sustainability

Special Issue Reprint

Socio-Economic Functions Across Sustainable Farming Systems

Edited by
Keshav Lall Maharjan

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Editor

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This is a reprint of articles from the Special Issue published online in the open access journal *Sustainability* (ISSN 2071-1050) (available at: www.mdpi.com/journal/sustainability/special_issues/socio_economic_sus_farming).

For citation purposes, cite each article independently as indicated on the article page online and as indicated below:

LastName, A.A.; LastName, B.B.; LastName, C.C. Article Title. *Journal Name* **Year**, *Volume Number*, Page Range.

ISBN 978-3-0365-7613-8 (Hbk)
ISBN 978-3-0365-7612-1 (PDF)

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About the Editor

Keshav Lall Maharjan

Maharjan, Keshav Lall, Doctor of Agriculture (Ph.D.), graduate of Kyoto University, Japan, currently is Professor at the Graduate School of Humanities and Social Sciences, Hiroshima University, Japan, where he gives lectures for graduate students on subjects including Agricultural Economics, Rural Development, South Asian Studies, International Development and Cooperation Studies. He conducts weekly seminars at the graduate school that address pertinent issues in Agricultural Economics, Rural Development, Sustainable Development, Climate Change, Environmental Conservation Agriculture and Rural Livelihood Strategies, which include issues concerning natural resource management, food security, poverty dynamics, human resources, local governance, rural society and community dynamics and offers support for writing master's and doctoral dissertations. More than 30 students have received their Ph.D. from Hiroshima University under his direct guidance. He regularly receives research funds from various funding agencies to conduct research. He contributes to SCI/SSCI journals and various related peer reviewed academic journals. He has published a dozen of books as an author or as an editor on the above issues from Springer and other publishers. He has also produced many books and journal articles in Japanese.

Preface to "Socio-Economic Functions Across Sustainable Farming Systems"

Agriculture faces major challenges, such as climate change, natural disasters, and food insecurity, that impact producers, processors, and consumers. Sustainable farming systems are seen as alternative solutions to these challenges, encompassing land-use change, environmental conservation agriculture, agricultural biotechnology, processing and marketing of farm produce, integration of non-farm activities, and related programs, plans, and policies. Despite the intuitive nature of these systems, their socio-economic functions are often contextual, leaving room for further exploration towards more effective practices, policy formulation, and theorization.

This reprint aims to present research on Socio-Economic Functions Across Sustainable Farming Systems, specifically on environmental conservation agriculture/climate-smart agriculture, which boosts nature-positive production, raises the welfare of producers; agricultural biotechnology, which contributes to economic and environmental sustainability; community-based extension and marketing of farm produce, which ensures the livelihood of producers and access to safe and nutritious food; and building a society resilient to all kinds of crises and hazards/disasters.

The first three chapters of this reprint focus on the farming system of Japan, which promotes environmental conservation agriculture and has 13 Globally Important Agricultural Heritage Systems designated by FAO, the highest number in the global north. These chapters reveal the drivers and dynamics of environmental conservation agriculture, the sustainable farming systems in Japan to address climate change, biodiversity conservation, sustainable production, welfare of producers, and leveraging their participation in Globally Important Agricultural Heritage Systems.

Chapter 4 discusses the ban on biotech crops in the Philippines, how farmers perceive it, and their attitudes towards it. The findings show the possibility of its coexistence with the practice of environmental conservation agriculture. Future research, which the authors are pursuing on this aspect, will provide further clarity.

Chapters 5, 6, and 7 discuss community-based activities, such as Farmer Field School, an extension program, flood adaptation strategy, and marketing strategy of farm products, and their socio-economic functions that enhance the welfare of the rural population in Bangladesh.

Chapters 8 and 9 delve into the socio-economic functions associated with farming practices, food safety, food security, and the constraints that small farmers face in South Africa and Senegal. Chapter 10 discusses financing agricultural cooperatives in Romania to enhance sustainable crop production.

I express my gratitude to all the authors for their valuable contributions, which have contributed to a better understanding of the issues providing useful insights for policymakers, researchers, and practitioners.

Keshav Lall Maharjan
Editor

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Article

Drivers of Environmental Conservation Agriculture in Sado Island, Niigata Prefecture, Japan

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Abstract: Sado Island in the Niigata prefecture in Japan is one of the first Globally Important Agricultural Heritage Systems (GIAHS) among developed countries and has since been involved in environmental conservation agriculture (ECA). While ECA is still in its early stage in Japan, it has proven to be effective in mitigating climate change in the agricultural sector; hence, this study aimed to identify drivers of ECA among Sado Island paddy farmers. The data revealed the prevalence of farmers' cognitive dissonance between ECA and its mitigating effects on climate change. Our findings confirmed the importance of perceived GIAHS involvement in the continuation of ECA. In addition, other identified drivers of ECA fall either on a macro-level (i.e., farmers' awareness of their role in improving their environment) or micro-level (i.e., farmers' differing farm optimizations). These perspectives highlighted the altruistic nature of the Sado Island ECA paddy farmers by valuing the improvement of their local and global environment as their main reason to continue ECA, whereas their various farm management optimizations support this observed farmer altruism by providing avenues to increase yield with only a moderate paddy land area. This study highlights the need to continuously develop sustainable strategies to maintain and improve a positive farmer mindset towards ECA.

Keywords: environmental conservation agriculture; Globally Important Agricultural Heritage Systems; climate change mitigation; *Tokimai* brand; Sado Island; Japan; biodiversity conservation; sustainable agriculture

Citation: Maharjan, K.L.; Gonzalvo, C.M.; Aala, W.J.F. Drivers of Environmental Conservation Agriculture in Sado Island, Niigata Prefecture, Japan. *Sustainability* **2022**, *14*, 9881. https://doi.org/10.3390/su14169881

Academic Editor: Luca Salvati

Received: 7 June 2022
Accepted: 7 August 2022
Published: 10 August 2022

1. Introduction

Climate change is a global phenomenon, and its irreversible effects on the agricultural sector and food security are evident today. In previous centuries, the repercussions of the industrial revolution and modernization have led to the rapid increase in greenhouse gas (GHG) concentration. Since agriculture is strongly dependent on weather patterns, climate change will significantly impact it [1]. The three determinants of food security are also affected, particularly availability, access, and utilization [2]. If not properly handled, this can contribute to severe yield losses and more challenges in feeding the surging global population, reaching the 10 billion mark by 2050 and projects the need to produce 60% more food [3,4]. The Japan Ministry of Environment reported that for the fiscal year (FY) 2019, Japan's total greenhouse gas emissions (GHGs) amounted to 1212 million tons. By the end of the 21st century, it is predicted that Japan's annual mean temperature will increase by around 2 to 3 °C in each region [5].

Japan's agriculture and food industries would be severely affected by the ongoing effects of climate change, and this trend will cause long-term regional differences, which can affect regional production activities. For example, one paper reported that climate change will increase rice production in Hokkaido and Tohoku prefectures while decreasing rice production in Kanto and its western region [6]. In order to avoid these negative

consequences, Japan is targeting to be carbon neutral by 2050 through its Green Growth Strategy, which emphasizes carbon recycling and the next-generation solar cells [7]. These global and national scenarios emphasize the need to develop viable solutions to mitigate the continuing effects of climate change, especially in the agricultural sector.

In the field of agriculture, one of Japan's main strategies to reduce its total emissions is to support and promote environmental conservation agriculture (ECA), especially through direct payment subsidies. Since 1992, Japan has taken initiatives to promote ECA and sustainable farming nationwide, such as providing subsidies for agro-environmental conservation activities and direct payments to eco-friendly farmers [8]. In general, ECA is a type of agriculture that aims to conserve the natural environment. It is formally defined as "sustainable agriculture, taking advantage of the material circulation function of agriculture, keeping in mind the harmony with productivity that takes into consideration the reduction of environmental impact caused by the use of chemical fertilizers and pesticides through soil management" [9].

In connection with the international movement to address climate change, ECA has been promoted not just in terms of chemical fertilizer and pesticide reduction but also in biodiversity conservation [10]. With ECA's flexible scope, various forms of agricultural methods can fall under it, such as special farming (which uses 50–80% less pesticide and fertilizer than conventional farming), organic farming, and eco-farming (environmentally friendly methods based on other standards, such as those set by local governments or in accordance with consumer agreements, among others), which means that the government can support more farmers. The promotion of ECA is important since almost 140,000 tons of GHGs are being reduced annually through activities supported by ECA direct payments [11]. Furthermore, ECA diffusion can also improve the efficiency of farming in Japan and the structure of agriculture [12]. Despite the proven benefits of ECA in mitigating climate change, a decrease in ECA utilization has been observed in 31 out of 47 prefectures (65.9%) from 2016 to 2020 [13] (Figure 1). ECA drivers should thus be identified and analyzed to ensure ECA's sustainability in Japan. This paper aims to contribute to this endeavor, specifically by identifying ECA drivers in Sado Island, Niigata prefecture–a globally important agricultural heritage system (GIAHS) situated in a prefecture with relatively higher ECA adoption than other prefectures (10th in Japan in 2016) [13].

1.1. Farmer Perceptions of Climate Change and Adoption of Environmentally Friendly Farming Methods

Numerous studies have explored farmers' knowledge, attitudes, and perceptions of climate change and its associated risks [14–18]. Many papers reported that farmers are aware of climate change; however, very few papers focused on analyzing how farmers view the role of environmentally friendly farming methods in mitigating climate change. Furthermore, farmers' views on climate change vary widely, and this heterogeneity influences their individual, community, and national decisions. In Japan, farmers' risk perceptions are greatly affected by their experiences and surrounding environments, which also impact their preferences and choices towards climate change adaptation and mitigation [19]. Furthermore, the willingness of Japanese farmers to participate in climate change adaptation measures is strongly determined by their preferences [20]. Hence, it is imperative to continue studying how farmers view their roles and responsibilities in these issues, which then affect the creation of future climate change policies for the agricultural sector.

Japan has been very active in the promotion of sustainable agriculture for several decades, of which the preservation of traditional farming, agro-culture, and biodiversity is highly valued. This enabled Japan's different prefectures to apply and get designated as Globally Important Agricultural Heritage Systems (GIAHS) [21]. The Food and Agriculture Organization of the United Nations (FAO) defined GIAHS as "outstanding landscapes of aesthetic beauty that combine agricultural biodiversity, resilient ecosystems, and a valuable cultural heritage". The GIAHS sites provide livelihood and food security for millions of small-scale farmers globally and contribute to producing sustainably produced goods and services [22]. The FAO has designated 62 systems in 22 countries since 2005 and is

currently reviewing 15 new proposals from eight countries. At present, there are 11 sites designated as GIAHS in Japan. These are in the prefectures of Ishikawa, Niigata, Shizuoka, Kumamoto, Oita, Gifu, Wakayama, Miyazaki, Miyagi, and Tokushima [21]. This paper particularly focused on Sado Island in Niigata prefecture, one of the first GIAHS sites designated in a developed country. The incorporation of ECA in GIAHS sites and various agri-environmental schemes has been documented in Japan, and a decline can be observed in 31 out of 47 prefectures [13]. For example, Shiga prefecture, which plays a big role in reducing the pollution in Lake Biwa by implementing ECA and agri-environmental policies, experienced a decline in the percentage of ECA utilization from 32.8% in 2016 to 25.3% in 2020. This declining trend in terms of ECA uptake stresses the need to identify factors that can retain or increase ECA adopters in Japan.

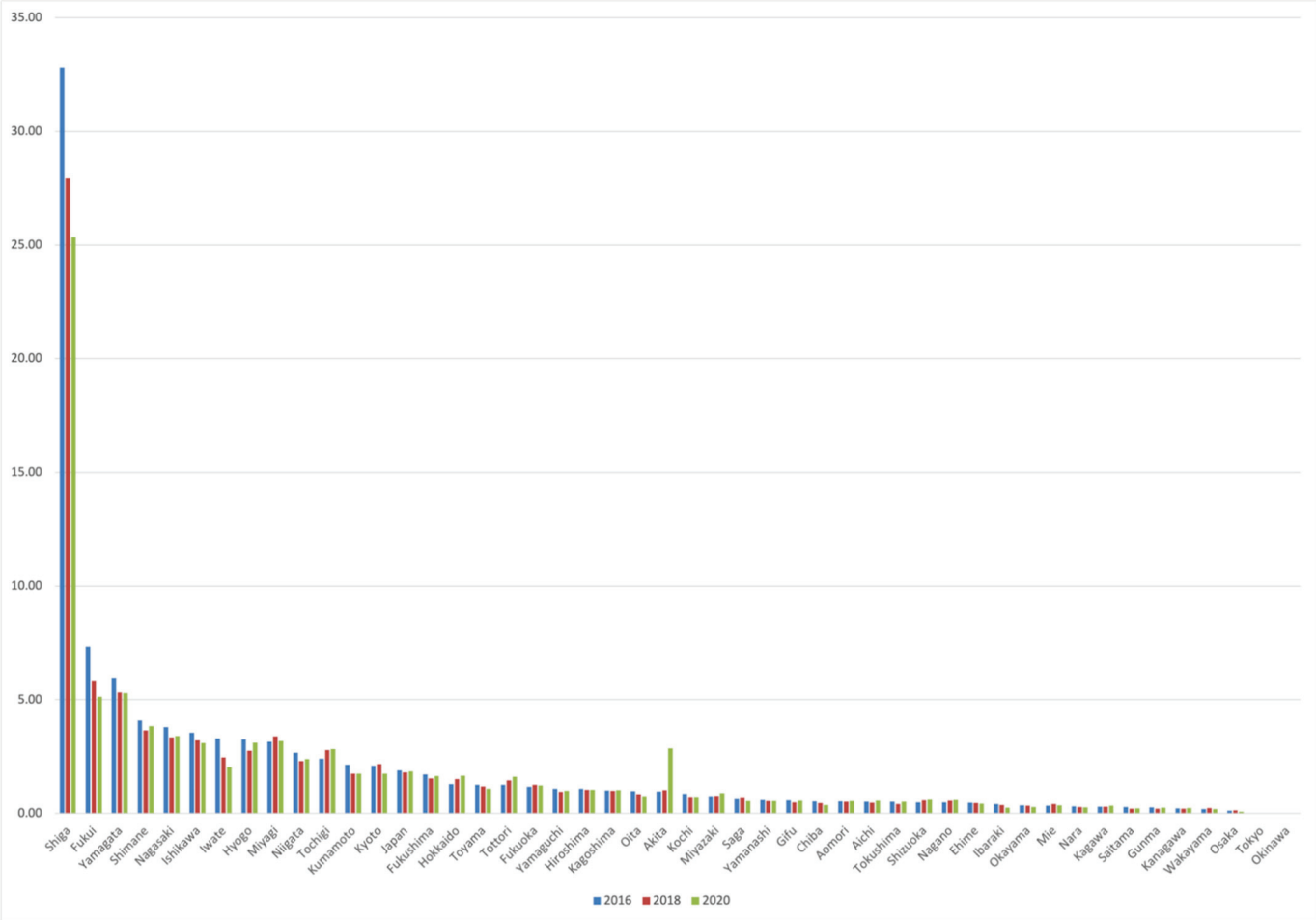

Figure 1. Percentage of ECA utilization in Japan. Source: Maharjan et al. (2022), with permission [13].

As discussed above, the application of ECA for mitigating climate change and promoting sustainable agriculture is ideal; however, it still faces a lot of challenges such as (1) aging of farmers and labor shortage; (2) technical issues (i.e., unstable yield and quality); (3) production costs; (4) low prices of agricultural products; (5) difficulty in securing sales channels or the lack of consumers' interest; and (6) wildlife damage, similar to challenges being faced by the agricultural sector in Japan. Along with these challenges, it is also vital to know how farmers perceive this farming method and what factors would influence their adoption or continuation. In line with this, this paper investigated the factors affecting farmers' ECA continuation of paddy farmers and their possible implications. Moreover, this study focused on Sado Island in Niigata prefecture, a GIAHS, thereby producing recommendations on how ECA may impact other GIAHS sites and ECA farmers.

1.2. Theoretical Foundations and Research Hypothesis

This paper is based on several theoretical underpinnings. First is the diffusion of innovations theory, which can support how the ECA farming method has diffused among Sado Island farmers. Rogers (2003) defined diffusion as a process by which an innovation is communicated through certain channels over time among members of a social system [23]. Based on the discussion above, it can be observed that even at its development stage, ECA uptake is slowly declining in Japan. Inside the diffusion process, different factors determine a technology's success or failure and the behavior of its adopters. Two of the most famous theories that explain this are social learning theory (SLT) and social cognitive theory (SCT) by Albert Bandura [24,25]. These theories provide an explanation of how people imitate behaviors of role models, how positive reinforcement can lead to a continuance of behavior, and how cognitive processes are driven by social consequences that occur in a person's environment. SLT and SCT can support how various factors positively or negatively affect the ECA continuation of Sado Island farmers. Lastly, the social movement theory explains how collective behavior can induce social change. This is commonly used in papers that aim to understand the impacts of people's actions on addressing climate change [26,27]. In the context of this paper, this theory can explain how the collective action of ECA farmers can increase ECA uptake on Sado Island. These theories comprise the theoretical foundations of this study, which mainly aim to identify drivers of ECA. In this paper, we hypothesized that various factors affect the ECA continuation of Sado island farmers, namely: (1) climate change effects; (2) socio-demographic factors; (3) ECA/GIAHS factors; and (4) farmer preferences. These factors will be listed in detail and tested in the subsequent sections.

2. Methodology

2.1. Data Collection

A cross-sectional survey method was employed to collect data from ECA farmers on Sado Island. Key persons were consulted to grasp the situation and research context on the island, which aided in designing the aims of the study. In February 2020, the study's research objectives and questionnaire were first discussed in the annual meeting of the Board of Directors of the Council for Promotion of "*Toki-to-kurasu-satojukuri suishin kyogikai*" (Council for Promotion of Community Development Living with Toki), in cooperation with the Sado Island Municipality Agriculture Policy Division. All the council members are ECA farmers; thus, questionnaires were sent to these farmers to gather their responses. The questionnaire was constructed by the research members of the joint research entitled "Moving Towards Climate Change Resilient Agriculture: Understanding the Factors Influencing Adoption in India and Japan" in accordance with the rules of the Research Ethics Committee of Hiroshima University's Graduate School for International Development and Cooperation. The survey was conducted with informed consent, and the respondents were assured that their identity and any information they would share will be kept private, securely stored, and will be used for research purposes only. The board approved the conduct of the survey, and questionnaires were distributed to the 415 council members, which essentially represent the target farmers of the study on Sado Island. By the end of April 2020, 279 (67%) responses were sent back by the respondents. The contents of the questionnaire include (1) basic information on farmers and agriculture; (2) opinions related to ECA; (3) perceptions and responses to climate change; (4) significance of ECA and its relationship to climate change; (5) practice of ECA and expectations on its effects; (6) ECA farmers' receiving of subsidy; and (7) prospects of Sado Island towards ECA. Questions related to ECA and climate change were adopted from MAFF [28–30], which were nationwide surveys regarding awareness of the impacts of global warming on agriculture, forestry and fisheries; adaptation measures, awareness of environmentally friendly agriculture (including organic farming and their produce); and awareness of the introduction of technologies contributing to environmentally friendly agriculture in Japan. The authors translated all the responses that are in local Japanese into English.

2.2. Data Analysis

To identify the significant drivers of ECA among Sado Island farmers, ordinal logistic regression was employed, and the resulting model was verified using model fit, goodness-of-fit, and test of parallel lines in SPSS v.27 (IBM, NY, USA). Qualitative data obtained in the survey were used to support the discussion of the findings.

In this study, the ECA farmers were asked whether they were planning to continue their ECA adoption or not using a three-point rating scale (i.e., 1 = yes, 2 = neutral, and 3 = no). This served as the dependent variable for all the regression analyses. We first sought to determine the effect of farmers' perception of climate change effects on their ECA continuation, followed by the effects of socio-demographic factors, ECA/GIAHS factors, and farmer preferences. Lastly, we created a summative heat map showing all the identified ECA drivers based on the results of the ordinal logistic regressions.

3. Environmental Conservation Agriculture on Sado Island

3.1. Description of Sado Island

The study was conducted on Sado Island, located west of the Niigata prefecture shoreline. It is the sixth-largest island in Japan, with a complex ecosystem and interdependent *satoyama* and *satoumi* landscapes. The areas included in the study are Ryotsu, Aikawa, Sawata, Kanai, Niibo, Hatano, Mano, Akadomari, Hamochi, and Ogi, spanning northern, central, and southern Sado Island (Figure 2). Sado Island is around 855 km^2 with a total of 7941.88 ha of cultivated land, of which 6128.41 ha are rice-producing fields. Since 1960, Sado Island has been experiencing a sharp population decline, from 113,296 to 57,355 in 2015. There was also a decline in the number of farmers from 7103 in 2010 to 5927 in 2015, wherein 1614 are those who produce food for self-consumption only [31]. This trend has been observed in a previous study, in which the major causing factor of population decline is the outward migration of younger people to urban areas to look for better education and employment opportunities [32]. The island has *satoyama* and *satoumi* landscapes, the former term defined as "landscapes that comprise a mosaic of different ecosystem types including secondary forests, agricultural lands, irrigation ponds, and grasslands, along with human settlements" and the latter as "Japan's coastal areas where human interaction over time has resulted in a high degree of productivity and biodiversity" [33]. In particular, the *satoyama* landscape of Sado Island provides suitable habitats for the endangered Japanese crested ibises (i.e., *Nipponia nippon,* locally called *Toki* in Japanese), and Sado Island is famous for its rice produce with *Tokimai* brand, which supports the revival of the endangered *Toki* birds. Another study concurs with this and reported that Sado Island's low-input rice system has successfully provided breeding grounds for the *Toki* birds, wherein more than 200 birds prey on small animals that cause rice production losses [34]. Farmers grow other agricultural crops like apples, oranges, pears, persimmons, cherries, strawberries, watermelons, and shiitake mushrooms, among others, for self-consumption and extra income. In line with this, various contributions from the public and private sectors were given to support Sado Island's biodiversity preservation through ECA to breed, raise, and provide a habitat suitable for the release of *Toki* in the wild, which is a significant factor in its designation as a GIAHS.

3.2. ECA's Diffusion in Sado Island

In 2008, the "Sustainable Agriculture for Living Creature Project" was established in Japan, and this was evident on Sado Island. During this time, there was a 50% reduction in chemical pesticide and fertilizer input for around 77.6% of the Sado Island rice paddies; moreover, 25% of the total paddy fields were engaged with the project by 2012 [8]. One of the biggest reasons why ECA has been highly adopted and implemented on the island is the preservation of the endangered Japanese crested ibises. The habitats of these birds are wetlands, and the paddy fields enable these species to thrive after being restored through extensive captive breeding programs. Local support was also received to improve the birds' feeding grounds, namely: reduction of chemical pesticide and fertilizer input by at least

50%; use of compost; making canals to connect nearby waterways/rivers and paddy fields for the free movement of fish/water animals; retaining water in the fallow paddy field in winter; making biotope for biodiversity; making a ditch to collect water during the dry season where living creatures survive; and conducting field surveys for species diversity in the field.

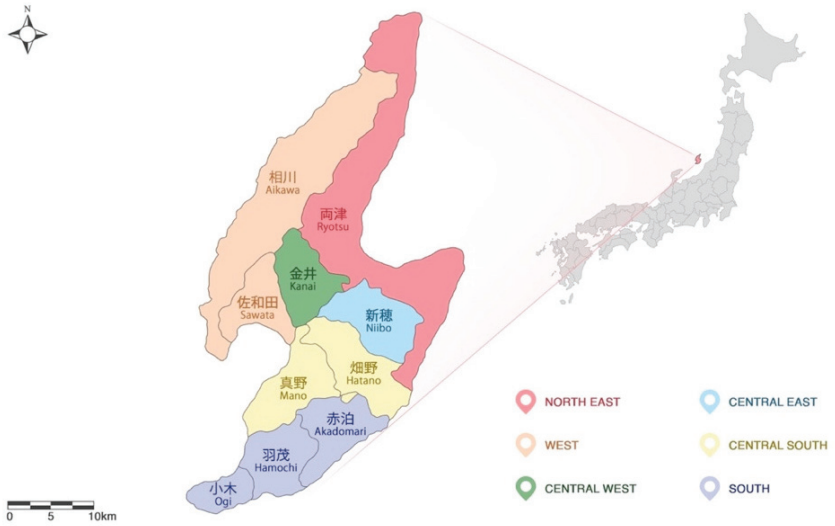

Figure 2. Map of Sado Island showing areas included in the study.

Sado Island was also able to obtain a rice certification with *Tokimai* branding in 2008, which enabled farmers to gain a reasonable profit for their harvest. Interestingly, rice produced in fields that provide habitat to birds has the highest price among rice brands produced in coexistence with living creatures [35]. Another important aspect of farmers' continuous ECA adoption is the community and government support. In terms of consumers' willingness to pay for eco-labeled rice, consumers in Osaka and Metropolitan areas were more willing to pay for the *Tokimai* brand than general consumers, most especially those who were concerned with safer cultivation methods and paddy field biodiversity [36]. Moreover, it was observed that consumers were willing to pay for the *Tokimai* rice brand to support the conservation efforts on Sado Island. The report also concluded that the taste of rice should be emphasized to further boost its marketing.

3.3. Socio-Demographic and Farm-Related Data of ECA Farmers on Sado Island

Based on Japan's 2015 Agriculture and Forestry census, Sado Island has a total of 5927 farmers, specifically comprising 4313 commercial farmers and 1614 farmers who produce food for self-consumption only [31]. There are 4248 farm management entities, including farmers and companies holding 7042 ha of land. Of them, 4204 are using 6128 ha of land to produce rice. The 415 council members of *Toki-to-kurasu-satojukuri suishin kyogikai* (Council for Promotion of Community Development Living with Toki) accounts for around 10% of the total commercial rice-producing farmers across Sado Island.

In this study, 77.4% of the farmers practice special farming which uses 50-80% fewer chemicals and pesticides than the conventional farming practice on the island, 10.8% practice organic farming, 9.3% conduct eco-farming or other ECA-related methods, and 2.5% employ ECA-oriented farming (Table 1). This data agrees with the high number of farmers who reported a high interest in ECA (83.5%), intention to continue ECA (86.7%), and seek opportunities to learn about ECA (73.8%) (Table 2). Such data appears to reflect the permeating spread of ECA among the farmers. Chief among the farmers' reasons for continuing ECA is to build trust with customers (48.4%), followed by their aim to improve their local and global environment (40.9%), to supply better products (39.1%), and advised by Japan Agricultural Cooperatives or local government (31.5%).

Table 1. Socio-demographic characteristics of the ECA farmers in Sado Island, Japan.

Variable	Frequency (n = 279)	Percentage (%)
Region		
Central East	59	21.1
Central West	57	20.4
West	45	16.1
North East	42	15.1
South	38	13.6
Central South	38	13.6
TOTAL:	279	100.0
Age		
15–39	5	1.8
40–49	10	3.6
50–59	40	14.3
60–64	53	19.0
65–79	143	51.3
80 and above	28	10.0
TOTAL:	279	100.0
Sex		
Male	260	93.2
Female	19	6.8
TOTAL:	279	100.0
Farming experience		
9 years and below	17	6.1
10–19	62	22.2
20–29	36	12.9
30–39	51	18.3
40 years and above	113	40.5
TOTAL:	279	100.0
Commercial farmer [1]		
Yes	267	95.7
No	12	4.3
TOTAL:	279	100.0
Family members have non-farming jobs		
Yes	177	63.4
No	102	36.6
TOTAL:	279	100.0
Farm income is higher than income from other jobs		
Yes	53	19.0
No	132	47.3
No answer	94	33.7
TOTAL:	279	100.0
Family farm registration type		
Family farm not registered as a company	257	92.1
Family farm registered as a company	7	2.5
Organized farm	7	2.5
Others	8	2.9
TOTAL:	279	100.0
Farming method [2]		
Special farming	216	77.4
Organic farming	30	10.8
Eco-farming or related	26	9.3
ECA-oriented farming	7	2.5
TOTAL:	279	100.0

Table 1. *Cont.*

Variable	Frequency (n = 279)	Percentage (%)
Farmland size		
Less than 1 ha	48	17.2
1–5 ha	144	51.6
5–10 ha	33	11.8
10–20 ha	28	10.0
20–30 ha	13	4.7
30–50 ha	7	2.5
50 ha and above	6	2.2
TOTAL:	279	100.0
Paddy land area/size		
Less than 1 ha	56	20.1
1–5 ha	145	52.0
5–10 ha	28	10.0
10–20 ha	29	10.4
20–30 ha	8	2.9
30–50 ha	7	2.5
50 ha and above	6	2.2
TOTAL:	279	100.0
Paddy yield (per tan) [3]		
Less than 5 hyo	4	1.4
5–6 hyo	10	3.6
6–7 hyo	28	10.0
7–8 hyo	113	40.5
8–9 hyo	121	43.4
10 hyo and above	3	1.1
TOTAL:	279	100.0

[1] A commercial farmer is required to have a farm area of at least 0.30 ha and sells farm products valued at more than JPY 500,000 per annum. This is also one of the criteria for becoming a council member for the promotion of the *Toki-to-kurasu-satojukuri-suishin kyogikai* (Council for Promotion of community development living with *Toki*). [2] Special farming (low-input farming): uses 50–80% fewer fertilizers and pesticides than the conventional farming practice of the locality, complies with GIAHS regulations; Organic farming: certified as organic by Japanese Agricultural Standards (JAS), or no JAS certification but does not use chemical fertilizers and synthetic pesticides; Eco-farming: low-input and environmentally friendly farming methods based on the standards set by the local government or in accordance with consumer agreements, among others; ECA-oriented farming: uses chemical fertilizers and pesticides prescribed and practiced in the ECA-farming region. [3] 1 hyo = 60 kg, 1 tan = 10a = 1000 sqm

On the other hand, water management (65.6%), soil management (40.5%), change in planting time (38.7%), and ameliorating pest/disease (21.5%) are among the top adaptations that the farmers were practicing to circumvent the effects of climate change (Table 2). This agrees with earlier studies wherein water management, utilization of organic manure, crop rotation, and crop diversification were among the top ECA practices implemented in other countries [37,38]. The perceived levels of GIAHS involvement and the enhancement of agricultural products/brand in Sado Island and their effects on youth and tourist promotion are also high at 43.7%, 59.1%, 38.7%, and 49.8%, respectively. Interestingly, in a recurring island-wide survey on Sado Island regarding biodiversity and biodiversity-related information, roughly more than half of the respondents have replied that they have minimal to zero knowledge regarding the designation of Sado Island as a Globally Important Agricultural Heritage System (GIAHS) [39].

Table 2. ECA-related and climate change-related factors of farmers in Sado Island, Japan.

Variable	Frequency (n = 279)	Percentage (%)
ECA interest [O]		
High	233	83.5
Not high	26	9.3
Neutral	20	7.2
TOTAL:	279	100.0
Status for receiving ECA subsidy		
Receiving subsidy up to now	156	55.9
Receiving before but not currently	38	13.6
Never received subsidy	56	20.1
Others	5	1.8
No answer	24	8.6
TOTAL:	279	100.0
ECA continuation [O]		
Yes	242	86.7
No	5	1.8
Neutral	32	11.5
TOTAL:	279	100.0
Reason for ECA continuation *		
To build trust with consumers	135	55.8
To improve local and global environment	114	47.1
To supply better products	109	45.0
Advised by Japan Agricultural Cooperatives or local government	88	36.4
Good price	68	28.1
Demand is high	48	19.8
Self-health	42	17.4
To decrease production cost of fertilizers and pesticides	39	16.1
Others	8	3.3
Relation of ECA with climate change *		
No impact on climate change	122	43.7
ECA is related with climate change as an adaptation	71	25.4
Reducing the effect	64	22.9
Others	9	3.2
Opinion on whether climate change influences agriculture or not [O]		
Strongly yes	148	53.0
Yes	126	45.2
No	3	1.1
Strongly no	1	0.4
Neutral	1	0.4
TOTAL:	279	100.0
Expectation in adopting ECA *		
Conservation of biodiversity	205	73.5
Add value to quality of products	186	66.7
Conservation of water (quality)	94	33.7
Increase farm related income	94	33.7
Promote local industry	59	21.1
Carbon sequestration	45	16.1
Decrease effect of weather hazards	36	12.9
Retain underground water	15	5.4
Retain residents in rural area	12	4.3
Others	8	2.9

Table 2. *Cont.*

Variable	Frequency (n = 279)	Percentage (%)
Reason for strengthening ECA adoption *		
To build trust with consumers	71	25.4
To improve local and global environment	61	21.9
To supply better products	50	17.9
Good price	31	11.1
Demand is high	30	10.8
To decrease use of fertilizers and pesticides	25	9.0
Advised by Japan Agricultural Cooperatives or local government	22	7.9
Self-health	16	5.7
Others	4	1.4
Effects of climate change *		
Temperature (i.e., rise of sea temperature, extreme hot days)	253	90.7
Heavy (torrential) guerilla rain, flood	174	62.4
Drought	149	53.4
Typhoon, cyclone, tornado	134	48.0
Damage to farm products	122	43.7
Change in season/duration	92	33.0
Change in distribution of plants/crops	64	22.9
Damage to land/farmland	53	19.0
Melting of glaciers, sea-level rise	50	17.9
Damage to houses/buildings	23	8.2
Others	7	2.5
Farming adaptation to climate change *		
Water management	183	65.6
Soil management	113	40.5
Change in planting time	108	38.7
Ameliorate pest/diseases	60	21.5
High-temperature tolerant variety	24	8.6
Change land use pattern	13	4.7
Choose different crop	5	1.8
Others	11	3.9
GIAHS involvement ^{O}		
Strongly yes	122	43.7
Strongly no	28	10.0
Not sure	129	46.2
TOTAL:	279	100.0
Opinion on GIAHS giving pride and confidence to youths ^{O}		
Strongly yes	108	38.7
Strongly no	33	11.8
Not sure	138	49.5
TOTAL:	279	100.0
Opinion on GIAHS enhancing agricultural products/brand of Sado Island ^{O}		
Strongly yes	165	59.1
Strongly no	24	8.6
Not sure	90	32.3
TOTAL:	279	100.0

Table 2. *Cont.*

Variable	Frequency (n = 279)	Percentage (%)
Opinion on GIAHS promoting tourism in Sado Island [O]		
Strongly yes	139	49.8
Strongly no	42	15.1
Not sure	98	35.1
TOTAL:	279	100.0
Farmers' wish for farming *		
Retain area size, retain farming method	160	57.3
Will expand area, retain farming method	42	15.1
Retain area size, but towards strengthening ECA adoption	32	11.5
Decrease area size, retain farming method	26	9.3
Will expand area, towards strengthening ECA adoption	10	3.6
Decrease area size, towards ordinary farming	1	0.4
Others	8	2.9

* Multiple responses. [O] ordinal level variable. Questions related to ECA, and climate change were adopted from MAFF (2015, 2016, and 2018).

In terms of age, 61.3% of the farmers are at least 65 years old, while sex distribution in Sado Island farming households remains male-dominated, as reported in other studies [40]. Similar to the age distribution, 58.8% of the farmers have a reported farming experience of at least 30 years. In terms of household income, 63.4% of farmers have family members who are in non-farming jobs, and 47.3% have farming income that is less than the income of family members from non-farming jobs. Farmland and paddy land size is at a moderate area of at most 5 hectares for 68.8% and 72.1% of the farmers, respectively. Interestingly, farmers appear to produce more with less land, as reflected in the moderate to high paddy yield for 85% of the farmers (at least seven hyo per tan or 4200 kg per ha) (Table 1).

Knowledge about climate change and/or its effects may have promoted the high number of Sado Island farmers practicing ECA and have intentions of continuing ECA. Interestingly, while 53% of the farmers strongly agree that climate change has an effect on agriculture, 43.7% expressed that ECA does not have an impact on climate change, thus indicating cognitive dissonance since ECA has been proven to be an effective farming method in mitigating climate change [11]. Only 22.9% of the farmers indicated that ECA can reduce the effects of climate change, and 25.4% perceive ECA as an adaptation to climate change (Table 2).

4. Results

Drivers of Environmental Conservation Agriculture on Sado Island

Among the climate change effects included in this study, only damage to land/farmland had a significant effect on ECA continuation (Table 3). It is a negative driver of ECA, which means the farmers are three times less likely to continue ECA when they perceive damage to their farmland incurred by climate change.

Among all the socio-demographic, ECA, and GIAHS variables, the identified drivers of ECA in descending order of odds ratio are farmer status for receiving ECA subsidy, level of perceived GIAHS involvement, farmer adaptation to climate change, and level of perceived interest in ECA (Table 4). Similar to the results in Arslan et al. (2014), age and farming experience did not show a significant effect on ECA continuation, which were labeled as household-level unobservables [41].

In terms of farmer preferences, the identified ECA drivers are biodiversity conservation and adding value to the quality of their products (Table 5). Specifically, those farmers who expect to conserve biodiversity and add value to the quality of their products are 40% and 47% times more likely to continue ECA than those who did not have these expectations,

respectively. Indeed, the farmers are highlighting that their farming method creates a good habitat for the Toki birds while consequently increasing the quality and price of their products. This observation is further strengthened when specific reasons to continue ECA were tested against ECA continuation. The results of the analysis revealed that only improvement of the local and global environment has a significant relationship with ECA continuation, such that farmers who chose ECA to improve local and global environment are 8% more likely to continue practicing ECA than those who did not choose this reason.

Table 3. Relationship of various climate change effects with ECA continuation among farmers in Sado Island, Japan, using ordinal logistic regression.

Variable	Estimate	Odds Ratio	Significance
Effects of climate change			
Heavy torrential rain	0.445	64.08%	0.230
Increase in temperature	0.588	55.54%	0.231
Typhoons	0.137	87.20%	0.716
Change in distribution of plants/crops	0.139	87.02%	0.762
Change in season duration	0.29	74.83%	0.477
Melting glaciers	1.211	29.79%	0.137
Drought	0.375	68.73%	0.286
Damage to houses	0.079	92.40%	0.926
Damage to land/farmland	−1.206	334.01%	0.009 **
Damage to farm products	0.003	99.70%	0.993

Link function: Complementary Log-Log f(x) = log(−log(1 − x)). Test of parallel lines—Chi-square: 16.186; df: 11; Sig: 0.134. Goodness of fit—Pearson Chi-square: 202.784; df: 209; Sig:0.608. ** significant at $p < 0.01$

Table 4. Relationship of various socio-demographic and ECA factors with ECA continuation among farmers in Sado Island, Japan.

Variable	Estimate	Odds Ratio	Significance
GIAHS factors			
Level of perceived GIAHS involvement	0.659	51.74%	0.022 *
Level of perceived youth confidence and pride from GIAHS	−0.293	134.04%	0.364
Level of perceived Sado Island agricultural product and branding enhancement	0.435	64.73%	0.168
Level of perceived tourism promotion from GIAHS	0.347	70.68%	0.225
Age variables			
Age of farmer	−0.227	125.48%	0.338
Farming experience	−0.345	141.20%	0.064
Farm demographics			
Farmland size	0.036	96.46%	0.906
Paddy land size	−0.030	103.05%	0.922
Paddy yield	−0.208	123.12%	0.315

Table 4. *Cont.*

Variable	Estimate	Odds Ratio	Significance
ECA factors			
Level of perceived interest in ECA	0.804	44.75%	0.000 **
Level of perceived opportunities in ECA	0.386	67.98%	0.055
Level of perceived climate change effects	0.180	83.53%	0.512
Farmer status for receiving ECA subsidy			
Receiving subsidy up to now	−16.267	1.2E9%	0.000 **
Received before but not currently	−16.417	1.3E9%	0.000 **
Never received subsidy	−15.735	-	-
Income variables			
Price satisfaction	0.279	75.65%	0.060
Family members have other jobs other than farming	−0.079	108.22%	0.829
Farm income is higher than other jobs	0.441	64.34%	0.280
Farming adaptation to climate change			
Farmer doing farming adaptation measures against climate change	0.766	46.49%	0.046 *

Link function: Complementary Log-Log f(x) = log(−log(1 − x)). * significant at $p < 0.05$. ** significant at $p < 0.01$

Table 5. Relationship of farmer preferences with ECA continuation among farmers in Sado Island, Japan.

Variable	Estimate	Odds Ratio	Significance
Expectation in adopting ECA			
Carbon sequestration	0.391	67.64%	0.528
Conservation of biodiversity	0.919	39.89%	0.011 *
Conservation of water quality	−0.241	127.25%	0.555
Retain underground water	19.67	-	-
Add value to quality of products	0.765	46.53%	0.031 *
Decrease effect of weather hazards	0.257	77.34%	0.69
Increase farm-related income	−0.027	102.74%	0.946
Promote local industry	1.157	31.44%	0.068
Retain residents in rural area	−0.326	138.54%	0.748
Reason for continuing ECA			
To build trust with consumers	0.017	98.31%	0.726
To improve local and global environment	0.125	88.25%	0.014 *
Self-health	−0.032	103.25%	0.643
Good price	0.097	90.76%	0.094
Demand is high	−0.026	102.63%	0.701
To supply better products	0.046	95.50%	0.359
To decrease production cost of fertilizers and pesticides	0.057	94.46%	0.421
Advised by Japan Agricultural Cooperatives or local government	−0.03	103.05%	0.578

Table 5. *Cont.*

Variable	Estimate	Odds Ratio	Significance
Reason for strengthening ECA adoption			
To build trust with consumers	0.636	52.94%	0.249
To improve local and global environment	0.781	45.79%	0.180
Self-health	0.46	63.13%	0.657
Good price	0.64	52.73%	0.400
Demand is high	−0.337	140.07%	0.554
To supply better products	−0.424	152.81%	0.458
To decrease use of fertilizers and pesticide	0.629	53.31%	0.416
Advised by Japan Agricultural Cooperatives or local government	−1.278	358.95%	0.006 **
Farmers' wish for farming			
Will expand area, retain farming method	2.511	8.12%	0.001 **
Will expand area, towards strengthening ECA adoption	21.457	0.00%	-
Retain area size, retain farming method	1.913	14.76%	0.000 **
Retain area size, but towards strengthening ECA adoption	2.649	7.07%	0.002 **
Decrease area, retain farming method	1.238	29.00%	0.046 *
Decrease area, towards ordinary farming	−0.984	267.51%	0.443

Link function: Complementary Log-Log f(x) = log(−log(1 − x)). * significant at $p < 0.05$. ** significant at $p < 0.01$.

In terms of reasons to strengthen ECA adoption, only the variable "advised by Japan Agricultural Cooperatives or local government" was found to significantly affect ECA continuation. This agrees with previous studies that regard farmers as active individuals that enforce internal farm decisions [42,43]. This is further supported by the significant positive effects of various farm management implementations that the farmers wish to implement in their farms (i.e., decrease or increase land area and shift towards ECA), which may allow them to improve yield and farm produce value. Using correspondence analysis and chi-square test, it was further found that region and paddy yield were related such that the Central West area is associated with high paddy yield, while southern regions are associated with low yields, respectively (Figure 3). Interestingly, while a greater proportion of the farmers (83.9%) reported having paddy yields of 7–9 hyo (420–540 kg), most of these are coming from small to intermediate paddy land sizes of at most 5 hectares (72.1% of the farmers). This observation aligns with the data on average cultivated land per farm household at 1.6 ha in Japan, which is in stark contrast with the higher values reported for other countries such as the USA (176.1 ha), UK (70.1 ha), Germany (30.3 ha) and France (38.5 ha) [44]. Indeed, an inverse relationship between paddy area and yield has been shown to exist in various countries such as China, Africa, Turkey, and even Japan in recent years, which was attributed to differences in labor intensity and level of commercialization [45–48].

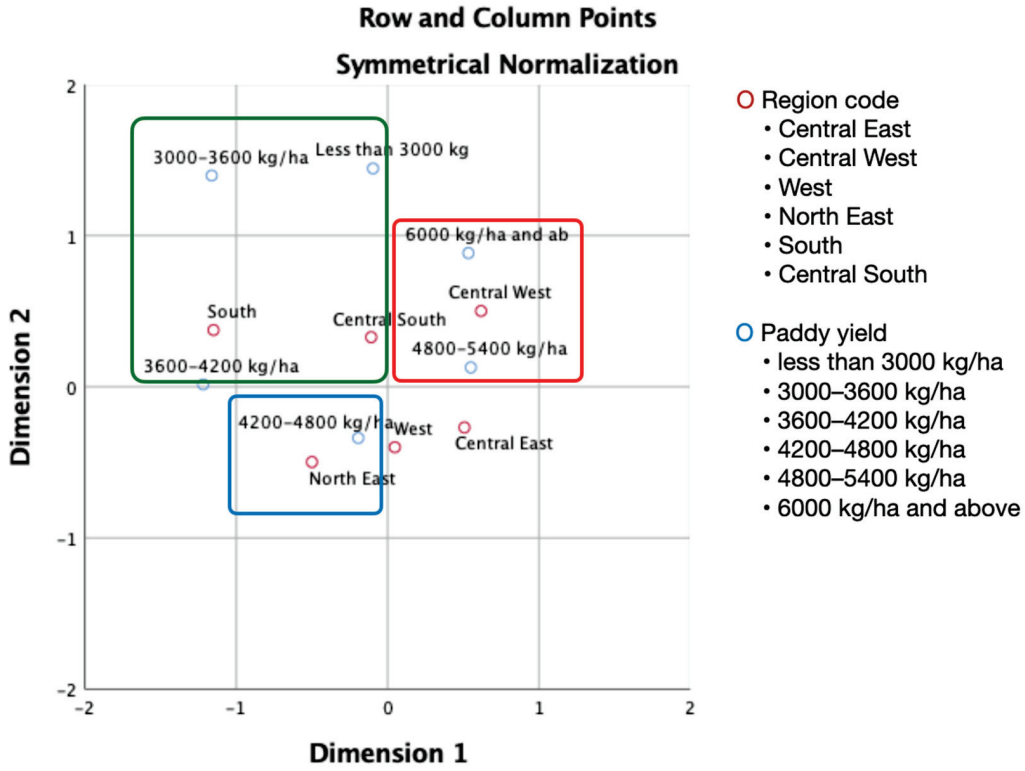

Figure 3. Biplot of region and paddy yield.

5. Discussion

While a lot of research has been conducted regarding farmers' perceptions of climate change and the adoption of environmentally friendly methods, only a few papers in Japan are focusing on what factors contribute to the ECA continuation of farmers. Analyzing this is vital to reducing GHGs produced in Japan's agricultural sector and further promoting the adoption of ECA in various prefectures. This paper addressed this by identifying factors that can contribute to the ECA continuation of Sado Island farmers. Figure 4 shows the factors identified with a significant relationship with ECA continuation. Estimates were transformed into a color value based on a two-color gradient, with green representing the increasing magnitude of negative relationship and red representing the increasing magnitude of a positive relationship.

5.1. Cognitive Dissonance between ECA Understanding and Its Capability to Mitigate Climate Change

ECA is an agricultural method that generally aims to conserve the environment and mitigate climate change; however, farmers may not yet fully understand this concept since ECA is still in its early stage in Japan [49]. Previous studies have shown that skepticism of the climate change theory is still common within the farming community. However, such uncertainties do not appear to affect farmers' attitudes toward the adoption of new farming methods, such as ECA [50]. The 2016 and 2013 surveys of the Sado Island government regarding biodiversity have shown that 61.2% and 66.5% of the respondents have no knowledge of the term biodiversity [39]. In Howden et al. (2007), it is posited that farmers are more likely to believe that climate change is happening if they perceive it as a direct threat to their livelihood [51]. Our data revealed that farmers are less likely to continue ECA when they perceive damage to their farmlands caused by climate change. This finding aligns with other papers which reported that farmers tend to focus more on short-term effects (immediate damage to their farm or their products) rather than long-term effects such as temperature increase and season duration changes [52–54]. This concurs with a case study on a Nepalese community that reported how short-term trends in climate change, such as rainfall, affect perception and decision-making [55]. This study's findings were

contradictory to the inference of Howden et al. (2007) since Sado Island farmers who relate climate change with damage to farmland are three times less likely to continue ECA. This cognitive dissonance may be partly due to the farmers' lack of understanding of the actual climate change mitigating effects of ECA.

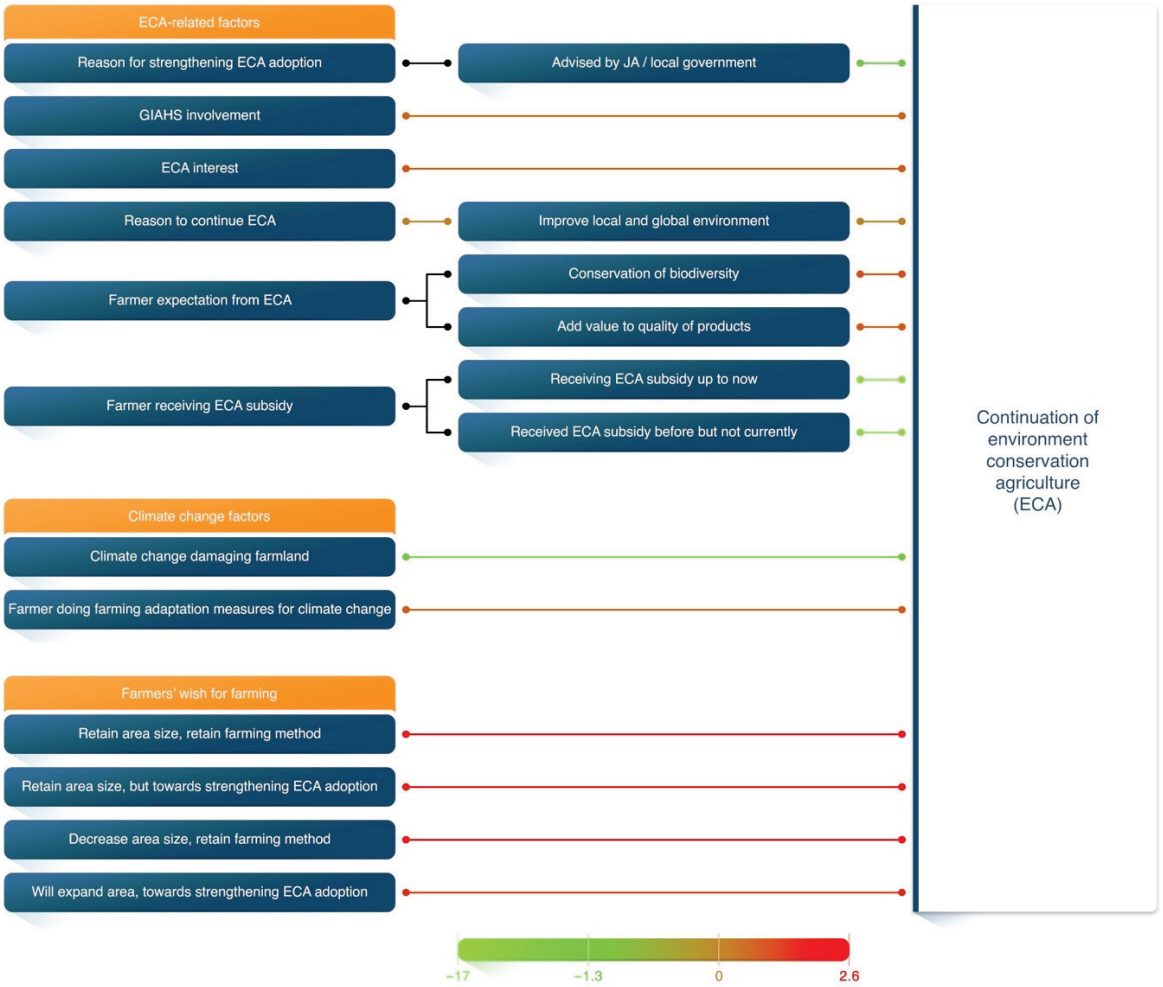

Figure 4. Relationship of identified factors affecting ECA continuation. The connecting lines in red indicate the positive intensity of the relationship with ECA continuation, while green indicates the negative intensity of the relationship.

To further contextualize the inference of Howden et al. (2007) in this study, it can be inferred that Sado Island farmers are more likely to believe that climate change is happening and take adaptive measures if they perceive it as a direct threat, and if they understand the mechanisms of current technologies developed to mitigate climate change (i.e., ECA). The data from this study strongly align with the findings of another paper that also focused on knowing the ECA interest of farmers in Fujioka, Japan. The Japanese farmers exhibited very high biodiversity conservation awareness and identified improving their local and global environment as their main reason to continue ECA; however, their ECA interest is low [13]. This proves that the concept of ECA is not yet fully understood or disseminated among rural communities, as also shown in the findings of this paper.

The Sado Island farmers have two conflicting beliefs since they are less likely to continue ECA adoption when they perceive damages to their farmland caused by climate change. These beliefs are contradictory since ECA is a proven climate change mitigator, so the expected relationship between climate change perception and ECA adoption should be direct and not inverse. In the cognitive dissonance theory of Leon Festinger, there are

three suggestions on how to reduce the inconsistency between two different beliefs, as well as contrasting actions and attitudes [56]. First, selective exposure to information can be done. In the case of Sado Island farmers, effective information dissemination regarding ECA can be done through various channels, most especially through farmers' main sources of information. Cognitive dissonance can be reduced by distributing easy-to-understand information regarding ECA and how it can mitigate climate change. Another method is to reduce the farmers' post-decision dissonance by generating avenues for reassurance regarding the new knowledge they were exposed to. Post-decision dissonance refers to doubts being experienced by people after making an important decision or a switch in a belief that may be difficult to reverse. In the case of Sado Island farmers, a sudden change in their ECA understanding may cause post-decision dissonance since it's different from what they currently believe in. By conducting workshops with leaders in the farming community whom the farmers highly respect and trust, they can reassure their co-farmers that their ECA understanding is correct, and post-decision dissonance can therefore be reduced. Lastly, Festinger also suggested the minimal justification hypothesis, wherein attitudinal change can be done by targeting behavioral change first and offering just enough incentive to elicit overt compliance. The case of Sado Island farmers is unique since the results of regressions have shown that receiving a subsidy negatively affects their ECA continuation. Furthermore, being advised by JA lessens their likelihood of strengthening their ECA adoption. This shows that instead of financial incentives, other types of rewards for Sado Island farmers can be explored, which can be related to the top factors that influence their ECA continuation (i.e., improvement of their local or global environment, biodiversity conservation, and adding value to the quality of their agricultural products). These strategies may reduce the farmers' cognitive dissonance and encourage ECA continuation.

In a study that conducted participatory experiments among Filipino rice farmers who had conflicting beliefs and misperceptions of pests and pesticides, it was found that dissonance resolution was proven to be effective [57]. Furthermore, labor reduction and money savings induced positive changes in the farmers' perceptions, attitudes, and practices. To improve the diffusion of farmer-to-farmer experiences, the authors recommended the use of media, such as newspapers, radio, and television. This approach may also be applied in resolving the cognitive dissonance among Sado Island farmers.

5.2. Negative Impact of Subsidies to ECA Continuation

The effect of subsidies and other government-issued financial aid on the uptake of conservation agriculture has been analyzed by different groups. In Sardinia, Italy, such financial instruments encouraged the adoption of conservation agriculture [58]. This is similar to reports from farmers in Ohio, USA, where a weak positive relationship between participation in state-funded assistance and conservation agriculture was observed [59]. On the other hand, a more recent study conducted in Scotland reported that compensation alone does not ensure the continued adoption of conservation agriculture, citing that lack of knowledge and perception of such activities tend to hinder farmer participation [60].

In addition, the cost of subsidy compliance, as well as administrative and transaction costs, have been found to deter farmer participation [61,62]. In this study, key informant interviews were conducted to gain critical insights on the role of subsidy on ECA continuation. Here, a respondent said that *" . . . since Good Agricultural Practice (GAP) became a condition for getting the subsidy of direct payments of ECA, the paper works have increased and became more complicated. So, I stopped applying for this subsidy."* Another respondent confirmed this and said that he was not receiving any ECA subsidy and added that there are more farmers like him. This also aligns with the findings of another paper focusing on Fujioka farmers who had the same sentiments regarding subsidies, such as the complex administrative process in applying and increased paperwork [13].

In the 2003 report of the Organization for Economic Cooperation and Development on environmentally harmful subsidies, it was highlighted that subsidies that scale with

production are more likely to be environmentally harmful when compared with direct payments decoupled from farm output [63]. Thus, such distribution methods may have played a role in the negative effects of ECA subsidy on ECA continuation. Currently, eligibility requirements of ECA subsidy for farmers are as follows: (1) commercial farms having at least 0.30 ha of farm area under cultivation and farm products sold at more than JPY 500,000 per annum, (2) complying with international standard GAP and practicing at least one of the 11 production activities promoted by MAFF, (3) jointly applying in a group, and (4) approved by local governments that contribute to the conservation of the natural environment.

Meanwhile, the requirements for being a council member of the *Toki-to-kurasu-satojukuri suishin kyogikai are* to be a commercial farmer and practice ECA living with *Toki*. In a study on newcomer organic farmers in Japan, it was found that subsidies were perceived as a double-edged sword and that subsidies push farmers towards a productivist pathway, wherein they are being driven to focus on economic benefits rather than environmental and social aspects [64]. From another perspective of subsidy, various studies have associated conservation agriculture as a risky investment due to difficulties in accessing insurance, the need for farmers to learn new farming techniques, and the return of investment that may reach up to four years or more [65,66]. In addition, it was also shown that in some countries, financial support policies have proven insufficient to drive ECA implementation [38,67,68]. Hence, other incentives should be explored aside from subsidies to encourage ECA adoption and continuation in Japan, as discussed earlier.

5.3. ECA's Environmental and Economic Sustainability

When asked about their opinion on ECA's sustainability, the farmers had mixed opinions, especially regarding this farming method's environmental and economic sustainability. On the positive side, some think that ECA has the potential to decrease the use of pesticides and thus contribute to climate change adaptation. They also think that ECA can be sustainable if there is better community participation and joint efforts between consumers and producers. Since the inclusion of GIAHS is the basis of ECA in Sado Island, the observance of significant effects from the level of perceived GIAHS involvement and level of perceived interest in ECA towards ECA continuation is expected, which agrees with various studies conducted in different areas globally [41,69,70]. In addition to GIAHS and ECA factors, farmer adaptation to climate change has also been identified to positively drive ECA continuation. This agrees with the findings of another paper which reported that farmers are more likely to undergo adaptation measures than mitigation in terms of addressing climate change [15]. In terms of the farmers' opinions regarding ECA as an adaptation to climate change, they are emphasizing ECA's difference from conventional farming, most especially regarding the use of chemical fertilizers, as shown in the following farmer testimonials:

> "*Conventional agriculture that depends on chemical fertilizers and pesticides cannot respond to sudden effects of climate change and prevent its impact*."
>
> "*In order to maximize the adaptive abilities of plants to climate change, it is necessary to use fewer chemicals and go organic. This will enhance the abilities of plants to resist the impacts of climate change*."
>
> "*Restriction and reduction of the use of chemical fertilizers are important for stabilizing climate change*."

On the negative side, the farmers are emphasizing that while ECA's adoption is possible, it does not currently present economic merits. Several studies have already established that farm income can enhance farmers' adoption of agricultural technologies [71–73]. In this case, some farmers are saying that the repercussions of using fewer or no chemical fertilizers are the increase in farming expenses and labor. These sentiments agree with the findings of other studies, which reported that while giving priority to environment-friendly agriculture may be beneficial in the long run, its sustainability may be difficult to attain

when farmers are resource-constrained and experience income reduction due to less agricultural productivity [74,75]. However, in the case of Sado Island farmers, this should be further analyzed since receiving subsidies may negatively impact their ECA continuation, as discussed earlier. Therefore, a study focusing on this aspect is recommended for future researchers on this topic.

6. Conclusions and Recommendations

Japan's initiatives to promote sustainable farming began in the early 1990s, with various prefectures implementing ecologically friendly farming practices in the early 2000s, such as Niigata and Ishikawa, both GIAHS sites. This study focused on analyzing the factors influencing the continuation of environmental conservation agriculture (ECA) among Sado Island farmers. In summary, 14 factors were identified that affect ECA continuation among Sado Island farmers. These can be seen in the heat map that shows the positive and negative relationships of the variables with ECA continuation (Figure 4). It can be inferred that farmers see their roles more from a macro perspective, specifically the role they are playing to improve their local and global environment. The positive ECA drivers identified that support this inference are the following: (1) level of perceived GIAHS involvement; (2) level of perceived interest in ECA; (3) reasons to continue ECA, particularly to improve the local and global environment; (4) farmer expectations from ECA, particularly biodiversity conservation and to add value to product quality; and (5) farmer doing adaptation measures for climate change. It is also important to highlight that farmer perception appears to take precedence over aligning with cooperative groups or the government in terms of farm-related decision-making [20].

Similar to the survey results of the Sado Island government, our findings suggest the presence of conflicting attitudes, beliefs, and behaviors between the farmers' prevalent farming methodology (i.e., ECA) and their perceived impact of ECA on mitigating climate change. A similar case was documented in Fujioka, Japan [13]. This, therefore, highlights the need to shift the highlight of information dissemination activities from the concept of ECA to how ECA can improve biodiversity and help address climate change issues. Effective strategies could also address the existing cognitive dissonance, such as selective exposure to easy-to-understand ECA information, addressing post-decision dissonance by training farmer leaders, and implementing the minimal justification approach posited by Leon Festinger [56] using other forms of incentives aside from subsidies.

Analysis of the effects of each variable on ECA continuation further revealed the enhancing effect of the farmers' perceived level of involvement towards Globally Important Agricultural Heritage Systems (GIAHS). For the continued success of GIAHS and ECA in Sado Island, concerted local efforts must be put in place to assure that farmers feel directly involved in GIAHS activities. Therefore, strategies to permeate not only the concept of GIAHS but its integration towards youth involvement, Sado Island tourism management, and branding should be strengthened, which can also contribute to a higher generation of revenues.

Critical farmer and farm dynamics that were observed in Sado Island involve the enhancing effects of the various farm management optimizations that farmers would wish to do, as well as the reducing effects of ECA subsidy on ECA continuation. Such micro effects are put side by side with farmers' macro perspectives involving the role they are playing in climate change mitigation. However, this promising future for ECA in Sado Island may be hampered by the aging age structure and declining population of the Island. Therefore, it is imperative to echo the testimonials of the farmers seeking enhanced youth activation and participation in the field of agriculture, such as by integrating other activities like processing and marketing of agricultural produce and the introduction of the concept of sixth industry. There is also a need for the continuous promotion of ECA-related policies, not only on Sado Island but in other GIAHS sites in Japan as well.

Author Contributions: Conceptualization, K.L.M., C.M.G. and W.J.F.A.; methodology, K.L.M., C.M.G. and W.J.F.A.; software, K.L.M., C.M.G. and W.J.F.A.; validation, K.L.M., C.M.G. and W.J.F.A.; formal analysis, K.L.M., C.M.G. and W.J.F.A.; investigation, K.L.M.; resources, K.L.M.; data curation, K.L.M., C.M.G. and W.J.F.A.; writing—original draft preparation, K.L.M., C.M.G. and W.J.F.A.; writing—review and editing, K.L.M., C.M.G. and W.J.F.A.; visualization, K.L.M., C.M.G. and W.J.F.A.; supervision, K.L.M.; project administration, K.L.M.; funding acquisition, K.L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Japan Society for Promotion of Sciences (JSPS); JP JSBP 120197904.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Graduate School for International Development and Cooperation, Hiroshima University, on 10 July 2020.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study in the annual meeting of the Board of Directors of the Council for Promotion of "Toki-to-kurasu-satozukuri" (Community development living in harmony with Toki).

Data Availability Statement: Questionnaire survey data can be available from the first author upon request.

Acknowledgments: This paper is part of the findings of the joint research project, "Moving Towards Climate Change Resilient Agriculture: Understanding the Factors Influencing Adoption in India and Japan", Principal Investigator: Keshav Lall Maharjan, funded by the Japan Society for Promotion of Sciences (JSPS); JP JSBP 120197904. The authors would like to thank the members of the project, Akinobu Kawai, by special appointment, The Open University of Japan and Akira Nagata, Visiting Research Fellow, United Nations University, Institute for the Advanced Study of Sustainability, Japan, for their valuable inputs in the conceptualization of the research project, constructing the questionnaire, and conducting the survey. The authors are also thankful to Shinichiro Saito, Chair, Board of Directors, and the members of the "*Toki-to-kurasu-satojukuri suishin kyogikai*" (Council for Promotion of Community Development Living in Harmony with Toki) and Sado Municipality Agriculture Policy Division for their cooperation in conducting the survey. The authors are grateful to Ruth Joy Sta. Maria for her expertise in the creation of figures for this paper. The earlier version of this paper was presented orally at the *International Conference of Agricultural Economists,* 17–31 August 2021, online. The authors and funding agency have no conflict of interest.

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

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Leveraging Japanese Sado Island Farmers' GIAHS Inclusivity by Understanding Their Perceived Involvement

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Abstract: Sado Island in the Niigata prefecture is among the first Globally Important Agriculture Heritage Systems (GIAHSs) in Japan and among developed countries worldwide. Recent studies have pointed out the need to incorporate culture and farmer opinions to further strengthen GIAHS inclusivity in rural farming. In connection to this, this study explored whether farmer visibility, which is highlighted by GIAHS designation, actually translates to farmers' actual perceptions of GIAHS involvement. A survey was conducted among Sado Island farmers to determine their knowledge and perception of their GIAHS involvement, in connection to their perspectives on youth involvement, Sado Island branding, and tourism management. Results showed that 56.3% of Sado Island farmers feel uninvolved or unsure towards the GIAHS, which is in stark contrast with the prevalent farming method in the area, special farming (which complies with GIAHS regulations) (77.3%). Further analyses revealed that farmers who feel that the GIAHS does not promote youth involvement, Sado Island branding, and tourism management have a higher predisposition to perceive themselves as uninvolved towards the GIAHS. This study highlights the need for careful reevaluation and integration of farmer insights and needs into the current GIAHS implementation in Sado Island and in other GIAHSs as well.

Keywords: GIAHS; farmer involvement; youth inclusivity; tourism management; Tokimai branding

Citation: Maharjan, K.L.; Gonzalvo, C.M.; Aala, W.F., Jr. Leveraging Japanese Sado Island Farmers' GIAHS Inclusivity by Understanding Their Perceived Involvement. *Sustainability* **2021**, *13*, 11312. https://doi.org/10.3390/su132011312

Academic Editor: Piotr Prus

Received: 20 September 2021
Accepted: 7 October 2021
Published: 13 October 2021

1. Introduction

In 2002, the Food and Agriculture Organization of the United Nations (FAO) first launched the Globally Important Agriculture Heritage System (GIAHS) Program during the World Summit on Sustainable Development in Johannesburg, South Africa. This is part of the Global Partnership Initiative which aims to tackle issues such as sustainable development, agriculture, and traditional farming practices [1]. In 2015, it became a corporate program of the FAO which was further developed to protect traditional agricultural systems of global importance and enhance the harmonious relationship between people and nature. Specifically, the FAO defines the GIAHS in 2002 as "remarkable land use systems and landscapes which are rich in globally significant biological diversity evolving from the co-adaptation of a community with its environment and its needs and aspirations for sustainable development" [2] (p. 1). The selection criteria to be designated as a GIAHS are: (1) food and livelihood security; (2) agrobiodiversity; (3) traditional knowledge; (4) cultures and social values; and (5) landscape features. Overall, the object of designation is an agricultural system composed of traditional knowledge and practices, landscapes, culture, and biodiversity [3]. Since 2005, the FAO has designated 62 systems in 22 countries and is currently reviewing 15 proposals from eight new countries. These selected sites worldwide provide food and livelihood security for millions of small-scale farmers, as well as sustainably produced goods and services. Furthermore, they contribute to the

2030 Agenda for Sustainable Development by bringing together economic, social, and environmental dimensions [1].

The overall objective of designating a GIAHS site is to highlight unique knowledge, practices, and landscapes, as well as supporting dynamic conservation of a site. The conservation of GIAHS sites is also highly advocated, entailing several developmental interventions, such as agritourism activities, adding value to GIAHS food products, technology transfer measures, awareness-raising campaigns, and supportive national policies [3]. It is important to note that designating different sites as GIAHSs can also increase awareness and visibility for farmers who are working in these areas and emphasize the critical role they play in global issues. According to the FAO, the backbone of many GIAHS sites are the small-scale and family farmers, since they contribute to achieving food security, preserving rural knowledge, and protecting agrobiodiversity and fragile landscapes [1]. Therefore, raising farmer visibility is essential, most especially in this modern era when the field of agriculture faces a range of issues, including the declining interest of youths, outmigration from rural to urban areas, farmland abandonment, the transfer of indigenous and traditional knowledge, the prioritization of modernization movements in conflict with agricultural land decline and environmental degradation, among others [4–8]. Improving the image of agriculture can help address these issues, such as highlighting farmer visibility in traditional agricultural systems, which in turn can boost the status of agriculture worldwide. While increasing farmer visibility is important, it is also crucial to know if the importance of GIAHS principles actually translates to the ground level, particularly the farmers' perceptions on their GIAHS involvement. This paper will focus on this aspect by analyzing Japanese farmers' GIAHS inclusivity and how this may affect the GIAHS development in Sado Island. In particular, this paper aims to answer the question: Does farmer visibility, which is highlighted by the GIAHS designation, translate to farmers' actual perceptions of GIAHS involvement?

Globally Important Agricultural Heritage Systems (GIAHSs) in Japan and Their Impact on Farmer Involvement

In Japan, sustainable agriculture has been promoted for several years and high importance is given in preserving traditional farming, agro-culture, and biodiversity. This led to the application and acceptance of different sites in Japan as a GIAHS. Aside from the FAO's initial five selection criteria, Japan added three additional criteria in 2015 to have a more holistic and comprehensive assessment of the GIAHS, which are: (1) enhancing resilience (ecological); (2) establishing the participation of multiple stakeholders and promoting institutions (social); and (3) creating new business models (economic) [9]. At present, there are 11 sites designated as a GIAHS in Japan (Figure 1) [10]. All these sites have demonstrated remarkable use of land systems and landscapes, a good interplay between nature and its surrounding communities, and rich biological diversities, which all contribute to sustainable development. This paper is particularly focused on Sado Island in the Niigata prefecture, which is one of the first GIAHS sites designated in not only in Japan, but also in a developed country.

GIAHS sites are categorized into three major types, namely: landscape, farming method, and genetic resource conservation, of which a majority of Japanese GIAHS sites are classified as landscape types (Table 1) [11]. Out of the 11 GIAHS sites in Japan, eight, including Sado Island are classified as landscape types. Landscape type GIAHS sites comprise 33 of the 62 sites worldwide. This type of GIAHS focuses more on the interconnectedness of various landscape components, such as farmlands, rivers, irrigation canals/ponds, human settlements, among others. In Japan, this is similar to the Satoyama and Satoumi mosaic landscapes, which establish ecosystem services in connection with human well-being [12]. The three remaining GIAHS sites in Japan have a farming method classification system. There are 17 of these in the world, and they focus on the unique, traditional agricultural systems which are effective in biodiversity conservation [11]. The last one is the genetic resource conservation type, whereby traditional agricultural systems

contribute to the conservation of genetic resources. There are 12 such GIAHSs in the world, but none in Japan.

