Chapter 14
Smart Farming Technology Adoption and Its Determinants in Japan

Jie Mi, Teruaki Nanseki, Yosuke Chomei, Yoshihiro Uenishi, and Thi Ly Nguyen

1 Introduction

Many scholars discuss that acute labor shortage due to shrinking and aging of farmers has become one of the critical constraints of agricultural development in Japan. According to census by the Ministry of Agriculture, Forestry and Fisheries (MAFF), the labor force primarily engaged in agriculture has decreased from 1.76 million in 2015 to 1.36 million in 2020. Alarmingly, more than 70% of farmers were above the age of 65 years in 2020, compared with 65% in 2015 (MAFF, 2020). Under these circumstances, the Japanese government has encouraged the vigorous development of smart agriculture to overcome the disadvantages of agricultural labor shortage, improve agricultural production efficiency, and revitalize the progress of agriculture and rural areas (MAFF, 2022). Moreover, the widespread application of information and communication technology (ICT) in agriculture has proven crucial for optimizing the market activities, promoting the succession of agricultural skills, and boosting the development of agricultural informatization in Japan.

J. Mi · T. Nanseki (✉) · Y. Uenishi
Faculty of Agriculture, Kyushu University, Fukuoka, Japan
e-mail: nanseki@agr.kyushu-u.ac.jp; info@nanseki.org

J. Mi
e-mail: mi.jie.013@m.kyushu-u.ac.jp

Y. Uenishi
e-mail: uenishi@agr.kyushu-u.ac.jp

Y. Chomei
Graduate School of Integrated Sciences for Life, Hiroshima University, Higashihiroshima, Japan
e-mail: chomei@hiroshima-u.ac.jp

T. L. Nguyen
Faculty of Economics and Rural Development, Vietnam National University of Agriculture (VNUA), Hanoi, Vietnam
e-mail: nguyenly@vnua.edu.vn

T. Nanseki (ed.), *Agricultural Innovation in Asia*,
https://doi.org/10.1007/978-981-19-9086-1_14

Meanwhile, a structural change toward consolidation is ongoing in Japanese agriculture, with the decline of agricultural households but the rise of large-scale farming and agricultural corporations in recent decades (EU-JAPAN CENTRE FOR INDUSTRIAL COOPERATION ECOS GmbH, 2021; Nanseki, 2021). The emergence of agricultural corporations has become the backbone of realizing large-scale production, heightening the strategic management of agribusiness and accelerating industrial clusters. Intensive adoption of ICT and smart farming (SF) by corporations is anticipated to allow for the technological optimization of agricultural production systems and food value chains, ultimately contributing positively to agricultural development. Ogata et al. (2019) analyzed the cost-effectiveness of ICTs for agricultural corporations using factor analysis and observed that the factors for production and accounting visualization are related to human resource development. Their factor scores comparisons by farm characteristics revealed three points: (1) ICT cost-effectiveness is greater for livestock farms than for farms producing other goods in terms of enhancing the profitability factor; (2) farms with higher sales place a greater value on production and accounting visualization factors than those with lower sales; and (3) farms with more employees place a higher value on production visualization factors than those with fewer employees. Nanseki (2019) and Nanseki et al. (2016) reported on interdisciplinary aspects based on ICT and smart farming technology by focusing on rice farming. Bucci et al. (2019) discussed factors affecting ICT adoption in Italian agriculture and reported Internet access, web pages, production standards, age, and educational background as the factors affecting successful adoption of management information systems on farms. However, the determinants of ICT and smart farming (ICT&SF) technology adoption by agricultural corporations in Japan remain unclear.

To this end, the objective of this chapter was to identify the determining factors of ICT&SF technologies adoption by Japanese agricultural corporations. Section 2 outlines empirical models, followed by a description of data sources and variables used in econometric analysis. Section 3 discusses the empirical results, and Sect. 4 presents the key conclusions.

2 Methodology and Data

2.1 Methodology

Previous studies have analyzed the adoption of a particular or several agricultural technologies by applying ordered probit models, multinomial logit regressions, and double-hurdle models (Knowler & Bradshaw, 2007; Zhang et al., 2020). In this chapter, we investigated the intensity of ICT&SF technologies adopted by agricultural corporations. Accordingly, the dependent variable is a count variable taking a non-negative integer value from 0 to 21. Thus, count data models were deemed appropriate to estimate the effect of potential influencing factors on the number of technologies adopted (Cameron & Trivedi, 1986; Isgin et al., 2008; Rahelizatovo & Gillespie, 2004). Count integer values were assumed to follow a compound Poisson regression, in which the number of technologies adopted and the probability density function of Y can be given as follows:

$$f(y_i|x_i) = P(Y_i = y_i) = \frac{e^{\lambda_o}\lambda_i^{y_i}}{y_i},\ y_i = 0,\ 1,\ 2,\ 3\ldots \quad (1)$$

where y_i is the total number of ICT&SF technologies adopted by the agricultural corporation i and x_i is the expected determinant of ICT&SF technology adoption. The expected mean parameter (λ) of this function is defined as $\lambda_i = \exp\left(x_i'\beta\right)$, the β can be estimated using the maximum likelihood.

