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Effects of Cultivating Rice and Wheat with and without Organic Fertilizer Application on Greenhouse Gas Emissions and Soil Quality in Khost, Afghanistan

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Abstract: The agricultural sector is the most important economic component in Afghanistan, as 80% of the population is involved. The improvement of cereal production is an urgent task to meet the nation's demand for the staple within the limited arable land. To promote a sustainable crop production system, this study examined the soil quality to learn the basic knowledge of soil fertility and the environmental impact of different rice–wheat cropping systems in Khost, Afghanistan by using the life cycle assessment (LCA) method. The economic analysis of each farming system was conducted by the data gathered by the farmers' interviews along with LCA data collection. The analysis considered the on-farm activities, which were required to produce 1 kg of wheat and rice. It included energy use, production, and farming inputs such as fertilizer and agrochemicals. Conventional farming with organic fertilizer application (CF+OF) was compared with conventional farming (CF). The LCA results showed the total greenhouse gas (GHG) emission was higher in rice production compared to wheat production. However, CO_2 absorption by the crops was far greater than the total GHG emission in both systems and showed great potential for soil carbon sequestration for mitigation of global warming. The soil examination revealed the CF+OF system increased soil total carbon (TC), active C (AC), total N (TN), soil organic carbon storage (SCS), P, and K^+ after four years of organic fertilizer application. The yield of each crop was slightly higher in the CF system; however, the CF+OF system increased net income by reducing the cost for fertilizer. The study concluded the CF+OF system can improve soil fertility in the long term while saving the farming operation cost. Further research is required to determine the best combination of practices to improve cattle manure characteristics and farm management for soil carbon sequestration to promote a sustainable farming system in the country.

Keywords: soil quality; cattle manure; wheat and rice production; life cycle assessment; soil carbon sequestration; GHG emission

1. Introduction

Afghanistan is a 65 million hectare land-locked nation, mostly occupied by high mountains (80%) and desert. Decades of war destroyed infrastructure and decimated economic development including the agricultural sector. The agricultural sector is the most important component of the country's economic development, as 80% of the population is engaged in agriculture [1]. Arable land is quite limited at only 7.5 million hectares (12%), of which 3.2 million ha are irrigated and 4.8 million ha are rain-fed [2,3]. Due to topographical conditions and lack of water, grain production has been intensively practiced in the north mountain range or around the Kabul river basin in the southeast part of the country where irrigation systems have been constructed. In addition, currently the population has exceeded 37 million, and increasing rural population pressure on available land has caused the environmental degradation [4].

Afghanistan's soils are formed under arid and semi-arid climatic conditions, classified mostly as clay loam and sandy loam textures. The soil in the region is high in calcium carbonate, with high pH and low soil organic matter content, ranging from 0.2 to 2.5%. The water holding capacity of the soil is low, while permeability and infiltration rates are high. Generally, soil salinity is not a problem; however, soil fertility tests show low levels of nitrogen, variable levels of phosphorus, and adequate levels of potassium due to intensive use of chemical fertilizers and lack of appropriate farming practice [5,6].

Many factors influence crop production. One of the main factors is fertilization, because soil nutrients are a key to plant growth [7]. Chemical fertilizers are commonly used in Afghanistan as the government subsidy of wheat production. However, the fertilizer inputs are not enough to increase the crop yield. Although organic fertilizers are known to improve soil quality [8], the use of organic fertilizer is rare here, because organic sources such as crop residues and animal dung compete with animal feed or fuel [9]. The current global scenario firmly emphasizes the need to adopt ecofriendly agricultural practices for sustainable food production. Organic matter is the key indicator of soil quality and provides macro and micro elements for plants, while improving soil structure and aeration, increasing water holding capacity, and regulating soil temperature [10,11]. The shift to conservation-based agriculture can improve soil properties, especially in terms of increased soil organic carbon (SOC), reduced bulk density, and distribution and stability of soil aggregates [12,13]. In low fertility soil, increasing SOC is essential for enhancing soil quality, affecting many physical and chemical processes such as the stabilization of soil structure and enhancement of available nutrients [14,15].

Typical farming practices in Afghanistan, such as lack of attention to crop rotation, limited use of organic residues, and extensive tillage have created serious problems in terms of decreasing yields and degradation of the land through soil erosion and soil structure degradation [6]. Erosion decreases soil fertility, aggregate stability, organic matter content, nutrient content, and biological activity [16,17]. Lal [18] reported that soil erosion problems in South Asia, especially in Afghanistan, are due to removal of crop residues and dung, excessive grazing, and lack of modern off-farm inputs.

Global agricultural food production has been increased thanks to the application of chemical fertilizers. However, it could lead to imbalanced nutrients in the soil and increase the loss of ammonia and greenhouse gases (GHGs) to the atmosphere. The soil erosion and salinization are enhanced because of increased fertilizer use and cause eutrophication, potable water resources reduction, and aquatic biodiversity loss, as well as depleting soil organic carbon stock [19].

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the main GHGs from the agricultural sector [20]. In particular, CH_4 emissions from paddy fields and N_2O emissions from chemical fertilizers are the major concern with regard to impacts on global warming [21,22]. On the other hand, agricultural lands have great potential as a carbon sequestration source when appropriate land management is applied [23,24]. Since agriculture is one of the major industries in Afghanistan, appropriate farming management is the key to mitigating greenhouse gas (GHG) emissions and soil degradation. Soil degradation is directly linked with GHG emission by farming practices [25,26].

The cereals such as wheat, rice, and maize have remained the most important source of food in the world since Neolithic era [27]. Since 80% of the population consumes wheat in Afghanistan, wheat and rice are the most important staples produced in 75% of the cultivated area to meet the demands [28]. However, domestic cereal production is not self-sufficient for the entire population; hence, 30–35% of the wheat demand is imported from neighboring countries to meet its domestic consumption [29]. Therefore, improving soil fertility is an urgent task to secure the food production system for the long term. Afghanistan's climate is suitable for producing high-yield and quality wheat and rice, but the cereal production is limited due to lack of new varieties, cultivation systems, and advanced milling processing [30]. Presently, more than 90% of wheat and rice is produced using manual processes; thus, the products cannot compete with those that have undergone internationally acknowledged standardization and processing. Moreover, the cost of inorganic fertilizers has been increasing enormously [28], to the extent that they are out of reach for small and marginal farmers. The current conventional agriculture in Afghanistan is under threat. However, the potential domestic production could alter this scenario toward self-sufficiency through appropriate farming practices, fertilizer management, agricultural policies, and technical knowledge of production management. Therefore, the hypothesis created in this study is that the regular organic manure application, along with chemical fertilizers, could improve soil quality and crop production in the region where there are limitations in agricultural and technical resources.

Khost province is one of the agricultural areas that can produce two crops per year thanks to irrigation systems [31]. Our former study showed the retention of plant residue improved soil water retention and bulk density [32]. However, there is little study on the sustainability of small-scale farming in this region. According to the National Renewable Energy Laboratory report, this region produces more than 75,000 tons of crop residues per year [9] and could have the potential to increase crop yields by using organic fertilizers.

In addition, lack of soil property data is one of the major constraints for local farmers as well as other groups involved in agricultural development in Afghanistan. There was also an absence of available data analyzing the impacts on GHG emissions of organic fertilizer application in Afghanistan. To promote sustainable agriculture in Afghanistan and improve soil quality and cropping systems, it is important to gather the basic knowledge of the regional soil properties, the environmental impacts of current farming practices, and the costs of a new farming method for adaptation to climate change.

Therefore, the objectives of this study are: (1) to evaluate the environmental impact on GHG emissions by life cycle assessment (LCA) of the current farming systems; (2) to present the information of soil quality in the region; and (3) to analyze the economic status of rice and wheat double cropping systems toward sustainable agricultural production.

2. Materials and Methods

2.1. Description of the Rice–Wheat Double Cropping System Analyzed in This Study

Khost province is one of the major wheat and rice producers in the country, covering an area of 4029 km^2. Figure 1 illustrates the geographical location of the study sites. It is located ~1180 m above mean sea level between 33°59′–33°46′ North latitudes and 69°19′–70°21′ East longitudes in southeast Afghanistan. Around two-fifths (59%) of Khost province is mountainous or semi-mountainous terrain, while more than one-third (37%) of the area is flat. Khost boasts 123,500 ha of forest and has 14,911 ha of agricultural land [33]. Farmers in this region grow various crops including wheat, rice, corn, and different vegetables. The main crops are wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), rice (*Oryza sativa* L.), and clover (*Trifolium* spp.). Wheat is cultivated in the autumn (mid-October), whereas maize and rice are grown in the summer (mid-April–mid-May) [4].

This region is a typical semi-arid climate with 478 mm annual rainfall [31]. The mean annual rainfall and temperature in 2016 are shown in Figure 2. The study area has dynamic climatic and agricultural settings compared to other provinces of Afghanistan. For example, the high temperature (39–42 °C) remains in the summer due to warm breezes from the north, while the temperature drops up to −4 °C in the winter due to cool breezes coming from the east [33].

