sustainability

MDPI

Article

Spatial-Temporal Characteristics and LMDI-Based Impact Factor Decomposition of Agricultural Carbon Emissions in Hotan Prefecture, China

Chuanhe Xiong [1,2], Degang Yang [1,*] and Jinwei Huo [1]

[1] Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China; xiongchuanhe521@126.com (C.X.); huojinwei412829@163.com (J.H.)

[2] University of Chinese Academy of Sciences, Beijing 100049, China

* Correspondence: dgyang@ms.xjb.ac.cn; Tel.: +86-991-788-5346

Academic Editor: Maren Oelbermann

Received: 20 December 2015; Accepted: 8 March 2016; Published: 10 March 2016

Abstract: Greenhouse gas emissions from the agricultural ecosystem account for 7%–20% of the world's total greenhouse gas emissions, while approximately 17% of China's carbon emissions are from agriculture. In this study, based on the scientific calculation system of carbon emissions in agriculture, we calculated the carbon emissions of agriculture in the Hotan prefecture between 1999 and 2013 and analyzed their spatial-temporal characteristics; next, we used the LMDI model to study the driving factors of agricultural carbon emissions. The results demonstrated the following: (1) in time series, the agricultural carbon emissions showed three stages of change, *i.e.*, "decline, continued to rise and decline", during the period of 1999 to 2013 in the Hotan prefecture; (2) In space, the carbon emissions from agricultural land use, paddy fields, enteric fermentation, and manure management were different due to the different sizes of cities and counties. The intensity of agricultural carbon emissions was varied and high, but the agricultural production structure, agricultural carbon emissions structure and other aspects had a high degree of consistency and homogeneity in the cities and counties of the Hotan prefecture; (3) Regarding the driving mechanism, the labor factor, agricultural labor productivity, and planting-animal husbandry carbon intensity are the main factors that increase agricultural carbon emissions in the Hotan prefecture. Compared with 1999, three major factors cumulatively achieved a 199.68% carbon emission increment from 2000 to 2013, of which the labor factor cumulatively increased by 120.04%, the agricultural labor productivity factor cumulatively increased by 54.94% and the planting-animal husbandry carbon intensity factor cumulatively increased by 24.70%. The agricultural production structure factor largely inhibited agricultural carbon emissions of the Hotan prefecture, which cut 99.74% of the carbon emissions from 2000 to 2013. Finally, we proposed policy recommendations, including the acceleration of labor transfer, the innovation and promotion of science and technology, the scientific breeding and rational disposal of livestock waste, and the adjustment and optimization of the agricultural industry structure.

Keywords: Hotan prefecture; agricultural carbon emissions; spatial-temporal characteristics; driving mechanism; LMDI model

1. Introduction

Global warming, caused by human activities since the Industrial Revolution, has become an indisputable fact. The fourth report of the Intergovernmental Panel on Climate Change (IPCC), published in 2007, clearly noted that there are sufficient observations to prove the warming of the global climate system; more than 90% of the climate change is due to mankind's activity over the last 50 years [1]. The increase of CO_2, CH_4, N_2O and other greenhouse gases is the leading cause of global

climate change [2]. The secondary industry (the processing of products or raw materials provided by the primary industry and the secondary industry, including manufacturing, production and supply of electricity, water and gas, and construction.) and tertiary industry (all industries apart from agriculture, forestry, animal husbandry, and fishing, mining and quarrying, manufacturing, production and supply of electricity, water and gas, and construction.) are the leading sectors of carbon emissions, but the rapid development of agriculture is also an important factor accelerating the warming of the climate. Greenhouse gas emissions from the agricultural ecosystem account for 7%–20% of the world's total greenhouse gas emissions [3]. CO_2, CH_4, and N_2O emissions from agricultural sources account for 21%–25%, 57%, and 65%–80% of total anthropogenic greenhouse gas emissions, respectively [4]. Land use change caused by human activities (changes in agricultural crops, land cover change, *etc.*) is the second largest source of greenhouse gases in the atmosphere, second only to the burning of fossil fuels [5]. The greenhouse gas emissions caused by the changing of land use every year total approximately 116 billion metric tons of carbon, or 20% of the total emissions from human activities [6]. Approximately 17% of China's carbon emissions are from agriculture [7]. Agricultural emissions of CH_4 and N_2O account for 50% and 92% of China's total CH_4 and N_2O emissions, respectively [8].

Therefore, more and more scholars have begun to pay close attention to agricultural emissions. These studies focus on the calculation of agricultural carbon emissions [9–11], regional comparison of agricultural carbon emissions [12–17], the relationship between agricultural carbon emissions and economic growth [18–20], carbon emission driving factor analysis [21–24], and carbon emission reduction mechanism and policy [25–31]. Some scholars have attempted to study the regional equity of agricultural carbon emissions [32], decision mechanisms of agricultural carbon emissions [33], and agriculturally embodied carbon emissions [34]. Many scholars have used the Logarithmic Mean Divisia Index (LMDI) decomposition method, based on Kaya identity, to study the driving factors of carbon emissions [35–40]; their results show that the efficiency factor, economic structure factor, and technological progress factor have an inhibiting effect on agricultural carbon emissions; however, the economy factor plays an important role in promoting agricultural carbon emissions.

Overall, the current studies mainly focusing on agricultural carbon emissions in the country or in developed provinces are limited to the cropland ecosystem, and are not extended to the field of animal husbandry. Meanwhile, agricultural carbon emissions research for a particular area is insufficient [41], especially in the backward areas. Xinjiang's Hotan prefecture is a region with an under-developed economy and fragile environment. Its economy is dominated by agriculture and its agricultural production method and agricultural technology is under-developed, and the agricultural management is extensive. The extensive growth mode of agricultural economy, the extreme dependence of agricultural yield increase and income increase on material inputs and a market with diseased development make the agricultural carbon emissions reduction of the Hotan prefecture unique, complex, and difficult to control. Thus, it is very important to accurately grasp the driving mechanism of agricultural carbon emissions in the Hotan prefecture. Therefore, based on the scientific calculation system of carbon emissions in agriculture, we calculate the carbon emissions of agriculture in the Hotan prefecture between 1999 and 2013 and analyze its spatial-temporal characteristics; next, we use the LMDI model based on Kaya identity to study the driving factors of agricultural carbon emissions; finally, we present the final conclusion and recommendations to provide important theoretical and data support for the government to formulate scientific and reasonable carbon emission mitigation policies in Xinjiang's Hotan prefecture, to provide a reference for the establishment of related policies in agriculture in arid areas and to make a useful contribution to alleviating global climate change.

