Open Access

Advances in Environmental and Engineering Research

LIDSEN Publishing Inc.

Review

Carbon Footprint Study of Korean Green Tea Industry Using the Methods of the Life Cycle Assessment and Calculating Carbon Absorption in Agricultural Land

Noh-Hyun Lim [1,*], Yongjin Lee [1], Jieon Lee [2], Jongsek Kim [3]

1. Dev. of Certification Business, Institute of Global Sustainability Certification, Seoul, 03371, Republic of Korea; E-Mails: nohyun.lim@gmail.com; yongjin.lee@igsc.kr
2. Dep. of Materials Chemistry and Engineering, Konkuk University, Seoul, 05029, Republic of Korea; E-Mail: lju9141@naver.com
2. Dep. of Environmental Engineering, University of Seoul, Seoul, 02504, Republic of Korea; E-Mail: gotop1@naver.com

* **Correspondence:** Noh-Hyun Lim; E-Mail: nohyun.lim@gmail.com

Academic Editor: Paul Dargusch

Special Issue: Case Studies of Carbon Management in Practice

Adv Environ Eng Res
2022, volume 3, issue 4
doi:10.21926/aeer.2204047

Received: September 02, 2022
Accepted: November 21, 2022
Published: December 02, 2022

Abstract

Due to recent global warming and climate change events, about 127 countries have declared themselves carbon neutral since the Paris Agreement was signed. Furthermore, agriculture is directly or indirectly affected by climate change. In particular, the importance of carbon neutrality is very high due to the high carbon absorption potential of forestry biomass. In the global beverage market, green tea is the second most consumed beverage after water, and the potential of tea tree biomass to absorb carbon during cultivation is quite high. Accordingly, major tea-producing countries such as China, Taiwan, India, and Sri Lanka are conducting life cycle assessment studies of tea which can be used to reference carbon neutrality in agriculture. In this study, net greenhouse gas (GHG) emissions over the entire life cycle of the Korean green tea industry were calculated by considering the changes in biomass carbon accumulation in green tea plantations according to the life cycle evaluation method and IPCC's Gain-loss method. The net GHG emission of green tea in Korea varies widely, with biomass carbon absorption as high as 59% and as low as 3% per year due to agricultural land maintenance, which significantly impacts the net GHG emission result. In other words, it is important to maintain the cultivation area for carbon neutrality in the future because the changes in the green tea cultivation area have a significant effect on biomass carbon stock, affecting the whole net GHG emission process.

Keywords
Green tea; LCA; carbon footprint

1. Introduction

The international community has recognized the need for joint efforts due to global warming and climate change, adopting the Paris Agreement in 2015 to launch a new climate system. After the Paris Agreement, carbon neutrality, matching emissions and absorption, has emerged as a global agenda to limit the rise in global average temperature from below 2°C to below 1.5°C by 2050. Accordingly, 127 countries, including many in Europe, the United States, China, and Japan, have declared that they have become or are in the process of becoming carbon neutral.

Korea has also declared carbon neutrality by submitting its "2050 Long-Term Low-Carbon Development Strategy" and "2030 National Greenhouse Gas Reduction Target" to the United Nations in December 2020. Although the agricultural sector is directly or indirectly affected by climate change with events such as crop death, flooding, sea ice, and loss of agricultural land, it also has the potential to reduce greenhouse gas (GHG) emissions.

Since 2018, Korea's livestock emissions have been approximately 11.2 million tons of CO2 eq. and 1.4 million tons of CO2 eq. of GHG emissions must be reduced to achieve carbon neutrality. In particular, the importance of carbon neutrality is very high due to the high carbon absorption potential of forest biomass. Regarding agricultural production in Korea, the Agricultural Promotion Administration conducted a carbon footprint study on major crops such as rice, barley, potato, sweet potato, and bean in 2010, and has not conducted carbon footprint studies of other agricultural products since then [1-5].

However, Korea does not yet have a formal methodology for evaluating the carbon uptake potential of biomass. In addition, research on calculating carbon emissions throughout the product life cycle for a specific industry has been slow in Korea.

In the global beverage market, green tea is the second most consumed beverage after water, and the biomass of tea trees has considerable potential to absorb carbon during cultivation. Accordingly, life cycle assessment studies of tea are being conducted in major tea-producing countries such as China, Taiwan, India, and Sri Lanka (as shown in Table 1). However, the cultivation environment, cultivation method, and tea manufacturing method of green tea produced in Korea have some differences from other countries. Furthermore, there are differences in the system boundary and the scenario part of the use stage.