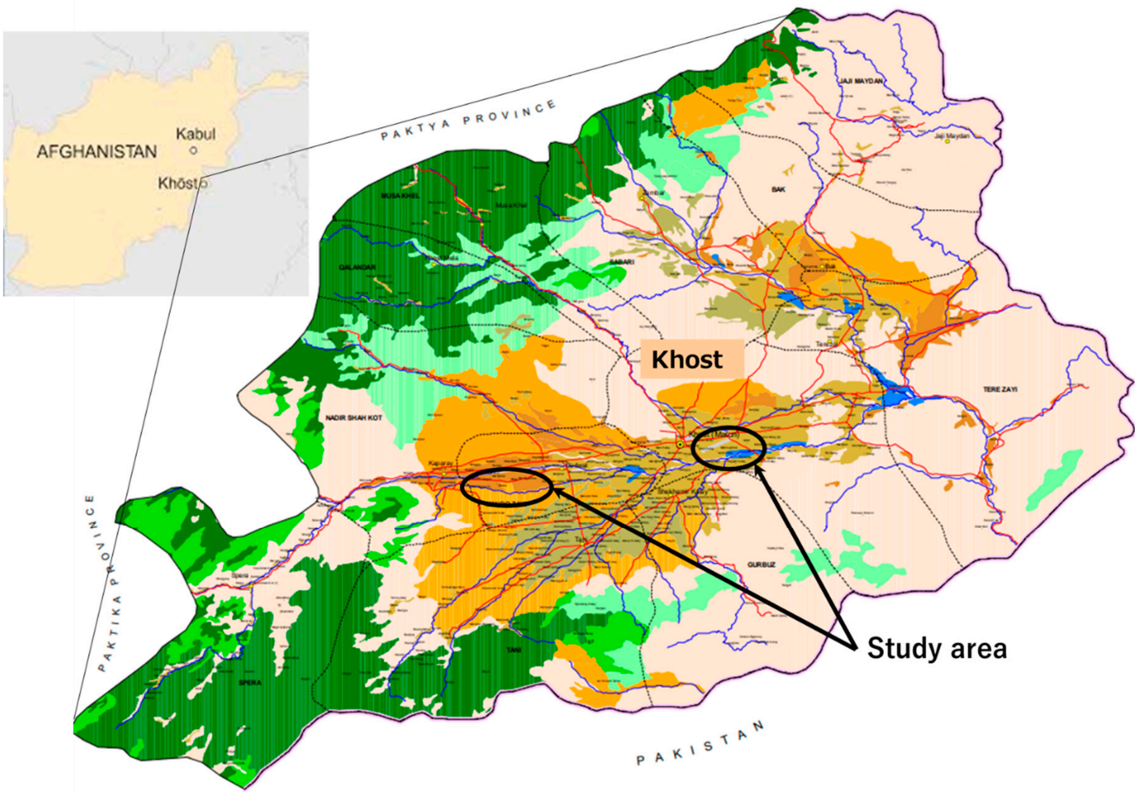

Figure 1. Geographical location of the study sites in Khost province, Afghanistan.

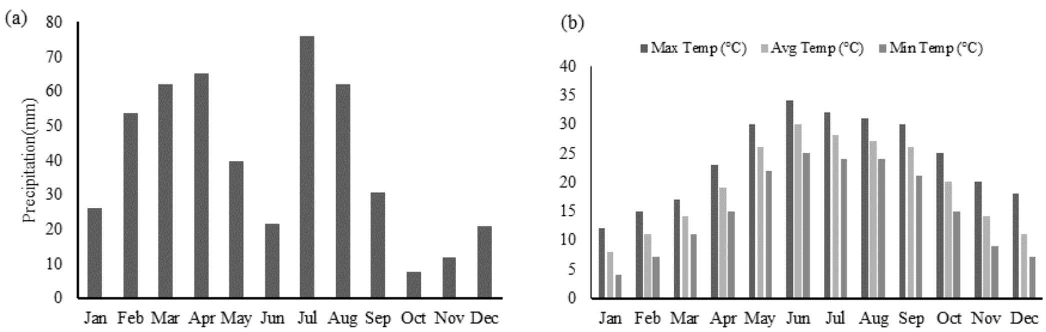

Figure 2. Monthly precipitation (**a**) and temperature (**b**) in 2016 in Khost province, Afghanistan [31].

2.2. Data Collection and Farming Practices

The field investigations and interviews with farmers were conducted to obtain farming practice details in June 2016. Data were collected through face-to-face interviews with 4 farmers in the local language (Pashto) on farm size, cultivars of crops, material inputs, cultivation methods, agronomic practices, harvest, processing techniques, weed control, fertilizer application methods, yield, gross income, and total expenditure in rice and wheat production. The collected data were used to conduct Life Cycle Assessment (LCA) and economic analysis of these two farming systems.

The farmers in this region apply 150 kg ha^{-1} di-ammonium-phosphate (DAP) and 200 kg ha^{-1} urea for wheat and rice production under the conventional farming (CF) practice. The other farmers use cattle manure (7.5 t ha^{-1}) along with a half dose of the chemical fertilizers under the conventional farming with organic fertilizer application (CF+OF) practice (Figure 3). The CF+OF farmers have been using cattle manure for four years. The nutrients of this farm-made cattle manure were 31.8% total C, 1.2% total N, 0.75% K_2O, 0.18% P_2O_5, 0.11% MgO, and 0.13% CaO, with a C:N ratio of 25.9.

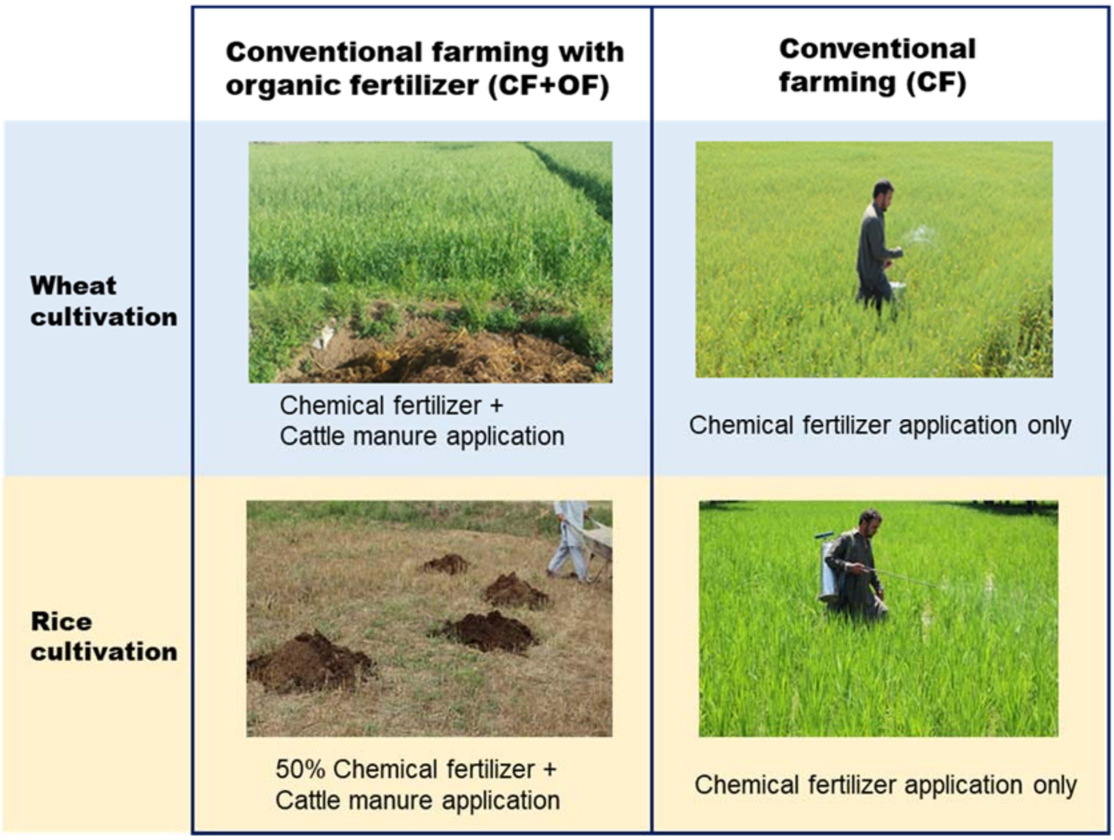

Figure 3. Description of fertilizer application of each farming system. 50% of chemical fertilizer means a half amount of chemical fertilizer used in CF farm. Chemical fertilizer is applied in July for rice and in February for wheat during the growing season.

In Khost province, farmers perform conventional rotary tillage to a depth of up to 15 cm prior to sowing any crop. In small fields, farmers manually plow by shawl. Most farmers use disk harrows for breaking clods and removing plant residues from the fields. During the growing season, farmers use hoes (locally called *rambai*) and hand weeding to remove weeds from vegetable and paddy fields, respectively. Generally, farmers in this area grow wheat using broadcasting methods and flood irrigation systems. In this area, the planting period for wheat cultivation starts in November and the harvest is in June. Paddy rice is grown by hand transplanting rice seedlings that are provided from their mature plants, neighbors, the local market, or agricultural organizations. In this area, the planting period for rice cultivation is from May–June, and harvest occurs at the end of October. Rice plants take approximately 130–160 days to mature from planting to harvesting, depending on the cultivars and field locations (Table 1).

Table 1. Summary of agricultural operations included in the analyzed rice–wheat cropping systems in Khost province, Afghanistan.