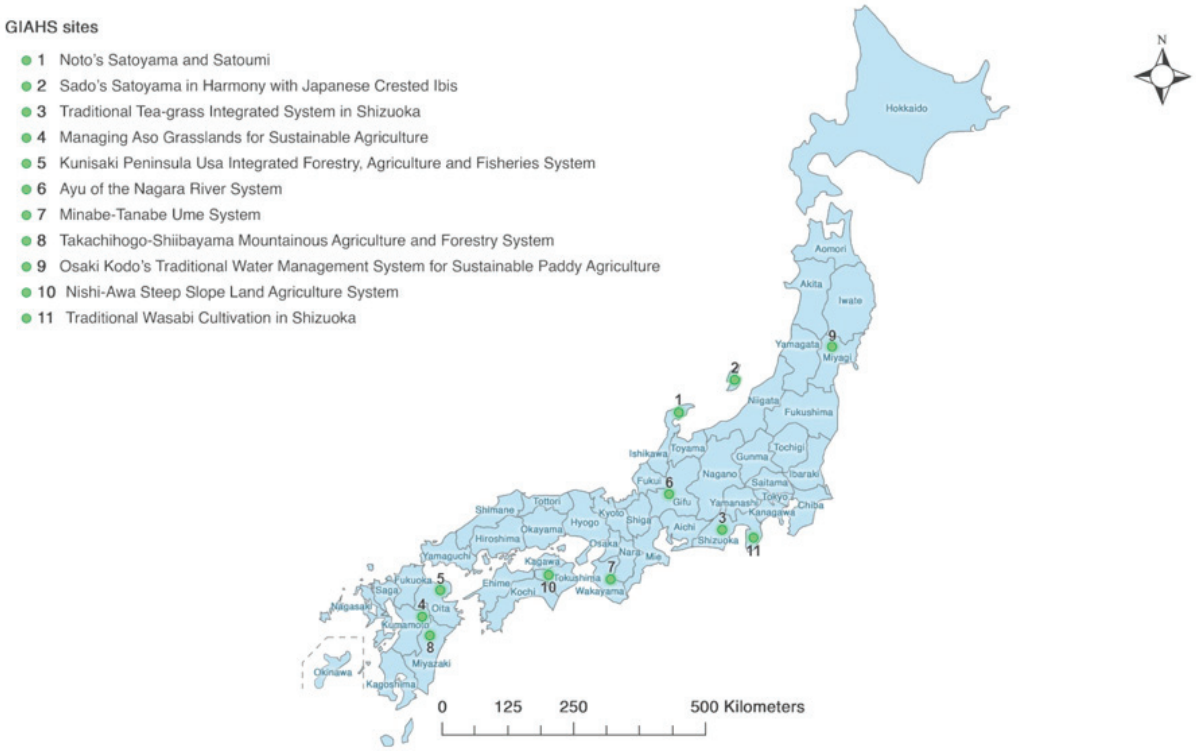

Figure 1. Japan's 11 designated GIAHS sites.

The FAO's initiative to designate GIAHS sites worldwide is essential to address various issues in the field of agriculture. Ever since it was launched in 2002, various studies have been conducted to analyze its sustainability, characterization, the vulnerability of sites, tourism management, biodiversity conservation, among others [13–17]. Most studies focused more on the macro perspectives of the GIAHSs and their potential environmental impacts, which thereby established a wide-ranging knowledge on GIAHSs as a supplement to what the FAO annually provides. These studies are also very useful in crafting environmental policies which can be used to alleviate increasing ecological threats [18]. Therefore, GIAHSs are recognized for their high contribution to rural revitalization and for ensuring the fulfillment of the multifunctional roles of agriculture, such as the creation of resilient landscapes, the preservation of cultural traditions, and the conservation of the natural environment, national land, and water resources [11]. With an expansive bank of research findings, it is ideal to think that this knowledge can actually be absorbed by one of the main caretakers of GIAHS sites: the farmers. However, there are limited studies that can support this. There is still limited literature focusing on micro perspectives, such as farmer participation and perceived GIAHS involvement.

In terms of socioeconomics aspects, it was observed in [19] that livelihood endowments and strategies directly affect GIAHS farmers' participation in eco-compensation policies. Particularly, the study found that the comprehensiveness of eco-compensation programs, land capital, and material capital are positive factors that provide farmers with incentives to participate in GIAHS conservation and agricultural production, whereas human capital was seen as a negative factor. With regards to sociocultural aspects, Kajihara et al. (2018) discussed the importance of understanding the relationship between culture and agriculture, and highlighted the need for the GIAHS criteria to incorporate culture for more effective management strategies [20]. It is important to note the interplay between farmers' cultural perspectives and their interaction with their immediate environment, which

thereby affects their involvement and mindset towards GIAHS initiatives. This, in turn, contributes to honing the overall cultural development of GIAHS sites and their sustainability. When magnified on a global scale, Sun et al. (2019) conclude that more efforts are needed to understand agricultural heritage systems by combining traditional practices and international experiences [21].

Table 1. Japan's 11 designated GIAHS sites.

GIAHS Designated Sites	System Type	Designation Highlights	Region	Prefecture	Year of Designation
1. Noto's Satoyama and Satoumi	Landscape	Terraced rice-fields that represent the farming, fishing, and mountain villages indigenous to Japan	Noto	Ishikawa	2011
2. Sado's Satoyama in Harmony with Japanese Crested Ibis	Landscape	Biodiversity conservation in paddy fields, particularly Toki birds (Japanese crested ibises: *Nipponia nippon*)	Sado	Niigata	2011
3. Traditional Tea-grass Integrated System in Shizuoka	Farming method	Tea production and cultivation	Kakegawa	Shizuoka	2013
4. Managing Aso Grasslands for Sustainable Agriculture	Landscape	Vast grasslands used to raise cows and horses	Aso	Kumamoto	2013
5. Kunisaki Peninsula Usa Integrated Forestry, Agriculture and Fisheries System	Landscape	Linkage of small irrigation ponds that stabilize agricultural water supply	Kunisaki Peninsula Usa	Oita	2013
6. Ayu of the Nagara River System	Landscape	Active inland water fisheries and fishing of ayu (Japanese sweetfish: *Plecoglossus altivelis altivelis*)	Nagara River	Gifu	2015
7. Minabe-Tanabe Ume System	Landscape	Preservation of forest and Trees of ume (Japanese apricot: *Prunus mume*)	Minabe-Tanabe	Wakayama	2015
8. Takachihogo-Shiibayama Mountainous Agriculture and Forestry System	Landscape	Establishment of a composite management system of agriculture and forestry	Takachihogo-Shiibayama	Miyazaki	2015
9. Osaki Kodo's Traditional Water Management System for Sustainable Paddy Agriculture	Landscape	Utilization of various coping mechanisms to protect rice paddies	Osaki	Miyagi	2017
10. Nishi-Awa Steep Slope Land Agriculture System	Farming method	Cultivation of multiple crops in steep slopes	Nishi-Awa	Tokushima	2018
11. Traditional Wasabi Cultivation in Shizuoka	Farming method	Terraced wasabi (Japanese horseradish: *Wasabia japonica*) fields	Wasabi Cultivation Region	Shizuoka	2018

Farmer involvement and decision making can be influenced by a lot of internal and external factors [22]. Various studies have shown that farmers' decision-making processes are being affected by critical influential factors and that they vary on a case-by-case basis [23]. In a study conducted in the Philippines which tried to measure farmers' perspectives on a strict agricultural ban, it was found that satisfaction in the farming method used, knowledge about the main crop being grown, and personal experiences in farming are very important factors in their crop adoption decision-making process [24]. Indeed, the perception of being involved in a bigger cause is shaped by farmers' individual differences and environmental influences. This was shown in another study conducted in the Philippines that focused on farmers' perspectives on coexisting farming methods, which observed that groups of farmers are affected differently by internal and external factors [25]. Therefore, this enhances the need to understand farmers' perspectives and opinions, which in turn affect their involvement in various agricultural programs. To gauge the perceived involvement of farmers in this study, it would be vital to know their opinions towards important issues related to GIAHSs. Opinions have the capacity to shape perceptions, whether in an individual or community scale. In this study, three main factors were specifically studied, and they revolved around farmers' opinions towards the GIAHS's effects on youth involvement, the capability to enhance agricultural products, and tourism management.

2. Study Area and Methods

The study was conducted in Sado Island, which is located west of the Niigata prefecture shoreline (Figure 2). It is the sixth largest island in Japan, and has a complex ecosystem, with interdependent satoyama and satoumi landscapes. It is widely known as a natural habitat of endangered Japanese crested ibises (locally called Toki in Japanese) because of its satoyama and satoumi landscapes. The Japan Satoyama Satoumi Assessment (JASS) defines the former term as "landscapes that comprise a mosaic of different ecosystem types including secondary forests, agricultural lands, irrigation ponds and grasslands, along with human settlements" and the latter as "Japan's coastal areas where human interaction over time has resulted in a high degree of productivity and biodiversity" [12] (p. 2). Sado Island is also famous for its rice produce with the Toki branding, which supports the revival of the Toki birds [26]. Other agricultural crops are also grown, such as persimmons, apples, pears, cherries, oranges, strawberries, watermelons, shiitake mushrooms, among others. Since the island provides suitable habitats for the endangered Toki birds, public and private sectors poured in efforts to support Sado Island's biodiversity preservation through the environmental conservation agriculture (ECA) program [27], which was a huge factor in its designation as a GIAHS.

Sado Island was selected since it is one of the first GIAHSs in Japan and because it is well supported by the local and national governments. A lot of people contribute to its development, such as the active local community, ECA-supportive consumers, and the research community, who all value the protection of Toki birds. Sado Island is a vulnerable rural region affected regularly by natural disasters, which cause crop failures and livelihood insecurity. One way to alleviate these problems are the Toki bird conservation efforts, which led to the production of certified rice, branded as Tokimai in 2008. It is marketed with a premium price and a portion of the income goes towards to conservation of the Toki birds [27]. This rice is produced in ECA lands which the Toki birds use as feeding grounds throughout the year. Sado Island is a GIAHS where people and Toki birds (wildlife) are living together in harmony. These characteristics of Sado Island warrant conducting research with the objectives mentioned above.

A questionnaire survey method was employed to collect data from ECA farmers in Sado Island. After prior discussion about the survey with key persons, the research objectives and questionnaire were explained in the annual meeting of the Board of Directors of the Council for Promotion of "Toki-to-kurasu-satozukuri" (community development living in harmony with Toki), in cooperation with the Sado Municipality Agriculture

Policy Division, in February 2020. The board made the resolution to allow the survey and 415 questionnaires were handed to Toki-to-kurasu-satozukuri council members during the annual general meeting. A total of 279 (67%) responses were received by the end of April 2020.

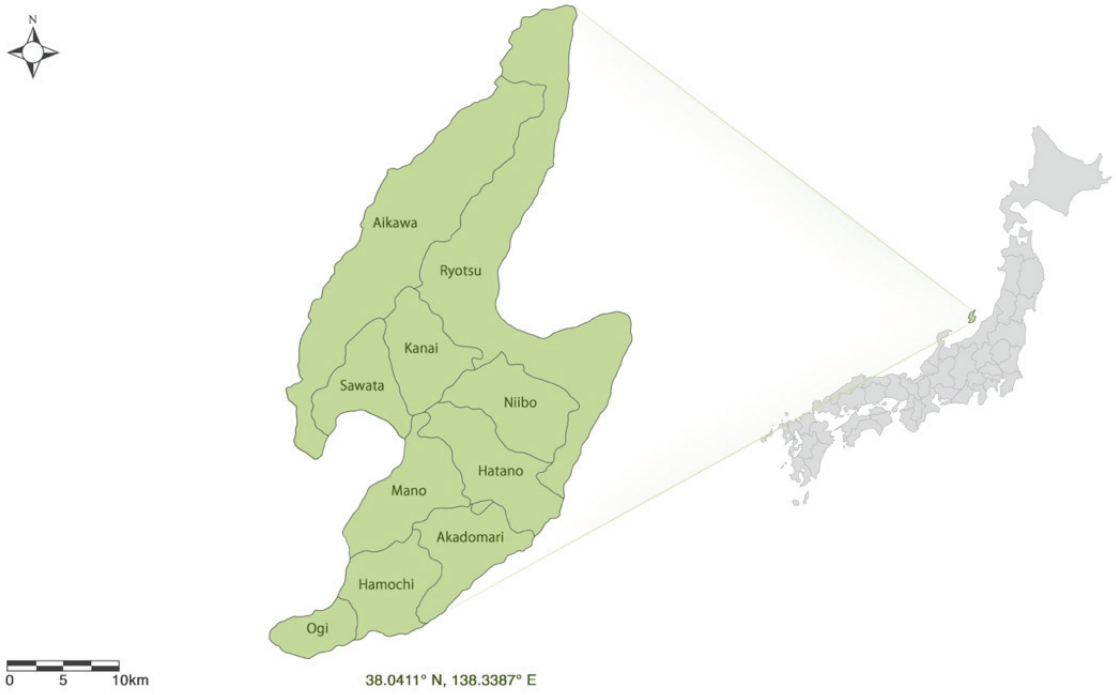

Figure 2. Map of Sado Island.

GIAHS-related factors (i.e., farmers' opinions towards the GIAHS's effects on youth involvement, the capability to enhance agricultural products, and tourism management) were incorporated in the questionnaire using a three-point ordinal scale (1–strongly yes, 2–not sure, and 3–strongly no). Sociodemographic factors were also gathered via the questionnaire to obtain baseline data for the farmers. Data were analyzed using ordinal logistic regression and a general linear model in SPSS v.27. Tests of parallel lines and model fit were conducted to determine whether statistical assumptions were met. Lastly, qualitative questions were gathered regarding the farmers' opinions on the impact of the GIAHS on youth involvement, Sado Island branding, and tourism management. The responses given in local Japanese were translated to English by the authors.

3. Results

To understand the current situation of farmer involvement with the GIAHS in Sado Island, their perceived level of involvement was determined using a three-point scale, which revealed that only 43.7% (122 of 279) of the sampled farmers feel that they are involved in the GIAHS, while 56.3% (157 of 279) feel uninvolved or unsure towards the GIAHS (Table 2). Similarly, only 38.7%, 59.1%, and 49.8% of the farmers feel that the GIAHS gives pride and confidence to youths, enhances agricultural products/brand, and promotes tourism, respectively. When viewed at the perspective of their current farming method, which is predominantly special farming (77.3%) (i.e., it complies with GIAHS regulations) and organic farming (10.8%), the farming method and high frequency of farmers who feel unsure or uninvolved towards the GIAHS do not appear to agree with each other.

Table 2. Frequency distribution table for GIAHS-related and sociodemographic factors among Sado Island farmers.

Variable	Frequency	Percentage (%)
GIAHS involvement		
Strongly yes	122	43.7
Not sure	129	46.3
Strongly no	28	10.0
TOTAL:	279	100.0
Opinion on the GIAHS giving pride and confidence to youths		
Strongly yes	108	38.7
Not sure	138	49.5
Strongly no	33	11.8
TOTAL:	279	100.0
Opinion on the GIAHS enhancing agricultural products/brand		
Strongly yes	165	59.1
Not sure	90	32.3
Strongly no	24	8.6
TOTAL:	279	100.0
Opinion on the GIAHS promoting tourism		
Strongly yes	139	49.8
Not sure	98	35.1
Strongly no	42	15.1
TOTAL:	279	100.0
Farming method		
Special farming [a]	215	77.3
Organic farming [b]	30	10.8
Eco-farming or related [c]	26	9.4
Conventional farming [d]	7	2.5
TOTAL:	279	100.0
Environment conservation agriculture's effects on climate change *		
As an adaptation	121	43.4
Reducing the effect	71	25.4
No effect	64	22.9
Others	9	3.2
Selling place for products *		
Agricultural cooperatives	260	93.2
Direct to consumers	60	21.5
Michi-no-eki (roadside farmers' market)	11	3.9
Supermarket	4	1.4
Restaurant	2	0.7
Internet	2	0.7
Central market	1	0.4
Food processors	1	0.4

* Multiple answer. [a] Special farming: uses 50%–80% less fertilizer and pesticide than the conventional farming practice of the locality, and complies with GIAHS regulations. [b] Organic farming: certified as organic by Japanese Agricultural Standards (JAS), or no JAS certification but do not use chemical fertilizers and synthetic pesticides. [c] Eco-farming or related: environmentally friendly methods based on other standards. [d] Conventional farming: uses chemical fertilizers and pesticides prescribed and practiced in the region.

3.1. Relationship between GIAHS Involvement and Youth Involvement, Tourism, and Branding

To provide an explanation for this observation, various sociodemographic, and GIAHS-related factors relating to Sado Island farmers were used as predictors against their level of perceived involvement towards the GIAHS. The three GIAHS factors evaluated in this study were the common themes of Japanese rural farming, namely: youth involvement, brand promotion, and tourism enhancement [28–30]. All three variables were found to be positively related with the GIAHS involvement score, such that farmers who feel that the GIAHS does not promote youth involvement, promote Sado Island brand, and enhance tourism are 17.4%, 38.8%, and 49.4% more likely to feel uninvolved with the GIAHS (Table 3).

Table 3. Relationship between various GIAHS variables and the farmers' perceived level of GIAHS involvement using ordinal logistic regression [a].

Predictor [b]	Estimate	Odds Ratio	Significance
GIAHS giving pride and confidence to youth in Sado Island	1.747	17.43%	0.000 **
GIAHS enhancing agricultural products and brand of Sado Island	0.946	38.83%	0.005 **
GIAHS promoting tourism in Sado Island	0.706	49.36%	0.004 **

[a] Link function: Cauchit: $\tan(\pi(F_k(x_i) - 0.5))$. [b] Test of parallel lines: Chi-square = 1.750, df = 3, sig = 0.626. Model fit: Chi-square = 117.612, df = 3, sig $\leq$ 0.001. ** significant at $p < 0.01$.

3.2. GIAHS Involvement and Youth Inclusivity

Eight sociodemographic factors were used as predictors of the Sado Island farmers' perceived level of GIAHS involvement (Table 4). The effects of age, farm/paddy area, yield, climate change effect perception, and farming method were found to have no significant impact on perceived GIAHS involvement. On the other hand, farmers who reported to be participating in exchange programs, either voluntarily or with subsidy, are more likely to feel involved with the GIAHS. In terms of age, 80.3% (224/279) of the sampled Sado Island farmers are 60 years old and above. Of the 15 farmers who are 49 years old or younger, only one third (5/15) reported being involved in the GIAHS. This underrepresentation of youth in GIAHS activities appears to have contributed to the dilution of the effect of age on GIAHS involvement.

Table 4. Relationship between various sociodemographic variables and the farmers' perceived level of GIAHS involvement using a general linear model.

Response Variable: GIAHS Involvement		
Predictor	**Estimate**	**Significance**
Age	3.519	0.111
Farming experience	−0.077	0.119
Farmland size	0.058	0.110
Paddy land size	0.119	0.057
Paddy yield	−0.143	0.371
Perceived intensity of climate change effect	−0.042	0.499
Farming method	0.045	0.749
(1) Organic farming	−0.012	0.393
(2) Special farming	−1.03	0.322
(3) Eco-farming or related	−1.166	0.984
(4) Traditional farming	0.019	-
Exchange program(s) participation/promotion	-	0.238
(1) Not participating	−1.514	0.167
(2) Participating with subsidy	−1.838	0.036 *
(3) Participating voluntarily	−2.199	0.028 *
(4) Participating with pay	−2.311	0.617
(5) Others	−0.238	-

* Significant at $p < 0.05$. White test for heteroskedasticity: Chi-square = 117.264, df = 107, sig = 0.234. Lack of fit test: F = 1.051, sig = 0.486.

3.3. GIAHS Involvement in Tourism and Branding

Sado Island has become known for their Tokimai brand of rice. This integration of the conservation of the local Toki bird population with local farming has contributed to the 0.6% growth rate of tourism in the Niigata prefecture, which amounts to roughly 400,000 guests using local accommodation since the introduction of the program [31]. This also helped to address the problems of livelihood insecurity in the island, as raised by Su and Kawai (2009) [27]. In this study, the effects of farmer expectations on ECA and selling location on perceived GIAHS involvement were also tested. In terms of selling location, farmers who sell directly to consumers were more likely to perceive themselves to be involved with the GIAHS than those who sell at other locations (Table 5).

Table 5. Relationship between various selling locations and the farmers' perceived level of GIAHS involvement using a general linear model.

Response Variable: GIAHS Involvement		
Predictor	**Estimate**	**Significance**
Direct to consumers	−0.201	0.050 *
Supermarket	0.199	0.552
Restaurant	0.679	0.216
Agricultural cooperatives	0.019	0.907
Central market	0.257	0.709
Michi-no-eki (roadside farmers market)	0.041	0.85
Food processors	−0.501	0.449
Internet	−0.34	0.53

* Significant at $p < 0.05$. White test for heteroskedasticity: Chi-square = 10.344, df = 13, sig = 0.666. Lack of fit test: F = 1.402, sig = 0.224.

In addition to micro-level predictors, the effect of farmer expectations of ECA on GIAHS involvement was also tested (Table 6). In line with the theme of GIAHSs that relates to ecological conservation, farmers who are participating in the ECA program for carbon sequestration and conservation of biodiversity reasons were more likely to feel involved with the GIAHS, which agrees with previous studies [9,13]. In addition, farmers who are doing ECA to promote the local industry are also more predisposed to feel involved with the GIAHS, which also agrees with other studies, such as in Vafadari (2013), which identifies tourism as a key stimulant of local industry because it opens new jobs and enhances the attraction of rural lifestyles in GIAHS communities [32]. Indeed, the Sado Island tourism webpage features Toki Museum tours, sightseeing, and forest parks [33].

Table 6. Relationship between farmer expectations of ECA and the farmers' perceived level of GIAHS involvement using a general linear model.

Response Variable: GIAHS Involvement		
Predictor	**Estimate**	**Significance**
Carbon sequestration	−0.304	0.012 *
Conservation of biodiversity	−0.252	0.005 **
Conservation of water quality	−0.005	0.956
Underground water terrain improvement	−0.333	0.070
Add value in quality of products	0.063	0.455
Decrease effect of weather hazards	0.09	0.518
Increase farm related income	0.121	0.152
Promote local industry	−0.224	0.019 *
Retain residents in rural area	−0.014	0.942
Others	−0.275	0.226

* Significant at $p < 0.05$; ** significant at $p < 0.01$. Breush–Pagan test for heteroskedasticity: Chi-square = 2.820, df = 1, sig = 0.093. Lack of fit test: F = 1.087, sig = 0.323.

To determine if the farmers' global perspective on ECA activities influences their perceived involvement towards the GIAHS, their answer regarding the effect of ECA on

climate change was used as predictors for their level of perceived involvement with the GIAHS. Here, farmers who believed that ECA is an adaptation to climate change were twice as likely to feel involved with the GIAHS than those who do not (Table 7). This agrees with the earlier observation on farmer expectations regarding ECA. Testimonials such as that by Respondent 153 reflect this trend from a farmer's point of view:

> *"Produce food that suits climate change. Sell them fresh with safety and good taste. This should be managed through institutional strategy under good leadership. Hotels should use the branded rice produced in Sado."*

Table 7. Relationship between farmer-perceived effects of ECA on climate change and the farmers' perceived level of GIAHS involvement using ordinal logistic regression [a].

Response Variable: GIAHS Involvement			
Predictor [b]	**Estimate**	**Odds Ratio**	**Significance**
ECA as an adaptation to climate change	−1.09	297.43%	0.002 **
ECA reduces the effect of climate change	−0.665	194.45%	0.068
ECA has no impact on climate change	−0.184	120.20%	0.618
Others	−0.027	102.74%	0.971

[a] Link function: Cauchit: $\tan(\pi(F_k(x_i)-0.5))$. [b] Test of parallel lines: Chi-square = 0.168, df = 4, sig = 0.997. Model fit: Chi-square = 22.906, df = 4, sig $\leq$ 0.001; ** significant at $p < 0.01$.

4. Discussion

Various studies have emphasized the importance of analyzing farmers' knowledge and opinions which heavily influence their involvement and productivity in different aspects of agriculture [34–36]. In Japan, which is dominated by landscape types that give high value to the linkage of nature, biological diversity, and its surrounding communities, GIAHS sites have been continuously increasing since 2011 [11]. While it is good to see the increase in GIAHS sites in Japan and worldwide, the main caretakers of rural communities—the farmers situated in these sites—should equally be considered. As Rhoades (1984) argues, a full circle should be completed when it comes to the implementation of agricultural technologies and activities, such that farmers are equally involved and a part of the process [36]. Otherwise, the diffusion of technologies would face difficulties and farmers may tend to feel uninvolved, thereby leading to less synchronicity between the agricultural initiative and its target stakeholders.

In this study, the Sado Island's farmers' perceived involvement in the GIAHS was explored, and it showed that more than half of the 279 farmers interviewed (56.3%) feel unsure or uninvolved, despite being situated in a decade old GIAHS site. This appears to be contradictory with the primary farming methods being used by the farmers, which focus on ECA and comply with GIAHS regulations. To further understand this disconnect, the study analyzed farmers' perceived involvement as it related to three common themes of Japanese rural farming, which are: youth involvement, brand promotion, and tourism enhancement. It was found that all three factors are positively related to the farmers' perceived GIAHS involvement, thereby accentuating their importance when it comes to crafting policies aiming to increase farmer involvement in the GIAHS.

Looking at the age demographics, a huge percentage (80.3%) of farmers are 60 years old and above, which highlights the lack of youth involvement, not only in GIAHS sites, but in various agricultural sectors in Japan. Recent papers, such as that by Reyes et al. (2020), have indeed highlighted the negative effects of farmland abandonment and the underuse of farming resources resulting from Japan's decreasing and aging rural population [13]. This same sentiment has been observed among the submitted testimonials of the interviewed farmers, such as that by Respondent 269, who stated the following:

> *"There are many abandoned lands due to lack of successors. Lands are overgrown by various weeds, such as* Solidago canadensis var. Scabra, Ambrosia artemisiifolia *which flowers yellow during autumn and winter, making it look ugly or not cared for,*

> *which is far from the image of GIAHS. First, such land should be managed properly and brought under proper cultivation."*

Sado Island farmers also recognize the alarming issue of farmer shortage in the future because of the increasing trend of youth exodus; hence, they are also voicing their opinions on how to attract people to farm in Sado Island. The narrative of Respondent 131 clearly shows this:

> *"There will be a shortage of people who will continue farming in the near future. Attract the people who are fed up of city life and loves the countryside to create a natural living environment. People with allergies, retired life, and kids can come to live in Sado. This will create circulatory connectivity in different aspects between Sado and the cities, which will eventually attract the youths to Sado, increase their movements to and fro, making the livelihood more active and connected with the cities as well."*

This highly agrees with the findings of Usman et al. (2021), who highlight the desperate need of rural areas for agricultural workers in connection with Japan's aging farmers' population, to mitigate the increase in Japan's dependency for international food products and high import expenses [37].

Further analyses have shown that farmers' participation in exchange programs also increases their likelihood to feel involved with the GIAHS. To this end, participation in exchange programs may thus play a key role in not only encouraging the younger generations of farmers, but also enhance the transfer of intangible farming inputs, such as techniques and managerial skills [30]. This view was also shared by Respondent 276, who stated that:

> *"There is a need to secure people to continue GIAHS. All the GIAHS sites in Japan should come together to promote and enhance it through public relations in universities and colleges and make it part of lectures to get the interest of students who would work on it in the future. First, orient them about GIAHS in general and different GIAHS in Japan, and let them participate in field studies and internships in a GIAHS of their choice for them to interact and learn the local culture, as well as experience the local livelihoods. Afterwards, let them reflect about it and how they can be involved in it in the future to improve."*

This theme was also explored by Yamashita (2021), who focused on how Japanese traditions can be saved by analyzing urban university students' participation in rural festivals [38]. Interestingly, the case site of the study is also a GIAHS in Japan, particularly the Noto region in the Ishikawa prefecture. The study recommended that better collaborations should be established between urban youths and their participation in rural festivals, which means that more focus should be given in the management of festivals and how outside support can be further increased. These can help alleviate the discontinuation of rural festivals and loss of cultural values. This is also in connection with what Sado Island farmers are voicing out in this study, which is the need to attract youths to Sado Island, thereby implying that they are also aware of the negative consequences if the common trends of youth exodus and rural disinterest will continue.

The narratives of Sado Island farmers and various literature that established the interlinked issues of farmland abandonment, the aging population, youth exodus, and farmer shortages clearly show the need for more policies that would cater to the strengthening of Japan's agriculture. Based on this paper's findings, participation in exchange programs may increase the chances of attracting people, especially the youth, to rural areas and help them become more involved in addressing issues in the field of agriculture. With the increase in youth participation, modern solutions can also be applied as rural areas struggle to adapt in the changing world.

With a high growth rate of tourism in the Niigata prefecture, it is not surprising that farmers in this study feel more involved in the GIAHS when they sell directly to consumers. However, looking at the frequency distribution, selling to agricultural cooperatives was the most predominant choice among the farmers (93.5%). This inconsistency was elaborated

upon in the testimonials of the farmers, with many entries commenting on the poor uptake of the Tokimai brand across other industries and markets, such as restaurants and supermarkets. This was clearly shown in the response of Respondent 121, who stated that:

> *"Last year, I participated in the public relations sale of rice in Tokyo station, along with the city officers. Nearly 100% of the passers-by did not know about GIAHS, which is so unfortunate."*

A similar sentiment has been shared by Respondent 141:

> *"GIAHS alone will not enhance the tourism to brand the hotels, other facilities and services using the branded products of the island."*

Respondent 162 also shared some sentiments on how the GIAHS should complement agriculture:

> *"It is good to make use of GIAHS for tourism development in the island. However, it is not clear how it helps in enhancing the island's farming and primary industry. If there is no clear picture/explanation how GIAHS and tourism development can enhance farming, the farmers and youth may not be interested (e.g., How will hotels use rice, vegetables, and fish produced in the island to serve the tourists with a delicious and attractive dish?). It is said that bigger hotels don't have repeaters (supposedly the food they provide is not delicious) while the homestay pensions serving local food have repeaters. City dwellers visit Sado not only for its nature but also for its food, as well as its hospitable people with warm personalities (heard that the cooks in bigger hotels are dispatched from Kansai (western part of Japan) or foreigners). The concept should be not agriculture for tourism but tourism for developing agriculture."*

These narratives are in line with the point raised by Ohe (2013), who highlights the generation gap between younger and senior generations in recognizing the value of rural tourism, as well as the urban–rural mismatch with regards to rural tourism desires and expectations [29].

This study also found that the Sado Island farmers give high importance to ECA as an adaptation to climate change, thereby highlighting how farmers also prioritize their concern for the environment, in addition to their economic needs. This is also in line with their ECA expectations to promote their local industry, sequestrate carbon, and conserve water quality. Various studies have also shown that farmers' abilities and individual decisions to adopt environmentally friendly farming methods contribute a lot to mitigating climate change [39,40]. Therefore, maintaining this mindset in farmers is crucial and more studies should be conducted on how to sustain it.

5. Conclusions

Results from the survey in this study have shown a higher incidence of reduced farmer involvement in the GIAHS. While it is one of the direct goals of GIAHS designation to promote awareness and visibility for the farmers working in these sites, results from this study do not support the notion of a direct relationship between farmer visibility and farmer involvement as previously hypothesized. To further understand this observation, the effects of various sociodemographic and GIAHS factors on farmers' perception towards GIAHS involvement were tested. Negative perceptions of the promotion of youth involvement, Sado Island branding, and tourism management has an enhancing effect on reduced farmer perceptions towards GIAHS involvement. Further evidence presented through the various farmer responses corroborate this observation, prompting an integration of farmer-level input towards the community-level implementation of GIAHSs.

Upon evaluation of the effects of farmer expectations on their perceived GIAHS involvement, it was found that the promotion of local industry has an enhancing effect on farmer involvement. This observation hints at the need for better diffusion of the resulting branding (Tokimai) from the GIAHS initiative to other local industries in Sado Island, as well as the need to target consumers who may not know about Tokimai. Based on farmer responses, there is a need for better uptake of the Tokimai branding across different local

industries, such as restaurants, hotels, and supermarkets, for the continuous development of farmer communities and GIAHS sites.

The enhancing effect of carbon sequestration and biodiversity conservation towards farmer perceptions on GIAHS involvement was also shown, as expected of an environment-conscious community. This is in alignment with the observation that farmers who feel that ECA is an adaptation to climate change have a higher likelihood of feeling involved with the GIAHS. A study focusing on the effects of various farmer-related factors towards ECA continuation may also provide additional insights on the holistic view of the integration between farmer activities with biodiversity conservation.

While the results of the study cannot be used to fully represent other GIAHS sites in Japan because of the differences in landscape types, locations, and typologies, it can serve well as a reference for local government officials and policymakers on strengthening and developing the GIAHS efforts across Japan, and other countries as well. The study further encourages more research on other GIAHS sites in Japan, with more robust samples and results, which can then contribute to their sustainability. Moreover, studies on GIAHSs around the world with similar characteristics will be needed to enhance the management of GIAHS sites, in connection with the findings of this paper. When magnified on a global scale, the themes explored in this study would lead to a deeper interplay between farmers' knowledge and perception and GIAHS objectives.

Author Contributions: Conceptualization, K.L.M., C.M.G., and W.F.A.J.; methodology, K.L.M., C.M.G., and W.F.A.J.; software, K.L.M., C.M.G., and W.F.A.J.; validation, K.L.M., C.M.G., and W.F.A.J.; formal analysis, K.L.M., C.M.G., and W.F.A.J.; investigation, K.L.M.; resources, K.L.M.; data curation, K.L.M., C.M.G., and W.F.A.J.; writing—original draft preparation, K.L.M., C.M.G., and W.F.A.J.; writing—review and editing, K.L.M., C.M.G., and W.F.A.J.; visualization, K.L.M., C.M.G., and W.F.A.J.; supervision, K.L.M.; project administration, K.L.M.; funding acquisition, K.L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Japan Society for Promotion of Sciences (JSPS); JP JSBP 120197904. Authors and funding agency have no conflict of interest.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of Graduate School for International Development and Cooperation, Hiroshima University on 10 July 2020.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study in the annual meeting of the Board of Directors of the Council for Promotion of "Toki-to-kurasu-satozukuri" (community development living in harmony with Toki).

Data Availability Statement: Questionnaire survey data can be available form the first author upon request.

Acknowledgments: This paper is the part of the findings of the joint research project, "Moving Towards Climate Change Resilient Agriculture: Understanding the Factors Influencing Adoption in India and Japan", Principal Investigator: Keshav Lall Maharjan, funded by Japan Society for Promotion of Sciences (JSPS); JP JSBP 120197904. Authors would like to thank the members of the project, Akinobu Kawai, Professor by special appointment, The Open University of Japan and Akira Nagata, Visiting Research Fellow, United Nations University, Institute for the Advanced Study of Sustainability, Japan for their valuable inputs in conceptualization of the research project, constructing questionnaire and conducting the survey. The authors are also thankful to, Shinichiro Saito, Chair, Board of Directors, and the members of the "*Toki-to-kurasu-satojukuri suishin kyogikai*" (Council for Promotion of Community Development Living in Harmony with Toki) and Sado Municipality Agriculture Policy Division for their cooperation in conducting the survey. The authors are grateful to Ruth Joy Sta. Maria for her expertise in the creation of figures for this paper. The earlier version of this paper was presented orally in, *International Conference of Agricultural Economists,* 17–31 August 2021—online.

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

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Dynamics of Environmental Conservation Agriculture (ECA) Utilization among Fujioka Farmers in Japan with High Biodiversity Conservation Awareness but Low ECA Interest

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Abstract: Japan aims to be carbon-neutral by 2050 by targeting various sectors including agriculture. One of the main strategies in this sector to mitigate climate change effects is environmental conservation agriculture (ECA); however, ECA utilization remains low in most of Japan's prefectures to this date. To address this problem and to know what factors influence ECA adoption, we collected data from Fujioka city, Gunma prefecture, which has low ECA utilization but has high biodiversity conservation efforts. Using factor analysis and binary logistic regression, two major themes emerged by which ECA continuation can be increased, namely: farmers' intent to improve their local/global environment and to enhance their production. The study highlighted the importance of ECA information dissemination as evidenced by the presence of a knowledge gap on how ECA translates into climate change advocacies. The promotion of farmer-consumer market channels and extension of ECA products in local industries by government and non-government institutions are also recommended to strengthen rural-urban linkages in the area. Increasing the ECA uptake of farmers would also have a positive impact on the ongoing preservation of endangered *yaritanago* fish species in Fujioka. Lastly, the results from this study highlight the heterogeneity of factors that affect any given farming community with respect to the strategies that can effectively drive ECA adoption.

Keywords: environmental conservation agriculture; biodiversity conservation; Fujioka; *yaritanago*; environmental concern; sustainable agriculture; climate change

Citation: Maharjan, K.L.; Gonzalvo, C.; Aala, W., Jr. Dynamics of Environmental Conservation Agriculture (ECA) Utilization among Fujioka Farmers in Japan with High Biodiversity Conservation Awareness but Low ECA Interest. *Sustainability* **2022**, *14*, 5296. https://doi.org/10.3390/su14095296

Academic Editor: Teodor Rusu

Received: 25 March 2022
Accepted: 26 April 2022
Published: 27 April 2022

1. Introduction

The link between agriculture and climate change has been well-established for the past decades, with negative far-reaching consequences coming from greenhouse gas (GHG) emissions, impacts on biodiversity, and land degradation, among others [1–3]. From 2007 to 2016, around 23% of the world's GHG emissions came from agriculture, forestry, and other land uses (AFOLU) [4]. Agriculture is one of the main drivers of climate change and many interventions will be necessary to reduce its role in going beyond the planetary boundaries [5]. Likewise, climate change negatively affects agricultural systems globally, which contributes to yield losses and thereby poses more challenges in feeding an escalating population that will reach the 10 billion mark by 2050 [6,7].

For the fiscal year (FY) 2019, Japan's total GHG emissions were 1212 million tons—a 14% reduction from the FY 2013 benchmark and the country's sixth straight year of lowering emissions. This shows that Japan is on track with its commitment to the United Nations Climate Change Convention to cut its emissions by 26% from 2013 levels by 2030. The country also ambitiously aims to be carbon neutral by 2050. For FY 2019, 47.47 million tons of GHGs were produced by Japan's agriculture, forestry, and fisheries sector, accounting for 3.9% of the total emissions [8]. To reduce this, one of Japan's strategies is to support

environmental conservation agriculture (ECA) activities, such as by giving direct payment subsidies to farmers practicing ECA and promoting organic farming. Simply put, ECA is a type of agriculture that contributes to the conservation of the natural environment, which is also termed environmentally friendly agriculture. ECA has a broader focus than the widely known conservation agriculture (CA) defined by the Food and Agriculture Organization (FAO), which focuses on three key principles (i.e., no-till, crop rotation, and residue retention) [9]. ECA has a wider and more flexible scope as compared to CA, which allows different forms of farming to be classified under it, such as organic farming, special farming (uses 50% less pesticide and fertilizer than conventional farming), and eco-farming (environmentally friendly methods based on other standards, such as those set by local governments or in accordance with consumer agreements, among others), thereby enabling more farmers to be supported. A more specific definition of ECA was given by the Ministry of Agriculture, Forestry, and Fisheries (MAFF) in 1994, which is "sustainable agriculture, taking advantage of the material circulation function of agriculture, keeping in mind the harmony with productivity, that takes into consideration the reduction of environmental impact caused by the use of chemical fertilizers and pesticides through soil management" [10]. MAFF (2020) reported that around 140,000 tons of GHGs are being reduced per year through the activities supported by ECA direct payments [11]; hence, increasing ECA adoption in Japan should be prioritized to aid in the country's pledge to be carbon neutral by 2050.

Various papers have reported that adopting climate-friendly agriculture methods and conservation measures can mitigate GHG emissions [12–14]. Such practices include reducing tillage, eliminating fallow, removing or reducing the use of chemical pesticides and fertilizers, manipulating manure management practices and animal diet, avoiding over-application and usage of split nitrogen to meet plant needs, implementing an integrated farming system, and covering the soil with perennial vegetation, residue, or cover crops. All these practices are included in ECA's scope which extends its role in mitigating climate change, most especially in Japan. In terms of biodiversity conservation, ECA methods led to the designation of Sado Island as a Globally Important Agricultural Heritage System (GIAHS), most especially because they helped to protect the endangered Toki birds (*Nipponia nippon*) [15]. This will be discussed in detail in the following section. This study also explored ECA's role in biodiversity conservation, particularly on the endangered *yaritanago* (*Tanakia lanceolata*) fish in Fujioka city, Gunma prefecture.

Japan's prefectures have low ECA utilization (ECA area based on direct payment subsidies divided by each prefecture's total cultivated land) according to MAFF's 2016–2020 reports (Figure 1). This finding agrees with Miyake et al. (2022) who stated that ECA's development is still in its early stage in Japan [16]. In 31 out of 47 prefectures (65.9%), a decreasing trend was observed for the percentage of ECA utilization. The biggest decline came from Shiga prefecture (from 32.8% in 2016 to 25.3% in 2020), which is the leading prefecture when it comes to ECA utilization. Shiga has a leading role when it comes to implementing agri-environmental policies to protect Lake Biwa, which is Japan's largest lake, and was proven to be a successful case. The implementation of ECA methods and agri-environmental policies significantly reduced the pollution in Lake Biwa. Furthermore, ECA adoption raises the willingness of Japanese farmers to expand their farm size, implement direct marketing, and increase the number of their market channels, which may improve the efficiency and structure of Japanese agriculture [17]. The data in Figure 1 shows that more efforts are needed in Japan to increase the ECA adoption rate among farmers. The percentage reported may still increase if other ECA farmers who did not apply for direct payment subsidy can be included; however, there is no available statistical data for that yet. Given the premise of declining ECA utilization in Japan, this paper thus aims to report the factors affecting ECA adoption of farmers in a prefecture with low ECA utilization (only 0.25% as of 2020) and decreasing ECA utilization from 2016 to 2020, specifically Gunma prefecture.

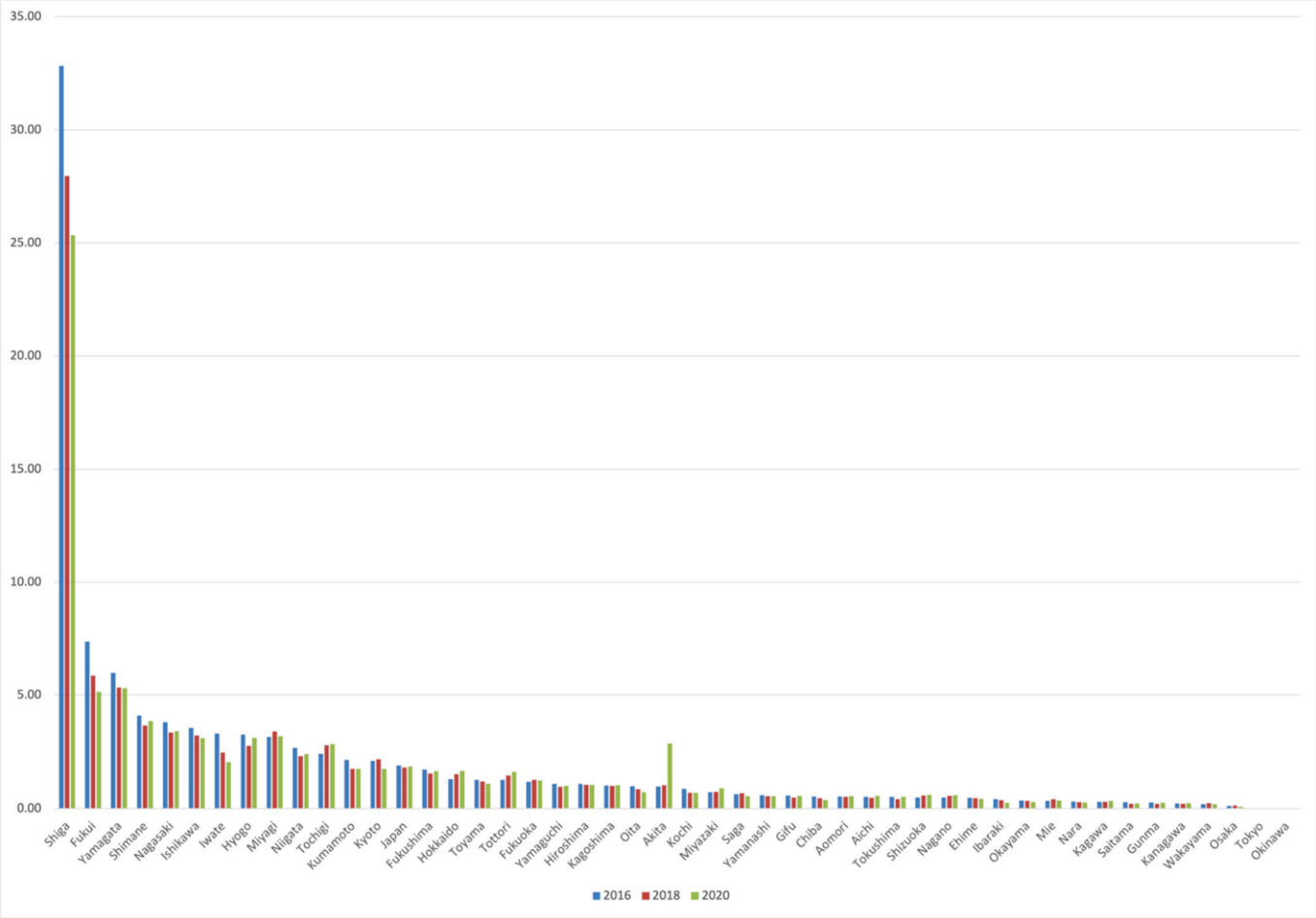

Figure 1. Percentage of ECA utilization in Japan.

Figure 2 shows a clearer perspective regarding the ECA utilization of each prefecture in Japan (ECA area based on direct payment subsidies divided by each prefecture's total cultivated land). Here, we observed that only three prefectures in Japan have greater than 5% ECA utilization in 2020, namely: Fukui (5.1%), Yamagata (5.3%), and Shiga (25.3%). This data also shows that Gunma prefecture, to which Fujioka city belongs (chosen research locale of the study), is the sixth least in percent ECA utilization (0.25%). Interestingly, prefectures with at least 1% ECA utilization appear to be situated along the western coastal line of Japan, while those that have marginal (<1%) ECA utilization are found on the eastern side. Although we could infer that this may be due to the urban-rural distribution of the prefectures, further exploration regarding the forces that drive this spatial pattern for ECA utilization, however, is well beyond the scope of this paper.

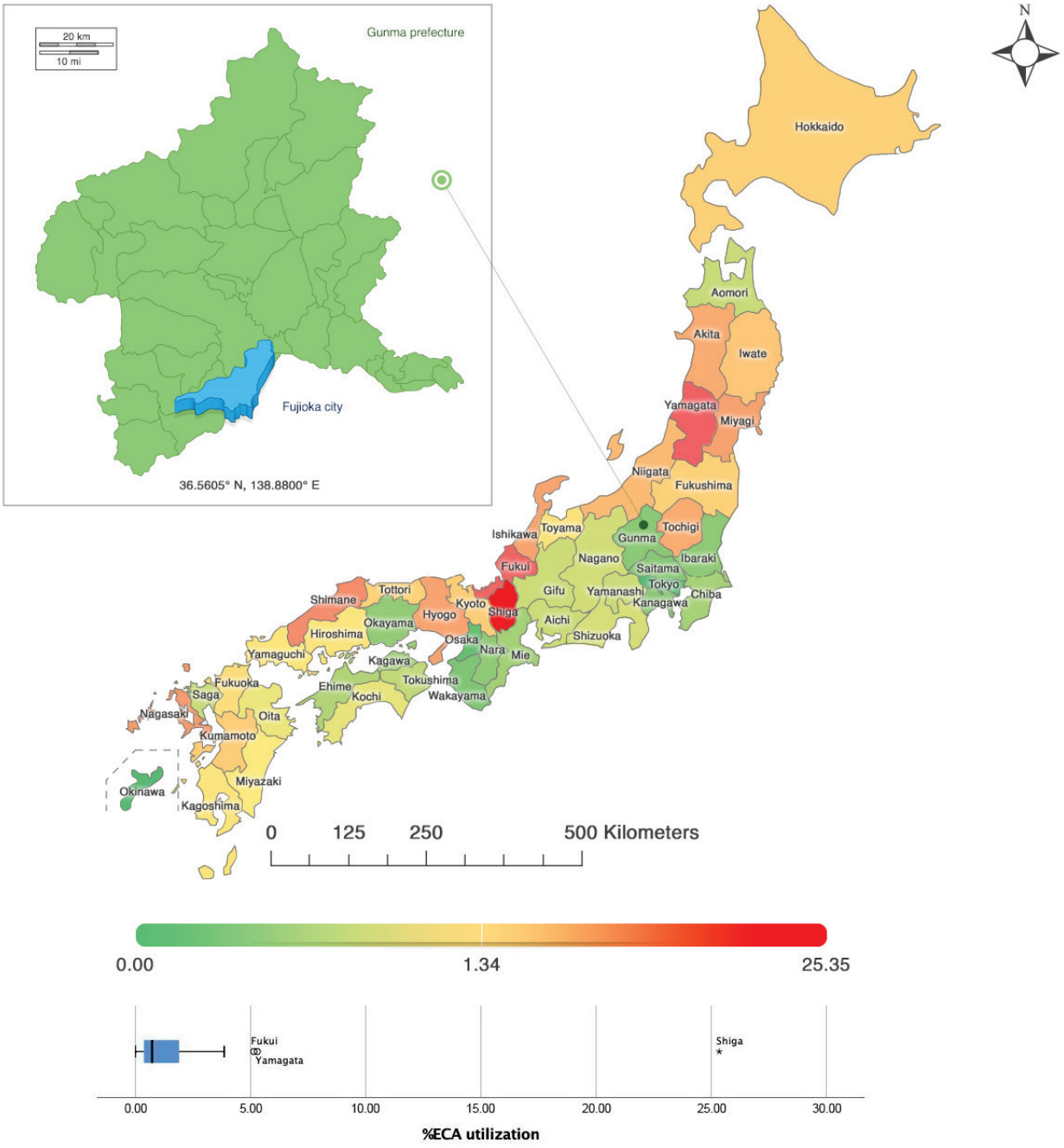

Figure 2. Heatmap showing percentage of ECA utilization per prefecture in Japan and Fujioka city in Gunma prefecture (chosen research locale).

1.1. Sustainable Agriculture and Biodiversity Conservation in Japan

For the past decades, Japan has been active in promoting biodiversity conservation and sustainable agriculture, which is why it currently has a total of 11 Globally Important Agricultural Heritage Systems (GIAHS) designated by FAO [15]. Japan has been proactive in preserving endangered species, such as butterflies [18], vascular plants [19], and birds [20]. Fujioka city in Gunma prefecture is also active in biodiversity conservation, which primarily aims to save rare species including the *yaritanago*. The *yaritanago* is an indigenous, freshwater carp that is classified as near-threatened (NT) in Gunma Prefecture's Red List or endangered animals. This was caused by several reasons such as habitat loss, water pollution, alterations in irrigation systems, biological invasion, and the decline of freshwater mussels where the fish breed by depositing their eggs [21,22]. Gunma prefec-

ture used to host various types of indigenous fish decades ago, including carps in river systems or waterways among the farmlands. The construction of concrete water canals for irrigation of paddylands after the 1950s destroyed most of the habitats of these fish and led to the extinction of many species in the 1980s. The *yaritanago* was thought to be extinct in Gunma for more than a decade until an angler in Fujioka city discovered it accidentally in 1998. Since then, the citizens of Fujioka city have been trying to save the *yaritanago*, which is well-supported by the local government. It was even designated as Fujioka city's national treasure. In 2001, with the formulation of a national law to build environmentally friendly water canals, the city invested more efforts to protect the *yaritanago's* habitats, which led to the population increase of the endangered carp [23]. It is vital to conserve the agricultural canal networks, not only for the *yaritanago* but also for other species, such as the freshwater mussels *matsukasagai* (*Pronodularia japanensis*) on which the carp lay their eggs [22]. Environmental conservation agriculture (ECA) can positively contribute to this biodiversity conservation; hence, this paper aims to know what factors can increase the Fujioka farmers' adoption of ECA.

The case of Sado island's Toki birds is a good example of ECA's positive impacts on preserving biodiversity. Sado island in Niigata prefecture is one of the first GIAHS in Japan and among developed countries. GIAHS is defined by FAO as "*remarkable land-use systems and landscapes which are rich in globally significant biological diversity evolving from the co-adaptation of a community with its environment and its needs and aspirations for sustainable development*" [24]. Due to Sado island's satoyama and satoumi landscapes, it is known as the natural habitat of endangered Japanese crested ibises (locally called Toki in Japanese). The paddylands serve as the habitats of the Toki birds, which is why Sado island is also famous for its rice produce with Toki branding [25]. This case shows a similarity with the biodiversity conservation efforts being carried out in Fujioka city and presents a possible future if these efforts will continue. It was reported that farmers in Sado island who give high value to biodiversity conservation feel more involved with GIAHS [15], therefore highlighting the importance of this factor in increasing farmer participation for environmentally friendly and sustainable agriculture initiatives.

1.2. Factors Affecting Farmers' Adoption of Environmental Conservation Agriculture Methods

In line with the profound contribution of the agricultural sector to the global GHG emissions [26], numerous scholars have analyzed the factors affecting farmers' adoption of methods that aim to mitigate climate change [27,28]. In a meta-analysis conducted by Mozzato et al. (2018) in developing and developed countries, several classifications of these influential factors have been defined, which focus on the farmer, the farm, as well as information, social, value-chain, and spatial factors [28]. It was observed that reports from different papers gave contrasting results due to differences in geographical contexts and varying levels of adoption. Meanwhile, Dessart et al. (2019) classified farmers' influential factors based on their proximity to the decision to adopt specific sustainable practices [27]. They were placed in a distal-proximal spectrum and were categorized as dispositional, social, and cognitive factors. Like the findings of Mozzato et al. (2018), the factors were observed to vary on a case-by-case basis. All these meta-analyses agree with Barlett (1980) who argued that farmers exhibit heterogeneity based on their area, farming context, community, among others, which imply that policies should be crafted on a bottom-up basis, and that future papers on this topic would vary per context as well [29].

In Japan, some scholars also determined factors affecting farmers' adoption of environmental conservation agriculture methods. Farmers' attitudes, risk preference, and farm size were found to be correlated with Shiga farmers' ECA adoption [17]. In Niigata prefecture, ECA farmers' involvement in GIAHS increases when GIAHS improves tourism management, youth involvement, and product branding [15]. Meanwhile, the satisfaction being derived from fellowship with co-ECA farmers in Ishikawa was found to be positively correlated with income change; hence, improving support networks of farmers is also being recommended [16]. Most of the ECA literature in Japan focused on areas with relatively

high ECA uptake, such as Shiga, Niigata, and Ishikawa prefectures; however, there is still a lack of papers reporting ECA adoption in areas with low ECA utilization. Furthermore, only a few papers are discussing the dynamics of incorporating ECA with biodiversity conservation in Japan.

2. Study Area and Methods

Since this paper aims to know the factors affecting the ECA adoption of farmers in an area with a low percentage of ECA utilization and active biodiversity conservation initiatives, Fujioka city was selected as the study area (Figure 2). It is located on the southern border of Gunma prefecture and has an abundant natural environment, mountains with vast greeneries, clear running streams, and seasonal flowers such as the winter cherry blossoms and Japanese wisteria. With its mild climate, a lot of fruits, vegetables, and agricultural crops are being grown, such as rice, strawberries, tomatoes, apples, pears, mandarin oranges, and blueberries [30]. The city is also known for its biodiversity conservation efforts to save endangered species including the *yaritanago.* However, in terms of agricultural data, Fujioka's total number of farmers decreased from 1985 in 2005 to 1798 in 2015. Consequently, the total area for cultivated land also decreased from 1133 ha in 2005 to 1066.9 ha in 2015. It also has a low and decreasing ECA utilization from 2016–2020 (Figures 1 and 2).

A questionnaire survey was employed in Japanese to collect data from farmers in Fujioka city regarding their ECA adoption. In September 2019, key informant interviews with the Fujioka city environmental groups and users of environmentally friendly water canals were held with the support of the local government to know the current situation and issues in the area. The questionnaire was approved by the research ethics committee of the Graduate School of International Development and Cooperation, Hiroshima University. Its contents were then explained to the key informants, who then explained them to the respondents. Consent was obtained from all the respondents for their participation in this research. The questionnaires were distributed to the Fujioka farmers belonging to various environmental groups and users of environmentally friendly water canals from October to November 2019, and key informant interviews were conducted again in February 2020 to verify the gathered data. Out of the 80 questionnaires distributed, a total of 46 (57.5%) responses were received. The contents of the questionnaire include: (1) socio-demographic and farm-related information of the farmers; (2) ECA-related opinions; (3) climate change perception and adaptation; (4) ECA's significance and its relationship to climate change; (5) ECA adoption and expectations on its effects; (6) ECA farmers' receiving of subsidy; and (7) prospects of Fujioka city towards ECA. ECA- and climate-change-related questions were adopted from MAFF [31–33]. All the responses that are in local Japanese were translated to English by the authors.

Data were analyzed using principal component analysis and binary logistic regression in SPSS v.25. Model fitting was performed to assure that the statistical assumptions are met. Since ECA-related variables appear to converge on a common theme, we inferred that there might be underlying latent factors that tie these common variables together. To confirm this, we employed factor analysis of the socio-demographic, ECA-related, and climate-change-related variables which reduced them into eight latent factors, namely: ECA farming method (Factor 1), assets (Factor 2), ECA continuation (Factor 3), immediate effects of climate change (Factor 4), weather effects of climate change (Factor 5), climate change and production variables (Factor 6), farming experience (Factor 7), and damage effects of climate change (Factor 8). Qualitative information was also gathered and was used for thematic analysis.

3. Results

3.1. Socio-Demographic and ECA-Related Variables of Fujioka Farmers

We characterized the farmers in Fujioka, Gunma, Japan in terms of socio-demographic and ECA-related variables. In agreement with previous studies [34,35], we also observed

that more than half of the Fujioka farmers in this study are at least 65 years old (58.7%), and are mostly classified as family farms (93.5%) with the purpose of selling (54.3%) and self-consumption (43.5%) (Supplementary Table S1). Half of them have no other family member whose main job is not farming, although they could lend a helping hand to the farmers during peak seasons. Only almost one-third (30.4%) have one family member whose main job is farming. The low number of farmers who reported conducting ECA farming (45.7%) in Fujioka reflects the national data for %ECA utilization in Gunma prefecture.

In terms of ECA-related variables, ECA interest is low for most of the interviewed farmers (63.0%) as further evidenced by the high number of farmers who are not interested in learning about ECA opportunities (73.9%) (Supplementary Table S2). Unsurprisingly, less than one-third (23.9%) of the farmers reported that they would continue ECA farming and 43.5% wanted to retain the same farming area and methods. The top reasons for those who would continue ECA farming are to improve the local and global environment (30.4%) and to supply better products (23.9%). Meanwhile, the farmers' top three expectations from ECA are conservation of biodiversity (39.1%), adding value to the quality of products (39.1%), and conservation of water quality (23.9%). Most of the farmers (84.8%) have never received ECA subsidies and do not participate nor promote exchange programs with local residents or consumers (82.6%). For those who participate, direct sale to consumers and harvesting (17.4%) and schoolchildren's extracurricular activities (17.4%) were the top exchange programs chosen.

While the farmers' disposition towards ECA may be low, more than half (60.9%) answered that climate change has a very high impact on agriculture (Supplementary Table S3). The top perceived effects of climate change are the following: increase in temperature and extremely hot days (76.1%), heavy torrential rain; flooding (60.9%), and change in season duration (52.2%). The top adaptations being carried out for these perceived effects are planting high temperature-tolerant varieties (47.8%) and water management (41.3%).

3.2. Factor Analysis of Socio-Demographic and ECA-Related Variables

There were eight latent factors that emerged in the factor analysis (Table 1). As expected, farming method is strongly correlated with ECA farming method (Factor 1), as well as ECA continuation and the farmers' intent to improve their local and global environment. ECA farming method (Factor 1) is correlated with ECA continuation (Factor 3), because of *building trust with consumers*, *self-health*, and *supplying better products*. It can also be seen that ECA continuation (Factor 3) is strongly correlated with *good/high price* and *high demand*, which shows that aside from environmental considerations, the farmers might also be ascribing high importance to the economic value of their products. In addition, farmers with high assets (Factor 2) are predisposed to have a high ECA farming method (Factor 1), due to *ECA interest*. Within Factor 2, ECA interest appears to be negatively associated with *damage to houses/buildings* and *damage to land/farmland*, and positively associated with *selling*. In addition, *ECA interest* and *ECA opportunities* also predisposes farmers with high climate change and production variables (Factor 6) to engage more in ECA farming method (Factor 1).

The climate change variable *typhoons*, *cyclones*, or *tornadoes* is associated with immediate effects of climate change (Factor 4), weather effects of climate change (Factor 5), and climate change and production variables (Factor 6). Farming experience (Factor 7) appears to be negatively related with farmers' interest to discuss or learn about ECA opportunities. In Factor 8, the farmers' opinion that climate change has a very high impact on agriculture increases due to *damage to houses/buildings* and *damage to land/farmland*.

Table 1. Exploratory factor analysis [a] of the variables observed among farmers in Fujioka, Japan.

Factor	Eigenvalue
Factor 1: ECA farming method	
ECA interest	0.595
ECA opportunities	0.580
ECA continuation	0.740
Farming method	0.802
Melting of glaciers, sea-level rise	0.324
To build trust with consumers	0.557
To improve local and global environment	0.824
Self-health	0.498
To supply better products	0.403
Factor 2: Assets	
ECA interest	0.332
Damage to houses/buildings	−0.398
Damage to land/farmland	−0.318
Self-consumption	−0.898
Selling	0.886
Factor 3: ECA continuation	
To build trust with consumers	0.440
Self-health	0.426
Good/high price	0.853
High demand	0.778
Want to supply better products	0.451
Factor 4: Immediate effects of climate change	
Heavy torrential rain; flooding	0.310
Typhoons, cyclones, or tornadoes	0.322
Change in season duration	−0.442
Melting of glaciers, sea-level rise	0.448
Damage to houses/buildings	0.546
Damage to land/farmland	0.305
Damage to farm products	0.797
Want to supply better products	0.339
Factor 5: Weather effects of climate change	
Heavy torrential rain; flooding	0.668
Increase in temperature and extremely hot days	0.694
Typhoons, cyclones, or tornadoes	0.507
Drought	0.524
Factor 6: Climate change and production variables	
ECA interest	0.332
ECA opportunities	0.377
Typhoons, cyclones, or tornadoes	0.331
Change in season duration	−0.340
Melting of glaciers, sea-level rise	−0.393
Decrease production cost of fertilizers and pesticides	0.723
Company farm	0.656
Factor 7: Farming experience	
Interest to discuss or learn about ECA opportunities	−0.274
Age	0.826
Farming experience	0.908
Factor 8: Damage effects of climate change	
Climate change has a very high impact on agriculture	0.826
Damage to houses/buildings	0.419
Damage to land/farmland	0.510

[a] Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

3.3. Associations with ECA-Related Factors

To complement the various themes observed using the factor analysis, we tested the association of *farming method*, *ECA continuation*, *ECA interest*, and *ECA opportunities* with other factors. Since ECA and climate change are closely connected [36,37], we first explored the relationship between *farming method* and perceived *climate change effects* identified by the Fujioka farmers using binary logistic regression (Table 2).

Table 2. Relationship of climate change and ECA-related variables with farming method.

Variable	Estimate	Odds Ratio	Significance
Perceived climate change effects [a]			
Heavy torrential rain; flooding	−0.053	0.948	0.944
Increase in temperature and extremely hot days	0.278	1.321	0.761
Change in distribution of plants/crops	−1.787	0.167	0.068
Change in season duration	1.789	5.986	0.031 *
Melting of glaciers, sea-level rise	1.933	6.914	0.046 *
Drought	−0.228	0.796	0.789
Damage to houses/buildings	−0.354	0.702	0.849
Damage to land/farmland	0.226	1.254	0.827
Damage to farm products	0.195	1.216	0.829
Selling place [b]			
Direct to consumers	1.829	6.225	0.048 *
Supermarket	−20.337	0.000	0.999
Restaurant	20.629	-	0.999
Agricultural corporations	0.940	2.560	0.300
Central market	0.491	1.634	0.744
Michi-no-eki (roadside farmers' market)	−1.312	0.269	0.368
Food processors	20.014	-	0.999
Reason for ECA continuation [c]			
To build trust with consumers	2.056	7.818	0.199
To improve local and global environment	4.197	66.459	0.007 **
Self-health	0.809	2.246	0.517
Good/high price	35.343	-	1.000
High demand	−18.056	0.000	1.000
To supply better products	−1.835	0.160	0.248
To decrease production cost of fertilizers and pesticides	2.235	9.351	0.218

* significant at $p < 0.05$; ** significant at $p < 0.01$. [a] Hosmer-Lemeshow goodness-of-fit: Chi-square = 7.858, df = 6, sig = 0.249. [b] Hosmer-Lemeshow goodness-of-fit: Chi-square = 1.031, df = 5, sig = 0.960. [c] Hosmer-Lemeshow goodness-of-fit: Chi-square = 2.571, df = 4, sig = 0.632.

Farming method is positively associated with *change in season duration* and *melting of glaciers and sea-level rise* which increases the odds of the farmers employing ECA farming by 6 times and 6.9 times, respectively. In terms of selling place, *direct to consumers* increased the odds of farmers employing ECA farming by 6.2 times. Notably, *to improve local and global environment* was the only reason for ECA continuation that significantly increased the odds of Fujioka farmers to use ECA farming by ~66 fold.

We also used the same independent variables with *ECA continuation* as the dependent variable (Table 3). Using binary logistic regression, we identified *damage to land/farmland* as a factor affecting ECA continuation. Specifically, farmers who perceive *damage to land/farmland* as a climate change effect are more likely to continue ECA by ~23 fold. Here, *direct to consumers* was also identified as a selling place which increases the odds of continuing ECA by ~15 fold. Looking at ECA continuation relationships with reason for ECA continuation identified *to improve local and global environment* and *decrease production cost of fertilizers and pesticides* as significant factors. Both increase the odds of ECA continuation among Fujioka farmers by ~12 fold and ~43 fold, respectively.

Table 3. Relationship of climate change and ECA-related variables with ECA continuation.

Variable	Estimate	Odds Ratio	Significance
Perceived climate change effects [a]			
Heavy torrential rain; flooding	0.949	2.584	0.349
Increase in temperature and extremely hot days	0.229	1.257	0.862
Change in distribution of plants/crops	−0.576	0.562	0.587
Change in season duration	1.520	4.572	0.139
Melting of glaciers, sea-level rise	0.145	1.156	0.898
Drought	−0.443	0.642	0.674
Damage to houses/buildings	1.202	3.325	0.541
Damage to land/farmland	3.137	23.041	0.037 *
Damage to farm products	−3.148	0.043	0.091
Selling place [b]			
Direct to consumers	2.752	15.674	0.040 *
Supermarket	−18.409	0.000	0.999
Restaurant	20.484	-	0.999
Agricultural corporations	−0.637	0.529	0.660
Central market	−17.281	0.000	0.999
Michi-no-eki (roadside farmers' market)	−0.769	0.464	0.677
Food processors	21.091	-	0.999
Reason for ECA continuation [c]			
To build trust with consumers	2.384	10.846	0.086
To improve local and global environment	2.501	12.198	0.029 *
Self-health	1.812	6.122	0.124
Good/high price	35.709	-	0.999
High demand	−17.002	0.000	1.000
To supply better products	−0.878	0.416	0.501
To decrease production cost of fertilizers and pesticides	3.779	43.788	0.041 *

* significant at $p < 0.05$. [a] Hosmer-Lemeshow goodness-of-fit: Chi-square = 9.237, df = 7, sig = 0.236. [b] Hosmer-Lemeshow goodness-of-fit: Chi-square = 1.770, df = 5, sig = 0.880. [c] Hosmer-Lemeshow goodness-of-fit: Chi-square = 1.383, df = 4, sig = 0.847.

Next, we explored associations that exist for ECA interest (Table 4). The variables *to improve local and global environment* and *promote local industry* were found to increase farmers' interest in ECA by ~10 fold.

Table 4. Relationship of ECA expectation and reason for ECA continuation with ECA interest.

Variable	Estimate	Odds Ratio	Significance
ECA expectation [a]			
Carbon sequestration	−22.563	0.000	0.999
Conservation of biodiversity	1.904	6.715	0.107
Conservation of water quality	−0.652	0.521	0.599
Retain underground water	21.522	-	0.999
To add value to quality of products	1.996	7.357	0.083
Decrease effect of weather hazards	−0.360	0.698	0.839
Increase farm related income	−1.526	0.218	0.226
Promote local industry	2.342	10.403	0.047 *
Retain residents in rural area	−1.370	0.254	0.464
Reason for ECA continuation [b]			
To build trust with consumers	0.541	1.718	0.676
To improve local and global environment	2.397	10.985	0.007 **
Self-health	0.367	1.443	0.734
Good/high price	−45.710	0.000	0.999
High demand	22.549	-	1.000
To supply better products	0.361	1.435	0.735
To decrease production cost of fertilizers and pesticides	1.652	5.219	0.263

* significant at $p < 0.05$; ** significant at $p < 0.01$. [a] Hosmer-Lemeshow goodness-of-fit: Chi-square = 4.521, df = 5, sig = 0.477. [b] Hosmer-Lemeshow goodness-of-fit: Chi-square = 4.429, df = 4, sig = 0.351.

Lastly, we explored associations for farmers' interest to discuss and learn about ECA opportunities (Table 5). *Conservation of biodiversity* is the only variable that increases the odds of participating in ECA opportunities, which agrees with the environmental activism and *yaritanago* preservation happening in Fujioka.

Table 5. Relationship of ECA expectation and selling place with ECA opportunities.

Variable	Estimate	Odds Ratio	Significance
ECA expectation [a]			
Carbon sequestration	−21.827	0.000	0.999
Conservation of biodiversity	5.532	252.546	0.015 *
Conservation of water quality	0.975	2.652	0.555
Retain underground water	17.563	-	0.999
To add value to quality of products	0.639	1.894	0.697
Decrease effect of weather hazards	−0.229	0.795	0.916
Increase farm related income	2.232	9.314	0.216
Promote local industry	−2.391	0.092	0.164
Retain residents in rural area	2.183	8.876	0.209

* significant at $p < 0.05$. [a] Hosmer-Lemeshow goodness-of-fit: Chi-square = 4.047, df = 5, sig = 0.543.

