

# Assessment of Carbon Dioxide Emissions from Biodiversity-Conscious Farming: A Case of Stork-Friendly Farming in Japan

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## Abstract

Although agriculture can contribute to ecosystem services, it can also be a source of disservices, including loss of biodiversity and emissions of greenhouse gases and pollutants. In this study, we evaluate the biodiversity-conscious farming method in terms of the impact on global warming by using the life cycle assessment (LCA) taking stork-friendly farming in Japan as a case of farming method. The results show that efforts for biodiversity conservation and countermeasures against global warming may be in a trade-off relationship. The results suggest that expansion of the farming scale and switch from low-agricultural to agricultural-free farming may be two possible paths towards a lower carbon dioxide emission than the current level.

## Keywords

Greenhouse Gas Emissions, Biodiversity, Life Cycle Assessment, Agriculture, Japan

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## 1. Introduction

Agriculture represents humankind's largest engineered ecosystem, and agricultural ecosystems are managed chiefly to meet food, fiber and fuel needs [1] [2]. Although agriculture can contribute to ecosystem services, it can also be a source of disservices, including loss of biodiversity and emissions of greenhouse gases (GHG) and pollutants [3]. However, agricultural management can be designed to host wild biodiversity of many types [4]-[6], and to reduce GHG emissions [7]-[9].

Stork-friendly farming (hereinafter referred to as SF farming), which has been practiced in Toyooka City in the prefecture of Hyogo in Japan, is a biodiversity-conscious farming method. It is characterized by the reduced

usage of chemical fertilizers and agrichemicals, and is an endeavor to assist with the reintroduction of storks into the wild [10]. Rice produced by the SF farming method has been marketed under the “stork-friendly rice” brand, and has its higher selling price than conventionally grown rice from the same geographical area. In addition to protection of storks and preservation of biodiversity, the stork-friendly farming method will be appreciated even more as a superior environment-friendly farming method, if it also helps mitigate climate change.

In the present study, we attempt to evaluate the SF farming method, which has established a good reputation as an endeavor to help biodiversity conservation, in terms of the impact on global warming. Specifically, the rice production by SF farming method is compared with that by conventional farming method on the basis of carbon dioxide (CO<sub>2</sub>) emissions estimated using the life cycle assessment (LCA). LCA can assist to identify more sustainable options [11].

Although few studies have applied LCA to organic or environment-friendly rice farming in Japan [9] [12] [13], the impacts on global warming of these farming systems compared to the conventional farming systems are debatable. Hokazono *et al.* [12] revealed that organic and sustainable rice production systems had the potential to mitigate global warming and eutrophication. Hokazono and Hayashi [13] applied LCA to organic rice farming taking the year-to-year variations of agricultural production into account by using time series data. They concluded that although environmental impacts associated with organic farming fluctuated widely, it was higher than those of conventional rice farming on average. Masuda and Tomioka [9] showed that GHG emissions from the environmentally friendly rice farming were much more than from conventional rice farming by using the LCA method.

## 2. Methodology

### 2.1. Stork-Friendly Farming

SF farming has been practiced in Toyooka City locating north-east parts of Hyogo Prefecture (Figure 1). The city started releasing white storks in the wild in 2005 [14]. According to [15], while white storks had nested and foraged in Toyooka, they became extinct in 1971. The pesticide contamination of prey animals and losses in genetic diversity are suggested to be the cause of extinction. In order to ameliorate the habitat quality of the paddy fields, SF farming was introduced in 2002 [16]. While it was adopted only 0.7 ha in 2003, the area where SF rice farming method is applied has been increasing and has reached more 304 ha in 2010 [14].

SF rice farming method consists of various live organs for stork’s food, such as water management of paddy field, and using no or less agrichemicals [14] [16]. The agrichemical-free type SF rice farming and low-agraceutical type SF rice farming is widely prevalent in Toyooka City. The amount agrichemical use is reduced to less than 75% of conventional farming by low-agraceutical type SF rice farming and zero by agrichemical-free type SF rice farming. It is pointed out that significant increase in prey biomass during summer time was found in rice fields where SF farming is applied [15].

