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Farm Business Model on Smart Farming Technology for Sustainable Farmland in Hilly and Mountainous Areas of Japan

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Abstract: Farmlands in Japan's hilly and mountainous (HM) areas face the critical challenges of aging farmers, depopulation, and disadvantageous conditions for farm management and economic performance, leading to the abandonment of farmland. Rice farming in HM areas is rarely profitable; however, it occupies 40% of Japanese agricultural production and affects food security. We proposed a farm business model to utilize smart farming technology (SFT) for rice production in the HM areas and analyzed the financial performance of the case study. The farm business model applying SFT has three stakeholders: collective activity by the farmers, farm operations by the enterprise, and a government subsidy. The model conceptualizes diversifying farm business into rice farming and other business units. Three scenarios of SFT in the farm business model consist of combinations of conventional and SFT machines: conventional machines, intermediate SFT, and advanced SFT. The results of the financial analysis on the case study were consistent with the theoretical framework of farm business models. This study revealed that the elasticity of labor productivity on fixed assets of advanced SFT (0.94) was more productive than intermediate SFT (0.63). To utilize SFT to sustain farmland in HM areas, balance between financial security and profitability, and linkage of the enterprise and community are indispensable.

Keywords: smart farming technology; rice; hilly and mountainous areas; sustainable farmland; Japan

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1. Introduction

Japan's geography consists of almost 7000 narrow and long-shaped islands and a mountain area occupying about three-quarters of the land. Japanese people have been cultivating rice since the late Jomon era (around 400 BC) and rice is widely grown in almost all prefectures. As of 2020, there are about 4325 thousand hectares (ha) of farmland involving 2352 thousand ha of paddy field [1], with 40% located in hilly and mountainous (HM) areas [2]. In Japan, there are four categorizations of agricultural areas: urban areas, flat areas, hilly areas, and mountainous areas [3], where hilly and mountainous areas are usually called HM areas. In general, HM areas are considered disadvantaged areas for agriculture [4,5] because they are topographically and/or economically disadvantaged for agriculture compared to flat and urban areas [6]. Therefore, many farms located in HM areas are facing difficulties in maintaining farming. Under this condition, the Japanese government is working hard to maintain agriculture in HM areas [5,6]. Therefore, why HM areas should be maintained and how the role of HM areas is important for Japan should be considered.

Table 1 shows the summary of HM areas and characteristics of farms in HM areas compared with other areas, which consist of urban and flat areas. Approximately 11% of population in Japan lives in HM areas. Furthermore, cultivated land, the number of farms, and agricultural production generated about 40% of total Japanese food production. The sustainable agriculture in HM areas is indispensable for Japanese food security [5]. However, the disadvantageous conditions of HM areas require higher costs and generate lower profitability. Characteristics of farms in HM areas in Japan are summarized in five features [7].

1. Small scale farmland area: 59% of farms cultivate farmlands less than 1.0 ha;
2. Small amount of labor input: 50% of farms use less than one laborer per day;
3. Small number of sales: 42% of farms make sales less than 500,000 yen per year;
4. Rice is the main crop: 60% of farms produce rice;
5. Many abandoned farmlands by many households: abandoning farmlands is worse than other areas.

Table 1. Summary of HM areas and characteristics of farms in HM areas.

Characteristics of Farms		**HM Areas**	**Other Areas**
Population		11%	89%
Cultivated land		38%	62%
Number of farms		43%	57%
Agricultural production		41%	59%
Farm size (ha)	<1.0	59%	49%
	1.0–3.0	29%	36%
	3.0–10.0	8%	11%
	>10.0	3%	4%
Labor input (heads/day) [1]	<1.0	50%	45%
	1.0–3.0	42%	42%
	>3.0	8%	13%
Sales size (1000/year)	<500	42%	38%
	500–1000	17%	17%
	>1000	33%	35%
Main product	Rice	60%	56%
	Vegetables	12%	19%
	Fruits	13%	12%
	Livestock	6%	4%
	Others	9%	9%
Abandoned farmland	Farmland [2]	18%	10%
	Landowner [3]	42%	28%

[1] Total yearly work hours/(220 days × 8 h). [2] Ratio of abandoned farmland in each area. [3] Ratio of landowners who own abandoned farmlands. Source: Ministry of Agriculture, Forestry and Fisheries [7].

Rice production in HM areas usually requires higher costs and more intensive workers than in other areas. Additionally, HM areas have disadvantages including smaller plot size, longer distance to another plot, sloped and narrow roads, and inconvenient irrigation facilities. Thus, rice farmers are restricted from working efficiently [8–10]. Moreover, HM areas have faced critical challenges such as aging farmers, depopulation, and an unfavorable climate [5,6], causing more serious problems in farm management, the slow adoption of smart farming technology (SFT), and the abandonment of farmland. As a result, the rice farmlands continuously declined over the years, especially in HM areas.

SFT or smart agriculture describes an advanced type of farming technology utilizing robot technology, and information and communications technology (ICT) to promote labor-saving, precision, and high-quality production [11]. SFT is expected to reduce the labor load and working time for farm production, improve farm profit through expanding farm size, and enable sustainable agricultural farmland [12,13]. For example, rice farming in Japan requires heavy agricultural activities and is labor-intensive; however, utilizing SFT improves farm productivity by reducing labor costs and working time. GPS-guided machines such as tractors or planters, remote-controlled weeding machines, drones for spraying chemicals, and other equipment can make the work more efficient for farmers [6]. Therefore, farmers in an advantageous area or with large-scale farmland can make an effort and benefit from the SFT machines and expand their farming area for improved profit [10,14]. Currently, SFT-enabling precision working devices and GPS-guided machines such as tractors, are commonly used in large scale farms, especially in flat areas. However, many SFT machines are too expensive for rice farmers in HM areas, where the economy of scale is limited due to terrain disadvantages. Such limitations imply minor benefits of SFT and some difficulties in developing economies of scale in such areas. The main cost of utilizing SFT is the depreciation cost, which usually cannot be covered by revenue generated from rice farming in HM areas [14,15]. Despite these constraints, preventing farmland abandonment in HM areas is essential for supporting the local community and traditional life, and protecting the natural landscape and environment [16].