2. Materials and Methods

2.1. Study Area

The Hotan prefecture is located in the southernmost tip of the Xinjiang Uygur Autonomous Region. It borders the Mongolian Autonomous Prefecture of Bayingolin in the east, the Kashi Prefecture in the west, the Tibet Autonomous Region in the south, the Kashmir region in the southwest and the Aksu Prefecture in the north. It covers an area of approximately 248,100 km^2. Mountains in the Hotan prefecture account for 33.3%, deserts account for 63% and the oasis accounts for 3.7%. The oasis is divided into more than 300 subsections by the Gobi Desert [42].

The Hotan prefecture has a population of 2.15 million people, with 30 nationalities represented. Approximately 82.71% of the population works in agriculture. Its regional economy is dominated by agriculture, which can be divided into three main industries: planting, animal husbandry, and commercial forestry and fruit. The region's agricultural output value is 10.981 billion yuan, including three industries: the planting industry output value is 4.111 billion yuan, 37.44% of the total output value of agriculture; the animal husbandry output value is 3.213 billion yuan, accounting for 29.26%; the commercial forestry and fruit industry output value is 3.471 billion yuan, accounting for 31.61% of the total output value of agriculture. The per capita net income of farmers is 4542 yuan. The Hotan prefecture is the nation's most impoverished area.

2.2. Calculation Method of Agricultural Carbon Emissions

Currently, academics generally believe that agricultural carbon emissions mainly come from the following three sources: first, the carbon emissions caused by the use of agricultural land, including agricultural material input, energy consumption, land tilling, agricultural waste treatment, and other aspects involving carbon emissions [43]; second, the CH_4 gas emissions produced during the growth and development of rice [44]; third, the carbon emissions from livestock farming, including the carbon emissions from livestock and manure management [15]. Jane M F Johnson and Tian Yun have estimated the agricultural greenhouse gas emissions of the United States and China based on the aforementioned framework and confirmed that these three sources are the main contributors to agricultural carbon emissions [9,15].

Based on the carbon emission equation of Song Deyong and other scholars [45], we establish the agricultural carbon emissions formula as follows:

$$E = \sum E_i = \sum T_i \mu_i \quad (1)$$

where E is the total carbon emissions, E_i is the carbon emissions of carbon source i, T_i is the amount of carbon source i and μ_i is the carbon emission coefficient of carbon source i. To facilitate the analysis, we convert CH_4, N_2O to standard carbon. According to the IPCC fifth assessment report, the greenhouse effect caused by one ton of CH_4 is equivalent to 25 t CO_2 (approximately C 6.8182 t), while that caused by one ton of N_2O is equivalent to 298 t CO_2 (approximately C 81.2727 t) [46].

2.2.1. Carbon Emissions Caused by the Use of Agricultural Land

In accordance with the results of past research and experts' suggestions, we believe that the carbon emissions of agricultural land use mainly include the following three aspects: carbon emissions directly or indirectly caused by agricultural material inputs, such as chemical fertilizer, pesticides, plastic sheeting or agricultural diesel, soil organic carbon released from the agricultural land, and carbon emissions caused by agricultural irrigation. The carbon sources and coefficients are shown in Table 1.

Table 1. Carbon emission coefficients of major carbon sources of agricultural land use.

Source	Coefficient	Reference
Chemical fertilizer	0.8956 kg·C/kg	Zhi and Gao [47]
Pesticides	4.9341 kg·C/kg	Zhi and Gao [47]
Plastic sheeting	5.18 kg·C/kg	Tian [21]
Diesel	0.8636 kg·C/kg	IPCC [3]
Cultivated land	312.6 kg·C/km^2	Wu [48]
Irrigation	266.48 kg·C/hm^2	West [49]

2.2.2. CH_4 Gas Emissions Produced during the Growth and Development of Paddies

This study will refer to Min Jisheng [50], who calculated the CH_4 emission coefficient of paddy fields in different regions of China. The CH_4 emission coefficient is in accordance with the relevant model input for weather, soil, hydrological characteristics, and related parameters. He measured the provincial CH_4 emission coefficients in the early paddy, late paddy, and seasonal paddy. The CH_4 emission coefficient of Xinjiang is 10.5 g per square meter.

2.2.3. Carbon Emissions from Livestock Farming

Livestock breeding is another important source of N_2O and CH_4. Livestock breeding includes CH_4 emissions caused by enteric fermentation and the discharge of CH_4 and N_2O from manure.

The CH_4 coefficient of enteric fermentation is derived from the IPCC [51]. The IPCC also indicates that there is a coefficient of uncertainty, which is approximately 30%–50%. The CH_4 coefficient from livestock waste is also derived from IPCC [51]. The FAO released a nitrous oxide emissions coefficient of Chinese poultry excrement in 2004, which we use [52]. Currently, the main varieties of livestock in the Hotan prefecture are cows, horses, donkeys, mules, camels, pigs, sheep, *etc.* The discharge coefficient of animal husbandry is shown in Table 2.

Table 2. Carbon emission coefficient of major livestock (kg/head/year).

Source	Enteric Fermentation	Emissions from Manure		Reference
	CH_4	CH_4	N_2O	
Cow	61	18	1	IPCC [51], FAO [52]
Cattle	47	1	1.39	IPCC [51], FAO [52
Horse	18	1.64	1.39	IPCC [51], FAO [52]
Donkey	10	0.9	1.39	IPCC [51], FAO [52]
Mule	10	0.9	1.39	IPCC [51], FAO [52]
Camel	46	1.92	1.39	IPCC [51], FAO [52]
Pig	1	4	0.53	IPCC [51], FAO [52]
Goat	5	0.17	0.53	IPCC [51], FAO [52]
Sheep	5	0.15	0.53	IPCC [51], FAO [52]

2.3. Decomposition of Carbon Emissions Factors

This research will use the LMDI model based on Kaya identity to decompose the Hotan prefecture's agricultural carbon emissions, which can eliminate the residual term, thus overcoming shortcomings such as the existence of residuals or improper residual decomposition caused by using other methods.