4. Discussion

Fujioka city in Gunma, Japan presents an interesting avenue to study environmental conservation agriculture diffusion among farmers and its interaction with local industries. Fujioka does not have enough agricultural yield to rank highly in terms of agricultural

output, but the distinct presence of environmental activism within the city makes it a good target for Japan for climate change policies. Our current data further verifies this statement by showing a high proportion of Fujioka farmers who perceive significant effects of climate change (60.9%). However, our data also shows that farmers in Fujioka do not appear highly interested nor engaged in environmental conservation agriculture, which mirrors the %ECA utilization of Gunma (Figure 1). Thus, we aimed to leverage the unique position of Fujioka farmers in the context of ECA to highlight critical factors that can aid in the diffusion of ECA farming in the area.

Dessart et al. (2019) categorized behavioral factors affecting farmers' adoption of sustainable practices into three clusters, namely cognitive, social, and dispositional factors arranged in increasing distance relevant to farmer decision-making [27]. We have observed similar themes in terms of ECA adoption among Fujioka farmers which encompass aspects of perceived costs and benefits, knowledge, and environmental concern. Using factor analysis, we found that ECA continuation is positively correlated with *good price*, *high demand*, and *self-health*. In addition, regression analysis also identified reduced production cost of fertilizers and pesticides as a significant factor that promotes ECA continuation among the Fujioka farmers. While some studies show that ECA may give added profit to farmers [38], other studies show that ECA does not appear profitable enough to support *good price* and *high demand* as factors affecting ECA continuation [39]. Some interviewed farmers are also voicing this out:

> "*ECA farming needs lots of time and hands-on effort. It also can't produce better or more profitable products [than conventional farming].*"

Targeting ECA profitability to diffuse ECA among Fujioka farmers is supported by the slightly higher proportion of farmers with the intent of selling (54.3%) compared to self-consumption (43.5%). The following testimonials of the interviewed farmers reflect the farmers' perspectives regarding the sustainability of ECA at the farm level:

> "*ECA farming is good enough so I will continue adopting it, but it will not be sustainable if we do not market the products with added value; hence, there is a need to establish marketing channels and improve the consumers' understanding of ECA products.*"

> "*As a producer, if you can't make a profit, then your farming method is not sustainable. Both environmental conservation and farm management & profitability should go side by side.*"

These sentiments align with the arguments of other studies which showed that prioritizing environmentally friendly practices—which can be beneficial in the long term—will be difficult when farmers are resource-constrained and suffer from net losses or poor agricultural productivity [40,41]. The direct payment subsidies that Japan is giving to ECA adopters can further supplement ECA profitability; however, most of the farmers (84.8%) chose not to apply for these subsidies, caused by several reasons such as the increase in the number of paperwork that needs to be accomplished and the complex administrative process of applying.

Other than production factors, we also identified improvement in the local and global environment as a factor that can enhance ECA continuation which seems to align with the high climate change awareness of the sampled farmers. We, therefore, looked at the degree of interest that Fujioka farmers have towards ECA. Some testimonials of the interviewed farmers highlighted the capability of ECA to mitigate climate change:

> "*So far, production growth in agriculture has been achieved primarily due to increased use of chemical fertilizers, pesticides, and petroleum energy. However, the constraints we face today, such as greenhouse gas emissions from energy use and negative environmental impacts are clearly becoming issues in agriculture. ECA is becoming a more rational way to farm.*"

Based on the regressions, *change in season duration*, *damage to land/farmland*, and *melting of glaciers and sea-level rise* emerged as the critical factors that increase the farmers' ECA

farming method and continuation. However, their knowledge of climate change and its effects did not translate to high ECA interest (37.0%) nor participation in ECA opportunities (26.1%). Most of the farmers (82.6%) also do not participate or promote exchange programs. The affective responses of the farmers towards climate change are indeed good predictors of climate change mitigation acceptance [42], although our data has revealed the gap between farmer awareness regarding climate change and knowledge that most agriculture-related climate change mitigation steps are actually under ECA. If this gap could be bridged, not only will farmers benefit from receiving ECA compensation, but the local government and industries could easily act in a more concerted way to promote ECA which is core to agricultural climate change mitigation [10]. As an example, we observed that ECA farming method and ECA continuation are enhanced by farmers opting to sell directly to consumers. Thus, the local government can promote and support these avenues to boost both ECA farmer income and local appreciation of ECA activities. In turn, the farmers' ECA interest increases when ECA promotes their local industry.

Lastly, we found the inverse relationship between farming experience and engagement in ECA opportunities. As the farmers' age and farming experience increase, they tend to be less interested in ECA. The lack of successors and aging are the reasons given by the Fujioka farmers, which agree with the findings of other studies [15,43]. Indeed, in this study, half of the farmers have no other family member whose main job is not farming, although they could lend a helping hand during peak seasons, and only almost one-third (30.4%) have one family member whose main job is farming. This narrative of an interviewed farmer clearly shows this:

> "*Before talking about ECA, it is necessary to think about the current problem of not having successors in agriculture.*"

5. Conclusions and Recommendations

In this study, we sought to identify factors that are relevant to the adoption of ECA in Fujioka city, Japan which presents a contrast between low ECA utilization and high biodiversity conservation initiatives. We provide evidence for this incongruence by showing that Fujioka farmers have a high concern for the impacts of climate change while simultaneously reporting very low interest in ECA. Since ECA directly translates to climate change mitigation efforts, it is therefore necessary to seek factors that can increase its uptake among farmers. To this end, we identified two major themes that have a positive impact to increase ECA uptake and continuation among Fujioka farmers.

First are the production-related factors, such as *good/high price*, *high demand*, and *want to supply better products*. Farm-related income is a well-documented factor that enhances technology adoption in the context of agriculture [44,45]. In the case of Fujioka, we observed that selling directly to consumers increases farmers' ECA uptake, which therefore provides a good reason for the local government to support ECA farmers. The second theme that emerged is the farmers' environmental concern, which is exemplified by their intent to improve the local/global environment. This factor was found to enhance various ECA components, such as ECA adoption, continuation, and interest. This can positively impact the biodiversity conservation efforts being implemented in Fujioka, such as the protection of endangered species such as the *yaritanago*. Such efforts may depict the altruistic nature behind ECA, given that the costs of adopting ECA accumulate at the farmer level but with few benefits to go along with such practices [46,47]. In Japan, the practice of ECA does come with practical benefits for the farmers in the form of direct payment subsidies, which may be used as another tool to further increase ECA adoption; however, reports of difficulties in applying for such subsidies serve as a barrier for this mechanism from being fully effective.

The findings of the study have also shown a cognitive dissonance between farmers' perception of climate change and ECA as a climate change mitigation method. To address this information gap, we therefore recommend information dissemination regarding ECA's climate change mitigation effects. This can also potentially increase ECA uptake among

prefectures in Japan. However, ECA's environmental and economic sustainability should be addressed as well to encourage more farmers to adopt it.

We infer that the farmers in this study value the potential long-term benefits of ECA in improving their environment. Such farmer characteristics are important in facilitating the easy uptake of climate mitigation methods/policies. Evident from this study and previous literature is the fact that while the costs of ECA production are shouldered by the farmers, the benefits manifest at the regional/national level [39]. It is therefore critical that we not only bridge the knowledge gap necessary to inform farmers on how ECA helps climate change mitigation, but also financially aid the farmers who shoulder most of the costs to make agricultural climate change mitigation possible.

Considering the findings in this study, we recommend the intensification of ECA information dissemination among rural communities and farmers alike. We also recommend the promotion of farmer-consumer market channels and the extension of ECA products to local industries, which can be conducted by both government and non-government institutions. Both strategies could serve to strengthen the rural-urban linkages in Fujioka city, Japan. Lastly, the data presented here could serve as a basis for intensifying ECA uptake among prefectures in Japan with a low percentage of ECA utilization.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14095296/s1, Table S1: Socio-demographic characteristics of the sampled farmers in Fujioka, Japan; Table S2: ECA-related variables of the sampled farmers in Fujioka, Japan. Table S3: Climate change-related variables of the sampled farmers in Fujioka, Japan.

Author Contributions: Conceptualization, K.L.M., C.G. and W.A.J.; methodology, K.L.M., C.G. and W.A.J.; software, K.L.M., C.G. and W.A.J.; validation, K.L.M., C.G. and W.A.J.; formal analysis, K.L.M., C.G. and W.A.J.; investigation, K.L.M.; resources, K.L.M.; data curation, K.L.M., C.G. and W.A.J.; writing—original draft preparation, K.L.M., C.G. and W.A.J.; writing—review and editing, K.L.M., C.G. and W.A.J.; visualization, K.L.M., C.G. and W.A.J.; supervision, K.L.M.; project administration, K.L.M.; funding acquisition, K.L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Japan Society for Promotion of Sciences (JSPS); JP JSBP 120197904. Authors and funding agency have no conflicts of interest.

Institutional Review Board Statement: The study was conducted according to the Declaration of Helsinki, and approved by the Research Ethics Committee of the Graduate School for International Development and Cooperation, Hiroshima University.

Informed Consent Statement: Informed consent was obtained individually from all the respondents during the survey.

Data Availability Statement: Questionnaire survey data can be made available from the first author upon request.

Acknowledgments: This paper is the part of the findings of the joint research project, "Moving Towards Climate Change Resilient Agriculture: Understanding the Factors Influencing Adoption in India and Japan", Principal Investigator: Keshav Lall Maharjan, funded by the Japan Society for the Promotion of Science (JSPS); JP JSBP 120197904. The authors would like to thank the members of the project: Akinobu Kawai, Professor by special special appointment at The Open University of Japan, and Akira Nagata, Visiting Research Fellow at the United Nations University, Institute for the Advanced Study of Sustainability, Japan for their valuable inputs in conceptualizing the research project, constructing the questionnaire and conducting the survey. The authors are also thankful to Yuko Kakekawa, Chairperson, Association of Yaritanago Conservation for her cooperation in conducting the survey. The authors are grateful to Ruth Joy Sta. Maria for her expertise in the creation of figures for this paper.

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

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Is Implementing a Biotech Ban Correct or Not? Analysis of Farmer Perceptions and Attitudes on the Philippine Supreme Court's Ban on Biotech Crops

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Abstract: Several studies have explored the effects of restrictive policies in different case-use instances; however, studies focusing on restrictive agricultural policies and their effects on major stakeholders are scarce. While the Philippines has been increasing its support for biotech-related technologies in agriculture, such as the recent approval of Golden Rice and *Bt* (*Bacillus thuringiensis*) eggplant for cultivation, the years prior to 2020 have not been as lenient in the acceptance of biotech crops. This paper explored the perceptions and attitudes of biotech corn farmers on the Philippine Supreme Court's ban on biotech crops in 2015 and discussed how this restrictive agricultural policy could affect rural Filipino communities. A bifurcation was observed regarding the farmers' ban perception, with almost half indicating that implementing the ban was an incorrect decision. The effects of the decision-making stages and influential factors on farmers' perceived correctness of the ban were modeled using ordinal logistic regression and Spearman correlation. It was observed that while farmers' initial instinct is directly related to their ban perception, succeeding decision-making stages enforce the notion of a pragmatic point of view leading to innate resistance effects towards the ban. Furthermore, internal factors (such as income and satisfaction) and external family-related factors perturb their ban perception. This information can offer guidance on how future restrictive agricultural policies may be framed to avoid conflicting interests between policymakers and stakeholders. This also highlights the need to understand farmer perspectives and attitudes to gain critical information regarding technology adoption and development.

Keywords: biotech corn; farmer perceptions; restrictive agricultural policy; biotech ban; consumer decision model; biotech crops

Citation: Gonzalvo, C.M.; Aala, W.J.F.; Maharjan, K.L. Is Implementing a Biotech Ban Correct or Not? Analysis of Farmer Perceptions and Attitudes on the Philippine Supreme Court's Ban on Biotech Crops. *Sustainability* **2022**, *14*, 7919. https://doi.org/10.3390/su14137919

Academic Editor: Flavio Boccia

Received: 1 June 2022
Accepted: 26 June 2022
Published: 29 June 2022

1. Introduction

According to the FAO 2020 report, 690 million people (8.9% of the world population) were undernourished prior to the COVID-19 pandemic, and the figures are continuously rising [1]. Sixty million more people have been affected by hunger since 2014 and if this trend continues, the number of undernourished people is estimated to exceed 840 million by 2030. These pressing issues of food insecurity and malnutrition are further aggravated by persisting problems pertaining to climate change, a booming population, urbanization, land degradation, migration, and the ongoing COVID-19 pandemic. Sustained efforts in addressing these problems involve the international and multisectoral collaboration of different fields, such as agriculture, food, and health. There is also a need to rebalance agricultural policies towards more nutrition-sensitive policy actions and focus on solutions that can mitigate the lingering problems affecting global food production, distribution, and sustainability. These are imperative to be on track with the world's SDG targets, particularly in ending hunger, food insecurity, and all forms of malnutrition for the decades to come.

Biotech crops are a prime example of agricultural modernization, which shows how the field of agriculture continues to adapt in the modern era, most especially in the 4th industrial revolution (4IR). Despite the persisting challenges faced by the field of agriculture, it was reported that from 1996 to 2018, the socio-economic benefits of biotech crops involved increasing food productivity, supporting nations' self-sufficiency in terms of arable lands, conserving biodiversity, mitigating climate change challenges, and contributing economic, health, and social improvements [2]. In the Asia and Pacific region, the leading country in terms of biotech crop propagation is India with 11.9 million ha of cotton, followed by China with 3.2 million ha of cotton and papaya, Pakistan with 2.5 million ha of cotton, and the Philippines with 875,000 ha of biotech corn [2].

In December 2002, the Philippines was the first among Southeast Asian countries to approve the application of biotechnology in agriculture, specifically biotech corn, for feed production. Biotech corn's commercial propagation was approved by the Department of Agriculture (DA) and Bureau of Plant Industry (BPI). It was fundamentally designed to be resistant to the Asiatic Corn Borer (ACB), *Ostrinia furnacalis* (Guenee), one of the most damaging corn pests in the Philippines. *Bt*, which stands for *Bacillus thuringiensis*, can enable corn borer resistance once certain genes from this bacterium have been isolated and inserted into the genes of corn plants. In the latest report of ISAAA (2019), the country ranked 12th worldwide in the list of biotech-mega countries, with 0.9 million ha allotted for biotech corn [2]. Through the years, farmers reported a sustained increase in yield and income as well as a reduction in insecticide use [3–5]. The specific accumulated income gains in the Philippines for biotech corn since its approval are US$553 million for insect-resistant (IR) corn and US$171 million for herbicide-tolerant (HT) corn [6]. Furthermore, the total factor productivity growth in the Philippines' corn industry was around 11.45% higher because of biotech corn adoption [7]. In July 2021, the Philippines was also the first country to approve the cultivation of Golden Rice, a biofortified rice variety with provitamin A, after the safe consumption approval of Australia, New Zealand, Canada, and the United States [8]. In the same month and year, the Philippines also approved the cultivation of *Bt* eggplant for food, feed, or processing (FFP) after it was declared safe for consumption by the DA-BPI. Ex-ante impact assessments regarding the adoption of *Bt* eggplant reported that its commercialization will increase marketable yield by 192% and reduce pesticide application by 48% per hectare [9].

Although the Philippines is currently increasing its support for biotech-related technologies in agriculture and the adoption of biotech cultivars, national policies pertaining to biotech crops have been strict from the early 2000s up to the latter years of the 2010s. As a case in point, the Supreme Court banned the nationwide field testing of *Bt* eggplant and the commercialization, propagation, and importation of genetically modified (GM) products in the Philippines on 8 December 2015. However, this ban was lifted on 26 July 2016, as a result of the appeals from the local and international scientific communities [10]. Nevertheless, this ban caused a decline in the harvested area for biotech corn up to 2017 [11], which had negative consequences for the livelihood of farmers growing this crop. In a span of 16 weeks, various media companies monitored the debates that developed around this issue, thereby placing agricultural biotechnology in the limelight, which is in contrast with the usual low media coverage given to science-related news [12]. Aside from the reversal of the Philippine Supreme Court's decision and high press attention given to this issue, it is also imperative to understand the perceptions of biotech farmers on this ban, since they are the prime stakeholders who would be heavily affected if the nationwide ban persists. With thousands of Filipino farmers relying on biotech corn for their main source of livelihood, the ban would equate to the loss of jobs and livelihood, which is a heavy blow to farmers' daily lives and communities. This aspect was not covered much by the press and mass media, but analyzing this angle is equally vital for the implementation of future government strategies and agricultural policies. This paper aims to contribute to this knowledge gap.

As argued earlier, the nationwide ban on biotech crops can be seen as a restrictive policy when applied to the case of biotech corn farmers. There are different theoretical lenses on how this can be viewed. First is the concept of deterrence and compliance. The implementation of nationwide restrictive policies requires compliance from its target population, and based on the traditional Deterrence Theory [13], it is generally assumed that the target population will follow the law because it is the right thing to do. The theory also assumes that people follow rules for fear of being punished and that people rationally calculate the potential cost of penalties and sanctions. Second is the concept of persuasion. People would comply with restrictive policies depending on the level of persuasion they have. The Elaboration Likelihood Model explains that people undergo two mental routes when it comes to persuasion and attitude change [14]. One is the central route, a cognitive processing path where a person scrutinizes a message and carefully thinks about issue-relevant arguments contained in persuasive communication. The other path is called the peripheral route or a mental shortcut process, where a person accepts or rejects a message based on irrelevant cues or if the persuader has high source credibility. In short, the difference between the two routes is how much cognitive effort a person is willing to give towards a certain issue that can lead to persuasion, and in this case, compliance with a policy. Third is the concept of costs and benefits. The theory of cost–benefit analysis assumes that decisions are evaluated in terms of their consequences [15]. Altogether, these theories, which focus on explaining the concepts of deterrence, compliance, persuasion, costs, and benefits, serve as foundations for understanding the perceptions and attitudes of biotech corn farmers on the ban on biotech crops.

Understanding Farmers' Perspectives on Restrictive Policies

Various papers on rural sociology and farmer decision-making have tried to understand farmers' perspectives towards different agricultural policies and model their cognitive behavior in adopting innovations [16–20]. Understanding farmers' perceptions and attitudes, as well as their causes and effects, can significantly aid in the creation and implementation of future policies. Gaining knowledge about the relationship between farmers and the technologies they are adopting, as well as the decision-making processes they are performing individually and collectively, would help in crafting better approaches towards the development of the agricultural sector.

While a lot of papers have focused on analyzing farmer decision-making regarding agricultural policies, there is still a limited amount of research on restrictive policies, which pertain to bans and prohibitions on certain technologies and farming methods. In a study that analyzed farmers' perceptions towards a decade-long grazing ban policy in Northern China, it was observed that farmers are more inclined to give more importance to short-term economic interest than ecological protection [21]. The study was conducted in ethnic minority areas where the grassland is a main source of income; hence, the farmers are experiencing difficulty in complying with the mandatory changes of the Grazing Ban Policy (GBP). As a result, more than 70% of the farmers engaged in illegal grazing after the GBP was implemented. Another study investigated farmers' attitudes towards stringent water-saving policies [22]. The policies involve restricting household agricultural water use, closing wells, reducing farmland, increasing water prices, and allocating surface water among upper, middle, and lower beaches, which all entail negative influences on the agricultural production of farmers. The study found that farmers' awareness of the positive consequences of the household agricultural water restriction and their perception of policy enforcement had significant relationships with their attitudes towards the stringent water-saving policies. The study recommended strengthening open and fair policy enforcement, cautiously utilizing water prices as a tool in controlling irrigation water and enabling the local farmers to be more informed about these policies. Meanwhile, another paper focused on qualitative approaches to knowing farmers' perceptions of the effectiveness of drought policy implementation [23]. It reported that farmers' past experiences are directly related to their policy implementation perceptions. Moreover, it was also observed that farmers' local

level adaptation is oriented towards income diversification and short-term market rewards. The study thus recommended strengthening local level long-term adaptation strategies such as awareness-raising, capacity building, watershed management, and source conservation to ensure the effectiveness of policy implementation. Meanwhile, a study conducted in Pakistan has shown that farmers are willing to abandon agricultural lands in search of better income-generating endeavors. The impacts of this agricultural land abandonment and land-use change are the increase in urban diffusion, weed infestation, farmland prices, and pressure on the present area infrastructure [24]. Another paper in the same country, which conducted a constraint analysis on livestock farmers, concluded that a comprehensive policy framework should be enacted that can address constraints on farmers' knowledge, awareness of diseases, and weak finances, among others [25]. These studies show the importance of understanding farmers' perceptions and attitudes towards restrictive policies since these may influence their future behavior and farm decisions. Furthermore, it can also determine the percentage of their possible compliance or non-compliance.

The goals of this paper are twofold, namely: to examine the perceptions and attitudes of farmers regarding the Philippine Supreme Court's ban on biotech crops, in connection with their decision-making stages and factors influencing their biotech corn adoption; and to highlight the potential impacts of restrictive agribiotech policies on rural communities. Since the Philippines is currently increasing its support for biotech crops because of their positive economic, environmental, and social impacts, it is vital to know how biotech corn farmers respond to changes in agricultural policies, most especially restrictive ones, as shown in this study. These data will be helpful in planning for future policies connected to biotech crop diffusion and adoption. Furthermore, this may contribute to the prevention of farmland abandonment since biotech corn can provide stability in the farmers' lives and communities. It is important to note that this study did not measure actual behavior but focused more on the decision-making process of farmers. Moreover, the farmers—who are normally treated as producers—were treated as consumers/adopters (i.e., biotech corn technology) in this study, which is why a model focusing on consumer decision-making was utilized to aid the data-gathering process.

2. Study Area and Methods

Since this paper aims to analyze the perceptions of biotech corn farmers towards the ban on biotech crops, the province of Pampanga, Philippines was selected as the study area (Figure 1). This is one of the provinces where biotech corn was first introduced in 2003 and it has been consistently producing biotech corn since then. The province of Pampanga is in the Central Luzon region and is classified as a first-class, highly urbanized city. Rice is grown in most lowland areas, while corn is the second major crop during dry seasons. Other top agricultural crops in the province are coconut, mango, and banana. The total farmland area of the province as of 2018 is 64,959 ha and the rural population is around 875,953 [26]. The Office of the Provincial Agriculturist (OPAG) stated that three of the top biotech corn-producing municipalities in the province are Arayat, Magalang, and Mexico, which is why they were chosen as the sampling sites for this study. The study employed a cross-sectional survey to interview 111 biotech corn farmers. Respondent-driven sampling—a specialized form of snowball sampling—was used to track down the target respondents of the study, with the help of government officials and farmer leaders. This employed a similar sampling approach used in previous studies that also tracked down and interviewed biotech corn farmers [27,28].

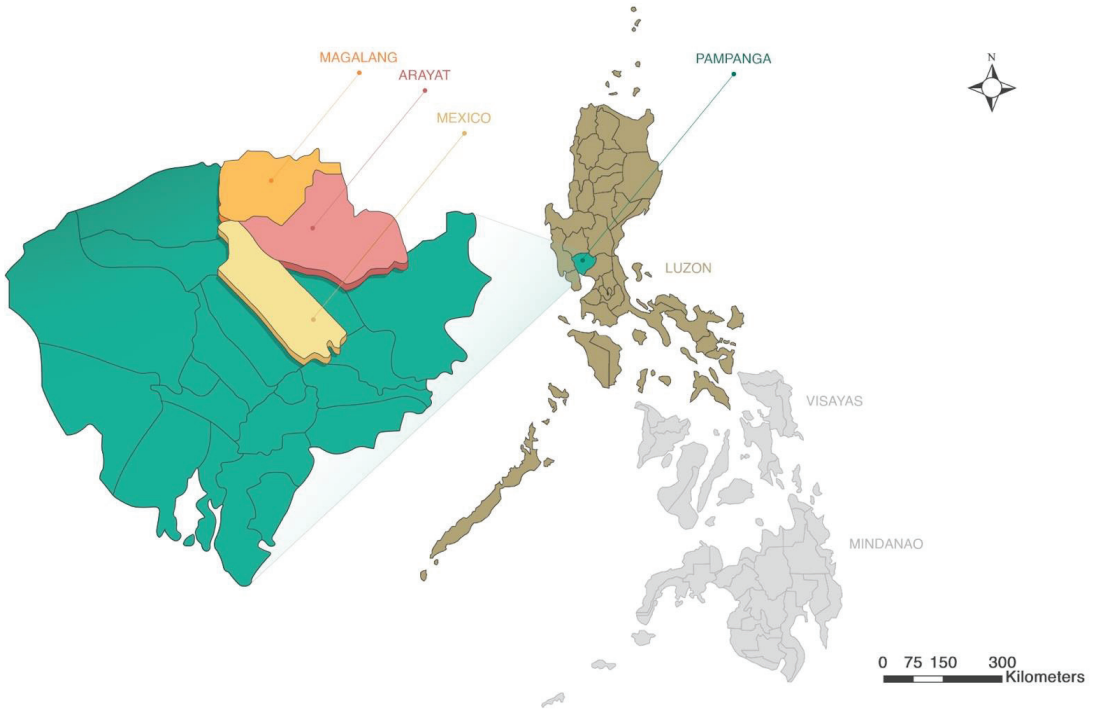

Figure 1. Sampling sites of the study showing the top producers of biotech corn in Pampanga province, Philippines.

All the farmers confirmed that they are planting the yellow corn hybrid with *Bt*-induced pest resistance, with the most common seed type being the Syngenta Agrisure NK8840 *Bt*/GT, which has big cobs and kernels, low ear placement, and high shelling recovery. They are also planting the yellow corn hybrid DEKALB 6919S Genuity 5% RIB with *Bt* technology, Roundup Ready (Monsanto, St. Louis, MO, USA) weed control technology, and high shelling recovery.

Data were collected using a standardized questionnaire from February to March 2018, which was administered through face-to-face interviews to obtain the answers and explanations of the farmers. All the respondents signed an informed consent form to confirm their participation in the study. The contents of the questionnaire included: (1) socio-demographic and farm-related information about the farmers; (2) information regarding their biotech corn adoption; (3) decision-making towards the biotech ban; (4) influential factors affecting their biotech farming practice; and (5) perceived correctness of the biotech ban.

Theoretical Framework

The study was guided by the Consumer Decision Model (CDM) [29]. In this study, the farmers are treated as consumers/adopters of the biotech corn technology, and since the study wanted to analyze their decision-making process on the biotech ban, the CDM was chosen. This model provides a linear, cognitive map regarding a person's decision-making stages and the factors influencing those stages. Upon exposure to a stimulus and after accepting that the information is deemed relevant to an adopter's wants and needs, this triggers a need recognition stage where a difference between an actual and alternative state is recognized. After a need is established, the search stage will be activated where an adopter evaluates his/her knowledge of the two states. Next, the pre-purchase evaluation of alternatives stage will occur where an adopter gauges the level of benefit derived from each state, which then leads to the purchase stage where the likelihood to purchase or subscribe to a certain state is evaluated. The adopter will then decide if he/she will continue to subscribe to the current state or go for the alternative state (consumption/adoption stage). Lastly, the adopter can choose whether he/she will recycle, dispose, or promote the chosen

state (post-consumption/adoption evaluation and divestment stage). It is also assumed that each decision-making stage is influenced by internal and external factors. These decision-making stages and influential factors were contextualized into farmer-specific variables and were used to understand the perceptions and attitudes of farmers on the biotech ban (Table 1).

Table 1. Contextualized decision-making stages and influential factors that were used in the study based on the Consumer Decision Model.

Consumer Decision Model (CDM) Variables	Contextualized Variables Used in the Study
Decision-making stages	**Decision-making stages of biotech corn farmers**
Need recognition stage	Desirability to plant alternative types of crops
Search stage	Level of familiarity and knowledge of biotech and non-biotech crops
Pre-purchase evaluation of alternatives stage	Level of benefit derived from biotech corn
Purchase stage	Likelihood to buy biotech corn seeds
Consumption/adoption stage	Desire to continue planting biotech corn
Post-consumption/adoption evaluation and divestment stage	Likelihood to sell and promote biotech corn
Individual differences	**Internal influential factors relative to current farming method**
Consumer resources	Time
	Capital
	Sources of information about biotech corn
Knowledge	Knowledge about biotech corn
	Knowledge about planting practices of biotech corn
	Knowledge about the requirements needed to plant biotech corn
	Knowledge about news on biotech corn (e.g., TV news and newspaper reports)
	Knowledge about the ban on planting biotech corn and *Bt* eggplant
Attitudes	Attitude towards planting biotech corn
	Attitude towards positive effects of biotech corn on environment and health
	Attitude towards the negative effects of biotech corn on environment and health
Motivation and involvement	Benefits of planting biotech corn
	Satisfaction in planting biotech corn
Personality, Values, and Lifestyle	Personal experiences in planting biotech corn
	Usage of income from biotech corn
Environmental influences	**External influential factors relative to current farming method**
Culture	Beliefs on acceptability of biotech corn
	Beliefs on acceptability of biotech corn in barangay or province
Social interactions	Experiences of co-farmers in planting biotech corn
Personal influences	Personal information regarding planting and purchasing biotech corn seeds
Family	Support of family in planting biotech corn
	Perception or opinion of family regarding biotech corn
Situation	Situation of co-farmers who are planting biotech corn
	Situation of economic demand of biotech corn in the market
	Situation after planting biotech corn

Each of the decision-making stages was framed as successive questions to mimic the CDM process and had a corresponding 5-point rating scale to measure farmers' responses. The desire to continue planting biotech corn was measured using a 3-point rating scale (i.e., 1 = will not continue adoption, 2 = unsure, 3 = will continue adoption). The ban perception was also measured using a 3-point rating scale (i.e., 1 = implementing the ban was an incorrect decision, 2 = unsure whether implementing the ban was correct or not, and 3 = implementing the ban was a correct decision). In terms of the influential factors, every farmer was asked how influential each variable was on their biotech farming practice using a 5-point rating scale (i.e., 1 = not at all influential, 2 = slightly influential, 3 = somewhat influential, 4 = very influential, and 5 = extremely influential). The stimulus used was a laymanized summary of the biotech ban issued by the Supreme Court. Qualitative data were also gathered during the interviews to verify all the answers given and were used for the thematic analysis in this paper.

This paper will mainly focus on analyzing the perceptions and attitudes of farmers towards the ban on biotech crops, in connection with their decision-making stages and influential factors. Data were analyzed using principal component analysis, Spearman correlation, correspondence analysis, and ordinal logistic regression in SPSS v.27. Model fitting was also performed to ensure that statistical assumptions are met. First, factor analysis was conducted to determine the underlying factors that tie the biotech corn farmers' common variables together. Next, the farmers' perceptions of the ban (the ban being correct or not) were modeled in the context of the 6 decision-making stages. Afterward, it was modeled against 24 influential factors affecting the decision-making of farmers. The narratives of farmers in the face-to-face interviews served as qualitative data to support the interpretation of research results.

3. Results

3.1. Socio-Demographic and Farm-Related Data of Biotech Corn Farmers in Pampanga

Out of the 111 biotech corn farmers in the study, there were a higher number of males than females, with a ratio of 93:7 (Table S1). This reinforces the traditional norm that farming is a male-dominated activity. Even though this is the case, it was seen that the wives of the male farmers played a significant role in the household decision-making, especially when it comes to income management for family expenses. Almost half of the farmers were between their middle adulthood and senior years, with 50 percent in the 45–64 age bracket. Interestingly, nearly one-third (27%) fell under the 65-and-above retirement age bracket, yet they were still active planters of biotech corn. The mean and median ages were 55 and 54, respectively. The youngest farmer was 24 years old and the oldest, 81. More than three-quarters of biotech corn farmers (89%) were married. More than half had access to primary-level education, with 51% having reached and/or completed elementary. Almost one-third (33%) had reached and/or completed high school, while less than one-tenth had reached and/or completed college or a vocational course. Most of them started farming at a young age since their parents handed down their farmlands to them. More than half (52%) had 1 to 5 members in the household, closely followed by 47 percent who had 6 to 11 household members. Most (66%) of them were affiliated with agricultural organizations. During the interviews, some of the farmers narrated how their organizational membership enhanced their biotech corn farming. According to them, their organization makes possible the practice of *bayanihan* or the spirit of communal unity, work, and cooperation, thereby enabling farmers to help one another in times of hardship. Furthermore, they meet regularly to discuss their harvest or other agricultural topics such as new farming methodologies and updates on their crops, among others.

Almost half (45%) have been planting biotech corn since it was approved for commercialization in 2003. This goes to show that many of the farmers included in the study are pioneers of the biotech corn technology in their respective municipalities. Almost all (97%) have a farm size of seven hectares and below, with an average size of 2.8 ha. This is similar to the findings of previous studies citing 2.7 ha [30], 2.17 ha [31], and 2.64 ha [3]

as the average farm size of biotech corn farmers. There were more (77%) lowland or plain areas allotted to biotech corn farming than those in the upland or mountainous areas (13%). A few (10%) farmers were planting biotech corn in both topographies. More than half (59%) of the farmers were farm owners, nearly one-third (26%) were tenants, and 15% were both owners and tenants. Based on their farm hectares and cropping season, a majority (73%) were earning Php 120,000 (~US$2290.27) at most by planting biotech corn during the dry season (based on the cost of biotech corn seeds, price of harvested biotech corn, and estimated expenses from farming biotech corn based on hectares and cropping season). Most of them stated that their main source of income is growing biotech corn, and emphasized how this crop increased their harvest and profit, thereby enabling them to pay their debts and support their family.

For the three municipalities, the usual practice was to buy and sell biotech corn from traders. According to a majority of farmers interviewed, traders often visit their barangays to sell biotech corn seeds and buy harvested biotech corn as well. The traders also offer loans to farmers who cannot afford to buy seeds in cash. Come harvest time, the charge for the seeds with corresponding interest will be deducted from the traders' overall payment for the produce. Looking at the bigger picture, traders serve as the farmers' middlemen, guaranteeing them a constant supply of biotech corn seeds and a regular buyer of their harvest. It is for this reason that most (74%) of the farmers purchase their biotech corn seeds from traders and a majority (84%) sell their harvest to traders as well. Meanwhile, less than one-third purchase or acquire their biotech corn seeds from seed companies (20%), cooperatives (18%), and town markets (11%). A few farmers purchase or acquire their seeds from barangay captains (4%), millers (4%), and agricultural technicians (2%). A few farmers also sell their biotech corn harvest to cooperatives (10%), town markets (8%), barangay captains (6%), and millers (5%). These numbers clearly show how the traders dominate the market channels of the farmers, thereby indicating their huge influence on the farmers' income and biotech corn adoption.

3.2. Biotech Corn Farmers' Perceived Correctness of the Ban on Biotech Crops

This study focused on exploring the decision-making process and various factors that may affect how farmers perceive the restrictive policy of banning biotech crops in the Philippines (2015 Supreme Court's Ban on biotech crops). Results of the survey indicated that among the 111 biotech corn farmers interviewed, 46% think that implementing the ban was an incorrect decision, and 35% indicated that implementing the ban was a correct decision, while the remaining 19% were unsure (Figure 2).

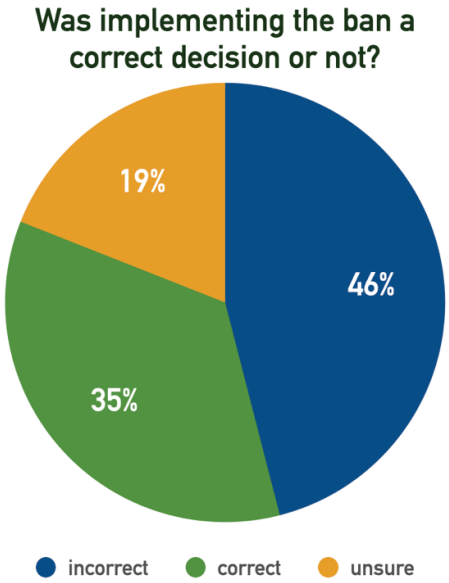

Figure 2. Biotech corn farmers' perceived correctness of the 2015 biotech ban.

In order to further understand the bifurcation among the farmers' responses, correspondence analysis and chi-square test were conducted between their ban perception and desire to continue biotech corn adoption (Figure 3). It was found that farmers who perceived the ban as incorrect would continue their adoption. Meanwhile, farmers who perceived the ban as correct were unsure whether they would continue their adoption or not.

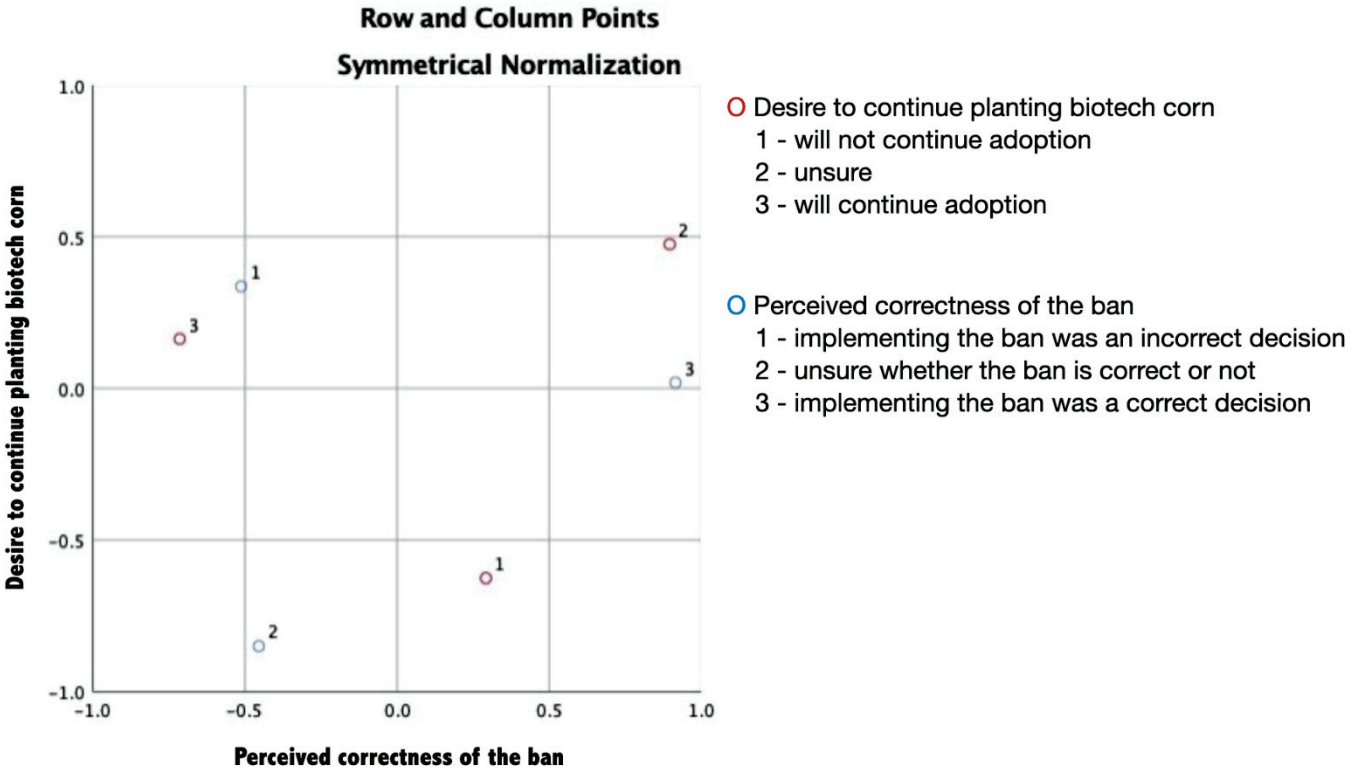

Figure 3. Correspondence analysis of farmers' perceived correctness of the biotech ban and desire to continue biotech corn adoption.

The bifurcation of the sampled group relative to perceived correctness of the ban may hint at the existence of possible factors that have induced different effects on individual farmers. Various internal influences (such as previous and current experiences and beliefs), as well as external influences (such as family, community, market situation, and local/national policy implementations), may affect an individual's perception. The succeeding sections deal with identifying the main factors influencing the farmers' perceptions and attitudes towards the ban.

3.3. Exploratory Factor Analysis of Candidate Influential Factors

A total of 30 variables were used in this study as predictors of farmers' perceived correctness of the ban. Of those, 6 variables comprise the decision-making stages, 16 variables represent internal factors, and 8 variables represent external factors. To determine how each of these variables relates to each other, an exploratory factor analysis was carried out (Table 2).

There were five latent factors that emerged. Most variables in Factor 1 coalesce to a common theme of outside influencers—co-farmers, family, and barangay/province—and were thus termed external factors. On the other hand, variables in Factor 2 correspond to internal influences and were referred to as internal factors. Variables in Factor 3 relate to farmer practices and gained experiences and were labeled farmer practices and experiences, while Factor 4 encompasses the decision-making stages and variables in Factor 5 as external knowledge sources.

Table 2. Exploratory factor analysis for all the variables used in the study.

Factor	Eigenvalue
Factor 1: External factors	
Beliefs on acceptability of biotech corn in barangay or province	0.747
Experiences of co-farmers in planting biotech corn	0.837
Personal information regarding planting and purchasing biotech corn seeds	0.412
Support of family in planting biotech corn	0.533
Perception or opinion of family regarding biotech corn	0.689
Situation of co-farmers who are planting biotech corn	0.769
Situation after planting biotech corn	0.486
Factor 2: Internal factors	
Benefits of planting biotech corn	0.667
Satisfaction in planting biotech corn	0.436
Personal experiences in planting biotech corn	0.439
Usage of income from biotech corn	0.686
Personal information regarding planting and purchasing biotech corn seeds	0.573
Situation of economic demand of biotech corn in the market	0.776
Situation after planting biotech corn	0.496
Factor 3: Farmer practices and experiences	
Sources of information about biotech corn	0.449
Knowledge about biotech corn	0.770
Knowledge about planting practices of biotech corn	0.702
Knowledge about the requirements needed to plant biotech corn	0.625
Attitude towards planting biotech corn	0.637
Factor 4: Decision-making stages	
Desirability to plant alternative types of crops	−0.744
Likelihood to buy biotech corn seeds	0.731
Desire to continue planting biotech corn	0.489
Likelihood to sell and promote biotech corn	0.604
Perceived correctness of the ban	−0.678
Factor 5: External knowledge sources	
Knowledge about news on biotech corn (e.g., TV news and newspaper reports)	0.426
Knowledge about the ban on planting biotech corn and *Bt* eggplant	0.756
Attitude towards positive effects of biotech corn on environment and health	0.456
Attitude towards the negative effects of biotech corn on the environment and health	0.805

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Farmers who have are highly influenced by external factors (Factor 1) are more predisposed to be highly influenced by internal factors because of their situation after planting biotech corn, and personal information regarding planting and purchasing biotech corn seeds. External factors (Factor 1) are strongly correlated with the experiences and situations of co-farmers in planting biotech corn, and the acceptability of biotech corn in barangay or province, which shows that aside from economic considerations, farmers also accord high importance to their fellow farmers and communities with regard to the crop they are collectively planting. Meanwhile, internal factors (Factor 2) are strongly correlated with the situation of economic demand of biotech corn in the market. Farmer practices and experiences (Factor 3) are strongly correlated with knowledge about biotech corn and planting practices of biotech corn, thereby emphasizing that farmers accord high importance to fully knowing and understanding their crop and how it affects their farming practice. In addition, the decision-making stages (Factor 4) have an inverse relationship with the first stage of decision-making (desirability to plant alternative types of crops) and the farmers' perceived correctness of the ban. Lastly, external knowledge sources (Factor 5) are strongly correlated with the farmers' knowledge about the ban on planting biotech corn and *Bt* eggplant and attitude towards the negative effects of

biotech corn on the environment and health (which were stated in the ban but were eventually disproven by scientists and major scientific organizations worldwide based on published scientific data regarding biotech crops).

3.4. Relationship of Decision-Making Stages with Perceived Correctness of the Ban

To determine the effects of the farmers' decision-making stages on perceived correctness of the ban, a Spearman correlation was conducted (Table 3). All the stages emerged to be significant and were related to the farmers' perceived correctness of the ban, except for Stage 2 (level of familiarity and knowledge of biotech and non-biotech crops).

Table 3. Spearman correlation of decision-making stages and farmers' perceived correctness of the ban.

Variable	Estimate	Significance
Desirability to plant alternative types of crops	0.359 **	0.000
Level of familiarity and knowledge of biotech and non-biotech crops	0.015	0.873
Level of benefit derived from biotech corn	−0.211 *	0.026
Likelihood to buy biotech corn seeds	−0.375 **	0.000
Desire to continue planting biotech corn	−0.359 **	0.000
Likelihood to sell and promote biotech corn	−0.300 **	0.001

* significant at $p < 0.05$ level; ** significant at the $p < 0.01$.

3.5. Relationship of Internal and External Factors with Perceived Correctness of the Ban

To further understand which factors affect farmers' ban perception, the 24 pre-identified influential factors were used as predictors in an ordinal regression model (Table 4). Among the internal factors, capital, knowledge about the requirements needed to plant biotech corn, attitude towards the negative effects of biotech corn on the environment and health, satisfaction in planting biotech corn, and usage of income from biotech corn were found to have significant effects towards farmers' ban perception. Most of the variables here fall within the latent internal factors (Factor 2) and farmer practices and experiences (Factor 3) in the previous exploratory factor analysis. Individual farmer profile characteristics have been identified in earlier studies to affect farmer participation in agricultural policies [32]. Meanwhile, personal information regarding planting and purchasing biotech corn seeds, support of family in planting biotech corn, and perception or opinion of family regarding biotech corn were external factors that have significant effects on the farmers' ban perception. All of these identified significant factors fall within the latent factor of external factors (Factor 1) in the factor analysis, which shows a good alignment between the two analyses conducted. These external factors are consistent with previous studies on farmer participation in agricultural policies [32,33]; however, the alignment between the conclusions of these previous studies are not straightforward [34,35]. Thus, context-specific details are highlighted as an important factor in understanding policy support [32].

Table 4. Ordinal regression [a] to determine the relationship of internal and external factors to farmers' perceived correctness of the Supreme Court's Ban on biotech crops.

Variable	Estimate	Odds Ratio	Significance
Internal Factors			
Time	−0.593	180.94%	0.101
Capital	1.003	36.68%	0.008 **
Sources of information about biotech corn	−0.354	142.48%	0.251
Knowledge about biotech corn	0.554	57.46%	0.163
Knowledge about planting practices of biotech corn	−0.77	215.98%	0.057
Knowledge about the requirements needed to plant biotech corn	−0.954	259.61%	0.011 **
Knowledge about news on biotech corn (e.g., TV news and newspaper reports)	−0.41	150.68%	0.098
Knowledge about the ban on planting biotech corn and *Bt* eggplant	−0.104	110.96%	0.624
Attitude towards biotech corn	−0.163	117.70%	0.622
Attitude towards positive effects of biotech corn on environment and health	−0.345	141.20%	0.161
Attitude towards the negative effects of biotech corn on the environment and health	0.944	38.91%	0.005 **
Benefits of planting biotech corn (e.g., increase in income)	0.499	60.71%	0.185
Satisfaction in planting biotech corn	−1.517	455.85%	0.004 **
Personal experiences in planting biotech corn	−0.342	140.78%	0.325
Beliefs regarding acceptability of biotech corn	−0.149	116.07%	0.595
Usage of income from biotech corn	1.379	25.18%	0.006 **
External Factors			
Acceptability of biotech corn in barangay or province	0.612	54.23%	0.103
Experiences of co-farmers in planting biotech corn	−0.04	104.08%	0.917
Personal information regarding planting and purchasing biotech corn seeds	1.232	29.17%	0.017 **
Support of family in planting biotech corn	−0.775	217.06%	0.047 *
Perception or opinion of family regarding biotech corn	−0.852	234.43%	0.037 *
Situation of co-farmers who are planting biotech corn	−0.382	146.52%	0.212
Situation of economic demand of biotech corn in the market	−0.489	163.07%	0.075
Situation after planting biotech corn	0.224	79.93%	0.523

* significant at $p < 0.05$ level; ** significant at the $p < 0.01$. [a] Link function: Cauchit: $\tan(\pi(F_k(x_i) - 0.5))$ Psuedo R-squared: Cox & Snell: 0.316; Nagerlike: 0.361; McFadden: 0.183 Test of parallel lines: Chi-square = 8.876, df = 24, sig = 0.998 Model fit: Chi-square = 42.191, df = 24, sig = 0.012.

4. Discussion

The Philippines is one of the frontrunners of agricultural biotechnology in Southeast Asia, having been the first Asian country to approve the cultivation and commercialization of two important genetically engineered crops (*Bt* corn in December 2002 and Golden Rice in July 2021). The Philippines also approved *Bt* eggplant—another genetically engineered crop first planted in Bangladesh that has brought benefits to many farmers and consumers—in July 2021 for food, feed, and processing. These recent approvals did not have a precedent in the years prior to 2020. In fact, the Philippine Supreme Court (SC) issued a ban on cultivating biotech crops in December 2015, but it was eventually lifted in July 2016, not even a year after its implementation, because of appeals from scientists and scientific organizations worldwide. One of the most important matters that need to be considered is how the primary adopters of biotech crops perceive this ban and how this would affect their future biotech crop adoption. This paper contributes to this issue by analyzing the perception and attitude of Filipino biotech corn farmers on the biotech ban.

4.1. Two Major Themes of Farmer Perception on the Ban: Livelihood Sustainability versus Law Abidance

Almost half (46%) of the biotech corn farmers answered that implementing the ban was an incorrect decision. A common reason that these farmers disagree with the SC's decision is that they have been planting biotech crops for more than a decade and they have not seen or felt any negative effects on their health and environment. It is also for this reason that a lot of the biotech corn farmers are seeking evidence from the government first before they believe and adhere to the ban. They are also saying that planting biotech corn is their number one source of income, from which they have reaped higher yields than the white corn they were planting previously; thus, stripping this crop from them and other rural communities in their province would have negative consequences on their lives. The farmers also emphasized that planting biotech corn is less laborious, and it has significantly reduced their pesticide application; hence, they are appealing for the government to provide alternative programs or other high-yielding crops applicable to their situation if the ban on biotech crops will persist. The following testimonials reflect the farmers' perspectives:

> *"The government will not subsidize the losses that we will suffer when we shift to non-biotech corn. The technicians have studied this crop, and we believe in what they advise because we can see for ourselves the good harvest it brings".*
>
> *"I continued to plant biotech corn because the government did not give any alternative seeds to sow, so we have no choice in the matter".*
>
> *"I have no choice but to plant biotech corn. If I switch to an alternative crop, all the pests will come to my farmland and my crops will get destroyed".*

Lastly, since the farmers think that they have the most direct experience in using and handling biotech corn, they strongly feel that they should be involved during the initial stages of any policy framing that involves this agricultural technology. They felt wrongly treated for being left out when they are the number one adopters of this biotech crop. For the 19% who were unsure whether the ban was correct or not, they are torn on whether they should adhere to the law or maintain the good livelihood they are experiencing with biotech corn. However, it is apparent from their interviews that they are also appealing to the government to provide an alternative crop that can match the high standards set by biotech corn. On the other hand, 35% indicated that implementing the ban was a correct decision. A common theme for these farmers is their desire to follow the law and their trust in the SC's decision. They believe that the government has done the necessary research and legal procedures before implementing the ban. However, many of the farmers are still voicing their appeal to government leaders for an alternative crop that can match the high standards set by biotech corn in their province. They were also saying that they will continue to plant biotech corn if seeds are still available:

> *"If biotech corn is still available in the market, we will still plant it; but if we can no longer find retailers/sellers for it, then we will stop planting".*

Based on the correspondence analysis, farmers who perceive the ban as incorrect would continue their adoption, whereas farmers who perceive the ban as correct were unsure whether they would continue their adoption or not. This indicates that even farmers who want to abide by the law as discussed earlier are not fully decided on whether to completely stop their biotech corn adoption. This bifurcation of farmers' perceived correctness of the ban shows an interesting take regarding how compliance and attitudinal change happen among farmers when a restrictive agricultural policy is implemented. To understand this better, we next sought to understand the farmers' decision-making process pertaining to the ban and the main factors which affected their decision-making.

4.2. Farmers' Decision-Making Process and Factors Affecting Farmers' Ban Perception

The first stage of decision-making in CDM (i.e., the needs recognition stage) compares an adopter's current situation with an alternative state usually encountered in the environment. Oftentimes, this falls within the first impression type of perception which may or may not affect individuals, depending on their thought process. This was termed "automatic processing" since needs recognition is attributed to an individual's subconscious level [36]. Here, the farmers' current state is biotech corn farming, and the alternative state is the adoption of non-biotech farming. It was found that the biotech corn farmers' desire to plant alternative crops is directly related to their ban perception, such that farmers who have expressed a higher desire to try planting non-biotech crops perceive the ban as being a correct policy implementation, while those who expressed low levels of desire to try planting non-biotech crops perceive the ban as an incorrect policy. This is clearly shown in the heat diagram (Figure 4) which was generated from the Spearman correlation analysis in Table 3. Correlation estimates were transformed into a color value based on a two-color gradient with green representing increasing magnitude of negative relationship and red representing increasing magnitude of positive relationship. The separation in the distribution of the farmers in terms of ban perception is consistent with this result.

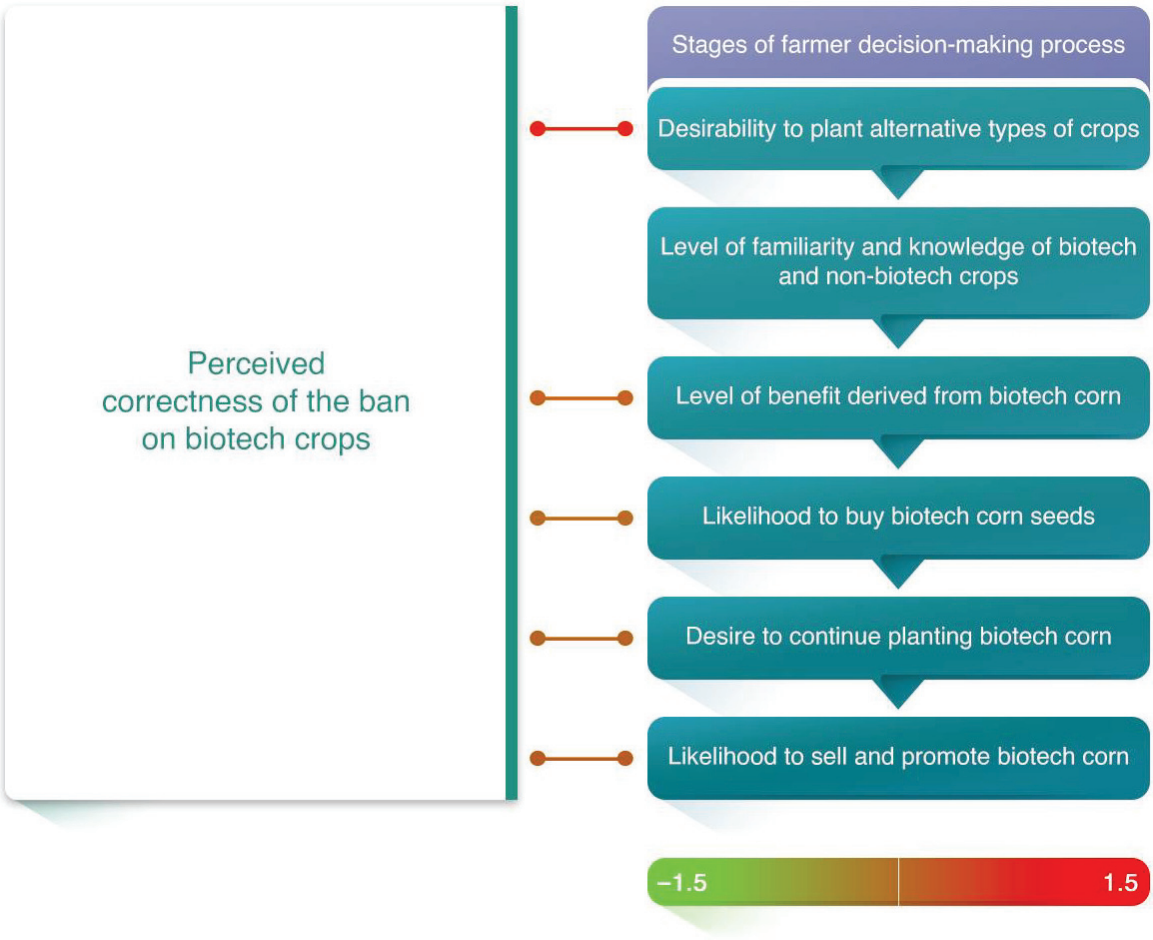

Figure 4. Heat diagram of the biotech corn farmers' decision-making stages and their ban perception.

In terms of compliance, farmers who adhere to the law regardless of their personal satisfaction, beliefs, and experiences, and exhibit a positive attitude towards the ban conform to the moral picture described in the Deterrence Theory [13]. The level of punishment also greatly affects people's compliance with the law. In this case, there was no actual penalty enforced by the law for biotech farmers who did not abide by the biotech ban, which may have greatly influenced the farmers' decision to continue adoption despite a

nationwide planting restriction. Meanwhile, in terms of mental processing of persuasion and attitude change, two routes are presented in the Elaboration Likelihood Model (ELM). Farmers who exhibit bottom-up thinking or objective elaboration are those who value their past experiences, satisfaction, and beliefs. These farmers rationalize external and internal inputs (such as knowledge of the ban) and tend to ascribe lower priority to first impressions or suggestions from credible information sources. On the other hand, farmers who exhibit top-down thinking or biased elaboration highly value inputs from credible sources and tend to prioritize this over other factors. This bifurcation of the population therefore leads to the formation of the dominance of extreme answers relative to their perception of the correctness of the ban, such that bottom-up thinkers (i.e., objective elaborators) are predisposed to think that the ban is incorrect, whereas top-down thinkers (i.e., subjective elaborators) indicate that the ban is correct.

An inverse relationship can be observed between the farmers' ban perception and each of the succeeding stages of pre-purchase evaluation (level of benefit derived from biotech corn), purchase (likelihood to buy biotech corn seeds), adoption (desire to continue planting biotech corn), and post-adoption evaluation and divestment (likelihood to sell and promote biotech corn) (Figure 4). When farmers perceive the ban as incorrect, they are more likely to ascribe positive values to the benefits they derive from biotech corn and the continued purchase, adoption, selling, and promotion of this crop. This indicates that the farmers' level of benefit from, and satisfaction with biotech corn is the primary driver of their perception of a restrictive ban that has the potential to affect their livelihood. Indeed, such dispositional behavioral factors affecting the adoption of agricultural policies have been reported previously [33,34].

In the theory of cost–benefit analysis, decisions are evaluated based on their consequences. Based on the data of this study, there are three main benefits to adopting biotech corn since 2002. First, the economic aspect: farmers generally earn US$2290.27 from planting biotech corn during the dry season. They were able to achieve this due to the innate resistance of biotech corn to major pests, thus translating to an increase in yields and less pesticide application. They also said that this income is comparably higher than the income they earn from planting white corn, which they also reported to be consistently eaten by pests when they were still planting it in the past. Second, the social aspect: almost all the farmers reported that aside from the increase in income, they were able to see the positive impact of biotech corn adoption within their rural communities. Based on the farmer interviews, these came in the form of improved houses as well as better access to education and healthcare. Furthermore, the reduction in labor allowed the aging farmers to continue working on the farm. Indeed, there is a direct relationship between the number of years planting biotech corn and the farmers' ban perception (Table S2), which means that the longer these farmers have been growing biotech corn, the more they will perceive the ban as incorrect. This sustained improvement within their social group is also one of the major reasons that biotech corn adoption is a success story among these farmers. Third, the environmental aspect: since biotech crops such as biotech corn reduce pesticide application, this also significantly reduces GHG emissions, as evidenced in previous studies [37–39]. These benefits comprise the three pillars of sustainable agriculture. Meanwhile, the costs of non-adoption as a result of the ban would also translate to three major consequences. The farmers' major source of income and livelihood would be disrupted, which would then result in a lack of resources for individual and social improvement, and a potential increase in pesticide application again. This cost–benefit analysis shows why most of the decision-making stages had an inverse relationship with their ban perception and why most farmers would want to continue biotech corn adoption despite a nationwide planting restriction. A recent study that conducted a risk–benefit analysis of genetically modified food also concluded that the economic, environmental, and health benefits definitely outweigh the costs; hence, biotech crops should be more accepted by the public, and phobias related to genetically modified organisms should be dispelled [40].

While the decision-making process of the farmers regarding the ban has been clarified, it is also important to understand the factors which affected their ban perception. A heat diagram was also generated based on the ordinal regression in Table 4 to clearly show the positive and negative relationships between the significant influential factors and the farmers' perceived correctness of the ban (Figure 5). Regression estimates were transformed into color values in a similar fashion as Figure 4. The results of the factor analysis and ordinal regression strongly aligned with each other and can be grouped into two major themes: the internal and external influential factors. For the internal factors, capital, income, and attitude towards the negative effects of biotech corn on the environment and health (as indicated in the ban) have a positive relationship with the farmers' ban perception, which means that when farmers highly value these factors, they are more likely to perceive the ban as correct. Since capital and income are very important for farmers, most especially in developing countries, maintaining their jobs is considered a top priority, which may be the reason that these variables have a direct relationship with ban perception. However, as seen in the correspondence analysis, farmers who perceive the ban as correct are not fully decided on whether to stop their adoption. This is because their biotech corn adoption yields three major benefits, the most important of which are the increase in yields and income. Meanwhile, the information provided in the ban pertaining to the safety of biotech crops on the environment and health was seen as a factor that leads to a positive ban perception. Even though this is the case, many farmers emphasize that they have been adopting biotech corn for a long time and they have never seen or felt any negative effects on their health and environment, as evidenced in the following testimonials:

> *"The health issues which they use as a basis for banning biotech corn are unfounded. The current trend in agriculture is continued research to help the farmers, so we should use the technology available".*

> *"The government should provide concrete evidence on why they are banning biotech corn and other biotech crops. If they can really prove that biotech corn is harmful to our health and the environment, then that is only the time to ban it in our country".*

Furthermore, major scientific organizations worldwide have attested to the safety of biotech crops. The National Academy of Sciences (Washington DC) reported that "there is no difference between traditional and biotech crops in terms of risks to human health, nor any negative effects on the environment" [41]. In a survey conducted by the European Union that covered 900 reports on research pertaining to the impact of biotech crops on human health, it was also reported that they are no more risky than conventional breeding techniques [42]. These refer to the substantial equivalence of biotech crops, which means that they are as safe and effective as their conventional crop counterparts. Taken together, the reports of these major scientific organizations and biotech farmers' testimonials highlight the safety of biotech crops and that the ban had no concrete scientific basis. On the other side of internal factors, knowledge about the requirements needed to plant biotech corn and satisfaction in planting biotech corn have an inverse relationship to farmers' ban perception. This means that when biotech corn farmers highly value these factors, they are more likely to perceive the ban as incorrect. The results of the correspondence analysis concur with this since farmers who perceive the ban as incorrect are more inclined to continue their biotech corn adoption. Indeed, previous studies on biotech farmers emphasized the importance of knowledge and satisfaction for continued adoption [27,28].

Figure 5. Heat diagram of significant internal and external factors with the farmers' ban perception.

For the external factors, farmers who highly value their personal information regarding planting and purchasing biotech corn seeds are more likely to perceive the ban as correct. In the CDM, this factor falls under the category of personal influences, which means that the behaviors of farmers are affected by those they closely associate with [29]. Furthermore, they will respond to the perceived pressure of conforming to norms and expectations provided by their immediate community. In the context of the study, the personal influences of biotech corn farmers when it comes to their farming practices are their co-farmers, farmer leaders, and agricultural technicians, which are also called reference groups in the CDM. The perceived pressure to conform to the law based on what these reference groups are thinking may have been one of the major reasons that this factor emerged as critical in their ban perception. On the other hand, farmers who highly value the support and perception/opinion of family regarding biotech corn are more likely to perceive the ban as incorrect. In this study, 89% of farmers are married and 47% had 6 to 11 household members. As breadwinners, these farmers prioritize the income they are obtaining from planting biotech corn to support their families. Hence, it is not surprising that farmers who highly value their families will perceive the ban as incorrect, as evidenced by the following testimonial:

> *"I benefit a lot from biotech corn. The money I provide to my family mainly comes from the biotech corn that I sell".*

5. Conclusions and Recommendations

As the prime stakeholders in the agribiotech industry, biotech farmers' perspectives are a valuable source of information regarding policy changes and strategies, market situation, and societal impacts. Had the 2015 Philippine Supreme Court ban on biotech crops persisted, severe impacts on farmers' quality of life and income are anticipated and thereby prompt research initiatives targeting key interactions among factors affecting farmer perspectives and decision-making. Results from this analysis have highlighted the critical importance of farmer consultations in policy framing and implementation to avoid

conflicts and farmer indifference. Indeed, farmer involvement in policy framing has proven to be a valuable piece of information [43,44].

This paper determined the relationship between the biotech corn farmers' decision-making stages and the perceived correctness of the ban. While farmers' perspectives at the initial stage of decision-making (need recognition stage) appear to separate the farmers into two distinct groups, the succeeding decision-making stages show otherwise. This hints at the resistive behavior among biotech corn farmers towards restrictive agricultural policies, more specifically towards the Supreme Court's ban on biotech crops. This, therefore, confirms the pragmatic nature of biotech corn farmers [27]. Taken together, it is shown that within the context of the 2015 Philippine Supreme Court's ban on biotech crops, biotech corn farmers thus have significant influences from their decision-making stages, internal factors, and external factors. A summative heat diagram was generated to illustrate all the significant decision-making stages and influential factors and their positive or negative interactions with the farmers' ban perception. (Figure 6). The dilemma of choosing whether to abide by the law or to sustain their livelihood is apparent in the results of this paper. The paper has also highlighted the importance of analyzing restrictive agricultural policies through different theoretical lenses which can explain the concepts of deterrence, compliance, persuasion, and cost–benefit analysis. This approach can potentially extend to future studies focusing on restrictive policies. Furthermore, the findings of this paper could be a pivotal source of information for farmer-informed data regarding agricultural policy support and product adoption. This, therefore, prompts immediate attention among policymakers and local government units who develop and improve agricultural policies regarding biotech crops, since the observed behavior among farmers may incite disagreements in policy implementations. Hence, better consultation and communication between farmers and policymakers should be carried out in future policy framing and implementation regarding biotech crops.

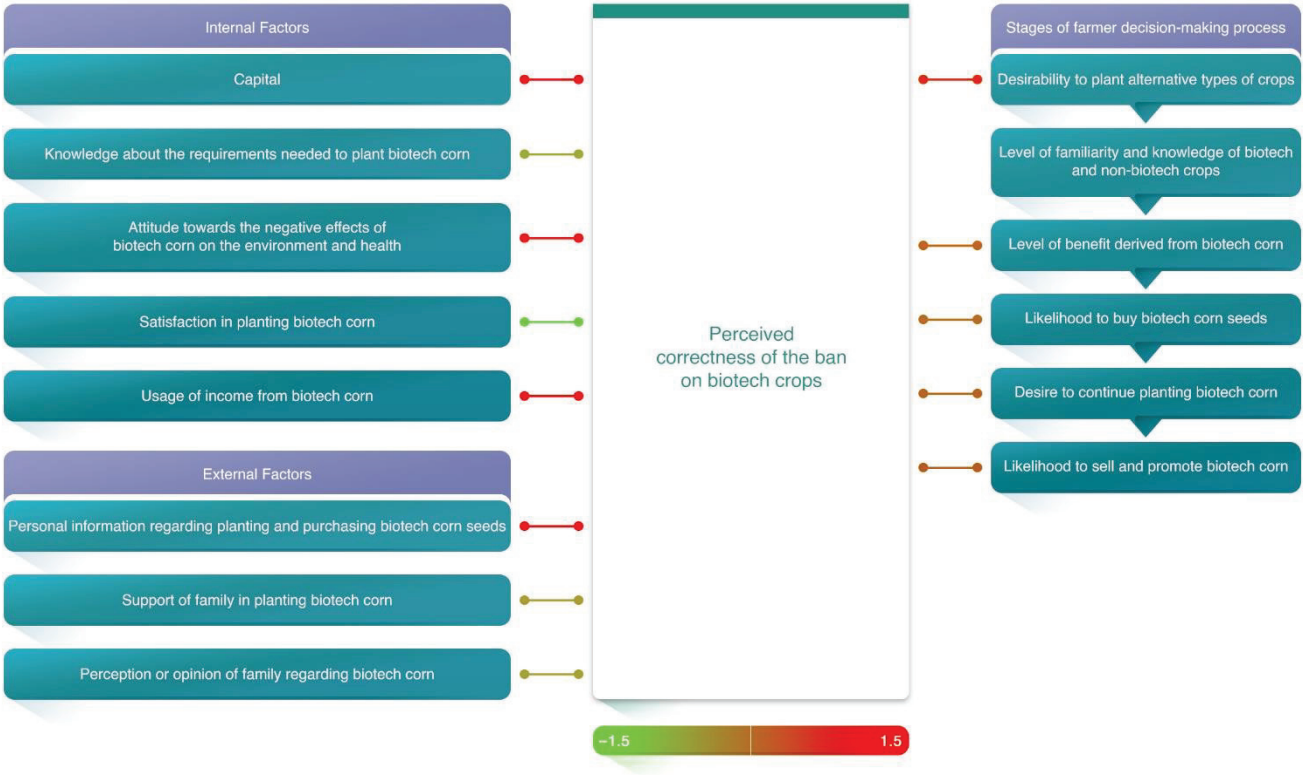

Figure 6. Integrated interaction map of significant internal and external factors (left), and decision-making stages (right) affecting farmers' ban perception.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14137919/s1. Table S1: Socio-demographic and farm-related data of the sampled biotech corn farmers in Pampanga, Philippines; Table S2: Spearman correlation of socio-demographic and farm-related data with farmers' perceived correctness of the ban.

Author Contributions: Conceptualization, methodology, validation, formal analysis, investigation, resources, data curation, and writing—original draft preparation: C.M.G. and W.J.F.A.; writing—review and editing, C.M.G., W.J.F.A. and K.L.M.; visualization, C.M.G. and W.J.F.A.; supervision, K.L.M.; funding acquisition, C.M.G. and K.L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Hiroshima University TAOYAKA Program through the Program for Leading Graduate Schools of the Ministry of Education, Culture, Sports, Science and Technology of Japan.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Graduate School of Humanities and Social Sciences, Hiroshima University (Approval code: HR-LPES-000277).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Research data in this paper are not publicly available due to privacy restrictions, but they can be requested from the corresponding author.