Table 1 Study case of life cycle assessment related to tea.

Country	Contents	Year	System Boundary	Carbon footprint results
China [6]	Carbon footprint and primary energy demand of organic tea in China using a life cycle assessment approach	2019	cultivation – processing-packaging/storage – transportation/distribution – consumption – disposal	Wuyangchunyu 19.2 kg CO2 eq./kg Longjing 19.9 kg CO2 eq./kg
Taiwan [7]	Environmental Implications of Taiwanese Oolong Tea and the Opportunities of Impact Reduction	2019	cultivation – processing-packaging-consumption	28.6 g CO2 eq./Each serving of Oolong tea
India [8]	Life cycle assessment of drinking Darjeeling tea – Conventional and organic Darjeeling tea	2010	cultivation – processing-transportation-packaging – distribution – consumption	48 g CO2 eq./cup 21.14 kg CO2 eq./kg
Iran [9]	Cradle to grave environmental-economic analysis of tea life cycle in Iran	2018	Cultivation – transportation – processing-packaging – consumption	2.13 g CO2 eq./12 g leaves
Kenya [10]	The global warming potential of production and consumption of Kenyan tea	2015	cultivation – transportation – processing/packaging-transportation-storage – distribution – consumption-disposal	12.45 kg CO2 eq./kg
Sri Lanka [11]	Energy usage and greenhouse gas emissions associated with tea and rubber manufacturing processes in Sri Lanka	2018	cultivation – transportation – processing	514.27 ± 68.66 kg CO2 eq./ton
Indonesia [12]	Life Cycle Inventory of Green Tea Production: Case of Gambung	2018	cultivation – processing	-

In this study, the environmental impact of green tea was quantified by performing a life cycle assessment of green tea produced in Korea that met the cultivation environment, cultivation method, and tea manufacturing method as well as the system boundary and the scenario part of the use stage in Korea. The carbon absorption amount of green tea biomass was calculated using the IPCC's gain-loss method, and the net GHG emission from green tea plantations was calculated [13, 14]. This study is the first study on carbon absorption in the green tea industry in Korea and aims to determine the carbon neutrality potential of green tea.

2. Methodology

In this study, the GHG emissions in the life cycle of green tea were calculated using the EPD guideline[15] from the Korea Ministry of Environment and the guideline[16] for Low Carbon Agricultural and Livestock Goods Certification of the Ministry of Agriculture, Food and Rural Affairs in Korea following the ISO 14040 and 14044 guidelines[17, 18]. In addition, the carbon uptake of green tea biomass was calculated using the IPCC's gain-loss method.

2.1 Goal and Scope of the Study

The target product of this study is green tea, which is used as an ingredient in food and food manufacturing, and the amount of green tea and water consumed when drinking a cup of green tea varies according to consumers' tastes and types of tea. Therefore, a cup of tea containing 2 g of tea leaves and 200 mL of water was set as a functional unit of the tea-drinking method recommended by the Korean Tea Culture Association (as shown in Table 2).

Table 2 Product specification.

Category	Contents
Function	Drinking water with tea leaves
Functional unit	a cup of green tea
Reference flow	2 g tea leaves, 200 mL water

The system boundary included in this study are shown in Figure 1, including the green tea cultivation stage of growing tea leaves, the primary processing stage of steaming and drying the tea leaves to prevent oxidation, the production stage of packaging materials to distribute the dried green tea, the transportation stage of transporting the packaging material to the secondary processing area, the secondary processing and packaging stages of tea roasting and packaging, and the distribution stage of providing finished products to consumers. It also includes the use stage of green tea consumed by consumers and the disposal stage of discarding the brewed tea leaves and packaging materials after consumption by the consumer.

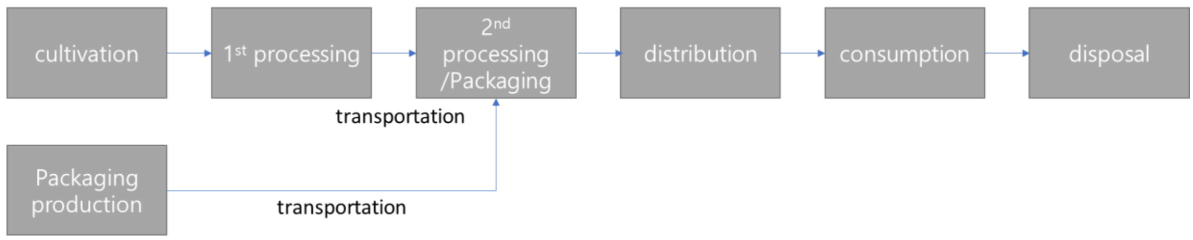

Figure 1 System boundary for green tea.