Currently, farmers in HM areas consider the introduction of SFT too expensive for rice production in Japan [6,17]. In summary, farmers working in the HM areas can only purchase SFT machines if they are supported by the government. Supporting initial investment for purchasing SFT can encourage farmers to introduce SFT into rice production. However, farmers must operate a profitable farm business using SFT to reserve internal resources such as depreciation costs and maintain sustaining farmland in the HM areas [14]. Therefore, the research question of this study is, "How can farmers continue to economically utilize SFT in rice production in the HM areas?". This study examines the farm business model to utilize SFT for sustainable farmland in the HM areas and provides case evidence on a hamlet in a HM area, Hyogo prefecture, Japan. The theoretical framework of the farm business model was derived from the enterprise operating a diversified business of rice farming and other business units. Business performance analysis of the enterprise implementing SFT was compared in three scenarios: conventional machines, intermediate SFT, and advanced SFT.

2. Factors of Sustaining Rice Farmland in HM Areas

The Japanese government aims to preserve farmland in the HM area for national food security. The government is working strenuously to prevent the increasing abandonment of farmland. The national government enacted a symbolic law, "Direct Payment Grant for HM area (DPG)", in 2000 to address this issue [18]. DPG provides the support grant based on differences in production costs between the HM areas and other areas. In the case of rice farming, a maximum of 210,000 yen per ha is annually subsidized per farm. To maintain farmland in the HM area and receive the grant approval, the beneficiary of DPG must not be an individual farmer, but a farmer organization consisting of farmers and/or landowners in the same area. Therefore, farmers and/or landowners must practice collective activities to continue receiving grant support. This DPG regulation requires collective activities among farmers because it is difficult for individual farmers to prevent abandonment of their disadvantaged farmlands.

Initially, the farmer organization was necessary to maintain all members' farmlands with a collective responsibility to receive the grants. However, some organizations facing aging and depopulation had to withdraw from the program because the members gradually reduced. Moreover, the government reforms the regulation of DPG every five years to adjust to the changes in current circumstances [18]. Therefore, for 2020–2024, the fifth DPG does not involve the collective responsibility regulations, which significantly impacts farmer organizations operating the farmland to continue committing to DPG.

What motivates Japanese farmers living in HM areas to continue farming even though profitability is difficult? There are three main reasons. First, some farmers practice ingenuity and innovative approaches proactively to find business opportunities to profit in the HM area. However, few farmers have these skills, and some struggle with low farm profitability [19,20].

Second, rice farming is a part of life, especially for older farmers who have family living in the hamlet or HM area [20]. Despite the fact that they could live off of a pension without farming, they find fulfillment in farming and keeping farmlands as family assets. They also feel pleasure in gifting the produce to family members, relatives, and/or friends. Rice is considered to be a special crop that strengthens relationships among members of a rural community [21].

Third, farmers keep farming, believing that they can contribute to sustaining the community and farmland through rice cultivation. In other words, farmers have a sense of responsibility to the community, and quitting rice farming causes challenges in the utilization of farming and community facilities such as irrigation. Therefore, additional maintenance works and costs for facilities result in worsening farming conditions and a poor community environment if they are imposed on other farmers [22]. This has accelerated the abandonment of farming and farmland in the HM areas. This behavior of farmers is based on ethics as a mutual assistance or collective responsibility among farmers belonging to a community [21]. Moreover, this ethical issue is cultural and provides a traditional sense of value in farming and daily life in Japanese rural society settling for several generations [23]. Therefore, this ethic has bonded family farming and daily life in the community. For example, the maintenance activities of canals for rice farming were found to be conducted not just by farmers but the whole community, including non-farming families [24].

It may even be possible to suggest that these three reasons motivate farmers consisting of part-time farmers mainly to continue family farming in the HM area to sustain their farmlands. In recent years, farmers with small family farmlands have reconsidered their functions to maintain community and regional farming. Some farming families work on maintaining farmlands through generating multi-functions including non-monetary benefits such as vitalization, motivation, and healthy life [25,26].

However, Figure 1 shows that the number of farmlands declined moderately over the past 20 years, given that the expansion of farmland underwent far fewer changes than the abandonment of farmlands.

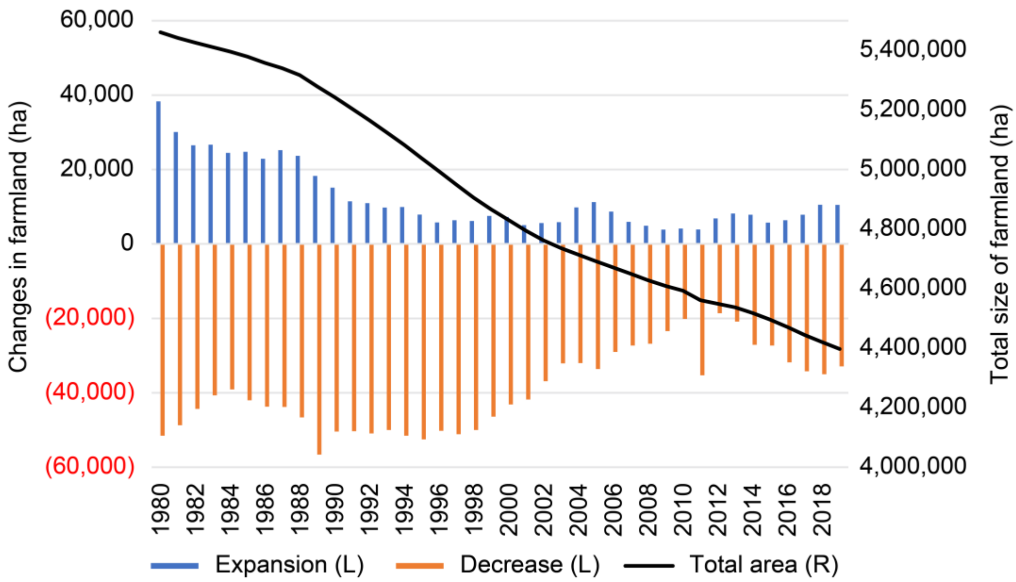

Figure 1. Changes in farmland area in Japan (ha) from 1980 to 2018. The number in parenthesis means the decreasing number of farmland (ha per year). Source: Ministry of Agriculture, Forestry and Fisheries [1].

Quitting rice farming in the HM areas is mainly caused by business irrationality and overburdened labor [2]. The first reason is the difficulty in making a profit from rice farming. Figure 2 presents the dramatic decline of producers' rice prices but a slight decrease in its cost over the past 30 years, shrinking the profitability of rice production. Figure 2 shows that the total production cost of rice farming for small-sized farms (0.3–0.5 ha) has not changed, while the total production cost for large-sized farms (more than 5 ha) decreased gradually. This indicates that the cost gap brought on by farm size has widened. Small-sized farms have been lessening their profitability due to two main factors: the worsening rice market situation and cost inefficiency under topographical limiting conditions. Therefore, abandoned farmland is increasing, especially in the HM areas, becoming a serious problem.