Based on the existing literature [21,24,53,54] and combined with the actual situation of the agricultural carbon emissions, we obtain the following basic formula.

$$C = \frac{C}{PGDP} \times \frac{PGDP}{AGDP} \times \frac{AGDP}{AL} \times AL \tag{2}$$

$$CI = \frac{PGDP}{AGDP}\ EI = \frac{C}{PGDP}\ SI = \frac{AGDP}{AL}$$

In Equation (2), *C*, *PGDP*, *AGDP*, and *AL* represent agricultural carbon emissions, planting-animal husbandry gross output value, agricultural gross output value, and employment labor of the agricultural industry, respectively. *EI*, *CI*, and *SI* represent planting-animal husbandry carbon intensity, agricultural structure, and agricultural labor productivity, respectively. The LMDI model uses two methods, namely, "product decomposition" and "plus decomposition", to achieve decomposition. The results of both methods are consistent [21]. For the model in Equation (2), the total carbon emissions of the base period and T period were set as C_0 and C_t, respectively, and the subscript *tot* represents the total change. Using plus decomposition, the difference is decomposed into: $\Delta C_{tot} = C_t - C_{0.}$

The expression of the contribution value of each decomposition factor is as follows:

$$\begin{array}{ll} \triangle EI = \sum \dfrac{C_t - C_{0.}}{\ln C_t - \ln C_0} \ln \dfrac{EI_t}{EI_0} & \triangle CI = \sum \dfrac{C_t - C_{0.}}{\ln C_t - \ln C_0} \ln \dfrac{CI_t}{CI_0} \\ \triangle SI = \sum \dfrac{C_t - C_{0.}}{\ln C_t - \ln C_0} \ln \dfrac{SI_t}{SI_0} & \triangle AL = \sum \dfrac{C_t - C_{0.}}{\ln C_t - \ln C_0} \ln \dfrac{AL_t}{AL_0} \end{array} \quad (3)$$

The total effect is: $\Delta C_{tot} = C_t - C_0 = \Delta EI + \Delta C + \Delta SI + \Delta AL$

2.4. Data Description

All the data of land use, livestock population, planting-animal husbandry gross output value, agricultural gross output value, and employment labor of the agricultural industry are available in the Hotan prefecture statistical yearbooks (2000–2014). Chemical fertilizers, pesticides, plastic sheeting, and agricultural diesel are subject to the actual usage. Irrigation area, tillage area, and rice planting area are subject to the actual area of planting crops. Taking into account that the agricultural production values, which were calculated with respect to actual price, cannot be compared longitudinally, we use the added value of agricultural comparable price, *i.e.*, the price in 2000, as the price of the benchmark year.

3. Results

3.1. Agricultural Carbon Temporal Change and Spatial Contrast

(1) We calculate the agricultural carbon emissions from 1999 to 2013 in the Hotan prefecture, as shown in Table 3. The results show that the total carbon emissions were 591.99 $\times$ 10^3 tons in 1999 and 781.05 $\times$ 10^3 tons in 2013. Agricultural carbon emissions increased by 31.93%, with an average annual growth rate of 2.00%. The carbon emissions caused by the use of agricultural land, paddy fields, enteric fermentation, and manure management were, respectively, 246.63 $\times$ 10^3 tons, 0.817 $\times$ 10^3 tons, 263.62 $\times$ 10^3 tons, and 269.98 $\times$ 10^3 tons, and the proportions were 31.58%, 0.10%, 33.75%, and 34.57%, respectively, in 2013.

The agricultural carbon emissions show three stages of change, *i.e.*, "decline, continued to rise and decline", during this period. In the first stage, from 1999 to 2002, carbon emissions decreased. In the second stage, from 2003 to 2011, carbon emissions continued to rise. In the third stage, from 2012 to the present, carbon emissions decreased.

Animal husbandry is the first major source of greenhouse gases in agriculture in the Hotan prefecture. The carbon emissions produced by animal husbandry accounts for approximately 68.32% of the total carbon emissions from agriculture, including 33.75% from enteric fermentation and 34.57% from manure emissions. The carbon emissions of animal husbandry and agricultural carbon emissions were consistent, showing the three stages of change, *i.e.*, "decline, continued rise, and decline", during this period. The lowest point was in 2001, when the carbon emissions produced by animal husbandry were 401.16 $\times$ 10^3 tons; the highest point was in 2011, when the carbon emissions were 565.88 $\times$ 10^3 tons. Agricultural land use is the second source of carbon emissions in the Hotan prefecture. The overall trend of carbon emissions of agricultural land use was increasing during this period. Carbon emissions from agricultural land use were 246.63 $\times$ 10^3 tons in 2013, which was an increase of 96.25 $\times$ 10^3 tons and 63.96% compared with the lowest point in 2002. The proportion of carbon emissions in paddy fields was small, being approximately 0.10% of agricultural carbon emissions.

Table 3. Agricultural carbon emissions in Hotan Prefecture between 1999–2013 (10^3 tons).

Year	Carbon Emissions from Land Use	Growth Rate %	Carbon Emissions from Paddy Fields	Growth Rate %	Carbon Emissions from Enteric Fermentation	Growth Rate %	Carbon Emissions from Manure Emissions	Growth Rate %	Total Carbon Emissions	Growth Rate %
1999	177.63	-	0.752	-	199.65	-	213.97	-	591.99	-
2000	181.67	2.27	0.768	2.09	192.93	−3.36	209.01	−2.32	584.38	−1.29
2001	183.46	0.99	0.767	−0.14	192.23	−0.37	208.93	−0.04	585.38	0.17
2002	150.38	−18.03	0.754	−1.64	200.98	4.55	215.54	3.16	567.64	−3.03
2003	157.87	4.98	0.768	1.81	211.50	5.23	225.59	4.66	595.72	4.95
2004	163.86	3.79	0.746	−2.87	225.82	6.77	236.77	4.96	627.20	5.28
2005	178.56	8.97	0.786	5.49	241.65	7.01	248.22	4.83	669.21	6.70
2006	186.72	4.57	0.779	−0.93	257.50	6.56	258.79	4.26	703.79	5.17
2007	203.22	8.84	0.789	1.21	255.43	−0.81	257.22	−0.60	716.66	1.83
2008	212.24	4.44	0.776	−1.53	261.66	2.44	262.15	1.92	736.83	2.81
2009	223.33	5.23	0.813	4.68	269.79	3.10	270.18	3.06	764.12	3.70
2010	238.96	7.00	0.816	0.34	276.58	2.52	276.49	2.33	792.85	3.76
2011	243.72	1.99	0.819	0.41	283.30	2.43	282.58	2.20	810.41	2.21
2012	242.75	−0.40	0.819	0.04	277.83	−1.93	278.85	−1.32	800.25	−1.25
2013	246.63	1.60	0.817	−0.25	263.62	−5.12	269.98	−3.18	781.05	−2.40

Table 4. Agricultural carbon emissions of one city and seven counties in Hotan Prefecture in 2013 (10^3 tons).