2.2 Data Collection and Calculation

Data collection by System boundary for green tea collected the average data of Korea in 2019, and if other data could not be collected, the international average data of LCI DB developed by ecoinvent was collected (as shown in Table 3).

Table 3 Data collection.

Coverage		Description
Internal Data	Time	2019
	Geology	Korea
	Technology	Best available technology
External Data	Time	Recent LCI database
	Geology	LCI DB developed by ecoinvent (International average)
	Technology	Data from similar technology

2.2.1 Pre-manufacturing

Cultivation Stage. Agricultural materials and energy consumption were collected using field data from green tea farms in Korea, "agricultural and livestock income data" and statistics from the Rural Development Administration. It also included the planting process of green tea seedlings, cultivation management such as fertilization, control, pruning, branch priming, and agricultural work such as tea leaf extraction.

The content of active ingredients in the crop protection agent used in the green tea cultivation stage refers to the "Common Guidelines for the Calculation of Greenhouse Gas Emissions from Agricultural Products" of the Agricultural Technology Commercialization Foundation. In addition, the IPCC 2006 Guidelines [19] and Methods were applied for nitrous oxide emissions from fertilizer use. In addition, the emission coefficients of each fuel in the Korea Environment Corporation's "Guidelines for Calculating Local GHG Emissions" [20] were applied for the air pollutant emissions from gasoline and diesel combustion. For the landfill/incineration/recycling waste generated from the use of other agricultural materials (light-shielding film, drip hose), the Agricultural Technology Commercialization Foundation's "Common Guidelines for Calculating Agricultural Product GHG Emissions" were applied. Lastly, since other agricultural materials are used for a long period, the annual usage was calculated by dividing by the lifespan.

Packaging Production Stage. The consumption of raw and subsidiary materials and the fuel used in the production stage of packaging material were collected, and air pollutants caused by liquefied petroleum gas combustion were calculated according to the guidelines of the Korea environmental industry & technology institute.

2.2.2 Manufacturing Stage

The manufacturing stage first included the processing of the tea leaves produced during the pre-manufacturing stage, secondary processing, product inspection, and packing and shipping of the final product.

First Processing. The consumption of electricity, liquefied natural gas (LNG), and kerosene was collected in the primary processing step of steaming and drying tea leaves to prevent oxidation. Air pollutants generated by combustion were calculated according to the guidelines of the Korea

Environment Corporation [21, 22].

Secondary Processing and Packaging. In the secondary processing step of roasting and packaging tea leaves, by-products other than green tea products are produced, which have economic value. Accordingly, the consumption of electricity and LNG, which were commonly used for products and by-products, were allocated by reflecting the economic value and production ratio. In addition, the packaging step for the produced product was also included.

Transportation. Transportation was calculated based on the distance from each region [23], including land transportation by truck and sea transportation to Jeju Island, based on the region where the delivered raw and subsidiary materials are input into the manufacturing process.

2.2.3 Distribution Stage

Distribution was calculated based on regional distance (EPD, 2019), including land transportation by truck and sea transportation to Jeju Island, and the region where the delivered product is sold to consumers.

2.2.4 Use Stage

According to the tea-drinking recommendation of the Korea Tea Culture Association, the amount of tea leaves used to drink a cup of tea was 2 g, and the amount of water was 200 mL. Assuming water was used as the energy source, from the standard temperature of 20°C to a boiling temperature of 100°C. In addition, electricity and city gas (LNG) were used as energy sources for boiling water at 46% and 54%, respectively. This conclusion was based on the assumption of electricity consumption and applied the 46% penetration rate of an electric port from the "2019 Home Appliance Supply Status Survey".