	Conventional Farming with Organic Fertilizer CF+OF	Conventional Farming CF	Month	Machinery Used for Cultivation	Type of Fuel
Nursery	Plow machine for nursery in field for seedling	Plow machine for nursery in field for seedling	Mid-May		
Land preparation	Application of cattle manure		Early-June	Massey-Ferguson 241 Tractor	Diesel
	Plowing field	Plowing field	Early-June	rotary tiller	Diesel
Transplanting	Paddy field leveling and preparation	Paddy field leveling and preparation	Mid June	Massey-Ferguson 241 Tractor	Diesel
	Rice transplanting by hand	Rice transplanting by hand	Mid-June		
Pest control	Weeding by hand and using herbicide	Weeding by hand and herbicide	July		
Harvesting	Rice harvesting by hand	Rice harvesting by hand	Mid-Sep		
Drying and cleaning	Rice grain straw transfer to special place	Rice grain straw transfer to special place	Oct	Massey-Ferguson 241 Tractor + trailer	Diesel
	Rice grain threshing from straw	Rice grain threshing from straw	Mid-Oct	Using Massey-Ferguson 241 Tractor	Diesel
	Making bundle from rice straw (Manually)	Making bundle from rice straw (Manually)	Mid-Oct		
	Husk removing from grain	Husk removing from grain	End of Oct	Huller	Diesel
	Cleaning rice grain by natural air (Manually)	Cleaning rice grain by natural air (Manually)	End of Oct		
Land preparation	Application of cattle manure		End of Oct	Massey-Ferguson 241 Tractor + trailer	Diesel
Nursery	Seeding and plowing field	Seeding and plowing field	Nov	rotary tiller	Diesel
Pest control	Weeding by hand and using herbicide	Weeding by hand and herbicide	Apr		
Water management	Irrigation by schedule	Irrigation by schedule	Nov–May		
Harvesting	Wheat harvesting using sickle by hand	Wheat harvesting using sickle by hand	End of May		
Drying and cleaning	Wheat straw transfer to special place (Darmand)	Wheat straw transfer to special place (Darmand)	End of May	Massey-Ferguson 241 Tractor +trailer	Diesel
	Using thresher for wheat grain	Using thresher for wheat grain	Early-June	Massey-Ferguson 241 Tractor attached wheat Thresher	Diesel

Note: This information about annual cultivation practices of CF+OF and CF was obtained by interviews with the farmers.

2.3. Life Cycle Assessment of the Double Cropping Systems

2.3.1. Goal and Scope Definition

LCA is one of the environmental assessment tools used to quantify and evaluate the environmental impacts of a product through all stages in its life cycle. According to ISO 14040 [34], an LCA comprises four steps: goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation of the results. The goal of this study is to generate a quantitative environmental profile of the cropping system in the Khost province of Afghanistan. This study aims to (1) present a full chain analysis of farm activities in the rice and wheat cultivation, and (2) compare it with the conventional farming system in the aspect of the total GHG emissions to analyze the impact on global warming. The sum of CO_2, CH_4, and N_2O emissions from each farming system were calculated from the total use of energy (fuels and electricity) and the amount of fertilizers, agrochemicals, and plastic wastes [35]. The global warming impact is evaluated in terms of global warming potential (GWP) over a 100-year time horizon and presented in units of kg CO_2 equivalent. The CH_4 and N_2O emissions from the cultivation system were converted into CO_2 emissions by using the global warming potential of each gas (CH_4: 21, N_2O: 310) [36]. Carbon dioxide absorption by crops was calculated by using the following equation [35].

$$CO_2\ (\text{kg}) = \text{kg}\ (\text{yield})\ \times 0.4 \times 44/12 \quad (1)$$

The cultivation system investigated in this study is a double cropping system to produce rice and wheat with organic fertilizer as an alternative cropping system. The results of the LCA, when combined with economic and soil analysis, will provide sufficiently broad information to be used by the agricultural extension sector of the Khost provincial government to understand the issues of the current farming system, namely to provide suggestions of better yields and soil quality for the future promotion of a sustainable farming system.

As the main function of the system under this study is to produce rice and wheat as the main staples, the functional unit selected is 1 kg of each grain. The scope of assessment is limited to the arable land (cradle-to-farm gate), excluding the manufacturing, packing, and transportation of raw materials (agrochemicals and farming tools such as nursery boxes and grain bags). The system boundaries of each cropping system are shown in Figure 4. This study covers the entire life cycle of farm activities including the field preparation, seeding, field management, harvesting, and grain adjustment before shipping to the market. For the LCA analysis, the environmental impacts considered include abiotic resource depletion (the fuel consumption), global warming (nitrogen input and agrochemical use), and land use (crop yields). These data were obtained from the interviews described in Section 2.2. The costs of each crop production were also calculated to optimize eco-efficiency as a financial function. The details of GHG emission basic units used for LCA calculation is described in Supplementary Materials. Table 2 shows the main process of the life cycle of rice and wheat production and their sources of data. Due to the limitations of data collection, agricultural materials such as nursery boxes and manual tools that could be used for more than one year were excluded from the LCA calculation. Plastic materials disposed of within one year were counted as plastic waste.

Table 2. Data sources for resource consumption and emissions related to the different subsystems.

Process	Subsystem	Sources of Data
1. Rice cultivation	Fertilizer	Measure data from farmer interview, NIAES [35], MOE [36]
	Pesticides	Data from questionnaire, JLCA [37]
	Mechanical field operations	Measure data from farmer interview, MOE [36]
	Plastic waste disposal	Data from questionnaire
	Transportation	Data from questionnaire, MOE [36]
2. Wheat cultivation	Fertilizer	Measure data from farmer interview, NIAES [35], MOE [36]
	Pesticides	Data from questionnaire, JLCA [37]
	Mechanical field operations	Measure data from interview session MOE [36]
	Plastic waste disposal	Data from questionnaire
	Transportation	Data from questionnaire, MOE [36]

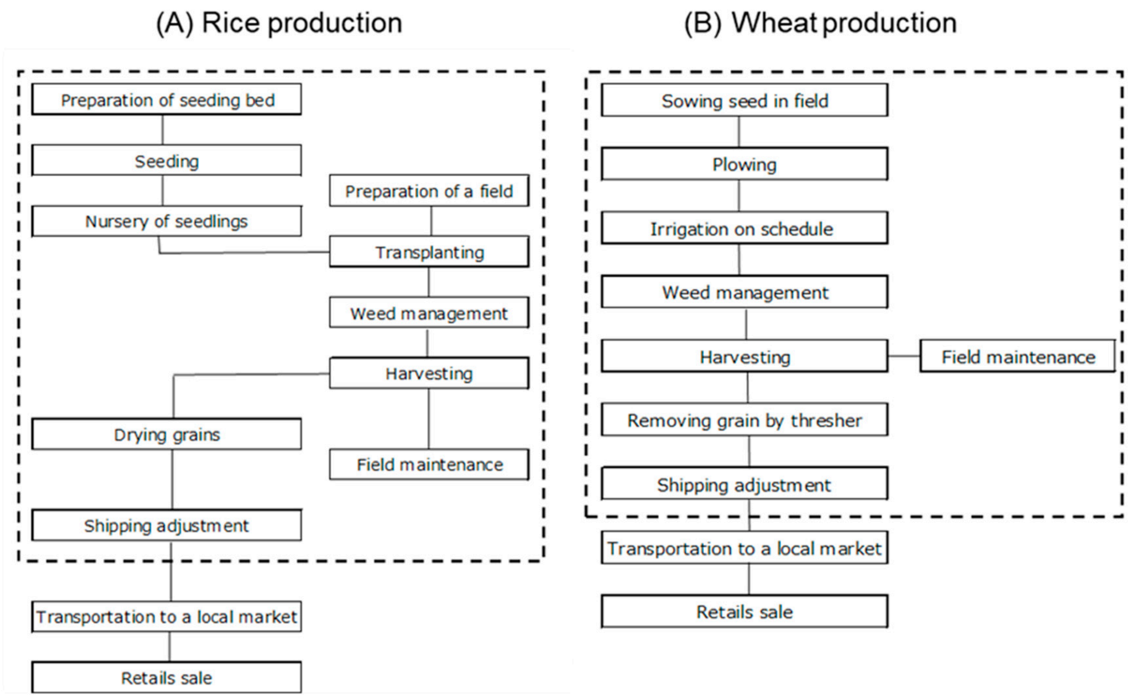

Figure 4. System boundary of the rice and wheat production system in Khost, Afghanistan. The dotted line shows the system boundaries of each crop production system.

2.3.2. Inventory Analysis

The life cycle inventory (LCI) is basically the collection of the data. This involves data collection for inputs and outputs of the crop production system gathered by the interviews. Some data were taken from literature sources. The farmers work only in the daytime due to the limited access to electricity in the region. Therefore, there was no use of electricity in the cultivation system. All the input and output data used in the production systems is listed in Table 3.

Table 3. Life cycle inventory (LCI) material input and output data of the two cropping systems. The figures in Energy consumption, Production cost and Nitrogen inputs are the average of total rice and wheat production used in 2016.

		Input		Output	
	Unit	**Conventional Farming**	**Conventional with Organic Fertilizer**	**Conventional Farming**	**Conventional with Organic Fertilizer**
Energy consumption					
Diesel	MJ ha^{-1}	7988.4	7512.9		
Electricity	kWh	0	0		
Production cost					
Chemical fertilizers	USD *	507	380.4		
Organic fertilizers	USD	0	51.9		
Agrochemicals	USD	136.5	167.1		
Fuels	USD	115.8	122.9		
Nitrogen inputs					
Chemical fertilizers	kg ha^{-1}	238	178.5		
Organic fertilizers	kg ha^{-1}	0	180		
Straw residues	kg ha^{-1}	0	0		
Yields					
Rice	Mg ha^{-1}			3.75	3.4
Wheat	Mg ha^{-1}			3.85	3.75

The data are presented as the average of two farms in each system. The input and output data were collected by the interviews in Section 2.2. The costs of fuel and fertilizers were converted into US dollars from Afghani (1 AFN = 0.013 USD).