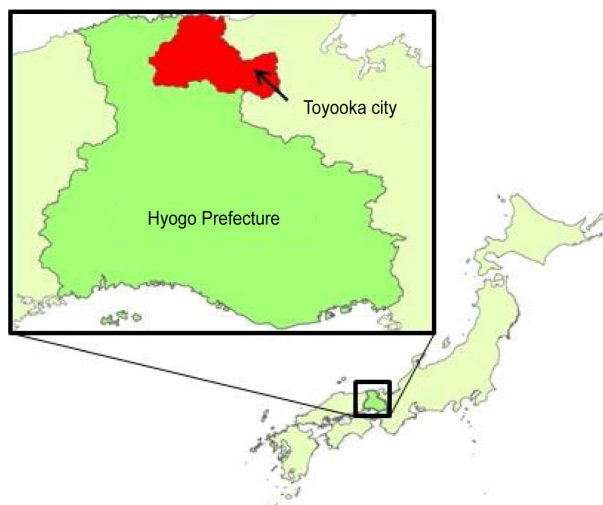


Figure 1. Location of Toyooka City.

## 2.2. Data

Data required for the analysis were collected through an interview survey of five farmers practicing stork-friendly farming and one farmer practicing the conventional farming, all in Toyooka City. The survey collected data on expense and quantity including those for materials and energy, data of products, such as rice yield, and data on machine utilization.

In the present study, farms where the greenhouse gas emission was measured were broken down into the following five types:

- 1) Small scale (smaller than 1 ha of harvested area), SF farming, agrichemical-free type (Type A);
- 2) Large scale (larger than 1 ha of harvested area), SF farming, agrichemical-free type (Type B);
- 3) Small scale (smaller than 1 ha of harvested area), SF farming, low-agrichemical type (Type C);
- 4) Large scale, SF farming (larger than 1 ha of harvested area), low-agrichemical type (Type D); and
- 5) Conventional farming type.

The following points should be taken into account when interpreting the results. The farm of conventional farming type studied in the present study had a management policy of reducing the material usage as much as possible. More specifically, the CO<sub>2</sub> emission from this farm may be lower than that from a typical farm practicing conventional farming in areas around Toyooka City.

## 2.3. System Definitions and Life Cycle Inventories

The aim of this study was to compare the CO<sub>2</sub> emissions from SF rice farming method and conventional rice farming method. The system boundary included the wet-rice cultivation process from sowing, rearing of seedlings, to harvesting (Figure 2). Since the focus was rice production on the farm, drying and co-ordination, and shipping and selling stages are not included in the boundary. The only greenhouse gas measured was CO<sub>2</sub>, and the functional unit was 10a of farming land.

The life cycle inventories are estimated as Table 1 by the following procedures. First, the energy consumption and expense for material inputs were estimated for each farming method based on the production cost data acquired by the interview survey. Subsequently, CO<sub>2</sub> emissions from the energy consumption and material inputs for each farming method were estimated by multiplying the energy consumption and material expense by appropriate CO<sub>2</sub> emission factors [17] [18], respectively.

## 3. Results and Discussions

Figure 3 shows the estimated CO<sub>2</sub> emissions for each of the farm types. In Figure 3, the emission from energy input denotes the CO<sub>2</sub> emission from the fossil fuel usage in the farm for rice production, and the emissions from material input denotes the CO<sub>2</sub> emission occurring in manufacturing of materials used such as seeds and fertilizers. The findings from the analysis are described below.

First, the type with the greatest CO<sub>2</sub> emissions per unit area was small scale SF farming, low-agrichemical

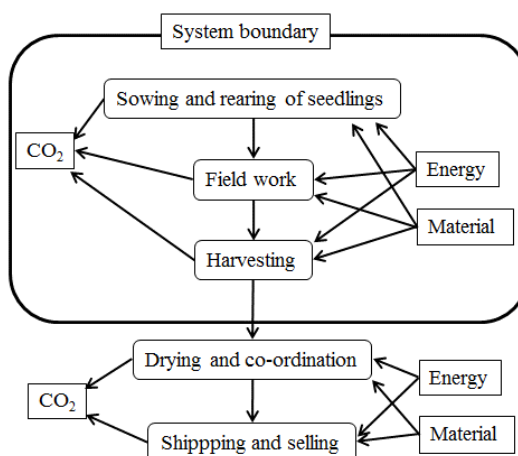
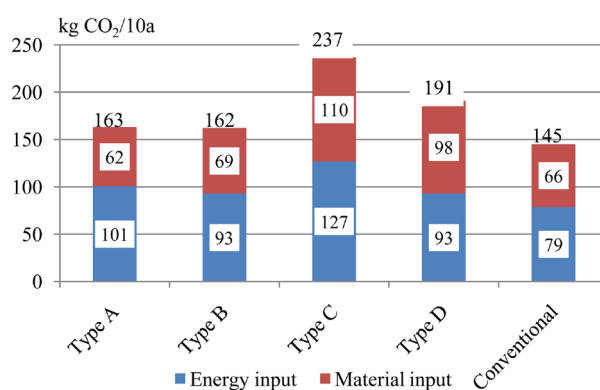