-Electricity required to boil 1 kg of water (kWh) = specific heat capacity of water (4.187 kJ/kg K) × temperature (80 K)/conversion factor (3600 kWh/kJ)/electric pot thermal efficiency (85%) = 0.109 kWh

-The amount of LNG required to boil 1 kg of water (L) = specific heat capacity of water (4.187 kJ/kg K) × temperature (80 K)/heat capacity of LNG (42.7 kJ/L)/thermal efficiency of gas range (50%) = 16 L

2.2.5 Disposal Stage

The disposal stage was calculated by considering the items to be recycled, incinerated, or landfilled by material and applying the disposal scenario and data from the Ministry of Environment's EPD certification guidelines [24, 25].

2.3 Carbon Uptake Calculation

Methods for estimating the carbon absorption in agricultural land are divided into three types according to the application of emission factors and activity data.

Tier 1 is the method that applies the basic formula and basic coefficients provided by the IPCC.

Tier 2 is the method that develops and applies country-specific coefficients. Tier 3 is a method to develop and apply country-specific coefficients with more detailed and clear data than Tier 2.

Currently, Korea has not developed a country-specific coefficient, so the Tier 1 method, IPCC's "Gain-loss method," was applied to calculate the changes in carbon stock (absorption) of green tea biomass.

* Annual change in carbon stocks in biomass (Gain-loss method): $\Delta CLB = \Delta CG - \Delta CL$

ΔCLB: annual change in carbon stocks in biomass for each land subcategory, considering the total area (ton C/yr)

ΔCG: annual increase in carbon stocks due to biomass growth for each land subcategory, considering the total area (ton C/yr)

ΔCL: annual decrease in carbon stocks due to biomass loss for each land subcategory, considering the total area (ton C/yr)

(LB: living biomass, G: growth, L: loss)

- 2006 IPCC GL, Chapter 2, Equation 2.7

The gain-loss method assumes that all carbon in the removed perennial woody biomass is released in the year it is removed and that the carbon accumulation period is the same as the mature tree cycle. In this study, the green tea planted area and reduced area in Korea were collected through the "Special Crop Production Performance" published by the Ministry of Agriculture, Food and Rural Affairs (as shown in Table 4).

Table 4 Planting area of green tea in Korea from 2010 to 2019 (unit: hectare).

Region	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gwangju	17	17	17	17	17	17	17	17	5	1
Ulsan										3
Chungnam	6	7	7	7	7	7	7	7	7	3
Jeonbuk	144	123	71	69	69	57	62	62	49	90
Jeonnam	1,599	1,615	1,434	1,453	1,420	1,237	1,397	1,384	1,291	1,271
Gyeongnam	1,157	1,201	1,137	1,135	1,088	1,150	1,125	989	824	884
Jeju	354	346	338	245	300	300	298	592	568	592
total	3,277	3,309	3,004	2,926	2,901	2,768	2,906	3,051	2,744	2,844

2.4 Net GHG Emissions Estimation

The net GHG emission of green tea was calculated considering the GHG emission of 1 kg of green tea calculated through the life cycle assessment method and the change in carbon dioxide accumulation in the green tea growing area calculated through the gain-loss method.

Net GHG Emissions = (GHG Emissions in the Product's Lifecycle − Changes in Carbon Dioxide Accumulation)/yield of green tea

3. Results and Discussion

3.1 Life Cycle Impact Assessment (LCIA)

The LCIA quantifies the magnitude of the environmental impact on the entire process of a product or system. In this study, the GHG emissions of the entire process were calculated by applying the Ministry of Environment's EPD certification guideline and the Korean Ministry of Agriculture, Food and Rural Affairs' Low Carbon Agricultural and Livestock Goods Certification guideline. Considerable influence categories included global warming (GWP), resource depletion (ADP), acidification (AP), eutrophication (EP), ozone layer depletion (ODP), and photochemical oxide production (POCP).

As shown in Table 5, the GWP for a cup of green tea is 0.0318 kg CO_2-eq., which is mainly caused by the production of fuel and packaging materials consumed when brewing green tea.

Table 5 Characterization results by cmpact Category.