Acknowledgments: This paper is based on a draft previously presented at the 31st Triennial International Conference of Agricultural Economists (ICAE), which was held last August 2021 virtually. The paper was then revised by incorporating feedback from the conference. The authors wish to thank Ruth Joy Sta. Maria for her expertise in creating the figures for this article. The authors are also grateful to all the farmers who participated in the study. Lastly, Clarisse Gonzalvo would like to thank the Japanese Government for her MEXT scholarship, which facilitated her Ph.D. study at Hiroshima University, Japan.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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Impact of Farmer Field School on Crop Income, Agroecology, and Farmer's Behavior in Farming: A Case Study on Cumilla District in Bangladesh

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Abstract: The Farmer Field School is a season-long training for farmers involving participatory activities and interactive learning with the doctrine of integrated pest management and agroecosystem analysis. It has become a popular education and extension approach worldwide. This study tried to evaluate the FFS as a vehicle for sustainable agriculture which has economic viability, ecological soundness, and social acceptability. The study aimed to analyze the impact of the FFS on crop income, agroecology, and farmers' behavior in farming. The empirical models, such as propensity score matching, Mahalanobis distance matching, and difference in differences, were applied for estimating the impact of FFS on crop income, more specifically, real income from brinjal. The environmental impact quotient was used to assess the agroecological impact of using pesticide, and a graded response model was used to investigate farmer behavioral changes in farming. The treatment effect based on the empirical models has shown a positive, significant effect on crop income. The findings also revealed that FFS farmers had a lower agroecological impact from pesticide use, and their behavior in farming practices was improved. Therefore, FFS was demonstrated to be a key strategy in strengthening agricultural extension services, which will contribute to promoting sustainable agriculture.

Keywords: farmer field school; integrated pest management; crop income; agroecology; sustainable agriculture

Citation: Bhuiyan, M.M.R.; Maharjan, K.L. Impact of Farmer Field School on Crop Income, Agroecology, and Farmer's Behavior in Farming: A Case Study on Cumilla District in Bangladesh. *Sustainability* **2022**, *14*, 4190. https://doi.org/10.3390/su14074190

Academic Editor: Piotr Prus

Received: 31 January 2022
Accepted: 28 February 2022
Published: 1 April 2022

1. Introduction

Non-formal agricultural education has played a vital role in the development of a sustainable agriculture sector in many developing countries where the emergence of farmer field school (FFS) was the influence for this method. The FFS approach, as pioneered by the Food and Agriculture Organization (FAO), is a way to introduce farmers to discovery-based learning for addressing the pest management issues. Rola et al. [1] identified FFS as a season-long training of farmers involving participatory activities, hands-on analysis, and decision making. It has been developed as a 'bottom-up' extension approach based on experiential and reflective learning to strengthen farmers' problem-solving capabilities by highly qualified facilitators working with farming communities, as judged by Larsen and Lilleor in 2014 [2]. According to the FFS guidance document [3], FFSs were mostly constructed for smallholder farmers who are resource-poor and often have limited access to education, information, extension services, and market access. The approach mandated to fill the gap in local knowledge, conduct holistic research on the agroecosystem, and increase awareness and understanding of phenomena that are not obvious or easily observable. The approach is very much practical, and farmers are taught directly in the field and the

physical place is normally close to the field under a tree or a small shelter. FFS learning was designed based on the theory of adult learning, theory of constructivism, and theory of experiential learning (Figure A1). Integrated pest management (IPM) and agroecosystem analysis (AESA) are the core activities of FFS, other activities are designed to support it [3] and IPM is treated as an economic threshold concept of FFS.

FAO has imputed a lot of effort in the incubation, development, and spread of FFS from the outset. FFS began in Southeast Asia and quickly spread to other parts of Asia in the early 1990s, Africa in the mid-1990s, and then the rest of the world [3]. The approach was schemed to respond to the lack of awareness among the Asian farmers relating to agricultural ecology, especially the relationship between insect pests and their natural enemies [4]. The first IPM-FFSs were started in 1989 in Indonesia to reduce farmer reliance on pesticides in rice [5]. It was originally implemented to address the challenge of ecological heterogeneity and integrated pest management that would allow farmers to reduce pesticide use, improve crop management, and secure better profit margins [6]. The agro-ecological content and experiential methodology of the FFS approach have influenced extension programs in various countries [4]. Now, the program has been actively forwarded by the FAO in the context of measures designed to enhance food security, farmer income, climate change adaptation, and agricultural sustainability [7]. The FAO continues to support FFS in the different regions, through expertise, networking, and funding [8].

Bangladesh is one of the most densely populated, smallholder farms, and intensive agricultural countries, with approximately 87% of rural inhabitants' income derived from agricultural activities [9]. Agriculture is the largest sector of employment in Bangladesh. 40.6% of the total working population is involved in the agriculture sector, contributing 14.23% of the national gross domestic product [10,11]. Even so, the farming community in Bangladesh has increasingly been threatened by population pressure on the use of arable land and natural resources; to produce more to meet the increasing demand of an ever-growing population with low per capita cultivable land of 0.05 hectare [11]. Hence, farmers use more chemical inputs, such as fertilizers to produce more and pesticides to safeguard crops against harmful insects, pests, and diseases. Only 4% of farmers are formally trained in pesticide use and over 47% of farmers overuse pesticides in Bangladesh [12]. The irrational use of pesticides pollutes the ecosystem through contaminating soil, groundwater, and surface water [13]. That is to say, the overuse of chemical inputs has a negative impact on soil, health, and the environment and leads to decreased agricultural income due to raised costs. To tackle this challenge, it is required to design an effective program that goes beyond the dissemination of the concept of IPM and AESA among farmers, helps them to get organized, and empowers the farming community in problem-solving. The FAO-induced FFS could be able to satisfy these needs which require investment to aware and educate farmers for good agricultural practices.

The agricultural extension system in Bangladesh has a long history of evolution which has taken different shapes over time [14]. The traditional training and visit extension approach which is "top-down" in nature was failing most of the developing countries to address the issue of overusing pesticides [14], and Bangladesh is not an exception. Afterwards, there was a need for a more participatory "bottom-up" extension approach considering the ecological aspect with a principle of integrated pest management, and the emergence of FFS met the situation demand policy [14,15]. In Bangladesh, the first Farmer Field Schools were organized in the early 1990s, assisted by the FAO intercountry program for rice [16]. It has now been conducted in different agricultural crops; FFS on vegetables is one of them. Most of these vegetable FFSs focused on brinjal (eggplant) [17]. Brinjal is the second most important vegetable in Bangladesh in terms of both production area and yield [18], and it is a primary source of cash income for farmers. Moreover, insect and pest attack is one of the most significant hurdles to large-scale brinjal cultivation in Bangladesh [19]. Raza et al. [19] claimed that brinjal is attacked by 17 species of insects and six types of different diseases in Bangladesh, and farmers sprayed insecticides more than

40 times in a single cropping season. Thus, this study tried to evaluate the brinjal-FFS in the context of ensuring sustainability in agriculture.

The Plant Protection Wing of the Directorate of Agriculture Extension (DAE) is responsible for the implementation of FFS activities in Bangladesh. Bangladesh's government is committed to supporting the education and betterment of its farmers through a field-level educational program aimed at the empowerment of farmers and local communities [20]. Investing in farmer education is treated as a necessary complement to research and extension services and as a strategy in accumulating wealth from agriculture [21]. Moreover, returns on investments in FFS cannot be appraised until the pesticide-use externalities have been considered and properly quantified [22].

Some previous studies focused on the economic aspect of the FFS program found that the FFS participants have significantly more knowledge about IPM practices; they have the potential to improve production and productivity [23,24]. Another study by Larsen and Lilleor [2] claimed that the FFS mechanism triggers to agricultural production may have led to strong positive effects on food security, but no effect on poverty. Some studies highlighted the environmental aspect and identified that intensification of agricultural production has raised concerns about environmental facts [25] and without sustainable management of variable agroecosystems—considering the major consequences in terms of declining soil quality, soil erosion, pollution of surface and groundwater, and loss of biodiversity—no agricultural development program would be successful [21]. Studies on the social aspect asserted that FFS can led to an entry point to establishing a link between farmer education, empowerment, and a pathway toward increased well-being [26]. A recent study argued that the FFS remains relevant at the field level, helping farmers to adapt their farming practices and livelihood situation to changing circumstances, contribute to the role in rural development [8]. When the FFS program was scaled up in Bangladesh, a lot of focus was placed on evaluating the impact of the new horizon of extension policy and how farmers' behavior changed over time in relation to IPM practice.

The reviewed papers indicate the substantial impact of FFS in terms of farm productivity and production, not to differentiate trained individuals with untrained in terms of agricultural income. Some papers showed that increased knowledge of IPM led to sustainable management of agri-environment but did not find and dissociate the effect of overusing pesticides on agroecology, nor did they study the changes of farmer behavior in farming towards the pathway of social well-being. Therefore, there remains a need to balance the economy, ecology, and improvement of behavior in farming practice. Above all, sustainable agriculture requires the consolidation of economic viability, ecological soundness, and the farmer's behavioral improvement. Therefore, the impact analysis of all the domains of sustainability aims to justify the success of FFS program. Moreover, no study has been done to determine the impact of brinjal-FFS on the domains of sustainable agriculture in the selected area of Bangladesh.

Therefore, this study aims to do so as a case study on Cumilla district examining whether the FFS program, more specifically, brinjal-FFS has played a significant role in generating more crop income, maintaining agroecology, and changing farmers' behavior in farming responding to the sustainable agriculture, and therefore, tried to find the answer to the following research questions:

Does the FFS program make a difference to crop income? How are other aspects of FFS beneficial towards sustainable agriculture?

To answer these identified research questions, this study set the general objective to find the impact of FFS on crop income, agroecology, and farmer behavior in farming. The specific objectives are to analyze the difference in crop income, to assess the difference of agroecological effect of using pesticides, and to identify the behavioral changes of farmers in farming by employing a causal inference technique with a thorough robustness check.

2. Materials and Methods

2.1. Study Site

This study took place in 3 upazilas (sub-districts) of Cumilla district in Bangladesh as a case study (Figure 1). Cumilla is situated between the capital city Dhaka and the port city Chattagram and is considered as one of the hot spots for vegetable production and sales. Cumilla has a wide coverage of FFS, especially since agriculture is the main occupation of most households (49.15%) [11]. This study examined the FFS on brinjal because it is the most vulnerable crop to pests and produces fruit almost year-round. Moreover, FFS on brinjal was conducted in the selected three sub-districts of Cumilla district during the treatment year 2019. The survey took place from October to November 2020.

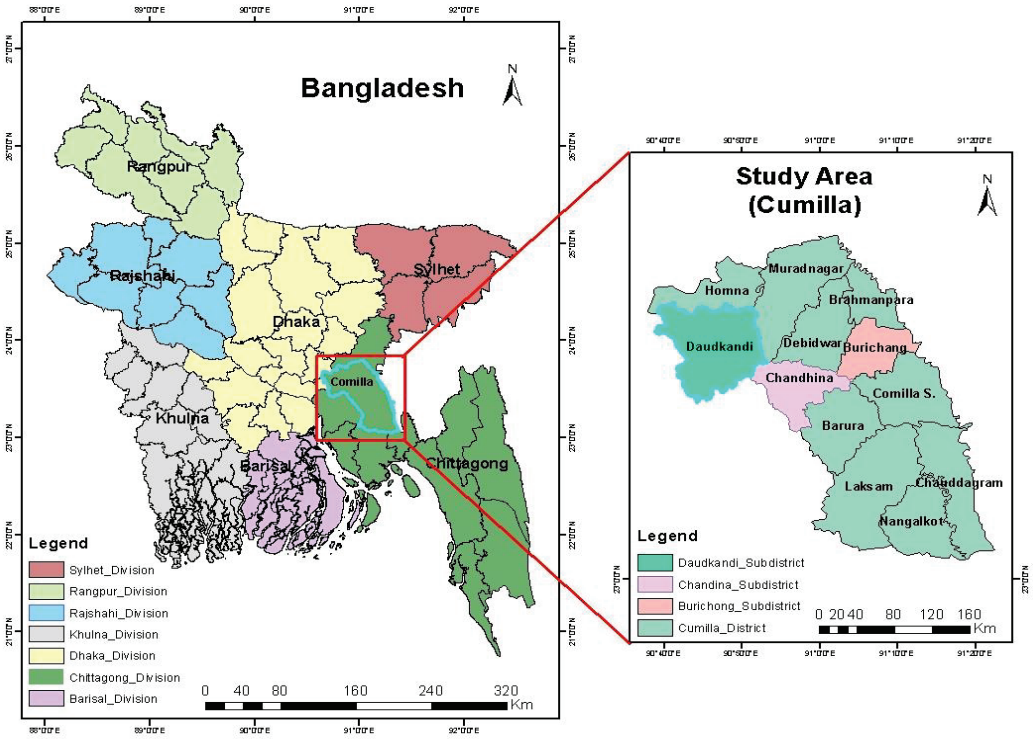


Figure 1. Study Area.

2.2. Sampling

Sub-districts, namely, Burichong, Chandina, and Daudkandi from Cumilla district, were purposively selected. The target population were the farmers who were cultivating brinjal in the selected sub-districts. A list of farmers who participated in FFS on brinjal in the treatment year was collected from the selected sub-districts. As there are some criteria for participating in the FFS program, treatment is nonrandomly assigned before participation. We strategically collected the list of common vegetable farmers (as there was no separate list of brinjal farmers) and from them brinjal farmers were identified by consulting the sub-assistant agriculture officer who usually works at the village level, from the villages where FFS on brinjal was done. Then, we constructed a sampling frame including FFS participants (75) and non-FFS brinjal farmers (636) from the sub-districts. Finally, 150 respondents were selected from the sampling frame for the interview where FFS participants were treated as treatment group (48) and non-FFS farmers were treated as the control group (86); 16 respondents were excluded as they only responded partially.

This study tried to gather data from a significant number of respondents with nearly the same farming characteristics, more specifically, brinjal farmers. Yet due to COVID-19 pandemic, this goal was not achieved. Although there have some other alternatives, it was not feasible due to lack of infrastructure, as well as a detailed questionnaire being very time-consuming.

2.3. Data Collection

As a participatory method, the data were collected via face-to-face interview by questionnaires, with semi-structured questions containing the FFS program as a treatment variable where agricultural income, field use environmental impact quotient (FEIQ) value, and farmers' behavior in farming as the outcome variables with different covariates, through an intensive survey. It is worth mentioning that the data before intervention were gathered on a recall basis. The survey was approved by the research ethics committee of IDEC, Hiroshima University.

2.4. Data Analysis

This study largely used case study leading quantitative analysis. Hollweck [27] proclaimed that a case study strategy was adopted when the researcher has no control over the conditions, contextual factors, and outcomes of an intervention. This study also attempted to outline the qualitative traits of farmer behavior in farming.

Determination of net crop income:

To determine net crop income from brinjal, the total value of brinjal production (Y) is multiplied by the average selling price (P) from which the total production cost (PiXi) is deducted. The total production cost is the summation of input quantity (x_i) multiplied by the unit cost (p_i).

$$\pi = \mathrm{P} \times \mathrm{Y} - \sum \mathrm{PiXi}$$

Calculation of real value:

For consistent comparisons of input costs and income before and after the treatment, the nominal value was divided by the January–December 2018 Consumer Price Index (CPI) of Bangladesh [28] to obtain the real value:

$$\text{Real value} = \frac{\text{Nominal Value}}{\text{CPI}} \times 100$$

Benefit–Cost Ratio (BCR):

This study calculates the benefit–cost ratio that determine the financial feasibility of the FFS program in future. To obtain the benefit–cost ratio, the following formula is used:

$$\text{BCR (Discounted)} = \frac{\text{Benifits (Value of TPP)}}{\text{Costs (Total Production Cost)}}$$

Two-sample *t*-test:

To compare the mean value and test the statistical significance of the socio-demographic characteristics, brinjal production-related information, and EIQ data, two-sample *t*-tests (two-tailed) were used. This test is essential for satisfying the matching principles, as well.

Variable Selection:

This study selected the covariates that are time-invariant in nature. Gender and education are absolutely time-invariant; age, farming experience are also treated as time-invariant due to their proportional change nature and the time variation of marital status, household size, farm hours, and other training is negligible. These covariates were selected according to the previous study of [24,29] and field reality. The selected covariates are also expected to affect the outcome variable of crop income and field use EIQ. The definition of the selected variables is shown in the Table 1.

Table 1. Variable Descriptions.

Variables	Definition
Outcome Variables:	
Crop Income	Real value of Crop Income from Brinjal (BDT)
Field Use EIQ	Value of field use Environmental Impact Quotient of pesticides
Farmer Behavior	Changes of farmer's behavioral skills in farming
Treatment Variable:	
FFS Participation	1 for participation in brinjal FFS, 0 for nonparticipation
Covariates:	
Age	Age of farmers (years)
Gender	0 for female, 1 for male
Marital status	0 for single, 1 for married
Household size	Number of family members
Education	Years of formal education
Farming experience	Length of years of farming
Farm hours	Average time spent in farm per day (hours)
Other training	1 for having training, 0 for no training

2.5. Empirical Models

2.5.1. Propensity Score Matching (PSM)

The matching approach is applied to predict causal treatment effects in a multifaceted field of study. The central role of the propensity score in observational studies is related to causal effects [30]. Ideally, the impact of an intervention would be measured with the participants by observing the outcome with and without the intervention [24]. However, we did not have both with and without FFS intervention farming data from the same farmers. Besides, to evaluate treatment effects, only comparing the mean of two separate groups is not advisable as there remains a difference in the outcome between the participant and non-participant groups even in the absence of treatment. Propensity score matching is a possible solution to the problem. Austin [31] proclaimed that an observational or nonrandomized study can be designed and analyzed using the propensity score to imitate some of the characteristics of a randomized controlled trial. Moreover, matching is likely to reduce the underlying selection bias with two assumptions—conditional independence assumption and common support assumption [32]. This study fulfills the necessary conditions to assess the impact of FFS program in terms of selecting covariates and ensure their sufficient balancing. Rosenbaum and Rubin [30] established the propensity score as the probability of treatment assignment based on observed baseline covariates. The propensity score p(x) of participation can be represented as follows:

$$\text{Propensity Score (PS), } p(x) = P\ (p = 1|x) \tag{1}$$

p is the treatment variable and x represent a set of time-invariant covariates (Table 1). In this study, the logit model is used to estimate the propensity score with balancing tests of covariates. This study performed the nearest-neighbor matching, Kernel matching, and Radius caliper (0.05) matching algorithms for checking the conformity of the results. Imbens [33] asserted that propensity score matching allows the researcher to estimate treatment effects for an individual, and the average treatment effect on treated (ATET). Even then, after matching the propensity score between treated and control groups is satisfactory with a set of covariates, we can compare the treatment effect on the outcome variable, using the following equations adopted from the study of Sanglestsawai et al. [34]:

$$\text{ATET}^{\text{PSM}} = [(y_1 \mid p = 1, p(x)) - (y_0 \mid p = 1, p(x))] \tag{2}$$

where p = participation in FFS (p = 1 if participated in FFS, and p = 0 if did not participate in FFS); y_1 = net income of the participant, y_0 = net income of the non-participant.

PSM may provide inconsistent estimates due to misspecification bias; the Inverse probability weighted regression adjustment (IPWRA) estimates are used to resolve such

issues [29]. Holmes [35] recommends applying weighted regression when working with a small sample size. Moreover, IPWRA has a double robust feature, which has a coherent impact on outcome. Even so, PSM may yield biased results due to some unobservable factors; Mahalanobis distance matching (MDM) is the effective measure to reduce the probable biasness in PSM as the distance normalized by the variance–covariance matrix of the covariates [36]. King and Neilsen [37] critique the non-robust estimates of PSM paradox which could be addressed by employing a potentially more robust approach such as MDM, which matches directly the covariate space, while PSM does not. The mathematic expression of Mahalanobis' distance is adopted from the study of King et al. [38]:

$$\mathrm{M}(\mathrm{X_i}, \mathrm{X_j}) = \sqrt{(\mathrm{Xi} - \mathrm{Xj})' S^{-1} (\mathrm{Xi} - \mathrm{Xj})} \quad (3)$$

Therefore, this study endeavored to justify the robustness of the treatment effect and reduce the bias from unobservable factors and small sample size by applying IPWRA and Mahalanobis distance matching.

2.5.2. Difference in Differences (DID)

The Difference in Differences (DID) measure the impact of a program or treatment by considering the interaction of the treatment and time variables. Larsen and Lilleor [2] argued that there might be potential bias in the cross-sectional comparison for determining impact (ATET) through PSM due to unbalanced observable; the DID estimation does not suffer such kind of biasness. This method accounts for unobservable time and group characteristics that can confound the treatment's effect on the outcome [39]. The concept of DID is adopted from Cunningham [40], as in the following equation:

$$\delta_{DID} = (\Delta \mathrm{y}|\mathrm{FFS} - \Delta \mathrm{y}|\mathrm{non-FFS}) = [y_1 \ |\mathrm{FFS} - y_0|\mathrm{FFS}] - [y_1 \ |\mathrm{non-FFS} - y_0|\mathrm{non-FFS}] \quad (4)$$

where y_1 = crop income after treatment, y_0 = crop income before treatment.

The current study intends to evaluate the impact of FFS program as a treatment on the outcome of crop income from brinjal. This study construct two groups from an indifferent sampling frame indexed by treatment status where non-FFS indicates the individuals who do not receive treatment, i.e., the control group, and FFS indicates individuals who do receive treatment, i.e., the treatment group. We collected data from individuals in two periods, where 0 indicates a period before the treatment group receives treatment, i.e., before FFS (2018), and 1 indicates a period after the treatment group receives treatment, i.e., after FFS (2020). This study used two points of data instead of multiple points to reduce the serial correlation problem highlighted by Fredriksson and Oliveira [41], having considered the parallel trends assumption and no spillover effects. In effect, FFS has no relation to agricultural income during the before-treatment period.

The DID delivers a non-experimental model for estimating the ATET by comparing the difference in outcome means between the control and treatment groups across time. Fredriksson and Oliveira [41] argued that matching of covariates may be a way to achieve a robust DID result. Therefore, this study adopted the potential treatment outcome regression model with matching of covariates to estimate the causal effect of the FFS program on crop income from Lang and Donald [42].

$$\mathrm{y_i} = \gamma_\mathrm{g} + \gamma_\mathrm{t} + \sum \beta i.Z \, gt \ + \delta \mathrm{D_{gt}} + \varepsilon_\mathrm{it} \quad (5)$$

Here, y = crop income, g = group, t = time, Z = covariates, D = treatment occurs at the group and time levels, and ε = error term.

In fact, this study tried to employ DID as a more robust technique, compared to corresponding methods for estimating economic causal inference of FFS.

2.5.3. Environmental Impact Quotient (EIQ)

The Integrated Pest Management (IPM) program of Cornell University developed a model, responding to the environmental impact of using pesticides, called the environmental impact quotient (EIQ) of pesticides. This model reduces the environmental impact information to a single value [43]. In Asia, the pesticide risk indicator model EIQ has been used in the assessment of environmental impact of Farmer Field Schools [5]. By using the field use EIQ value, this study tried to incorporate agroecological effects along with the efficacy of using pesticides through the intervention of the FFS program. The following equation based online EIQ calculator was used to find the field use EIQ value of pesticides [43]:

$$\text{Field use EIQ} = \text{EIQ} \times \%\text{ of active ingredient} \times \text{use rate} = (\text{Farmworker EI} + \text{Consumer EI} + \text{Ecological EI})/3 \quad (6)$$

The EIQ Value for Active Ingredient was found in the New York State IPM EIQ Database, the FEIQ value for pesticide is calculated by considering the average effect of *consumer, farmworker, and ecological* components [44]. To compare the FEIQ value and its components between two groups, a *t*-test was performed.

2.5.4. Graded Response Model (GRM)

The graded response model (GRM) developed by Samejima [45] is applied in the analysis of data collected from a Likert-type attitude scale. The model runs in a two-step process; the first step estimates the probability of a certain skill that an individual has chosen from the given scale by the following equation, as adopted from Aune et al. [46]:

$$\mathrm{P}*_{\mathrm{m}}(\theta) = \frac{1}{1 + e^{-1.7a(\theta - \mathrm{bm})}} \quad (7)$$

Here, a is the discrimination parameter of skills (slope); $\mathrm{b_m}$ is a set of threshold parameter; e is the natural log; θ is the latent trait, in this study—behavioral skill; $\mathrm{P*_m}(\theta)$ is the probability of responding in a scale; $\mathrm{P*_{(m+1)}}(\theta)$ is the probability of the next responding scale.

The second step estimates the probability of the subtraction that an individual responds in each scale and the next one is defined as the following equation:

$$\mathrm{P_m}(\theta) = \mathrm{P}*_{\mathrm{m}}(\theta) - \mathrm{P}*_{(\mathrm{m}+1)}(\theta) \quad (8)$$

2.6. Data Analysis Programs

Data were tabulated using Microsoft Excel Worksheet. The STATA[17] program was applied for descriptive statistics, obtaining the result of ATET, and behavioral change. The online EIQ calculator was used to calculate the overall field use EIQ value, as well as the EIQ values of its components.

3. Results and Discussion

3.1. Socio-Demographic Information of FFS and Non-FFS Farmers

Table 2 presents and compares the socio-demographic characteristics, including age, gender, marital status, education, household size, farming experience, average daily farm hours, and other training. The result shows that out of 134 farmers, most of them are male and married in both groups. The number of female respondents of FFS is greater than of non-FFS farmers, but the overall number of female respondents is lower due to the local social customs. The selected characteristics showed no significant difference among the brinjal farmers except for gender and education, due to some requirement of FFS participation, although they usually do not strictly resemble field reality. The FFS farmers are more educated and experienced in farming than the non-FFS farmers. Moreover, non-FFS farmers have invested more time in farming activities, but they have less training than FFS farmers. Therefore, the groups would be statistically fit for comparison in propensity

score matching after conducting the balance property test (Table A1) and propensity score matching quality test (Table A2).

Table 2. Summary Statistics of socio-demographic characteristics.

Variables	FFS (n = 48)			Non-FFS (n = 86)			t-Stat.	p-Value
	Mean (SD)	Min.	Max.	Mean (SD)	Min.	Max.		
Gender	0.75 (0.44)	0	1	0.89 (0.32)	0	1	2.24	0.026 **
Marital Status	0.96 (0.20)	0	1	0.92 (0.30)	0	1	−0.877	0.382
Age	45.00 (12.85)	22	70	44.73 (12.85)	19	70	−0.114	0.909
Household size	5.79 (1.87)	3	12	6.31 (2.10)	4	12	1.433	0.154
Education	7.35 (3.72)	0	15	5.74 (3.94)	0	15	−2.314	0.022 **
Farming Experience	19.31 (12.35)	3	50	18.76 (12.53)	2	50	−0.248	0.805
Daily Farm hours	6.19 (1.92)	3	10	6.40 (2.51)	2	12	0.498	0.619
Other Training	0.375 (0.46)	0	1	0.291 (0.49)	0	1	−0.998	0.319

SD = Standard Deviation; Min. = Minimum; Max. = Maximum; ** = Significant at 5% level.

3.2. Brinjal Production Information at before FFS

Total production cost consists of the land preparation cost, seedling cost, fertilizer cost, labor cost, irrigation cost, pesticide cost is treated as variable costs, and fixed costs include land use cost and interest on cash capital. The real value was used for better comparison.

Before FFS, fertilizer, irrigation, pesticide, and fixed cost showed that both groups used nearly the same input costs except for land preparation, seedling, and labor cost, which showed significant difference (Table 3). However, there was no significant difference in total production cost, total physical production, and crop income of FFS and non-FFS farmers. The results indicate that the farming practice of using inputs and gaining return between the groups was mostly the same before the treatment. The BCR of FFS and non-FFS farmers are 1.668 and 1.669 times, respectively, and no significant difference was revealed.

Table 3. Summary Statistics of Brinjal Production information in real value (before FFS).

Variables (Unit: BDT)	FFS (n = 48) Mean (SD)	Non-FFS (n = 86) Mean (SD)	Diff.	S.E.	t-Stat.	p-Value
Land Preparation Cost	4664.56 (212.35)	4793.20 (477.87)	−128.64	72.76	−1.77	0.079 *
Fertilizer Cost	11,967.52 (444.45)	11,934.52 (531.95)	33.00	90.54	0.36	0.716
Seedling Cost	5301.62 (418.19)	5019.47 (562.98)	282.15	92.99	3.03	0.003 ***
Labor Cost	21,785.61 (430.59)	21,560.18 (796.85)	225.43	124.16	1.82	0.072 *
Irrigation Cost	2677.28 (172.00)	2628.87 (270.22)	48.41	43.22	1.12	0.265
Pesticide Cost	10,336.00 (352.14)	10,355.26 (253.95)	−19.26	52.74	−0.36	0.715
Fixed Cost	6515.33 (315.19)	6439.42 (484.98)	75.90	77.88	0.97	0.331
Total Production Cost	63,247.92 (1654.06)	62,730.94 (3002.72)	516.98	469.14	1.10	0.272
TPP (Kg)	12,220.83 (810.82)	12,098.84 (828.39)	121.99	148.13	0.82	0.412
Value of TPP	105,501.2 (3042.02)	104,644.7 (3803.76)	856.47	639.84	1.39	0.183
Crop Income	42,253.25 (1899.61)	41,906.82 (1958.35)	346.43	349.34	0.99	0.323
BCR	1.668 (0.027)	1.669 (0.041)	−0.001	0.0067	−0.19	0.848

*** = Significant at 1% level, * = Significant at 10% level ($1 = Bangladeshi Taka (BDT) 85).

3.3. Brinjal Production Information at after FFS

Before FFS, the groups were indifferent to using inputs for brinjal production, especially for pesticides and fertilizer, which were the main concern of this study in addition to the agricultural income. After FFS, the result showed that the FFS participants use a significantly lower cost of inputs than that of non-FFS farmers. The focal point is that the reduction of using fertilizer and pesticides is a principle of IPM practice which ultimately reduces the total cost and eventually translates to increasing income. Interestingly, the average total production of FFS farmers is lower but the average real crop income of them is significantly higher than that of non-FFS farmers (Table 4). A study in Cambodia demonstrated that the FFS approach allows for the efficient use of farm inputs and is expected to be successful in improving rice production sustainability [47]. Two other studies from the Philippines showed that onion FFS reduced pesticide usage, reduced pesticide expense, and increased income while maintaining the same yield [34,48]. BCR of FFS and non-FFS farmers are 1.98 and 1.70 times, respectively, and there is a significant difference in BCR between the two groups after FFS. The increased BCR of FFS participants indicate the economic viability of the FFS program. Moreover, the crop income of FFS farmers increased by 10.36% compared to before FFS and the crop income of non-FFS farmers also increased by 1.37%; however, this may have been caused by unobservable factors.

Table 4. Summary Statistics of Brinjal Production information in real value (After FFS).

Variables (Unit: BDT)	FFS (n = 48) Mean (SD)	Non-FFS (n = 86) Mean (SD)	Diff.	S.E.	t-Stat.	p-Value
Land Preparation Cost	4797.76 (228.15)	5205.11 (380.46)	−407.34	60.23	−6.763	0.00 ***
Fertilizer Cost	8086.45 (652.57)	9541.62 (474.89)	−1455.16	98.16	−14.82	0.00 ***
Seedling Cost	5227.98 (365.58)	5811.88 (278.60)	−583.89	56.28	−10.37	0.00 ***
Labor Cost	15,311.64 (530.52)	21,532.94 (303.81)	−6221.29	71.99	−86.42	0.00 ***
Irrigation Cost	2687.21 (151.79)	2976.13 (291.34)	−288.91	45.17	−6.39	0.00 ***
Pesticide Cost	5261.90 (380.99)	8386.72 (487.08)	−3124.82	98.18	−31.82	0.00 ***
Fixed Cost	6254.72 (335.27)	7115.92 (252.83)	−861.20	73.01	−11.79	0.00 ***
Total Production Cost	47,627.68 (1625.23)	60,570.31 (1962.33)	−12,942.63	333.19	−38.84	0.00 ***
TPP (Kg)	9563.54 (380.61)	10,094.19 (520.48)	−530.64	85.66	−6.19	0.00 ***
Value of TPP	94,257.58 (2964.90)	103,049.70 (3544.43)	−8792.16	603.49	−14.57	0.00 ***
Crop Income	46,629.90 (2268.59)	42,479.43 (2501.63)	4150.47	436.23	9.51	0.00 ***
BCR	1.98 (0.055)	1.70 (0.041)	0.28	0.008	33.08	0.00 ***

*** = Significant at 1% level ($1 = Bangladeshi Taka (BDT) 85).

3.4. Results for Economic Domain

Effects of FFS Program on Farmers' Income from Brinjal in Matching Estimation

To estimate the impact of the FFS program on the crop income from brinjal production, propensity score matching was used after the balance property test of the sociodemographic characteristics and propensity score matching quality test between the groups. The average treatment effect on treated (ATET) using nearest-neighbor matching, kernel matching, and radius caliper matching have shown a positive and significant effect on income from brinjal farming by BDT 4885.46, BDT 4399.05, and BDT 4266.45, respectively (Table 5). Whereas, the MDM model showed a positive significant effect on brinjal farming income by BDT 4191.32 (Table 6), which verified the robustness of PSM results. The IPWRA findings also verify that the FFS program significantly increases the brinjal farming income by BDT 4300.44 (Table 7), corroborating the findings of Moahid et al. [29]. Increased income was also reported in the study from the Philippines by using a PSM model, with which they found that IPM-FFS farmers profited more than non-FFS farmers [34]. Despite reduced pesticide use, a study on IPM in rice in Thailand found no significant impact of the FFS on gross margin [49]. As the MDM and IPWRA aim to reduce the bias of PSM results, this study highlights the results of MDM and IPWRA.

Table 5. Average Treatment Effect on Treated (ATET) between FFS and non-FFS farmers.

Crop Income (BDT/Acre)	Nearest Neighbor (1) Matching		Kernel Matching		Radius Caliper (0.05) Matching	
	Coef.	t-Stat.	Coef.	t-Stat.	Coef.	t-Stat.
ATET FFS Training (1 vs. 0)	4885.46 (563.03)	8.68 ***	4399.05 (484.92)	9.07 ***	4266.45 (477.78)	8.93 ***

*** = Significant at 1% level.

Table 6. MDM Estimation for ATET on Net Income.

Crop Income (BDT/Acre)	Coef.	Std. Err.	*t*-Stat.
ATET FFS Training (1 vs. 0)	4191.32	526.85	7.96 ***

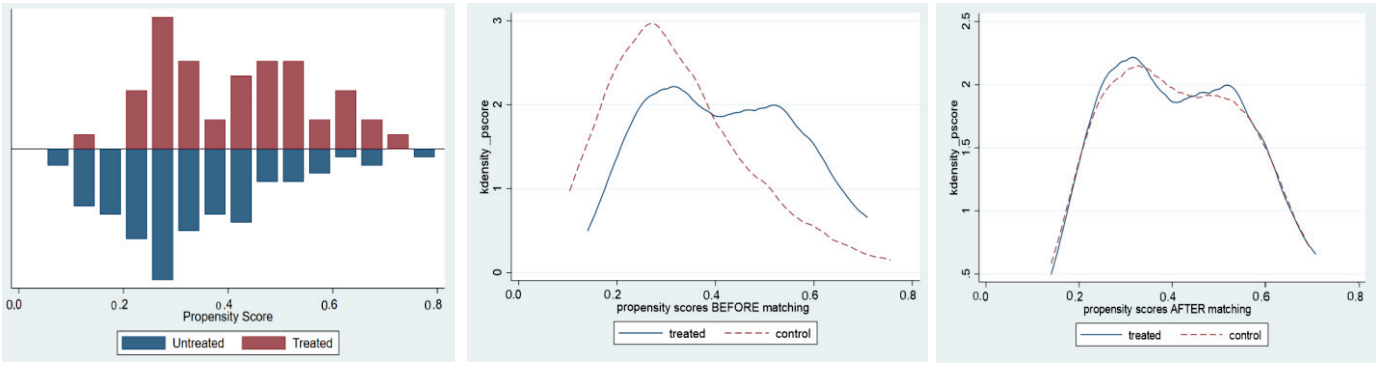
*** = Significant at 1% level.

Table 7. IPWRA Estimates for Net Income.

Crop Income (BDT/Acre)	Coef.	Std. Err.	z	P > | z |
ATE FFS Training (1 vs. 0)	4300.44	446.25	9.64	0.000 ***

*** = Significant at 1% level.

A sufficient overlap between the treatment and control group is expected in the process of matching. The propensity score graph (Figure 2) showed that there is some overlap in the range of propensity scores between treatment and control groups. Moreover, the distribution of propensity scores between treated and control groups have some dissimilarities (Table 1). The balancing property test (Table A1) was conducted to match the distribution of covariates among control and treatment groups. Additionally, the smaller sample size also reduced the chance of overlapping. Nonetheless, after the matching of propensity score between control and treated observations, the graph shows homogenous distributions of propensity score among the brinjal farmers.



(**a**) (**b**) (**c**)

Figure 2. Propensity score graph (**a**) overlaps of treated and untreated groups; (**b**) before matching; (**c**) after matching.

3.5. Effects of FFS Program on Farmers' Income from Brinjal in Difference in Differences Estimations

To test the conformity of matching results, this study applied the DID approach where time and treatment effect were envisaged with covariates. The average treatment effect on treated (ATET) in DID estimation has shown a significant positive change in crop income from brinjal by BDT 3809.91 (Table 8). A study on cotton FFS found that FFS caused significant increases in household income for cotton farmers in China, India, and Pakistan by lowering the cost of insecticide [50], which supports the result of this study. Another study conducted by Feder et al. in 2003 [51] used a DID model and found that the impact of the FFS program did not provide evidence of increased yield or lower pesticide usage for either trained or control group farmers in Indonesia. The ATET in DID estimation is lower than that of matching results, which implies that there may have selection bias in matching methods. Thus, DID have imparted a more robust outcome by comparing the results of

matching techniques, removing the constraints in the matching models. Therefore, the ATET in DID estimation was more prominent in this study as an economic impact of FFS.

Table 8. Difference in Differences (DID) effect on net income.

Crop Income (BDT)	Coef.	Robust Std. Err.	t	$p > \|t\|$
ATET FFS training (1 vs. 0)	3809.91	543.54	7.01	0.000 ***

*** = Significant at 1% level.

Results for Agroecological Domain

Table 9 presents the frequency and the average use of pesticides among the farmers. It was found that non-FFS farmers used pesticides more frequently than FFS farmers. Similar results were obtained in the study by Sharma et al. [52]. According to the WHO hazard class, Ridomil is slightly hazardous and other pesticides are moderately hazardous [52]. The field reality is that the FFS participants are more concerned by using hazardous pesticides. Based on the pesticide use data, this study calculates and compares the FEIQ value in Table 10. It was also found that both groups use different traps (Figure 3), but FFS farmers have more practice in using traps instead of using pesticides.

Table 9. Pesticide utilization information.

Pesticides Name	No. of Farmers		Average Use Rate/Acre	
	FFS	Non-FFS	FFS	Non-FFS
Cypermethrin/Rolethrin	45 (93%)	61 (71%)	1.8 Kg	2.5 Kg
Cartap	12 (25%)	-	0.8 L	-
Ridomil	30 (62%)	42 (49%)	5.0 Kg	7.0 Kg
Indofil	1 (2%)	8 (10%)	2.0 Kg	3.0 Kg
Voliam Flex	03 (6%)	27 (31%)	160 mL	200 mL
Tundra	03 (6%)	-	3.0 L	-
Success/Tracer	03 (6%)	07 (8%)	250 mL	250 mL
Thiovit	-	10 (12%)	-	4.0 kg

Source: Field Survey, 2020.

Table 10. Mean Value of Field use EIQ and its component values.

Value of EIQ	FFS	Non-FFS	|Diff.|	*t*-Stat	*p*-Value
Field use EIQ	213.26 (44.35)	255.28 (59.95)	42.02	4.24 ***	0.000
Consumers	65.89 (24.89)	76.71 (24.89)	10.82	1.65 *	0.099
Farmworkers	92.93 (25.11)	110.65 (36.07)	17.72	3.02 ***	0.003
Ecological	480.89 (91.39)	565.55 (137.60)	84.66	3.81 ***	0.002

SD in parentheses; *** = Significant at 1% level; * = Significant at 10% level.

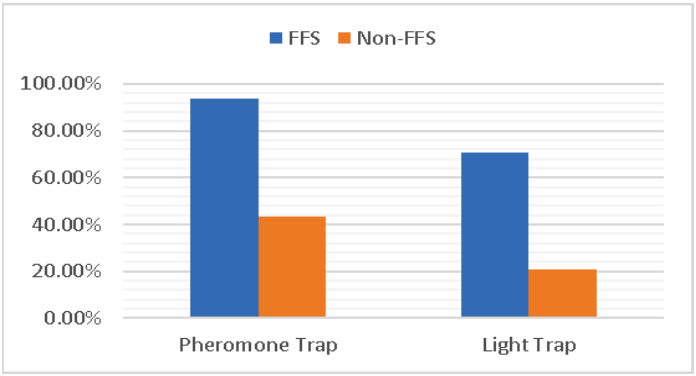


Figure 3. Distribution of using traps instead of pesticides. Source: Field Survey, 2020.

3.6. Effect of FFS Program on Agroecology in FEIQ Estimation of Pesticides

As the mean scores of field use EIQ of non-FFS farmers were higher than that of FFS farmers are, it is implied that non-FFS farmers have had a greater environmental impact than FFS farmers. Even then, we can observe that the average EIQ values for consumers, farmworkers, and ecological components among the non-FFS farmers were 76.71, 110.65, and 565.55 respectively, while among FFS farmers, the components were valued at 65.89, 92.93, and 480.89 (Table 10), respectively. Therefore, it is obvious that non-FFS farmers have had a significant impact on agroecology by applying pesticides in brinjal production. Mwungu et al. [53] found the environmental component of the EIQ was high among both the IPM and non-IPM farmers, but there was a significant difference in the EIQ field use between the two categories of farmers. Ahamad et al. [54] found that improvement in the consumer, ecology, and farmer environment quotients is the plausible outcome of the FFS training.

3.7. Effects of FFS Program on the Value of Field use EIQ in Matching Estimation

Table 11 presents the average treatment effect on treated (ATET) applying nearest-neighbor matching, kernel matching, and radius caliper matching of the value of field use EIQ of using pesticides. These matching models reveal that the FFS training significantly reduced the FEIQ value. The IPWRA findings, used for checking the robustness, marked the FFS program's significant decrease of the FEIQ value by 55.17 (Table 12), which conform the consistency of the result found in the above three matching scores. The FEIQ results indicate the agroecological impact of FFS which is inversed to agricultural income. As we could not locate any previous study checking the effect of using pesticide on agroecology through PSM, this study attempts to do so to provide novel findings.

Table 11. Average Treatment Effect on Treated (ATET) of FEIQ value for using pesticides.

FEIQ Value	Nearest Neighbor Matching		Kernel Matching		Radius Matching	
	Coef.	*t*-Stat.	Coef.	*t*-Stat.	Coef.	*t*-Stat.
ATET FFS Training (1 vs. 0)	−54.95 (13.28)	−4.14 ***	−59.94 (10.70)	−5.60 ***	−60.36 (10.51)	−5.74 ***

*** = Significant at 1% level.

Table 12. IPWRA Estimates for FEIQ value.

FEIQ Value	Coef.	Std. Err.	z	$p > \|z\|$
ATE FFS Training (1 vs. 0)	−55.17	9.27	−5.95	0.000 ***

*** = Significant at 1% level.

Results for the Behavioral Domain

This study tried to explore the changes in farmers' farming practice, one of the crucial parts of social behavior, in terms of different behavioral skills. Most of the respondents were agreed with the quick decision, leadership, farmer-to-farmer extension, IPM knowledge, and community network skills, but most of them were neutral towards agroecosystem knowledge (Table 13). The response rate implies that the FFS participants have improved their farming skills. Muhammad et al. [55] identified that the different aspects of social well-being (decision making, confident building, leadership quality, resource management) of the farming community had improved in the project area because of the FFS program.

Table 13. Degree of response to different behavioral skills of FFS farmers.

Skills	Strongly Agree (%)	Agree (%)	Neither Agrees nor Disagree (%)	Disagree (%)	Strongly Disagree (%)	Total (%)
Quick Decision	27%	48%	17%	8%	0%	100%
Leadership	21%	48%	19%	10%	3%	100%
F-to-F extension	19%	43%	25%	13%	0%	100%
IPM Knowledge	19%	54%	27%	0%	0%	100%
Agroecosystem	4%	31%	33%	29%	3%	100%
Community Network	17%	46%	21%	10%	6%	100%

Source: Field Survey, 2020.

The development of skills through different methods of learning led to a positive change in behavior according to the logic behind the response in the Likert scale. Most of the respondents were rational in assessing themselves as they became expert in managing agroecology by changing their traditional practice in farming. These behavioral changes satisfied the concepts of learning theories of the FFS program in the sense that FFS participants were mostly skilled enough to construct their own understanding together. Talibo [56], as cited by Hansen and Duveskog, claims that in line with best practice, inputs, complexity, and yields, FFS enables the farmer to contrast the new practices to their own. This process is grounded in constructivism learning theory. This study indicated that the FFS farmers were able to build up their personal (quick decision, leadership ability), technical (IPM knowledge, agroecosystem), and social (F-to-F extension, community network) constructivism (Table A2). Moreover, they improved their knowledge on IPM and agroecosystem through experiential learning, i.e., learning by doing. The FFS farmers gained more knowledge in pest and nutrient management and actively exercised interpersonal networks to share knowledge among themselves, but very little with other farmers [1], joint decision making, and group capacity building based on learning outcomes [6]. The best change in the behavioral aspect is that the knowledge can be translated into practice in farming. Field realities also support findings on the behavioral aspects.

3.8. Effect of FFS Program on Farmer's Behavior in Farming under Graded Response Model

The item thresholds parameter ranges from −6.20 (b_1 item community network) to 2.28 (b_4 item IPM knowledge) and the item discrimination parameter ranges from 0.65 to 3.78 (Table 14). The item with the lowest discriminative ability was quick decision and that with the highest discriminative ability was agroecosystem. Analysis of the behavioral items with the GRM provides evidence that the skills provide a greater level (b_4) of information in behavioral change where quick decision, leadership, community network, F-to-F extension, and IPM knowledge have a significant impact. Therefore, it may presage that the FFS program has improved the farming behavior of FFS farmers in brinjal cultivation, consequently introducing them to sustainable agriculture.

Table 14. Graded Response Model (GRM) parameter estimates for the behavioral change.

Items (Skills)	a (s.e.)	B_1 (s.e.)	b_2 (s.e.)	b_3 (s.e.)	B_4 (s.e.)	*p*-Value
Quick Decision	0.69 (0.37)	-	−3.70 (1.93)	−1.58 (0.87)	1.74 (0.94)	0.061 *
IPM Knowledge	0.69 (0.36)	-	-	−1.64 (0.87)	2.28 (1.18)	0.056 *
F-to-F Extension	0.86 (0.40)	-	−2.59 (1.11)	−0.73 (0.46)	1.94 (0.88)	0.030 **
Community Network	0.65 (0.35)	−6.20 (3.43)	−3.22 (1.67)	−1.16 (0.73)	1.59 (0.97)	0.061 *
Leadership	1.06 (0.41)	−4.06 (1.66)	−2.26 (0.81)	−1.04 (0.44)	1.48 (0.58)	0.010 **
Agroecosystem	3.78 (1.81)	−2.11 (0.61)	−0.59 (0.23)	−0.34 (0.21)	1.98 (0.46)	0.247

** = Significant at 5% level; * = Significant at 10% level.

4. Conclusions and Policy Implication

4.1. Summary of Results and Conclusion

FFS acts as a vehicle to improve the knowledge level of farmers in the doctrine of IPM and AESA. This study showed that FFS can empower farmers so that they can decide on resource allocation properly, and the more efficiently use of inputs resulted in lowering overall production costs, which leads to higher income. The findings of this study have shown that there is a reduction of brinjal production after FFS, which differed from the results of the study of Cai et al. [57], where they found that FFS has a positive impact on the yield of tomato in Beijing. Higher BCR of FFS-trained farmers implies the future feasibility of the intervention.

The most significant findings of this study are that the PSM, MDM, and DID model has shown a positive change of the crop income from the selected vegetable and significantly reduced the FEIQ value, which has led to the robustness of impact analysis. Behavioral change, another domain of sustainability, also showed a positive indication as per GRM parameter. Therefore, the effects of FFS on improvements in farmer's social, agroecological, and economic livelihood are desirably sustainable in nature [58]. Furthermore, apart from the objective of assessing the impact of FFS on crop income, agroecology, and farmer's behavior in farming, more academic interest and debate may have emerged to motivate future study.

The summary suggests that the FFS program could serve as a key strategy to widen the agricultural extension services by targeting sustainable agriculture where all the domains would be positively impacted. Therefore, the marginal contribution of this study is to improve impact analysis of FFS by addressing the gap of previous studies and all the pillars of sustainability.

Thus, it can be concluded that the FFS program will make a positive change in agricultural practice and has the potential to change farmers' livelihoods by increasing their income. It can also contribute to promoting sustainable agriculture, as indicated by SDG-2 [59], by orienting farmers to use fewer chemical inputs that positively impact on crop income, agroecology, and farmers' behavior in farming.

4.2. Policy Implications

Agricultural extension and farmer education initiatives are important policy tools for policymakers aiming to boost agricultural income while also protecting the environment [60]. This study has provided the evidence that FFS-trained farmers practice reducing the use of chemical inputs and improving crop income, which is justification for policymakers to devote more resources to this program and possibly expand it to cover more crops.

FFS curricula should be developed in a flexible manner that allows each FFS to be customized for diverse target groups and local conditions. Furthermore, Extension officials should be well trained in using a participatory approach to effectively deliver the message of the FFS program. An action plan might be followed by the government on how these would be ensured.

FFS intervention should be planned with the goal of maximizing the potential to build on previous efforts and create more significant change by focusing more on agroecology and sustainable farming practices.

4.3. Limitations of the Study

In this study, the major limitation is that the treatment was not randomly assigned; rather, it was taken ex post facto and we cannot make measurements with and without treatment effects from the same individuals. The small sample size is another limitation of this study due to the COVID-19 pandemic, the comprehensive questionnaire, and not being able to conduct an online survey or telephone interview due to insufficient facilities. This study tried to mitigate the above-mentioned limitations by applying different methods of empirical analysis, as per suggestions in the literature.

Author Contributions: M.M.R.B. and K.L.M. formulated the idea and research design. M.M.R.B. conducted the survey, wrote the manuscript, and carried out the formal analysis. K.L.M. supervised the research and revised the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: There is no funding for this research.

Institutional Review Board Statement: This study was done as per the guidelines of the research ethics committee of graduate school for international development and cooperation (IDEC), Hiroshima University, Japan and duly approved on 30 July 2020.

Informed Consent Statement: Informed consent was taken from all respondents involved in the study.

Data Availability Statement: The detailed data besides presented in this study are available on request from the corresponding author.

Acknowledgments: We would like to thank to the project for Human Resource Development Scholarship (JDS) arranged by the Japan International Cooperation Agency (JICA) for their financial support throughout the study period of M.M.R.B. at Hiroshima University, Japan.

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

Appendix A

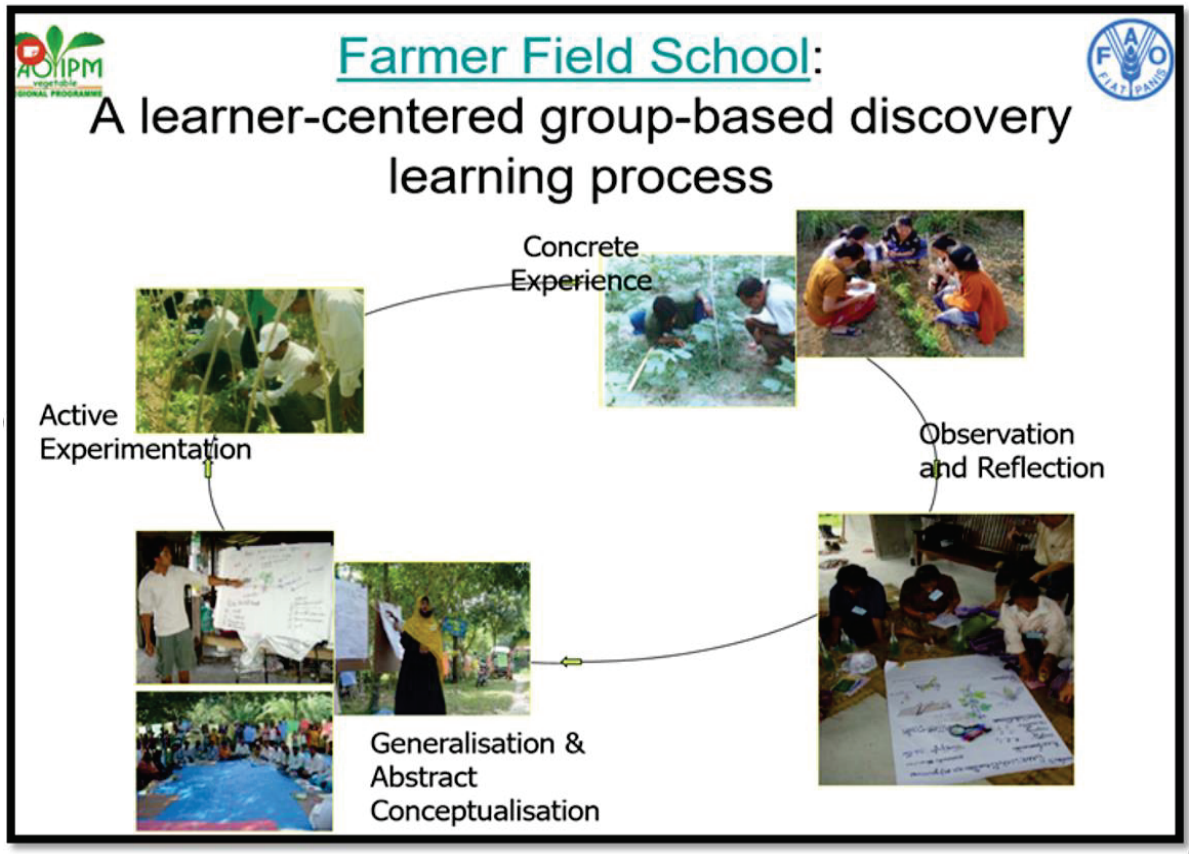


Figure A1. FFS learning process [3].

Table A1. Balancing property of FFS vs. non-FFS farmers.

	Mean		Bias Reduction (%)	*p*-Value
	Treated	Control		
		Before matching:		
Gender	0.75	0.89		0.026 **
Marital Status	0.96	0.919		0.382
Age	45.00	44.73		0.910
HH Size	5.79	6.31		0.154
Education	7.35	5.74		0.022 **
Farming Experience	19.31	18.76		0.805
Farm Hours	6.19	6.39		0.619
Other Training	0.375	0.291		0.320
		After matching:		
Gender	0.75	0.81	57.0	0.464
Marital Status	0.96	0.917	−4.9	0.404
Age	45.00	44.67	−24.6	0.898
HH Size	5.79	5.81	96.0	0.955
Education	7.35	7.79	72.8	0.550
Farming Experience	19.31	19.52	62.6	0.937
Farm Hours	6.19	5.67	−150.6	0.248
Other Training	0.375	0.417	50.6	0.680

** = significant at 5% level.

Table A2. Propensity score matching quality test.

Items	Before Matching	After Matching
Pseudo R2	0.079	0.031
p-value	0.085	0.842
Mean Standardize Bias (%)	19.6	10.3

Table A3. Qualitative findings in changing behavior.

Attributes	Skills	Method of Learning	Changes in Behavior
Personal	Quick Decision	Practical application	Regularity in checking the state of farmland
	Leadership	Classroom activities	Playing role as a day leader
Knowledge	IPM	Technical lectures	Gaining knowledge about the demerits of overusing chemical inputs and practice duly
	Agroecosystem	Technical and practical experimentation	Ability to identify friend insects and enemy insects; correct installation of traps
Social	F-to-F Extension	Collective activities	Knowledge sharing with neighbor farmers
	Community Network	Follow-up activities	Continuous development through farmers club

Source: Field Survey, 2020.

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Impact of Farmers' Participation in Community-Based Organizations on Adoption of Flood Adaptation Strategies: A Case Study in a Char-Land Area of Sirajganj District Bangladesh

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Abstract: Community-based organizations (CBOs) are gaining popularity in Bangladesh as a tool for relaying flood risk information and adaptation strategies. However, to our knowledge, no attempts have been made to determine the impact of CBOs on farmers' adoption of flood adaptation strategies. Therefore, in this paper, we identify the determinants that influence farmers' decisions to participate in CBOs and how this participation impacts farmers' adoption of flood adaptation strategies. A multistage sampling procedure was employed to select 359 farmers for the study. An endogenous switching regression model was applied to control for possible selection bias due to unobserved factors, while propensity score matching (PSM) and inverse probability-weighted regression adjustment (IPWRA) were employed to test for the robustness of the results. The results reveal a positive selection bias, indicating that farmers with above-average flood adaptation strategies are more willing to participate in CBOs. Farmers' flood experience, having children under 10 years, distance to the village center, and access to information mainly determine the participation in CBOs. It is also found that CBO participation significantly increases farmers' adoption of flood adaptation strategies. ESR results show that farmers who participated in CBOs have 3.76 higher average flood adaptation strategies compared to CBO non-participation, and this finding is also consistent with PSM and IPWRA results. Therefore, policy intervention aimed at further strengthening and institutionalizing CBOs is necessary for successful flood adaptation.

Keywords: farmers; flood; community-based organization; char-land; adaptation strategies; endogenous switching regression model

Citation: Faruk, M.O.; Maharjan, K.L. Impact of Farmers' Participation in Community-Based Organizations on Adoption of Flood Adaptation Strategies: A Case Study in a Char-Land Area of Sirajganj District Bangladesh. *Sustainability* **2022**, *14*, 8959. https://doi.org/10.3390/su14148959

Academic Editor: Luca Salvati

Received: 16 June 2022
Accepted: 19 July 2022
Published: 21 July 2022

1. Introduction

Bangladesh is one of the world's most flood-prone countries. Thousands of people are affected by floods every year, claiming lives and causing property damage [1]. More than three-fourths of the country is represented by the floodplains of the Ganga, Brahmaputra, and Meghna (GBM) river basins and some other smaller rivers [2]. The sand and silt landscapes near the rivers are called "char-land" in Bengali [3]. About 4–5% of the Bangladeshi population lives in char-lands, which cover an area of nearly 7200 km^2 [4,5]. These char-lands are vulnerable to widespread monsoon flooding that damages settlements, crops, houses, infrastructure, and communication networks. This is because the hydro-morphological characteristics of the char-lands differ significantly from those of the shorelines and other floodplains in Bangladesh [6]. The inhabitants of char-lands rely heavily on agriculture for their livelihood [7], which makes them more vulnerable to flood damage. However, the flood warnings from the Flood Forecasting and Warning Center (FFWC) do not address the needs of char-land residents and sometimes are too technical to be understood and irrelevant to local conditions [6]. Moreover, most of the people in the rural char-lands are illiterate and have no proper knowledge of floods [8]. Rural

communities are also not aware of flood early warnings [9], which highlights the gaps in current flood risk communication systems. As a result, potentially vulnerable people do not take flood adaptation measures [10].

The government of Bangladesh has taken steps to institutionalize disaster management at the union level through Union Disaster Management Committees (UDMCs). However, the committees mainly focus on relief, rescue, and rehabilitation activities after floods rather than disseminating flood early warnings (FEWs), and UDMCs cannot reach all villages and communities with FEWs [9]. The government, on the other hand, disseminates flood warnings in a top-down approach through policies, the media, and the internet, which is a one-way passive risk communication because people may or may not read these materials [11]. This one-way message communicates only flood risk but fails to assess the particular risk to the local communities. In contrast, the two-way message informs people of the particular risk, defines the problem, and then identifies appropriate solutions [12]. As a result, top-down approaches need to be replaced with participatory bottom-up approaches that emphasize risk reduction, preparedness, and the role of individuals and communities [13]. Many scholars and stakeholders are concerned about the failure of the top-down approach and argue for a new approach that takes communities at risk directly into the planning and execution of mitigation, readiness, response, and recovery efforts, as communities are best able to assess vulnerability and make decisions about their well-being [14]. The significance of community participation in disaster risk reduction has been well documented in the recent literature [12,14,15]. As the number of disasters and viral epidemics has increased worldwide, the importance of community participation has also increased [16]. Most of the community's participation occurs through a structure such as a community-based organization (CBO), which is formed to achieve a common goal [17]. CBOs have received significant recognition to increase farmers' understanding of climate change issues and build their adaptation capacity [18].

In Bangladesh, CBOs have been established by people voluntarily under various non-governmental organizations (NGOs). In the char-lands, CBOs were established under a local NGO called "Manab Mukti Sangstha". There is a CBO in each village in the study area. Each CBO has a committee consisting of twenty-one members, and the CBO is operated by this committee with the collaboration of that NGO. The CBO's main goal is to provide flood risk information to raise flood risk awareness among char-land farmers. As the char-lands are far from the mainland, they have limited access to flood risk information, and the local government sometimes fails to provide timely risk information when flooding occurs. In addition, most char-lands do not have electricity, so residents cannot obtain flood risk information from traditional media, such as television. As a result, residents in char-lands rely heavily on CBOs to obtain flood risk information. Flood risk information consists of not only flood early warning but also necessary flood adaptation information [19]. CBO provides essential information on various flood adaptation strategies. Before flood season, farmers are invited to participate in a CBO meeting where they learn by sharing their knowledge and experience. Additionally, farmers have the chance to see the adaptation choices of other CBO members, which may strengthen their faith in adaptation strategies and boost adoption rates [20]. Moreover, experts from different organizations, such as local extension agents, conduct different sessions regarding different flood adaptation measures, especially flood-tolerant agricultural practices, including suitable crop varieties, adjustment of planting and harvesting times, mixed cropping techniques, etc. In these sessions, farmers are provided information on how to save their crops, livestock, and household properties so that they can better adapt to floods. CBOs also play a significant role in flood risk management through some collective actions performed by their different volunteer groups, such as rescuing family members, transferring necessary goods during an emergency, food saving through a food bank for an emergency food crisis, etc.

Sustainable agricultural production is a major concern in char-lands since agriculture is the primary source of livelihood and flooding is a frequent event. Farmers incur a huge loss on their crops and livestock due to flooding. For sustainable farm production, the

adoption of effective flood adaptation measures is crucial in the context of the char-lands. Community-based organizations (CBOs) are an ideal platform from which farmers can improve their flood adaptation knowledge. CBOs are thought to increase farmers' adoption of agricultural flood adaptation by convincing their members to switch from traditional agricultural practices to new practices that are more resilient to climate shocks [20]. Farmers may be able to adapt to the floods by sustaining their agricultural livelihoods because of these adaptation strategies.

However, the literature does not adequately address the impact of these CBOs on farmers' flood adaptation. Shaw [21] compared the critical issues of community-based flood mitigation in the socio-political context between Bangladesh and Vietnam, focusing on linking the community activities with local government. Huq [14] conducted a literature analysis to examine grassroots community participation in disaster management in Bangladesh. Thompson [22] investigated the sustainability of community-based organizations (CBOs) in Bangladesh, where the author highlighted the prospects of CBOs on floodplain resources and identified the need for a co-management policy for the sustainability of CBOs. Most of the previous studies are qualitative and have focused on the prospects and challenges of community-based approaches. However, no empirical study has established whether farmers' participation in CBOs improves their flood adaptation strategies. Khanal et al. [20] estimated the impact of CBOs on climate change adaptation in Nepal using propensity score matching (PSM). However, PSM does not account for unobserved characteristics that lead to selection bias, while both observed and unobserved factors can be accounted for using endogenous switching regression (ESR).

Specifically, in this study, we employed an endogenous switching regression (ESR) to evaluate the impact of CBO participation on farmers' adoption of flood adaptation strategies using survey data from 359 char-land farmers. Propensity score matching (PSM) and inverse probability-weighted regression adjustment (IPWRA) were also applied to verify the robustness of the results. Robust impact evaluation is also necessary for policy decisions [23], such as the development and implementation of appropriate support measures.

Therefore, this study extends the literature in two ways. First, we evaluated the CBO participation impact on farmers' flood adaptation using ESR with the addition of PSM and IPWRA methods. To our understanding, no empirical study has evaluated the impact of CBO participation on flood adaptation using causal inference. Second, this work is unique because it is the first attempt to analyze the impact of CBO participation on respondents who reside in the remote char-lands that are highly vulnerable to floods. Aside from the introduction, the remainder of this article includes the following. Section 2 describes the methodology, data, and outline of our empirical approach. Section 3 represents the main findings of the study, while Section 4 focuses on discussing the factors affecting CBO participation and the impact of CBO participation on flood adaptation strategy adoption. Section 5 contains the conclusions, policy recommendations, and limitations of the study.

2. Materials and Methods

2.1. Description of the Study Area

This study was carried out in the Chowhali sub-district of the Sirajganj district. Sirajganj is a northern district of Bangladesh consisting mainly of char-lands and is regarded to be at high risk of flooding. The region lies on the banks of the Brahmaputra, often referred to as the Jamuna. The monsoon flow of the Jamuna is so great that it often overflows its banks, causing flooding in most of the upazilas (sub-districts) of Sirajganj. The Chowhali sub-district of Sirajganj district was selected for this study (Figure 1).

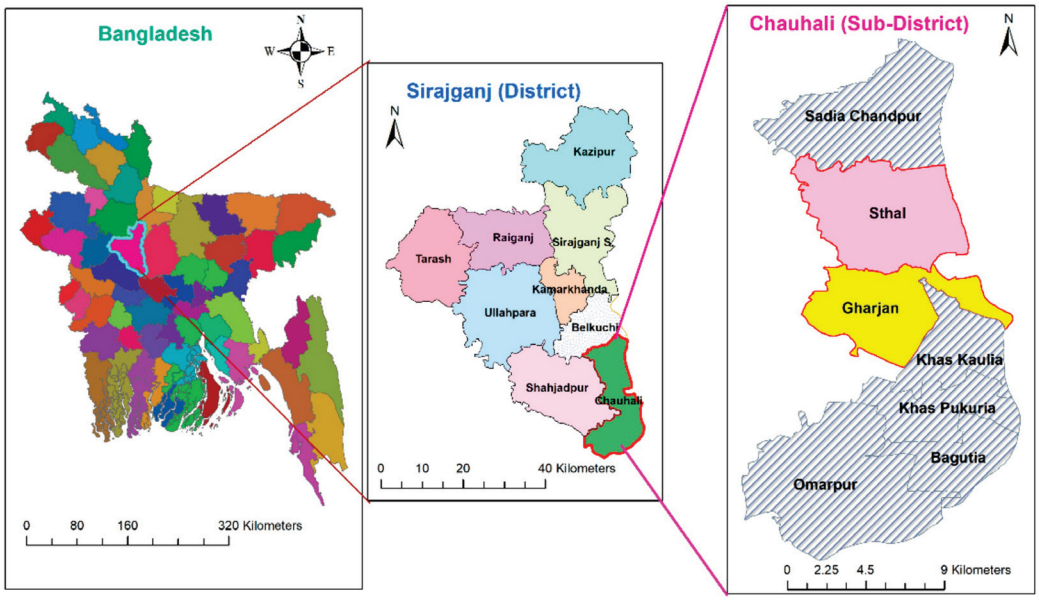


Figure 1. Map of the study area. Source: Authors.

The Chowhali sub-district is divided into two parts by the Jamuna. The main disasters in this area are river-bank erosion and regular flooding. The land of the sub-district is frequently lost in the river due to the erosion of the Jamuna at different times. Most of the land in this sub-district is river islands, locally known as the char-lands. The dissolution and collapse of the country's major rivers have created the char-lands.

2.2. Sampling and Data Collection

The sample was chosen by a multi-stage sampling technique. First, the Chowhali sub-district in Sirajganj was purposively selected based on flood intensity and the existence of char-lands. Second, two unions (Ghorjan and Sthal) under the Chowhali sub-district (Figure 1) were selected based on the presence of CBO activities. In the third stage, from the list of villages run by CBOs in each union, three villages were chosen at random. The village-wise list of farmers was collected from the sub-district agriculture office. Finally, farmers were selected by simple random sampling. A total of 359 farmers (about sixty farmers per village on average) were selected for the study. After data collection, it was found that 164 farmers participated in the CBOs, and 195 farmers did not participate in the CBOs. The distribution of the sample size is shown in Table 1.

Table 1. Sample size distribution.

Unions	Villages	Total Farmers	Sample Size		
			CBO Farmers	Non-CBO Farmers	Total
Ghorjan	Muradpur	500	33	27	60
	Har Ghorjan	300	26	34	60
	Boro Ghorjan	250	25	35	60
Sthal	South Nouhata	295	28	32	60
	North Nouhata	223	23	37	60
	Chaluhara	225	29	30	59
Total		1793	164	195	359

Source: Survey, 2021.

This study is based on the results of a cross-sectional survey conducted in August 2021. Face-to-face interviews with farmers using a semi-structured questionnaire were performed to collect primary data. The questionnaire was developed to gather information on farmers' socioeconomic characteristics as well as their adoption of flood adaptation

strategies in response to the 2020 flood. Descriptions of all the variables are shown in Table 2. The study ethics committee at the Graduate School of Humanities and Social Sciences, Hiroshima University, authorized the questionnaire for conformity with ethical concerns such as basic human rights, the protection of personal information, and data security before we conducted the final survey. The questions were pre-tested before the final survey.

Table 2. Description of variables.

No.	Variables	Definition and Measurement
1.	Outcome variable Total flood adaptation strategies scores	1 if adopted by farmers, 0 otherwise
2.	Treatment variable CBO participation	1 if farmer participated, 0 otherwise
3.	Age	Age of farmers in years
4.	Gender	1 if male, 0 otherwise
5.	Years of schooling	No. of years of schooling
6.	Family size	No. of family members
7.	Children under 10 years	No. of children under 10 years old
8.	Disabled family member	1 if a disabled member in the family, 0 otherwise
9.	Farm size	Land under cultivation in decimal
10.	Annual income	Income in thousand BDT
11.	Distance to the village center	Distance in minutes
12.	Flood experience	No. of severe floods experienced in the past 10 years
13.	Instrumental variable Access to information	1 if farmers received information regarding CBO participation, 0 otherwise

Source: Authors' own elaborations.

2.3. Analytical Framework

2.3.1. Impact Analysis and Selection Bias

The differences in average adaptation scores between the two groups can be assessed but assigning merely the differences in adaptation scores between the two groups would be too simplistic and biased. Another way is to use the ordinary least squares method and regress CBO participation as a binary variable. However, this model presupposes that CBO participation is determined exogenously, while it may be determined endogenously.

Propensity score matching (PSM), introduced by [24], is a commonly used econometric model to study the impact of interventions, especially when self-selection is a concern. Propensity score estimation merely attempts to balance the observed distribution of covariates between the groups of CBO participants and non-participants. In this study, an endogenous switching regression (ESR) was used to evaluate the determinants and impact of CBO participation while controlling for both observable and unobservable factors to efficiently address selection bias. However, ESR estimates may be affected by a model assumption, such as the choice of instrumental variable (IV); on the other hand, PSM does not depend on IV [25]. For this, PSM has been employed to check the robustness or sensitivity of the used instrument in the ESR model. In addition, IPWRA has been included in this study for a further robustness check of the former models. If the treatment or outcome variable is not properly specified, it can produce an inconsistent treatment effect. IPWRA has doubly robust characteristics and can produce consistent estimates by considering the possible model misspecification bias [26,27].

