. Methane is a greenhouse gas produced by methanogenic bacteria in rice under submersion. Nitrous oxide emissions from agricultural land are caused by fertilization and straw returning [6]. CO$_2$ equivalent emissions are the toal of CH$_4$ emissions and N$_2$O emissions.

\[ \text{Emission} = \text{Emission}_{CH_4} \times \text{WGP}_{CH_4} + \text{Emission}_{N_2O} \times \text{WGP}_{N_2O} \]  

(1)

\[ \text{Emission}_{CH_4} \] is the CH$_4$ emissions from rice plant (kg CO$_2$·ha$^{-1}$), \[ \text{Emission}_{N_2O} \] is the N$_2$O emissions from farmland (kg N$_2$O·ha$^{-1}$), \[ \text{WGP}_{CH_4} \] and \[ \text{WGP}_{N_2O} \] are the sum of N$_2$O and CH$_4$ emissions per the 100 yr horizon, 25 and 298.

2.1.1. Paddy Field CH$_4$ Emission Calculation. CH$_4$ emissions are calculated by using the amount of rice-seeded area multiplied the respective emission factor (EF$_{CH_4}$):

\[ \text{Emission}_{CH_4} = \sum EF_{CH_4,i} \times \text{activity data}_i \]  

(2)

where \( i \) means paddy types; Activity data means amount of sown area for rice \( i \); \( EF_{CH_4,i} \) is the emission factor of CH$_4$ emissions for type \( i \).

2.1.2. Agricultural Land N$_2$O Emission Calculation. N$_2$O emissions from farmland include the direct emission and the indirect emission. N$_2$O emissions was calculated as follows:

\[ \text{Emission}_{N_2O} = N_1 + N_2 \]  

(3)

where \( N_1 \) represents the sum of direct N$_2$O emissions from farmland; \( N_2 \) represents the indirect emission from farmland.

Synthetic fertilizers, organic manure and crop residues as the three main sources of direct N$_2$O emissions was calculated from farmland by using IPCC methodology as:

\[ N_1 = (F_{SN} + F_{AW} + F_{CR}) \times EF_1 \]  

(4)

where \( F_{SN} \) means total amount of synthetic fertilizer N were used (kg N·yr$^{-1}$), \( F_{AW} \) is total amount of animal manure N were used to soils (kg N·yr$^{-1}$), \( F_{CR} \) is sum amount of N in crop residues returned to soils (kg N·yr$^{-1}$), \( EF_1 \) is the factor for N$_2$O emissions from N inputs (kg N$_2$O·N·kg$^{-1}$ N input) [7].

Indirect N$_2$O emissions from the use of agricultural land result from atmospheric deposition of N volatilized and transport of N into ground and surface waters through drainage and surface runoff [7]. The emissions from atmospheric deposition of N volatilized is due to the 20% grazing animals manures and NH$_3$, NO$_3$-N volatilizing which accounting for 10% of the use of agricultural land, were calculated multiplying the amount of N volatilized by the default EF (EF$_2$) provided by IPCC [7]. To estimate indirect N$_2$O emissions from leaching and runoff that accounting for 20% of the total nitrogen input in agricultural land, IPCC methodology proposes a default N$_2$O emission factor (0.0075 kg N$_2$O-N/kg N leaching).

\[ N_m = (F_{AW} \times 20\% + N_1 \times 10\%) \times EF_2 \]  

(5)
\[ N_n = N_1 \times 20\% \times 0.0075 \]  
\[ (6) \]

where \( N_n \) is the \( \text{N}_2\text{O} \) emissions from atmospheric deposition of \( \text{N} \) volatilized; \( EF_2 \) is the emission factor recommended by IPCC. \( N_n \) represents the indirect \( \text{N}_2\text{O} \) emissions from leaching and runoff.

### 2.2. Carbon Intensity of Planting Industry

Carbon intensity is the amount of carbon emitted per unit of GDP. Carbon emission intensity is an important index to measure the development level of planting industry. GHGI was employed by dividing total Global Warming Potential (GWP) weighted emissions from planting industry by farming GDP [6]:

\[ \text{GHGI} = \frac{T_c}{T_{GDP}} \]  
\[ (7) \]

which GHGI means carbon intensity (kg\( \text{CO}_2 \text{eq} \cdot \text{t}^{-1} \)); \( T_c \) represent Total greenhouse gas emissions from farming; \( T_{GDP} \) represent the total GDP from farming [6].