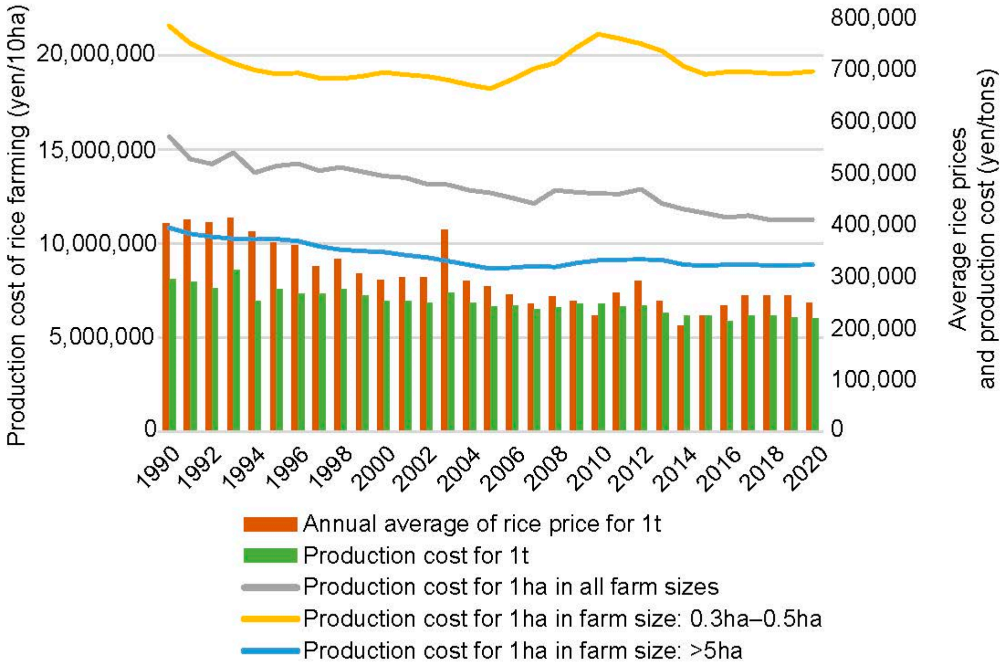

Figure 2. Changes in rice production cost and average rice price (yen/tons) during 1990–2020. Source: Ministry of Agriculture, Forestry and Fisheries [27]. Costs and prices are deflated by consumer price index (2020 = 100) [28].

3. Introduction of SFT to the HM Area

Rice farmers in the HM region incur two additional costs that are greater than those in other regions: physical burden, and average depreciation cost per ha attributed to inefficient work on small-sized farmland [15,29]. These two costs are interrelated and have accelerated the quitting of farming and abandonment of farmland in HM areas [20]. Previous studies indicated that farmland abandonment was affected by economic, social, and institutional factors, leading to limited opportunities for agricultural activities and profits [16,30,31]. This caused the farmland in HM areas to become uncompetitive compared to other areas. The cessation of farming activities resulted in different outcomes depending on the characteristics of each HM area. SFT is expected to ease the disadvantages of the HM area by making fieldwork efficient, lightening the labor burden, and increasing the competitiveness of mountain farming [13]. Regarding rice farming, there are many kinds of SFTs which can be adopted; for example, auto drive tractors, remote controlled irrigation systems, support of cultivation management systems, and multi-field cultivation management systems [32]. The implementations and conditions of SFT machines to rice paddy field were studied from the viewpoint of machinery work efficiency and investments on SFT [14], but not on business performance analysis. The results under scenarios without the limitation of land expanding showed that SFT machines can expand cultivation of farmland areas with reduced labor work hours and increased farm income. However, the additional costs for introducing SFT machines must be feasible for operating farm businesses and expanding cultivated farmlands.

In general, using SFT to expand operating farmlands is an ordinal way to reduce the average depreciation cost and develop economies of scale. However, the disadvantages of farmland in the HM areas in terms of higher cost and lower productivity attributed to geographical characteristics prevents effective farmland management and efficient economic performance [16,31]. Additionally, the average working time per ha in HM areas is longer than in other areas because the average plot size of farmland in HM is smaller [29]. Poor labor efficiency is another condition limiting farm expansion in the HM areas. When farmland operations reach their optimal scale, expanding farmland makes farming inefficient under any condition. This is the "diseconomy of scale", which limits the development and operations of farmland depending on the area's conditions [33]. The more disadvantageous the farmland conditions, the lower the chance of expansion of the farmland. Therefore, the expansion of a farmer's operation scale in the HM areas is generally smaller than in other areas. In particular, the average depreciation cost becomes larger than in other areas [15]; thus, farmlands in the HM areas have been limited in expansion and barely use SFT.

To overcome these challenges, diversifying a farm's business divisions is expected to improve financial performance and reduce risks [34–36]. This is called the "sixth industrialization", which was enacted by Japanese government since 2010. The main purpose of this program was to encourage farmers to increase their income by themselves through business diversification. The sixth industrialization means the comprehensive and integrated promotion of agriculture as the primary industry, the manufacturing industry as the secondary industry, and the retail industry as the tertiary industry, and the utilization of local resources. It is an initiative to create new added value by utilizing current resources [37]. Currently, the six industrialization was developed in a variety of business forms; for example, direct marketing, farmer's restaurants, farm stays, and educational programs. The sixth industrialization was expected to not only generate several economic values, but also work to revitalize family farming and community socio-economically [35]. However, it is necessary for farmers, especially in HM areas, who embark on the sixth industrialization to balance the investment and procure additional resources for diversifying their business [38]. Building networks among related stakeholders can procure additional resources and labor allocation for operating new business [39].

The development of diversifying businesses is supposedly helpful to maintain farming operations [34,40] and enhance cost effectiveness [6], such as the depreciation cost of SFT from direct and indirect ways.

One way is to utilize SFT machines effectively to operate the farming and business divisions with the addition of contract farm work businesses. Therefore, increasing the operation of SFT can directly improve economic performance. The other option is to make indirect use of the labor resource allocation that results from effectively integrating SFT into farm production and other business divisions. When SFT machines replace the labor workload, unused labor can be allocated to new business divisions and earn additional gains to compensate for the depreciation cost of SFT machines. Thus, diversifying business divisions should make using SFT machines possible by improving the financial condition. Three factors drive the availability of SFT on farm production: the cost of SFT machines, the performance of SFT machines to reduce labor, and total revenue, including other business divisions.