Counties and Cities	Carbon Emissions from Land Use	Proportion	Carbon Emissions from Paddy Fields	Proportion	Carbon Emissions from Enteric Fermentation	Proportion	Carbon Emissions from Manure Emissions	Proportion	Total Carbon Emissions	Carbon Emission Intensity (kg/1000AGDP)
Hotan prefecture	246.63	0.3158	0.817	0.0010	263.62	0.3375	269.98	0.3457	781.05	1470.49
Hotan city	18.85	0.3598	0.047	0.0009	16.53	0.3154	16.97	0.3239	52.39	1486.98
Hotan county	34.24	0.2775	0.251	0.0020	45.49	0.3687	43.40	0.3518	123.37	1516.24
Moyu county	53.32	0.2645	0.224	0.0011	76.42	0.3790	71.67	0.3554	201.63	1670.92
Pishan county	36.15	0.4284	0.000	0.0000	22.09	0.2618	26.13	0.3097	84.37	1053.13
Luopu county	29.78	0.3314	0.001	0.0000	30.60	0.3405	29.48	0.3281	89.86	1653.17
Cele county	23.87	0.3294	0.000	0.0000	22.68	0.3129	25.92	0.3577	72.48	1518.23
Yutian county	44.36	0.3728	0.294	0.0025	35.48	0.2982	38.85	0.3266	118.98	1921.68
Minfeng county	6.06	0.1564	0.000	0.0000	14.86	0.3836	17.82	0.4600	38.75	2873.51

(2) In space, according to Equation (1), we calculate the agricultural carbon emissions of one city and seven counties in the Hotan prefecture in 2013 (Table 4).

From the ranking of the Hotan prefecture's eight counties' and cities' agricultural carbon emissions in 2013, the top three counties were Moyu county (201.63 × 10^3 tons), Hotan county (123.37 × 10^3 tons), and Yutian county (118.98 × 10^3 tons), which accounted for 56.85% of the total agricultural carbon emissions in the Hotan prefecture. The county ranked last was Minfeng county (38.75 × 10^3 tons), which accounted for 4.96% of the total agricultural carbon emissions in the Hotan prefecture. Thus, the total agricultural carbon emissions of one city and seven counties varied greatly.

The intensity of carbon emissions can objectively reflect every county's agricultural carbon emissions degree and make horizontal comparison among the different counties convenient. From the ranking of the Hotan prefecture's eight counties' and cities' intensity of carbon emissions in 2013, the top three counties were Minfeng county, Yutian county, and Moyu county, whose intensities of carbon emissions were, respectively, 2873.51 kg, 1921.68 kg, and 1670.92 kg of agricultural carbon emissions generated per 10,000 CNY agricultural output value. The county ranked last was Pishan county (1053.13 kg of agricultural carbon emissions generated per 10,000 CNY agricultural output value).

In conclusion, the carbon emissions from agricultural land use, paddy fields, enteric fermentation, and manure management were different due to the different sizes of the cities and counties. The intensity of agricultural carbon emissions was varied and high. However, agricultural production structure, agricultural carbon emissions structure, and other aspects had a high degree of consistency and homogeneity in the cities and counties of the Hotan prefecture.

3.2. Driving Mechanism Decomposition Results

Based on the LMDI model analysis, using Equations (2) and (3), we calculated the factors of the decomposition results of the Hotan prefecture's agricultural carbon emissions, as shown in Table 5.

Table 5. Decomposition results of agricultural carbon emission driving mechanism in Hotan Prefecture (10^3 tons).

Year	Planting-Animal Husbandry Carbon Intensity	Agricultural Structure	Agricultural Labor Productivity	Labor Factor	Total Effect
2000	−3.04	2.92	−14.91	7.41	−7.61
2001	11.01	−8.34	0.31	−1.98	1.00
2002	−2.81	−12.82	−17.92	15.80	−17.74
2003	41.81	−16.67	−7.30	10.24	28.08
2004	16.35	−11.22	0.51	25.84	31.48
2005	41.83	−21.96	11.79	10.36	42.01
2006	49.23	2.64	−19.21	1.92	34.58
2007	8.60	−25.76	19.23	10.80	12.88
2008	−28.05	3.90	40.14	4.17	20.17
2009	5.10	−28.59	56.58	−5.80	27.29
2010	−19.69	−23.87	59.34	12.95	28.74
2011	10.57	−16.60	1.49	22.10	17.56
2012	−70.29	−2.36	28.55	33.94	−10.16
2013	−13.89	−29.85	−54.70	79.24	−19.20
Total	46.73	−188.58	103.91	226.99	189.06

(1) The labor factor, agricultural labor productivity and planting-animal husbandry carbon intensity increased the Hotan prefecture's agricultural carbon emissions to various degrees. Compared with 1999, three major factors cumulatively achieved a 199.68% (377.63 × 10^3 tons) carbon emission increment from 2000 to 2013.The labor factor is the most contributing factor to the increase of agricultural carbon emissions. Compared with 1999, the labor factor cumulatively increased by 120.04% (226.99 × 10^3 tons) the carbon emissions from 2000 to 2013, that is, if other factors remain the same, the growing of agricultural labor results in the increasing of the Hotan

prefecture's agricultural carbon emissions, with an average rate of 16.21 $\times$ 10^3 tons per year. The agricultural labor productivity which represents the agricultural economic level to some extent is the second most contributing factor to the increase of agricultural carbon emissions. Compared with 1999, the economic factor cumulatively increased by 54.94% (103.91 $\times$ 10^3 tons) the carbon emissions from 2000 to 2013, that is, if other factors remain unchanged, the growing of the economy increases the Hotan prefecture's agricultural carbon, with an average rate of 7.42 $\times$ 10^3 tons per year. Compared with 1999, the planting-animal husbandry carbon intensity which represents efficiency factor of agricultural production means cumulatively increased by 24.70% (46.73 $\times$ 10^3 tons) the carbon emissions from 2000 to 2013, that is, if other factors remain unchanged, the efficiency factor decreases the Hotan prefecture's agricultural carbon emissions, with an average annual decrement of 3.32 $\times$ 10^3 tons.