Stage		GWP (kg CO_2-eq.)	ADP (kg Sb-eq.)	AP (kg SO_2-eq.)	EP (kg PO43-eq.)	ODP (kg CFC11-eq.)	POCP (kg C_2H_4-eq.)
Pre-manufacturing	Packaging production	7.86E-03	1.60E-04	2.21E-04	3.29E-05	2.98E-10	2.78E-04
	Green tea cultivation	4.37E-03	1.95E-05	1.14E-05	1.38E-06	6.94E-10	4.55E-06
Manufacturing	Primary processing	6.05E-03	3.86E-05	7.34E-05	1.24E-05	3.09E-11	1.34E-06
	Secondary processing and packaging	2.68E-03	1.66E-05	8.97E-06	1.16E-06	8.44E-11	1.37E-06
	Transport	2.27E-04	1.54E-06	1.16E-06	1.91E-07	8.47E-11	5.42E-07
Distribution		1.77E-04	1.20E-06	8.76E-07	1.43E-07	6.60E-11	4.20E-07
Use		9.55E-03	5.92E-05	2.87E-05	3.87E-06	2.39E-10	3.85E-06
Disposal		9.00E-04	3.00E-07	6.67E-07	1.85E-06	5.58E-12	5.68E-08
Total		3.18E-02	2.97E-04	3.47E-04	5.40E-05	1.50E-09	2.90E-04

By analyzing the environmental impact on each cup of green tea at each stage of its life cycle, we observed that the use stage, the packaging material production stage, and the primary processing stage have larger impacts in the GWP and ADP impact categories. In addition, the packaging material production stage was identified as the major issue in the AP, EP, and PODP impact categories, and green tea cultivation was identified as the major issue in the ODP impact category (as shown in Table 6).

Table 6 Contribution analysis by impact category.

Contribution	GWP (kg CO_2-eq.)	ADP (kg Sb-eq.)	AP (kg SO_2-eq.)	EP (kg PO43-eq.)	ODP (kg CFC11-eq.)	POCP (kg C_2H_4-eq.)
value	3.18E-02	2.97E-04	3.47E-04	5.40E-05	1.50E-09	2.90E-04
First priority	Use (30.3%)	Packaging material production (53.9%)	Packaging material production (63.9%)	Packaging material production (62.8%)	Green tea cultivation (46.2%)	Packaging material production (95.8%)
Second priority	Packaging material production (24.7%)	Use (19.9%)	Primary processing (21.2%)	Primary processing (23.0%)	Packaging material production (19.9%)	Green tea cultivation (1.6%)
Third priority	Primary processing (19.0%)	Primary processing (13.0%)	Use (8.3%)	Use (7.2%)	Use (15.9%)	Use (1.3%)

3.2 Calculation of Changes in Carbon Stocks

To calculate the change in carbon stock using IPCC's gain-loss method, the change in the cultivated area was examined using the "Special Crop Production Performance" published by the Ministry of Agriculture, Food and Rural Affairs. For calculating the basic coefficients of carbon stock and carbon loss, we applied a temperate climate region (as shown in Table 7).

Table 7 Basic coefficients of aboveground perennial woody biomass.

Climate region		Aboveground biomass carbon stock at harvest (ton C/ha)	Harvest /Maturity cycle (yr)	Biomass accumulation rate (ton C/ha·yr)	Biomass carbon loss (ton C/ha)
Temperate (all moisture regimes)		63	30	2.1	63
Tropical	dry	9	5	1.8	9
	moist	21	8	2.6	21
	wet	50	5	10.0	50

However, it is difficult to apply the 30-year gain-loss method of IPCC as the mature age of green tea is 8 years in the "Measures for Stability of Green Tea Supply and Demand and Competitiveness Enhancement" of the Korea Rural Economic Research Institute. Therefore, we compared the biomass carbon loss by considering 30 years of temperate climate region of IPCC's gain-loss method and 8 years of the mature tree age of Korean green tea (as shown in Table 8).

Table 8 Basic coefficients of green tea biomass in Korea (estimated value).

Climate region	Aboveground biomass carbon stock at harvest (ton C/ha)	Harvest /Maturity cycle (yr)	Biomass accumulation rate (ton C/ha·yr)	Biomass carbon loss (ton C/ha)
Temperate (all moisture regimes)	63	30	2.1	63
Green tea (expected)	16.8	8	2.1	16.8

The gain-loss method is a simple formula that subtracts the decrease from the increase in carbon stock, and the increase in biomass occurs due to the growth of green tea and the planting of driftwood seedlings in the existing green tea plantation. The increase in carbon accumulation was calculated by multiplying the green tea planting area by the carbon accumulation factor of 2.1 tons C/ha yr. The removal of tea trees resulted in a decrease in biomass. The reduction in carbon stock was calculated by multiplying the area reduced compared to the previous year by a carbon loss factor of 63 (or 16.8) tons C/ha. The results were presented in Table 9 and Table 10.