4. Methodology and Data Collection

This study was structured in two stages: developing a farm business model and proving the model via a case study. In the first stage, the farm business model was built based on the concept of diversifying business divisions to utilize SFT in the HM areas. Diversifying business was conceptualized on the sixth industrialization, which encourages farmers to generate additional income by diversifying their farm business to non-farm businesses [34,36]. The farm business model conceptualized diversifying farm business into rice farming and other business units with the conditions on labor constraint. Both rice farming and other business units are operated by the farm business enterprise.

The theoretical framework of the farm business model was derived from the enterprise operating SFT under the optimization approach [41]. The payoff of farm business model is calculated by the total sales of diversifying farm businesses minus the total costs. A farm business's payoff is optimized with labor constraint. Three scenarios of the farm business model included combinations of conventional machines, intermediate SFT, and advanced SFT. The choices of SFT machines drive labor allocation and machine cost.

The second stage applied a mixed methods approach in a survey, in-depth interviews, and accounting data to prove the farm business model. A hamlet in an HM area in Hyogo prefecture was selected as a case study. The survey was conducted as a part of the "Smart Agriculture Demonstration Project" supported by Ministry of Agriculture, Forestry and Fisheries [42] from April 2019 to March 2020. First, an in-depth interview was conducted with the community representatives to analyze the relationship between the community and the enterprise. Second, an in-depth interview was conducted with the president of the farm business enterprise to collect data on farm management and the introduction of SFT. Third, accounting data and a working record of the enterprise in 2020 were evaluated to simulate SFT's economic and business performance. To compare the business performance of three scenarios, a financial analysis, mainly focused on fixed costs and labor costs to clarify the efficiency and effectiveness of SFT machines, was carried out. Financial ratio analysis [43] is conducted by employing ten indicators: sales, ordinary deficit, fixed assets, fixed asset turnover, fixed cost, fixed cost ratio, labor productivity in total (yen/hour), elasticity of labor productivity in total for fixed cost, labor productivity (yen/hour), and elasticity of labor productivity in rice farming division (RFD) for fixed cost.

In Japan, the rice production method is so subtle that there is no yield gap between farmers or farmlands in the same area. This means rice production inputs are standardized. Therefore, this study captured two kinds of costs for rice farming: the depreciation cost of machines, and labor cost (unit: yen per ha). Three machine combinations, CON, SFT1, and SFT2, were analyzed. CON and SFT1 were simulated based on real accounting data and working records, where SFT1 included a drone for spraying chemicals and fertilizer. SFT2 was based on real accounting data and working records, and included a drone, tractor, and transplanter.

5. Theoretical Framework of the Farm Business Model

The theoretical framework proposed a farm business model to sustain farmland in HM areas by implementing SFT. The actors in the farm business model included farmers, the farm business enterprise, and the government. Farmers represented the community. The farmer and the enterprise were interested in optimizing their payoffs, behaving rationally, and working together (Equation (1)). The enterprise decided on two conditions: labor allocation and types of fixed cost of machine combination (FCi). The farm business model employed two types of business divisions: rice farming division (RFD) and other business division (OBD), labors (Lr, Lo) allocated into two business divisions (Equation (2)), three types of machine combination i (where i = CON, SFT1, SFT2), and three kinds of cost (FCi, VCi, TCi) (Equation (3)) to simulate the logic of introducing SFT to farmers in the HM area. The payoff maximization of farm business model for introducing SFT through diversifying business is as follows:

$$\max_{\mathrm{FC}} \pi = \mathrm{S}\,(\mathrm{Lr},\ \mathrm{Lo}) - \mathrm{TC}i \quad (1)$$

$$\text{Labor constraint } \mathrm{L} = \mathrm{Lr}(\mathrm{FC}i) + \mathrm{Lo} \quad (2)$$

$$\text{Total cost: } \mathrm{TC}i = \mathrm{FC}i + \mathrm{VC}i(\mathrm{FC}i) \quad (3)$$

where π represents the payoff; Lr represents labor for rice farming; Lo represents labor for other business divisions; L represents total labor, which remains constant; CON represents conventional machines; SFT1 represents intermediate smart farming machines; SFT2 represents advanced smart farming machines; FCi represents fixed cost of machine combination i; VCi represents the variable cost of machine combination i; TCi represents the total cost of machine combination *i*; S represents the total amount of sales, which includes the total sales from rice farming division and other business division.

Figure 3 shows the theoretical model of how an enterprise introduces SFT by operating two business divisions (RFD, OBD). Assume that the value of sales (S) from the two business divisions is greater than the cost of SFT and the labor allocated into the two divisions. The first quadrant shows that the enterprise has a constraint condition of total labor (constant L= Lr + Lo), to allocate for the rice farming division with a constant farmland area and other businesses division. Labor is allocated into two business divisions depending on the type of FC*i* to maximize their sales and profit. Each FC*i* type is utilized continually in a range scale of farmland because of its indivisibility. Additionally, the profitability of Lo depends on the business types of other business division (OBD). Therefore, the enterprise must find an optimal combination of labor allocation and type of fixed cost of machine combination (FC*i*).

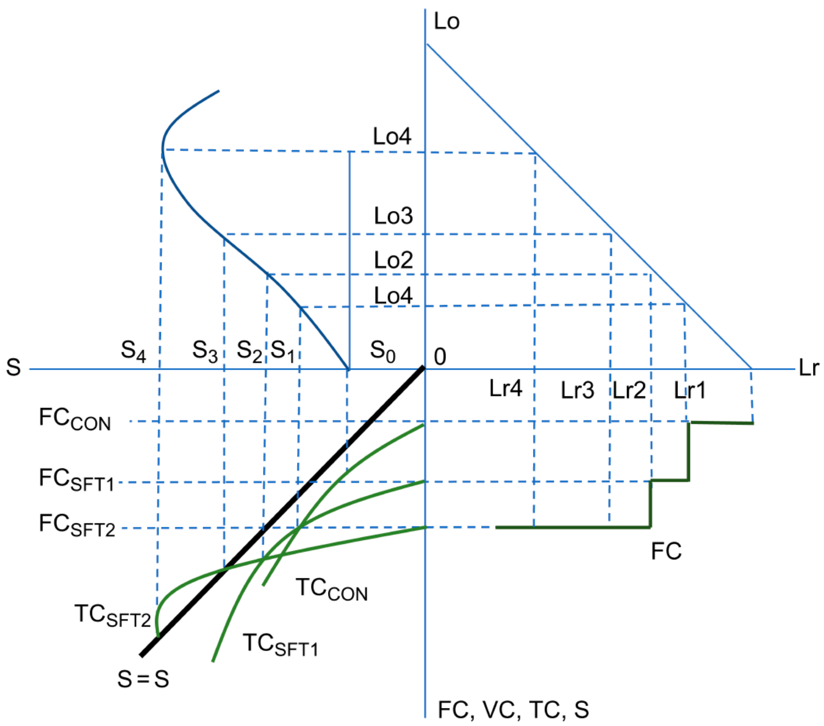

Figure 3. Theoretical model for introducing SFT by diversifying the business.