(2) Agricultural production structure largely inhibited the agricultural carbon emissions of the Hotan prefecture. Compared with 1999, the structure factor cumulatively cut 99.74% (188.58 $\times$ 10^3 tons) of the carbon emissions from 2000 to 2013, which indicates that continuous optimization of the agricultural structure, promotes the Hotan prefecture's agricultural carbon emissions, with an average annual decrement of 13.53 $\times$ 10^3 tons, if other factors held constant.

4. Discussion

In time series (Table 3), the agricultural carbon emissions showed three stages of change, *i.e.*, "decline, continued rise, and decline", during the period of 1999 to 2013 in the Hotan prefecture. There were three reasons for the decline of carbon emissions in the first stage: first, the agricultural production structure began to change, from the production structure of the planting industry, animal husbandry, and the commercial forestry and fruit industries to the production structure of the commercial forestry and fruit industries, animal husbandry, and the planting industry, the result being the reduction of agricultural material inputs; second, due to the fall of meat product prices, the number of livestock declined year by year; third, cotton was affected by prices in 2002, with the plant area changing from 40.94 $\times$ 10^3 hectares in 2001 to 16.92 $\times$ 10^3 hectares in 2002 and the total area decreasing by 24.02 $\times$ 10^3 hectares, *i.e.*, by 58.80%, resulting in a significant reduction in the use of chemical fertilizers, pesticides, and plastic sheeting and resulting in carbon emissions of land use plummeting to 18.03%. There were two reasons for the increase of carbon emissions in the second stage: on the one hand, with the rapid development of the characteristic forestry and fruit industry and fruit trees in the fruiting stage, agricultural material inputs increased, resulting in the rapid increase of carbon emissions of agricultural land use; on the other hand, the amount of livestock breeding continued to increase, resulting in a substantial increase in carbon emissions of livestock husbandry. The most important reason for the decline of carbon emissions in the third stage was that the number of livestock had declined year by year. The Hotan prefecture's agricultural production pattern was an alternation of forest and agriculture crops, the ratio of which was approximately 83.74%. Along with the growth of fruit trees, it had great impact on the growth of wheat and corn. As a result, it led to a serious shortage of foraging and the number of livestock decreased year by year [42].

China's average agricultural carbon emissions intensity is 497.19 kg of agricultural carbon emissions generated per 10,000 CNY agricultural output value [15]. Xinjiang's agriculture belongs to the "low emission and high efficiency" agriculture, with the agricultural carbon emission intensity being 375.44 kg of agricultural carbon emissions generated per 10,000 CNY agricultural output value [32]. However, Hotan prefecture's eight counties' agricultural carbon emissions intensities are more than 1053.13 kg of agricultural carbon emissions generated per 10,000 CNY agricultural output value (Table 4). The Hotan prefecture's agricultural carbon emission reduction task is arduous.

Regarding the driving mechanism, the results of this study are different from the results of previous studies on the agricultural carbon emissions in the country or in developed provinces [21–24]. The extensive growth mode of the agricultural economy, the extreme dependence of agriculture yield increase and income increase on material inputs and the market with diseased development

make the agricultural carbon emissions driving factors of the Hotan prefecture unique and complex: (1) the labor factor is the most contributing factor to the increase of agricultural carbon emissions. There are two reasons: the first is that the natural population growth rate is high; the annual population natural growth rate was as high as 19.25% between 2000 and 2013, a net increase of the population of 473.00×10^3. The second reason is that the development of secondary industry and tertiary industry is seriously lagging behind, which makes labor transfer difficult. The Hotan prefecture is the area of the minority called Uighurs; thus, language is the biggest obstacle to the outward transfer of the agricultural labor force, leading to a large number of laborers being in rural areas. The labor factor will be the main driving force of agricultural carbon emissions increase in the future and will also become the difficult point of agricultural carbon emission reduction; (2) The Hotan prefecture's agricultural economy level is relatively backward, with agriculture as the foundation of economic and social stability and the key point of economic development [42]. Therefore, it can be predicted that the Hotan prefecture will speed up the development of its agricultural economy in the future; agricultural economic growth will gradually become the main driving force of the agricultural carbon increment; (3) In many studies [21–24], the results show that the efficiency factor (planting-animal husbandry carbon intensity) is the most important factor inhibiting agricultural carbon emissions. The extreme dependence of agricultural yield increase and income increase on material inputs and the agricultural production pattern of an alternation of forest and agriculture crops (the ratio of alternation of forest and agriculture crops was approximately 83.74%, and the net area of grain was very small in 2013) are the main reasons why the efficiency factor resulted in the increasing of the Hotan prefecture's agricultural carbon emissions; (4) Agricultural production structure largely inhibited the agricultural carbon emissions of the Hotan prefecture. Hotan prefecture's regional economy is dominated by agriculture, which can be divided into three main industries: planting, animal husbandry, and commercial forestry and fruit [42]. To make full use of local resources, expand the economic benefits of agriculture, and increase the income of farmers, the Hotan prefecture has developed its commercial forestry and fruit industries (walnut and jujube) for more than 15 years. The woodland area was 134.72×10^3 hectares in 1999 and was increased to 365.93×10^3 hectares in 2013. The Hotan prefecture has formed the production structure of the commercial forestry and fruit industries, animal husbandry industry, and planting industry. Thus, the proportion of farming-animal husbandry gross output value over the overall agricultural gross output value decreased. As a result, it contributes to the reduction of carbon emissions. This is the main reason why the structure factor resulted in the decreasing of the Hotan prefecture's agricultural carbon emissions.

5. Conclusions and Recommendations

5.1. Basic Conclusions

The following basic conclusions can be drawn:

(1) Through agricultural carbon temporal change and spatial contrast analysis, in time series, the agricultural carbon emissions showed three stages of change, *i.e.*, "decline, continued rise, and decline", during the period of 1999–2013 in the Hotan prefecture.