### 2.3. Carbon Emissions Impact Factors from Planting Industry

Kaya identity and the LMDI method were used to decompose the Carbon Emissions [6]. Based on the existing literature, the method was shown as follows [8]:

\[ C = \frac{C}{PGDP} \times \frac{PGDP}{AGDP} \times \frac{AGDP}{AL} \times AL \]  
\[ (8) \]

The above equation is simplified as:

\[ C = CI \times EI \times SI \times AL \]  
\[ (9) \]

\( C, \) PGDP, AGDP, AL are carbon emission from planting industry , GDP of planting industry, agricultural gross output value and the employment labor of agricultural industry. CI, EI, SI, AL are efficiency factor(CI), structure factor(EI), economy factor(SI) and labor factor(AL) respectively.

\[ \Delta CI = \sum \frac{C_t - C_o}{\ln C_t - \ln C_o} \cdot \ln \frac{C_t}{C_o} \]

\[ \Delta EI = \sum \frac{C_t - C_o}{\ln C_t - \ln C_o} \cdot \ln \frac{E_t}{E_o} \]

\[ \Delta SI = \sum \frac{C_t - C_o}{\ln C_t - \ln C_o} \cdot \ln \frac{SI_t}{SI_o} \]

\[ \Delta AL = \sum \frac{C_t - C_o}{\ln C_t - \ln C_o} \cdot \ln \frac{AL_t}{AL_o} \]

\[ \Delta C_{tot} = C_t - C_o = \Delta EI + \Delta SI + \Delta AL \]  
\[ (10) \]

### 2.4. Data Sources

Data were come from the China Agricultural Yearbook of Tibet (1991-2015) and Rural Statistical Yearbook (1991-2015) of China. In this paper, the price of 1990 is taken as the base price, and the GDP of other years is converted into comparable prices [6].

### 3. Results and Discussion

#### 3.1. The Volume of Greenhouse Gases Emissions

The total emission of greenhouse gas from planting Industry of Tibet fluctuated with the annual change (figure 1). Judging from the results of the analysis, from 1991 to 2015, the overall carbon emissions of the Tibetan plantation industry showed a “U”-shaped change trend. On the overall planting industry carbon emissions in Tibet showed three stages of change. Since 1991 to 1996,
carbon emissions in Tibet's crop industry fluctuate between $103 \times 10^6$ tons CO$_2$-eq and $110 \times 10^6$ tons CO$_2$-eq; From 1997 to 2007, carbon emissions were starting to fall, which fluctuate between $66 \times 10^6$ tons CO$_2$-eq and $73 \times 10^6$ tons CO$_2$-eq. From 2008 to 2014, the total carbon emissions from Tibet’s plantation industry remain steady at $114 \times 10^6$ tons CO$_2$-eq to $120 \times 10^6$ tons CO$_2$-eq. Carbon emissions from plantation mainly come from land-use nitrogenous oxide and rice field methane. Due to natural conditions, N$_2$O from farmland is the leading source of greenhouse gas emissions from Tibet’s plantation industry.

![Figure 1. Greenhouse gas emissions from planting in Tibet (1997-2015).](image)

3.2. Greenhouse Gases Intensity
During the study period, the greenhouse gas emissions per unit of GDP of the crop planting industry showed a continuous decrease first, and since 2005, it has fluctuated between 5 t CO$_2$ equivalents per 10,000 CNY to 8 t CO$_2$ equivalents per 10,000 CNY. When expressed on a per unit grain production basis, greenhouse gases emissions showed a continuous decline, then remained unchanged, and then gradually decreased. After 2010, the carbon emission of ten thousand yuan of GDP in Tibet is below 1.2. Due to the high emphasis on crop production, especially the implementation of a series of projects represented by the “one river and two rivers” comprehensive agricultural development, Tibet’s crop production conditions have been greatly improved, and the value of crop production has been greatly improved, therefore, the intensity of carbon emissions has decreased significantly. The production method of Tibet's crop industry is relatively primitive, so it is not greatly affected by agricultural modernization. Although the production of crop industry has made great progress, due to the low efficiency of crop production, especially the low level of agricultural industrialization, the income of herders has not continued to grow, so the intensity of carbon emissions is fluctuating.