The second quadrant shows the total sales (S) obtained by labor allocation in the two business divisions. The simulation operated from stages 1 to 4, representing the optimal payoff depending on labor allocation into two business divisions. The total amount of sales started at S0 under the condition of Lr = L, where L is total labor. S0 is fixed sales of RFD. Sales added to S0 is of OBD. Then, the total sales began to increase with Lo, which resulted in additional sales of OBD. The sales continued to increase until they reached the maximum point at S4; after that, the sales started to decrease when excessive labor (Lo4 < Lo) was allocated in OBD. For example, a lack of cultivation management skills resulted in a declining rice yield, which affected not only the sales of rice but also the efficiency of other businesses.

The fourth quadrant shows that three types of machine combinations *i*, CON, SFT1, and SFT2, can be used to farm a constant land area for rice. Each machine combination costs FC*i* and had a labor allocation constraint. The more advanced the machine combination, the more expensive and labor-saving it was. The condition (FCCON < FCSFT1 < FCSFT2 and LrCON > LrSFT1 > LrSFT2) holds. For example, CON consists of conventional machines, and FCCON is the cheapest of the three combinations. However, just a few laborers can be allocated to OBD. Additionally, CON does not have enough workforce for rice farming when Lo is less than Lr1.

The third quadrant shows the relationship between the function of the total cost (TC*i*) consisting of both fixed cost (FC*i*), variable cost (VC*i*), and total sales (S). As long as CON or SFT1 was used, the total sales attributed to any labor allocations cannot cover TC*i*. SFT1 generated the optimal payoff between S1 and S2, but the sales cannot cover TC*i*. While SFT2 generated the optimal payoff between S2 and S3, sales cannot cover TC*i*. Eventually, sales between S3 generated by (Lr3, Lo3) to S4 generated by (Lr4, Lo4) surpassed TCSFT2 spent. In other words, the advanced smart farming machines (SFT2) scenario between S3 and S4 can make the business economically rational.

By implementing SFT under two conditions—effective labor allocation on diversifying farm business and the performance of SFT machines deriving the cost and potential benefits to society—the model can explain how to sustain farmland in the unfavorable conditions of the HM areas. Utilizing SFT to sustain farmland in the HM areas raises significant issues regarding farm business diversification, important partners, and cooperative actions among farmers and the enterprise.

6. Case Study of the Community and the Farm Business Enterprise

6.1. Summary of the Farm Business Enterprise

The farm business enterprise was operating in Yabu city, Hyogo prefecture, since 2015. Since then, the enterprise embarked on a farming and food processing business. Its parent company, working mainly in the construction industry, embarked on the farming and food processing business four years earlier than the enterprise. The parent company established the enterprise based on its experience. The enterprise committed to participating in the "Smart Agriculture Demonstration Project" conducted by the national government from 2019 to 2020 [44]. With project support, it introduced SFT machines such as a GPS-attached tractor, rice transplanter, drone for spraying chemical materials, remote-controlled weeding machine, and others (such as a rice harvester with ingredient measurement).

The current business of the enterprise consists of rice production as the main division and four other business divisions: food processing, contracting farm work, bean production, and crop trading. The enterprise started rice production with 3 ha of farmland in 2015 and expanded the scale of farmland to 16 ha in 2020. The enterprise had three employees, along with clerical staff, to manage and expand its business.

The enterprise aimed to succeed in the farm business but was also willing to contribute to communities in the same area by maintaining rice production. Planting crops is important for building a sustainable community and maintaining farmland in the HM areas. The enterprise must cooperate with farmer organizations and the community to make rice production efficient and rational. The community convinces landowners to lend their farmlands to the enterprise and coordinates the process. However, some field works, such as irrigating paddy fields and weeding, are difficult to mechanize and require manual labor [45]. The enterprise pays the community members appropriate wages for the work that is deemed rational to consign to them. Without this cooperation, abandoned farmland would increase and the community would be increasingly depopulated.

6.2. Summary of a Community in the Hamlet

In 2020, a hamlet of 30 households was located in the HM area in Yabu city. The 30 households included 18 landowning farming families and 10 landowning non-farming families. The population was 79, with 62% over 65 years old. Depopulation and aging have progressed rapidly in the last few decades. In the past 30 years, over 60 households lived in this hamlet. There were farmlands of 14 ha for rice farming, and all were very small plots of approximately 0.1 ha each. Large gaps and the steeply sloped area between plots required more manual labor to weed. Additionally, it took significant time for farmers to irrigate paddy fields using only mountain water. Although many farmers can support themselves without farming and by relying on their pensions, to maintain the farmland and the community, they are motivated to continue growing rice.

Under this condition, the community was committed to DPG since 2005 and received a grant of about thirty thousand dollars yearly. However, the support grant was insufficient for the farmers to continue rice production because of economic irrationality and drudgery. Therefore, it was difficult for them to envision how to continue rice production. This situation suddenly changed when the enterprise entered the hamlet as a new farmer in 2015. The community sought collaborating with the enterprise to continue rice production. Eventually, the community officially designated the enterprise as the main target farmer in 2020 to accumulate farmland in the "Plan for Human resource and Farmland" (PHF), which is usually made by a community and authorized by the local and national government [46]. It must outline the strategy for allocating and balancing farmland and human resources in order to keep farming in the hamlet. Depending on the PHF, the enterprise can accumulate farmland preferentially. In addition, many community members agreed to cooperate with the enterprise as not only a lender of farmland but also an outsourced worker for farming. They believed that cooperation with the enterprise was the best way to extend rice production for a long period in the hamlet. Therefore, in 2020, the enterprise cosigned a contract to outsource the irrigation work and farming activities to the community. Contrary to some of the other field works, the HM area currently has few SFT instruments to ease irrigation work.