2.4. Soil Sampling and Its Analyses

2.4.1. Soil Sampling

To understand the effects of organic fertilizer application, four replications of soil samples were collected from each field by sinking a 5-cm diameter steel cylinder into the soil to a depth of 30 cm. Each soil core sample was then sliced with a sharp knife into two layers of 0–15 and 15–30 cm depths. The soil samples were placed in paper bags and dried at room temperature for one week. The dry samples were passed through a 2 mm sieve to prepare them for chemical analyses (total carbon, active carbon, inorganic N, K^+, Mg^{2+}, Ca^{2+}, and P). To measure carbon content, subsamples were further dried at 105 °C for 72 h and measured using a CN analyzer (JM3000N/CN, J Science Lab Co. Ltd., Kyoto, Japan). The soil active carbon (AC) concentration was measured from 2.5 g air-dried samples combined with 20 mL of 0.02 mol $KMnO_4$ solution and shaken for 2 min. The absorbance of each sample was then recorded using mass spectrometry at 550 nm [38]. AC was determined as:

$$AC = [Ci - (a + b \times abs)] \times MC \times (Vsol/Ws) \quad (2)$$

where Ci is the initial solution concentration (0.02 mol L^{-1}), a is the intercept, b is the slope of the standard curve, MC is the mass of carbon (9000 mg, 0.75 mol) that is oxidized from Mn^{7+} to Mn^{4+} by 1 mol of MnO_4, Vsol is the volume of $KMnO_4$ solution (0.021 L), and Ws is the soil weight (0.0025 kg). To measure soil inorganic nitrogen, 5 g soil samples were combined with 40 ml of 1 mol L^{-1} KCl and shaken for 1 h. Absorption was measured using UV-visible absorption spectrophotometry [39] and the indophenol blue method [40] for soil NO_3-N and NH_4-N, respectively. To measure soil exchangeable K^+, Mg^{2+}, and Ca^{2+}, 2 g air-dried soil samples were combined with 40 mL of 1 mol L^{-1} ammonium acetate and shaken for 1 h. To measure soil available phosphorus, 0.2 g air-dried soil samples were combined with 40 mL of 0.002 N sulfuric acid and shaken for 30 min. The nutrient concentrations were then measured using a soil and plant clinical analyzer (SPCA-6210, Shimadzu, Kyoto, Japan). Soil pH was measured using a LaMotte field kit. Soil texture was determined using the Gee and Bauder pipette method [41], and soil organic carbon storage (SCS) was calculated using the following equation.

$$SCS\ (Mgha_{-1}) = BD \times TC \times DP \times 100 \quad (3)$$

where, BD: bulk density; TC: total carbon content (%); and DP: soil depth (m).

2.4.2. Statistical Analysis

The statistical analyses were performed using STAT View (STATView for Windows, version 5; SAS Institute, Cary, NC) [42]. By using the soil property data of the four samples in the four farms, Analysis of variance (ANOVA) was performed within each treatment, and means were compared using Tukey-Kramer test.

2.5. Economic Analysis

To understand the cost benefits of each farming system, benefit–cost ratio was used as an indicator for the cost–benefit analysis to summarize the overall value for money of the farming practice [43]. The data collected by the farmer's interviews, such as the yield of crop, the sales price, gross/net income, and the total expenditure, were used for the calculation. The data was obtained as Afghani (AFN), the local currency, and converted into United States Dollar (USD) with the exchange rate on 1 June 2020 as 1 AFN = 0.013 USD.

3. Results

3.1. Life Cycle Impact Analysis

The GHG emissions per kg of grain in the CF+OF system were 0.53 kg–CO_2 for wheat and 0.87 kg–CO_2 for the rice production. In the CF system, the GHG emissions were 0.32 kg–CO_2 for wheat and 0.96 kg–CO_2 for rice. The total CO_2 emissions were higher in the rice cultivation than those in the wheat production. The fuel consumption was the major contributor of GHG emission in wheat production. On the other hand, in the rice production systems, CO_2 emissions from the soil accounted for almost half of the total CO_2 emissions because of CH_4 emission from paddy fields (Figure 5).

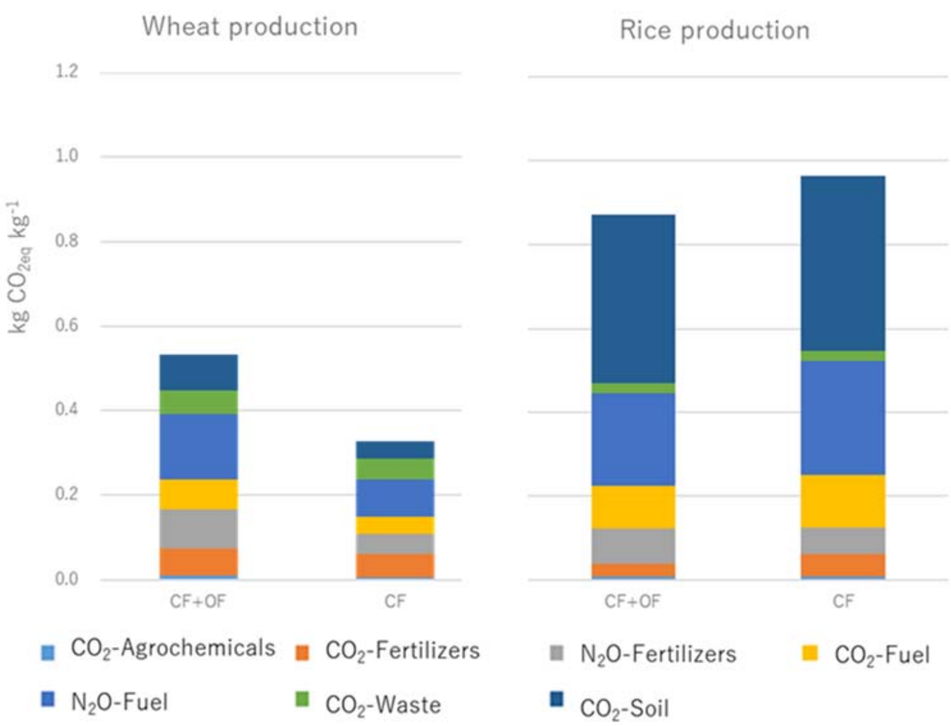

Figure 5. Total CO_2 emissions in conventional farming (CF) and conventional farming with organic fertilizer (CF+OF) systems.

The emission from the LCI of each cropping system was presented in Table 4. CO_2 absorption by crop was greater than the total GHG emission. In total production of the two crops, 11.14 Mg ha^{-1} of CO_2 was absorbed by the CF system, and 10.48 Mg ha^{-1} of CO_2 was absorbed in the CF+OF system. The GHG balance of the two crops in the CF was 637 kg CO_2 greater in the CF because of higher yields.

Total GHG emission shows the sum of CO_2 emissions from fuel, plastic wastes, and fertilizers and agrochemicals per crop. The W+R (wheat and rice) sum counted the figures of GHG emission and CO_2 absorption in the entire double cropping system. CO_2 absorption of each crop was calculated by the Equation (1). Negative quantity means CO_2 absorption was greater than GHG emissions.

Table 4. Emission from the LCI of each farming system.

	Unit	Wheat	Rice	Total	Wheat	Rice	Total
GHG emission from							
Fuel	kg CO_2	243	382		153	485	
Plastic wastes	kg CO_2	186	193		186	93	
Fertilizers + agrochemicals	kg CO_2	248	148		225	231	
Total GHG emissions	kg CO_2	**677**	**723**	**1400**	**564**	**809**	**1373**
CO_2 absorption by crop	kg ha^{-1}	−4987	−5500	−10,487	−5500	−5647	−11,147
GHG balance		−4310	−4777	−9087	−4936	−4838	−9774

3.2. Total Carbon, Active Carbon, and Total Nitrogen

The type of farming system significantly affected TC, AC, and total N (TN). TC and TN were also significantly different between depth layers, but AC was not affected by soil depth. In the 0–15 cm layer, TC, AC, and TN were significantly higher in the CF+OF system than the CF system (Table 5); TC concentration was 29.5% higher in CF+OF than CF. A similar trend was observed for AC and TN in the 0–15 cm layer, in which they were 18% and 45.5% higher in CF+OF than CF, respectively. In the subsoil layer (15–30 cm), TC, AC, and TN concentrations were 31.8%, 6.1%, and 44.4% higher in CF+OF than CF, respectively. The soil C:N ratio was higher in CF than in CF+OF in the in 0–15 cm layer, but in the 15–30 cm soil layer, the C:N ratio did not differ between farm types.

3.3. Soil Chemical Properties

Soil inorganic N content showed significant differences between farming systems but did not significantly vary with soil depth; the interaction effect was also significant (Table 5). In the 0–15 cm layer, the inorganic N content was 55 mg kg^{-1} in CF, which was 7.2% higher than in CF+OF. The highest inorganic N content was recorded in the 15–30 cm layer in CF, which was 33.2% higher than in CF+OF. The farming system (FS) significantly affected soil P, and the interaction of FS × depth was also significant. The CF+OF system produced significantly higher soil P in both layers. In the 0–15 and 15–30 cm layers, P concentration was 77.9% and 109.9% higher in CF+OF than CF, respectively. The soil potassium (K^+) content showed no significant variation between FSs and soil depths. The farming system significantly affected Ca^{2+} and Mg^{2+} contents, but the depth layer and the FS × depth did not impact on these contents. In both layers, the soil Ca^{2+} content was higher in CF+OF than in CF (6.3%, 0–15 cm layer; 7.1%, 15–30 cm layer). There was the same trend in the soil Mg^{2+} content (4.2%, 0–15 cm layer; 3.0%, 15–30 cm layer). The farming system did not affect soil pH and showed the character of alkaline soil.