3.3. Factors Driving Greenhouse Gases Emissions
Figure 2 highlights several characteristics from the decomposition analysis of planting sector carbon emissions since 1991 of Tibet. Generally speaking, the $\Delta SI$ increased mostly, meanwhile $\Delta CI$ decreased mostly. As can be seen from Figure 2, that SI and CI determined the development trend of the total greenhouse gases emissions. Economic factors changed from suppressing carbon emissions to promoting carbon emissions, from $-0.97 \times 10^6$ tons in 1991 to $71.68 \times 10^6$ tons of carbon dioxide in 2015. Conversely, the efficiency factor changed from promoting carbon emissions to suppressing carbon emissions, from $6.59 \times 10^6$ tons in 1991 has increased to $-94.41 \times 10^6$ tons of carbon dioxide in 2015. The
CI is the most contributing factor to cut the greenhouse gases emissions, whereas SI was the main factor that inhibited the greenhouse gases emission. AL also had a facilitate effect on agricultural greenhouse gases emissions. The SI changed a little, which had less impact on greenhouse gases emissions of agricultural relative to the impact from the efficiency factor and economic factor. Therefore, Tibet should adjust the agricultural industrial structure, vigorously develop a circular economy, and minimize the carbon emissions of the plantation industry.

![Figure 2](image_url)

**Figure 2.** The cumulative effect of the various drivers of greenhouse gas emitted by the Tibet’s crop farming over the period 1991-2015.

### 4. Conclusion

This study attempted to analyse the changes in farming industry carbon emissions and carbon intensity in Tibet by taking 1991-2015 as a sample period. Then we decomposed planting industry carbon emissions into agricultural efficiency factor, structure factor of agricultural, economy factor, and the labor factor by using the LMDI method, the main conclusions of this paper are as follows: From 1991 to 2015, the overall carbon emissions of the Tibetan plantation industry showed a “U”-shaped change trend. Due to natural conditions, N$_2$O from farmland is the leading source of greenhouse gas emissions from Tibet’s plantation industry. During the study period, both the greenhouse gas emission intensity of 10,000 yuan of GDP and the greenhouse gas emission intensity of unit food showed a downward trend, and then fluctuated within a certain range. The LMDI decomposition results showed the economic development and agricultural efficiency determined the trend of the total greenhouse gas emission. CI is the most important factor to cut the greenhouse gases emissions, whereas the main factor inhibiting carbon emissions was the SI, the AL also had a facilitate effect on promoting agricultural greenhouse gases emissions. The SI and AL had an increasing effect on promoting agricultural greenhouse gases emissions.

### References

[1] Netz B, et al. 2007 Climate change 2007: Mitigation. Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change *Summary for Policymakers* 18 (2) 95-123.

[2] Johnson M F, et al. 2007 Agricultural opportunities to mitigate greenhouse gas emissions *Environmental Pollution* 150 (1) 0-124.
[3] Ye B, et al. 2017 Quantification and driving force analysis of provincial-level carbon emissions in China Applied Energy 198 223-238.

[4] Norse D 2012 Low carbon agriculture: Objectives and policy pathways Environmental Development 1 (1) 25-39.

[5] Wang Z and Yang L 2015 Delinking indicators on regional industry development and carbon emissions: Beijing-Tianjin-Hebei economic band case Ecological Indicators 48 41-48.

[6] He J, et al. 2019 Research on characteristics and effecting factors of crop farming carbon emission in Henan Province, China IOP Conference Series: Earth and Environmental Science.

[7] Merino P, et al. 2011 Regional inventory of methane and nitrous oxide emission from ruminant livestock in the Basque Country Animal Feed Science & Technology 166-167 628-640.

[8] Li N, et al. 2020 Drivers of the national and regional crop production-derived greenhouse gas emissions in China Journal of Cleaner Production 120503.