(2) In space, the carbon emissions from agricultural land use, paddy fields, enteric fermentation, and manure management were different due to the different sizes of the cities and counties. The intensity of agricultural carbon emissions was varied and high, but agricultural production structure, agricultural carbon emissions structure and other aspects had a high degree of consistency and homogeneity in the cities and counties of the Hotan prefecture.

(3) Regarding the driving mechanism, the labor factor, agricultural labor productivity, and planting andanimal husbandry carbon intensity are the main factors that increase agricultural carbon emissions in the Hotan prefecture. Compared with 1999, the three major factors cumulatively achieved a 199.68% (377.63×10^3 tons) carbon emission increment from 2000 to 2013, of which the labor factor cumulatively increased by 120.04% (226.99×10^3 tons), the agricultural labor

productivity factor cumulatively increased by 54.94% (103.91 $\times$ 10^3 tons) and the planting and animal husbandry carbon intensity factor cumulatively increased by 24.70% (46.73 $\times$ 10^3 tons). The agricultural production structure factor largely inhibited agricultural carbon emissions of the Hotan prefecture, cutting 99.74% (188.58 $\times$ 10^3 tons) of the carbon emissions from 2000 to 2013.

5.2. Policy Recommendations

Through the foregoing agricultural carbon temporal change and spatial contrast analysis, we know that the Hotan prefecture's agricultural carbon emissions have increased rapidly and the agricultural economy has developed slowly. China's average agricultural carbon emissions intensity is 497.19 kg/10,000 yuan AGDP [15]. Xinjiang's agriculture belongs to the "low emission and high efficiency" agriculture, with the agricultural carbon emission intensity being 375.44 kg/10,000 yuan AGDP [32]. However, the Hotan prefecture's agricultural carbon emissions intensity is 1470.49 kg/10,000 yuan AGDP. From LMDI-based impact factor decomposition analysis, we know that the Hotan prefecture is a region with a large population base, high natural growth rate of the population, a large number of laborers in rural areas, backward agricultural economy, backward agricultural production methods and agricultural technology. Meanwhile, the Hotan prefecture is a region with a backward economy and fragile environment that is dominated by an agricultural economy. Therefore, maintaining the rapid growth of the agricultural economy, with no substantial increase in agricultural carbon emissions, and ensuring that the intensity of carbon emissions per unit of agricultural GDP continues to decline will be the future development strategy. Thus, we propose the following policy recommendations:

(1) Promoting the formation of a characteristic industry chain, improving the quality and skills of rural labor, and speeding up the transfer of rural labor. The Hotan prefecture should focus on building a modern agriculture and agricultural products processing industry chain, national culture, national handicraft industry, and a tourism industry chain, establishing the flow of the commerce and logistics industry chain, accelerating economic development, and promoting rural labor employment. To improve the quality and employment ability of workers as the focal point, the Hotan prefecture should: strengthen bilingual education (Chinese and Uighur), quality education, and vocational education training; accelerate the cultivation of workers with higher cultural quality, labor skills, and information exchange capacity; and promote the docking of vocational education and technical training with an industry system to promote the population burden and employment pressure into the demographic dividend.

(2) Controlling the population growth rate and strengthening the existing family planning policy. The Hotan prefecture had a population of 2.15 million people in 2013. According to the forecasted growth rate from 2000 to 2013, the population is expected to experience a net increase of 850 $\times$ 10^3 people by 2030. To control the rapid population growth, the Hotan region should strengthen existing family planning policies, promote the effective implementation of the family planning policy, and form a long-term mechanism for family planning.

(3) Strengthening scientific and technological innovation and promotion and improving the scientific and technological guidance and support of low carbon agriculture. In many studies [21–24], the results show that the efficiency factor (planting-animal husbandry carbon intensity) is the most important factor inhibiting agricultural carbon emissions. Thus, efficiency factors have much carbon emission reduction space. The Hotan prefecture should give full play to the role of the national agricultural science and Technology Park of the Hotan prefecture and other platforms, strengthening the protection of the ecological environment. The aim should be to conserve land, save water, reduce the use of fertilizers, reduce the use of pesticides, save energy, and reduce agricultural ecological environment construction. The Hotan prefecture should increase the intensity of science research and technology integration of assembling complete sets, continue to carry out the research and promotion of low carbon agricultural technology for conserving land, saving water, reducing the use of fertilizers, reducing the use of pesticides, saving energy,

and reducing agricultural waste generation. At the same time, the Hotan prefecture should introduce a variety of low carbon agricultural technology with the corresponding equipment, knowledge, and talents; carry out technical guidance and training for the various low carbon agriculture practices through related colleges and universities, scientific research institutions, and social organizations; and promote the application of water-saving irrigation technology, energy conservation tillage technology and soil testing, and formula fertilization technology and other low carbon agricultural technology. Through scientific and technological innovation and promotion, modern agricultural science and technology will become an important support for reducing carbon emissions and increasing carbon sink in the process of agricultural development.

(4) Breeding scientifically, the rational disposal of livestock waste and reducing livestock greenhouse gas emissions. Scientific feeding technology can effectively reduce the greenhouse gas emissions of animal husbandry. The research shows that a reasonable proportion of fine feedstuff can effectively improve the efficiency of feed utilization and reduce greenhouse gas emissions [55]. The cultivation of fine animal breeds is also an important measure for reducing the emission of greenhouse gas in animal husbandry [55]. Therefore, the reduction of greenhouse gas emissions from livestock must be followed by scientific breeding in the Hotan prefecture. The Hotan prefecture should improve the efficiency of livestock production and reduce greenhouse gas emissions by adjusting the feed structure, breeding good livestock species, and other means.

Animal waste is the main contributor to the CH_4 and N_2O emissions of livestock; reasonable management measures can effectively reduce environmental pollution and reduce greenhouse gas emissions. Animal husbandry is given priority over family husbandry in Hotan prefecture. We can use different treatments to reduce the greenhouse gas emissions from animal waste during different seasons. Animal waste can be stacked in the air during the summer, but the composting process must be sealed during winter [56]. Currently, the best solution is to use an anaerobic fermentation system to produce methane as a source of energy. For villages with methane pools, vehicles can be used to collect the waste and the scattered animal waste can be used for resource reuse. To promote the clean treatment of livestock waste is an effective means of ensuring the safety of the rural environment and reducing the emissions of greenhouse gases in the Hotan prefecture.