2.3.2. Endogenous Switching Regression Model (ESRM)

The choice equation in our scenario, which is based on random utility, is a binary participation model in which farmers decide whether or not to participate in a CBO depending on socio-economic characteristics.

$$M = Z\gamma + \mu \tag{1}$$

where M is a binary variable that considers 1 for CBO participation and 0 otherwise, Z is a vector of explanatory factors, γ is a vector of coefficient, and μ is an error term with zero mean and constant variance $\sigma^2\mu$. For outcome equations, farmers' adoption of flood adaptation strategies is in two regimes:

$$Y_P = X\beta_P + \varepsilon_P \tag{2}$$

$$Y_N = X\beta_N + \varepsilon_N \tag{3}$$

where Y_P and Y_N are the flood adaptation strategies adopted by farmers with CBO participation and non-participation, respectively. β_P and β_N are parameters to be estimated, while ε_P and ε_N are respective error terms for two regimes. X is a set of explanatory variables, such as socio-economic characteristics. For the error terms μ, ε_P, and ε_N, a trivariate normal distribution with zero mean and a non-singular covariance matrix is assumed.

The error terms for Equations (2) and (3) are expected to be different from zero in the presence of selection bias.

$$E(\varepsilon_P \mid M = 1) = \sigma_{P\mu}\lambda_1 \tag{4}$$

$$E(\varepsilon_N \mid M = 0) = \sigma_{N\mu}\lambda_0 \tag{5}$$

The inverse Mills ratios are λ_1 and λ_0, respectively, for two regimes, when measured at $Z\gamma$ [28]. To account for selection bias in a two-step estimate technique, λ_1 and λ_0 can be added into Equations (2) and (3) [29]. The ESR model can be estimated more efficiently and consistently using the full information maximum likelihood (FIML) method [28,30].

FIML also provides $\rho_{P\mu}(\sigma^2_{P\mu}/\sigma_\mu\sigma_P)$ and $\rho_{N\mu}(\sigma^2_{N\mu}/\sigma_\mu\sigma_N)$, which are estimates of the correlation coefficients between the error terms in the outcome and selection equations. The presence of selection bias is indicated by the significance of either $\rho_{P\mu}$ or $\rho_{N\mu}$, which emphasizes the importance of the endogenous switching model. When $\rho_{P\mu} < 0$, this implies a positive selection bias; it means that farmers with better-than-average adaption strategies are more inclined to participate in CBOs. On the other hand, $\rho_{P\mu} > 0$ would imply a negative selection bias.

To address the endogeneity problem, access to information has been identified as an instrumental variable in the selection model. Access to information has been selected as an instrument because farmers could be informed regarding CBO participation from the announcement of the leading NGO or from friends or relatives, by which they could be motivated to participate in the CBOs. Farmers who receive information regarding participation in CBO meetings are more likely to participate in CBOs. The validity of this instrument was checked with a simple falsification test [31–33]. According to [31], a variable is considered a valid selection instrument when it affects farmers' decisions to participate in the CBOs but does not directly affect flood adaptation strategies of farmers with CBO non-participation. From the falsification test, it is found that access to information has a significant positive influence on CBO participation but has no significant influence on farmers' adoption of flood adaptation strategies with CBO non-participation (Table A1).

The overall objective of ESR is to determine the average treatment effect on treated (ATT) and the average treatment effect on untreated (ATU), providing a comparison between flood adaptation with CBO participation and without participation. From the coefficient estimates in the ESR model, the following expected adaptation strategies of farmers under the real and counterfactual scenarios can be estimated.

Farmers with CBO participation (real):

$$E(Y_P \mid M = 1) = X\beta_P + \sigma_{P\mu}\lambda_1 \quad (6)$$

Farmers with CBO participation (counterfactual):

$$E(Y_N \mid M = 1) = X\beta_N + \sigma_{N\mu}\lambda_1 \quad (7)$$

Farmers with CBO non-participation (counterfactual):

$$E(Y_P \mid M = 0) = X\beta_P + \sigma_{P\mu}\lambda_0 \quad (8)$$

Farmers with CBO non-participation (real):

$$E(Y_N \mid M = 0) = X\beta_N + \sigma_{N\mu}\lambda_0 \quad (9)$$

As a result, the difference between Equations (6) and (7) computes the average treatment effect on the treated (ATT), while the difference between Equations (8) and (9) computes the average treatment effect on the untreated (ATU). Other research literature has used this strategy [31–33].

Using Carter and Milon [34] as a guide, "the effect of base heterogeneity" for CBO participation is defined as the difference between Equations (6) and (8). Similarly, for CBO non-participation, "the effect of base heterogeneity" is the difference between Equations (7) and (9). Finally, transitional heterogeneity (TH) is calculated from the difference between ATT and ATU.

3. Results

3.1. Socio-Economic Characteristics of the Farmers

We conducted a *t*-test to obtain a better understanding of the differences in characteristics between farmers with and without CBO participation, and the findings are presented in Table 3. The average age difference between the farmers with CBO participation (45.21) and non-participation (47.35) is not statistically significant. However, the age of non-CBO farmers is comparatively higher than that of CBO farmers, which indicates the higher participation of younger farmers in CBOs. Similarly, there is no significant difference between the two groups when it comes to gender. The proportion of gender is almost similar for both CBO and non-CBO farmers. About 71% of farmers with CBO participation and 70% of farmers with non-participation are male, indicating that the proportion of female respondents is comparatively lower in both groups. Farmers who participated in CBOs are not significantly different from farmers who did not participate in CBOs in terms of family size. With respect to the disabled family members, there also appears to be an insignificant difference between the farmers with CBO participation and non-participation. The average number of years of schooling of CBO farmers (3.35) is significantly higher compared to non-CBO farmers (2.62), but the average number of years of schooling in the char-lands is the primary level of education (5 years of schooling). A similar result was found in the Padma floodplain, where the average number of years of schooling was 1.9 years [6]. This is also consistent with the study [35], which found that 45% of the people in the floodplain have only primary education.

Table 3. Farmers' socio-economic characteristics.

Variables	CBO Participation (n = 164)		CBO Non-Participation (n = 195)		Mean Difference	*p*-Value
	Mean	SD	Mean	SD		
Age	45.21	14.00	47.35	14.31	2.14	0.155
Gender	0.71	0.45	0.70	0.46	−0.01	0.741
Years of schooling	3.35	3.04	2.62	3.03	−0.73 **	0.023
Family size	5.74	2.27	5.39	1.77	−0.35	0.103
Children under 10 years	1.53	0.90	1.17	0.80	−0.36 ***	0.000
Disabled family member	0.20	0.40	0.13	0.34	−0.07	0.114
Farm size	151.01	106.71	115.79	68.27	−35.22 ***	0.000
Annual income	48.62	25.18	40.38	18.38	−8.24 ***	0.000
Distance to the village center	25.76	11.42	27.64	11.28	1.88	0.121
Flood experience	2.73	0.72	2.31	0.71	−0.42 ***	0.000
Access to information	0.88	0.32	0.40	0.49	−0.48 ***	0.000

Note: *** and ** denote significance level at 1% and 5%. SD = standard deviation. Source: Authors' own calculation.

Farm size is significantly higher among farmers with CBO participation than among non-participants, indicating that higher CBO participation is associated with larger farm areas. Annual income is also significantly higher for the CBO farmers, implying that farmers with higher incomes participate more in the CBOs. There is no significant difference between the two groups in terms of distance to the village center. CBO farmers experienced significantly more flood severity in the past decade than non-CBO farmers, indicating higher CBO participation for the farmers who experienced higher numbers of flood severity in the past. Farmers who participate in CBOs have significantly greater access to information about CBO participation than farmers who do not participate in CBOs.

3.2. Farmers' Adoption of Flood Adaptation Strategies

Table 4 shows the difference in the adoption of twenty-one flood adaptation strategies between the farmers with CBO participation and non-participation. After a preliminary survey, twenty-one flood adaptation strategies related to farming and non-farming were found to be mostly adopted by farmers. For each adoption of an adaptation strategy, a score was assigned as 1 if adopted and 0 otherwise. Out of twenty-one adaptation strategies, total flood adaptation scores are considered as an outcome variable. The scores may range from 0 to 21. It is assumed that the higher the score, the better the flood adaptation. A chi-square test for the adoption of each adaptation strategy and a *t*-test for showing the difference in average scores for flood adaptation represent the difference in adoption of flood adaptation strategies between two groups of farmers (Table 4).

From Table 4, it is observed that farmers with CBO participation have significantly higher average scores in flood adaptation strategies compared to farmers without CBO participation. For each adaptation strategy, the percentage of adoption is higher for the farmers with CBO participation than for non-CBO farmers for both farming and non-farming strategies. As agriculture is the main livelihood strategy in the char-lands, local char farmers have long used various agricultural and livelihood adaptation strategies.

More CBO farmers (50.61 percent) engage in the practice of growing vegetables in pots or sandbags compared to non-CBO farmers (27.69 percent). Farmers collect early growing vegetable seeds and grow them in pots, sandbags, and other containers during floods when their fields are flooded, and they are unable to produce vegetables. After flooding, they transplant the seedlings in the main field and reduce the crop duration in this way. CBO farmers (69.51 percent) are more found to use the strategy of mixed cropping compared to farmers with CBO non-participation (45.13 percent). Farmers in the study area grow sesame with Aman paddy for risk diversification and early planting to reduce damages to crops. The percentage of changing crop varieties is significantly higher for CBO farmers compared to non-CBO. CBO farmers use more flood-tolerant rice varieties, including hybrids, than the farmers with CBO non-participation. To reduce crop damage, adjustment of planting

and harvesting times is very crucial. More CBO farmers (60.37 percent) adjust planting and harvesting times compared to non-CBO farmers (46.67 percent). Farmers are especially concerned about the safety of their livestock in char-lands since livestock are as vulnerable to floods as farmers. To rescue livestock, CBO farmers have a much greater adoption percentage for fodder arrangement (87.80 percent), raising livestock place (81.71 percent), and relocating livestock to a safer place (60.37 percent) than non-CBO farmers, with 76.92, 73.85, and 34.36 percent, respectively. More CBO farmers (59.76 percent) use precautionary money savings as a risk management strategy for dealing with floods' consequences, compared to non-CBO farmers (42.05 percent). Similarly, more CBO farmers receive credit from formal (73.78 percent) and informal (62.80 percent) sources for household income diversification in comparison to non-CBO farmers. Furthermore, CBO farmers are more likely than non-CBO farmers to participate in non-farming activities as an alternative to supplement their income during floods.

Table 4. Farmers' flood adaptation strategies adoption by CBO participation status.

Variables	Frequency and Percentage of Adoption		*p*-Value
	CBO Participation (n = 164)	CBO Non-Participation (n = 195)	
Farming and livelihood adaptation strategies			
Growing seedling in pot or sandbag	83 (50.61)	54 (27.69)	0.000 ***
Mixed cropping	114 (69.51)	88 (45.13)	0.000 ***
Changing crop variety	87 (53.05)	58 (29.74)	0.000 ***
Adjustment of planting and harvesting time	99 (60.37)	91 (46.67)	0.010 **
Fodder arrangement	144 (87.80)	150 (76.92)	0.008 **
Raising of livestock place	134 (81.71)	144 (73.85)	0.076 *
Relocating livestock	99 (60.37)	67 (34.36)	0.000 ***
Money savings	98 (59.76)	82 (42.05)	0.001 ***
Informal credit	103 (62.80)	119 (61.03)	0.730
Formal credit	121(73.78)	66 (33.85)	0.000 ***
Alternative occupation during flood	95 (57.93)	65 (33.33)	0.000 ***
Non-farming adaptation strategies			
Construction or raising the plinth of the house	93 (56.71)	57 (29.23)	0.000 ***
Fencing house	81 (49.39)	56 (28.72)	0.001 **
Raising tube wells	98 (59.76)	66 (33.85)	0.000 ***
Flood-proof sanitation	103 (62.80)	59 (30.26)	0.000 ***
Portable stoves	143 (87.20)	160 (82.05)	0.181
Arrangement of boat	78 (47.56)	57 (29.23)	0.001 ***
Macha preparation	128 (78.05)	132 (67.69)	0.029 **
Dry food collection	106 (64.63)	101 (51.79)	0.014 **
Shifting family	99 (60.37)	110 (56.41)	0.449
Shifting valuable goods	106 (64.63)	106 (54.36)	0.049 **
Total adaptation strategies scores (mean + SD)	13.49 (2.76)	9.68 (3.02)	0.000 ***

Note: Significance at *** 1%, ** 5%, * 10%. Percentage in parentheses. Source: Authors' own calculation.

Non-farming strategy adoption is also significantly higher for farmers who participate in CBOs compared to non-participants. When compared to non-CBO farmers, CBO farmers have significantly higher adoption rates for constructing or raising the plinth of the house (56.71 percent), fencing the house (49.39 percent), raising tube wells (59.76 percent), flood-proof sanitation (62.80 percent), boat arrangement (47.56 percent), macha (a bamboo-made high stage or bed) preparation (78.05 percent), and dry food collection (64.63 percent). However, there is no significant difference in the adoption of portable stoves between the two groups. CBO farmers' adoption of emergency strategies such as shifting valuable goods is significantly higher compared to non-CBO farmers, while there is an insignificant adoption difference for shifting family members between CBO and non-CBO farmers.

These differences suggest that farmers' participation in CBOs plays an important role in improving their adaptive capacity to floods. However, in our study, the treatment was not randomly assigned, so a simple mean difference of average flood adaptation strategies is not conclusive. Moreover, in this case, the unobserved characteristics of farmers cannot be considered, which may lead to a biased estimate of the mean difference. For this reason, in order to provide more solid evidence of the impact of CBO participation on farmers' flood adaptation, we employed an endogenous switching regression model. In addition, PSM and IPWRA were used to check the robustness of the results.

3.3. ESR Results

Table 5 illustrates the results of the endogenous switching regression model. Column 2 contains the equation for CBO participation, which provides the determinants for CBO participation, while columns 3 and 4 contain the determinants for adopting flood adaptation strategies for CBO participation and non-participation, respectively. Probit estimates are used to interpret the coefficients in the selection equation. Table 5 shows that the likelihood ratio test for joint independence of the ESR specification is significant at the 1 percent level, indicating that the three equations are interdependent and should not be estimated separately. Based on the findings of the likelihood ratio test of independence, the null hypothesis of no correlation between CBO participation and flood adaptation strategies is rejected, showing that CBO participation is correlated with the adoption of flood adaptation strategies. The covariance terms ($\rho_{P\mu}$ and $\rho_{N\mu}$) reveal that the correlation between the error terms of the selection equation and the outcome equation for CBO participation ($\rho_{P\mu}$) is statistically significant, showing that CBO participation was self-selected.

Table 5. Parameters estimates of CBO participation and flood adaptation equations.

Variables	CBO Participation	Adoption of Flood Adaptation Strategies	
		CBO Farmers (n = 164)	Non-CBO Farmers (n = 195)
Age	−0.004 (0.006)	−0.000 (0.010)	0.001 (0.011)
Gender	0.159 (0.174)	−0.851 ** (0.312)	−0.477 (0.310)
Years of schooling	−0.009 (0.028)	0.174 *** (0.053)	0.056 (0.046)
Family size	−0.049 (0.043)	0.043 (0.072)	0.211 ** (0.091)
Children under 10 years	0.234 ** (0.097)	0.359 **(0.169)	−0.159 (0.182)
Disabled family member	0.135 (0.205)	0.121 (0.343)	−0.648 (0.397)
Farm size	0.001 (0.001)	−0.001 (0.002)	−0.001 (0.003)
Annual income	0.005 (0.006)	0.018 ** (0.008)	0.048 ***(0.012)
Distance to the village center	−0.020 *** (0.007)	0.055 ***(0.012)	0.116 *** (0.014)
Flood experience	0.311 ** (0.120)	1.121 ***(0.264)	0.974 ***(0.213)
Access to information	1.328 *** (0.165)	-	-
Constant	−1.517 ***(0.402)	8.474 ***(0.815)	1.497 **(0.767)
σ_P	1.841 *** (0.159)		
σ_N	1.832 *** (0.100)		
$\rho_{P\mu}$	−0.819 *** (0.095)		
$\rho_{N\mu}$	−0.239 (0.201)		
Wald chi2(10) = 165.30	Log likelihood = −871.047; Prob > chi2 = 0.000		
LR test of independence	Chi2(1) = 15.80 Prob > chi2 = 0.000		

Note: *** and ** denote significance level at 1% and 5%. Standard errors in parentheses. Source: Authors' own calculation.

This means that if farmers decide to participate, CBO participation may not have the same impact on farmers as CBO non-participation. Since the sign of $\rho_{P\mu}$ is negative, this indicates a positive selection bias, implying that farmers with above-average adaptation strategies are more likely to participate in CBOs. This result is consistent with the studies [33,36], but differs from the results of other previous studies [37,38]. Since $\rho_{P\mu} < \rho_{N\mu}$ shows that farmers with CBO participation adopt higher adaptation strategies than farmers who do not participate in CBOs, the required conditions for consistency are also met [30]. However, the impact of CBO participation on flood adaptation strategy adop-

tion is estimated in two steps. First, the results for the determinants of CBO participation are presented, and then the factors that influence farmers' adoption of flood adaptation strategies are discussed.

3.3.1. Determinants of CBO Participation

Table 5 shows that the number of children under 10 years, distance to the village center, flood experience, and access to information are the most important factors that affect farmers' participation in CBOs. Having a higher number of children under 10 years old has a significant influence on whether farmers participate in CBOs. This suggests that farmers with more children under 10 have a higher probability of participating in CBOs to prepare for an impending flood threat. Flood experience is a positive predictor that significantly influences farmers' participation in CBOs. That implies that farmers who have previously been exposed to more severe floods tend to have higher participation in CBOs. The distance of farmers' houses from the village center is negatively associated with CBO participation, suggesting that farmers who live near the village center are more willing to participate in CBOs. The purpose of the selection equation is to account for unobserved heterogeneity that might influence the flood adaptation obtained from the outcome equations, not to perfectly explain participation in CBOs. To this end, one or more valid instruments must be included in the selection equation. Access to information was identified as an instrumental variable that is highly significant in determining participation in CBOs, suggesting that those who receive information about participation in CBOs from leading NGOs, friends, or relatives may be more motivated to participate in CBOs.

3.3.2. Factors Affecting the Adoption of Flood Adaptation Strategies

The positive and significant determinants of flood adaptation strategies are gender, years of schooling, family size, children under 10 years, annual income, distance to the village center, and flood experience. Although male farmers seem to have higher participation in CBOs, gender shows a significant negative correlation with the adoption of flood adaptation strategies for the farmers with CBO participation. Female farmers who participate in CBOs improve their average flood adaptation by 85.1 percent, while those who do not participate in CBOs improve their average adaptation strategies by 47.7 percent. Years of schooling significantly increase adaptation strategies for farmers with CBO participation. Precisely, the results showed that with CBO participation, each year of schooling increases average flood adaptation strategies significantly by 17.4 percent, but with CBO non-participation, they increase by only 5.6 percent. Having children under 10 years is also significant at the 5% level for farmers who participate in CBOs. CBO participation, in particular, has increased average flood adaptation strategies by 35.9 percent among farmers with more children. Family size only increases average flood adaptation strategies for farmers without participation in CBOs but does not appear to significantly increase adaptation strategies for farmers with CBO participation.

For both categories of farmers, annual income is significantly and positively associated with the adoption of flood adaptation strategies, implying that farmers with higher incomes adopt more flood adaptation strategies. Annual income raises average adaptation by 1.8 percent for CBO participation and by 4.4 percent for non-participation in CBOs. Distance to the village center is positive and significantly correlated with farmers' adoption of flood adaptation strategies for both CBO participation and non-participation, implying that farmers' living far from the village center increases the probability of adopting higher average flood adaptation strategies. Flood experiences for both CBO and non-CBO farmers are highly significant and positively correlated with the adoption of flood adaptation strategies, indicating that farmers who have experienced higher numbers of severe floods tend to adopt more flood adaptation strategies. Some variables, such as age, children under 10 years, and disabled family members vary with the sign of the coefficients for CBO and non-CBO due to heterogeneity.

3.3.3. Estimation of Treatment and Heterogeneity Effects

The impact of CBO participation on the adoption of flood adaptation strategies can be shown by estimating the average treatment effect on the treated (ATT), the average treatment effect on the untreated (ATU), and the heterogeneity effect (HE), which are presented in Table 6. The ESR estimates ATT and ATU, considering the selection bias that derives from the fact that CBO and non-CBO farmers may be systematically different, whereas the mean differences in Table 4 may bias the impact of CBO participation on farmers' adoption of flood adaptation strategies.

Table 6. Average expected treatment and heterogeneity effects.

Outcomes	Participation Status	Participation Decision		CBO Participation Effect
		CBO	Non-CBO	
Flood adaptation strategies scores	ATT (CBO)	(a) 13.47 (0.18)	(b) 9.71 (0.20)	3.76 *** (0.27)
	ATU (non-CBO)	(c) 14.50 (0.12)	(d) 9.68 (0.17)	4.82 *** (0.21)
	Heterogeneity effect	−1.03 *** (0.21)	0.03 (0.26)	−1.06 *** (0.14)

Note: *** denotes significance level at 1%. Standard errors in parentheses. Source: Authors' own calculation.

Table 6 shows the expected value of the average flood adaptation strategies scores in the counterfactual analysis for CBO participants and non-participants. Cases (a) and (d) are the observed expected average adaptation scores, which is 13.47 for CBO participants and 9.68 for non-participants. A *t*-test analysis between the two groups reveals that CBO farmers have significantly higher adoption of flood adaptation strategies compared to non-CBO. However, it cannot be attributed to CBO participation alone. Table 6 also reports the treatment effect of CBO participation. In counterfactual case (b), the CBO farmers would have adopted 3.76 fewer adaptation scores if they had not participated in the CBOs.

On the other hand, if the actual non-CBO farmers had participated (counterfactual case (c)), they would have produced 4.82 more flood adaptation scores. The difference between ATT and ATU shows that the transitional heterogeneity effect is negative (TH −1.06), implying that the impact of CBO participation is significantly higher for the actual non-CBO farmers than for the real CBO farmers. The actual non-CBO farmers would have gained 1.06 more adaptation strategies scores compared to the actual CBO farmers if they had participated. The base heterogeneity effects reveal that the non-CBO farmers would have adopted more strategies than the CBO farmers in the counterfactual case (c) but fewer in the counterfactual case (b).

3.4. Robustness Check with PSM and IPWRA

The findings of the ESR model may be limited due to model assumptions, such as the use of instrumental variables to identify the selection process [25]. A robustness test was performed using PSM approaches with two algorithms, nearest neighbor matching (NNM) and kernel-based matching (KBM). From Figure A1, it is found that the probit estimates guarantee a substantial overlap in the propensity score distributions between farmers' CBO participation and non-participation. This finding indicates that propensity scores of farmers with and without CBO participation are in good overlap, which highlights the necessity of proper matching and the application of the common support requirement to prevent poor matches. Following that, a test of balance checking was run to determine if the covariates are balanced as well as to see if the group differences (farmers who participated in the CBO and those who did not) have been removed. The mean standardized bias decreases from 27.0 percent before matching to 7.7 percent (NNM) and 6.1 percent (KBM) after matching, as shown in Table A2. The test also shows that before matching, all regressors' joint significance on treatment status cannot be rejected before matching but can be rejected after

matching. Similarly, the pseudo-R^2, which measures how well the regressors explain the CBO participation probability, falls from 12.2 percent to 1.3 percent (NNM) and 0.8 percent (KBM) at the end of matching. The propensity score estimation is acceptable and indicates no systematic difference after matching in the covariates' distribution between the treatment and control group since the *p*-value from the likelihood ratio test is insignificant, and the values of pseudo-R^2 and standardized mean bias are low. Table A3 reveals the balance checking of selected covariates between CBO and non-CBO before and after matching. The results show that covariates between CBO participation and non-participation were imbalanced before matching, but the overall balance increased after matching.

When it comes to ATT from robustness tests with PSM and IPWRA (Table 7), we found that farmers' participation in CBO has a positive and significant influence on their adoption of flood adaptation strategies regardless of the matching technique. Specifically, the impact of CBO participation is 3.36 in NNM and 3.44 in KBM, indicating that the overall adoption of flood adaptation strategies increases by 3.36 and 3.44 for the NNM and KBM, respectively, when farmers participate in CBOs.

Table 7. Robustness check with PSM and IPWRA.

Item	Average Treatment Effect on Treated (ATT)		
	PSM (NNM)	**PSM (KBM)**	**IPWRA**
Flood adaptation strategies score	3.36 *** (0.47)	3.44 *** (0.37)	3.23 *** (0.25)

Note: *** denotes significance level at 1%. Standard errors in parentheses. Source: Authors' own computation.

The ATT estimation from IPWRA shows that participation in CBOs increases the adoption of flood adaptation strategies by 3.23 compared to non-participation. The IPWRA result is consistent with the PSM results, suggesting that PSM was not misspecified. Most noticeably, as compared to the ESR findings, the PSM and IPWRA results are comparatively low, likely due to considering unobservable characteristics in ESR that are not possible to control when using the PSM technique [39] as well as in the IPWRA method.

4. Discussion

From the descriptive analysis, the test of the mean difference in some selected socioeconomic characteristics of farmers reveals significant differences between CBO and non-CBO farmers. This is a sign of sample selection bias, and ESR results also confirm the positive selection bias, indicating that farmers with above-average flood adaptation strategies have more participation in CBOs, which may be due to some unobserved characteristics such as farmers' inherent ability, i.e., knowledge and awareness, or the extent of motivation to participate in CBOs. The mean difference in the adoption of flood adaptation strategies is significantly higher for CBO farmers. The reason may be that farmers not only receive flood early warnings from the CBOs but also actively participate in identifying their flood adaptation problems and learn how to take appropriate flood adaptation measures. Moreover, experts from different organizations are invited to the CBO meetings, and farmers learn from the sessions about different adaptation techniques. Furthermore, they can also share their ideas to be more adaptive to flood risk. However, this mean difference is not conclusive, as this finding is only based on observed characteristics. To confirm the net impact of CBO participation, we employed ESR, which simultaneously specifies the participation and adaptation equation.

With respect to the participation equation, it is observed that farmers' flood experience is a vital driver influencing farmers' participation in CBOs. In char-lands, farmers are frequently affected by flooding, but the experience of flood severity is not the same for all. Farmers who were more affected by flooding in the past are more likely to participate in CBOs. This result was expected, since earlier literature [40–42] has shown that previous experiences are important in the learning process of dealing with floods. This result is also consistent with [43] that people who have been previously exposed to hazards are far

more aware than those with no experience of hazards. In this study, farmers with more flood experience are likely to have more flood risk awareness, which may motivate them to participate in CBOs to learn about flood adaptation by sharing knowledge and experiences. It is found that there is a positive correlation between farmers' number of children under 10 years and CBO participation. Because parents are more concerned about their children's safety and what they will experience during a natural disaster, they may feel compelled to foresee the repercussions and prepare ahead of time to reduce any negative outcomes [44]. This intention to prepare in advance may motivate farmers to participate in CBOs to learn flood adaptation techniques. The negative correlation of farmers' house distance to the village center implies that long distance discourages the farmers from participating in CBOs, which is consistent with the findings of Arcand and Fafchamps [45]. It is plausible that riverbank erosion and frequent flooding are acute in char-lands, often causing farmers' houses to be moved from one location to another in the village, which may reduce their participation. Gender is not significant, but the magnitude of the coefficient is larger, indicating higher male participation compared to female farmers. Jaafar et al. [46] reported that gender has a significant effect on community participation, which may be due to the fact that women from socially weaker backgrounds often have low self-confidence, which hinders their participation.

In the second stage, ESR identifies the factors affecting farmers' adoption of flood adaptation strategies, which is another important aspect of this study. The coefficient estimates for the CBO participation and non-participation regimes differ considerably for several of the variables, showing that the switching regression technique is preferable to a simple treatment effects model. Results find a significant negative correlation of gender with adoption of flood adaptation strategies for CBO farmers that females adopt more compared to males. Several studies examining the relationship between gender and flood preparedness have shown that women are more prepared than men [47], particularly when it comes to making a family emergency plan, keeping family members safe, and carrying out preparedness messages [48]. Women are more concerned about flooding than men and are more likely to take action to adapt to flooding [49]. Ruslanjari et al. [50] also found that the role of women in reducing disaster risk is in the emergency phase, i.e., saving themselves and their family members. Farmers' years of schooling is also significant for flood adaptation of CBO farmers. Flood adaptation is related to how people perceive and respond to risk information [51]. Because educated individuals are better equipped to interpret risk information, they are more conscious of flood risk. Muttarak and Pothisiri [52] also found that formal education is positively correlated with taking precautionary measures at the individual, family, and societal levels, but numerous studies have shown that the influence of education on precautionary behavior is small or nonexistent [43,53,54]. The number of children under 10 years also significantly affects farmers' flood adaptation strategies for CBO participation. This is because high numbers of small children and other dependents are associated with increased vulnerability [55]. Children under 10 years old in Bangladesh are dependent on their parents and often cannot swim, making them more vulnerable and causing parents to be more concerned about their safety during floods. This finding is also consistent with farmers' higher participation in CBOs with more children under 10 years of age. Stojanov et al. [56] also found that individuals with a larger number of children are more inclined to implement additional flood-prevention measures. Family size is a significant predictor only for the farmers with CBO non-participation. The average number of family members in char-lands is high, and many joint families with more elderly people and more resources are found in char-lands, making it easier for them to adopt more adaptation strategies. On the other hand, small households have potentially limited resources [57], and people living alone tend to be less prepared for disasters [58]. Similar results were found by [59,60], according to which family size is positively correlated with flood adaptation behavior.

Annual income significantly increases adaptation strategies for both CBO and non-CBO farmers. Flood adaptation strategies, such as the construction of houses, flood-proof

sanitation, raising tube wells for safe drinking water, boat preparation, etc., require adequate financial resources in Bangladesh that are affordable only to farmers with sufficient income. This finding is also consistent with [56,61], that income is largely correlated with the implementation of flood control measures, but some studies still found an insignificant relationship between income and adaptation strategies [43,62]. Farmers' house distance to the village center was negatively correlated with CBO participation but positively associated with flood adaptation strategies for both CBO and non-CBO farmers. A reasonable explanation for the positive effect may be that people living far from the village center are more vulnerable to flood risk because they are less likely to seek help from others due to their greater distance from larger communities, which may influence their higher adoption. In addition, farmers living in char-lands with higher distances from the village center appear to have comparatively more proximity to the river in the char-lands, which may also influence their adaptation behavior. Flood experience has a significant influence on the adoption of flood adaptation strategies by both CBO participants and non-participants, which is consistent with other results [59,63]. Previous flood experience was associated with increased risk perception and flood preparedness, and individuals who had experienced floods had stronger feelings about future floods and stronger intentions to take adaptation measures than those who had not [54]. According to [64], previous experience with flood damage and future damage projections increases the probability of mitigation.

Results from treatment effect analysis show that CBO participation grants higher adaptation strategy adoption in comparison with non-participation. This result indicates that farmers who participated in CBOs would have gained less if they had not participated, and those who did not participate would have gained more if they had participated in CBOs for flood adaptation adoption. The average treatment effect estimated from PSM and IPWRA is also consistent with ESR results.

This study concentrated on the role of CBOs in response to the 2020 flood. The country experienced 0.3 percent more rainfall than usual during the 2020 monsoon. The Jamuna flowed above the danger level (13.35 m) at Sirajganj point for 37 days during the monsoon. The maximum flooding occurred during the 2020 monsoon season, covering 40% of the country [65], and it was the country's longest flooding period in 22 years [66]. In some of the areas, notably in the char-lands, there was severe riverbank erosion and flooding. Results show that farmers who participated in CBOs employed significantly more flood adaption strategies than non-CBO farmers. From the farmers' opinions during the survey, it was noted that CBO participation had enabled them to lessen flood loss in response to the 2020 flood since they had effective adaptation measures, which supports the findings of this study. As a future perspective, CBOs are expected to help the farm communities in the char-lands adapt to future extreme flood events like the 2020 flood or worse.

Based on the evidence of significant contributions by CBOs, it can be assumed that CBOs have the potential to make farm communities resilient to flood shocks. Alhassan [67] also highlighted the importance of farmer-based organizations (FBOs), where FBOs enhance farmers' resilience to flood effects. In this study, CBOs have been found as an effective tool for disseminating agricultural flood adaptation knowledge, and as a result, they may contribute to sustainable farming through the dissemination of flood-tolerant agricultural technologies. However, the sustainability of these CBOs in the char-lands is a concern. Adequate trust, knowledge, leadership, and funding are the major challenges to the sustainability of these organizations [22]. Datta [68] highlighted the importance of leadership for the sustainability of CBOs in Bangladesh. Government interventions are obvious to sustain the CBO activities for sustainable adaptation to flooding effects.

5. Conclusions and Policy Recommendations

5.1. Summary of Results and Conclusions

Flooding is a frequent disaster in Bangladesh. People living in char-lands are most exposed to floods and rely on community-based organizations (CBOs) for flood adaptation. Based on data obtained from the char-lands of the Sirajganj district, Bangladesh, we

explored the potential impact of CBO participation on farmers' adoption of flood adaption strategies. ESR results reveal evidence of positive selection bias in the covariate distribution between CBO and non-CBO farmers, implying the justification of selection bias consideration. From the ESR estimates in the first stage, it is found that CBO participation favors farmers who have access to information on CBO participation, more children under 10 years old, and those who experienced more severe floods and reside close to the village center. In the second stage of ESR, socio-economic factors such as the number of children under 10 years, years of schooling, family size, annual income, distance to the village center, and flood experience significantly influence the farmers' adoption of flood adaptation strategies. The ultimate finding from the impact assessment in ESR is that CBO participation has increased average flood adaptation by 3.76, while from PSM estimates, farmers' average flood adaptation has increased by 3.36 for NNM and by 3.44 for KBM due to CBO participation. The CBO participation impact obtained from IPWRA is 3.23, which is consistent with ESR and PSM approaches. In counterfactual analysis, it is found that CBO participation is also effective for farmers who did not participate in CBOs. This positive and significant impact of CBO participation on farmers' flood adaptation reaffirms the potential role of CBO participation in raising farmers' flood adaptation capacity.

5.2. Policy Recommendations

These findings are especially significant in developing strategies for effective community-based flood risk communication to adapt to the potential consequences of flooding. Public policies can play a critical role in assisting farmers in adapting to floods. Though male participation in CBOs seems to be higher, female participation is notable in the adoption of flood adaptation measures. Thus, attention can be drawn to the enhancement of female participation in CBOs. As flood experience drives the farmers' participation in CBOs, raising awareness and capacity-building programs in rural char-lands can be useful to increase farmers' flood risk awareness that can increase CBO participation. Since farmers with better access to information on CBOs have more participation in CBOs, the facilitation of access to information regarding CBO participation is important.

The government of Bangladesh has prepared a National Plan for Disaster Management (NPDM) for 2021–2025 under the Ministry of Disaster Management and Relief (MoDMR), which takes a "whole society approach" involving all public and private sectors and communities themselves. However, this plan lacks adequate attention to community involvement through the platform of CBOs for effective flood risk communication in remote rural areas such as char-lands. Therefore, the government can focus on community-based flood risk communication through CBOs with the collaboration of NGOs and local authorities. The most important challenge of CBO performance is its sustainability because it is common to find that most CBOs stop their activities when they become independent from the leading NGOs. Thus, the government should take interventions regarding the strengthening and institutionalization of existing CBOs to promote successful flood adaptation. Empowerment of these CBOs can enhance their sustainability, which will contribute to sustainable farming in char-lands through improving farmers' flood adaptation capacity. Although the outcome of this research is confined to char-lands, the evidence from this research can guide policymakers to expand CBO activities in other flood-prone areas of Bangladesh.

5.3. Limitations of the Study

The key limitation of this study is that the treatment was not assigned at random; rather, it was given ex post facto, so it is not possible to compare adaptation strategies with and without treatment effects on the same people. Another limitation of this study is that it was difficult to increase our sample size due to the COVID-19 pandemic. This study is limited to one sub-district where CBOs are operated by one local NGO. Future studies considering other CBOs operated by different organizations in other areas are required to elucidate the differential impact of the CBOs so that policy makers can formulate a common policy for the upscaling of existing CBO activities. Moreover, future research should look at

the motives for participating in CBOs as well as expectations for outcomes and barriers to participation in CBOs. Furthermore, potential future research could be to provide different dimensions to the present analysis, including actual climate variables such as precipitation, rainfall, temperature, etc.

Author Contributions: Conceptualization, M.O.F. and K.L.M.; methodology, M.O.F.; validation, M.O.F. and K.L.M.; software, M.O.F.; formal analysis, investigation, resources, data curation, M.O.F.; writing original draft preparation, M.O.F.; writing review and editing, M.O.F. and K.L.M.; visualization, M.O.F.; supervision, K.L.M. All authors have read and agreed to the published version of the manuscript.

Funding: There was no external funding for this research.

Institutional Review Board Statement: The study was conducted according to the guidelines and approved by the Ethics Committee of Graduate School for International Development and Cooperation (IDEC), Hiroshima University, Japan, on 31 August 2021.

Informed Consent Statement: All farmers who took part in this study provided their informed consent.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors would like to thank the Project for Human Resource Development Scholarship (JDS) organized by Japan International Cooperation Center (JICE), which facilitated the master's study of M.O.F. at Hiroshima University, Japan.

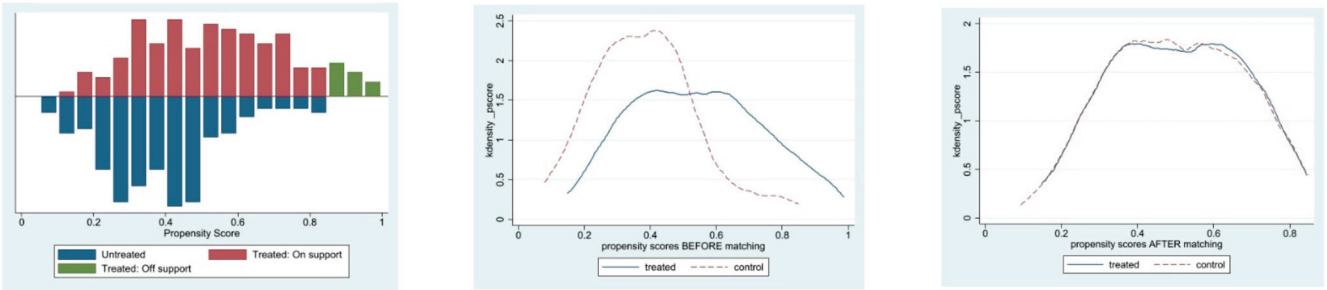
Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Validity test of the selection instrument.

Parameter Estimates	Model 1 (CBO Participation, 1 for Participation, 0 for Otherwise)	Model 2 Adoption of Flood Adaptation Strategies
Access to information	1.322 *** (0.169)	0.30 (0.278)
Constant	−1.526 *** (0.411)	1.522 * (0.782)
Wald test on instrument	χ^2 = 96.30 ***	F-stat = 0.01
Observations	359	195

Note: *** and * denote significance level at 1% and 10%. Standard errors in parentheses. Source: Authors' own calculation.



(**a**) (**b**) (**c**)

Figure A1. Propensity score graph: (**a**) overlap of the treated vs. untreated (**b**) before matching, (**c**) after matching.

Table A2. Matching quality test.

Matching	Pseudo R2		LR $\chi 2$		*p*-Value		Mean Bias		Med Bias	
	Before	After	Before	After	Before	After	Before	After	Before	After
NNM	0.122	0.013	60.36	5.18	0.000	0.879	27.0	7.7	20.6	6.8
KBM	0.122	0.008	60.36	3.24	0.000	0.975	27.0	6.1	20.6	6.8

Source: Authors' own calculation.

Table A3. Balance checking of the covariates for CBO participation and non-participation.

Covariates	Before Matching			After Matching (NNM)				After Matching (KBM)			
	Mean		*p*-Value	Mean		*p*-Value	% Bias Reduction	Mean		*p*-Value	% Bias Reduction
	Treated	Control		Treated	Control			Treated	Control		
Age	45.21	47.34	0.155	45.62	46.58	0.533	54.8	45.62	44.32	0.412	39.4
Gender	0.71	0.70	0.742	0.70	0.73	0.608	−68.0	0.70	0.72	0.743	−8.1
Years of schooling	3.35	2.62	0.023	3.05	2.53	0.133	29.4	3.05	2.75	0.386	59.7
Family size	5.74	5.39	0.103	5.60	5.28	0.149	5.8	5.60	5.47	0.548	60.5
Children under 10 years	1.53	1.17	0.000	1.44	1.36	0.433	79.6	1.44	1.35	0.377	77.3
Disabled family member	0.20	0.13	0.114	0.19	0.20	0.885	89.1	0.19	0.19	0.935	94.0
Farm size	151.01	115.79	0.000	135.60	131.18	0.606	87.5	135.60	129.26	0.481	82.0
Annual income	48.62	40.38	0.000	44.98	43.47	0.490	81.7	44.98	43.50	0.514	82.0
Distance to the village center	25.76	27.64	0.121	26.50	25.71	0.519	57.5	26.50	25.77	0.577	60.8
Flood experience	2.73	2.31	0.000	2.64	2.65	0.873	96.8	2.64	2.64	0.961	99.0

Note: $p < 0.01$ and $p < 0.05$ denote 1% and 5% level of significance, respectively. Source: Authors' own calculations.

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Participation of Brinjal Farmers in Large and Small Wholesale Markets: Factors Influencing Farmers' Decisions and Impact on Producers' Prices

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Abstract: This research aims to explore the factors associated with the decisions of brinjal (aubergine) farmers to participate in large wholesale markets and estimate the impact of large wholesale markets participation on producers' prices in the Jashore and Narsingdi districts of Bangladesh. A linear probability model (LPM) was used to identify the factors associated with decisions to participate in large wholesale markets, and propensity score matching (PSM) was applied to estimate the impact of large wholesale markets on producer prices. The results showed that the decision to participate in a large wholesale market is significantly associated with years of schooling, farm size, the distance from the farm to the large wholesale market, road quality from the farm to the market, access to extension services, market information, group marketing, trust-based credit, yield, and transportation cost. Moreover, this study consistently showed that participation in a large wholesale market had a positive effect on producer price. Therefore, this study suggests the policy implication that comprehensive strategies must be adopted by the government to increase small-scale farmers' participation in large wholesale markets and improve the welfare of these farmers.

Keywords: brinjal; Bangladesh; linear probability model; PSM; large wholesale market; comprehensive strategies; trust-based credit

Citation: Rana, M.; Maharjan, K.L. Participation of Brinjal Farmers in Large and Small Wholesale Markets: Factors Influencing Farmers' Decisions and Impact on Producers' Prices. *Sustainability* **2022**, *14*, 2357. https://doi.org/10.3390/su14042357

Academic Editor: Julio Berbel

Received: 8 January 2022
Accepted: 14 February 2022
Published: 18 February 2022

1. Introduction

The instability of growers' prices is a central reason for their unstable income [1] and has been a challenge for farmers [2] as well as agricultural policy makers over the years in developing countries [1]. Understanding the dynamics [3] of market participation, the ability of farmers to participate in a market effectively and efficiently [4] can facilitate an exploration of the market's potential [3] to obtain better prices for farmers. Sustained price-stabilization mechanisms [1] for farmers are a key policy tool to make agriculture sustainable in a developing country such as Bangladesh by means of improving the income and food security of the nation [5]. Bangladesh is committed to doubling the agricultural productivity and income of small-scale food producers, as defined at the 2030 Agenda for Sustainable Development Goals 2.3 [6]. In order to maximize the benefits that farmers earn, farmers must make an appropriate decision as to where they should sell their product [7]. Generally, to ensure income from their harvests, farmers depend on traders, temporary roadside markets, and nearby markets. However, accessing better prices depends on the choice of market and sales channels. Thus, market participation and the subsequent choice of market is a major gateway to raising the income, reducing the poverty, and improving the general welfare of farmers [5,8]. This paper examines the factors influencing brinjal (aubergine) farmers' decisions regarding large wholesale market participation and

estimates the impact of large wholesale market participation on producers' prices in the Jashore and Narsingdi districts of Bangladesh.

There are two types of determinants for the market participation of smallholders as well as commercial farmers, namely, external and internal factors. The external factors that influence the market participation of farmers include the existing physical and institutional infrastructure such as roads, electricity, transport systems, communication, markets, and the rules of the law [4]. On the other hand, farm size, experience, capital, schooling, asset ownership, human skill, and the utilization of market information are the internal factors that affect market participation. In addition, many studies [9–15] argued that socioeconomic factors, physical factors, institutional factors, and marketing factors are pivotal in the determination of market participation. Socioeconomic factors such as age, gender, household size, source of labor, farming experience, farm size, and volume of production can positively affect market participation decisions among smallholder farmers and subsequently increase the level of participation [11,16–19]. Furthermore, the availability of physical and market infrastructure, access to equipment, and the positive attitude of the head of the household towards risk significantly affect the decision of a household to participate in the market [20]. Moreover, Sizibia et al. [21] identified that not only institutional factors, such as public assets, extension services, and price information, but also market factors, such as the distance to the market and the road networks, are crucial for market participation decisions. In addition, Kyaw et al. [5] found that the transportation of goods from rural areas to urban areas influenced market participation by smallholder rice farmers in Myanmar due to better road conditions.

Approximately 142 types of vegetables are grown in Bangladesh in both the summer and winter seasons, some even all year round [22]. Brinjal (known as aubergine in many parts of the world) is the second most important vegetable in Bangladesh in terms of both production area and yield, and is a popular source of income for small and marginal farmers, only surpassed by potatoes [23]. In 2019, 82 thousand acres were used for brinjal (aubergine) cultivation, with a production of 530 thousand metric tons [24]. Brinjal (aubergine) enters the marketing chain immediately after harvesting. Farmers normally harvest two to three times a week during the harvesting season [23]. Therefore, brinjal (aubergine) is an important source of income for small-scale, poor Bangladeshi farmers. Vegetables are perishable in nature and cannot be stored for long periods, which necessitates their immediate sale after harvesting [25]. However, the prices offered by producers vary according to the nature of market in which the product is sold. Therefore, farmers' income depends on their market choice decision and their efforts to access more income from the market. Linking farmers to high-value markets is crucial for their economic development [26].

As Bangladesh is now moving from subsistence to commercial agriculture, priority is given to the field of value-added agricultural products, extension services, information, fair prices for farmers, and access to high-value markets [27]. Nevertheless, the success of commercialization depends on the secure connection to better prices and access to premium markets. Market infrastructure and marketing facilities are not well-developed in Bangladesh. In addition, there are weaknesses in the proper coordination between research, extension services, and the marketing of agricultural produce [28]. There are gaps in the coordination of the system, regarding, for example, the invention and development of new varieties, the timely transfer of technology to farmers by extension workers, and the provision of assistance to market linkage facilities. Even the trading system and nature of the market vary from market to market. This sometimes creates difficulties for the supply of reliable market information required to access the market. However, a very limited numbers of studies have been conducted in Bangladesh to identify the factors responsible for the market participation decisions of farmers. Osmani and Hossain [29] focused on the determinants of smallholder farm commercialization and recommended the development of market infrastructure and institutional market information services to enhance commercialization. Most of the previous studies focused on the determinants of

smallholder farmers commercialization. Therefore, there is a gap in the factors associated with market choices made by commercialized farmers and the effect that this participation has on prices.

A few studies, for example, [30–32] attempted to measure the impact of market participation on outcomes such as producer's price, profitability and income. Negi et al. [32] used an ordinary least square (OLS) estimation; however, OLS suffers from selection bias. Retsef et al. [31] used propensity score matching (PSM) but failed to use multiple robustness checks to show the consistency of their findings. Moreover, Mulubrhan et al. [30] applied difference in differences (DID), but the assumed common trend of their study remains questionable. As a result, there remains a need to address the gaps in previous studies by employing a causal inference method with proper robustness checks.

A linear probability model (LPM) was used to identify the factors associated with large wholesale market participation decisions, and propensity score matching (PSM) was applied to estimate the impact of the decision to participate in the large wholesale market on producer price. In addition, inverse probability weighted regression adjustment (IPWRA) and Mahalanobis distance matching (MDM) were used as robustness checks to complement our main findings. To the best of our knowledge, no studies have been conducted to determine the influencing factors on the decisions of brinjal (aubergine) farmers to participate in the large wholesale market, and to measure the effect of this on producer price in the country. Therefore, this study was an effort to fill the research gap and aid policymakers by understanding the factors behind this subject. Thus, the main objective of this study was to identify the influencing factors on farmers' large wholesale market participation decisions for selling their produce and, subsequently, the impact on producer price for brinjal (aubergine) farmers.

2. Materials and Methods

2.1. Study Sites

The study was conducted in two districts, namely Jashore and Narsingdi. Jashore district is located in southwestern region, whereas Narsingdi district is located at central region of Bangladesh (Figure 1). These two districts are geographically separate from each other in Bangladesh. However, the economy of Jashore and Narsingdi are predominantly dependent on agriculture. Nearly, 63.38% and 51.22% of the total households in Jashore and Narsingdi districts are agriculture farm holdings [24]. Due to fertile land and favorable climate conditions, these two districts are very suitable for brinjal (aubergine) production. About 30-60% of the locally produced vegetables in Jashore are transported to the capital city, Dhaka [33].

One sub district from each district, "Sadar" sub-district from Jashore and "Belabo" sub-district from Narsingdi, were selected for this study (Figure 1).

In the study areas, there are two types of wholesale markets: one is a large wholesale market situated near the main center of the sub-district and the others are small wholesale markets (locally known as *haat*) located in the village areas. Generally, farmers participate in either the large wholesale market or small wholesale market in these study areas.

Small wholesale market: In the small wholesale market, trade is operated by the direct sales by the producers to small wholesale market traders or the partners of large wholesale traders. Small wholesale markets are usually arranged on a periodic basis or on specific weekdays. These markets are commonly organized at a central place in villages or beside a main road connected with a district highway. In small wholesale market, local retailers, local commission agents, and local wholesalers are the buyers of farmers' brinjal (aubergine), but local commission agents work as commission agents between the farmers and traders (local retailers, local wholesalers). Local wholesalers (locally known as *bepari*) are the most important actors who supply different types of vegetables, mostly to capital city of Dhaka and other parts of the country. These local wholesalers are mostly the partners or appointed staff of the large wholesalers who normally buy brinjal (aubergine) from the large wholesale market.

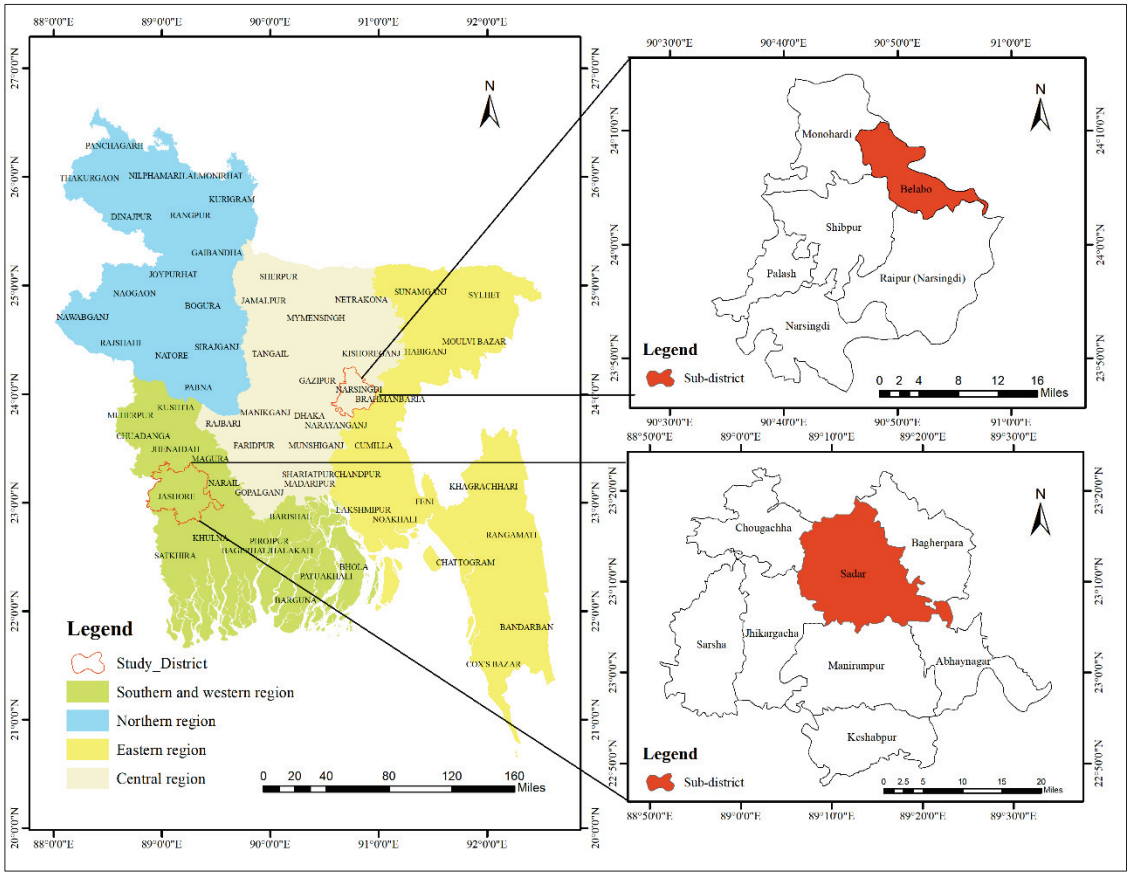

Figure 1. Study area, Bangladesh. Source: Authors.

Large wholesale market: A market in which producers and buyers are in large number; the size of market is also large since a large volume of produced is traded, there is a large number of producers and buyers, the market operates every day, and the market is located in the center of a sub-district. Local wholesalers (who purchase large in bulk sizes) are the direct buyers from the farmers in large wholesale markets. They supply vegetables mostly to the capital city of Dhaka and other regions in the country.

2.2. Conceptual Framework of Market Participation

The conceptual framework (Figure 2) implies the interrelationships of explanatory variables used in this study and how they are interdependent. The socio-economic factors were age, gender, marital status, family size, years of schooling, farming experience, brinjal cropped area, cultivated varieties, and yield. The institutional factors were road quality from farm to market, access to extension services and group marketing. The marketing factors were distance from farm to large wholesale market and transportation cost.

The physical factor was road quality from farm to market, and the informal factor was trust-based credit from traders. Due to the above factors, farmers' participation decisions in large and small wholesale markets and producer's prices vary.

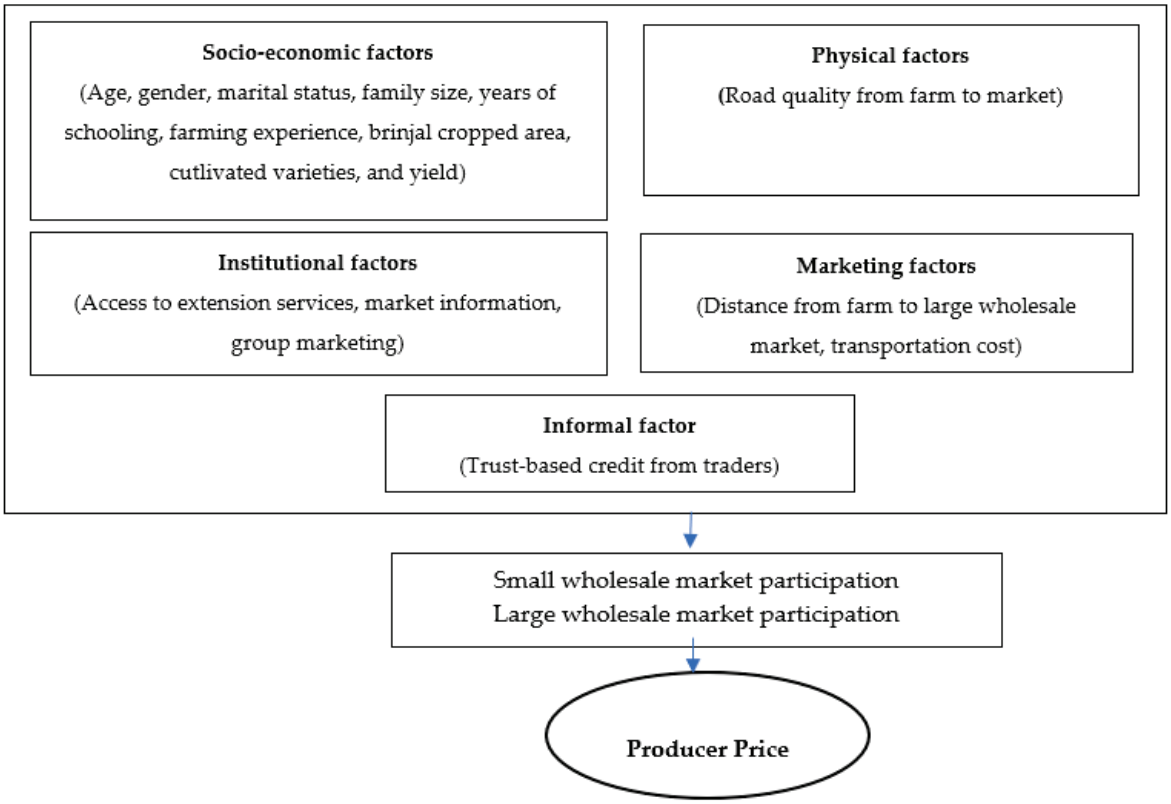

Figure 2. Conceptual framework of market participation Source: Authors' own elaboration.

2.3. Sampling Procedure

The target population was all farmers engaged in brinjal (aubergine) cultivation who sold their produce to markets in two districts, Jashore and Narsingdi. As per information from subdistrict agricultural offices, there are 1541 farmers who cultivate brinjal and mostly depend on market participation for selling their brinjal (aubergine). Among them, 250 brinjal (aubergine) farmers were randomly selected. However, a total 209 farmers responded to the survey during the study period. After completing the survey, we found that 193 respondents completed the questionnaire; the remaining farmers were not included in the sample due to incomplete the questionnaire. Among 193 respondents, 108 farmers participated in the small wholesale market and 85 farmers participated in the large wholesale market.

2.4. Data Collection

Data were collected through face-to-face interviews with the semi-structured questionnaire. The questionnaire included both open- and closed-ended questions. The data included socioeconomic characteristics, household characteristics, yield, sales price (Table 1). Before conducting final survey, the questionnaire was approved by the research ethics committee, Graduate School of International Development and Cooperation (IDEC), Hiroshima University, Japan, with compliance to ethical aspects such as basic human rights, the protection of personal information and security of data. Questionnaires were pretested on farmers before conducting the final survey. Data were collected in the period from 15 August 2020 to 30 September 2020.

Table 1. List of variables with descriptions and expected signs.

Variables	Measurement	Category	Expected Sign
	Dependent Variables		
Market participation	1 = if participate in large wholesale market 0 = if participate in small wholesale market	Dummy	+/−
	Independent Variables		
	Socio-economic Factors		
Age	In years	Continuous	+/−
Gender	1 = Male, 0 = Otherwise	Dummy	+
Marital status	1 = married, 0 = otherwise	Dummy	+/−
Family size	No. of family members	Continuous	+/−
Years of schooling	Number of years	Continuous	+
Farming experience	Number of years	Continuous	+
Brinjal cropped area	Acre	Continuous	+
Cultivated varieties	1 = High yield varieties, 0 = otherwise	Dummy	+
Yield	Kilogram/Acre	Continuous	+
	Physical Factor		
Road quality from farm to market	1 = if paved road, 0 = if unpaved road	Dummy	+
	Institutional Factors		
Market information	1 = if yes, 0 = if no	Dummy	+
Access to extension services	1 = if yes, 0 = if no	Dummy	+
Group marketing	1 = if yes, 0 = if no	Dummy	+
	Informal Factor		
Trust based credit from traders	1 = if yes, 0 = if no	Dummy	−
	Marketing Factors		
Distance from farm to large wholesale market	Kilometers	Continuous	−
Transportation cost	BDT/yield	Continuous	−
	Outcome Variable		
Producer price	BDT/Kilogram	Continuous	+/−
	Treatment Variable		
Large wholesale market participation	1 = if participate in large wholesale market, 0 = if participate in small wholesale market		

Source: Authors' own elaborations.

2.5. Variable Selection

This study selects various relevant explanatory variables that represent the conceptual framework of farmers market participation decisions (Figure 2). The justification for choosing each explanatory variable is discussed later in the justification part. Table 1 reveals and defines all the explanatory variables used in the study. Specifically, age, gender, marital status, family size, years of schooling, farming experience, and distance from farm to large wholesale market was used as farmers pretreatment characteristics to evaluate the effect of large wholesale market participation on outcome variable. Gender, education, and distance are considered as time invariant; age and farming experience were also treated as time invariant due to their proportional change of nature; and time variation of marital status, family size was considered negligible. These pre-treatment variables were selected according to the previous study of [10,34,35]

2.6. Outcome Variable

This study's outcome variable is producer's price, the price received from the market which the farmers participated in (either in large or small wholesale market). Table 1 also describes the outcome variable used in this study.

2.7. Data Analytical Method

Two types of statistical methods were used to analyze the collected data. Independent variables were categorized based on socio-economic factors, physical factors, institutional factors, marketing factors and informal factors. Based on the independent variables, the linear probability model equation was derived to identify the probable factors associated with large wholesale market participation by farmers. The following linear probability model shown in Equation (1):

$$Y\ (0,1) = \beta_0 + \beta_1\ X_1 + \beta_2\ X_2 + \ldots\ \ldots\ \ldots\ \ldots\ . + \beta_n\ X_n + \varepsilon_i \quad (1)$$

where Y (0, 1) is a dependent variable, market participation is denoted by (0, 1), large wholesale market participation is denoted by 1, and small wholesale market participation denoted by 0. The variable β_0 is a constant, $\beta_{1,\ldots,}\ \beta_n$ are parameters to be estimated, $X_{1,\ldots,}\ X_n$ are the vectors of the explanatory variables, and ε_i is the error term.

In a non-experimental study, treatment is non-random [36]. If the treatment is not randomly assigned, a mere comparison of the treated and the control group will induce bias estimation. In our study, large wholesale market participation is not randomly assigned to farmers' levels of participation, so if the farmers who participate in large wholesale markets are compared to those who do not participate in these markets, this will cause selection bias. For instance, in this study, many farmers did not participate in large wholesale markets due their dependence on the observable and unobservable characteristics. In such cases, the potential observed, and unobserved confounding variables may affect both the response and treatment variables, which causes a selectivity bias [34]. The best identification strategy is randomized control trial (RCT) to address the selection bias, but RCT is often expensive and infeasible to implement. Quasi-experimental designs are the best alternative under proper assumptions. To address the selection bias, this study applies quasi experimental identification propensity score matching (PSM) because it imitates randomized experiments. PSM define randomization [37] while assigning the treatment by matching the treated observations with the untreated observations. Many studies even apply the matching method as a useful tool to relieve potential selection bias issues [36,38]. Thus, propensity score matching (PSM) was used to estimate the effect of treatment variables (large wholesale market participation) on producer price. The difference of outcome variable between treatment and control group of producer price by applying average treatment effect on treated (ATET) can be expressed as:

$$\text{ATET}\ (\ ) = E\ [(Y_1 \mid p = 1, p(x)) - (Y_0 \mid p = 1, p(x))] \quad (2)$$

where p = participation in large wholesale market (p = 1 if participated in large wholesale market), X is a set of pretreatment characteristics, Y_1 is the potential outcome when treated (producer price for large wholesale market participants as treated group), Y_0 is the potential outcome when the unit is untreated (producer price for small wholesale market participants as control group). Despite the benefits of PSM, due to misspecification in PSM, the ATET estimation from PSM may be biased. According to [34], utilizing the inverse probability weighted regression adjustment (IPWRA) method solves such a predicament. IPWRA has a double robust characteristic, which provides consistent outcomes. It avoids misspecification bias by giving the outcome and treatment model for misspecification. Thus, IPWRA was used to check the robustness of PSM estimation results in this study. To complement the findings, this study further used Mahalanobis distance matching (MDM). Propensity score matching (PSM) and Mahalanobis distance matching (MDM) differ in the estimation of treatment effect. PSM reduces the space of covariates to a single dimension as it depends on pairing treated and control units that have similar propensity scores. On the other hand, MDM depends on pairing treated and control units that are close in terms of pretreatment covariates.

2.8. Justification for Inclusion of Independent Variables

2.8.1. Age

Age of brinjal (aubergine) farmers was measured in years. Age influenced participation in market choice through diverse ways such as experience, risk preference and access to resources [39,40]. Younger farmers are expected to take more risks and be more energetic and innovative in making decision on market choice. On the contrary, older farmers are expected to have more experience and access to resources [41]. Therefore, our hypotheses were that the expected sign might be positive or negative in this study.

2.8.2. Gender

Gender influences market choice decisions made by male- and female-headed households [39]. The gender of the farmer was set as dummy variable, where male farmers took the value of 1; otherwise, the value was zero. It was assumed as a negative sign that male farmers have better access to input and output markets with more communicative knowledge, which might provide wider options for market decisions compared to female farmers.

2.8.3. Marital Status

Farmers who are young and unmarried might have a positive influence on participation in the large wholesale market, or those who are married might have more experience that can influence participation in the large wholesale market. Maspaitella et al. [42] argued that younger farmers were more innovative and risk takers. Thus, it was expected to be positive/negative sign in this study.

2.8.4. Family Size

Family size was used as a continuous variable indicating the number of family members in a household. Jaleta et al. [43] argued that a larger household size leads to market participation decisions that can help farming activity. In contrast, [21] found that a larger household negatively influenced participation in the market due to dependence on consumption and more family labor required for farming activity. Thus, it was expected to be a positive/negative sign in this study.

2.8.5. Years of Schooling

Years of schooling of farmers was taken as continuous variable meaning the number of years spent in formal educational institution. Farmers with more schooling years may have better skills, knowledge and utilize market information to improve their marketing practices. The higher level of schooling years was found to positively affect farmers' participation in their ability to make quick decisions compared to those who had a lower level of schooling years [5,41,44]. Thus, it was considered that years of schooling might have a positive correlation with market choice decision.

2.8.6. Farming Experience

Farming experiences improve long-term relationships with traders and have more bargaining power in market output for selling brinjal, connecting with traders, and acquiring more market information. According to [45], the farming experience improves farmer's negotiation skills. Thus, it was expected as a positive sign in this study.

2.8.7. Brinjal Cropped Area

Farmers who cultivated a large area of brinjal might have an increased probability of participating in the large wholesale market. It was also assumed that a large farm size might have other multiple agriculture produces, which indicates more experience and market knowledge that helps to make the decision to participate in the market. The increase in land under vegetables cultivation and a large farm size positively influenced the choice

of market and channels [46,47]. Thus, it was measured as a continuous variable per acre and expected to be a positive sign.

2.8.8. Cultivated Varieties

Cultivated varieties were measured as dummy variables that took the value of 1 if the farmer adopted high yielding varieties or Bt brinjal and zero otherwise. In each district, farmers typically cultivate hybrid and local varieties most suited to the local conditions and markets. Some preferred varieties in the study areas are hybrid (such as BARI-2, and BARI-4 developed by Bangladesh Agricultural Research Institute (BARI)), Bt (Bacillus thuringiensis) brinjal and locally improved varieties (local varieties are developed seed/seedlings grown by storing seeds from the harvest and maintain them at a household temperature over the years). The color, size, and taste of fruits of brinjal (aubergine) depend on the cultivated varieties. Kangile et al. [8] noted that the decision of farmers to select a particular market or channel is complex and influenced by the type of product. Therefore, it was expected as positive sign in this study that farmers' decisions might have a positive influence on large wholesale market participation decision.

2.8.9. Distance from Farm to Large Wholesale Market

The distance from farm to large wholesale market is a continuous variable measured in kilometers, and it was expected to be a negative sign. The closer the distance from farm location to market, the lesser transportation cost, and the nearer the market, the more preferable market participation. Several studies found a negative influence of distance on smallholder farmers participation in the market [21,47–50]. Farmers who had a farm located far away from large wholesale markets might be less likely to sell produce in large wholesale markets and would participate in a nearer market.

2.8.10. Road Quality from Farm to Market

The road quality from farm to market was expected to be a positive influence on market participation and assumed that farmers' decisions depended on the quality of the road directly between the farm location to market. This was categorized as a dummy variable for paved road and unpaved road connections from farm location to market. Farmers who had access to paved road connections from farm location to market may have better access to transportation facilities, better market information, and would save time accessing the market, positively influencing their market participation decisions. Two studies found that farmers near the main road had better access to market information and transportation [51,52].

2.8.11. Access to Extension Services

Farmers who had access to extension services regarding market linkages with large wholesalers, free weight facilities for produce at large wholesale markets, training and advisory services regarding soil treatment, seed and seedling preparation, application of optimal input use such as fertilizer and pesticides preparation, sorting, and packaging might positively influence market participation decisions. Mcnamara and Tata [53] found that access to extension services brought knowledge, market information and technical skills for smallholder's vegetable farmers. Therefore, it was assigned as positive sign for this dummy variable.

2.8.12. Market Information

Farmers who had prior contracts with Farmers Information and Advice Center (FIAC) and fellow farmers via telephone and social network contact, the relationships between price information, information about the buyers and operational information about the market might have a positive influence on making the appropriate decisions for market participation. Market information helped to improve farmer knowledge of the market and

form an appropriate plan to sell rice in the market [5]. Thus, it was measured as a dummy variable and expected as positive sign in this study.

2.8.13. Group Marketing

Farmers who were members of Common Interest Group (CIG), hired transport in a group, or shared transport costs were considered as a performing marketing group in the study areas. Shiferaw et al. [54] found that farmers' group and collective action enhanced their ability to negotiate better prices and improved their market power.

2.8.14. Trust-Based Credit from Traders

Farmers who had trust-based credit from their traders before harvesting, at the next selling, or at the time of cultivation were given the promise that they could sell their produces to traders. This is not like formal credit services; it was totally dependent on trust-based credit services between producers and traders. However, regarding formal credit services, some studies found that access to credit was positively related with output market participation and more value addition [41]. On the contrary, it was assigned as dummy variable and expected as a negative sign that may have constrained farmers to make decisions on market choice freely in order to participate in the market.

2.8.15. Yield

Yield was considered as a proxy measure of the total production of brinjal (aubergine) in cultivated land size. It was measured in kilogram per acre as a continuous variable. An increase in production was found to increase farmer's market participation [5]. Therefore, the total yield of brinjal (aubergine) was hypothesized to have a positive influence on market participation decision.

2.8.16. Transportation Cost

Transportation cost was considered as the amount spent per season for transporting brinjal (aubergine) from farm to market where he/she participated in the market. The higher the transportation cost, the lesser the possibility of participate in the large wholesale market. Thus, it was considered as a continuous variable and expected as negative sign in this study.