6.3. Evaluation and Business Performance Analysis of the Enterprise

The theoretical framework of the farm business model was proved by analyzing the business data of the enterprise. Three scenarios of the model included combinations of conventional machines (CON), intermediate SFT (SFT1), and advanced SFT (SFT2). To simulate these scenarios, CON and SFT1 were assumed based on the real data on SFT2. The model with SFT2 had three kinds of SFT machines: tractor, transplanter, and drone. The drone for spreading fertilizer and chemicals was equipped with SFT1, but the tractor and transplanter were not. The model with CON operated conventional machines, but not any SFT machine. Labor and operating costs of SFT2 were comparable with SFT1 and CON, simulated based on machine performance data, as shown in Table 2.

Table 2. Labor and operating costs of the three scenarios.

Machines and Other Fixed Assets	Scenario	Machine	Work Efficiency [1] (h/ha)	Work Efficiency Ratio (SFT/CON)	Machine Price (1000 yen)	Depreciation Cost [2,3] (1000 yen)
Tractor	CON	Normal	12.2	66%	6281	897
	SFT2	With GPS to assist precise cultivation	8		7810	1116
Transplanter	CON	Normal	7	106%	2321	332
	SFT2	With GPS to assist straight planting	7.4		2574	368
Chemical sprayer	CON	Knapsack sprayer for chemicals	4.2	21%	176	25
	CON	Fertilizer applicator	1.9	45%	125	18
	SFT1, SFT2	Drone	0.9		3250	464
Others	CON and SFT1, SFT2				50,545	6751

[1] Total working hour included preparation, working on the field, maintenance, etc. [2] Depreciation cost used straight-line method. [3] Legal durable years for tractor, transplanter, and chemical sprayer was 7 years and for others were 6–15 years. Source: Ministry of Agriculture, Forestry and Fisheries [42].

Several conditions were necessary to simulate the business results of SFT1 and CON.

1. The three scenarios have common sales and variable costs in RFD but different labor costs depending on the calculation with machine performance data;
2. The three scenarios have common labor constraint as 3600 h a year for the whole business. Labor hours for each business comprising OBD are based on SFT2 data;
3. Depreciation costs are only captured by machines of RFD;
4. OBD's sales and variable costs are simulated using labor hours for running OBD, which includes food processing, contracting farm work, and dealing crops.

Table 3 shows the simulated business performances of each scenario: CON, SFT1, and SFT2. Depreciation costs of SFT machines were corrected to simulate the economic performance of SFT machines under the three scenarios. Fixed costs were accounted for RFD, not divided between RFD and OBD, to evaluate the effectiveness of developing OBD. Annual DFG and other supports (e.g., single fiscal-year subsidy for COVID-19) were subsidized to the enterprise in 2020 and presented in the simulation analysis as a part of the subsidies.

Table 3. Simulated business performance of three scenarios (1000 yen).

Scenarios	Business Performances	RFD	OBD	Total
CON	Sales	11,168	11,898	23,067
	Total cost [1]	21,511	12,492	34,003
	Fixed cost	9418	221	9639
	Depreciation	7801	221	8023
	Variable cost	6740	7230	13,971
	Labor cost	5352	5041	10,393
	Gross income [2]	−10,343	−594	−10,936
	Subsidies (DPG and others)	8938		8938
	Ordinary profit [3]	−1405	−594	−1998
SFT1	Sales	11,168	12,614	23,782
	Total cost [1]	21,629	13,230	34,859
	Fixed cost	9839	221	10,060
	Depreciation	8223	221	8444
	Variable cost	6740	7665	14,406
	Labor cost	5049	5344	10,393
	Gross income [2]	−10,461	−616	−11,077
	Subsidies (DPG and others)	8938		8938
	Ordinary profit [3]	−1523	−616	−2139
SFT2	Sales	11,168	13,629	24,798
	Total cost [1]	21,453	14,277	35,731
	Fixed cost	10,094	221	10,315
	Depreciation	8477	221	8698
	Variable cost	6740	8282	15,023
	Labor cost	4619	5774	10,393
	Gross income [2]	−10,285	−648	−10,933
	Subsidies (DPG and others)	8938		8938
	Ordinary profit [3]	−1347	−648	−1995

[1] Total cost was calculated by adding fixed, variable, and labor costs. (See more detail on fixed cost and variable cost in Table S1.) [2] Gross income was calculated by sales minus total cost. [3] Ordinary profit was calculated by the sum of gross income and subsidies. Source: Author's calculation based on accounting record of the farm business enterprise.

Table 3 reveals that the SFT2 scenario showed the best business performance, followed by the CON and SFT1 scenarios. These differences in business performances were attributed to the results of RFD, especially labor costs. Given that the use of SFT2 improved labor allocation in RFD and more labor allocation to OBD, enabling the sales from OBD to continue to increase, the enterprise under SFT2 generated the highest annual sales of 24,798 thousand yen with the lowest total cost of RFD (see more details on OBD in Table S1).

When comparing SFT2 to CON, less labor was required on RFD under SFT2, but the scenario produced a similar level of ordinary profit, which benefited older farmers and the community more. The subsidy nearly eliminated the deficit that resulted in the ordinary profit at −1995 thousand yen (SFT2), −1998 thousand yen (CON), and −2139 thousand yen (SFT1), despite the fact that all scenarios faced a loss of 10 million yen. Although the enterprise had a deficit in 2020, RFD would utilize SFT more efficiently, and OBD is expected to become a profitable division in the future. In reality, the majority of the deficit is eventually covered by annual subsidies and financial support for the introduction of SFT machines. Even though SFT2 has the highest depreciation cost, SFT machines economize the labor force enough to offset the higher depreciation cost. Simultaneously, the results of the SFT1 scenario revealed insufficient SFT machines to operate the farm business in the HM area. Therefore, the three machine combinations scenarios provide evidence on how to utilize SFT for sustainable farmland in the HM areas.

6.4. Comparison of the Financial Performances Analysis

The financial performance analysis of three scenarios, CON, SFT1, and SFT2, were evaluated to compare the economic efficiency and effectiveness of SFT in HM areas. Financial indicators and ratio analysis [43] were useful for this study, especially fixed assets, fixed cost, and labor productivity employed to relate with utilizing SFT. Table 4 shows the results of financial performance analysis that evaluated the changes and differentiation among scenarios. First, sales of business, fixed assets, and fixed cost increased from CON to SFT1 and SFT2, respectively. The enterprise reduced the labor force for RFD and allocated more labor into OBD (SFT1: 1851 h per year, SFT2: 2000 h per year) with utilizing SFT machines. As the result, the enterprise with SFT2 generated 7.5% higher sales than that with CON.

Table 4. Financial performance analysis results.