Table 9 Calculation results of green tea cultivation area and reduced area (unit: hectare).

Area	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Cultivation area	3,277	3,309	3,004	2,926	2,901	2,768	2,906	3,051	2,744	2,844
Area less than the previous year			-305	-78	-25	-133			-307	

Table 10 Calculation result of carbon stock change (unit: ton C).

Carbon stock		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Carbon stock increasing		6,949	6,308	6,145	6,092	5,813	6,103	6,407	5,762	5,972
Carbon stock reduction	30 years		-19,215	-4,914	-1,575	-8,379			-19,341	
	8 years		-5,124	-1,310	-420	-2,234			-5,158	
Carbon stock change	30 years	6,949	-12,907	1,231	4,517	-2,566	6,103	6,407	-13,579	5,972
	8 years	6,949	1,184	4,834	5,672	3,578	6,103	6,407	605	5,972

The above results were converted to CO_2 standards (the atomic weight of carbon is 12 and the atomic weight of carbon dioxide is 44) and the amount of carbon accumulation change was converted to 1 kg of green tea by reflecting the annual green tea production (as shown in Table 11).

Table 11 Changes in CO_2 accumulation per 1 kg of green tea (unit: kg CO_2).

Comparison	2011	2012	2013	2014	2015	2016	2017	2018	2019
30 years	9.42	-9.95	1.20	3.30	-2.03	4.38	4.55	-10.01	3.59
8 years	9.42	0.91	4.73	4.14	2.83	4.38	4.55	0.45	3.59

3.3 Net GHG Emissions Estimation

As shown in Table 12, the variation in net GHG emissions on an 8-year basis is smaller than on a 30-year basis. In addition, it was confirmed that carbon uptake from farmland varies greatly depending on the area of farmland cultivated, ranging from as high as 59% to as low as 3% compared to the GHG emission during the entire production process.

Table 12 Net GHG emissions per kg of green tea (unit: kg CO_2-eq).

Comparison	2011	2012	2013	2014	2015	2016	2017	2018	2019
30 years	6.48	25.85	14.70	12.60	17.93	11.52	11.35	25.91	12.31
8 years	6.48	14.99	11.17	11.76	13.07	11.52	11.35	15.45	12.31

4. Conclusions

In this study, the GHG emission was calculated using the life cycle assessment method for green tea, and the change in biomass carbon stock was calculated by the IPCC's gain-loss method to quantify the net GHG emission of green tea in Korea.

(1) According to the Ministry of Environment's EPD certification guidelines, the calculated GHG emissions for 2 g green tea was 0.0318 kg/CO_2, which was converted to 15.9 kg CO_2/kg for 1 kg green tea.

(2) The change in biomass carbon stock calculated according to the IPCC's gain-loss method was compared with the 30-year mature tree age of the gain-loss method and the 8-year mature tree age of green tea. 30 years, which is the mature tree age of the gain-loss method, had a large deviation. Therefore, we suggested that it would be better to apply it based on the 8-year mature tree age of green tea.

(3) The net GHG emission of green tea in Korea varies greatly from as high as 59% to as low as 3% in the carbon absorption of biomass due to farm maintenance, which significantly affects the net GHG emission result.

Considering the results of this study, the role of green tea producers is most important in achieving carbon neutrality in green tea. Producers should maximize carbon absorption at the planting stage by reserving farmland, simplify packaging materials in the design of green tea products, and seek to develop products that can use cold water instead of hot water to brew green tea.

In this study, the IPCC's gain-loss method used to estimate carbon stock changes is a method that is applied to all perennial woody crops except tea trees. Therefore, if future studies are conducted on the absorption estimation method specific to tea trees, and absorption and loss coefficients specific to Korean tea trees are developed, we believe that net GHG emissions can be calculated with a high degree of accuracy.

Author Contributions

N.-H.L.(Ph.D) conducted the experiments and wrote the manuscript. Y.L. (Ph.D. student), J.L. (Master) and J.K. (Ph.D. student) wrote and revised the manuscript. All authors have read and agreed to the published version of the manuscript.

Competing Interests

The authors have declared that no competing interests exist.