The soil textural class was sandy loam, and there was no significant difference between farming systems (Table 6). The CF+OF soil had higher silt content than CF, while the CF sand and clay contents were higher than in CF+OF. There were no significant differences in soil bulk density between the two farming systems. The soil carbon content was higher in the CF+OF system than in the CF system. The SCS in the CF+OF system increased by an average of 27.5% compared to the CF system.

Table 5. Comparison of soil pH, total carbon (TC), active carbon (AC), total nitrogen (TN), C:N ratio, inorganic N, P, K^+, Ca^{2+}, and Mg^{2+} in conventional farming (CF) and conventional farming with organic fertilizer (CF+OF) systems in Khost Province, Afghanistan. The figures of AC were obtained by Equation (2).

Soil Depth (cm)	Farming System	pH	TC (%)	AC (mg kg^{-1})	TN (g kg^{-1})	C/N	Inorganic N (mg kg^{-1})	P (mg kg^{-1})	K^+ (mg kg^{-1})	Ca^{2+} (mg kg^{-1})	Mg^{2+} (mg kg^{-1})
0–15	CF+OF	8.4	1.7 a	1098.1 a	1.6 a	10.2	51.3 ab	84.85 b	122.1	4740.6 a	433.8 a
	CF	8.3	1.3 c	930.6 b	1.1 c	12.4	55.0 a	47.7 c	123.4	4457.1 b	416.3 b
15–30	CF+OF	8.0	1.4 b	990.1 ab	1.3 b	11.7	47.3 b	94.9 a	96.8	4690.1 a	435.0 a
	CF	8.0	1.1 d	932.4 b	0.9 d	11.4	63.0 a	45.2 c	93.8	4381.3 b	422.5 b
ANOVA Significance											
Farming system (FS)		NS	***	**	***	NS	**	***	NS	*	**
Depth (D)		NS	**	NS	**	NS	NS	*	NS	NS	NS
FS × D		NS	NS	NS	NS	*	*	**	NS	NS	NS

Note: *, **, *** denote significant differences at the 5%, 1%, and 0.1% significance levels, respectively. NS indicates no significant difference. Values in columns followed by different letters indicate significant differences between treatments at 5% using the Tukey–Kramer test.

Table 6. Comparison of soil carbon sequestration (SCS) in the 0–15 cm soil layer between conventional farming (CF) and conventional farming with organic fertilizer (CF+OF) systems in Khost Province, Afghanistan. SCSs were calculated by Equation (3).

Farming System	Sand	Silt	Clay	Bulk Density ($Mg\ m^{-3}$)	SOC (%)	SCS $Mg\ ha^{-1}$
		(%)				
CF+OF	46.4	40.6	13.1	0.74	1.7	18.5
CF	48.0	36.7	15.4	0.75	1.3	14.5
ANOVA Significance						
Farming system	NS	NS	NS	NS	***	***

Note: *** denotes significant differences at $p < 0.001$; NS indicates no significant difference.

The correlation coefficients of the soil properties are presented in Table 7. TC was significantly positively correlated with AC, TN, P, and K^+ and negatively correlated with C/N, inorganic N, and Mg^{2+}. AC showed a significant positive correlation with TN and P and a negative correlation with the other soil properties. TN also exhibited a significant positive correlation with P and K^+. C/N was significantly negatively correlated with K^+ and Ca^{+2}. P was significantly positively correlated with Mg^{+2}.

Table 7. The correlation coefficient of each soil property variable.

	TC	AC	TN	C/N	Inorganic N	P	K^+	Ca^{2+}
AC	0.519 ***							
TN	0.859 ***	0.457 ***						
C/N	−0.048	−0.021	−0.094					
Inorganic N	−0.109	−0.125 *	−0.093	−0.071				
P	0.263 *	0.169 *	0.401 **	−0.061	−0.273 *			
K^+	0.402 ***	0.032	0.337 **	−0.263 **	0.011	0.002		
Ca^{2+}	0.014	−0.017	0.011	−0.205 *	0.002	0.098	0.058	
Mg^{2+}	−0.007	0.024	−0.018	0.077	−0.159 *	0.205 *	−0.487 **	0.02

Note: *, **, and *** denote significant differences at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

3.4. Wheat and Rice Yield and Economic Analysis

The economic analyses of wheat and rice production for both FSs are shown in Table 8. The rice yields were slightly greater in the CF system as 3.7 t ha^{-1}, while the wheat yields were not affected by the FS.

Table 8. Comparison of wheat and rice production economic analyses between the conventional farming (CF) and the conventional farming with organic fertilizer (CF+OF) systems in Khost Province, Afghanistan.

Crop	Farming System	Yield (ha^{-1})	Price (USD kg^{-1})	Gross Income (USD ha^{-1})	Total Expenditure (USD ha^{-1})	Net Income (USD ha^{-1})	Benefit Cost Ratio
Wheat	CF+OF	3.7	0.3	962.0	536.6	425.4	1.8
	CF	3.8	0.3	988.0	572.7	415.4	1.7
Rice	CF+OF	3.4	0.6	1878.5	762.6	1115.9	2.5
	CF	3.7	0.6	2044.3	822.3	1222.0	2.5

The CF+OF farming system reduced the cost of wheat and rice production. The CF farmers paid an average of 253.5 USD for chemical fertilizers, while the CF+OF farmers paid an average of 187.5 and 182.2 USD for wheat and rice production, respectively (Figure 6). Therefore, the CF+OF system can reduce fertilizer costs by 26.0% and 28.1% for wheat and rice production, respectively. The average total expenditure for farmers with CF were 572.7 and 822.3 USD for wheat and rice production, respectively, compared to an average of 536.6 and 762.6 USD for wheat and rice production in the CF+OF system, respectively (Table 8). Therefore, the farmers with CF+OF systems could reduce total costs by 6.3% and 7.2% for wheat and rice production, respectively. For wheat production, the average net income was 2.4% higher in CF+OF than CF, while this difference was not observed for rice production. CF+OF systems required more labor to apply cattle manure to the fields.

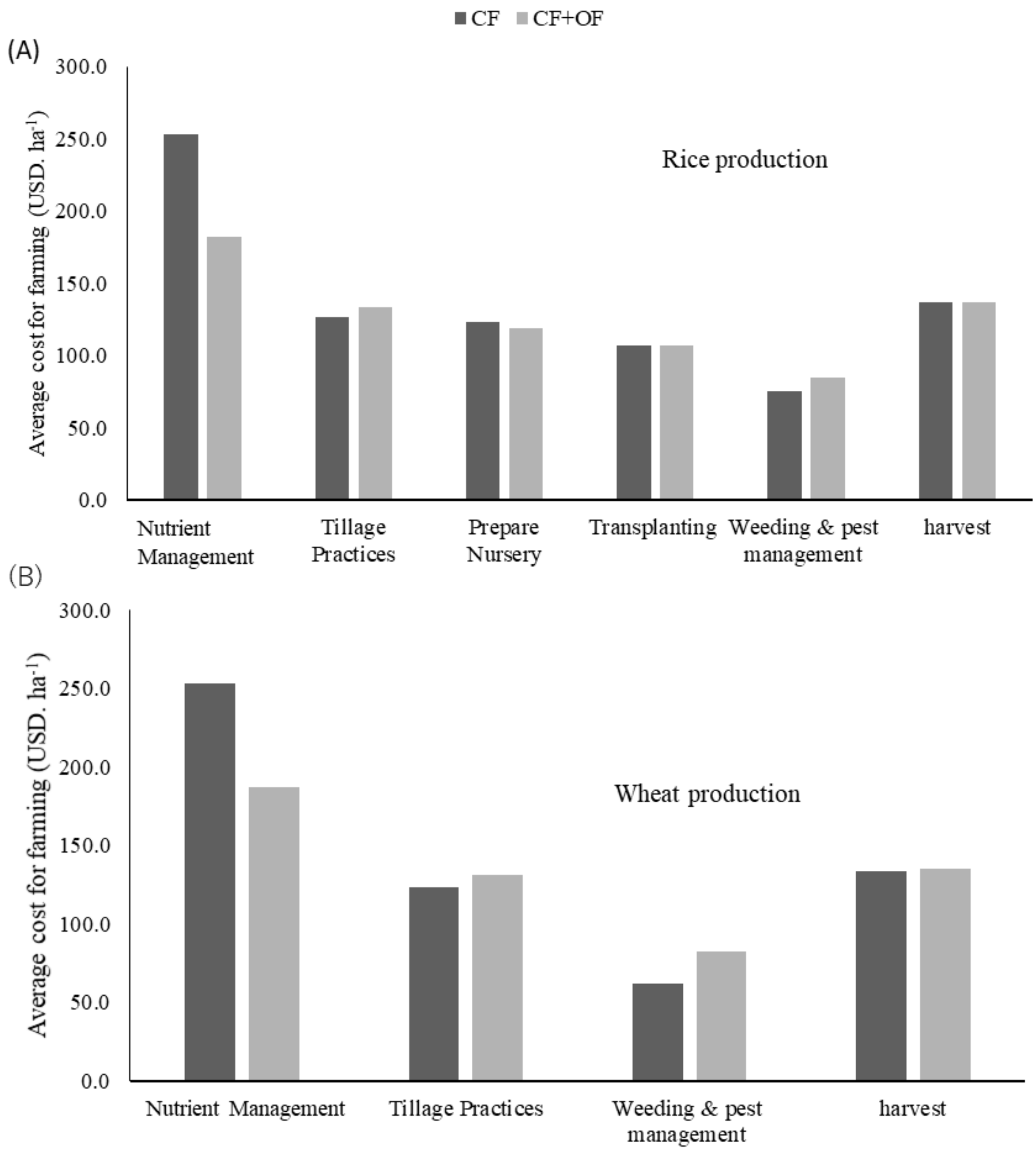

Figure 6. Average farming costs (USD ha^{-1}) for rice production (**A**) and wheat production (**B**) in conventional farming (CF) and conventional farming with organic fertilizer (CF+OF) systems in Khost Province, Afghanistan.