3. Results and Discussion

3.1. Demographic, Socioeconomic, Farm and Market Related Characteristics of Farmers

Table 2 describes the descriptive statistics of the farmer's demographic, socio-economic, farm- and market-related characteristics between the participants of the large and small wholesale markets. The sample of 193 farmers identified that 85 farmers participated in the large wholesale market and 108 farmers participated in the small wholesale market. Among the sample, 44.04% farmers participated in the large wholesale market and 55.96% participated in the small wholesale market. The variables of age, marital status, family size, farming experience and transportation cost are not significantly different between the large wholesale market and small wholesale market participants. On the other hand, the variables of gender, years of schooling, brinjal cropped area, distance from farm to large wholesale market, yield and producer's price were significantly different between the large wholesale market and small wholesale market participants.

Table 2. Descriptive statistics of selected variables of brinjal (aubergine) farmers.

Variables	Large Wholesale Market (N = 85)			Small Wholesale Market (N = 108)			Mean Difference	*p*-Value
	Mean	Min.	Max.	Mean	Min.	Max.		
Age	43.41 (10.99)	22	70	45.45 (10.00)	24	65	2.04	0.179
Gender	0.94 (0.23)	0	1	0.85 (0.36)	0	1	−0.09 **	0.048
Marital status	0.87 (0.33)	0	1	0.92 (0.26)	0	1	0.05	0.202
Family size	5.02 (1.18)	3	8	5.12 (1.29)	3	9	0.09	0.593
Years of schooling (years)	7.24 (3.23)	0	17	5.02 (3.29)	0	12	−2.21 ***	0.000
Farming experience (years)	23.72 (10.05)	3	43	24.12 (10.78)	5	52	0.39	0.797
Brinjal (aubergine) cropped area (acre)	0.45 (0.28)	0.08	2.00	0.27 (0.13)	0.05	1	−0.18 ***	0.000
Distance from farm to large wholesale market (kilometers)	3.55 (1.26)	1.50	8.50	4.68 (1.18)	3	8	1.14 ***	0.000
Yield (kilogram)/acre	14,010 (1143)	10,900	16,500	12,932 (905)	11,200	15,500	−1077 ***	0.000
Producer Price (BDT/kilogram)	24.68 (2.58)	19	30	20.67 (2.51)	15	26	−4.01 ***	0.000
Transportation cost (BDT/yield)	9251 (2805)	5000	18,000	8713 (2684)	4500	18,500	−537	0.177

Note: Numbers in the parenthesis are standard deviation; min = minimum; max = maximum; significance at *** 1 percent, ** 5 percent (USD 1 = BDT 85) Source: Authors' own calculation.

In Table 3, the results show the frequency of selected dummy variables of brinjal (aubergine) farmers for road quality from farm to market, access to extension services, market information, group marketing, trust-based credit from traders, and cultivated varieties between the two market participants.

Table 3. Frequency of selected dummy variables of brinjal (aubergine) farmers.

Variable	Measurement	Large Wholesale Market (N = 85)		Small Wholesale Market (N = 108)		Overall Frequency
		Frequency	%	Frequency	%	
Road quality from farm to market	Paved road	63	74	14	13	77
	Unpaved road	22	26	94	87	116
Access to extension services	Yes	60	70	32	29	92
	No	25	30	76	71	101
Market information	Yes	60	70	30	28	90
	No	25	30	78	72	103
Group marketing	Yes	61	72	24	22	85
	No	24	28	84	78	108
Trust-based credit from traders	Yes	4	5	38	35	42
	No	81	95	70	65	151
Cultivated varieties	HYV	80	94	67	62	147
	Local varieties	5	6	41	38	46

Source: Authors' own calculations.

3.2. Factors Associated with Large Wholesale Market Participation Decision by The Farmers

The results in Table 4 indicate the factors that influenced the probability of participating in the large wholesale market by the brinjal (aubergine) farmers in Jashore and Narsingdi districts.

Table 4. Linear Probability Model- Factors that were associated with large wholesale market participation decisions by farmers.

Variables	Coefficient	Std. Err.	Significance
Age	−0.00008	0.00352	0.816
Gender	0.07074	0.07216	0.328
Marital status	0.03420	0.08466	0.687
Family size	−0.01012	0.17109	0.555
Years of Schooling	0.01487 **	0.00694	0.034
Farming experience	0.00059	0.00344	0.864
Brinjal (aubergine) cropped area	0.18316 *	0.10135	0.072
Cultivated varieties	0.07109	0.05544	0.201
Distance from farm to large wholesale market	−0.08387 ***	0.02149	0.000
Road quality from farm to market	0.28003 ***	0.05182	0.000
Access to extension services	0.08381 *	0.04670	0.074
Market information	0.13093 ***	0.04567	0.005
Group marketing	0.22487 ***	0.04675	0.000
Trust based credit from traders	−0.09814 *	0.05384	0.070
Yield	0.00009 ***	0.00002	0.000
Transportation cost	0.00001 *	0.00001	0.068
Constant	−1.08221	0.31112	0.001
R-squared		0.7087	

Note: Significance at *** 1 percent, ** 5 percent, * 10 percent. Source: Authors' own calculations.

Years of schooling: Years of schooling of the household head was positively related to the probability of a household's decision to participate in the large wholesale market, and it was significant at a 5% level. The positive coefficient implies that the increased education level of household heads increased large wholesale market participation by 1.48%. This means that education level is important in the choice of market as it enables more information to be acquired, as well as new ideas and technology that increase their surplus production, therefore increasing farmers' participation in the large wholesale market. For example, Ref. [55] identified that farmers who participated in conventional markets were typically less educated.

Brinjal cropped area: The brinjal cropped area had positive correlation on the participation of the large wholesale market and was significant at a 10% level. This implied that the probability of participation from farmers in the large wholesale market increased by 18.31% if the one-acre brinjal (aubergine) cropped area increased. The farmers who had more land allocation for brinjal (aubergine) cultivation positively affected participation in large wholesale markets due to increased yield, and they might have multiple crop cultivations and a long-term relationship with the large wholesale market. This finding is corroborated by Xaba and Masuku [47], who found that having more land had a positive impact on the choice of large sales channels by vegetable farmers in Swaziland.

Distance from farm to large wholesale market: This variable had negative correlation with participation in the large wholesale market, and it was significant at a 1% level. It indicated that the probability of participation by the farmers in the large wholesale market decreased by 8.38% if the distance from the farm location to the large wholesale market

increased by one kilometer. According to Kyaw et al. [5], the distance to the market was an indicator of travel time and transportation cost. Therefore, the larger the distance from farm to large wholesale market, the lower the participation of large wholesale market by the farmers.

Road quality from farm to market: Road quality from farm location to market was expected to have positive relationship with participation in the large wholesale market. It indicated that farmers with paved roads have a 28% higher probability of participating in the large wholesale market, compared to farmers with unpaved roads (1% significance level). Slamet et al. [15] found that small-scale vegetable farmers located near paved roads were more likely to participate in the modern market, such as supermarkets, in Indonesia.

Access to extension services: Access to extension services increased the probability of participating in the large wholesale market by 8.38% at a 10% significance level. It implied that farmers who had access to extension services, such as training and advisory services regarding seed bed preparations, fertilizer and pesticides application, packaging method, and market linkages, facilities a positive influence on participation in large wholesale market with the buyers.

Market information: The coefficient of market information showed a positive correlation with participation in the large wholesale market, and it increased the probability of participating in the large wholesale market by 13.09% at a 1% significance level. Farmers used market price information and operational activities, such as market open days, by communicating with the Farmers Information and Advice Center (FIAC) and fellow farmers via telephone to find price information on the market, and thus the premium price. This emphasizes the importance of institutional services, social networking with fellow farmers and the usage of technology to obtain market information. Similarly, some studies show that the availability of market information positively influenced the choices of market and channel participation [5,51,56–58].

Group marketing: The positive coefficient of group marketing indicates that it increased the probability of participation in the large wholesale market by 22.48%, provided that farmers practiced group marketing, and it was significant at 1% level. This means that farmers who were members of the Common Interest Group (CIG), hired transport and shared costs in a group positively influenced participation in the large wholesale market. Mukarumbwa et al. [59] found a positive relationship between members of the association and small groups of farmers and participation both in local and urban markets.

Trust-based credit from traders: Trust-based credit from traders had a negative impact, as expected, and it had a negative association with participation in the large wholesale market with a significance at the 10% level. It implied that the probability of farmers' participation in the large wholesale market decreased by 9.81% if farmers had trust-based credit from traders. Negi et al. [32] identified that small farmers in India who availed inputs and credit from traders via informal channels compelled them to sell their produce as collateral. In the study areas, there was an informal agreement between the farmers' and traders' relations, more specifically with the local commission agent in the small wholesale market, which was fully based on mutual trust where traders invest money to farmers for temporary periods for farmers' cultivation activities (purchase inputs such as labor, land preparation, fertilizer, pesticides) before harvesting. This was one kind of liability and tied transaction that negatively influenced participation in the large wholesale market, and farmers were limited to selling produce at the small wholesale market. Such informal settings also influenced producers price realizations.

Yield: The positive coefficient implies that the probability of participating in the large wholesale market increased by 0.009%, if one kilogram of brinjal (aubergine) per acre increased and was statistically significant at 1% level. This implied that farmers with a higher yield of brinjal (aubergine) monitored the daily operation of the market and the large wholesalers that were present in the large wholesale market, and this was positively associated with the participation on large wholesale market.

Transportation cost: Transportation cost had a positive relationship with the large wholesale market participation and was statistically significant at 10%. This seems counter-intuitive and contradicts prior expectations. Meanwhile, from a field survey, transaction cost could be fixed or proportional depending on the road quality, distance to market, mode of transportation and the level of production. Transportation cost was fixed when the road quality was unpaved and mode of transportation was a manually operated engine or semi-auto engine, but this variation depending on the paved road connection, availability of transportation and level of production marketed. Therefore, the higher the volume of sales, the more costs were incurred. The positive coefficient implied that it increased the probability of participation in large wholesale markets by 0.001% if transportation cost increased by BDT 1. This result was consistent with the study of Harriet et al. [3] that transportation cost positively influenced market participation decisions due to the higher volume of sold produce in the market.

3.3. Effect of Large Wholesale Market Participation on Producer's Price

The causal effect of large wholesale market participation on producer price is estimated using the propensity score matching (PSM) procedure.

By applying propensity score matching, this study first estimated average treatment effect on treated (ATET). Table 5 reveals the results of the PSM that show the average treatment effect on treated (ATET) estimates and explains how the producer price changes because of participation in the large wholesale market.

Table 5. Propensity score matching estimates.

Variables	Caliper (0.05)			Nearest Neighbor Matching			Kernel		
	Producer Price (BDT/Kg)	**S. E**	**T-Stat.**	**Producer Price (BDT/Kg)**	**S. E**	**T-Stat.**	**Producer Price (BDT/Kg)**	**S. E**	**T-Stat.**
Large wholesale market participation	ATET 4.63	0.57	8.07 ***	ATET 5.36	0.74	6.98 ***	ATET 4.80	0.66	7.18 ***

Note: Significance at *** 1 Source: Authors' own calculations.

The treatment effect based on the propensity score matching showed a positive effect (Table 5) of large wholesale market participation on producer price for per kilogram brinjal (aubergine) than participation in the small wholesale market. The average treatment effect on treated (ATET) was measured using radius caliper matching (0.05), nearest neighbor matching, and kernel matching (Table 5) using a psmatch2 command implemented on STATA 17. The PSM results of three algorithms—caliper (0.05), nearest neighbor matching, and kernel—showed a differentiated positive effect on producer price for per kilogram brinjal (aubergine) by BDT—4.63, 5.36, and 4.80, respectively—than the small wholesale market.

However, the impacts of large wholesale market participation on producer price in all three matching methods were statistically significant at the 1% level. The inverse probability weighted regression adjustment (IPWRA) results also confirm that farmers' participation in the large wholesale market increased the producer price by BDT 4.83, more than the small wholesale market at a 1% significance level (Table 6).

Table 6. Robustness check: inverse probability weighted regression adjustment (IPWRA).

IPWRA	Producer Price (BDT/kg) Coeff.	Std. Err.	z	*p*-Value	(95% Conf. Interval)	
ATE						
Large wholesale market participation	4.83	0.42	11.28	0.000 ***	3.98	5.66

Note: Significance at *** 1 percent Source: Authors' own calculations.

To complement the findings of our main results, the treatment effect based on Mahalanobis distance matching (MDM) also showed a positive effect (Table 7) of large wholesale market participation on producer price for per kilogram brinjal (BDT 3.79).

Table 7. Robustness check: Mahalanobis distance matching (MDM).

MDM	Producer Price (BDT/Kg) Coeff.	Std. Err.	T-Stat.
ATT Large wholesale market participation	3.79	0.39	9.62 ***

Note: Significance at *** 1 percent. Source: Authors' own calculations.

There is an overlap and treatment off support regions (Figure 3c) in the range of the propensity score between the treatment and control groups before matching. The graph (Figure 3c) shows the propensity score for all untreated observations (108) for small wholesale market participants and treated observations (85) for large wholesale market participants. However, out of 85 treated observations, 12 farmers were off support regions and 73 farmers were from common support regions. Farmers from off support regions were not included in the matching process. According to Aku et al. [35], the exemption of a minimum number off support observations had a minimal effect on the reliability of the matching process. In fact, the common support provides an adequate sample for estimating the PSM effect parameter. However, after the matching (Balancing property in Table 8) between control and treated observations, the graph shows nearly homogeneous distributions (Figure 3b).

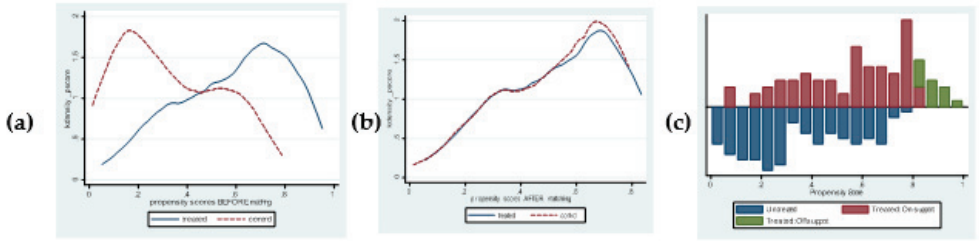

Figure 3. Propensity score graph: (**a**) before matching, (**b**) after matching and (**c**) overlap of the treated vs. untreated groups of market participants.

Matching Quality Analysis

The matching quality analysis was performed using a *pstest* command with the assigned covariates, which were used in the propensity score matching: age, gender, marital status, family size, years of schooling, farming experience, and distance from farm to large wholesale market between treatment group (large wholesale market participants) and control group (small wholesale market participants). Based on the balancing property (Table 8), we found that some covariates (gender, years of schooling and distance from farm to large wholesale market) in the unmatched sample were statistically significantly different between the treated and control groups. This implies that, before treatment, the covariates between the large and small wholesale market participants were imbalanced. According to Caliendo and Kopeining [60], the primary purpose of PSM is to balance all decided covariates. Therefore, this study also checks the balance of the chosen covariates across the treatment groups. Overall, the balance is considerably increased after matching. This indicates that the matching process is satisfied in balancing the pre-treatment characteristics.

Since the reliability of PSM and IPWRA results depends on the quality of our matching, we present the extent of overall covariate balancing, and the overlap of the common support and support regions. The overall covariate balancing test (Table 9) shows that

the standardized mean difference for all covariates used in the PSM reduces from 34.2% pre-matching to 17.9% post-matching.

Table 8. Balancing property for large and small wholesale market participants.

Before Matching	Mean		Bias Reduction (%)	*p*-Value
	Treated	Control		
Age	43.412	45.454		0.179
Gender	0.94118	0.85185		0.048 **
Family size	5.0235	5.1204		0.593
Marital status	0.87059	0.92593		0.202
Years of schooling	7.2471	5.0278		0.000 ***
Farming experience	23.729	24.12		0.797
Distance from farm to large wholesale market	3.5471	4.6843		0.000 ***
After matching				
Age	43.274	40.825	−19.9	0.190
Gender	0.94521	0.91553	66.8	0.485
Family size	5.137	4.9473	−95.9	0.364
Marital status	0.86301	0.84397	65.6	0.747
Years of schooling	6.6849	7.5118	62.7	0.109
Farming experience	23.466	20.821	−576.4	0.123
Distance from farm to large wholesale market	3.7329	3.9767	78.6	0.165

Note: Significance at *** 1 percent, ** 5 percent. Source: Authors' own calculations.

Table 9. Propensity scores matching quality test.

Items	Before Matching	After Matching
Pseudo R2	0.210	0.033
p-value	0.000	0.474
Mean standardized bias	34.2	17.9

Source: Authors' own calculations.

Moreover, the joint significance of all covariates was never rejected before matching for small and large wholesale market participants ($p > x2 = 0.000$). However, the propensity score matching quality tests (Table 9) indicate that the joint significance of all covariates can be rejected after matching ($p > x2 = 0.474$). The low mean standardized bias and joint insignificance of the covariates are indicative of the successful balancing of the distribution of covariates between treated and untreated farmers.

4. Conclusions and Policy Recommendation

4.1. Summary of Results and Conclusions

The marketing of vegetables is important for ensuring better income, sustainable agriculture and promoting the betterment of farmers in local areas. This study found that the large wholesale market participation decision by brinjal (aubergine) farmers was associated with several factors such as socio-economic, physical, institutional, informal, and marketing factors. Large wholesale market participation by brinjal farmers was positively influenced by years of schooling, farm size, road quality from farm to market, access to extension services, market information, group marketing, yield, and transportation cost. On the other hand, large wholesale market participation was negatively influenced by distance from farm to large wholesale market and trust-based credit from traders.

This study also implies that farmers' participation and sales of their brinjal (aubergine) in the large wholesale market had a positive effect on producer price. This study addresses the gaps of previous studies because it considers commercial farmers. In addition to socio-economic and institutional factors, it also considers physical and informal factors. Moreover,

this is the first attempt in terms of estimating a causal impact of large wholesale market participation on producer's price, since previous studies merely identified an association.

4.2. Policy Recommendation

Through this study, we can provide some policy implications, as these variables have a significant effect on large wholesale market participation. All of the resulting factors require different policies, but some factors, especially socio-economic factors and market factors such as education level, farm size, yield, distance, and transportation cost cannot be easily changed by policy interventions. Therefore, the results of this study recommend that the Government adopt a comprehensive strategy for improving physical factors and institutional factors that ensure farmers' welfare. The Government should improve the road quality from farm locations to markets, ensure access to extension services, secure availability, provide accurate market information, and form a farmers marketing group, so that farmers' participation and selling activities in the remunerative markets can enhance and obtain better prices to ensure their welfare.

Moreover, trust-based credit from traders' customs should be agreed in the way that can positively affect farmers' freedom of choice to participate in market, or it could formally strengthen the long-term relationship between traders and farmers with no negative effects on farmers' price realization and market participation decisions. Moreover, the market should be organized to reduce the price differentials between the large and small wholesale markets.

4.3. Limitations of the Study

This study includes only the few factors that identify the probable relationship with market participation decisions. However, there are many other observable and unobservable factors such as cultural factors (religion; attendance of religious rituals; ethnic group; attitude towards risk and cultural beliefs of farmers about the capitalist market, etc.) and other socio-economic factors (ratio of hired labor and family labor employed in farming, physical and institutional factors; subsidies from the Government and other sources; market monitoring services, etc.) that might have a probable relationship with market participation decisions. To check the robustness of the relationship between market participation decisions and the impact of producer's price, this study did not employ any instrumental variable (IV) approach that could address the more unobserved bias and identify a robust causal relationship. Moreover, it did not cover the list of the samples in all villages in the study site; therefore, an insufficient sample size is one of the major limitations of this study. Considering cultural and other factors such as the instrumental variable approach, additional future studies are required to corroborate these findings and explore in more detail the factors influencing farmers' participation decisions in their choice of market and the robust impact on producer's price.

Author Contributions: Conceptualization, M.R.; Methodology, M.R. and K.L.M.; Software, M.R.; Formal analysis, investigation, resources, data curation, M.R.; Validation, M.R. and K.L.M.; Writing-original draft preparation, M.R.; Writing-Revision, review, editing, M.R. and K.L.M.; Visualization, M.R.; Supervision, K.L.M. All authors have read and agreed to the published version of the manuscript.

Funding: There is no funding for this research.

Institutional Review Board Statement: The study was conducted according to the guidelines and approved by the Ethics Committee of Graduate School for International Development and Cooperation (IDEC), Hiroshima University, Japan on 30 July 2020.

Informed Consent Statement: Informed consent was obtained from all farmers involved in this study.

Data Availability Statement: The survey data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors would like to thank Project for Human Resource Development Scholarship (JDS) organized by the Japan International Cooperation Agency (JICA) for financial support throughout the study period of M.R at Hiroshima University, Japan.

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

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Socioeconomic Characteristics Associated with Farming Practices, Food Safety and Security in the Production of Fresh Produce—A Case Study including Small-Scale Farmers in KwaZulu-Natal (South Africa)

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Abstract: Farmer practices may influence the microbial quality and safety of fresh produce. The increasing demands to create ready-to-eat (RTE) fresh produce while providing potential niche markets for smallholder farmers might be contributing to increased numbers of fresh produce-associated foodborne disease outbreaks. This study determined the demographic and socioeconomic characteristics and farmer hygiene practices of farmers using open-ended questionnaires and key informant interviews. Additionally, the relationships between farmer socioeconomic characteristics and hygiene practices were statistically analyzed. The semi-organic smallholder farmer population and the farmworkers of the organic farm were female-dominated. Tertiary education was a predominant characteristic in the organic and semi-conventional workforces. While the semi-organic and semi-conventional farms relied on a combination of 'store-bought' synthetic and composted organic fertilizers, the organic farm owner only used composted organic fertilizer. The irrigation water sources varied amongst the farm types. However, most of the semi-organic farmers did not pre-treat irrigation water prior to use. The irrigation water source and fertilizer type selected by farmers varied and might affect the microbial quality and safety of fresh produce. Socioeconomic factors such as gender and education may influence farmer hygiene practices. These characteristics should therefore be considered when planning farmer support interventions.

Keywords: sustainable farm practices; socioeconomic characteristics; fresh produce; food safety; food security; organic; conventional

Citation: Beharielal, T.; Thamaga-Chitja, J.; Schmidt, S. Socioeconomic Characteristics Associated with Farming Practices, Food Safety and Security in the Production of Fresh Produce—A Case Study including Small-Scale Farmers in KwaZulu-Natal (South Africa). *Sustainability* **2022**, *14*, 10590. https://doi.org/10.3390/su141710590

Academic Editor: Keshav Lall Maharjan

Received: 18 July 2022
Accepted: 15 August 2022
Published: 25 August 2022

1. Introduction

There is a strong pressure to increase food production and availability globally due to population growth; another factor is the presence of nearly 811 million people being identified as food insecure and 768 million being classified as chronically undernourished [1,2]. The FAO recorded the sharpest increases in moderate and severe food insecurity in the year 2020, with more than one-third (282 million) of this tally being identified in Africa [2]. Agriculture is essential to meet these demands; however, sustainable production methods need to be employed in order to meet these demands without negatively affecting the environment [3–6]. Furthermore, sustainable agriculture must also produce food that is safe for consumption and of good quality to negate public health concerns [3,6]. COVID-19 lockdowns have exposed the weaknesses in international and local food supply chains and have directed attention to the proximity of the food producers and consumers [5,7,8]. Fresh produce consumption is an essential part of the human diet and provides micronutrients and vitamins, which are essential in contributing to the nutritional dimension of food security [5,8,9]. Consumption trends and government recommendations have increased the

demand for fresh and ready-to-eat produce due to the apparent health benefits [5,9]. In light of the COVID-19 pandemic, the importance of more robust immune systems and the necessity of access to a healthy diet has become even more apparent [2,5]. Despite the positive narrative, fresh produce has been a cause of global food-borne disease outbreaks, highlighting the need for safer, sustainable production practices [3,6,10]. In developing countries such as South Africa with dual agricultural systems, conventional commercial farming is practiced by fewer individuals but contributes to a larger proportion of the agricultural output. However, the larger number of individuals practicing semi-organic, sustainable agriculture produce smaller but still crucial outputs [11]. Such subsistence/smallholder farmers have been earmarked as potential contributors in alleviating food insecurity in South Africa through their potential participation in supplying local markets and retailers [12,13]. In addition, these smallholder farmers could become an important factor in overcoming the underrepresentation of fresh fruits and vegetables in the African diet by supplying their communities [5]. Furthermore, smallholder farming has been identified as an important player in achieving sustainable development goals [4,14].

The agricultural methods employed in fresh produce farming are diverse and include conventional practices, organic practices, and an array of hybrid methods. Considering the potential role of primary production practices for the quality and safety of fresh produce, conducting evaluations of the farming systems and employed practices are essential for safeguarding consumers' health [3,5,6,10]. In developing countries such as South Africa, pressure from large retailers and the formal market system, especially for high-value products such as fresh produce, has led to the development of a "structured agrifood system" [15]. However, dual agrifood systems [11] are prevailing in South Africa wherein modern practices, typically involving regular monitoring to maintain fresh produce safety on a larger scale, co-exist with the traditional sustainable farming systems; these traditional systems mostly yield produce without appropriate safety and quality certifications [15]. Studies comparing the farming systems and practices have often focused on which farming system produces higher yields, contributes to less degradation of the environment, or—in the view of food safety—which system has a greater tendency for microbial contamination potentially affecting consumer health [16–18]. Although smallholder farming has a vital role to play in feeding communities, a limited number of studies have focused on the socioeconomic factors that may contribute to a farmers' decision on which farming systems or farming practices to utilize, especially in the small-scale production of fresh produce [12,19,20]. With the majority of South African farmers being identified as smallholder farmers [21], challenges facing such farmers, while not being identical across the entire country, may be similar in nature.

South African smallholder farmers are often characterized by similar socioeconomic characteristics, such as limited access to education or reliance on social grants as their income sources [21]. Socioeconomic characteristics have been highlighted as some of the most influential aspects in the farmers' decision-making processes, including their adoption of farming practices, the type of farming systems utilized, and even what is farmed [22]. South African farmers, especially smallholder farmers, display various socioeconomic characteristics that have been reported to be crucial contributors to their decision-making processes, particularly concerning the adoption of certain farming production practices and market participation [23,24]. Socioeconomic characteristics, such as gender, age, education level, and income sources, have been previously reported to affect production practices, including fertilizer and pesticide use, irrigation water sources, and the area (size) of land farmed [25]. A study on smallholder farmers and their access to market channels in Myanmar reported that factors such as gender, age, and income affected the market channel participation [26]. European studies on the characteristics that affect farmers' adoption of organic farming practices highlighted financial constraints, land farm size, and age as prominent socioeconomic characteristics influencing decision-making [27]. Understanding the socioeconomic backgrounds of the farmers, especially South African smallholder farm-

ers, is imperative in designing facilitation strategies to improve food safety, sustainable production, and graduation into supplying more formalized markets.

A recent report on the state of food security in South Africa highlighted that the South African provinces characterized as predominantly rural with high levels of poverty, such as KwaZulu-Natal, were often the provinces where most households were involved in agricultural activities [13]. KwaZulu-Natal, contributing to 8.5% of South Africa's total agricultural production, is home to almost one-fifth of all South African smallholder farmers [21]. Of the households involved in agriculture in KwaZulu-Natal, 8.1% relied on agricultural activities as a source of income, with a large number of them (16.2%) practicing agriculture as an additional food source [21]. The South African National Development Plan [28], considering the state of South African food security and the high proportion of smallholder agricultural households, has recognized agricultural productivity and rural development as an essential priority for employment, economic growth, poverty reduction, and is essential in alleviating food insecurity.

This case study determined and compared, for the first time, the demographic and socioeconomic characteristics and farming practices used by selected organic, semi-organic, and semi-conventional farmers involved in fresh produce farming in the uMgungundlovu District of KwaZulu-Natal, South Africa. Additionally, the demographic and socioeconomic characteristics of the farmers, particularly those of the informal smallholder farmers, were evaluated in view of their potential to influence the adopted farming practices, and how this may affect fresh produce microbial quality, food safety, and potential market access.

2. Materials and Methods

2.1. Study Site

The study was conducted from 2018 to 2020. It included three different study sites within the uMgungundlovu District of KwaZulu-Natal, namely an organic farm (Karkloof), a semi-conventional farm that was part of a school community garden project (Howick), and a semi-organic farm (Appelsbosch), all located in KwaZulu-Natal, South Africa (Figure 1). More than one-third (38%) of the uMgungundlovu District's population resides in rural areas, many of whom are characterized as subsistence smallholder farmers. The livelihoods of such farmers, particularly the semi-organic farmers from Appelsbosch, depend on agricultural activities [29].

Figure 1. The three study sites, located in the uMgungundlovu District Municipality of the KwaZulu-Natal province in South Africa (adapted from https://commons.wikimedia.org/w/index.php?curid=15195874, accessed on 1 July 2022. CC BY-SA 4.0, and https://commons.wikimedia.org/w/index.php?curid=15195930, accessed on 1 July 2022. CC BY-SA 4.0.

2.2. Sampling Procedures and Data Collection

The research approach employed a case study methodology, comprising a mixed method of both qualitative and quantitative data collection due to the limited number of farmers available in two of the three farming systems in this study. Purposive sampling was used in order to include suitable farmers from each farming system, namely, semi-organic, organic, and semi-conventional farmers. Data collection tools included key informant interviews (qualitative method) and open-ended questionnaires (quantitative method) to collect information and provide insight into the farmers' socioeconomic characteristics, decision-making processes, and personal beliefs regarding hygiene-oriented farming practices. Key informant interviews were held with the owner of the organic farm and the manager and staff of the semi-conventional farm. The open-ended questionnaire (Supplementary Table S1) was administered to semi-organic informal smallholder farmers (n = 40), and an alternate open-ended questionnaire (Supplementary Table S2) was developed and used specifically for the smaller groups of farmworkers of the organic (n = 6) and semi-conventional (n = 5) farms. The questionnaires that were administered were initially prepared in English and later translated into isiZulu. Additionally, on-site native-speaking isiZulu translators were present for all study sessions.

The informal smallholder farmers mainly classified themselves as practicing "organic farming" methods. Their products were thus "organically produced", referring to produce that is produced using low and more sustainable agricultural inputs, such as composted and organic fertilizers and limited organic pesticides, but does not meet the certified organic production guidelines outlined by the respective organic certification organizations (e.g., SGS (Société Générale de Surveillance) Woodmead, South Africa (Pty) Ltd. and Ecocert, Cape Town, South Africa). For the remainder of this paper, the smallholder farmers are thus referred to as semi-organic farmers and their farms as semi-organic farms. Farmers, including both farmers that were already supplying markets and farmers that were interested in supplying markets, made up the purposively sampled informal smallholder sample population. In addition, the school community garden project will hereafter be referred to as the semi-conventional farm site and farmers, as the manager identified with more conventional farming methods, making use of pesticides and store-bought fertilizers more frequently (Table S3).

2.3. Data Analysis

Data were coded, captured, and analyzed using IBM's Software Package for Social Scientists (SPSS (V.27), 2021 (Chicago, IL, USA) and Graph Pad Prism (V.8) (San Diego, CA, USA). Sample descriptions were generated using descriptive statistics, including the frequency analysis. The normality of data distribution was assessed using the Shapiro–Wilk and Anderson–Darling tests at an alpha value of 0.05. The Spearman's rank correlation coefficient (ρ) was used to evaluate the relationships between the selected pre- and post-harvest practices (e.g., pre-treatment of water/compost prior to use) and relevant nominal or categorical demographic and socioeconomic variables [30]. p-values of <0.05 were considered to be significant.

3. Results

The current study sought to determine the demographic and socioeconomic characteristics of farmers and their farming practices from three different farming sectors. Furthermore, the associations between the demographic and socioeconomic factors and selected farming practices were identified. This approach was employed to evaluate whether these characteristics do affect farmer practices, especially with respect to practices that potentially contribute to the microbial contamination of fresh produce, thereby affecting food safety and potential market access.

3.1. Demographic and Socioeconomic Characteristics of Farmers

For the smallholder farmer sample population representing semi-organic farmers, we identified the sample population to be female-dominated (82%). Similarly, while a male owned the organic farm, female workers (67%) dominated the workforce. Contrastingly, the semi-conventional farm was again managed by a male but consisted of only male workers (100%). The semi-organic farmer population displayed an aging population, with 32% of respondents aged between 55 and 65 years. Interestingly, the age group that made up the sample's second-highest proportion (30%) was over 65 years old. However, the organic and semi-conventional farms displayed younger workforces, mainly consisting of workers aged under 45 years old (Table 1). The semi-organic farmers of this study presented themselves as an educated sample, with a large amount (43%) of the participants having received a secondary level of education. Similarly, the organic and semi-conventional farm staff had all received formal education up to the secondary level. Both the owner and manager of the organic and semi-conventional farm reported having obtained a tertiary education. The income sources of the semi-organic farmers showed a reliance on governmental grants, with 35% of respondents relying solely on grants and a further 38% relying on a combination of government grants and farming as income sources (Table 1). Contrastingly, the workers representing the other farming systems received wages or salaries as income. The interest level in farming among the semi-organic farmers differed, with many farmers (42%) being only interested in farming as a means to earn additional income. Only 10% of the semi-organic farmers displayed a high interest in farming, as it was their sole source of income. The farmers in all of the farming sites sampled were exposed to some sort of farmer training (Table 1), while discussions revealed that many had received farmer training to varying extents and on a variety of different farming aspects (e.g., composting processes, intercropping, and soil health) (Supplementary Table S3).

Table 1. Frequency table of smallholder farmer demographic and socioeconomic variables.

Demographic and Socioeconomic Variables	Characteristics	Semi-Organic Farmers (n = 40)	Organic Farm Workforce (n = 6)	Semi-Conventional Farm Workforce (n = 5)
Gender	Male	7 (18%)	2 (33%)	5 (100%)
	Female	33 (82%)	4 (67%)	0 (0%)
Age	<45 Years Old	4 (10%)	5 (83%)	5 (100%)
	45 $\leq$ 55 Years Old	11 (28%)	0 (0%)	0 (0%)
	55 $\leq$ 65 Years Old	13 (32%)	1 (17%)	0 (0%)
	>65 Years Old	12 (30%)	0 (0%)	0 (0%)
Marital Status	Single	10 (25%)	2 (33%)	2 (40%)
	Married	27 (67%)	3 (50%)	3 (60%)
	Divorced/Widowed	3 (8%)	1 (17%)	0 (0%)
Level of Education	No Formal Education	9 (22%)	0 (0%)	0 (0%)
	<Grade 7	14 (35%)	0 (0%)	0 (0%)
	Grade 8–12	17 (43%)	4 (67%)	2 (40%)
	>Grade 12	0 (0%)	2 (33%)	3 (60%)
Income Source	Combination of Farming and Grants	15 (38%)	0 (0%)	0 (0%)
	Government Grants	14 (35%)	0 (0%)	0 (0%)
	Farming	9 (22%)	1 (17%)	0 (0%)
	Wages/Salary	2 (5%)	5 (83%)	5 (100%)

Table 1. *Cont.*

Demographic and Socioeconomic Variables	Characteristics	Semi-Organic Farmers (*n* = 40)	Organic Farm Workforce (*n* = 6)	Semi-Conventional Farm Workforce (*n* = 5)
Monthly Income Bracket	<R1000	9 (22%)	0 (0%)	0 (0%)
	R1000–R1500	9 (22%)	0 (0%)	0 (0%)
	R1501–R3500	17 (43%)	0 (0%)	0 (0%)
	>R3500	5 (13%)	6 (100%)	5 (100%)
Main Livelihood Strategy	Farming	22 (55%)	1 (17%)	0 (0%)
	Casual/Permanent Employment	11 (28%)	5 (83%)	5 (100%)
	Combination of Farming and Self-employment	5 (12%)	0 (0%)	0 (0%)
	Combination of Farming and Casual labor	2 (5%)	0 (0%)	0 (0%)
Interest Level in Farming	Only for Consumption	5 (12%)	0 (0%)	0 (0%)
	Interested if there was no Alternative	7 (18%)	0 (0%)	0 (0%)
	Interested in Consumption and Sale	7 (18%)	0 (%)	0 (%)
	Interested in Additional Income	17 (42%)	0 (%)	0 (%)
	Very Interested, Sole Source of Income	4 (10%)	0 (%)	0 (%)
Membership in a Farmer's Group	Yes	36 (90%)	0 (0%)	0 (0%)
	No	4 (10%)	6 (100%)	5 (100%)
Involved/Exposed to Farmer Training	Yes	40 (100%)	6 (100%)	5 (100%)
	No	0 (0%)	0 (0%)	0 (0%)
Type of Farming Practiced	"Organic"	17 (43%)	n/a	n/a
	Conventional	23 (57%)	n/a	n/a

Percentages were rounded to the nearest whole number.

3.2. Farmer Practices

General farm practices that have previously been reported to contribute to microbial contamination of fresh produce, such as the type of irrigation water used, fertilizer, and preparation of the fertilizers employed, were the focal points of the current study. The irrigation water sources were found to vary (Figure 2), with semi-organic farmers reporting the use of multiple sources such as river water (48%), rainwater (30%), "grey wash water" (13%), and in some instances a mixture of these source waters (10%). However, the organic and semi-conventional farmers reported only using two irrigation water sources; the organic farmer owner used dam and river water, while the semi-conventional farmers used municipal tap and rainwater. The fertilizer types used by the farmers included synthetic "store-bought" fertilizers, organic composted fertilizers, and a combination of both in some instances. Semi-organic farmers used the greatest variety of fertilizer types when compared to the other farm systems, with the organic farmer solely relying on organic, composted fertilizer.

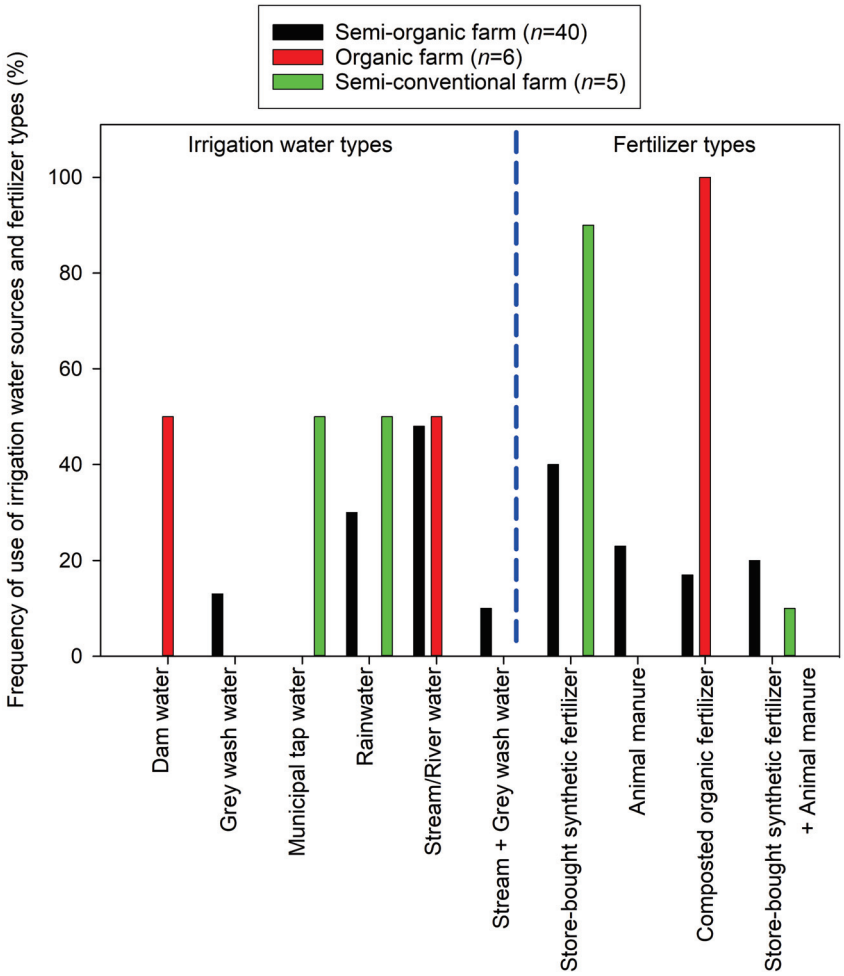

Figure 2. Frequency of the irrigation water sources and fertilizer types used by the different farming systems.

Farmers and farmworkers from the organic and semi-conventional farms frequently acknowledged farming equipment, soil, and water as potential sources of bacterial contamination (Figure 3). Contrastingly, only the semi-organic farmers frequently acknowledged soil as a potential contamination source. At least 23% of the semi-organic farmers did not acknowledge any consequences of fresh produce bacterial contamination. However, nearly half of the population (48%) deemed the loss of trust of customers as a consequence of bacterial contamination. Washing hands prior to entering the farm was a general hygiene practice observed by a high percentage of individuals belonging to each of the different farms (Figure 3). The washing of pre- and post-harvest equipment was a practice that was more commonly observed among the semi-organic farmers (63%), followed by semi-conventional farmers (40%), whereas the organic farmer did not report the washing of farming equipment before use. A low percentage of semi-organic farmers reported pre-treating irrigation water (25%) prior to use, with pre-treatments including the boiling of water or the addition of household bleach products before use (Table S3). More than half of the semi-organic farmer sample population (53%) did not pre-treat manure prior to use (Figure 3).

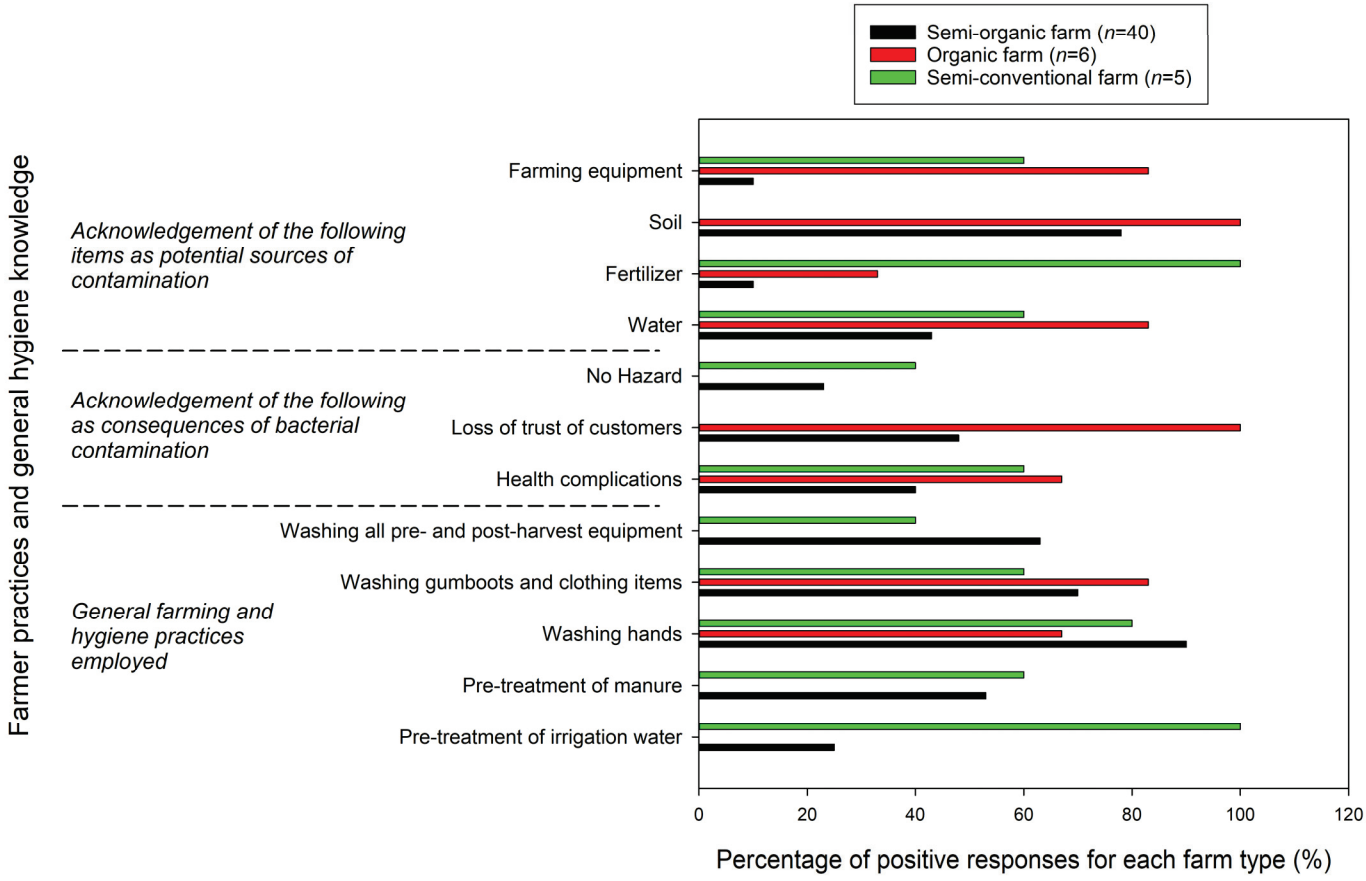

Figure 3. Responses on the general farmer practices and general hygiene opinions of farmers from the different farming systems.

3.3. Relationships between Farming Practices and Socioeconomic Characteristics of the Farmers from the Different Farming Sectors

Among the socioeconomic characteristics analyzed, gender, education level, income source, and income bracket displayed statistically significant relationships with selected farming practices employed by the 40 semi-organic farmers (Table 2). Statistically significant relationships were not observed between socioeconomic characteristics and farming practices for the semi-conventional and organic farming systems. Additionally, for the 40 semi-organic farmers, the ρ-values observed may indicate possible, though weak, associations between demographic and socioeconomic characteristics and selected hygiene practices and beliefs. For example, the ρ-value for education and the type of irrigation water used (ρ = −0.253, 95% CI = −0.530–0.074, p = 0.116) was not significant. At the same time, the confidence interval (CI) indicated the absence of a relevant relationship between these two variables. Thus, some demographic and socioeconomic characteristics may affect selected hygiene practices and beliefs, though not at a significant level (Figure 4).

Table 2. Correlation between the selected farming practices and demographic and socioeconomic characteristics of the semi-organic farmers (n = 40).

Selected Farming Practices	Spearman's Rank Correlation Coefficient (ρ)				
	Gender	**Age**	**Education Level**	**Income Source**	**Income Bracket**
Type of Farming Practiced	0.403 * (0.095–0.640)	−0.242 (−0.522–0.084)	0.023 (−0.299–0.341)	0.036 (−0.287–0.352)	0.002 (−0.318–0.322)
Type of Fertilizer Used	−0.200 (−0.489–0.128)	0.183 (−0.146–0.475)	−0.067 (−0.379–0.258)	0.073 (−0.253–0.384)	−0.479 ** (−0.693–−0.188)

Table 2. *Cont.*

Selected Farming Practices	Spearman's Rank Correlation Coefficient (ρ)				
	Gender	Age	Education Level	Income Source	Income Bracket
Pre-treatment of Fertilizer	0.438 ** (0.137–0.665)	0.000 (−0.320–0.320)	−0.090 (−0.399–0.237)	0.403 ** (0.095–0.640)	−0.016 (−0.334–0.306)
Pre-treatment of Irrigation Water	0.190 (−0.139–0.481)	−0.170 (−0.465–0.159)	0.430 * (0.127–0.659)	0.203 (−0.126–0.491)	0.016 (−0.306–0.334)
Harvest Time	0.317 * (−0.004–0.578)	−0.165 (−0.461–0.163)	−0.086 (−0.395–0.241)	0.389 * (0.079–0.631)	0.196 (−0.132–0.486)

** $p < 0.01$, * $p < 0.05$. The numbers in parentheses represent the 95% confidence interval (CI) for ρ.

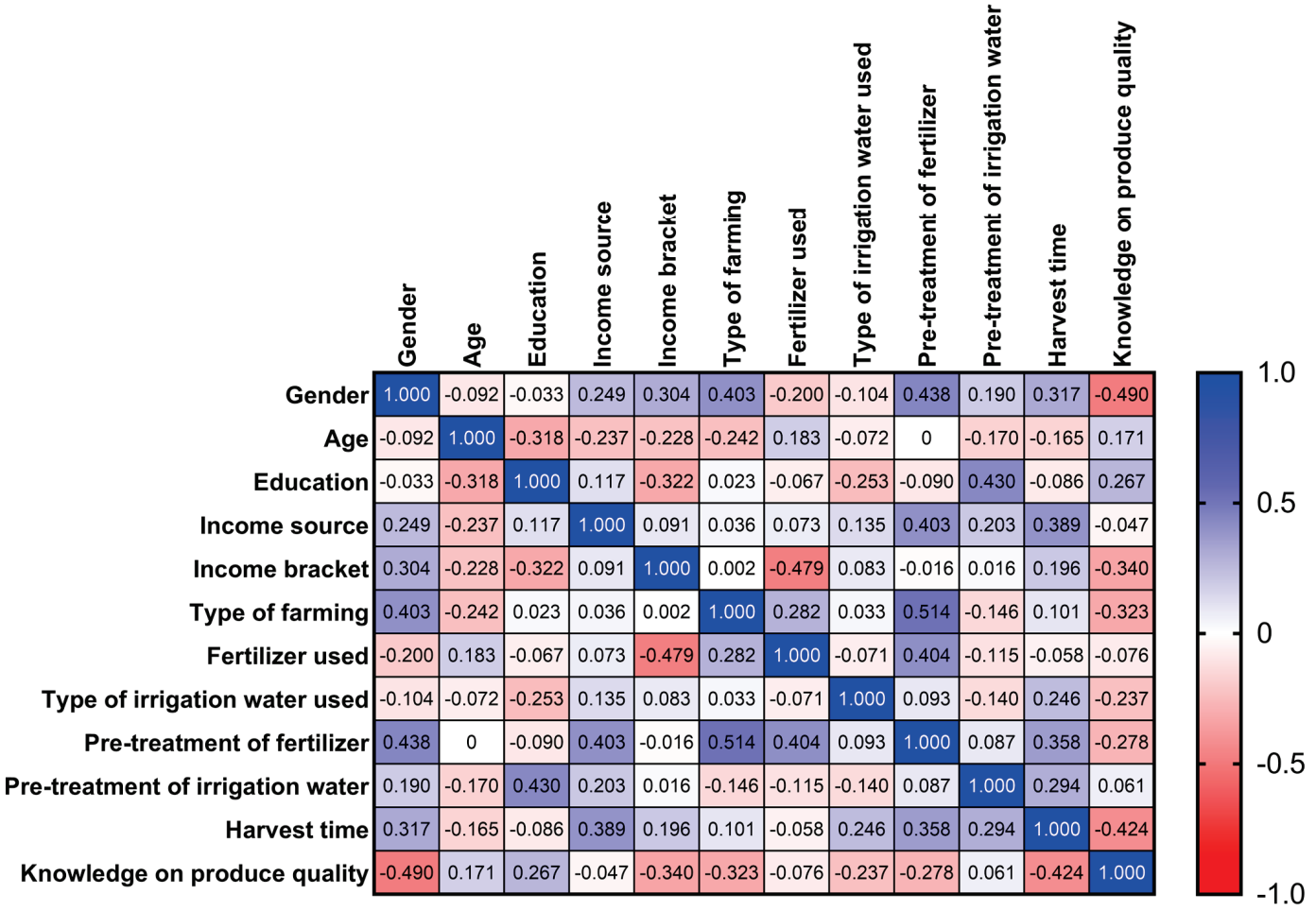

Figure 4. Spearman rank correlation matrix of 12 selected demographic and socioeconomic characteristics, farm hygiene practices, and knowledge of quality for the semi-organic farmers ($n = 40$).

4. Discussion

4.1. Demographic and Socioeconomic Characteristics of the Different Farming Populations

4.1.1. Gender

Agricultural surveys and studies, especially those focusing on smallholder farming, often found that females represent the majority of participants involved in smallholder farming [13,25,31]. Because of females being more involved in smallholder farming, programs supporting smallholder farm models have been directed toward female participants, such as the Awards Incentives and Competition (AIC) in South Africa and the "buy from women" initiative in Rwanda. There have been continuous suggestions that female participants have been the primary recipients of improvement initiatives,

such as training or funding [32–34]. The current study displays a similar finding where a majority of the semi-organic farmer population, as well as the organic farmworkers, were female (Table 1). The high proportion of female farmers in the current study mirrors the findings of a recent South African report, which highlights that among most of the South African households involved in agriculture, ≈53% are headed by females [13]. Additionally, there was a significant correlation between gender and knowledge of fresh produce quality ($\rho = -0.490$, 95% CI = -0.700–-0.201, $p < 0.01$) (Figure 4), suggesting that higher involvement rates of females in farming are associated with female farmers being more knowledgeable regarding farming practices. Two recent studies [26,35] investigated the impacts of socioeconomic characteristics on smallholder farmers in Myanmar and Indonesia and found, with similar observations to the current case study for the semi-organic farmers, that females comprised the majority of the smallholder farmer population. Unsurprising, considering the essential role of female smallholder farmers, aspects of the farmers' gender are often crucial for the success of agricultural interventions and development due to the specific roles and responsibilities of each gender in the agricultural system [36].

4.1.2. Age

The low percentage of younger farmers among the semi-organic farmers in the current study (10%) has been mirrored in a South African study in the Free State [37], which reported that only 8% of the farmers were under the age of 35 years. A study focusing on the socioeconomic challenges facing European agriculture also found that many farmers were older than 55 years (≥31%), with only ≈6% being younger than 35 years [38]. Factors such as the limited availability of other professions in rural areas have been regarded to impact the number of younger people involved in the smallholder farming sector in developing countries similar to South Africa. Sumberg et al. [39] also suggested that the low involvement of African youth in agriculture may be attributed to their migration to urban areas in search of better opportunities. The younger workforces of the organic and semi-conventional farms sampled in this study could be attributed to similar causes, where the younger individuals, although not participating in farming on their own, were participating in farming as a source of income.

4.1.3. Education Level

Education in the South African farming sector has often been characterized by large-scale commercial farmers having higher education levels, even leading up to and including tertiary education [40]. Synonymous with such reports, several organic and semi-conventional farmers in this study have reported having tertiary-level (e.g., > grade 12) education qualifications. The rural resource-poor farmers of South Africa have often been reported to have limited access to education [11]. However, many (43%) of the semi-organic farmers in the current study reported having education up to at least the secondary level. The importance of education in the current study is highlighted by the correlation between education and the practice of pre-treating irrigation water ($\rho = 0.430$, 95% CI = 0.127–0.659, $p < 0.01$). Contrastingly, similar studies on the socioeconomic characteristics of informal South African smallholder farmers have reported populations with mostly lower levels of education [25,41]. Furthermore, the South African Department of Cooperative Governance and Traditional Affairs has described the education levels of low-income households to be cyclic in nature [29]. Low levels of education limit individuals from receiving better employment opportunities and higher wages; however, the wage level directly affects the spending capacity of the individual and the related household. Due to the limited incomes and thus limited spending capacity, children from low-earning households are more likely to drop out of school [29].

4.1.4. Income Source

Multiple studies [13,23,37] have noted that incomes from fresh produce farming contribute a relatively small amount to total household incomes. This challenge was similarly displayed by the semi-organic farmers in the current case study, where 35% of farmers relied on government grants as the primary source of income. These findings are concurrent with the findings of the uMgungundlovu District profile report, which highlighted a high dependency ratio within the district, and assigned a high expenditure on social grants [29]. Alternate income sources such as wages, social grants, and remittances have been reported to make up the majority of income streams for these farming households [21,24,41]. As both the income source and income bracket of semi-organic farmers significantly correlated with the selected farming practices (Table 2), the financial situation of such farming households is an essential socioeconomic parameter. According to a recent South African General Household Survey, government grants are the primary source of income for about one-fifth of South African households [21].

4.1.5. Interest in Market Access

The expansion of modern markets has important implications for agriculture in many developing countries as it provides both opportunities and challenges for smallholder farmers [26]. The interest in market access for the organic farmer was not of importance in this study, as the farm was already a supplier of organic produce to fresh produce markets and a retail store (Supplementary Table S3). Similarly, the semi-conventional farmers did not have market access concerns, as the main interest in farming was reported to be that of consumption rather than sale (Supplementary Table S3). The semi-organic farmers varied in their degrees of interest in farming for an intended market access, with many (42%) only being interested in farming for additional income purposes. An Indonesian study found that socioeconomic factors had significant associations with smallholder farmers' decisions on market participation [35]. Therefore, market access remains one of the confounding factors affecting not only South African smallholder farmers, but also farmers in Myanmar and Indonesia [25,26,35], countries that are currently at a similar developmental level as South Africa.

4.1.6. Farmer Group Memberships and Training

Membership in a farmer's group or associations are a common relationship observed among smallholder farmers. Semi-organic farmers in the current study were no different, with a majority (90%) of farmers reporting membership in a farmer group. Although not belonging to formal organizations, fresh produce farmers have been reported to form "farmer groups" with family and neighbor networks [42]. Such networks allow smallholder farmers to engage with each other in different manners, such as in educational initiatives, support networks, and even the collective marketing of products, thus affecting their farming practices, the type of markets they supply, and the income that can be earned [43]. However, the organic and semi-conventional farmer or the respective workers did not belong to any farmers' group. All farmers and farmworkers in the current study were exposed to some farmer training (Table 1 and Supplementary Table S3). Amongst the semi-organic farmers, exposure to training is not surprising, as many extension programs aimed at facilitating smallholder farmers have engaged in the training of farmers.

4.2. Farmer Practices

4.2.1. Irrigation Water

Irrigation water is a critical component in the production of fresh produce and has been highlighted as one of the primary contamination sources in fresh produce farming [44,45]. However, access to safe, good-quality water is progressively becoming a challenge in South Africa, resulting in potentially increased food safety risks and decreased production yields [13,46,47]. Figure 2 highlights the multiple irrigation water sources used by the

different farmers surveyed in the current case study. Dam and stream/river water have previously been highlighted as irrigation water sources used by fresh produce farmers in South Africa [25,46,47]. Rainwater, utilized by semi-conventional farmers and at least 30% of the semi-organic farmers (Figure 2), has been described as an irrigation water source that is currently gaining popularity among farmers due to its eco-friendly nature and affordability [48]. While rainwater is frequently used by farmers worldwide and in South Africa, it was found in South Africa to contain higher microbial indicator counts than what is considered acceptable for safe irrigation [44,46,48,49]. From a food security perspective, microbial contamination of ready-to-eat fresh produce is concerning, given that the uptake of enteropathogens via contaminated fresh produce can lead to severe diarrhea, which in turn can affect nutrient uptake [50]. The use of rainwater as an irrigation water source should thus be carefully monitored to avoid the transfer of further microbial contamination to fresh products, as this could affect microbial safety and saleability. Wastewater reuse, or the use of "grey wash" water, has been described as a possible means to cope with the depletion of conventional water resources, particularly in areas where water is mainly assigned for direct human use [51,52]. In South African rural areas, safe tap water is frequently scarce, and if available, most municipal water is required for direct human use [53]. Therefore, the use of "grey wash" water and mixtures of stream and "grey wash" water by at least 13% of farmers and 10% of the semi-organic farmers in this study is not surprising. A study from South Africa [46] similarly illustrated that fresh produce farmers used process wash water (e.g., "grey wash" water) as a source of irrigation. The pre-treatment of irrigation water sources other than potable tap water was overall low in the current study, with the organic farmer and under 50% of the semi-organic farmers pre-treating such irrigation water types prior to use (Figure 3); this is especially relevant, with most of the irrigation water sources not being municipal potable water. Pre-treatment of irrigation water, such as through boiling, filtration, and SODIS, has often been correlated with safer production and thus, a higher quality of fresh produce [54,55].

4.2.2. Fertilizer

Fertilizers are an essential component of crop production, with the fertilizer type being used to distinguish between conventional and organic farming. Organic agriculture relies on the use of biological soil amendments (BSAs) (partially, non-composted, or "raw" animal manure), whereas conventional agriculture is reliant on synthetic fertilizers [56]. A common practice used by farmers across all farming systems in the current case study was the use of animal manure as a component of fertilizer or, in the case of the semi-organic smallholder farmers, sometimes directly as a substitute for fertilizer (Figure 2). While BSAs have positive effects on agricultural soils [57], the use of partially composted or "raw" manure has been linked to an increased prevalence of pathogenic microorganisms in agricultural soils, compared with soils that only utilize synthetic fertilizers [58]. Livestock manure may carry pathogenic bacteria such as *E. coli* O157:H7 and *Salmonella* spp., which can contribute to fresh produce contamination if the manure is directly applied as a fertilizer [25,58]. A previous study evaluating the rural fresh produce farmer practices similarly highlighted the potentially risky use of so-called "raw" manure as a substitute for fertilizer [25]. Appropriate composting of manure is crucial for the production of safe, ready-to-eat (RTE) fresh produce in organic farming, as there is typically no "inactivation step" (such as cooking) that takes place between harvest and consumption [59,60]. In the current study, pre-treatment of fertilizer displayed a significant correlation ($\rho = 0.404$, 95% CI = 0.097–0.641, $p < 0.01$) with the type of fertilizer used by the semi-organic farmers (Figure 4). The preparation time of fertilizers comprising manure differed for the farm systems, with the organic farmer using a six-month minimum preparation time for the fertilizer to be applied directly to soils (Supplementary Table S3). Contrastingly, the semi-conventional farmer, due to more frequent use of "store-bought" synthetic fertilizer, did not prepare organic fertilizer comprising of manure before use (Supplementary Table S3). The appropriate preparation and use of organic manure-based fertilizers are imperative in

sustainable fresh produce production to avoid possible health risks due to microbial contamination and the subsequent effects on fresh produce food safety and saleability [61,62]. The path toward producing good quality and hygienically safe fresh produce should include the development of efficient sanitizing treatments for biological solids (including animal and human wastes), particularly when used as a source of fertilizers, with the treatments adapted to the demographic and socioeconomic situation of the farmer [57,63].

4.2.3. General Hygiene Practices

A study by Bartz et al. [64] investigating the routes of contamination of fresh produce on farms identified soil, hands of farmworkers, and farm equipment as potential sources of contamination. An official European Union guidance document highlighted the microbiological risks that can affect the safety and quality of fresh produce at the primary production level in the absence of appropriate hygiene procedures, and noted similar sources (e.g., soil, water, and farmworker hygiene) [65]. In the present study, the organic farmer and farmworkers most often recognized farming equipment, soil, irrigation water, and fertilizer as potential sources of microbial contamination (Figure 3) compared with individuals from the other two farming sectors. Mdluli et al. [25] found that the farmer's knowledge of the sources of bacterial contamination differed among trained and untrained farmers of the uMbumbulu District in South Africa. However, the sources of contamination recognized in that study also included soil, water, and equipment. The consequences of bacterial contamination were more often recognized by the individuals of the organic farm in the current study (Figure 3). The loss of customers' trust as a consequence of bacterial contamination was the most recognized consequence by the individuals of the organic farm, which may be a direct result of them already being market participants (Supplementary Table S3). Contrastingly, the individuals of the semi-conventional farm did not acknowledge the loss of customer trust as a consequence of bacterial contamination, potentially resulting from their minimal interest in gaining market access (Supplementary Table S3). The semi-organic farmers often did not link health complications or customer trust with bacterial contamination and were the only group to identify "no hazards" as a result of bacterial contamination. So far, only a limited number of studies is available [25,66] in the South African context, with respect to those specifically focusing on farmer hygiene practices and the awareness required for the microbiological safety of fresh produce when farming, and thus the implications of these factors on food safety and market access. Therefore, the implementation of good farming hygiene practices and the raising of awareness of potentially risky agricultural practices among smallholder farmers is essential for enabling their access to regulated markets.

4.3. Relationships between Farmer Socioeconomic Characteristics and Farming Practices

Gender has continually been highlighted as an influential factor governing smallholder farmer decision-making [35,67,68] and was also identified as a critical factor affecting food security [13,69]. In the current study, gender displayed the largest degree of significant association with the selected farmer practices (Table 2). Age has previously been described as a demographic and socioeconomic characteristic affecting farming practices among smallholder farmers [25,27], but it did not display a significant relationship with any farming practices in any of the farming systems that we studied. The farmer's education level has been described as a crucial characteristic in agricultural settings [27]. A significant correlation between the education and pre-treatment of irrigation water among the semi-organic smallholder farmers was observed in the current study (Table 2). Kyaw et al. [26] reported that higher education levels of smallholder farmers correlated with their adoption of better general farm management and hygiene practices. Reports by the South African Agricultural Research Council (ARC) have highlighted that poor education levels and illiteracy continue to be important contributing factors that prevent smallholder South African farmers from meeting retailers' requirements of record-keeping and safety standards [70]. The income bracket that the farmers belonged to was another observed socioeconomic characteristic of the semi-organic farmers, and was significantly associated with the type of fertilizer

that they used (Table 2). Often, the financial status of a farmer dictates the type of farming practices that are used [23]. Studies undertaken in Europe have highlighted that financial characteristics often impact farmers' decisions to adopt organic farming practices, which are considered to be more costly than conventional farming practices [27]. Additionally, the education levels of the semi-organic farmers displayed a significant correlation with the farmer's income bracket ($\rho = -0.322$, 95 CI = -0.582– -0.003, $p < 0.05$). This may suggest, similarly, that farmer income may also impact the level of education that farmers have had access to or aspire to achieve.

5. Conclusions

Farming systems and practices are known to contribute to the microbial contamination of fresh produce. This case study showed that the farming systems assessed mainly differed in terms of the fertilizer type and irrigation water sources used, as well as the methods of fertilizer preparation. These differences are important in fresh produce production, as they have been previously highlighted as potential contributors to the microbial contamination of fresh produce, which in turn may affect food safety, food security, and market access. Additionally, this study highlights the potential role of demographic and socioeconomic characteristics in influencing farmer practices. Gender was one of the demographic characteristics that most affected farming practices. Considering the female-dominated farmer population of both the semi-organic and organic farm samples analyzed, policy and development initiatives that focus on improving sustainable farming practices should closely consider the gender dynamic to allow for the participation of female farmers given their other time-consuming productive roles.

A limitation of the current case study was the restriction on traveling and social interactions imposed by the South African government due to the COVID-19 pandemic, which restricted the size of the sample population. This limitation made it impossible to identify the specific practices of conventional farmers. It is noteworthy that farmers already supplying regulated markets, such as the organic farmer in the current case study, could disseminate information on good agricultural practices to informal smallholder farmers, resulting in improved microbiological quality and saleability of the fresh produce generated.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su141710590/s1. File S1. Table S1: Questionnaire 1, administered to the semi-organic farmers; Table S2: Questionnaire 2, administered to the organic and semi-conventional farmworkers; Table S3: Summary of the responses from key-informant interviews with the organic farm owner, semi-conventional farm manager, and key themes within the semi-organic farmer surveys. File S2. Farmer data.

Author Contributions: Data acquisition and original draft: T.B.; design of study and conceptualization: T.B., J.T.-C., and S.S.; data analyses and interpretation: T.B., J.T.-C., and S.S.; visualization: T.B. and S.S.; review and editing: J.T.-C. and S.S.; funding and supervision: J.T.-C. and S.S. All authors have read and agreed to the published version of the manuscript.

Funding: T.B. acknowledges the award of a DAAD-NRF (Germany/South Africa) PhD scholarship. This research was funded partially by the NRF (Grant No. 132700 and 134128, SS) and the WRC (K5/2555/4, JTC).

Institutional Review Board Statement: This study was ethically approved (University of KwaZulu-Natal, HSSREC/00000795/2019, 20 November 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are provided in the manuscript and included as supplementary information.

Acknowledgments: The authors would like to acknowledge the participating farmers, Denver Naidoo for critically reading sections of the draft and providing valuable input, and Maike Claussen for continuous support.

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

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Socio-Economic Constraints of Adopting New Cowpea Varieties in Three Agro-Ecological Zones in the Senegalese Peanut Basin

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Abstract: Socio-economic constraints like gender, education, age, and income significantly affect the adoption of improved agricultural technologies. The objective of this study was to determine socio-economic factors that affect the adoption of improved cowpea varieties in the Senegalese peanut basin. The study was conducted in three (Bambey, Kebemer, and Kaffrine) of six regions of the peanut basin based on regional importance of cowpea production and rainfall gradient. In each study region, ten villages were selected, and random sampling was used to select eight heads of agricultural households within each village. The questionnaires were administered to 240 randomly selected farmers across the three study regions, 7 communes, and 30 villages. Results showed most heads of households were middle-aged (52–54 years old), married (95–100%), illiterate (84%), and men (95–100%). Households were mostly agriculture dependent (87%), low literacy rates (26% least primary school), and large family sizes (average of 15 members). The median cowpea yields across the study area varied from 35–100 kg ha^{-1}, well below the ~300–400 kg ha^{-1} average yields reported for Senegal and Sub-Saharan Africa. The majority of farmers (67%) in the study regions did not use improved varieties, and the main reasons were low seed availability (78.8%) and limited access to technical knowledge and information (76.3%), but only 5.8% indicated seed price as a barrier to improved variety adoption. Major uses of cowpea in the study area were for marketing, livestock feed, and human consumption. In Kaffrine, fodder production was the major (85%) criterion for cowpea variety selection, whereas in the north (Bambey and Kebemer), taste, maturity date, and grain yield were major selection criteria. Factors that had positive effect on the likelihood of using improved cowpea varieties include; access to extension services, membership in farmers' organization, cowpea being the main crop of production, organic farming, market, and livestock-oriented production systems, access to farmland and credit, dependence on agriculture as the main source of household income, and education of head of household. We conclude that there is a critical need for training, access to improved seeds, awareness, and financial support to producers to increase the adoption of new improved cowpea varieties, yields, profitability, and nutritional security among smallholder farmers in the Senegalese peanut basin.

Keywords: characteristics of household; cowpea varieties; dryland; socio-economics; Senegal agriculture

Citation: Beye, A.; Diakhate, P.B.; Diouf, O.; Faye, A.; Obour, A.K.; Stewart, Z.P.; Assefa, Y.; Min, D.; Prasad, P.V.V. Socio-Economic Constraints of Adopting New Cowpea Varieties in Three Agro-Ecological Zones in the Senegalese Peanut Basin. *Sustainability* **2022**, *14*, 14550. https://doi.org/10.3390/su142114550

Academic Editor: Keshav Lall Maharjan

Received: 20 September 2022
Accepted: 28 October 2022
Published: 5 November 2022

1. Introduction

Agriculture production in Senegal is dominated by staple food crops including, pearl millet (*Pennisetum glaucum*; 38%), cowpea (*Vigna unguiculata*; 24%), maize (*Zea mays*; 20%), rice (*Oryza sativa*; 9%), and sorghum (*Sorghum bicolor*; 9%) which are mainly grown in the rainy season [1]. Groundnut or peanut (*Arachis hypogaea*) is important both in terms of volume of production and area harvested but is mainly market-oriented for local industries or export. Faced with growing food and nutritional needs of a population of more than 14 million, with projections to increase to 19 million in 2030 and 26 million by 2050 [2], increasing agricultural production to meet food demand is an important challenge.