References

1. Kyuho So. Calculation of carbon emissions and life cycle evaluation in the production process of sweet potatoes. J Korean Soc Soil Fertilizers. 2010; 43: 892-897. Available from: https://ksssf.org/.
2. Kyuho So. Calculation of carbon emissions and life cycle evaluation in the production process of bean. J Korean Soc Soil Fertilizers. 2010; 43: 898-903. Available from: https://ksssf.org/.
3. Kyuho So. Calculation of carbon emissions and life cycle evaluation in the production process of rice. J Korean Soc Soil Fertilizers. 2010; 43: 594-599. Available from: https://ksssf.org/.
4. Kyuho So. Calculation of carbon emissions and life cycle evaluation in the production process of barley. J Korean Soc Soil Fertilizers. 2010; 43: 600-605. Available from: https://ksssf.org/.
5. Kyuho So. Calculation of carbon emissions and life cycle evaluation in the production process of potato. J Korean Soc Soil Fertilizers. 2010; 43: 606-611. Available from: https://ksssf.org/.
6. Xu Q, Hu K, Wang X, Wang D, Knudsen MT. Carbon footprint and primary energy demand of organic tea in China using a life cycle assessment approach. J Clean Prod. 2019; 233: 782-792.
7. Chiu YW. Environmental implications of Taiwanese oolong tea and the opportunities of impact reduction. Sustainability. 2019; 11: 6042.
8. Doublet G, Jungbluth N. Life cycle assessment of drinking Darjeeling tea. Conventional and organic Darjeeling tea [Internet]. Switzerland: ESU-services Ltd. Uster: Schaffhausen; 2018. Available from: http://www.avnir.org/documentation/bdd/sg/doublet-2010-LCA-Darjeeling-tea-1.0.pdf.
9. Soheili-Fard F, Kouchaki-Penchah H, Raini MG, Chen G. Cradle to grave environmental-economic analysis of tea life cycle in Iran. J Clean Prod. 2018; 196: 953-960.
10. Azapagic A, Bore J, Cheserek B, Kamunya S, Elbehri A. The global warming potential of production and consumption of Kenyan tea. J Clean Prod. 2016; 112: 4031-4040.
11. Vidanagama J, Lokupitiya E. Energy usage and greenhouse gas emissions associated with tea and rubber manufacturing processes in Sri Lanka. Elsevier: Environmental development. 2018; 26: 43-54.
12. Waluyo J, Haq MS, Sari AA, Putri AM, Mastur AI, Bardant TB, et al. Life cycle inventory of green tea production: Case of gambung. E3S Web of conferences. 2018; 74: 07002.
13. Korea Forestry Promotion Institute. Carbon Storage Amount Certification [Internet]. KFPI. 2021. Available from: https://www.kofpi.or.kr/.

14. Lee, H.-S. A study on estimating method of absorption in agricultural land sector in LULUCF field; Daejeon, Korea: Korea statistical development institute; 2016.
15. Korea Environmental Industry & Technology Institute. Environmental Product Declaration and Low Carbon Product Certi-fication [Internet]. KEITI. 2021. Available from: http://www.edp.or.kr/.
16. Foundation of Agri. Tech. Commercialization & Transfer. Low Carbon Agricultural and Livestock Product Certification [Internet]. FATCT. 2021. Available from: http://www.smartgreenfood.org/.
17. Environmental management: Life cycle assessment; principles and framework; Geneva, Switzerland: International organization for standardization; 2006.
18. Environmental management: Life cycle assessment; requirement and guidelines; Geneva, Switzerland: International organization for standardization; 2006.
19. Environmental management corporation. 2006 IPCC Guidelines for national greenhouse gas inventory. Geneva, Swit-zerland: IPCC; 2008.
20. National academy of environmental sciences. Handbook of national air pollutant emission calculation methods. Inchon, Korea: NIER; 2013.
21. Green forest livestock and food ministry. Production performance of special crops [Internet]. MAFRA. 2021. Available from: https://lib.mafra.go.kr/.
22. Rural development administration. Standard farming textbook. Jeonju Korea: RDA; 2018.
23. Korea environmental industry & technology institute. Certification guideline of environmental product declaration. Seoul, Korea: KEITI; 2019.
24. Korea environmental industry & technology institute. National LCI DB [Internet]. KEITI. 2020. Available from: http://www.epd.or.kr/lci/lciDb.do.
25. Korea national cleaner production center. National LCI DB. KNCPC [Internet]. 2020. Available from: https://www.kncpc.or.kr/resource/lci_pass_db.asp.