4. Discussion

4.1. Interpretation of LCA

The GHG emissions per kg of rice were higher than those in wheat because paddy fields produce CH_4 during the cultivation period. The GHG emissions from fertilizers and agrochemicals are considered low in general compared to India or the United States, where the use of chemical fertilizers is more than tenfold compared to Afghanistan [44]. CO_2 absorption by crops was greater than the total GHG emission in both cropping systems. Livestock manure provides a good source of essential nutrients for plants and is an excellent agent for improving soil quality and productivity. Although manure is the second largest source of GHG emissions in the agricultural sector [45], this amount of cattle manure application in the study had a benefit to soil improvement rather than an environmental impact. Shahzad et al. [46] reported that the capacity of carbon sequestration by cattle manure application was 1–1.2 Mg h^{-1} higher than chemical fertilizer application [46]. A long-term application of manure can increase the capacity of soils to act as a carbon sink when soil quality is low [47]. In addition, since N_2O emissions in crop fields directly correlate to chemical fertilizer application [48], the use of less chemical fertilizer naturally contributes to reduce N_2O emissions as well as farming operation costs. This data revealed that GHG emissions per wheat yield were greater in the CF+OF system; however, for rice production, the CF system produced more GHG emissions. The CF+OF crops absorbed less CO_2 than the CF crops (Figure 5). Aguirre-Villegaset et al. reported that efficient manure management is essential for GHG emission reduction [47]. Many studies show evidence that mid-season drainage significantly reduces CH_4 emissions and exerts a positive impact on rice yields by increasing N mineralization in the soil and increasing rice plant root development [49–51]. In the CF+OF system, additional use of tractors was required to bring cattle manure into the field and for mixing manure into the soil, resulting in more fuel consumption that directly affected the GHG emissions. In these farming systems, another approach is required to reduce the amount of CO_2 emission per hectare. In terms of energy consumption, mechanical systems are more energy efficient than diesel-based tractor systems for manure operations [47]. Future research is needed to assess the effects of manure management strategies on GHG emissions in this region.

4.2. Changes in Soil Properties by Organic Fertilizer Application

Greater organic matter input increases SOC and AC in the surface layer [32]. In this study, TC and AC in the 0–15 cm soil layers were significantly higher in the CF+OF system than CF (Table 5). In the CF+OF system, farmers used organic fertilizer (cattle manure) for four years and, as a result, TC and AC contents were significantly increased, suggesting that cattle manure application contributed to improved soil carbon storage. This increase was associated with a greater amount of organic fertilizer input; thus, the organic fertilizer amendment was adequate for improving soil quality in Afghanistan's soil. Based on the data obtained from the farmers' interviews, the farmers used pure cow dung as organic fertilizer in their field. To increase future soil organic carbon content in soil, they should mix plant residues with their cow dung to make it rich in SOC contents and avoid crop failure. The distribution of total nitrogen content followed a similar trend to the TC distribution and was relatively higher in the CF+OF system than TC in the CF system (Table 5). This result is consistent with Zibilske et al. [52], who reported that changes in soil organic N are often directly related to changes in soil organic C. Overall, the SOC level in Afghanistan is lower than in other Asian countries [12,53], which may be attributed to the low organic input and low rainfall in the region. In addition, the wet and dry cycles caused by intermittent irrigation might enhance soil organic matter decomposition, resulting in low TC, AC, and TN levels. Due to the lack of energy source in Afghanistan, farmers use animals dungs as a fuel source; therefore, the animal manure usage for crop production is not sufficient to produce a high yield [54]. According to the interviews, rice and wheat straw are removed from the fields and fed to animals in this region. From this brief observation, this study suggests that farmers have to grow separate crops for animal feeding on a crop rotation base and return plant residue to soil, which will contribute to improving soil quality and protecting soils from erosion and degradation.

The change in the soil carbon storage ability among farming systems was also observed (Table 6). The CF+OF system increased the SCS per hectare compared to the CF system. This result is consistent with Komatsuzaki and Syuaib's study [55], which reported that organic farming can increase SCS by 1.85-Mg per hectare per year compared with conventional farming systems in paddy fields in Indonesia. These results demonstrate that cattle manure application has the potential to improve soil carbon sequestration in Afghanistan. In general, if organic manure or crop residues are returned and supplemented with nutrient inputs, these systems can maintain adequate soil organic matter and production levels [56]. However, in the CF system, chemical fertilizer input only supplies nutrients to crops and does not improve soil quality [57]. Thus, this study revealed that the SOC contents in the CF+OF farming system were higher than in the CF system, due to the input of appropriate organic matter such as cattle manure.

Soil carbon, nitrogen, potassium, and phosphorus are among the most important plant essential elements because the soil C:N:K:P ratio can reflect soil fertility and plant nutritional status; changes in the content and ratio of these elements can affect the growth and distribution of vegetation [58]. The ratio of soil C, N, and P is strongly influenced by soil type, vegetation community characteristics, climatic conditions, and the vegetation development stage [59,60]. In this study, TC and TN had a significantly positive correlation between soil P and K^+ (Table 7). C:N ratio is an index of nutrient mineralization and immobilization, where a low C:N ratio indicates higher rates of mineralization [61]. In the study, the C:N ratio was found to be higher than the normal range of 10:1 that is expected in mineral soils [62]. However, Chesworth [63] reported that nitrogen is immobilized at higher C:N ratios due to the formation of only slightly biodegradable complexes that are low in nitrogen. Thus, in this study, C:N ratio had a negative correlation with soil P and K^+.

Soil pH did not significantly differ across farming systems or soil depths. The soil pH in the 0–15 cm soil layer (8.5) was higher than in the 15–30 cm soil layer (Table 5). These results suggested that changes in pH were not detected in the short term [64]. Soil inorganic N content was significantly different between farming systems. In both systems, higher inorganic N was observed in the subsoil layer. The higher observed inorganic N in the subsoil layer might be due to nitrate leaching from the surface soil. In both layers, the CF+OF farming soil contained higher soil P than the CF soil, which is likely related to the application of cattle manure in these fields. Moreover, farmers have been applying DAP fertilizer to the fields. The lower P content might be related to phosphorus fixation [64], although the averages were lower than those reported in tropical Asia [12]. The low P availability was probably due to the scarcity of P from fertilizer or other amendments to the soil and P fixation by calcium under alkaline soil conditions. David reported that pig manure application increased soil K^+ concentration [65]. In this study, the 15–30 cm layer in the CF+OF system had slightly higher K^+ than in the CF system. The observed highest concentration of K^+ was attributed to the application of household wastes like cattle manure. The observed highest concentration of Ca^{2+} in this area was attributed to the high calcium carbonate content and high pH caused by carbonate-rich geology and dry climate conditions. The CF+OF system's 15–30 cm layer also had higher Mg^{2+} than the CF system.

4.3. Challenges to Overcome Low Crop Productivity

In general, crop residues along with nutrient inputs maintain adequate soil organic matter and plant production levels [66]. However, removing crop residue for animal feeding is a common practice in conventional farming systems in Khost province. In this system, only the crop root systems are recycled and as a result, soil fertility becomes very low. This is why farmers use chemical fertilizers and perform tilling for weed control to achieve optimum yield. According to this data, the average rice yield (3.6 t ha^{-1}) was lower than in another Asian country where 200:50:50 N-P_2O_5-K_2O kg ha^{-1} fertilizer obtained 4.3 t ha^{-1} rice yield [66]. In Pakistan, a study reported that using 120 kg ha^{-1} N, 90 kg ha^{-1} P and 60 kg ha^{-1} potash increased wheat yield (4.6 t ha^{-1}) [67]. In this study, the average wheat yield in Khost province was 3.8 t ha^{-1}. This result suggests that due to lack of soil fertility, the application of essential plant nutrients is required to achieve adequate yield. In this region, beside soil degradation, some other problems seem to directly affect crop production. Kakar et al. [28] reported that the majority of farmers saved self-produced seed for future rice cultivation and suggested that government should lead the way in the distribution of improved rice cultivar to farmers throughout the country. Lal [18] also proposed that improved varieties with fertilizer input under better irrigated conditions can increase wheat and rice crop yield in Afghanistan. To maintain long term soil fertility and crop productivity, adding organic fertilizer to the fields is a very practical way to increase soil organic carbon in Afghanistan. In addition, making organic fertilizer from livestock has several benefits, such as reducing organic wastes and the cost of fertilizer.