Cowpea plays a significant role in food and feed, supplying a needed protein source [3], and generating income for Senegalese rural households. Cowpea is among the most cultivated grain legumes with important nutritional, economic, and cultural significance in semi-arid regions of west Africa [4]. In regions of low rainfall or delayed cropping season, farmers rely on cowpea because of the short production cycle and drought tolerance [5]. In normal growing seasons, the availability of cowpea green pods in early September provides food at a time of the year when granaries are almost empty. Cowpea marketing is an opportunity to generate income for smallholder producers. With food production lagging behind population growth and demand for livestock products booming due to rapid urbanization and climate change, cowpea cultivation is very valuable. Cowpea leaves and stems have high protein content and serve as nutritious fodder for cattle and other farm animals and its roots provide nitrogen to improve soil fertility.

Cowpea is a short duration crop well adapted to the erratic rainfall, extreme heat, and nutrient-deficient soils that prevail in semi-arid environments in west Africa. In Senegal, cowpea is grown in all agro-ecological zones, particularly in the north-central region of the peanut basin, which covers an average of 82% of the sown area and 80% of national production [6]. However, its role in rural households is affected by low productivity and the limited availability of fodder to support livestock, especially during the dry season. New cowpea varieties of dual-use offer both the ability to achieve greater grain yields for human consumption and high-quality fodder for animal production. Therefore, the adoption and scaling up of dual-use cowpea varieties has become very important with the aim of increasing rural incomes and supporting human food security and livestock production systems.

Since the 1980s, most research on the cowpea sector in Senegal has focused on the determinants of cowpea yield [7], adoption determinants of improved varieties, and market information systems [5]. Few studies have attempted to identify constraints to adoption in other semi-arid environments in West Africa [8,9] and in other parts of Africa [10,11]. Moreover, in the identification of new varieties' adoption determinants, the context of cropping system used in cowpea production is usually not considered. Notwithstanding the importance of socio-economic characteristics and access to information, cropping system including the choice of crop associations, the use of chemical and/or organic fertilizers, and the preference of farmers towards the production of fodder for animal feed or grain for marketing and income generation, improve the understanding of factors likely to influence adoption of new crop varieties. This study investigated the effect of socio-economic conditions and production choices of farmers on the adoption of new cowpea varieties to improve human food and animal fodder in Senegal. The specific objective was (i) to analyze the socio-economic characteristics of cowpea production systems and (ii) determine the profile of new cowpea varieties adopters in the Senegalese peanut basin through descriptive analysis and econometric analysis to see whether socio-economic conditions and production choices influence new cow variety adoption.

2. Materials and Methods

2.1. Study Area

The study was conducted in the peanut basin of Senegal, which covers the west and the center of the country, corresponding to the administrative regions of Louga, Kaolack, Fatick,

Thies, Diourbel, and Kaffrine (Figure 1). It covers a third of the land area of Senegal, home to about half of the population, and is characterized by tropical ferruginous soils. Major agricultural crops grown are mainly dry cereals (i.e., millet and sorghum) and legumes (i.e., groundnut and cowpea). Three of the six regions of the peanut basin were chosen for the study based on annual rainfall amounts [Louga (arid), Diourbel (semi-arid) and Kaffrine (semi-humid)] and the acreage and importance of cowpea production. In each of the three regions, a study area was selected based on cowpea acreage produced. The selected study areas included Bambey in the Diourbel region, Kebemer in the Louga region, and Kaffrine in the Kaffrine region (Figure 1).

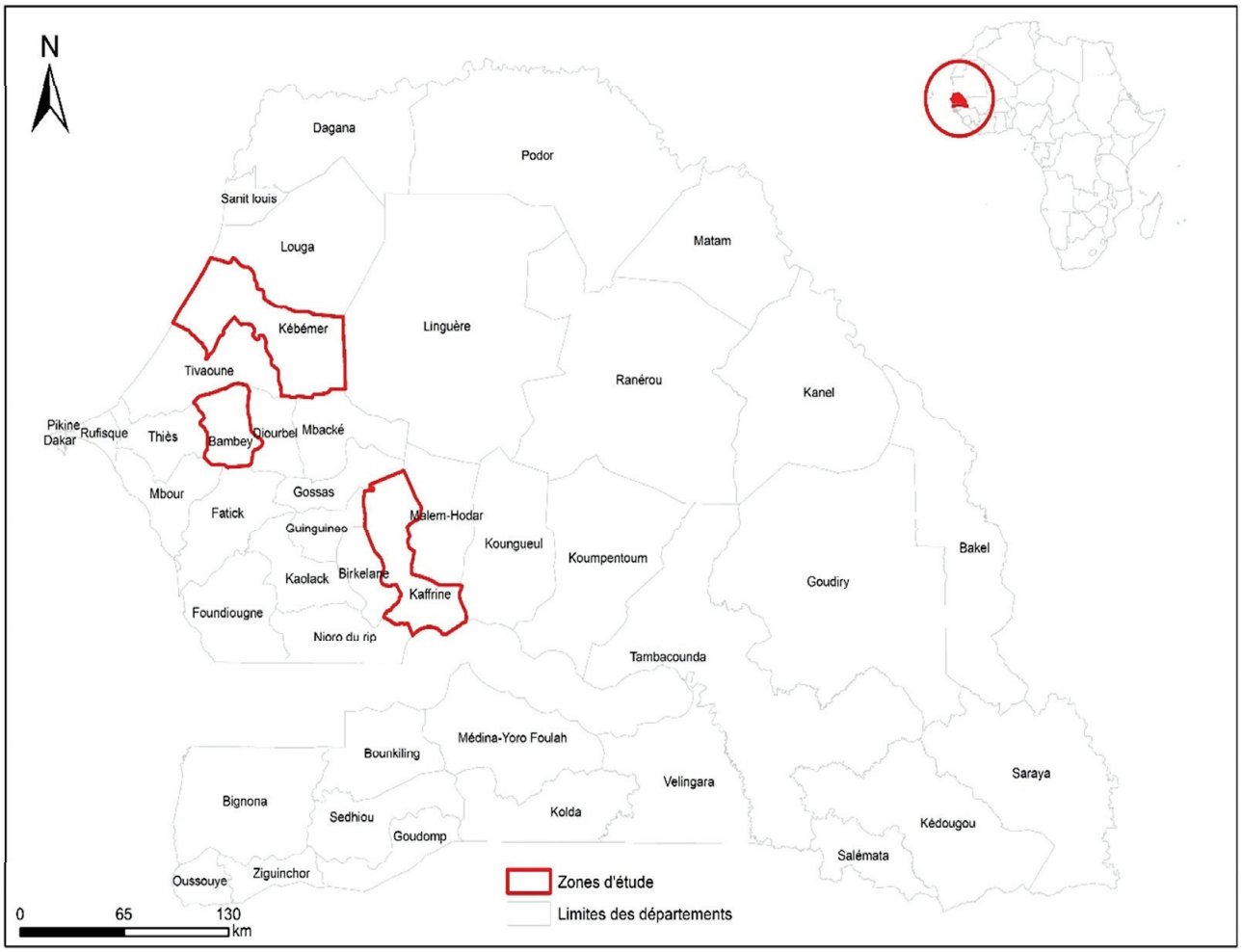

Figure 1. Map of location of Senegal in Africa and study regions (Kebemer, Bambey, and Kaffrine) and boundaries.

2.2. Sampling of Sites, Villages, and Targeted Population

We used a three-stage sampling procedure to select first, the communes, then the villages, and finally the agricultural households for the study. The objective of the selection was to balance the number of villages and communes chosen in each region, minimize the effects of sampling error or bias resulting from the proximity of the villages, and constitute a group of beneficiaries and control for the impact assessment study. Thus, 10 villages were randomly selected in each of the study regions at Bambey, Kebemer and Kaffrine. Climate type, average rainfall, and temperature, in each of the three study regions are indicated in Table 1. In each village, random sampling was conducted to select eight heads of agricultural households. In total, the questionnaire was administered to 240 selected farmers in three regions, seven communes, and 30 villages.

Table 1. Details of climate in study regions, average production, standard deviation (SD), minimum (Min), and maximum (Max) values reported by individual household by study area (in kilograms).

Study Region	Climate Type	Average Rainfall (mm)	Average Temp. (°C)	Average Prod.	SD	Min	Max
Bambey	sahelian	350	34.7	146.5	158.8	0	1000
Kebemer	sudano-sahelian	464.1	30	481.7	1140.6	0	9500
Kaffrine	sudano-sahelian	1000	29	124.9	138.6	0	800
Average	-	-	-	251.0	686.7	0	9500

2.3. Questionnaire

A baseline survey was conducted in the three study regions between April and May 2021. The questionnaire used for data collection consists of fourteen sections (see Supplementary Materials, with only relevant sections of questionnaire for this specific study). The first section had information on the identification of the household, and collected information on geographical, communal, and regional location. The next information collected was on the characteristics of the head of household including age, gender, marital status, type and level of education and experience. Characteristics of the household included information on composition, the cultural practice, sources of income and level of food security. The third section focused on farmland owned by the household, their location in relation to the family concession, method of acquisition, land tenure, farm size, cropping system practices and person responsible for decision-making. The fourth section collected information on cowpea production system by focusing on the methods used for each farming operation ranging from soil preparation, planting, harvesting and post-harvest operations. This section also covered aspects of labor mobilized in cowpea production as well as types of cowpea varieties and inputs used.

The fifth section requested information on contracts between producers and traders while the sixth section focused on the production tools used in the fields. Information on the quantity of crops produced and the distribution was the next subject covered in the seventh section before information on pest, diseases, storage methods and participation in demonstration field trials. Information on access to financial and extension services was collected in the next section before the approaches used for cowpea marketing were studied. Data was also collected on a role of livestock in the generation of household income.

2.4. Methodology for Data Analysis

To understand the constraints to new cowpea varieties adoption, we combined a descriptive statistical analysis with a Probit model to analyze the data collected from the survey. The descriptive analysis of the responses from the questionnaire was conducted on household characteristics, cowpea use and productivity, and use of improved varieties. The data collected were disaggregated and analyzed according to the agro-ecological zone and averaged when generalization was needed for the entire study. STATA software summarize commands were used to obtain average, standard deviation, minimum and maximum for quantitative data analysis by region. However, for qualitative data, the table command of STATA version 14 software generated proportions of modalities crossed with regions. Graphs and charts were developed using a sigma plot (Systat Software Inc., Palo Alto, CA, USA).

First, the characteristics of the head of household (CHH), including age, sex, marital status, and level of education, were analyzed for each of the three agro ecological zones. For a CHH with a continuous variable (i.e., age), average site CHH was calculated as the sum of the ages of the head of household from each individual respondent at the site divided by the total number of respondents (Equation (1)). Across regions, the average was calculated as the sum of the average CHH of each of the three regions divided by three.

$$Average\ age\ in\ a\ region\ (AAG) = \frac{\sum_{x=1}^{n} age\ of\ HH\ in\ respondant\ x}{n} \quad (1)$$

X = individual respondent, n = total number of respondents, and HH = head of household.

For CHH with discrete values (like gender, marital status, level of education), The percent CHH of each region was calculated as the total count of similar characteristic responses from individuals from a region divided by the total number of respondents multiplied by a hundred (Equation (2)). Across regions, percentages were calculated as the sum of the percent of each of the three regions divided by three.

$$CHH\ (gender,\ marital\ status,\ \ldots) = \frac{Number\ of\ responses\ with\ similar\ CHH}{n} \times 100 \quad (2)$$

Second, household characteristics were described by zone with a focus on household size, main source of income of the household and the highest level of education attained by a household member. Calculations of household characteristics were conducted similarly as described for the head of the household.

The third sub-section of the results focused on cowpea production inputs, management practices, production and utilization. Adoption rates and reasons for a variety of adoptions, and family or farm locations were first analyzed to determine if differences in adoption can be explained by the climatic context. Then, the labor used by men, women and children in relation to farming operations including threshing, weeding, fertilization, soil preparation, and harvesting and transporting were analyzed. In addition, the types of diseases affecting cowpea production and post-harvest utilization are presented. Furthermore, prices and selling periods within the study regions were characterized as well as the different storage methods used in the different regions.

Finally, an econometrics analysis was performed using the Probit model in STATA to determine the effect of all gathered socio-economic information on new cowpea variety adoption by producers. The Probit model of the form (Equation (3)) was fitted:

$$Y_i^* = \theta_0 + \theta_1 X_{1i} + \theta_1 X_{2i} \ldots + \theta_K X_{Ki} + \varepsilon_i = X_i\,\theta + \varepsilon_i \quad (3)$$

where $\varepsilon_i \sim N(0,1)$. The vector $X_i = (X_{1i},\ X_{2i},\ \ldots\ ,\ X_{Ki})$ corresponds to the observable characteristics of the individual i and the vector $\theta = (\theta_0,\ \theta_1,\ \ldots\ \theta_K)$ represents the coefficients of each of these characteristics in order to qualify the variable, under the assumption that the above model is representative of reality. Theoretically, the binary variable Y_i, is such that $Y_i = 1$ where producer i adopts at least one new variety of cowpea, and when $Y_i = 0$, indicates the producer does not adopt a new variety of cowpea.

Empirically, the model used in this work is written as follows in Equation (4):

$$\begin{aligned}
&\textbf{\textit{Improved variety adoption}}\ (\boldsymbol{Y_i})\\
&= \theta_0 + \textbf{\textit{Information access}}\ (\theta_1\ Village - field - distance + \theta_2\ Extension\ service\ access\\
&+\theta_3\ village - road - distance + \theta_4\ Information\ farmer - farmer\\
&+\theta_5\ Member\ of\ a\ producer\ group i) + \textbf{\textit{Production system}}\ (\theta_6\ Cowpea\ monoculture\\
&+\theta_7\ Use\ of\ chemical\ fertilizer\ + \theta_8\ Use\ of\ organic\ fertilizer + \theta_9\ Market\\
&-oriented\ cowpea\ production + \theta_{10}\ Livestock - oriented\ cowpea\ production)\\
&+\textbf{\textit{Household characteristics}}\ (\theta_{11}\ Age\ of\ household\ head + \theta_{12}\ Height\ of\ household\ head\\
&+\theta_{13}\ Gender\ of\ household\ head + \theta_{14}\ Literacy\ of\ household\ head + \theta_{15}\ Area\ farmed\\
&+\theta_{16}\ Presence\ of\ diseases\ in\ plants + \theta_{17}\ Main\ source\ of\ income + \theta_{18}\ Access\ to\ credit)\\
&+\theta_{19}\ \textbf{\textit{study area}} + \varepsilon i
\end{aligned} \quad (4)$$

3. Results

3.1. Characteristics of Head of Household

The average age of the heads of household surveyed across the study region was 53 years old (Figure 2a). However, this varied among regions, with an average of 52 years at Bambey or Kaffrine and 54 years in Kebemer. The minimum age of the head of a household was 22 years old. This minimum age was registered in Kebemer while in Bambey and Kaffrine, the minimum age of the

head of the household was 24 and 25 years old, respectively. The maximum age of 85 years old was recorded at Kaffrine, while the maximum age was 79 years in Bambey and 84 years old in Kebemer.

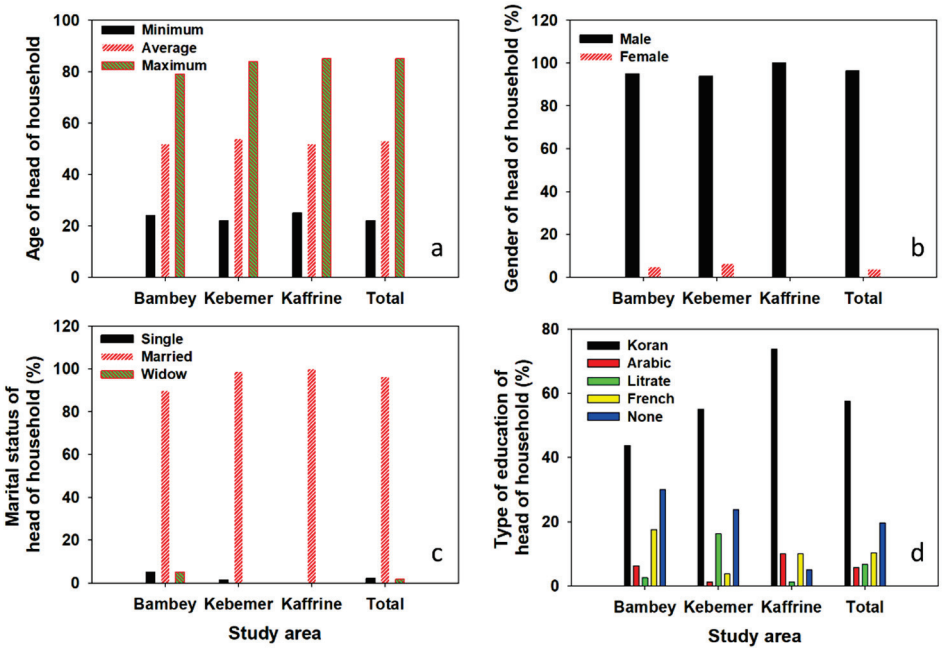

Figure 2. Characteristics of head of the household (**a**) age, (**b**) gender, (**c**) marital status, and (**d**) highest education level by study regions (Kebemer, Bambey, and Kaffrine) in Senegal.

Men were heads of households in 96% of the households surveyed (Figure 2b). This proportion was greater in Kaffrine, where men headed 100% of households surveyed. However, there were a few female-headed households in Bambey (5%) and Kebemer (6%). These observations were consistent with the configuration of households in rural areas where the heads of households were mainly men [12].

The majority (96%) of heads of household were married (Figure 2c). In Kaffrine, the households interviewed were all married. However, there were few singles in Bambey (5%) and Kebemer (1%). In addition, there were few widowed heads of household at Bambey (5%). These results were in agreement with the social reality of rural households because marriage promotes the formation of new households and a certain autonomy in use of land resources.

The percentage of heads of households enrolled in French schools was generally low (Figure 2d). Most heads of household had only received a Koranic education (58%). Kaffrine had the highest proportion of heads of household who received only a Koranic education (74%), followed by Kebemer with 55% of the heads of household and Bambey with 44%. Across regions, 10% of heads of household received French education with a higher proportion in Bambey (18%), followed by Kaffrine (10%) and Kebemer (4%). This finding agrees with Beye et al. (2018) who reported a French school rate of 10% among smallholder households in the Senegal River valley. Moreover, it was observed that only 6.6% of heads of households were literate. The Kebemer region had the highest proportion (16%) of heads of households who received formal education (Figure 2d). This was possibly because of government intervention programs implemented to reduce the school enrolment deficit in the region. The Arabic education level represented the lowest percentage in terms of education (5%). Arabic education of the head of the household was more at Kaffrine with 10% of heads of household, followed by Bambey (6%) and Kebemer (1%) (Figure 2d).

Across the study area, about 26% of households had at least attained primary school education (Figure 3a). By study region, the percentage for primary education was 34% in Kebemer, 25% in Bambey, and in 20% in Kaffrine. After primary school, middle school level was the next high-level education reached by a member of the household with 26% of the households surveyed. A university level education represented a significant proportion of households, with an average of 18% across the three regions. Approximately 25% in Kebemer, 20% in Bambey and 10% in Kaffrine had university level education. The secondary school level represented the lowest proportion of households with an average of 10% across the three regions. This was mainly in Kaffrine (20%). However, there were

households where no member had received a level of education in French. This proportion was 19% across the regions, but with a greater percentage in Kebemer (35%).

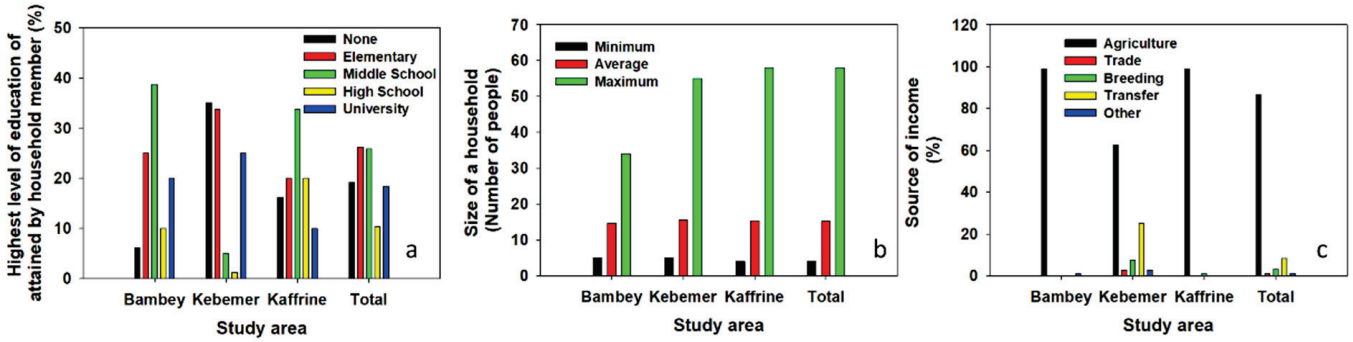

Figure 3. Characteristics of a household (**a**) highest level of education of the household, (**b**) size of household, and (**c**) income source by study regions (Kebemer, Bambey, and Kaffrine) in Senegal.

The average size of the households surveyed had 15 members (Figure 3b). The highest average household size was observed in Kebemer with 15.5 members, 15.4 in Kaffrine and 14.7 in Bambey. The minimum household size was four members was recorded in Kaffrine (Figure 3b). The maximum household size of 58 members was observed in Kaffrine, while the maximum was 55 members in Kebemer and 34 members in Bambey. It is worth noting that smallholder agricultural operations usually mobilize the entire available family and external labor, which is taken care of by the household. Therefore, it is possible households with large members may include external labor or farm help who may not be family members.

Agriculture was the main source of household income among 87% of households in the study regions (Figure 3c). This proportion was greater in Bambey and Kaffrine (99%). In these two regions, there was low diversification of incomes with only 1% of households in Kaffrine and in Bambey who had income from livestock and other commercial activities. However, there has been some income diversification in Kebemer where only 63% of households relied on agriculture as their main source of income but others receive remittances (25% of households), livestock (7.5% of households), trade (2.5% of households) and other activities (2.5% of households).

3.2. Cowpea Production, Input, Management, and Use

3.2.1. Cowpea Production

Cowpea production varied between minimum of 0 and maximum of 9500 kg per household across the three study regions (Table 1). Kebemer, had the greatest planted acreage of cowpea, with average production per household of 482 kg, while the average was 147 kg in Bambey and 125 kg in Kaffrine. The minimum production (which was zero) was the same in all the study areas. The maximum household production was 800, 1000, and 9500 kg at Kaffrine, Bambey, and Kebemer, respectively (Table 1).

In Bambey, 25% of the reported yield per hectare was less than or equal to 50 kg ha^{-1} and 75% of the grain yields were less than or equal to 200 kg ha^{-1}. The median yield was 100 kg ha^{-1}. This suggests that 50% of reported yields were less than or equal to 100 kg ha^{-1} and others above 100 kg ha^{-1}. At Kebemer, 50% of producers obtained grain yields ranging from 35 kg ha^{-1} to 200 kg ha^{-1}. The median reported yield at Kebemer was 77 kg ha^{-1}. At Kaffrine, half of the producers reported yields between 17.7 and 60 kg ha^{-1}. The median yield was 35 kg ha^{-1}. Cowpea position as an associated rather than a main crop could explain the relatively lower yields of cowpea in traditional cropping systems in the study region. Cowpea is often planted in relatively small areas of managed land as well as limited application of organic and chemical fertilizers. Indeed, Mbaye et al. [13] emphasized the place of cowpea as an associated crop because of its virtues in controlling crop pests, fighting diseases, improving cereal production for food security and conserving soil and water resources.

3.2.2. Inputs for Cowpea Production (Varieties and Labor)

The proportion of households using new dual-purpose cowpea varieties varied among regions (Figure 4a). The proportion of farmers adopting new dual-purpose cowpea varieties was greatest in Bambey with 48% of households surveyed, 32% in Kaffrine, and 20% in Kebemer. Indeed, access to

improved varieties was generally explained by the presence of state or multi-national organizations sponsored research projects and programs in the region, this is particularly the case in Kaffrine. Similarly, in some regions, farmer proximity to agricultural research or extension centers can promote access to information on improved varieties. For example, the ease of access to information at Bambey can be explained by the presence of the Centre National de Recherches Agronomiques (CNRA) of Bambey which offers educational programs to scale up adoption of new agricultural technologies and innovations.

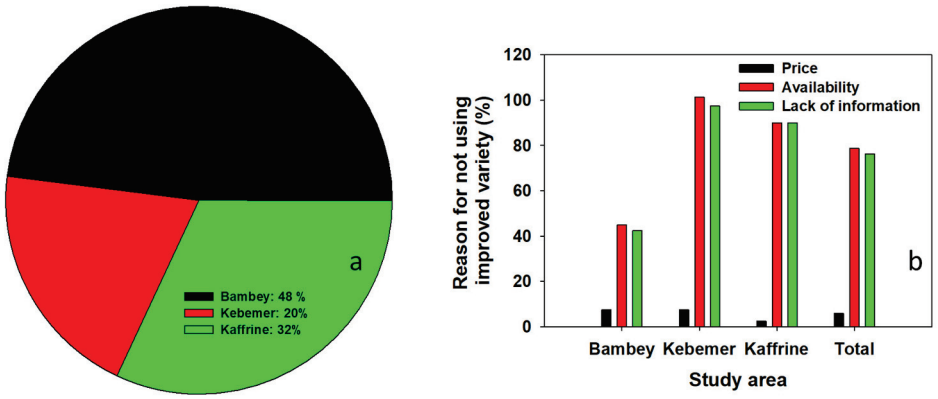

Figure 4. Cowpea (**a**) variety adoption and (**b**) reason for not adopting by study regions (Kebemer, Bambey, and Kaffrine) in Senegal.

The adoption of improved varieties was constrained by the unavailability of seeds of new cowpea varieties (79%), lack of knowledge and information about cowpea varieties (76%), and to a lesser extent, high seed prices (6%) (Figure 4b). The constraints of availability and lack of knowledge of improved varieties decrease from Kebemer to Kaffrine and from Kaffrine to Bambey. Possibly, because of the presence of CNRA, farmers in Bambey have access to information on new cowpea varieties.

Surveyed households provided varied reasons that contributed to the choice of cowpea varieties. Observation of preferences showed that households rely mainly on five major criteria in selecting cowpea varieties. This included high grain yield, fodder production, taste, early maturity, and producer visual preferences of seed color (Table 2). There are other lesser selection criteria such as the price of seeds (29% of farmers surveyed), low market demand because of the price (26%), and availability of seeds (19%). The criteria for choosing varieties are different across regions. For example, at Bambey, the choice of cowpea varieties was mainly explained by the preferences of farmers and the production of fodder. In addition, households use cowpea varieties because of their early maturity (60% of households) and taste (58.75% of households) at Bambey. In Kebemer, the reasons for the use of cowpea varieties are diverse but dominated by taste (50% of households), grain yield (44% of households) and fodder production (12.5%). At Kaffrine, cowpea variety selection was mostly determined by its early maturation (96% of households), fodder production (85%), affordable seed price (74% of households), and to a lesser extent its taste (63.75% of households). Aside from human consumption, cowpea was also used for fodder for livestock at Kaffrine and Bambey (Table 2). The southern region of the peanut basin which include Kaffrine is an area of reception for transhumant herders. Indeed, little forage availability from pasturelands in breeding areas (such as Kebemer) leads to the seasonal movement of herders towards the peanut basin, particularly in the dry season. The presence of herders and their animals create a market for cowpea fodder, which explained farmer selection and preference of cowpea varieties with greater fodder yields in the Kaffrine region.

Table 2. Reasons for new cowpea variety adoption by study regions in Senegal. In bold are the greatest reason for new variety adoption in each region and average across regions.

Reason for New Cowpea Variety Adoption	Study Region			Average
	Bambey	Kebemer	Kaffrine	
Affordable seed prices	3.75	10.00	73.75	29.17
Producer preferences	**83.8**	33.75	41.25	52.92
Weed tolerant	12.5	12.50	12.50	12.5
Drought tolerant	6.25	5.00	12.50	7.92
Early ripening/drought escape	60.0	5.00	**96.25**	**53.75**
High efficiency	55.0	**43.75**	88.75	74.58
Seed availability	11.25	15.00	30.00	18.75
High price problem in the market (high demand)	23.75	38.75	26.25	26.25
Suitable for conservation	12.50	22.50	41.25	25.42
Good performance under low soil fertility	5.00	2.50	7.5	5.00
Taste	58.75	50.0	63.75	57.5
Fodder	80	12.5	85	62.08

All family members (men, women, and children) participated in cowpea cultivation operations (Figure 5). Labor participation is greatest at fertilizer application (mostly applied to the cereal intercrop) with an average of 1.4 men, 2.8 women and 1.3 children. Cowpea is often used in intercropping with cereals because of their nitrogen-fixing attributes as a legume. When cowpea is fertilized, it is often organic manure; chemical fertilizer is mostly reserved for cereal intercrop. The workforce is also heavily mobilized for threshing, winnowing, and sorting operations, which required a maximum number of 8 men, 7 women and 7 children. However, few individuals are used in weeding operations which is mostly done by the female workforce (0.9 women on average). The results also showed that children are utilized more in soil preparation and planting operations (Figure 5d). On the other hand, adult men and women do harvesting operations because this activity requires a relatively intense labor force (Figure 5e).

3.2.3. Cowpea Management

The major diseases and pests encountered in cowpea fields in the study regions were termites (33%), rodents (29%), Striga, bacterial and fungal (24%), stem borers (15%), grasshoppers (7%) and birds (0.42%) (Table 3). Analysis by region showed that rodents (54%), termites (30%), Striga, bacterial and fungal (23%) are the main problems affecting cowpea farming in the Bambey region. Birds do not pose a major threat to cowpea in Bambey and Kebemer. Birds were only identified as a threat to cowpea in the Kaffrine region. The main diseases and pests found in the Kebemer region are Striga, bacterial and fungal (36%), stem borers (25%) and termites (20%). Again, in Kaffrine, the most recurrent threats to cowpea production were caused by termites (48%), rodents (31%), grasshoppers (15%), Striga, bacterial and fungal (13%), and stem borers (11%).

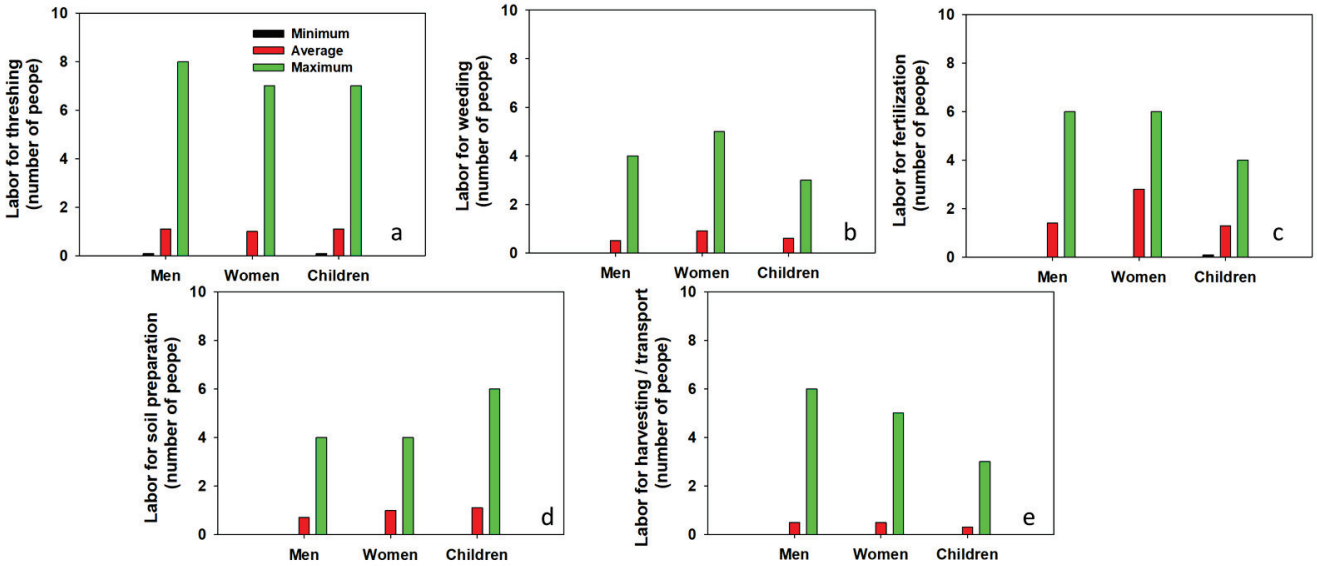

Figure 5. Family labor used at (**a**) threshing, (**b**) weeding, (**c**) fertilization, (**d**) soil preparation, and (**e**) harvesting and transporting cowpea in Senegal.

Table 3. Types of pests or diseases that affects production of cowpea and part of the plant they affect.

	Grasshoppers	Termites	Rodents	Birds	Rod Drillers	Striga, Bacterial and Fungal	None
Bambey (n = 80)	3.75	30.00	53.75	0	7.50	22.50	15.00
Kebemer (n = 80)	1.25	20.00	1.25	0	25.00	36.25	0.00
Kaffrine (n = 80)	15.00	47.50	31.25	1.25	11.25	12.50	8.75
Total (n = 240)	6.67	32.50	28.75	0.42	14.58	23.75	7.92
Part of plant affected							
Leaf	13.98	55.91	13.98	1.08	12.90	43.01	-
Seed	7.46	24.63	49.25	0.00	15.67	17.16	-
Stem	6.82	45.45	18.18	2.27	40.91	38.64	-

Leaves of cowpea suffer the most attacks from termites (56%), Striga, bacterial and fungal (43%), grasshoppers (14%) as well as attacks by rodents, stem borers (13%), and birds (1%). Seeds suffer the most attacks from rodents (49%), termites (25%), Striga, bacterial and fungus (17%), and from grasshoppers (7%). The major finding is that seeds do not suffer attacks from birds. Finally, stems suffer the most recurrent attacks from termites (45%), stem borers (41%), Striga, bacterial and fungal (39%), rodents (18%), grasshoppers (6.82%), and birds (2.27%).

Farmers in the study regions used several methods to control diseases and pests. These methods included chemicals (27.1%), cultural methods (5.9%), biopesticides (5.6%), and biological controls (1.4%). Among these methods, chemical controls are the most used to control diseases and pests (48%), termites (45%), grasshoppers (36%), rodents (19%), Striga, bacterial and fungal (12%), and stem borers (9%). Individuals who have not developed control strategies for diseases and pests represent 60% of the producers surveyed.

3.2.4. Cowpea Use

Cowpea has several functions in the regions studied, including marketing, consumption and use as fodder for livestock feed (Figure 6). While most of the cowpea produced was intended for marketing (119 kg on average), a large part is used for livestock feed (82 kg) and home consumption (62 kg). However, other uses included seed reserve and storage for food. Cowpea uses by households differed among regions. Farmers in Kebemer marketed most of their cowpea, while the amount of cowpea intended for animal feed is greater in Bambey (156 kg year^{-1}). At Kaffrine, cowpea is mainly used for household consumption.

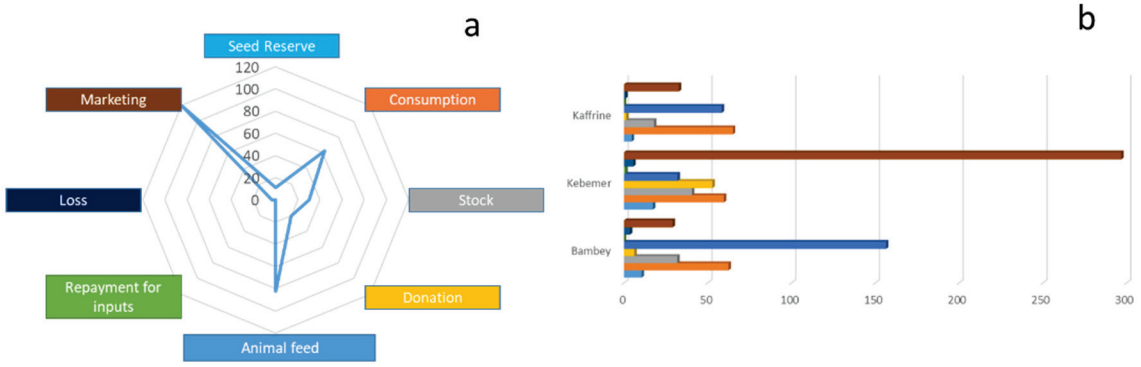

Figure 6. Uses of cowpea produced (**a**) across the study regions and (**b**) by three study areas (Kebemer, Bambey, and Kaffrine) in Senegal. Background color for cowpea use in (**a**) are legend for bars in (**b**).

Households mainly use cowpea fodder for feeding cattle (81% of households) and sheep (74%). Only 30% of households use cowpea fodder for goat feeding (Figure 7). This relatively smaller proportion is explained by the fact that goats are more mobile and can find their own food within their environment. The results also showed that cowpea fodder intended for cattle feed is more common in Kaffrine and Kebemer (Figure 7). The proportion of households using cowpea fodder for feeding sheep is more common in Kaffrine (79%) and Bambey (76%). Using cowpea fodder for feeding goats was more common in in Kebemer (43%) and Bambey (11%).

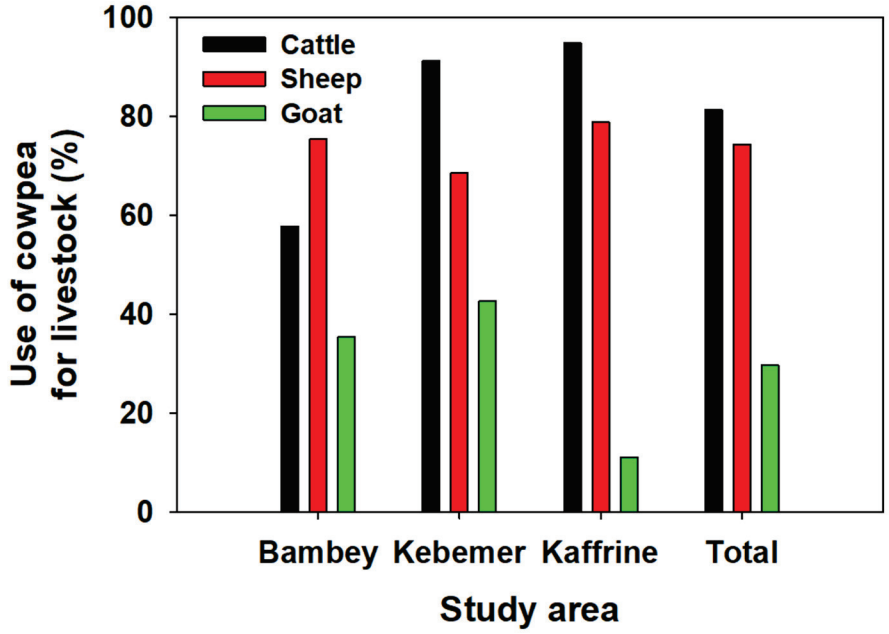

Figure 7. Use of cowpea for livestock by study regions (Kebemer, Bambey, and Kaffrine) in Senegal.

3.3. Sales Price and Period

Out of a total of 240 households surveyed, half (50%) made sales from their cowpea production. Farmers in Kebemer are more market-oriented compared to Bambey or Kaffrine. Out of 119 farmers who have carried out cowpea sales, 96% of them were in Kebemer followed by Bambey (31%), and only 21% in Kaffrine.

The average selling price of a kilogram of cowpea grain was estimated at \$0.58 with a large variation around the mean of up to \$0.17 kg^{-1} (Table 4). Kaffrine, which recorded the lowest proportion of sales had the highest grain price of \$0.74 kg^{-1}. This is explained by the fact that cowpea has become rare in the region and its price was increased based on the quantity offered and the quantity demanded. The average cowpea grain price at Bambey was \$0.67, and Kebemer with the highest cowpea acreage among the study regions had the lowest grain prices, averaging \$0.51 kg^{-1}.

Table 4. Average selling price in US dollars per kilogram of cowpea grain by study area.

Study Region	Obs	Mean	SD	Min	Max
				$ kg^{-1}	
Bambey (N = 25)	25	0.67	0.28	0.33	1.47
Kebemer (N = 77)	77	0.51	0.08	0.33	0.82
Kaffrine (N = 17)	17	0.74	0.10	0.65	0.98

About 38% of households claimed they sold cowpea shortly after harvest while 28% of farmers sold their cowpea in the second quarter after harvest (Table 5). The latter was greater in the region of Kebemer where 23% of the producers surveyed said they marketed their cowpea in the first quarter after harvest. About 19% of producers marketed their cowpea just before next year's sowing, especially in Kaffrine and 15% of producers during the first quarter after harvest. In the Bambey region, most of the households surveyed conducted cowpea sales shortly after crop harvest (68%), but in Kebemer, sales are made over all periods but mostly in the second quarter (35%) after harvest.

Table 5. Cowpea sales period and Storage techniques by study area in % from respondents.

Study Region	Sales Period			
	Shortly after Harvest	**First Quarter after Harvest**	**Second Quarter after Harvest**	**Just before Next Year's Sowing**
Bambey (*n* = 25)	68.0	0.0	4.0	28.0
Kebemer (*n* = 77)	33.8	23.4	35.1	7.8
Kaffrine (*n* = 17)	11.8	0.0	29.4	58.8
Total (*n* = 119)	37.8	15.1	27.7	19.3
	Storage technique			
	Metal silos	Bags	Metal drums	Cans
Bambey (*n* = 80)	0.0	5.2	11.7	87.0
Kebemer (*n* = 80)	1.3	15.0	61.1	47.5
Kaffrine (*n* = 80)	0.0	1.9	0.0	98.2
Total (*n* = 240)	0.5	8.1	27.5	74.9

3.4. Cowpea Storage Methods

Cowpea occupies second place in the dietary habits of Senegalese households. About 88% of the households surveyed store part of their cowpea produced compared with 12% who did not store cowpea from their farming operations. In the Kebemer region, all households surveyed stored part of their cowpea produced. This is explained by the fact that cowpea occupies a strategic place after groundnuts and millet in the region. In Bambey, almost 96% of households stored a portion of cowpea produced compared to 68% in Kaffrine. It is worth highlighting the breakthrough of cowpea in the region of Kaffrine located in the heart of the groundnut basin, which currently records a high rate of integration of cowpea in the farming system.

The canister method is the most widely used cowpea storage technique (Table 5). Mostly used by 98% of cowpea farmers in the Kaffrine region, 87% by farmers in Bambey and 48% in the Kebémer region. The use of metal drums was the next popular method (27%), and was generally used by 61% of farmers in the Kebemer region. This region has the largest acreage of cowpea production in Senegal. Storage in bags (8%) and metal silos (0.5%) are also storage techniques used in some regions.

3.5. Estimated Impact of Socio-Economic Conditions on Variety Adoption

The result of the econometrics analysis indicated that access to extension services and membership in producer organizations significantly affected variety adoption compared with other information accessing opportunities (Table 6). The production system practiced also had a significant influence on variety adoption by farmers. Those farmers that solely grow cowpea, organic farmers, and market oriented production and livestock farmers tend to use new varieties. Household characteristics such as area of farmland, access to credit, dependence on agriculture as the main source of household income and the literacy of the head of household had a positive effect on the likelihood of using improved cowpea varieties. However, household size appeared to be a constraint to the adoption of new cowpea varieties because the increase in household size tended to decrease the

likelihood for the household to use new and improved varieties. Lastly, agro-ecological zone or study location affected the adoption of cowpea varieties. For example, farmers in Kebemer are more likely to use the improved cowpea varieties compared to those in Bambey and Kaffrine.

Table 6. Variables used in probit model and resulting coefficient from econometrics analysis in STATA to identify their importance in determining cowpea adoption by individual farmers. ***, ***, * indicate significance at *P* less than 0.001, 0.01, or 0.05 level.

Probit Regression						Number of observations	240
						LR chi^2 (2)	98.79
						Prob > chi^2	0.0000
						Pseudo R^2	0.3111
Description	unit	Mean	SD	Min	Max	Coefficient	SE
Information Access							
distance to market	Miles	7.939	5.645	0	25	0.00601	−0.0064
distance to extension services	Miles	0.667	0.472	0	1	1.382 ***	−0.327
distance to main road	Miles	4.23	4.111	0	16	−0.0227	−0.0366
farmer-to-farmer information	[1 = yes]	0.287	0.454	0	1	0.00338	−0.0278
Membership of farm cooperative	[1 = yes]	0.412	0.493	0	1	−0.596 **	−0.304
Cultural System							
monoculture cowpea	[1 = yes]	0.563	0.497	0	1	0.796 ***	−0.211
chemical fertilizer user	[1 = yes]	0.412	0.493	0	1	0.401	−0.285
organic fertilizer user	[1 = yes]	0.542	0.499	0	1	0.142 *	−0.0741
market oriented	[1 = yes]	0.483	0.501	0	1	0.135 **	−0.0631
livestock oriented	[1 = yes]	0.912	0.283	0	1	1.225 ***	−0.192
Household Characteristics							
Age of household head	years	52.846	13.365	22	85	−0.000398	−0.0059
Household size	person	13.875	5.705	4	28	−0.0515 ***	−0.0158
gender of the head of household	[1 = man]	0.963	0.19	0	1	0.984 **	−0.399
alphabetization	[1 = yes]	0.804	0.398	0	1	0.645 ***	−0.138
Cultivated area	hectare	2.651	2.091	0	8.5	0.0767 ***	−0.0079
diseases presence	[1 = yes]	0.921	0.271	0	1	−0.526	−0.386
agriculture as main source of income	[1 = yes]	0.867	0.341	0	1	0.893 **	−0.366
Credit access	[1 = yes]	0.033	0.18	0	1	1.004 ***	−0.179
Study Arae **(ref: Bambey)**							
Kebemer						0.581 ***	−0.146
Kaffrein						−0.384	−0.299
Constant						−4.290 ***	−0.901

4. Discussion

From the results of our study, we can define the average head of the household in our three study regions as middle aged (52–54 years old), married (95–100%), and -illiterate (84%) and male (95–100%). These results are consistent with the last Senegalese census where the average age was estimated at 55 years old, the overwhelming majority of whom are married and illiterate in the rural area [12]. There was only little variation across our study regions that do not fit this description of the head of the household. Auman et al. [14] compared male versus female household headship and concluded that compared with male household heads, female heads of households were significantly

less educated, owned land and cultivated smaller land parcels, were less efficient in agricultural production and disposed of a significant portion of the produce in the local market. The reasons were that most female heads of household in agriculture were divorced, marginalized, and reside in places where there was a male labor migration. The latter occupies an increasingly important place in the income of rural households in the groundnut basin of Senegal [15]. Other researchers also agree with the conclusion that there is a significant difference in male and female heads of household [16,17]. When based on gender and marital status, most heads of household in our study regions being male and married might project a stable environment compared with the alternative discussed in the literature. However, literacy levels reported for most of the heads of the household in our study were low. Despite a married male-dominated head of household in the study region, the low literacy rate could decrease the tendency of adopting efficient agriculture practices to improve crop yields.

The characteristic of the entire household in our study regions could also be summarized as highly agriculture dependent (87%) household, with low literacy (26% least primary school), and big family size with an average of 15 members. Purwantini et al. [18] concluded that the level of education of the households, the number of people in the household, and cropping intensity affect household agricultural income significantly. When households are highly educated, there is an increased diversification of income sources, a general increase in household income, and an improvement in household livelihood [19,20]. Household size determines per capita income of the household and that in turn determines access to financial credit and government subsidies when necessary [21].

The median cowpea yields significantly varied across the study regions from 35–100 kg ha^{-1}. These yields are well below the average cowpea yield of 300–400 kg ha^{-1} reported for Senegal and sub-Saharan Africa [22,23]. Only a few respondent farmers in our study reported cowpea yields above 200 kg ha^{-1}. This situation is explained mainly by the secondary nature of traditional cowpea varieties in most agricultural production systems in Senegal, since it is essentially used as an associated legume crop to fix nitrogen and thus boost the yields of cereals such as millet and sorghum. This low cowpea yield in West Africa is explained by Baoua et al. [24] in a study in Niger and listed factors such as poor agronomic management practices (e.g., inadequate weed control, seeding rates, fertilizer application), pressure from crop pests, aphids and caterpillars, diseases and weeds that cause significant yield losses. Participatory farmer field school (FFS) approach could be one channel for communication and dissemination of improved technologies to improve cowpea yields. Similarly, Omomowo and Babalola [25] described drought, salinity, excessive demand among farmers for synthetic chemicals, the impacts of climate change, declining soil nutrients, microbial infestations, and pest issues as challenges of cowpea production. The authors suggested the deployment of bio inoculants, applying climate-smart agricultural (CSA) practices, agricultural conservation techniques, and multi-omics smart technology in the spheres of genomics, transcriptomics, proteomics, and metabolomics, for improving cowpea yields and productivity. However, these climate smart technologies suggested might be appealing to researchers and educated farmers but considering household education and awareness at the farm level in our study regions, there is more work to be done at a more basic level. Among those basic things are short-term trainings regarding best crop management practices, demonstration of different varieties, creating extension systems for delivery information on available technologies, and marketing opportunities (timing of sales of grain and fodder) for cowpea grain and fodder.

A major reason why reported yields were very low was that majority of farmers in the study regions did not use improved varieties. In addition, the main reasons for not using improved varieties were the limited availability of seeds and little awareness of improved varieties and agronomic management practices. Institutions that study cowpea within the region and extension services should be supported to increase the availability of improved varieties and use by farmers. Studies conducted elsewhere reported seed cost as a major barrier to adopting and using improved crop varieties [26]. However, our findings showed seed costs are not the major barrier for cowpea use in our study region as only 6% of the respondents indicated seed price as a problem.

The three major use of cowpea in the study region were for marketing, livestock feed, and human consumption. The dual- use of cowpea grain for human and fodder for animal consumption should increase government interest in this crop, which provides quality fodder for livestock during the lean season, which coincides with the beginning of fieldwork and the low availability of fodder from other crops (such as peanut or millet stover). To increase the production of cowpea, the use and demand need to increase and be a driver. This seems to be the case with the multiplication of cowpea fodder programs, which could replace peanut fodder, whose prices are increasing at a very steady pace. As a highly drought-tolerant crop with low water requirement and greater heat

tolerance, cowpea has the potential for food security in Africa and around the world. Besides cowpea grain, its pods and leaves are also nutritious and edible [27]. It is a leguminous crop, that should also be promoted for N fixation as part of a crop rotation or as a cover crop to maintain soil fertility [28]. However, with most of the crop residues being removed, very little residual N is likely to return to the soil. More research is needed to compare the value of the residue for crop production as compared to being used for livestock feed. Promotion on the various uses of cowpea in and outside the study region, creates a demand for the crop, motivates farmers to increase production, and creates a fertile environment, more markets, and profit.

The effect of socio-economic status of producers extends beyond the choice of cowpea varieties. Once cowpeas are planted, management of the crop and after harvest, choice of proper storage also require knowledge and economic potential. In our study region, 60% of producers have not developed control strategies for diseases and pests. The popular cowpea storage is using cans. Due to the large number and diversity of cowpea diseases and pests, an integrated set of management at different stages of cowpea growth was recommended [29,30]. Dissemination of chemical free hermetic bags for cowpea storage has also improved cowpea storage in most parts of Africa, but due to several alternative hermetic bags, testing and making the best storage available to producers may be essential [31]. To increase productivity and to reduce post-harvest losses in storage, training, awareness, and financial support may be required.

The adoption of improved varieties was explained by three sets of variables including access to information, production system, and the characteristics of the household. These groups of variables are defined by the literature and the context of the study. While some research had focused particularly on household and producer characteristics or market practices to estimate the probability of adopting a new crop variety [32–34], to our knowledge, no study considered these three groups to estimate the adoption of new cowpea varieties in the West-African Sahelian region. Access to information regarding the usage of new varieties is an important factor that affects adoption [35]. The importance of information capability through multidimensional sources to improve producers' production and marketing decisions have been reported in recent studies [36,37]. Our descriptive analyses showed producers could access information on improved varieties through five channels: markets, extension services, urban centers, their peasant neighbors, and producer organizations. In the current study, extension services and producers' organizations were important factors affecting the use of improved cowpea varieties. Compared to producers using cowpea as an associated crop, farmers dedicated to sole cowpea production are more likely to use improved varieties. In addition, farmers using organic fertilizer are more likely to use the improved cowpea varieties possibly to take advantage of biological N fixation. Market-oriented producers and those who use cowpea fodder for livestock are also likely to adopt improved varieties with greater fodder production.

5. Conclusions

The specific objective of the current study was to analyze the socio-economic characteristics of cowpea production systems, gather baseline information on adoption of improved dual-use cowpea varieties in the Senegalese peanut basin, and study correlation between socio-economic characteristics and variety adoption. Results of the study showed most heads of the household in our three study regions as a middle aged (52–54 years old), married (95–100%), illiterate (84%), and mostly men (95–100%). The characteristic of the entire household in our study region could also be summarized as highly agriculture dependent (87%), with low literacy (26% least primary school), and big family size with an average of 15 members. The median cowpea yields significantly varied across the study region and varied from 35–100 kg ha^{-1}, which was well below the average yield reported for sub-Saharan Africa. The Majority of farmers do not use improved varieties, and the main reasons for not using improved varieties were lack of seed availability and little awareness of improved varieties. The three major uses of cowpea in the study region were for marketing, livestock feed, and human consumption. The effect of socio-economic status of producers extends beyond the choice of cowpea varieties to cowpea production, management, and storage. Access to extension services, membership in producers' organization, sole cowpea production, organic farming, market, and livestock oriented production systems, access to large acreage of farmland, access to credit, dependence on agriculture as the main source of household income, and literacy of the head of household seem to have a positive effect on the likelihood of using the improved varieties. We concluded the need for training, access to improved seed, awareness, and financial support to producers to increase the adoption of new and improved cowpea varieties to increase yields, profitability, and nutritional security among smallholder farmers. The results presented in this paper are based on baseline survey data in the three regions of Senegal and it is a unique (novel) contribution connecting technology adoption with

socio-economics of the region. Results have to be taken with the context of the regional and other limitations and further research on the impact of recommended interventions (training, access to improved varieties, awareness, and financial support) in technology adoption is crucial.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su142114550/s1, Table S1: Questionnaire.

Author Contributions: Conceptualization, A.B., P.B.D., O.D., A.F. and A.K.O.; methodology, A.B. and O.D.; formal analysis, O.D. and Y.A.; investigation, A.B., A.F. and A.K.O.; data curation, O.D.; writing—original draft preparation, A.B., O.D. and Y.A.; writing—review and editing, Z.P.S., D.M. and P.V.V.P.; supervision, A.B., A.F. and A.K.O.; funding acquisition, A.B., A.F., A.K.O., Z.P.S., D.M. and P.V.V.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded in whole (or part) by the United States Agency for International Development (USAID) Bureau for Food Security under Agreement #7200AA18LE00003 as part of Feed the Future Innovation Lab for Legume Systems Research. Any opinions, findings, conclusions, or recommendations expressed here are those of the authors alone. This is contribution number 23-054J from the Kansas Experiment Station.

Institutional Review Board Statement: Ethical review and approval were waived for this study because this was a non-interventional study, and a formal ethics committee approval was not required.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data can be available from authors with reasonable request.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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Financing Romanian Agricultural Cooperatives' Investments for the 2023–2027 Horizon

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Abstract: Agriculture represents an important sector of the Romanian economy, with certain vulnerabilities under the current geo-political context and pedoclimatic changes with a direct impact upon food security at national and European levels. This paper analyzes the possibilities for revitalizing the Romanian agricultural sector, which was affected by the excessive inflation (especially via the price increases of fertilizers and fuels) and drought, both generating significant cereal and agricultural production losses. The current research highlights the main investment options for the managers of 219 Romanian agricultural cooperative companies, including the available financing alternatives. In our view, the investments realized within the agricultural cooperative companies support the creation and increase in value added and reduce specific risks, consolidating the role and status of agricultural producers within the food chain. The research evaluates the Romanian agricultural investment typologies and establishes a model of assessing these investments by correlating the information obtained from the questionnaire distributed. The research methods include analyzing the reference literature, building the database, collecting and processing the questionnaires' observations, transforming the qualitative data into quantitative ones and modeling them with econometric instruments. The results obtained using the econometric model reveal the main investment directions to be integrating the production chains through economic association forms, including constructing and modernizing the warehouses, processing the primary products and obtaining higher value-added products, identifying various distribution channels, making the most of all available resources and focusing on digitalization, efficiency, circular economy and short supply chains. The study is of interest for the investors and managers of agricultural cooperative companies from Romania and Europe in view of securing sustainable development, enhancing the role of agricultural producers within the food chain and increasing efficiency of the agricultural activity, with a direct impact upon European food security.

Keywords: agricultural cooperative companies; investments; economic model; sustainable development

Citation: Zlati, M.L.; Florea, A.M.; Antohi, V.M.; Dinca, M.S.; Bercu, F.; Fortea, C.; Silvius, S. Financing Romanian Agricultural Cooperatives' Investments for the 2023–2027 Horizon. *Sustainability* **2023**, *15*, 2306. https://doi.org/10.3390/su15032306

Academic Editor: Keshav Lall Maharjan

Received: 23 December 2022
Revised: 22 January 2023
Accepted: 24 January 2023
Published: 27 January 2023

1. Introduction

Agriculture represents a very important sector of the Romanian economy, which was confronted with a severe crisis in 2022, induced by the Ukraine war blockages, generating significant increases in the price of fuels, fertilizers and medicines for plants and aggravated by the severe pedological drought and high temperatures. In the context of climatic changes and of a tense geopolitical situation, securing the food supply for the population has become of outmost importance. The Strategic National Plan for the 2023–2027 period envisions

enhancing Romanian farmers' resilience and competitiveness to ensure food security. This goal can be achieved only through investments, made available for the majority of potential beneficiaries (associated in cooperative companies or groups of producers) which jointly use the fixed assets, under a previously established schedule, ensuring a full and efficient use of those assets and a proper amortization of the initial investment.

Collective investments have been implemented, providing higher value-added, integrated production and processing chains and quality products at accessible prices for the final consumers.

The agricultural sector is confronted with a series of economic, environmental and social challenges, and a possible solution to overcome these challenges is the increase in resilience, an objective supported by the European Union through its specific policies [1]. The predictability of agriculture revenues is affected by the Ukraine war and by the exaggerated increase in energy, fuel, fertilizers and plants protection products' costs, as well as by the unfavorable climate and environmental conditions, which call for better instruments for managing the catastrophic and other specific agricultural risks. At the same time, this calls for improving the European legislation regarding modern amelioration techniques to have plants with a better drought and heat tolerance and improved resistance to specific bio-pests, which appear only in some EU regions or states, and providing efficient alternatives in terms of the price-quality ratio prior to forbidding the substances which were used previously and bypassed the rigors of EU regulations. Resilience in agriculture also encompasses preparing farmers to deal with external shocks by securing their minimal living standards and capacity to cultivate plants [2]. Some of these shocks can be predictable whilst some are not, and they can manifest in the short or long term, whereas governments have an essential role in providing a favorable environment for continuing and developing agricultural activity [3]. In this context of mitigating the risks generated by natural hazards, an ex ante approach is recommended, which prevents and limits the effects of disasters [4].

Increased poverty leads many consumers to buy the cheapest, lower quality products, which somehow contradicts the declarations of European leaders. To avoid double standards, an equal treatment in terms of quality and use of phytosanitary products should be applied for both EU and third countries' food products. Moreover, at the European level, viable alternatives in terms of quality–price ratio for pesticides should be offered, and only after that the pesticides which previously met the rigors of EU legislation and were deemed as safe for humans should be forbidden; each member state, as well between states correlating to the European level, has an obligation of setting up and maintaining protective forest curtains for the agricultural crops, creating and maintaining the microclimate, increasing the population living standards to be able to consume eco and bio products, increasing the share of ecological products into total agricultural production, increasing the association of farmers in economic entities (cooperative companies and producers groups) and developing and consolidating the economic cooperation forms via strategic investments at regional and national level to support competitiveness, capitalization and sustainability of member farmers in the single market competition.

By means of associative forms with an economic role and as a key factor in the horizontal coordination with the role of collecting production and ensuring a continuous flow within the distribution chains, the foundations of transport and processing networks can be laid [5]. At the same time, they also contribute to the development of vertical supply chains, eliminating competition imbalances and strengthening farmers' market power [6].

The integration of collaboration structures within supply chains to adapt production processes to consumers' demand, the increase in accessibility and the reduction of costs related to production, storage and delivery can be achieved by implementing technological and innovative processes [7].

At the European level, according to the Global Index of food security (GSI), high levels are registered by countries such as Finland (first place in 2022 in the ranking of the 113 countries considered, with a score of 83.7 points) [8], followed by Ireland (second best place with 81.7 points), France (80.2 points, fourth place), Holland (80.1 points, fifth

place) and Sweden (seventh place, 78.7 points). Romania is in 23rd place with 68.8 points and ranks last within EU member countries in terms of accessibility, sustainability and adaptation. In what concerns availability, Romania with 60.6 points outranks Greece and Slovenia, being third in the end of the rankings. This situation is due to the decline in the domestic industrial capacity, which made Romania a net importer in almost every sector (for many inputs), although it has a high potential and considerable natural resources. In what concerns food quality and food safety, Romania ranks 17th out of 26, before Slovakia, Czech Republic, Hungary and Italy. Also compared to Ukraine, Romania has a better standing for all monitored categories of accessibility, availability, quality and safety, sustainability and adaptation. The data regarding Romania's position according to the GSI were summarized in Table 1.

In dynamics, in the ranking realized by The Economist Intelligence Unit, part of The Economist Group, Romania has vulnerabilities, compared to the EU average, regarding the change in average price of food items (with 84 points compared to 88 points, the EU average [9]), with 95.8 points as a share of the population affected by absolute poverty (people living with less than 3.2 USD per day), as compared to 99.2 points, the EU average. Romania also displays an unfavorable index of the inequality adjusted income, with a 66.4 point index compared to 76.3 points, the European average. In the agricultural trade chapter, Romania stands above the average of European countries, with 76 points in its 2022 score, with import tariffs for agricultural products also higher than the European average (data from World Trade Organization). In the same chapter of agricultural trade (from the point of commercial freedom, quantified through the tariff and non-tariff barriers to trade), the global index of food security, according to Heritage Index of Freedom [10,11], placed Romania around the European average (79.2 points compared to 79.5 points, the European average score).

Concerning food safety programs, Romania is well represented, with an index of 100 points compared to the European average of 96 points and stands out in financing food security programs, the nation-wide coverage and functionality of the programs implemented by the Romanian government [8].

In the availability chapter, the measure of access to agricultural inputs, as a composite index of measuring the resources available for farmers [8], places Romania a little above the European average (73.8 points against the European average of 72.9 points). Romania stands in the upper echelon concerning access to basic financial services, annual variation of farmers' prices and access to consultancy and agricultural development services. In research and innovation in agriculture, there is a deficit of governmental financing (the proxy index of agricultural evaluation), of technology access, of education and of agricultural resources which could promote agricultural production by ensuring an integrated use of land, labor and investments [8]. According to the same source, Romania is above the European average with policies facilitating the development of innovating agricultural technologies (with a score of 100 points compared to 75.6 points, the European average) [12].

Table 1. Romania's position towards EU countries according to the Global Index of food security.

Rank by GSI	UE27 Country	Overall Score	% by Romanian Overall Score	Affordability	% by Romanian Affordability Score	Availability	% by Romanian Availability Score	Quality and Safety	% by Romanian Quality Score	Sustainability and Adaptation	% by Romanian Sustainability Score
1st	Finland	83.7	121.7%	91.9	108.0%	70.5	116.3%	88.4	113.5%	82.6	175.4%
2nd	Ireland	81.7	118.8%	92.6	108.8%	70.5	116.3%	86.1	110.5%	75.1	159.4%
4th	France	80.2	116.6%	91.3	107.3%	69	113.9%	87.7	112.6%	70.3	149.3%
5th	Netherlands	80.1	116.4%	92.7	108.9%	70.7	116.7%	84.7	108.7%	69.2	146.9%
7th	Sweden	79.1	115.0%	91.9	108.0%	68.3	112.7%	85	109.1%	68.3	145.0%
10th	Portugal	78.7	114.4%	90	105.8%	77	127.1%	79.8	102.4%	64.5	136.9%
12th	Austria	78.1	113.5%	91.3	107.3%	67.1	110.7%	81.2	104.2%	69.7	148.0%
14th	Denmark	77.8	113.1%	92.1	108.2%	63.2	104.3%	89.1	114.4%	63.8	135.5%
16th	Czech Republic	77.7	112.9%	91.3	107.3%	69.4	114.5%	76.3	97.9%	70.3	149.3%
17th	Belgium	77.5	112.6%	92.6	108.8%	64.6	106.6%	88.4	113.5%	61	129.5%
19th	Germany	77	111.9%	87.9	103.3%	67	110.6%	79.9	102.6%	70.8	150.3%
20th	Spain	75.7	110.0%	89	104.6%	63.1	104.1%	81.2	104.2%	66.4	141.0%
21st	Poland	75.5	109.7%	87.4	102.7%	63.8	105.3%	81.5	104.6%	66.7	141.6%
27th	Italy	74	107.6%	89.5	105.2%	68.7	113.4%	75.9	97.4%	57.3	121.7%
29th	Bulgaria	73	106.1%	85.8	100.8%	66.5	109.7%	79.5	102.1%	56.6	120.2%
31st	Greece	72.2	104.9%	88.5	104.0%	58.3	96.2%	80.8	103.7%	57.3	121.7%
34th	Hungary	71.4	103.8%	86.7	101.9%	63.3	104.5%	74.4	95.5%	57	121.0%
36th	Slovakia	71.1	103.3%	89.1	104.7%	55.3	91.3%	77.9	100.0%	57.6	122.3%
45th	Romania	68.8	100.0%	85.1	100.0%	60.6	100.0%	77.9	100.0%	47.1	100.0%

Source: Adapted by the authors after [8].

To improve Romania's position to the European Union's level, the authors consider investments in agricultural cooperatives as the main solution. The methods of improving Romania's position to the European Union's level refer to supporting, creating and increasing added value, reducing specific risks and consolidating the role and status of agricultural producers in the food chain. In 1990, all Romanian agricultural cooperatives were dissolved or transformed into agricultural societies. Until 1st January of 2005, no agricultural cooperatives were established. Starting with this date, modern cooperatives were founded, operating according to the International Alliance of Agricultural Cooperatives' principles. They are currently in full reform, development and efficiency of activity. In Romania, according to National Trade Registry Office, in 2021, 2641 agricultural cooperatives were established [13]. In 2021, a number of 1152 agricultural cooperatives generated a turnover of 588 million euros. Of the total 2641 cooperatives registered at the National Trade Office, 170 appeared as deregistered and 2389 in operation. In the last 5 years, the number of agricultural cooperatives that submit their financial statements (and hence prove interest for continuing their activity) increased at an annual average of 17.4% during the 2015–2021 period [13]. As such, in 2021 the number of cooperatives submitting their financial statements increased by 153.7%, compared to 2015. Also, almost half (46.9%) of the profitable cooperatives carry out agricultural activity or auxiliary activities, while 48% carry out trading activities.

The overall table of agricultural cooperatives' financial indicators indicates a favorable evolution, yet there is a need for increasing the capitalization via new investments.

These considerations require improving investments' financing methods, which is the object of the current research, with the following specific objectives:

1. Identifying the current context's vulnerabilities for Romanian farmers and cooperative agricultural companies;
2. Identifying the opportunities for development and for limiting Romanian agricultural sector's vulnerabilities;
3. Creating an econometric model for optimizing Romanian agricultural cooperatives' access to financial funds;
4. Creating a balanced scorecard with viable solutions for agricultural development and leveling Romania's agricultural food products' trade balance in accordance with the needs of the current unfavorable context.

The study continues with presenting a review of the reference literature, the research methodology and the logical scheme, the results and the discussions, whilst the final section is dedicated to presenting the relevant conclusions with an impact upon national level decision makers.

2. Literature Review

The interest of specialists for agricultural sector's sustainable development increased significantly starting with the 2010s, especially in areas such as food security and climate change, global food crisis, sustainable development, agricultural management, ecological agriculture, funding micro-farms, agricultural management systems, agriculture value-added and agriculture under uncertain conditions.

Studying the 1953 sector articles published by the Web of Science platform during the 1975–2022 period, we find that over 900 articles pertain to the last 5 years (2018–2022); the Hirsch index of the publications was of 64 points, whereas the average citation for one article is of 11.34.

Using the 1.6.18 version of the Vosviewer software, we have realized a diagram which groups the 1953 articles in clusters of research interests such as agricultural investments, agricultural credit, agricultural markets, the management of agricultural entities, food security and agriculture in Romania from the efficiency, European funds financing, sustainable agriculture and Common Agricultural Policies (Figure 1).

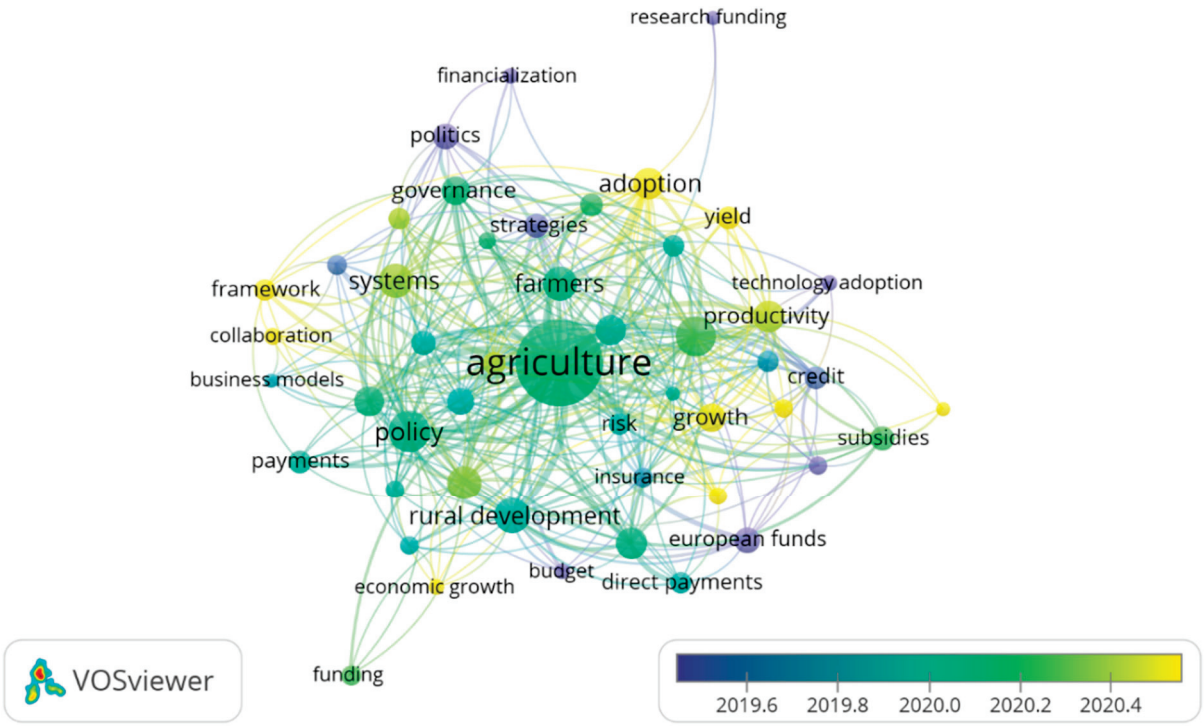

Figure 1. The bibliometric analysis regarding research interests concerning agriculture funding in the reference literature. Source: Elaborated by the authors, using Vosviewer software.