(5) Adjusting and optimizing the structure of the agricultural industry and reducing agricultural carbon emissions. Forests are highly important, acting as absorption "sinks" of CO_2. The Hotan prefecture has formed the production structure of the commercial forestry and fruit industries, animal husbandry, and the planting industry. The woodland area was 134.72×10^3 hectares in 1999 and increased to 365.93×10^3 hectares in 2013. The Hotan prefecture should strive to ensure food security, further adjust and optimize the structure of the agricultural industry, and constantly optimize the regional layout and structure of agricultural production.

Acknowledgments: This work was supported by the Study on Oasis Population Evolution and Transfer Way: A Case in Moyu County (Y435131001).

Author Contributions: All authors contributed equally to this work. In particular, Chuanhe Xiong developed the original idea for the study and conceived of and designed the methodology. Chuanhe Xiong drafted the manuscript, which was revised by Degang Yang and Jinwei Huo. All authors have read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

LMDI	Logarithmic Mean Divisia Index

References

1. IPCC. *Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Climate Change 2007: Synthesis Report; Pachauri, R.K., Reisinger, A., Eds.; IPCC: Geneva, Switzerland, 2007; p. 104.
2. IPCC. *The Science of Climate Change. The Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change*; Climate Change 1995; Cambridge University Press: New York, NY, USA, 1996.
3. IPCC. *Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge*; Climate Change 2007; Cambridge University Press: London, UK, 2007.
4. Lin, E.D. *Climate Change and Sustainable Development of Agriculture*; Beijing Press: Beijing, China, 2001. (In Chinese)
5. Li, X.B. Research on Environmental Impact of International Land-Use/Cover Change. *Adv. Earth Sci.* **1999**, *14*, 395–400. (In Chinese).
6. Paustian, K.; Cole, C.V.; Sauerbeck, D.; Sauerbeck, D.; Sampson, N. CO_2 Mitigation by Agriculture: An Overview. *Clim. Chang.* **1998**, *40*, 135–162. [CrossRef]
7. Ran, G.H.; Wang, J.H.; Wang, D.X. Study on the carbon emissions of modern agricultural production in China. *Issues Agric. Econ.* **2011**, *2*, 32–38. (In Chinese).
8. Li, B. *Agricultural Carbon Emissions in China: A Case Study of the Agricultural Land Use*; People Press: Beijing, China, 2013. (In Chinese)
9. Johnson, J.M.F. Agricultural opportunities to mitigate greenhouse gas emissions. *Environ. Pollut.* **2007**, *150*, 107–124. [CrossRef] [PubMed]
10. Massey, R.; Ulmer, A. Agriculture and greenhouse gas emissions. Available online: http://extension.missouri.edu/p/G310 (accessed on 12 December 2015).
11. Tian, Y.; Li, B.; Zhang, J.B. Research on stage characteristics and factor decomposition of agricultural land carbon emission in China. *J. China Univ. Geosci.* **2011**, *11*, 59–63. (In Chinese).
12. Tasman, P.L. *Agriculture and GHG Mitigation Policy: Options in Addition to the CPRS*; Industry & Investment NSW: Dubbo, Australia, New South Wales, 2009.
13. Li, B.; FU, S.Y.; Zhang, J.B.; Yu, H.S. Carbon Functions of Agricultural Land Use and Economy across China: A Correlation Analysis. *Energy Procedia* **2011**, *5*, 1949–1956.
14. Wu, X.R.; Zhang, J.B.; Kulatunga, A.K.; Tian, Y. Provincial agricultural carbon emissions in China: Calculation, efficiency change and convergence test. *J. Food Agric. Environ.* **2014**, *12*, 503–508.
15. Tian, Y.; Zhang, J.B.; Li, B. Agricultural carbon emissions in China: Calculation, spatial-temporal comparison and decoupling effects. *Resourc. Sci.* **2012**, *34*, 2097–2105. (In Chinese).
16. Li, B.; Zhang, J.B.; Li, H.P. Research on Spatial-temporal Characteristics and Affecting Factors Decomposition of Agricultural Carbon Emission in China. *China Popul. Resour. Environ.* **2011**, *21*, 80–86.
17. Pang, L. Empirical study of regional carbon emissions of agriculture in China. *J. Arid Land Resour. Environ.* **2014**, *28*, 1–7.
18. Su, Y.; Ma, H.L.; Li, F. Xinjiang agriculture and animal husbandry carbon emissions and its decouping relationship with agricultural economic growth. *Arid Land Geogr.* **2014**, *37*, 1047–1054.
19. Li, B. Empirical study on relationship between economic growth and agricultural carbon emissions. *Ecol. Environ. Sci.* **2012**, *21*, 220–224. (In Chinese).
20. Zaman, K.; Khan, M.M.; Ahmad, M.; Khilji, B.A. The relationship between agricultural technologies and carbon emissions in Pakistan: Peril and promise. *Econ. Model.* **2012**, *29*, 1632–1639. [CrossRef]
21. Tian, Y.; Zhang, J.B.; He, Y.Y. Research on Spatial-Temporal Characteristics and Driving Factor of Agricultural Carbon Emissions in China. *J. Integr. Agric.* **2014**, *13*, 1393–1403. [CrossRef]
22. Yang, J. The Effects of Technological Advances on Agricultural Carbon Emission- Evidence from Chinese Provincial Data. *Soft Sci.* **2013**, *27*, 116–120. (In Chinese).
23. Lu, Z.Y. The influence from the progress of agricultural science and technology to agricultural carbon emission based on provincial point. *Stud. Sci. Sci.* **2013**, *31*, 674–683. (In Chinese).
24. Li, G.Z.; Li, Z.Z. Carbon emissions decomposition analysis on agricultural energy consumption—Based LMDI model. *J. Agrotech. Econ.* **2010**, *10*, 66–72. (In Chinese).