4.4. Economic Advantages of Organic Fertilizer Application

The cost of the CF system is on average twice as expensive as is it for organic products, while production levels are almost the same [68]. The wheat and rice yields were higher in the CF than the yields in the CF+OF system, but the cost of chemical fertilizers reduces the net income of the CF farmers. For example, the net income for wheat crops was 2.4% higher for the CF+OF farmers than the CF farmers (Table 8). This indicates that the CF+OF system reduced the chemical fertilizer cost, increasing the farmers' income in Afghanistan. In the past comparison study of farming systems in Indonesia, organic farming was able to cut 90% of the total cost of rice production in West Java region [55]. In Khost province, the cost of organic fertilizers (cattle manure) is very reasonable compared to that of chemical fertilizers because the local farmers keep a couple of cows in their farms and their dung can be utilized as fertilizer. A double amount of organic fertilizer could have the potential to increase more soil carbon and change soil properties in the long term. However, crop residues as a secondary material for cattle manure would compete with animal feed in this region. For further improvement of soil quality, another approach, such as the use of weeds or pasture, is required along with cattle manure application for better manure quality. The quality of cattle manure is very critical for soil management because the timing of the manure application is limited in the double cropping system. The appropriate manure management technology needs to be transferred to the local farmers. Since the low soil productivity in the Afghan farmland has been a serious issue for years, this study was able to present an example to improve soil quality using a practical and economical approach for small-scale farmers. This research is limited to the discussion of GHG emissions, soil quality, and cattle manure management systems in Afghanistan. Therefore, further research is required to determine the best combination of farming practices to improve soil quality and crop yield in the long term. In addition, a better way to increase good quality of organic fertilizer is needed for the farmers to shift to better economical farming practices.

5. Conclusions

A comparative LCA of double cropping systems, including conventional farming and conventional farming with organic fertilizer, was conducted along with soil and economic analysis to provide sufficiently broad information to understand the issues of the current farming system in Khost province in Afghanistan. Since there is little study on environmental impacts of the current farming system, this study aimed to provide practical suggestions for better yields and soil quality for the future promotion of a sustainable farming system. The LCA results revealed that conventional farming with organic fertilizer reduced the GHG emissions per kg of grain in rice production. CO_2 absorption by rice and wheat grain production was greater than total GHG emission in both cropping systems. The soil analysis discovered that four years' use of cattle manure improved soil total C, active C, total N, P, Ca^{2+}, and Mg^{2+} content. In addition, cattle manure may help not only to improve soil quality by increasing carbon sequestration, but also to increase crop production and to create sustainable food systems in Afghanistan. In the economic aspect, conventional farming with organic fertilizer system was able to cut the average cost of farming by 6.7% while producing almost the same crop yields compared with the conventional farming system. However, further research is required to determine the best combination of practices (ratio of organic fertilizer and chemical fertilizer), manure characteristics, and management systems to reduce GHG emissions and farming operation costs. Social challenges such as the adaptation of new technologies, improvement of irrigation systems, and application of organic fertilizers may obstruct sustainable farming in Afghanistan. However, the best agronomic approach and cooperative systems based on scientific research may help to increase rice and wheat production in this region. Therefore, the collaboration with researchers, the extension sector, and the local farmers will become increasingly important to establish a sustainable crop production system in Afghanistan and to ensure food security for the nations.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/16/6508/s1, Table S1. GHG emission basic unit per energy, Table S2. CH_3 and N_2O emission during the grain cultivation, Table S3. GHG emission basic unit from plastic waste, Table S4. GHG emission basic units from different type of fertilizers.

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References

1. Cemtrala Intellligence Agency. The World Fact Book 2012. Available online: https://www.cia.gov/library/publications/the-world-factbook/geos/af.html (accessed on 26 March 2020).
2. Kelly, A.T. *Rebuilding Afghanistan's Agriculture Sector*; Asian Development Bank: Mandaluyong, Philippines, 2003; Volume 5, p. 14.
3. Abdiani, S. Effects of war on biodiversity and sustainable agricultural development in Afghanistan. *J. Dev. Sustain. Agric.* **2012**, *7*, 9–13.
4. Favre, R.; Kamal, G.M. *Watershed Atlas of Afghanistan*; Government of Afghanistan, Ministry of Irrigation: Kabul, Afghanistan, 2004; pp. 137–144.
5. Ayubi, A.G. *Principle of Irrigation and Drainage*; Aazem Publication: Kabul, Afghanistan, 2016; Volume 31, p. 174.
6. Sameen, A.Q.; Zaghard, M.A. *Soil Chemistry and Plant Nutrients*; World Bank: Kabul, Afghanistan, 2008; pp. 58–295.
7. Heeb, A.; Lundegardh, B.; Savage, G.P.; Ericsson, T. Impact of organic and inorganic fertilizers on yield, taste, and nutritional quality of tomatoes. *J. Plant Nutr. Soil Sci.* **2006**, *169*, 535–541. [CrossRef]
8. Oyewole, C.I.; Opaluwa, H.; Omale, R. Response of Tomato (*Lycopersicon esculentum*): Growth and yield, to rates of mineral and poultry manure application in the guinea savanna agro- ecological zone in Nigeria. *J. Biol. Agric. Healthc.* **2012**, *2*, 44–56.
9. Milbrandt, A.; Overend, R. Agricultural resources. In *Assessment of Biomass Resources in Afghanistan*; NREL: Golden, CO, USA, 2011; pp. 6–7.
10. Tadesse, T.; Dechassa, N.; Bayu, W.; Gebeyehu, S. Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem. *Am. J. Plant Sci.* **2013**, *4*, 309–316. [CrossRef]
11. Akinrinde, E.A. *Soils: Nature, Fertility Conservation and Management*; AMS Publishing: Providence, RI, USA, 2004; Volume 78.
12. Yagioka, A.; Komatsuzaki, M.; Kaneko, N. The effect of minimum tillage with weed cover mulching on organic daikon (*Raphanus sativus* var. *longipinnatus* cv. Taibyousoufutori) yield and quality and on soil carbon and nitrogen dynamics. *Biol. Agric. Hortic.* **2014**, *30*, 228–242. [CrossRef]
13. Arai, M.; Minamiya, Y.; Tsuzura, H.; Watanabe, Y.; Yagioka, A.; Kaneko, N. Changes in water stable aggregate and soil carbon accumulation in a no-tillage with weed mulch management site after conversion from conventional management practices. *Geoderma* **2014**, *221*, 50–60. [CrossRef]
14. Hashimi, R.; Afghani, A.K.; Borhan, I.; Moqbal, M.I.; Hashimi, M.H. Effect of land-use change on water-stable aggregates and soil chemical properties within of two cultivated fields in khost province, Afghanistan. *Int. J. Dev. Res.* **2019**, *9*, 30187–30192.
15. Lal, R. Soil carbon sequestration and aggregation by cover cropping. *J. Soil Water Conserv.* **2015**, *70*, 329–339. [CrossRef]

16. Mustafa, A.; Minggang, X.; Shah, S.A.A.; Abrar, M.M.; Nan, S.; Baoren, W.; Núñez-Delgado, A. Soil aggregation and soil aggregate stability regulate organic carbon and nitrogen storage in a red soil of southern China. *J. Environ. Manag.* **2002**, *270*, 110894. [CrossRef] [PubMed]
17. Galati, A.; Gristina, L.; Crescimanno, M.; Barone, E.; Novara, A. Towards more efficient incentives for agri-environment measures in degraded and eroded vineyards. *Land Degrad. Dev.* **2015**, *26*, 557–564. [CrossRef]
18. Lal, R. Soil degradation and environment quality in south Asia. *Int. J. Ecol. Environ. Sci.* **2007**, *33*, 91–103.
19. Batabyal, K. Nutrient Management for Improving Crop, Soil, and Environmental Quality. In *Essential Plant Nutrients*; Springer: Cham, Switzerland, 2017; pp. 445–464.
20. Choudhury, A.T.M.A.; Kennedy, I.R. Nitrogen fertilizer losses from rice soils and control of environmental pollution problems. *Commun. Soil Sci. Plan Anal.* **2005**, *36*, 1625–1639. [CrossRef]
21. Dutreuil, M.; Wattiaux, M.; Hardie, C.A.; Cabrera, V.E. Feeding strategies and manure management for cost-effective mitigation of greenhouse gas emissions from dairy farms in Wisconsin. *J. Dairy Sci.* **2014**, *97*, 5904–5917. [CrossRef] [PubMed]
22. Weil, R.R.; Brady, N.C. *The Nature and Properties of Soils*, 15th ed.; Pearson Education Limited: London, UK, 2017; pp. 615–616.
23. Oertel, C.; Matschullat, J.; Zurba, K.; Zimmermann, F.; Erasmi, S. Greenhouse gas emissions from soils—A review. *Geochemistry* **2016**, *76*, 327–352. [CrossRef]
24. Lal, R.; Delgado, J.A.; Groffman, P.M.; Millar, N.; Dell, C.; Rotz, A. Management to mitigate and adapt to climate change. *J. Soil Water Conserv.* **2011**, *66*, 276–285. [CrossRef]
25. Ross, S.M. Organic matter in tropical soils: Current conditions, concerns and prospects for conservation. *Prog. Phys. Geogr.* **1993**, *17*, 265–305. [CrossRef]
26. Malhi, S.S.; Lemke, R.; Wang, Z.H.; Chhabra, B.S. Tillage, nitrogen and crop residue effects on crop yield, nutrient uptake, soil quality, and greenhouse gas emissions. *Soil Till. Res.* **2006**, *90*, 171–183. [CrossRef]
27. Galati, A.; Oguntoyinbo, F.A.; Moschetti, G.; Crescimanno, M.; Settanni, L. The cereal market and the role of fermentation in cereal-based food production in Africa. *Food Rev. Int.* **2014**, *30*, 317–337. [CrossRef]
28. Kakar, K.; Xuan, T.D.; Haqani, M.I.; Rayee, R.; Wafa, I.K.; Abdiani, S.; Tran, H.D. Current situation and sustainable development of rice cultivation and production in Afghanistan. *Agriculture* **2019**, *9*, 49. [CrossRef]
29. Ahmadzai, M.K.; Eliw, M.; Zhou, D. Descriptive and Econometric Analysis of Wheat Production in Afghanistan (A Case Study in Paktia Province). *South Asian J. Soc. Stud. Econ.* **2019**, *5*, 1–10. [CrossRef]
30. Jalal, A.; Jeff, A. *Grain and Feed in Afghanistan*; Global Agricultural Information Network: Kabul, Afghanistan, 2013; pp. 1–8.
31. World Weather Online. Statistics of Rainfall and Temperature of Khost Province. Available online: https://www.worldweatheronline.com/khost-weather-averages/khowst/af.aspx (accessed on 18 April 2020).
32. Hashimi, R.; Komatsuzaki, M.; Mineta, T.; Kaneda, S.; Kaneko, N. Potential for no-tillage and clipped-weed mulching to improve soil quality and yield in organic eggplant production. *Biol. Agric. Hortic.* **2019**, *35*, 158–171. [CrossRef]
33. Wali, E.; Datta, A.; Shrestha, R.P.; Shrestha, S. Development of a land suitability model for saffron (*Crocus sativus* L.) cultivation in Khost Province of Afghanistan using GIS and AHP techniques. *Arch. Agron. Soil Sci.* **2016**, *62*, 921–934. [CrossRef]
34. International Organization for Standardization 14040. Methodological Framework. Available online: https://web.stanford.edu/class/cee214/Readings/ISOLCA.pdf (accessed on 25 June 2020).
35. National Institute for Agro-Environmental Sciences. Data collection. In *Manual for Life Cycle Assessment of Agricultural Practices in Japan*; National Institute for Agro-Environmental Sciences: Tsukuba, Japan, 2003; pp. 8–23.
36. Guideline for Prediction Procedure of Greenhouse Gas Emissions. Available online: https://www.env.go.jp/policy/local_keikaku/data/guideline.pdf (accessed on 2 May 2020).
37. Life Cycle Assesssment. In Proceedings of the Council of LCA Promotion, Tokyo, Japan, 5 February 1998.
38. Weil, R.R.; Islam, K.R.; Stine, M.A.; Gruver, J.B.; Samson-Liebig, S.E. Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use. *Am. J. Altern. Agric.* **2003**, *18*, 3–17.
39. Yamaki, A. A rapid UV absorption method for determination of nitrate in soil extracts. *Jpn. J. Soil. Sci. Plant. Nutr.* **2003**, *74*, 195–197.