Financial Indicators	CON	SFT1	SFT2
1. Sales (1000 yen)	23,067 100.0%	23,782 103.1%	24,798 107.5%
2. Ordinary deficit (1000 yen)	(1998) 100.0%	(2139) 107.0%	(1995) 99.8%
3. Fixed assets (1000 yen)	59,448 100.0%	62,397 105.0%	64,178 108.0%
4. Fixed assets turnover [1]	38.8%	38.1%	38.6%
5. Fixed cost (1000 yen)	9639 100.0%	10,060 104.4%	10,315 107.0%
6. Fixed cost ratio [2]	41.8%	42.3%	41.6%
7. Labor productivity in total business [3] (yen/h)	6407	6606	6888
8. Elasticity of labor productivity on total fixed cost [4]		0.63	0.94
9. Labor productivity (yen/h) in RFD	6024	6385	6980
10. Elasticity of labor productivity in RFD on fixed cost [5]		1.21	2.00
Labor hour [6]			
RFD (h/year) OBD (h/year)	1854 1746	1749 1851	1600 2000

[1] Fixed assets turnover was sales divided by fixed assets. [2] Fixed cost ratio was fixed costs divided by fixed assets. [3] Labor productivity was sales of business divided by labor hour. [4] Elasticity of labor productivity on total fixed costs was the change in labor productivity in total divided by the change in fixed costs. [5] Elasticity of labor productivity in RFD on fixed costs the change in labor productivity (yen/hour) in RFD divided by the change in fixed costs. [6] Total annual labor hour was 3600 h for three scenarios. Source: author's calculation based on accounting record of the farm business enterprise.

Second, the enterprise can improve labor productivity by introducing SFT. Labor productivity was calculated using two indicators: total business (both RFD and OBD) and RFD. The larger labor productivity is, the more productive the economic output per labor force becomes. To measure the sensitivity of labor productivity to a change in fixed asset rate, elasticity of labor productivity with respect to fixed assets of SFT2 (total: 0.94, RFD: 2.00) was more elastic than SFT1 (total: 0.63, RFD: 1.21).

Third, the enterprise faced a loss for all scenarios, where SFT2 had the lowest ordinary deficit (99.8%) compared to CON (100%) and SFT1 (107%). Simultaneously, the changes of fixed assets turnover (CON: 38.8%, SFT1: 38.1%, SFT2: 38.6%) and fixed cost ratio (CON: 41.8%, SFT1: 42.3%, SFT2: 41.6%) indicate that financial security was improved at SFT2.

We identified that as SFT machines were introduced to the HM areas, larger sales of business from OBD were conducted. These changes were attributed to the labor-saving function of SFT machines. However, it is worth noting that high costs of SFT machines do not allow the enterprise to improve its profitability until introducing enough SFT machines to cover depreciation costs and reach the optimal payoff as discussed in Figure 3. In other words, a small number of SFT machines can worsen the profitability of the whole business. This was evidenced in the outcome of SFT1, which did not generate sufficient effectiveness to impact the business. On the other hand, as the total amount of SFT machines exceeds an optimal level, the payoff could change from increasing to losing profit. In addition, not enough investment in SFT causes reduced financial security of a farming entity through decreasing fixed assets turnover [47] and increasing fixed cost ratio. This means that scale of investment to SFT should be considered from the viewpoint of financial security of the enterprise.

6.5. Key Drivers of the Enterprise Operating SFT on Farmland in the HM Areas

First, the subsidies and support by national and local governments drive the connection between the enterprise and farmers in the HM areas. Second, employing SFT could improve the low productivity of rice in comparison to fixed costs and lower the use of labor forces. Third, the improvement of the farm business enterprise's financial structure makes the development of OBD more important. OBD also contributes to revitalizing the local community by improving sales and creating new value in the business [40,48]. For example, selling processed food and crop trading can boost farm business sales by acquiring customers and enhancing the value of the business. Machine contracting businesses can support farmers who have trouble continuing farming by providing the service. As a result, these services can support farming and livelihoods in the community.

The last driver is collaboration in farming activities between the enterprise and people who distribute additional income to the community [48,49]. In this context, the variable costs of RFD included payment for commissioned work for irrigation and weeding by community members. This cost occupied 18.6% of variable costs in RFD. The payment can be applied to the employees' additional 730 h of work, which was insufficient to cover the needs of two different types of work. Irrigation and weeding in HM areas are labor-intensive. Irrigation, in particular, necessitates three to four hours of light work per day, several days per week. Therefore, it is not efficient for employees to handle the two kinds of work, but it is suitable for the older people living in the community. Actually, the enterprise reduced costs and labor by commissioning the works to community members. Simultaneously, the payment amount has significance for the community members, especially the older residents. The opportunity to earn money through the commission work is extremely valuable to them. Furthermore, they can feel as though their participation in the job helps to maintain farming in the community. For the older residents, this is something worth living for.

7. Discussion

This study introduced the farm business model on diversifying farming business in HM areas to cover the additional costs of utilizing SFT and sustaining farmland. The survey results and financial performance analysis on the enterprise highlighted two challenges to maintaining farming in the HM areas while implementing SFT. First, without altering the business structure, the cost of implementing SFT was too high to cover the depreciation cost. In order to cover costs, new businesses must be created by operating SFT, which can economically minimize costs and labor hours. That is, operating SFT generates capital resources to invest in new businesses and supplies, as well as enabling a surplus labor force for existing ones. This is supported by [14], who revealed that SFT could reduce working hours, allowing farmers to expand cultivation land and allocate labor to additional businesses. The conditions to introduce SFT into paddy fields in flat areas with profitability required economies of scale and the expansion of land for rice cultivation [14]. If costs on cultivation land expansion is too high, as it is in HM areas, SFT is not economically worthwhile to the farm business model. In addition, expanding similar cultivation land in HM areas is not feasible to implement SFT, but other non-farming business units generated by SFT's labor allocation could possibly operate a profitable farm business.

Second, SFT alone is insufficient for maintaining family farming and farmlands in HM areas because rice farming in HM areas is not conducive to advanced mechanization, particularly regarding weeding and irrigation and requires human labor. As a result, community stakeholders must work together to take action. The farm business model for introducing SFT to sustainable farmland is shown in Figure 4.