Figure 2. System boundary for rice production.

**Table 1.** Life cycle inventories estimated from the collected data.

	Unit	Type A	Type B	Type C	Type D	Conventional
Energy input						
Gasoline	L/10a	19.9	13.5	28.4	11.4	20.8
Mixed gasoline	L/10a	2.0	0.8	3.0	0.7	0.0
Light oil	L/10a	16.4	12.3	18.8	13.4	21.7
Electricity	kWh/10a	18.6	60.3	11.9	60.3	20.1
Material input						
Seed	Yen/10a	4,194	3,307	5,689	2,941	2,096
Fertilizer	Yen/10a	15,670	6,677	16,822	7,909	9,841
Agrichemical	Yen/10a	0	0	5,427	3,860	7,309
Other material	Yen/10a	2,387	8,806	3,088	8,723	2,719

**Figure 3.** Comparison of CO<sub>2</sub> emissions of the five types of rice farming.

type (Type C) with the estimated emission of 237 kg CO<sub>2</sub>/10a. The conventional farming type was estimated least in the emission (145 kg CO<sub>2</sub>/10a). Thus, the CO<sub>2</sub> emission per unit area from SF farming was greater compared with the emission from conventional farming, with the difference of up to 1.6-fold (=237/145).

Second, within the farms of the SF farming type, large scale farms (type B and type D) were found to emit a lower level of CO<sub>2</sub> per unit area than small scale farms (type A and type C) in both agrichemical-free and low-agrchemical types.

Third, within the farms of the SF farming type, agrichemical-free farms (type A and type B) were found to emit a lower level of CO<sub>2</sub> per unit area than low-agrchemical farms (type C and type D) in both large scale and small scale types.

The results show that the efforts for preservation of storks and CO<sub>2</sub> emissions reduction may be in a trade-off relationship, since the CO<sub>2</sub> emissions from all type of SF rice farming are greater compared with the emission from conventional farming. The results also imply that within the farms of the SF farming type, large scale farms and agrichemical-free type farms are considered favorable in terms of CO<sub>2</sub> reduction, comparing with small scale farms and low-agrchemical farms respectively.

Masuda and Tomioka [9] and Hokazono and Hayashi [13] showed that GHG emissions from the environmentally friendly rice farming is higher than from conventional rice farming by using the life cycle assessment method. Masuda and Tomioka [9] pointed out that the organic fertilizer used in environmentally friendly rice farming caused a large increase in methane emissions from paddy field and it increased GHG emissions from environmentally friendly rice farming. Hokazono and Hayashi [13] pointed out that although agrichemical and chemical fertilizers are eliminated in organic rice farming, large quantities of organic fertilizer are required.

In addition to CO<sub>2</sub> emission from energy and material input, CH<sub>4</sub> emission from paddy field needs to be studied in the future. Application of organic materials, which are believed to effectively absorb greenhouse gases by acting as a carbon reservoir, should also be included in the future analysis.

## 4. Conclusions

We evaluate the biodiversity-conscious farming method in terms of the impact on global warming by using the life cycle assessment (LCA) taking stork-friendly farming in Japan as a case of farming method. The results show that efforts for preservation of storks and countermeasures against global warming may be in a trade-off relationship. The results suggest that expansion of the farming scale and switch from low-agricultural to agricultural-free farming may be two possible paths towards a lower CO<sub>2</sub> emission from stork-friendly farming than the current level.

SF farming is also considered to have several positive effects such as the biodiversity local brand development for biodiversity friendly consumer market, eco-tourism and environmental education [10] [19]. Evaluating these effects needs to be focused in future research.

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