40. Editorial Committee of Soil Environmental Analysis. *Soil Environmental Analysis*, 4th ed.; Hakuyu Press: Tokyo, Japan, 2008.
41. Gee, G.W.; Bauder, J.W. Particle-size Analysis. In *Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods*; Klute, A., Ed.; ASA: Madison, WI, USA, 1986; pp. 399–404.
42. *StatView for Windows*; v. 5.0.1; SAS Institute, Inc.: Cary, NC, USA, 1998.
43. Huan-Ping, H.; Shi-Ming, M.; Er-Da, L.; Ying-Chun, L.; Heng-Yang, Z. Benefits comparison analysis of different rice and wheat cropping patterns to adapt to climate change. *Adv. Clim. Chang. Res.* **2013**, *4*, 182–189. [CrossRef]
44. The World Bank. Fertilizer Consumption. Available online: https://data.worldbank:indicator/AG.CON.FERT.ZS (accessed on 15 June 2020).
45. Antonious, G.F. Biochar and animal manure impact on soil, crop yield and quality. *Agric. Waste Residues Intech Open* **2018**, *29*, 45–67.
46. Shahzad, K.; Khan, A.; Richards, M.; Smith, J.U. The impact of treatment of organic manures on future soil carbon sequestration under different tillage systems in Pakstan. *Pak. J. Agric. Sci.* **2017**, *54*, 277–286. [CrossRef]
47. Aguirre-Villegas, H.A.; Larson, R.A. Evaluating greenhouse gas emissions from dairy manure management practices using survey data and lifecycle tools. *J. Clean. Prod.* **2017**, *143*, 169–179. [CrossRef]
48. Galloway, J.N.; Townsend, A.R.; Erisman, J.W.; Bekunda, M.; Cai, Z.; Freney, J.R.; Martinelli, L.A.; Seitzinger, S.P.; Sutton, M.A. Transformation of the nitrogen cycle: Recent trends, questions, and potential solutions. *Science* **2008**, *320*, 889–892. [CrossRef]
49. Cai, Z.; Yan, X.; Yan, G.; Xu, H.; Tsuruta, H.; Yagi, K.; Minami, K. Methane and nitrous oxide emissions from rice paddy fields as affected by nitrogen fertilizers and water management. *Plant Soil* **1997**, *196*, 7–14. [CrossRef]
50. Wassmann, R.; Neue, H.U.; Lantin, R.S.; Makarim, K.; Chareonsilp, N.; Buendia, L.V.; Rennenberg, H. Characterization of methane emissions from rice fields in Asia: II. Differences among irrigation, rainfed, and deepwater rice. *Nutr. Cycl. Agroecosyst.* **2000**, *58*, 13–22. [CrossRef]
51. Yan, X.; Ohara, T.; Akimoto, H. Development of region-specific emission factors and estimation of methane emission from rice fields in the East, Southeast and South Asian countries. *Glob. Chang. Biol.* **2003**, *9*, 237–254. [CrossRef]
52. Zibilske, L.M.; Bradford, J.M.; Smart, J.R. Conservation tillage induced changes in organic carbon, total nitrogen and available phosphorus in a semi-arid alkaline subtropical soil. *Soil Till. Res.* **2002**, *66*, 153–163. [CrossRef]
53. Matsuura, E.; Komatsuzaki, M.; Hashimi, R. Assessment of soil organic carbon storage in vegetable farms using different farming practices in the Kanto Region of Japan. *Sustainability* **2018**, *10*, 152. [CrossRef]
54. Masunaga, T.; Kamidohzono, A.; Nezam, A.W.; Sadat, S.A. Paddy Soil Properties in Nangarhar Province, East Afghanistan. *Jpn. Agric. Res. Q.* **2014**, *48*, 299–306. [CrossRef]
55. Komatsuzaki, M.; Syuaib, M.F. Comparison of the farming system and carbon sequestration between conventional and organic rice production in West Java, Indonesia. *Sustainability* **2010**, *2*, 833–843. [CrossRef]
56. Hutchinson, J.J.; Campbell, C.A.; Desjardins, R.L. Some perspectives on carbon sequestration in agriculture. *Agric. For. Meteorol.* **2007**, *142*, 288–302. [CrossRef]
57. Hui, L.I.; Feng, W.T.; He, X.H.; Ping, Z.H.U.; Gao, H.J.; Nan, S.U.N.; Xu, M.G. Chemical fertilizers could be completely replaced by manure to maintain high maize yield and soil organic carbon (SOC) when SOC reaches a threshold in the Northeast China Plain. *J. Integr. Agric.* **2017**, *16*, 937–946. [CrossRef]
58. Mooshammer, M.; Hofhansl, F.; Frank, A.H.; Wanek, W.; Hämmerle, I.; Leitner, S.; Schnecker, J.; Wild, B.; Watzka, M.; Keiblinger, K.M.; et al. Decoupling of microbial carbon, nitrogen, and phosphorus cycling in response to extreme temperature events. *Sci. Adv.* **2017**, *3*, e1602781. [CrossRef]
59. Jacques Agra Bezerra da Silva, Y.; Williams Araújo do Nascimento, C.; Jacques Agra Bezerra da Silva, Y.; Miranda Biondi, C.; Cordeiro Atanázio Cruz Silva, C.M. Rare Earth Element Concentrations in Brazilian Benchmark Soils. *Rev. Bras. Ciênc. Solo* **2016**, *40*, 1–13.
60. Wang, S.Q.; Yu, G.R. Ecological stoichiometry characteristics of ecosystem carbon, nitrogen and phosphorus elements. *Acta Ecol. Sin.* **2008**, *28*, 3937–3947.
61. Brady, N.C.; Weil, R.R. *The Nature and Properties of Soils*; Pearson Prentice Hall: Upper Saddle River, NJ, USA, 2002; pp. 413–436.

62. Landon, J.R. (Ed.) *Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics*; Longman Scientific and Technical: New York, NY, USA, 1991; pp. 106–156.
63. Chesworth, W. *Encyclopedia of Soil Science*; Springer: Dordrecht, The Netherlands, 2008.
64. Johnson, A.H.; Andersen, S.B.; Siccama, T.G. Acid rain and soils of the Adirondacks. I. Changes in pH and available calcium. *Can. J. For. Res.* **1994**, *24*, 39–45. [CrossRef]
65. David, J.M. Biochar and compost increase crop yields but the effect is short term on sandplain soils of Western Australia. *Pedosphere* **2015**, *25*, 720–728. [CrossRef]
66. Manzoor, Z.; Awan, T.H.; Zahid, M.A.; Faiz, F.A. Response of rice crop (super basmati) to different nitrogen levels. *J. Anim. Plant Sci.* **2006**, *16*, 52–55.
67. Tahir, M.; Tanveer, A.; Shah, T.H.; Fiaz, N.; Wasaya, A. Yield response of wheat (*Triticum aestivum* L.) to boron application at different growth stages. *Pak. J. Life Soc. Sci.* **2009**, *7*, 39–42.
68. The Jakalta Post Economic Crisis Helps Boost Growth in Indonesia's Organic Fertilizer Sector. 2009. Available online: http://www.thejakartapost.com/news/2009/03/02/economic-crisis-helps-boost-growth-indonesia039s-organic-fertilizer-sector.html (accessed on 26 March 2020).

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