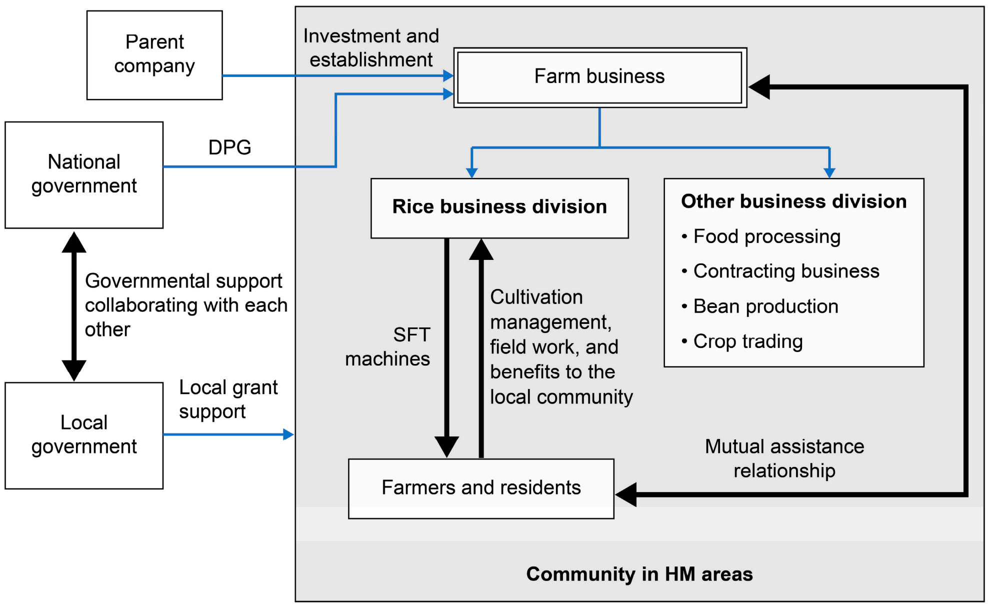

Figure 4. Diagram of the farm business model on introducing SFT to sustainable farmland.

Addressing the first issue, the development of diversified businesses alleviates some challenges on introducing SFT in HM areas. The sixth industrialization was applied to the farm business model, enabling farms to operate diversified businesses and improve farm incomes [34,36]. However, the sixth industrialization is diversified into various businesses and each business required specific conditions and management to become successful [36]. In general, farmers who embarked on business diversification typically need to procure additional resources for the business development. Some resources and facilities are not able to be procured under the farm business; thus, many farmers build networks with various actors both internally and externally in the community. Building networks with farming industries not only procures new resources but also creates business partners and market opportunities [38,39]. Figure 4 shows that the enterprise operates diversifying business units efficiently based on a network involving various actors. However, this management skill can be explained as an ability to adopt social factors and individual characteristics [30,31]. Furthermore, creating job opportunities for the residents in the community is another factor to make the sixth industrialization successful [34]. Revitalizing a community can drive and maintain farming in HM areas. One suggestion is to make efficient use of labor and equipment, including SFT machines. In other words, new businesses can maximize benefits by limiting additional operating costs [6,40]. Furthermore, for businesses operating in a labor-force constrained environment, collaboration with other firms is effective. For instance, the enterprise operates other business divisions with machines and labor rather than making sizable new investments. One example is the enterprise that makes the rice cake "Mame Mochi", which continues to hire regular staff throughout the year. The processed food businesses can be operated throughout the year, unlike rice farming. An essential goal for running an enterprise is to create opportunities to earn an income throughout the year. For some products requiring advanced machines, the enterprise acts as the original equipment manufacturer (OEM), supplying raw materials (such as rice) to an associate food processing company and selling the processed rice product (such as sake). In other words, to maintain farming in the HM area, the enterprise must ensure economic prudence rather than focusing on maximizing its short-term profit.

For the second issue, SFT makes rice farming work efficiently to an extent and stimulates agricultural structural changes in a region. That is, SFT opens up the possibility of extending the limitation of the economy of scale in HM areas, causing larger farms to realize greater profits. However, there are some inefficient tasks associated with rice farming, such as weeding or irrigation, which require significant manual labor and cannot be easily mechanized. This indicates that a farm seeking to expand must forge new ties with the community in order to produce rice. In concrete terms, the community is expected to assume responsibility for some fieldwork as contracted work. For example, the enterprise consigned the farm works (i.e., irrigation and weeding) to the community in 2020 and paid 2107 thousand yen (see more detail on commissioned work in Table S1). The development of relationships of mutual support for rice farming between the enterprise and the community is necessary and useful to make farming sustainable. The development of diversified businesses and collaboration between the entities requires a mutual assistance relationship. Another prominent driver is government support (such as DPG and SFT investment grants). Finally, finding the right enterprise that works with the community will create sustainable farmland in the HM areas and motivate community residents to stay in the disadvantageous area and maintain a vibrant environment.

8. Conclusions

This study investigated a farm business model that made use of SFT for farming in the HM areas in Japan. By analyzing the business performance and financial analysis in the case study of a hamlet in a HM area, three scenarios of SFT machine combinations: CON, SFT1, and SFT2, were analyzed. The theoretical framework of the farm business model was developed and tested. The farm business model for applying SFT had three stakeholders: collective activity by the farmer organization, farm operations by the enterprise, and a government subsidy. The model also conceptualized diversifying the farm business into rice farming and other business divisions. The findings from financial analysis of the case study were consistent with the theoretical framework of the farm business model. Scenarios SFT1 and SFT2 could increase sales of the farm business (SFT1: 100.3% and SFT2: 107%) by reducing annual labor force in RFD (SFT1: 105 h and SFT2: 254 h) and allocating these labor forces to OBD, leading to an improvement in labor productivity. Therefore, diversifying the farm business, key partners, and collective actions are prominent drivers in utilizing SFT to sustain rice farmland in the HM areas.

However, without suitable SFT machines, some financial indicators can become inefficient. For example, SFT1 (107%) generated higher deficit than SFT2 (99.8%), and the fixed costs ratio of SFT1 (42.3%) was higher than SFT2 at 41.6%. The elasticity of labor productivity to fixed assets explains these changes sufficiently, where the elasticity of SFT2 (0.94) was greater than the elasticity of SFT1 (0.63). This indicated that the change in fixed assets of SFT2 was more productive than that of SFT1, giving the potential of utilizing SFT to sustain farmland in HM areas.

There were two main difficulties with introducing and continuously utilizing SFT to maintain farming in the HM areas, which serve as a conclusion to this study. First, farms must create a successful business division structure using the idle resources produced by SFT in order to offset the depreciation cost of SFT machines. Second, even in the HM areas, SFT works to make farming operationally efficient. However, to maintain the business, it must secure its profitability. Hence, creating a profitable business division structure is essential to pay for maintaining the farmland in the HM areas and ensuring farming continuity using SFT.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12030592/s1, Table S1: Business performance of each business in SFT2 scenario.

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