The analysis of the specialized literature regarding agriculture financing options in the European Union highlighted a concern of researchers for this field through 158 articles published in the specialized literature and included on the Web of Science platform, with a Hirsch index of 14 points and a citation rate of 3.69 citations per item. This proves this issue is of interest for the academic and scientific environment, responding to the need for the efficiency of the agricultural sector through adequate financing (Figure 2).

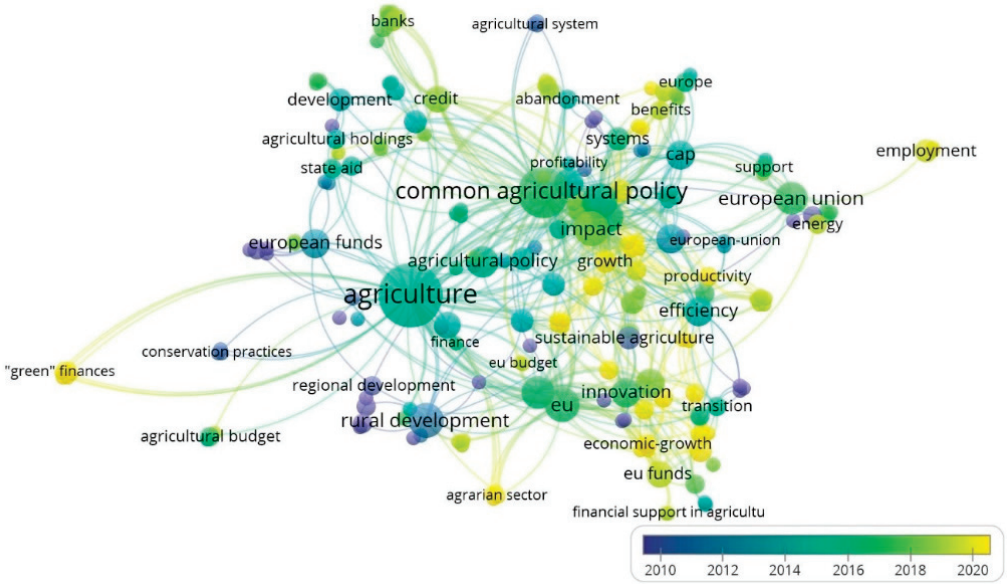

Figure 2. The bibliometric analysis on the financing options for the European agriculture in the reference literature. Source: Elaborated by the authors, using Vosviewer software.

Based on the analysis carried out, the areas of interest were grouped according to the competition criteria, 22 in number, and their financing through government aid financing programs and the economic financing conditions that have an effect on regional and rural development and make more effective the agricultural sector. Also, the researchers' interest was directed towards investment mechanisms, agricultural financing, agricultural banks and agricultural cooperatives for agricultural support, agricultural structural funds, the multiannual financing framework, direct payments in agriculture, the development of green agriculture, the common agricultural policy and the financing of this European policy, the support mechanisms for financing agriculture, agricultural cooperatives, conservation practices, agricultural investments, European funds for agriculture, dedicated financing programs, the level of allocating funds for agriculture and the absorption rates for agriculture, the degree of implementation of the reforms, structural and investment funds, programs for farmers, co-financing in agriculture, agricultural development strategies, costs in agriculture, agricultural management and agribusiness.

In the paper [14] Territorial differences in agricultural investments co-financed by the European Union in Poland, the authors identified the relationship between the support investments of the European programs for the development of agriculture and economic development in Poland, based on the fragmentation and heterogeneity of agricultural land and by comparisons with the agricultural conditions and the structure of the Polish agricultural sector. The authors showed that the agricultural development and financing are in a direct proportional relationship for agricultural farms with more than 10 hectares in operation, this being supported by much previous research, as the authors show in the conclusions of their study. Access to European funds for support investments was mostly achieved by large farms with high productive potential, which led to production concentration and specialization, respectively, to technological progress in agriculture. Another interesting conclusion of the study was that investing in capital resources reduced labor demand, which bolstered labor force's specialization and access to better paid sectors of support services and maintenance, an aspect appreciated by the authors as essentially positive for economic development.

The research of Paun C. and Ivascu C. [15] analyzes the impact of European financial support measures on the agricultural sector's development, highlighting that the financial instruments related to the common agricultural policy will focus ever more on rewarding innovation, the efficient and profitable development of the sector minimizing the state's aids and subsidies and on increasing agriculture's resilience and sustainability in the global market. The authors show that there are some very important aspects that require innovative solutions, these being dependent on the pedoclimatic conditions and the climatic changes in relation to the geographic location. The current use of expensive climate change forecasting technologies could make the difference in the efficiency of agricultural policies, land improvement and optimizing the profitability indicators needed in a global competition. According to the study, at a historical level, a direct relationship was determined between net subsidies and the volume of agricultural production in the European Union. The authors believe that the future agriculture policies and reforms should stimulate investments and the adoption of revolutionary technologies so that the common agricultural market and the common agricultural policy are completely reformed and prepared for global competition. Another significant aspect discussed by the authors is the flexibility of the investment programs, considered too rigid and not very sensitive by farmers.

According to Kiryluk-Dryjska E. et al. [16], the financial support for investments in agriculture increases the structural homogeneity of agricultural holdings and the consolidation of operators that manage to attract financing. The key factors resulting from the study in Poland are represented by access to financing, the size of the agricultural entity and the level of efficiency of the agricultural management. The authors reveal that the efficient use of investments requires a balance between the primary factors, namely land ownership and the size of the capital. As such, the investment balance ensures, under conditions of continuity, managerial efficiency, while the imbalance of these elements weakens agricultural

entities and decreases their ability to use funds, reducing the effects of the financing. In the conclusions, the authors show that the application for the pro-investment measure is differentiated according to the farmers' interest in the program, based on the geo-spatiality criterion. The results suggest that investment financing programs increase disparities between the agricultural entities, depending on the availability of labor resources and geo-climatic conditions (geospatial differentiation).

In another approach [17], the authors show that significant additional capital is needed to achieve a sustainable agricultural production, with an appropriate quality and affordable prices for consumers, capital that cannot be attracted solely from financial markets, but through a combination of public funds and private dissociated funds. In this sense, the financing from the concessional development-oriented fund can be the solution to ensure the additional financing to achieve the objectives of sustainable development in agriculture. These funds are usually grants, concessional loans, subordinated loans or financing tranches between affiliated entities, but they usually add risks regarding the perception of private investors, guarantee risks and require technical support measures, including a feasible and efficient development plan. During mixed financing, it is important to follow the investments' impact on the entity and the regional socio-economic development through key monitoring items such as: socio-economic performance, development of investment strategies, improvement of the structure of agricultural entities, reduction of risks and control of intermediate transactions. According to the authors, there are four levels of mixed financing, respectively: permanent mixed financing whereby the financing requirement is provided only from the combination of public-private financing with additional surplus from concessional loans; transitional mixed financing whereby some government agencies partially guarantee for agricultural investment funds (government backed guarantees); adjustable mixed financing of the Social Impact Incentives type; mixed impact financing whereby the concessional capital covers the monitoring or impact costs (agricultural risk management tools).

Rolfe, J. et. al. [5] show that accessing public funds requires consistency (achieving the proposed goal), demonstrating the compliance with the access guidelines through plan documents and confirming the legitimacy of access to financing and the traceability of the activity (control). Instead, accessing private financing requires compliance with the principles of efficiency (transfer of funds), equal access to financing, mutual solidarity and legitimacy.

According to some authors [18], agriculture financing represents an essential factor for sector development, especially in underdeveloped countries. The authors showed that agriculture investments are the guarantee of food security and sustainable agriculture, securing the food sources for the population of underdeveloped countries. Other authors [19] showed that technological development represents the key for reaching agricultural efficiency, and blockchain technology could be key for improving credit access and reducing the informational asymmetry, lowering the cost of agricultural financing.

In financing small farms [20], the authors of a study called Rural Finance, Capital Constrained Small Farms, and Financial Performance: Findings from a Primary Survey showed that financial constraints and capital access limitations reduce entities' capacity to use optimally their resources and hinder small agricultural entities' sales increase.

Financing through government agricultural policies [21] generates conditions for sustainable economic growth, especially for emergent markets, where limited funding access impairs agricultural efficiency by reducing market opportunities of sector companies. As such, the authors appreciate that governmental financial policies can reduce the pressure of food security especially by reducing creditors' risk aversion and supporting agricultural insurance. A study realized for ASEAN countries for the 2009–2020 period [22] highlighted the role of agricultural financing for rural sustainable development. This study used a fixed-effects model (FEM) to prove that the congruence of adequate agricultural financing and of rural development has a significant positive role in sustainable development and generates durable economic growth.

The authors of this study [23] used the scenarios method to analyze four agriculture financing schemes for the 2025 horizon, showing that a multidimensional and complex agricultural sector, including agricultural financing, using technology and innovation in agriculture, financial chains, configuring markets and institutional innovation, support agricultural sector's development by increasing convergence and economic diversification, especially for rural economies, which are fully dependent upon the agricultural sector.

A group of authors [24] examined US agricultural cooperatives' financial performances and proved that reducing or eliminating financial stress increases their rate of return on equity (ROE) and rate of return on assets (ROA) and decreases interest rates over time.

By decomposing the risk function, the authors concluded that the financial stress appears because assets have a reduced efficiency, and the profitability is low. The authors [25] used an equation system to analyze US agricultural cooperatives' financial performances according to their dimensions and specialization and concluded that risks are influenced by the diversification of the cooperative company production, such as that profitability, indebtedness degree and size of debt positively influence financial performances.

Another study [26] analyzes the effect of capital constraints upon agricultural cooperatives' economic growth, using a data panel with 669 US sector companies. The authors of this study show that long-term debt funding and company size had a positive influence upon agricultural companies' economic growth and that free cash flows and reinvested equity had a critical contribution for small and medium agricultural cooperatives' assets increase. The authors concluded that large agricultural cooperatives are less financially exposed and have a lower cash flow pressure.

A study based on a literature review [27] analyzed agricultural entities' performance, governance and financing, revealing that the causal evidence of the relations between these units' management and governance determines performances, even under long-term debt constraints, whilst the heterogenous component of members' objectives and attitudes in terms of commitment and participation leads to inefficiency.

Marcis, J. et al. [28], using the meta-analysis method to evaluate the sustainability of agricultural cooperatives' performances, showed that the context of performances' evaluation has not reached a scientific consensus in the reference literature, as there are many evaluation models based on different items, most of them focusing on the values and preferences of decision factors which are then incorporated into assessing the sustainability. The authors propose all three dimensions of sustainability to be included in the evaluation model in an integrative way, preserving a balance between the economic, social and environmental aspects.

Other authors [29] show that agricultural supply chains impact the small agricultural farms' capital constraints, forcing the usage of intermediary platforms to secure the economic flows. This aspect creates a financial strain, which directly threatens the supply of resources needed for the primary production cycle and generates high financing fees, which significantly increase the overall costs, even though production costs are not very high. The use of intermediary platforms supports efficiency increase for small companies, whilst intermediaries' social responsibility could become essential in providing a win–win situation for farmers, platforms and the entire supply chain.

Markus Hannish [30] claims that economic association forms, respectively, the agricultural cooperatives which keep the private domestic sector fair and strong. The author states there are significant economic size differences between the ten biggest Romanian agricultural cooperatives (they are about 100 times smaller) and their EU counterparties. These differences manifest themselves also in what concerns the average number of members of an agricultural cooperative company, with Romania recording 100 to 500 times fewer members in an association (the biggest agricultural cooperative from UE-27 counts in excess of 8000 members).

Romania needs to increase the weight of profitable agricultural cooperatives, which requires a significant increase in their sales revenues to become more attractive for investors/financing entities.

Programs of supporting the investments "to create rural infrastructure services, such as supply, warehouses, post-harvesting services, logistic and marketing services for the development, professionalizing, integrating the production of small, middle and also big farmers provided they associate into cooperatives and comply with the cooperative principles" are also needed.

To secure strong agricultural cooperatives in Romania, Hannish [30] suggested the following lines of actions:

Identifying the main obstacles for the growth and integration of cooperative companies inside the chain;

Setting up a chain of "test cooperatives" for which to secure the financing of research and development activities;

Building a statistical data management system to have a long-term analysis of cooperatives' economic and financial activity;

Analyzing the registration procedure and the follow-up procedures. In many EU-27 countries, the sectorial/federations of cooperatives accompany this process with the verifications of business plans and standardized documents;

Consolidating the reporting activities and centralizing the data, as a first step toward a cooperative auditing organization, as in most EU-27 countries.

The specialized literature shows that the impact of agricultural financing is significant; the financing action is necessary and useful for the development of the agricultural sector based on professional investment opportunity analyses. However, in the conditions of the global orientation of European agricultural trade, a reprioritization of financing is required in the sense of supporting the innovative act and the contribution of technology in the field which should balance the link between the need for labor and capital, with an emphasis on the efficiency of productive processes, increasing profitability and ensuring production sustainability.

3. Methodology

The research is based on the logical schematic presented in Figure 3.

To evaluate the Romanian agricultural investments' typology, the research used a questionnaire investigating the available investment options, which was send to 230 agricultural cooperatives in the January 2021–March 2022 period. The sample is representative, as verified by the Cohran test, with a 2% error margin and a 98% significance threshold (the minimum required sample was of 188 agricultural cooperatives).

At the time of the questionnaire's release, 2641 agricultural cooperatives were registered in Romania, of which only 1200 had submitted their financial statements.

The selection criteria imposed active agricultural cooperatives, with a positive sales turnover of more than 20,000 euros, profit of more than 5000 euros and with fully Romanian private property in the last three years. A number of 230 agricultural cooperatives met these conditions.

The interrogation was performed via e-mail, with confirmation of receival and with returning in cases of no initial response. The questionnaire was addressed to managers of the cooperatives, and after sending the questionnaire, they were also contacted by phone. An online questionnaire (via Google Forms) was also sent, with the respondent having the opportunity to fill it in either in written or electronic format. Of the total 230 selected cooperatives, 219 offered complete responses to all the items from the questionnaire and were included in the sample. Three cooperatives did not answer, whereas eight were excluded as they offered incomplete answers to questionnaire items.

The structure of the questionnaire was developed based on the most used financing options available in Romania. It started from the idea of quantifying the investment directions of the cooperatives and the selected sources of financing. The questionnaire was structured starting from the need for investment and identifying the appropriate funding sources. Accordingly, the possibility of financing (Figure 3) from own funds, from bank loans, from mixed funds (bank loans–own funds, European funds–bank loans or European

funds–own funds) and European funds (the identification of the funds to cover own contribution and the need to call on guarantee funds was included in the questionnaire) had been identified.

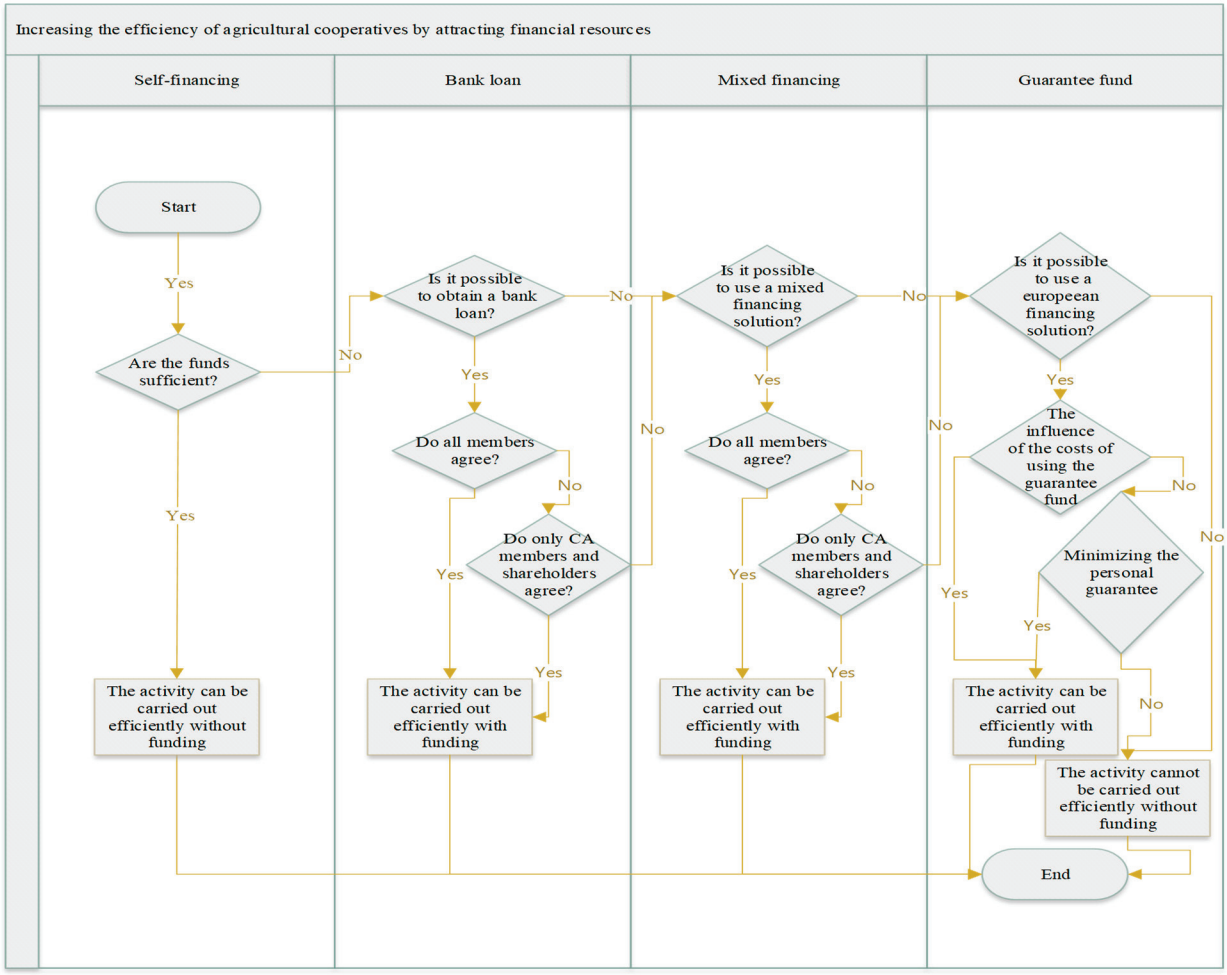

Figure 3. Schematic logic of the study. Source: Realized by the authors.

The variables included in the questionnaire and subsequently used in the modeling are presented in Table 2.

Table 2. The variables studied via the structured questionnaire.

Null Hypothesis	Description of the Variables	Type of Answer	Sig.	Decision
f0	Application for grants	Yes (2)/No (1)	0	Reject the null hypothesis.
f1	Destination of grants: acquisition of machinery	Yes (2)/No (1)	0	Reject the null hypothesis.
f2	Destination of grants: warehousing-processing	Yes (2)/No (1)	0	Reject the null hypothesis.
f3	Destination of grants: new technologies	Yes (2)/No (1)	0	Reject the null hypothesis.
f4	Destination of grants: common investments	Yes (2)/No (1)	0.001	Reject the null hypothesis.
f5	Destination of grants: horticulture	Yes (2)/No (1)	0	Reject the null hypothesis.
f6	Destination of grants: zootechnics	Yes (2)/No (1)	0	Reject the null hypothesis.
f7	Lack of application from lack of funds	Yes (2)/No (1)	0	Reject the null hypothesis.
f8	Lack of application from lack of collaterals	Yes (2)/No (1)	0	Reject the null hypothesis.

Table 2. *Cont.*

Null Hypothesis	Description of the Variables	Type of Answer	Sig.	Decision
f9	Lack of application from excessive indebtedness	Yes (2)/No (1)	0	Reject the null hypothesis.
f10	Lack of application from not having enough capital	Yes (2)/No (1)	0	Reject the null hypothesis.
f11	Acquisition of commonly used machinery	Yes (2)/No (1)	0.003	Reject the null hypothesis.
f12	Acquisition of specific machinery	Yes (2)/No (1)	0	Reject the null hypothesis.
f13	Acquisition of solar equipment	Yes (2)/No (1)	0	Reject the null hypothesis.
f14	Acquisition of zootechnical equipment	Yes (2)/No (1)	0	Reject the null hypothesis.
f15	Warehousing investments	Yes (2)/No (1)	0	Reject the null hypothesis.
f16	Primary investments	Yes (2)/No (1)	0	Reject the null hypothesis.
f17	Investments in processing of finished products	Yes (2)/No (1)	0.043	Reject the null hypothesis.
f18	Labor investments	Yes (2)/No (1)	0.037	Reject the null hypothesis.
f19	Financing project contribution with self-financing generated funds/equity	Yes (2)/No (1)	0	Reject the null hypothesis.
f20	Financing project contribution with loans	Yes (2)/No (1)	0	Reject the null hypothesis.
f21	Financing project contribution with mixed funds, equity and loans	Yes (2)/No (1)	0	Reject the null hypothesis.
f22	Co-financing by each member according to its share in the agricultural cooperative	Yes (2)/No (1)	0	Reject the null hypothesis.
f23	Co-financing from previously gathered funds	Yes (2)/No (1)	0	Reject the null hypothesis.
f24	Covering the loan guarantees by each and every member	Yes (2)/No (1)	0	Reject the null hypothesis.
f25	Covering the loan guarantees according to the share in the agricultural cooperative	Yes (2)/No (1)	0	Reject the null hypothesis.
f26	Covering the loan guarantees by other means	Yes (2)/No (1)	0	Reject the null hypothesis.
f27	Most likely intention to make appeal to the Guarantee Fund	Yes (2)/No (1)	0.047	Reject the null hypothesis.
f28	Clear and certain intention to make appeal to the Guarantee Fund	Yes (2)/No (1)	0	Reject the null hypothesis.
f29	Not appealing to the Guarantee Fund due to supplementary costs	Yes (2)/No (1)	0	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is 0.05. Source: Realized by the authors.

The following working hypotheses were formulated to test the investment typology:

H1: Financing the agricultural cooperative via the Guarantee Fund is accepted by the producers only if the financing entails no supplementary costs and if it is useful for developing the main activity sectors, ensuring technological development or developing the key sectors of warehousing/conditioning/processing/selling as the market registers deficits in these areas;

H2: Financing the agricultural cooperative via the Guarantee Fund is accepted by the producers in view of minimizing the personal guarantees, allocating the funds only to the base activity or to the warehousing/conditioning/processing/selling sectors, following the investment priorities toward technologization and development to enhance social equity inside the cooperative;

H3: In the absence of the access to the Guarantee Fund or after it was spent, the easiest financing solution is covering the guarantee by other means, aspect which covers the basic

economic needs of the cooperative and ensures the efficient use of the loan, corelated with co-financing from already collected funds.

The model of evaluating the investment typology is based on measures' correlations, using the Pearson coefficient after applying the correlation testing procedures.

We hereby define the intensity of the correlation of the model measures using the Equation (1):

$$\rho_{F_x,F_y} = \frac{cov(F_x, F_y)}{\sigma_{F_x}\sigma_{F_y}} = \frac{\mathbb{E}\left[(F_x - \mu_X)(F_y - \mu_y)\right]}{\sigma_{F_x}\sigma_{F_y}} \quad (1)$$

where:

ρ_{F_x,F_y}—Pearson coefficient;
cov—covariance;
Fx, Fy—the models' variable, correlated via Pearson test
$\sigma_{F_x}\sigma_{F_y}$—variables standard deviation
$\mathbb{E}$—expected value
μ_X, μ_y—average values of the measures.

The qualitative variables of the model were transformed into dichotomic variables, each *Yes* option being assigned the value of 1, whereas the *No* option received the value of 0. A database resulted, which was subsequently tested on a regression using the Pearson correlation test from equation 1.

The values were interpreted using a structural matrix, which responded to the following correlation intensity tests (see Equations (2)–(5)).

$$\rho_{F_x,F_y} < 0, \sum f_x\left(\rho_{F_x,F_y} < 0\right) < 4 \text{ Weak intensity, lack of financing interest} \quad (2)$$

$$\rho_{F_x,F_y} < 0.2, \sum f_x\left(\rho_{F_x,F_y} < 0\right) < 8 \text{ Average intensity, minimum financing interest} \quad (3)$$

$$\rho_{F_x,F_y} < 0.3, \sum f_x\left(\rho_{F_x,F_y} < 0\right) < 12 \text{ Average intensity, average financing interest} \quad (4)$$

$$\rho_{F_x,F_y} > 0.3, \sum f_x\left(\rho_{F_x,F_y} < 0\right) \geq 12 \text{ High intensity, high financing interest} \quad (5)$$

After applying the hierarchy algorithm, the representation diagram from Figure 4 emerged:

Figure 4 shows that a number of items have a higher frequency in the agricultural cooperatives' options, allowing the prioritization of investment options, according to a cumulative scheme of frequencies in the correlation matrix.

The representation diagram has generated the variables from the first echelon of interest of Romania's agricultural cooperative's investments, according to the data from Figure 5.

By applying the frequency calculation methodology, a diagram on the maximum correlations of investment interest in the agricultural sector was obtained in Figure 5. This diagram shows that the options: covering the loan guarantees according to the share in the agricultural cooperative; co-financing from previously gathered funds; clear and certain intention to appeal to the Guarantee Fund; covering the loan guarantees by other means; not appealing to the Guarantee Fund due to supplementary costs, represent the main orientation directions in the investment field of the agricultural entities' management.

The results of the study confirm Romanian farmers' interest for financing collective investments realized by agricultural cooperatives, using a combination of equity/internal generated funds and banking loans, co-financing the investment from previously collected funds, providing credit collaterals with money from the Guarantee Fund and financing investment by other means than banking credit. The detailed aspects are approached in the Section 4.

	f29	f28	f27	f26	f25	f24	f23	f22	f21	f20	f19	f18	f17	f16	f15	f14	f13	f12	f11	f10	f9	f8	f7	f6	f5	f4	f3	f2	f1
f1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	1	0	0	0	0	0	1	1	0	0	0
f2	0	1	0	0	1	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	1	0	0	0
f3	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
f4	0	1	0	1	1	0	1	1	0	1	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
f5	0	1	0	1	1	0	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0
f6	0	1	0	1	1	0	0	1	1	1	1	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
f7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f11	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
f12	1	0	0	0	1	1	1	0	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
f13	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f14	0	0	0	0	0	0	1	1	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f15	1	1	1	1	1	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f16	0	1	0	0	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f17	0	1	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f18	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f19	1	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f20	1	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f21	1	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f22	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f23	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f24	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f26	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f27	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4. The diagram of variables representation in the panel type correlation structure. Source: Elaborated by the authors using Excel software.

Figure 5. The diagram of maximum correlation points on interest sectors of agricultural investments. Source: Elaborated by the authors.

4. Results and Discussions

To demonstrate the H1 hypothesis (financing the agricultural cooperative by appealing to the Guarantee Fund is accepted by the producers only if the financing entails no supplementary costs and it is useful for developing the main activity sectors, ensuring technological development or developing the key sectors of warehousing/conditioning/processing/selling as the market registers deficits in these areas), we have conceived a neuronal model with a basis radial function with six testing units and 14 factors (f1; f2; f3; f4; f5; f6; f11; f12; f15; f16; f19; f21; f23; f24) in connection with the dependent variable (f25), using the statistical identification function and error testing with the sum of squares residuals (SSE = 34.113).

After running the model, the incorrect predictive percentage was of 29%, the estimated parameters being presented in the Table 3.

Table 3. Estimating the parameters with the neuronal method, covering the credit collaterals according to the existing share into the agricultural cooperative.

Parameter Estimates									
Predictor		**Predicted**							
		Hidden Layer [a]						**Output Layer**	
		H(1)	**H(2)**	**H(3)**	**H(4)**	**H(5)**	**H(6)**	**[f25 = 1]**	**[f25 = 2]**
Input Layer 1 = NO 2 = YES	[f1 = 1]	0.750	0.652	1.000	0.977	0.677	0.774		
	[f1 = 2]	0.250	0.348	0.000	0.023	0.323	0.226		
	[f2 = 1]	0.500	1.000	0.739	0.955	0.161	0.790		
	[f2 = 2]	0.500	0.000	0.261	0.045	0.839	0.210		
	[f3 = 1]	0.917	0.826	0.913	0.977	0.484	0.919		
	[f3 = 2]	0.083	0.174	0.087	0.023	0.516	0.081		
	[f4 = 1]	0.722	0.739	1.000	0.068	0.581	0.774		
	[f4 = 2]	0.278	0.261	0.000	0.932	0.419	0.226		
	[f5 = 1]	0.889	1.000	0.913	0.977	0.935	0.919		
	[f5 = 2]	0.111	0.000	0.087	0.023	0.065	0.081		
	[f6 = 1]	0.917	1.000	0.739	0.773	0.710	0.790		
	[f6 = 2]	0.083	0.000	0.261	0.227	0.290	0.210		
	[f11 = 1]	0.222	0.261	1.000	0.386	0.065	0.500		
	[f11 = 2]	0.778	0.739	0.000	0.614	0.935	0.500		
	[f12 = 1]	0.778	0.957	0.696	0.750	0.774	0.855		
	[f12 = 2]	0.222	0.043	0.304	0.250	0.226	0.145		
	[f15 = 1]	0.556	0.348	1.000	0.795	0.645	0.758		
	[f15 = 2]	0.444	0.652	0.000	0.205	0.355	0.242		
	[f16 = 1]	0.806	1.000	0.870	0.659	0.323	0.726		
	[f16 = 2]	0.194	0.000	0.130	0.341	0.677	0.274		
	[f19 = 1]	1.000	1.000	1.000	1.000	1.000	0.129		
	[f19 = 2]	0.000	0.000	0.000	0.000	0.000	0.871		
	[f21 = 1]	0.194	0.043	0.000	0.068	0.097	1.000		
	[f21 = 2]	0.806	0.957	1.000	0.932	0.903	0.000		
	[f23 = 1]	0.806	0.783	0.609	0.932	0.968	0.806		
	[f23 = 2]	0.194	0.217	0.391	0.068	0.032	0.194		
	[f24 = 1]	0.972	0.130	0.696	0.773	0.419	0.645		
	[f24 = 2]	0.028	0.870	0.304	0.227	0.581	0.355		
Hidden Unit Width		0.921	0.761	0.752	0.792	0.962	0.945		
Hidden Layer	H(1)							−0.173	1.173
	H(2)							1.493	−0.493
	H(3)							1.057	−0.057
	H(4)							1.066	−0.066
	H(5)							1.003	−0.003
	H(6)							0.881	0.119

Source: Elaborated by the authors. [a] Displays the center vector for each hidden unit.

Table 3 reveals that the prediction variable covering the loan collaterals according to existing share into the agricultural cooperative is represented at the predictors level (14 factors) at 96.2% in prediction layer no. 5 and at 76.1% in the prediction layer no. 2, which favors the prediction of the variable in the higher than one variation of the NO category. The results of the neuronal model also show a 78.1% percentage associated to the variation layer no. 2 of YES, whilst 82.2% associated to the layer 1 of NO. The value of the correction is of 78.1%, according to Figure 6.

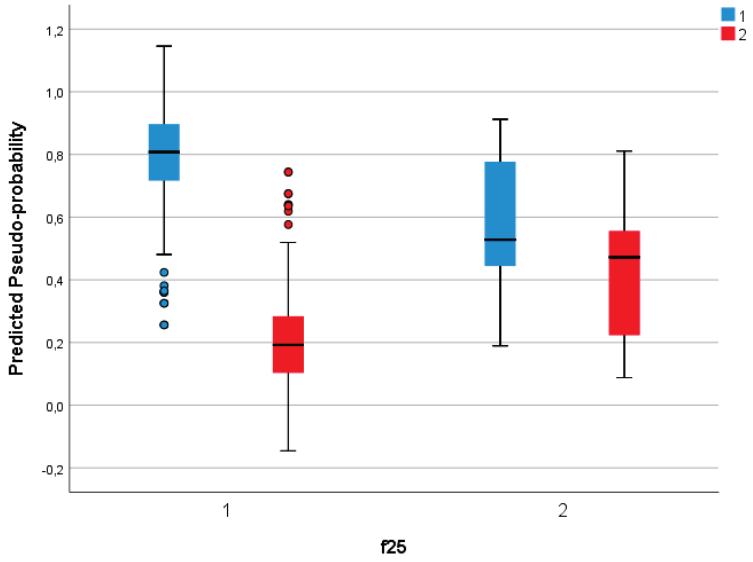

Figure 6. The representation diagram of pseudo-probable distributed variables for the two options (1 of NO, respectively, 2 of YES) of the f25 dependent variable. Source: Elaborated by the authors using SPSS software.

The sensitivity analysis of the function shows a favorable distribution of the financing decision by using guarantee funds, under the H1 hypothesis, according to Figure 7.

According to the sequential analysis method based on the Pearson correlations resulted that the size of the distribution gaps (lags) for the variable financing using the guarantee funds is the maximum of the analyzed financing possibilities, being net superior to the general sample inside the sample with declared financing pre-disposition, which confirms that the main challenge for the agricultural producers is the necessity of covering the support costs from the financing line, during the financing period. Thereby, the producers have to temporary provide financing from their own funds, which discourages access to financing and indirectly the agricultural production.

Superior correlations on the subsample favorable opinion for financing were registered for economic supported investments, the most representative of the entity, as well as in the warehousing/conditioning/processing/selling sectors, considering the growing experience accumulated by the producers in the market in each year.

To demonstrate the H2 hypothesis (financing the agricultural cooperative by appealing to the Guarantee Fund is accepted by the producers in view of minimizing the personal guarantees, allocating the funds only to the base activity or to the warehousing/conditioning/processing/selling sectors, following the investment priorities toward technologization and development to enhance social equity inside the cooperative), we have conceived a neuronal model with a basis radial function with six testing units and 12 factors (f1; f12; f13; f15; f19; f20; f21; f22; f23; f24; f25; f26) in connection with the dependent variable (f29), using the statistical identification function and error testing with the sum of squares residuals (SSE=13.825). After running the model, the incorrect predictive percentage was of 24.7%, the estimated parameters being presented in the Table 4.

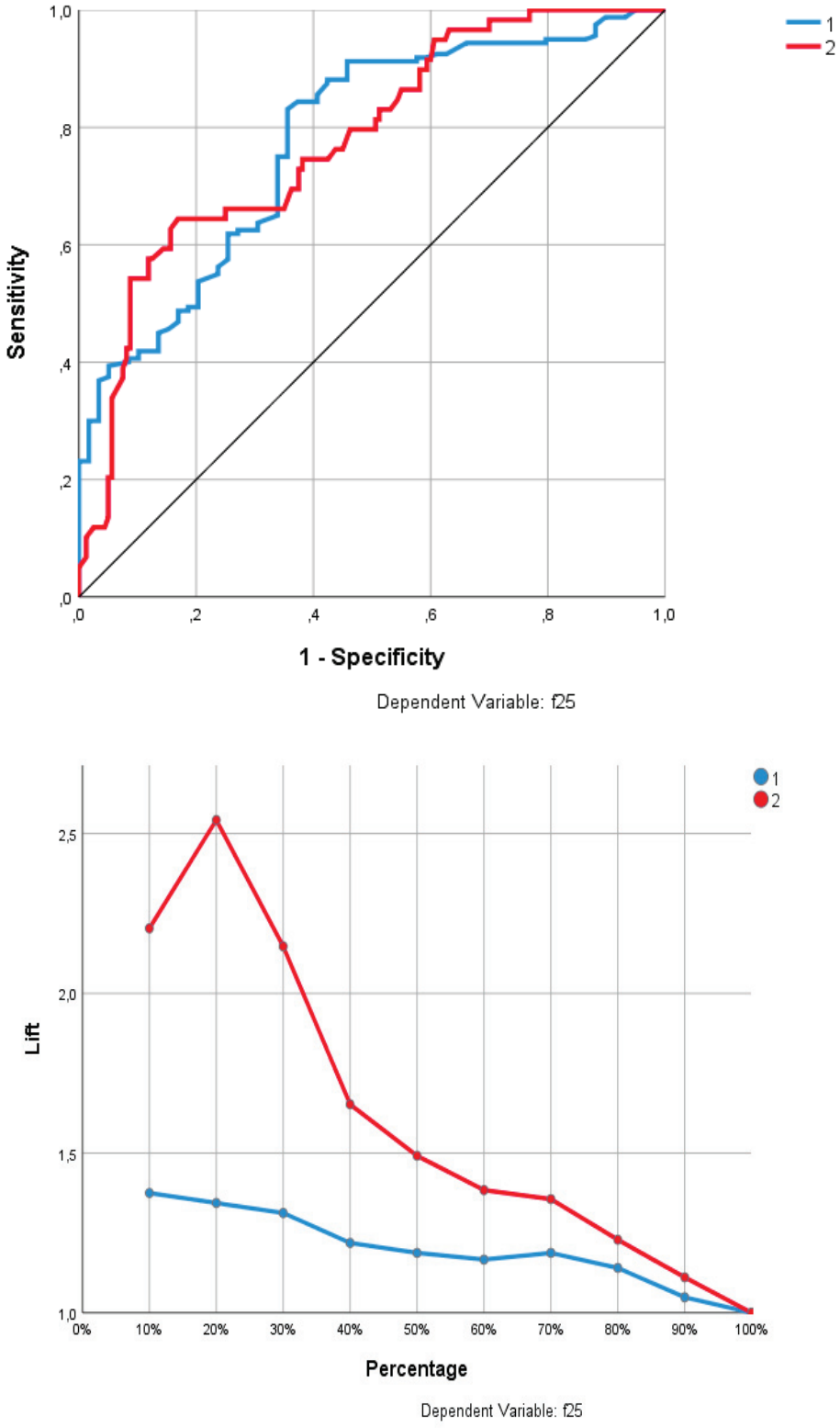

Figure 7. The sensitivity analysis of the options declared by the 219 polled agricultural entities using the structured questionnaire administered for the f25 dependent variable. Source: Elaborated by the authors using SPSS software v.25.

Table 4. Estimating the parameters with the neuronal method for not appealing to Guarantees Fund because of supplementary costs.

Parameter Estimates									
Predictor		**Predicted**							
		Hidden Layer [a]						**Output Layer**	
		H(1)	**H(2)**	**H(3)**	**H(4)**	**H(5)**	**H(6)**	**[f29 = 1]**	**[f29 = 2]**
Input Layer 1 = NO 2 = YES	[f1 = 1]	0.727	0.722	0.737	0.857	0.765	1.000		
	[f1 = 2]	0.273	0.278	0.263	0.143	0.235	0.000		
	[f12 = 1]	0.879	0.889	0.737	0.929	0.676	0.889		
	[f12 = 2]	0.121	0.111	0.263	0.071	0.324	0.111		
	[f13 = 1]	0.970	0.944	1.000	0.929	0.971	0.963		
	[f13 = 2]	0.030	0.056	0.000	0.071	0.029	0.037		
	[f15 = 1]	0.727	0.722	0.895	0.500	0.588	0.704		
	[f15 = 2]	0.273	0.278	0.105	0.500	0.412	0.296		
	[f19 = 1]	1.000	0.000	0.000	1.000	1.000	1.000		
	[f19 = 2]	0.000	1.000	1.000	0.000	0.000	0.000		
	[f20 = 1]	1.000	1.000	1.000	0.000	1.000	1.000		
	[f20 = 2]	0.000	0.000	0.000	1.000	0.000	0.000		
	[f21 = 1]	0.000	1.000	1.000	1.000	0.000	0.000		
	[f21 = 2]	1.000	0.000	0.000	0.000	1.000	1.000		
	[f22 = 1]	0.091	0.333	0.000	0.571	0.382	0.000		
	[f22 = 2]	0.909	0.667	1.000	0.429	0.618	1.000		
	[f23 = 1]	0.970	0.667	1.000	0.929	0.647	1.000		
	[f23 = 2]	0.030	0.333	0.000	0.071	0.353	0.000		
	[f24 = 1]	0.000	1.000	0.421	0.714	1.000	1.000		
	[f24 = 2]	1.000	0.000	0.579	0.286	0.000	0.000		
	[f25 = 1]	1.000	1.000	0.579	0.714	0.118	1.000		
	[f25 = 2]	0.000	0.000	0.421	0.286	0.882	0.000		
	[f26 = 1]	1.000	0.000	1.000	0.571	0.882	0.000		
	[f26 = 2]	0.000	1.000	0.000	0.429	0.118	1.000		
Hidden Unit Width		0.568	0.706	0.696	0.857	0.819	0.414		
Hidden Layer	H(1)							0.892	0.108
	H(2)							0.285	0.715
	H(3)							0.651	0.349
	H(4)							0.799	0.201
	H(5)							0.646	0.354
	H(6)							0.874	0.126

Source: Elaborated by the authors. [a] Displays the center vector for each hidden unit.

Table 4 reveals that the prediction variable not appealing to Guarantee Fund because of supplementary costs is represented at predictors' level (14 factors) at 85.7% on the fourth prediction layer and at 41.4% on sixth prediction layer, which favors the location of the variable in the NO floor with a lower than one variation. The results of the neuronal model show a 12.4% percentage for the variation layer of 2—YES and 87.6% percentage for the 1—NO layer. The value of the correction is of 78.1%, according to Figure 8.

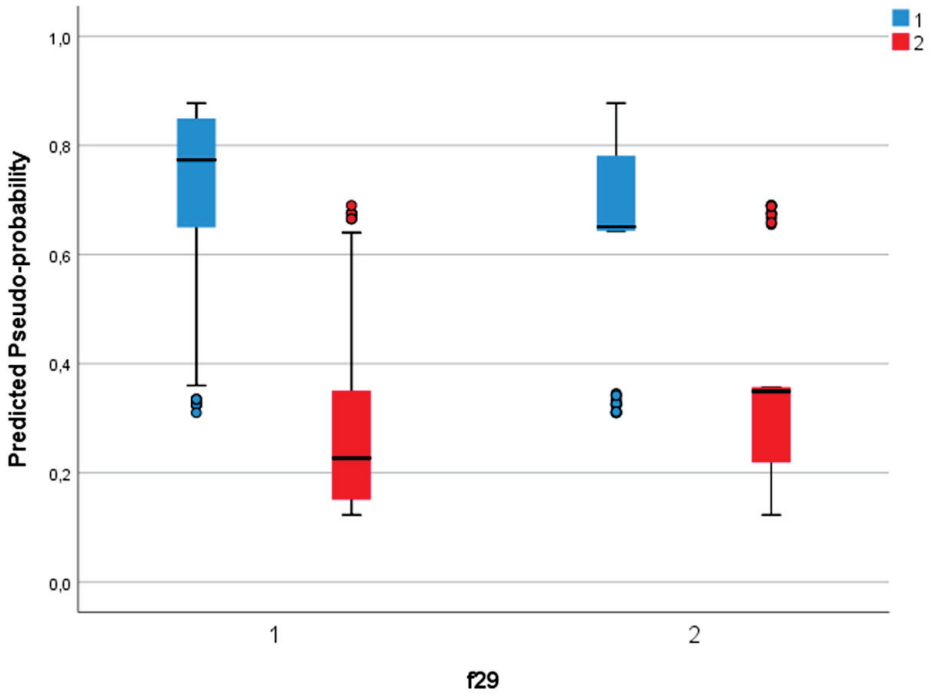

Figure 8. The representation diagram of pseudo-probable distributed variables for the two options (1 of NO, respectively, 2 of YES) of the f29 dependent variable. Source: Elaborated by the authors using SPSS software.

The sensitivity analysis shows a favorable distribution of the financing decision by appealing to guarantee funds under the H2 hypothesis, according to Figure 9 from.

According to the sequential analysis method based on the Pearson correlations, the size of the distribution gaps (lags) for the variable financing using the guarantee funds is a priority, resulting a declared predisposition on financing of the deciding entities in relation to the general sample. This confirms that minimizing the personal collaterals can be quintessential in the context of the growing financial and fiscal pressures, as otherwise the producers have to temporarily provide financing from their own funds, which discourages the access to financing and indirectly the agricultural production.

From the lag distribution perspective, superior correlations on the subsample favorable opinion for financing were registered for economic supported investments, the most representative of the entity, as well as in the warehousing/conditioning/processing/selling sectors, considering the growing experience accumulated by the producers in the market in each year.

This proves the H2 hypothesis.

To demonstrate the H3 hypothesis (in the absence of the access to the Guarantee Fund or after it was spent, the easiest financing solution is covering the guarantee by other means, aspect which covers basic economic needs of the cooperative and ensures the efficient use of the loan, corelated with co-financing from already collected funds), we have conceived a neuronal model with a basis radial function with six testing units and 12 factors (f1; f4; f5; f6; f13; f15; f18; f19; f20; f21; f22; f23) in connection with the dependent variable (f26), using the statistical identification function and error testing with the sum of squares residuals (SSE=16.521). After running the model, the incorrect predictive percentage was of 32%, the estimated parameters being presented in the Table 5.

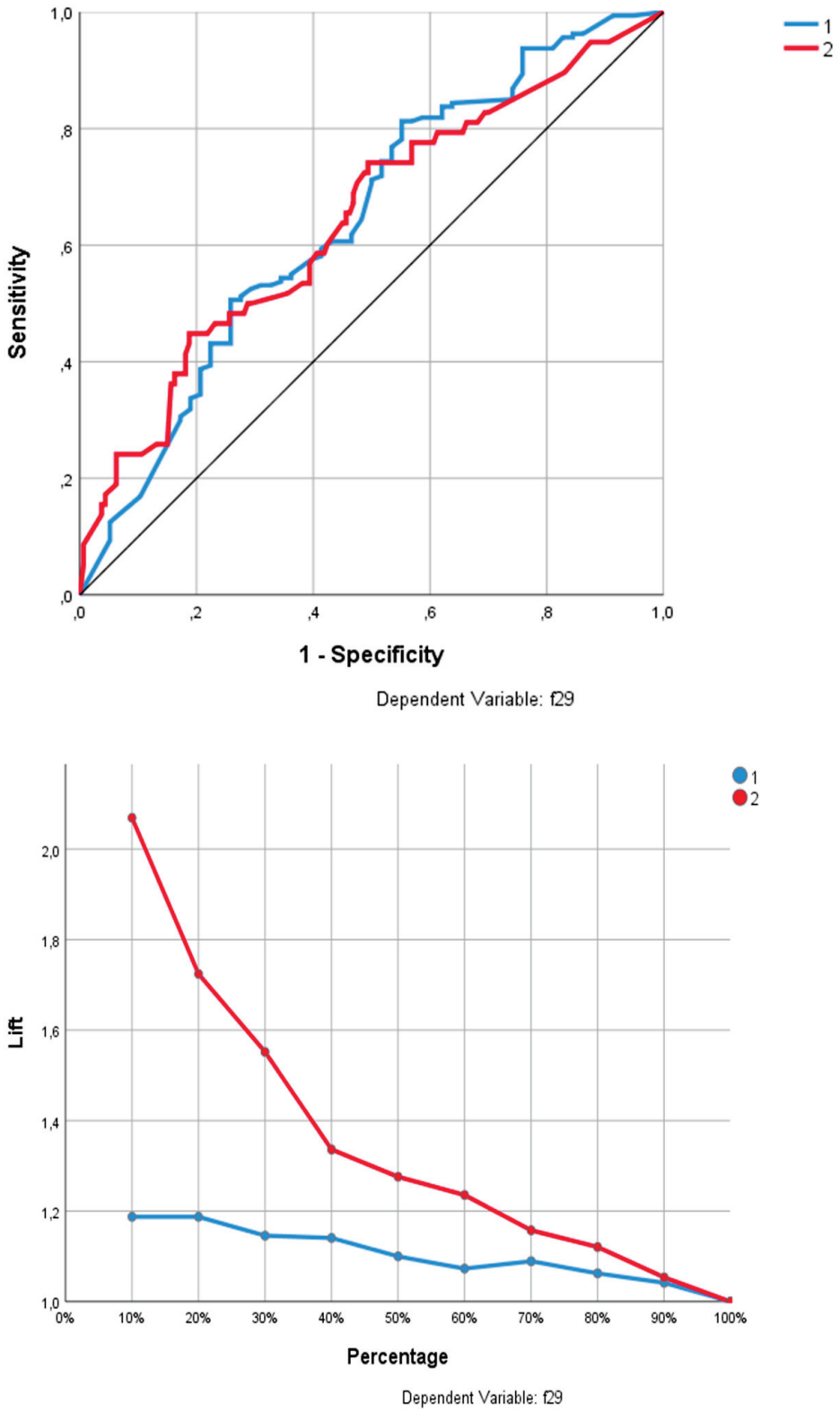

Figure 9. The sensitivity analysis of the options declared by the 219 polled agricultural entities using the structured questionnaire administered for the f29 dependent variable (1—NO, 2—YES). Source: Elaborated by the authors using SPSS software v.25.

Table 5. Estimating the parameters with the neuronal method for covering the loan collaterals by other solutions.

Parameter Estimates									
Predictor		**Predicted**							
		Hidden Layer [a]						**Output Layer**	
		H(1)	**H(2)**	**H(3)**	**H(4)**	**H(5)**	**H(6)**	**[f26 = 1]**	**[f26 = 2]**
Input Layer 1 = NO 2 = YES	[f1 = 1]	0.714	0.710	0.977	0.781	0.625	0.857		
	[f1 = 2]	0.286	0.290	0.023	0.219	0.375	0.143		
	[f4 = 1]	0.857	0.387	0.614	0.844	0.875	0.643		
	[f4 = 2]	0.143	0.613	0.386	0.156	0.125	0.357		
	[f5 = 1]	0.857	0.903	1.000	0.969	1.000	0.929		
	[f5 = 2]	0.143	0.097	0.000	0.031	0.000	0.071		
	[f6 = 1]	0.714	0.935	0.795	0.781	0.750	0.643		
	[f6 = 2]	0.286	0.065	0.205	0.219	0.250	0.357		
	[f13 = 1]	0.929	0.871	0.977	0.969	0.875	0.929		
	[f13 = 2]	0.071	0.129	0.023	0.031	0.125	0.071		
	[f15 = 1]	0.714	0.129	0.977	0.750	0.875	0.643		
	[f15 = 2]	0.286	0.871	0.023	0.250	0.125	0.357		
	[f18 = 1]	0.714	0.419	0.477	0.563	0.500	0.571		
	[f18 = 2]	0.286	0.581	0.523	0.438	0.500	0.429		
	[f19 = 1]	1.000	1.000	1.000	0.000	0.000	1.000		
	[f19 = 2]	0.000	0.000	0.000	1.000	1.000	0.000		
	[f20 = 1]	1.000	1.000	1.000	1.000	1.000	0.000		
	[f20 = 2]	0.000	0.000	0.000	0.000	0.000	1.000		
	[f21 = 1]	0.000	0.000	0.000	1.000	1.000	1.000		
	[f21 = 2]	1.000	1.000	1.000	0.000	0.000	0.000		
	[f22 = 1]	1.000	0.032	0.000	0.000	1.000	0.286		
	[f22 = 2]	0.000	0.968	1.000	1.000	0.000	0.714		
	[f23 = 1]	0.071	1.000	1.000	1.000	0.000	1.000		
	[f23 = 2]	0.929	0.000	0.000	0.000	1.000	0.000		
Hidden Unit Width		0.773	0.738	0.598	0.696	0.707	0.835		
Hidden Layer	H(1)							0.827	0.173
	H(2)							0.861	0.139
	H(3)							0.349	0.651
	H(4)							0.637	0.363
	H(5)							0.204	0.796
	H(6)							0.587	0.413

Source: Elaborated by the authors. [a] Displays the center vector for each hidden unit.

Table 5 reveals that the prediction variable covering loan collaterals by other solutions is represented at predictors' level (14 factors) at 83.5% on the sixth prediction layer and at 69.6% on the third prediction layer, which favors the location of the variable in the NO floor with a lower than one variation. The results of the neuronal model show a 21.7% percentage for the variation layer of 2—YES and 78.3% percentage for the 1—NO layer. The value of the correction is of 63.6%, according to Figure 10.

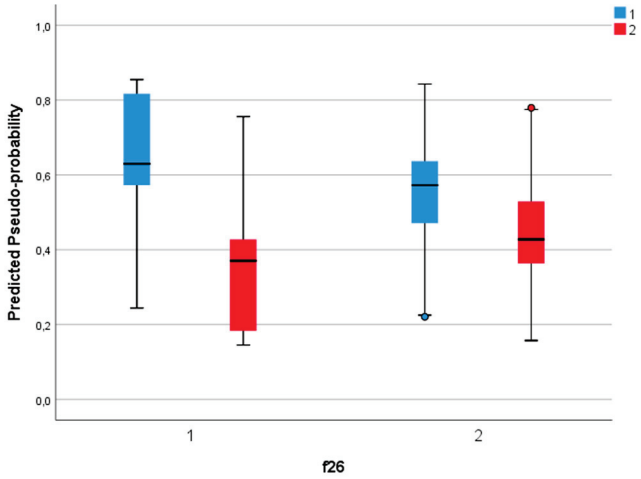

Figure 10. The representation diagram of pseudo-probable distributed variables for the two options (1 of NO, respectively, 2 of YES) of the f26 dependent variable. Source: Elaborated by the authors using SPSS software v.25.

The sensitivity analysis shows a favorable distribution of the financing decision by appealing to financing by other means under the H3 hypothesis, according to Figure 11.

According to the sequential analysis method based on the Pearson correlations the size of the distribution gaps (lags) for the variable financing using attracted funds—loans has a principal representation on the base economic segment of the entity, following the cover of supplementary need for guarantees after the exhaustion of the guarantee fund.

The distribution is realized in relation to the base economic sector, respectively; its technologization at the same time shows the vulnerabilities resulting from non-applying due to lack of equity and capital.

The solutions proposed for reaching the objective of the program are presented in Figure 12.

At the European level, the strategic Common Agricultural Policy (CAP) Plans approach agriculture in an efficient manner, based on 10 objectives, which are individually developed, according to EU agricultural entities' specific needs. From the strategic plans we can mention the orientation towards sustainable development, protecting the environment, social protection, sustainability of the agriculture and agri-food sectors, ensuring food security and safety, using innovation and digitalization and encouraging the exchange of information within the common agricultural policy.

In the economic field, the support offered to farmers refers to ensuring the functionality of the producing enterprises in the context of the challenges regarding food security, which requires supporting local production to ensure quality food at accessible prices, at the expense of products originating from countries which do not observe the same quality and environmental standards and pollute much more than the local products coming from short supply chains. In the authors' opinion, the subsidy represents short-term aid elements to compensate for the losses and continue the production activity, after natural calamities or crisis situations; the viable long-term solution is represented by the prioritization of investments of the producers' association forms with economic roles. European agriculture has met many transformations in the last 7 years, due to crises and differences in the approach of cultivation of genetically improved plants, their import and use for animal and human consumption and the corresponding objectives assumed by the European bodies.

Predictability is currently affected by exogenous events (the economic, geopolitical, pedoclimatic, sanitary and war induced crises, conditions imposed on European Union farmers and their products, such as halving of pesticides' use in agriculture, although non-EU imports do not comply with the same requirements).

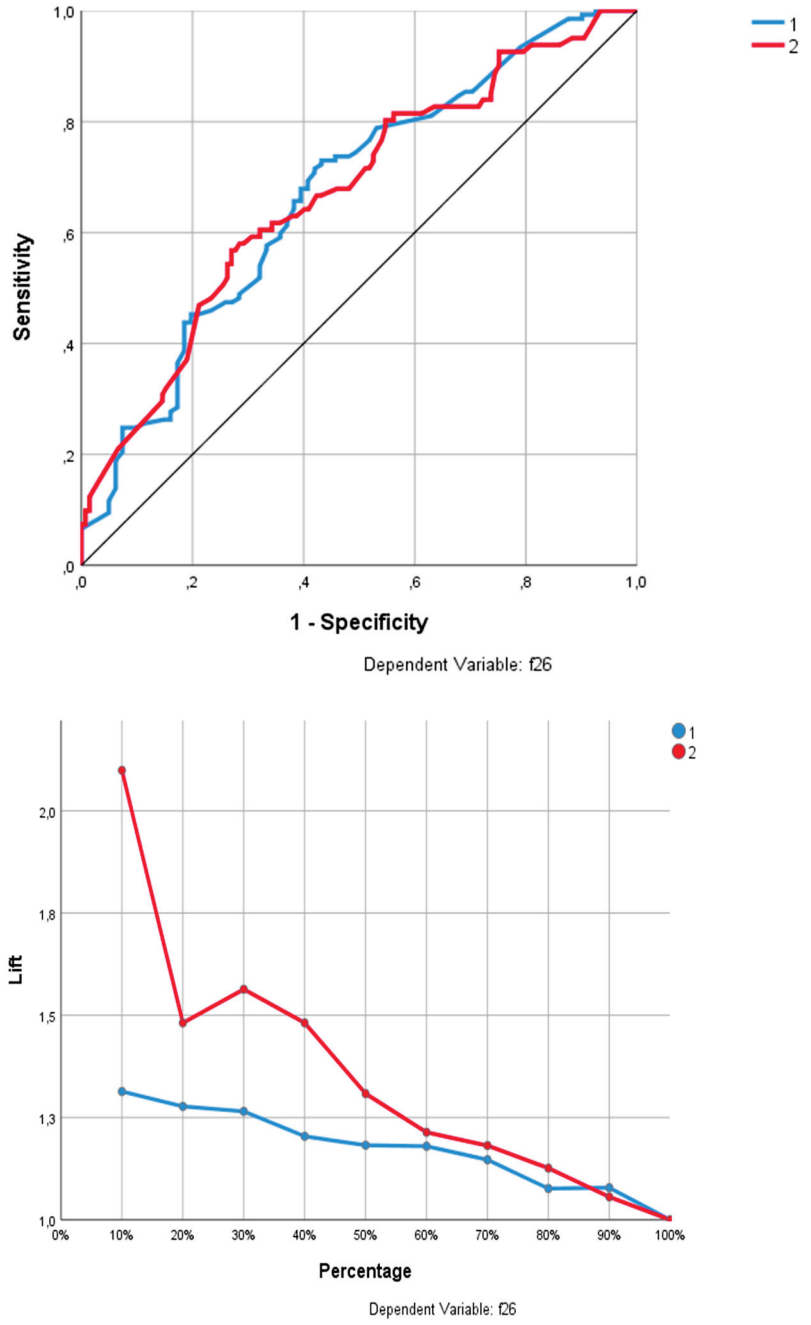

Figure 11. The sensitivity analysis of the options declared by the 219 polled agricultural entities using the structured questionnaire administered for the f26 dependent variable (1—NO, 2—YES). Source: Elaborated by the authors using SPSS software v.25.

Romania is confronted with a dependence of agricultural production on weather conditions, which leads to high fluctuations in revenues from one year to another [31]. The impact of unfavorable phenomena, either climatic, represented by pedological drought, extreme heat waves or sole erosion or ones caused by pests, leads in many instances to stopping the activities or insolvency for some farmers, as there is not yet in place a National System of Integrated Management and Control of Agricultural Catastrophic Risks.

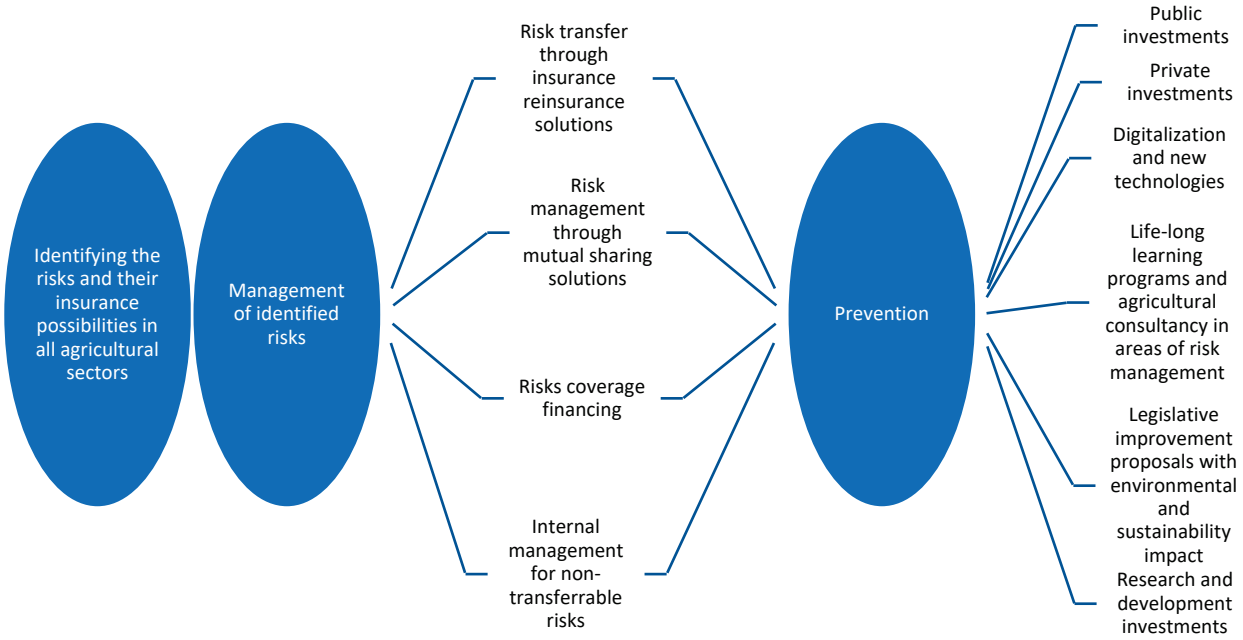

Figure 12. The solutions of the National Program for Catastrophic Risks Management in Agriculture. Source: Elaborated by the authors.

In the general context of increasing the impact of climate and environmental changes, of the socio-economic and political changes, of pest and disease proliferation and in the specific Romanian context and of including the food and agricultural sector as a strategic component, the system is based upon the development and implementation of some complementary risk management instruments, such as assuming and creating the National Program of Agriculture Catastrophic Risks Management, the introduction of an integrated national scheme of insurance–reinsurance in agriculture to cover predefined risks, support for optional insurance schemes, supporting financial stability instruments including independent mutual funds and support for using financial instrument to prevent and mitigate risks.

Finally, this can enhance the risk management, improve transparency and increase competitiveness of agricultural companies, making full use of digitalization promoted through the National Program of Recovery and Resilience. It is important to realize a European and national strategy for the creation and maintenance of protective forest curtains, to create a favorable microclimate for agricultural production, which should be interconnected with the ones from neighboring countries, and to limit or stop the climate changes' negative effects [32,33].

At the same time, the agricultural policies promoted by EU, even if they promote sustainability and durability, at least in the short term lower the competitiveness of European agriculture and indirectly encourage the cheap imports of agricultural and food products that do not comply with same quality rules and criteria as the EU produced ones.

It seems essential to update the legal framework to permit the use of modern amelioration techniques and allow modern science to make an objective analysis, granting decision making ability for the European Authority for Food Safety (EFSA) to reduce the use of pesticides and fertilizers, inclusively for the countries which have consumptions well below the European average. At the same time, the imports of non-conformant agricultural products and fertilizers, low quality and replacements of meat, milk and vegetables, which are falsely labeled using deceiving marketing practices, should be prohibited.

Simultaneously, of utmost importance is speeding up the civil works of the National Program of Irrigation and Drainages and attracting funding through the National Program of Recovery and Resilience, as well as attracting European funds to gradually increase

the irrigated areas in Romania to about 3 million hectares in 2035. Attaining this objective will allow Romania to become the main producer of soy and soy derivatives from the EU so that the internal EU consumption is secured and phases out the 85% imports from the total vegetable protein necessary to secure the feeding sources for the European zootechnical sector.

On the basis of Figure 12, a balanced scoreboard of viable solutions for Romanian agriculture development in accordance with the needs generated by the current unfavorable context was realized, as in Table 6 below.

Table 6. Balanced scorecard of solutions for Romanian agriculture development.

(f0) Applying for Grants		
Financing types S1–S6	Exclusively self-financing (f19): 24.7% S1: Creating a national framework for good practices for active agricultural cooperatives S2: Implementing integrated risk and control management instruments S3: Facilitating the access to irrigation and draining systems S4: Optional insurances of the agricultural activities/revenues Bank Loans (20): 10% S5: Access to diversified financial products, specific to agricultural cooperatives and easy access (such as mobile banking) S6: Contribution according to the shares held within the cooperative and/or the size of each member exploitation	Each member contributes according to his/her share into the Cooperative (f22): 77.2% S1–S2 Collected funds (23): 16.9% S3–S4 All members agree upon (24): 35.6% S5 Only the members and shareholders of the cooperative (25): 26.9% S5 Another solution required (26): 37.4% S6
Guarantee fund S7–S11	Mixt (21): 65.3% S1–S6 Dependent upon the level of costs (27): 54.8% S7: Solutions for cost reductions and accessing the risk management instruments in agriculture S8: Granting preferential guarantees for investments of strategically important national and regional agricultural cooperatives for warehousing/conditioning/processing/selling of agricultural products of cooperative members Reducing the weight of collaterals (28): 18.7% S9: Reducing the weight of collaterals compared to the value mentioned in the projects for agricultural cooperatives Direct provision of collaterals by the cooperatives and/or their members (29): 26.5% S10: Setting a special fund at cooperative level to ensure the money needed for investments or financing cost and fees related to financing the investment by banking loans S11: Requiring a letter of guarantee from a single or a group of members	
Purpose of funding S12–S13	Machinery (1): 19.1% S12: Ensuring the optimal use of transport and harvesting/treatment machinery in relation to the activity size of all members to ensure quality and timely activities Warehousing/conditioning/processing (2): 29.7% S13: Investments to increase the value added of primary production of the members	Common machinery (11): 60.3% Specific machinery (12): 19.6% Machinery for greenhouses (13): 5% Machinery for zootechnic activities (14): 27.9% Warehousing (15): 30.1% Primary processing (16): 28.8% Processing of finished products (17): 42.9% Local development (18): 48.9%
	Technologization (3): 14.2%—S12 Processing (4): 38.4%—S13 Horticulture (5): 6.4%—S12–S13 Zootechnics (6): 18.7%—S12–S13	

Source: Elaborated by the authors.

Romania needs to plan and implement an ambitious agricultural strategy to become the biggest soy producer in Europe. The European Union is a big importer of protein crops, of which 70% are soy and soy derivatives. The Romanian agricultural potential is very big, and it can hold supremacy in Europe for soy production and ensure the vegetal protein for

the entirety of Europe. The EU's high demand of soy and soybean products is a guarantee that this objective can help level the Romanian trade balance.

5. Conclusions

The current research showed that the lack of national policies and strategies in the field of natural disasters and climate changes' risk management (Figure 12) are the main sources of vulnerabilities for Romanian agriculture producers in the current context, amplified by a low technology level, low resources for research and agricultural development and limited access to mobile banking services and to diversified financial products (Table 6).

Also, the poor infrastructure of the supply chain represents a barrier for the economic growth of agricultural entities, hindering the sustainable economic performance of these units.

The research showed that the financing needs of agricultural cooperatives are scarcely represented at stakeholders' interest level, the macroeconomic impediments hindering their preferential or easier access to financing.

The research extracted valuable information from the poll of the 219 Romanian agricultural cooperatives, identifying the development opportunities and limiting the vulnerabilities faced by the Romanian agricultural cooperatives. The authors of this study have realized a panel of discussions, which generated a series of solutions for increasing efficiency, improving the level of economic and financial measures and helping the Romanian farmers to become significant actors, with negotiation power in the European single market, in accordance with the current global and regional trends.

The Romanian agricultural cooperatives have experienced a significant growth starting with 2019, inclusively as a result of active implication of the Sector Union of Vegetal Cooperatives, yet this should be accompanied by investments to support the increase in value added, the creation of a national level union of cooperatives for each sector, mandated to negotiate supply of inputs, integrate strategic investments at regional and national level and trading the products at fair prices for farmers and accessible for consumers.

The study demonstrated the proposed objectives of the research in the sense of identifying the vulnerabilities of farmers and agricultural cooperatives in Romania by referring to the current situation presented in the research. Investment directions were identified, and the econometric model was created to optimize access to financing for Romanian agricultural cooperatives. Within the model, three working hypotheses were elaborated, tested and validated according to which: financing using the guarantee funds is the maximum of the analyzed financing possibilities (H1); financing using the guarantee funds is a priority, resulting in a declared predisposition on financing of the deciding entities in relation to the general sample (H2); in the absence of the access to the Guarantee Fund or after it was spent, the easiest financing solution is covering the guarantee by other means, aspect which covers basic economic needs of the cooperative and ensures the efficient use of the loan, correlated with co- financing from already collected funds (H3).

The economic model of optimizing the financing is a novelty brought about by this study, which analyzed the financing decision via the three working hypotheses, from both the financing sources and the final goals' perspectives. An important aspect revealed is that the lack of proper warehousing/processing facilities represent the main vulnerability, which impede achieving maximum efficiency of the primary production.

Other lagging chapters are the production integration chain to obtain high value-added products and the current low market share of agricultural cooperatives for the main food items, which all require targeted investments at regional and national levels and increase the economic exchanges between the cooperatives.

Based on the above topic, the main public policies proposed through this study are: updating the legal framework to facilitate access to innovation; technologies and modern science throughout the European Union; compliance with the manufacturers' instructions on the labels regarding the use of pesticides; the application of the technologies regarding the improvement of the resistance of plant species to drought, to the attack of pests or

diseases, under the conditions of maintaining the biological characteristics and the quality imposed at the European level; the adoption of integrated and flexible instruments for risk management in agriculture adapted to the specific needs of each state of the European Union; establishing a framework of good practices for European agricultural enterprises and measures to develop sustainable and sustainable agricultural cooperatives.

The authors have not identified any other similar studies in the specialized literature from Romania, aimed at reducing the risks that threaten the smooth running of the activity of agricultural cooperatives by means of an integrated financing model. Previous studies show the need for financing and some vulnerabilities regarding the absorption of European funds, or the maintenance of cohesion between members of associative forms [2,30,33].

As future research directions, the authors propose extrapolating the study to the European Union level but weighted by a series of variables that reflect the level of development of agricultural cooperatives in each state and its influence on investment options and directions.

Author Contributions: Conceptualization, M.L.Z., A.M.F. and V.M.A.; Data curation, A.M.F., F.B., M.S.D. and S.S.; Formal Analysis, M.L.Z., C.F. and V.M.A.; Investigation, A.M.F., F.B., M.S.D. and S.S.; Methodology, M.L.Z., A.M.F., C.F. and V.M.A.; Project Administration, M.S.D. and S.S.; Resources, A.M.F., S.S. and F.B.; Visualization, F.B., M.S.D. and S.S.; Supervision, M.S.D., C.F. and V.M.A.; Writing—original draft, M.L.Z., A.M.F., F.B., C.F. and V.M.A.; writing—review and editing, A.M.F., F.B. and M.S.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

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ISBN 978-3-0365-7612-1