25. Peters, M.; House, R.; Lewandrowski, J.; Mcdowell, H. Economic impacts of carbon charges on U.S. agriculture. *Clim. Chang.* **2001**, *50*, 445–473. [CrossRef]
26. Mccarl, B.A.; Schneider, U.A. U.S. agriculture's role in a greenhouse gas emission mitigation world: An economic perspective. *Rev. Agric. Econ.* **2000**, *22*, 134–159. [CrossRef]
27. Paustian, K.; Six, J.; Elliott, E.T.; Hunt, H.W. Management options for reducing CO_2 emissions from agricultural soils. *Biogeochemistry* **2000**, *48*, 147–163. [CrossRef]
28. Kragt, M.E.; Pannell, D.J.; Robertson, M.J.; Thamo, T. Assessing costs of soil carbon sequestration by croplivestock farmers in Western Australia. *Agric. Syst.* **2012**, *112*, 27–37. [CrossRef]
29. Burney, J.A.; Davis, S.J.; Lobell, D.B. Greenhouse gas mitigation by agricultural intensification. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 12052–12057. [CrossRef] [PubMed]
30. Bracmort, K. Nitrous oxide from agricultural sources: Potential role in greenhouse gas emission reduction and ozone recover. *Congress. Res. Serv.* **2010**, *1*, 1–9.
31. Steenblik, R.; Moise, E. Counting the Carbon Emissions from Agricultural Products: Technical Complexities and Trade Implications. 2010. Available online: http://www.agritrade.org (accessed on 24 December 2014).
32. Tian, Y.; Zhang, J.B. Fairness Research of Agricultural Carbon Emissions between Provincial Regions in China. *J. Arid Land Resour. Environ.* **2013**, *23*, 36–44. (In Chinese).
33. Zhang, G.S.; Wang, S.S. China's Agricultural Carbon Emission: Structure. *Effic. Determ.* **2014**, *35*, 18–26. (In Chinese).
34. Dai, X.W.; Qi, Y.B.; Tang, H. Embodied CO_2 emission calculation and influence factors decomposition in China's agriculture sector. *Resour. Sci.* **2015**, *37*, 1668–1676. (In Chinese).
35. Mahony, T.O. Decomposition of Ireland's carbon emissions from 1990 to 2010: An extended Kaya identity. *Energy Policy* **2013**, *59*, 573–581. [CrossRef]
36. Duro, J.A.; Padilla, E. International inequalities in per capita CO_2 emissions: A decomposition methodology by Kaya factors. *Energy Econ.* **2006**, *28*, 170–187. [CrossRef]
37. Duro, J.A. Weighting vectors and international inequality changes in environmental indicators: An analysis of CO_2 per capita emissions and Kaya factors. *Energy Econ.* **2013**, *39*, 122–127. [CrossRef]
38. Zhang, L.; Lei, J.; Zhang, X.L.; Dong, W.; Yang, Y. Changes in carbon dioxide emissions and LMDI-based impact factor decomposition: The Xinjiang Uygur autonomous region as a case. *J. Arid Land* **2014**, *6*, 145–155. [CrossRef]
39. Tang, J.R.; Zhang, B.Y.; Wang, Y.H. Research on the driving factors of carbon emissions in China based on LMDI. *Stat. Inf. Forum* **2011**, *11*, 19–25. (In Chinese).
40. Han, Y.F.; Zhang, L. Study on the factors of agricultural carbon emissions in China: LMDI decomposition method based on energy consumption and trade. *Contemp. Econ. Res.* **2013**, *4*, 47–52. (In Chinese).
41. Zhang, X.P.; Fang, T. Influence factors of carbon emission in Gansu Province. *Arid Land Geogr.* **2012**, *35*, 487–493. (In Chinese).
42. Hotan Statistical Bureau. *Hotan Statistical Yearbook*; Hotan Statistical Bureau: Hotan, China, 2013. (In Chinese).
43. Zhao, Q.G.; Qian, H.Y. Low carbon economy and thinking of agricultural development. *Ecol. Environ. Sci.* **2009**, *18*, 1609–1614. (In Chinese).
44. Li, Y.C.; Lin, E.D.; Zhen, X.L. Advances in methods of agricultural greenhouse gas inventories. *Adv. Earth Sci.* **2007**, *22*, 1076–1080. (In Chinese).
45. Song, D.Y.; Lu, Z.B. The Factor Decomposition and Periodic Fluctuations of Carbon Emission in China. *China Popul. Resour. Environ.* **2009**, *19*, 18–24. (In Chinese).
46. IPCC. *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Climate Change 2014; Pachauri, R.K., Meyer, L.A., Eds.; IPCC: Geneva, Switzerland, 2014; p. 151.
47. Zhi, J.; Gao, J.X. Analysis of carbon emission caused by food consumption in urban and rural inhabitants in China. *Prog. Geogr.* **2009**, *28*, 429–434. (In Chinese).
48. Wu, F.L.; Li, L.; Zhang, H.L.; Chen, F. Effects of conservation tillage on net carbon flux from farmland ecosystems. *Chin. J. Ecol.* **2007**, *26*, 2035–2039. (In Chinese).
49. West, T.O.; Marland, G. A Synthesis of Carbon Sequestration, Carbone Missions, and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States. *Agric. Ecosyst. Environ.* **2002**, *91*, 217–232. [CrossRef]

50. Min, J.S.; Hu, H. Calculation of Greenhouse Gases Emission from Agricultural Production in China. *China Popul. Resour. Environ.* **2012**, *22*, 21–27. (In Chinese).
51. IPCC. *IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Agriculture, Forestry and Other Land Use*; IPCC: Geneva, Switzerland, 2006.
52. FAO. *Livestock Long Shadow*; FAO: Rome, Italy, 2006; pp. 97–110.
53. Kaya, Y. *Impact of Carbon Dioxide Emission on GNP Growth: Interpretation of Proposed Scenarios*; Presentation to the Energy and Industry Subgroup, Response Strategies Working Group, IPCC: Paris, France, 1989.
54. Liu, L.H.; Fan, Y.; Wu, G. Using LMDI method to analyze the change of China's industrial CO_2 emissions from final fuel use: An empirical analysis. *Energy* **2007**, *35*, 5892–5900. [CrossRef]
55. Chen, Y.; Shang, J. Estimation and Effecting Factor Decomposition of Green House Gas Emission of Animal Husbandry Industry in Four Pastoral Areas. *China Popul. Resour. Environ.* **2014**, *24*, 89–95. (In Chinese).
56. Thomas, J.; Eberhard, H.; Gregor, B. Greenhouse gas emissions from animal houses and manure stores. *Nutr. Cyling Agroecosyst.* **2001**, *60*, 133–145.



© 2016 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons by Attribution (CC-BY) license (http://creativecommons.org/licenses/by/4.0/).