The Poisson model assumes the mean and variance of dependent variable are equal; that is, λ_i=mean $(y_i|x_i)$= variance $(y_i|x_i)$. However, when the conditional variance is greater than the conditional mean, overdispersion is the most likely situation (Ehiakpor et al., 2021). Thus, a negative binomial (of which Poisson is a special case) may be an appropriate count data handling procedure to accommodate the overdispersion issue by modeling variance as a function of mean. The variance in negative binomial model is given as follows:

$$Var(Y_i|x_i) = \lambda_i + \alpha\lambda_i^2 \quad (2)$$

where α is the dispersion parameter to be estimated. If α is zero, the negative binomial model is the same as the Poisson regression model, and the corresponding log-likelihood is $\log \mathrm{L} = \sum_i log[\Pr(y_i)]$. In this chapter, the test indicated the presence of overdispersion, which led to the selection of a negative binomial model.[1]

2.2 Data

2.2.1 Data Collection

The data used in this chapter were obtained from the "Business Development and Innovation in Agricultural Corporation Management" survey conducted by the Laboratory of Farm and Management at Kyushu University in 2019 (Nanseki, 2021). Information was gathered through mail questionnaires sent to agricultural corporations across Japan. The names of agricultural corporations were collected from the relevant publications, reports, and website of the Japan Agricultural Corporations Association (https://hojin.or.jp/).

In the survey, respondents were asked questions covering six parts: (1) basic information and operating policy of the corporation, such as corporate form, location,

[1] The variance of the dependent variable is approximately 15.907, which is nearly two-times greater than mean (6.623), implying that the count data present overdispersion.

establishment year, development stage, annual sales/profit margin, operating targets in the next 5 years, and so on; (2) innovative realization of corporations within the past 3 years; (3) current status of ICT&SF technologies adoption; (4) detailed business content, management strategy, and self-evaluation; (5) social contribution and perception of the Free Trade Agreement (FTA); and (6) profile of corporate representatives, such as age and education.

The questionnaires were sent to 2885 corporations, and 505 corporations provided valid answers, resulting in the effective response rate of 18% (Nanseki, 2021). The outline and basic survey results is shown in Nanseki (2021). In this study, we eliminated the observations without sufficient supporting information on questions of technology adoption and deleted the missing data of corporate and representative attributes. After screening for the missing data of all variables, most respondents made a single selection for the indicators of corporate attributes, and only one respondent made multiple selections for corporation's establishment background. Finally, 183 valid observations were used for further analyses.[2]

2.2.2 Variable Description

The dependent variable used in this chapter was the number of technologies adopted by an agricultural corporation. It is a count variable that can be used to estimate the intensity of technology adoption. Specifically, we counted the number of combined technology categories involved in both ICT and SF technologies. According to the Food and Agriculture Organization of the United Nations (FAO), ICT is defined as "a broader term for Information Technology (IT), which refers to all communication technologies, including the internet, wireless networks, cell phones, computers, software, middleware, video-conferencing, social networking, and other media applications and services enabling users to access, retrieve, store, transmit, and manipulate information in a digital form.[3]" According to MAFF (2022), "smart agriculture" or "smart farming" refers to the utilization of cutting-edge technologies, such as robots, artificial intelligence (AI), and the Internet of Things (IoT), in agricultural or farm management. Recent studies have distinguished SF technologies into the following types: (1) recording and mapping technologies, which collect precise data for subsequent site-specific application; (2) tractor GPS and connected tools, which use real-time kinetics to appropriately apply variable rates of inputs and accurately guide tractors; (3) apps and farm management and information systems, which integrate and connect mobile devices for easier monitoring and management; and (4) autonomously operating machines, such as weeding and harvesting robots (Fountas et al., 2015; Knierim et al., 2019). In this study, the ICT&SF technologies adopted by Japanese agricultural corporations are tentatively identified as two types. One

[2] The results of analysis including 195 observations (12 missing data were replaced by 0 in independent variables; See Appendix for details) were previously presented orally at the 10th Asian Society of Agricultural Economists International Conference (Mi et al., 2021).

[3] http://aims.fao.org/information-and-communication-technologies-ict.

refers to the smart farming technologies (SFTs) contained ICT and (2) common ICTs applied in SF.

The definitions and adoption rates of each technology categories are shown in Table 1. Three aspects including data monitoring and collection, operation automatization, and robotization, and business management, were involved, and 21 ICT&SF technology categories were described. The most frequently adopted technology category was financial management systems, such as bookkeeping and accounting, with an adoption rate of 84.2%. Advertisement for companies and products was a relatively frequently used technology category with an adoption rate of 65.0%. The third most frequently adopted technology category was sales information management, with an adoption rate of 61.7%. In contrast, technologies with relatively low adoption rates included "automation of crop cultivation machines/robots", "automatic measurement of product harvest", and "measurement of crop growth using drones and artificial satellites", with adoption rates of 8.2, 7.7, and 5.5%, respectively. These trends are consistent with the statistics reported by Nanseki (2021).

The independent variables in our count data modelling covered wide range of corporation attributes and representatives characteristics, classified into the following 17 groups: (1) corporate form; (2) eligibility to own farmland; (3) location of corporations; (4) age of corporations; (5) establishment background; (6) human capital; (7) annual sales; (8) profit margin, (9) development stage of the corporations; (10) sales target for the next 5 years; (11) profit target for the next 5 years; (12) major product; (13) self-evaluation of ICT utilization and information management; (14) perception of FTA participation of Japan; (15) age of representatives; (16) educational background of representatives; (17) non-agricultural experience of representatives. The definition, along with the unit and expected signs, are listed in Table 2.

3 Results and Discussion

3.1 Descriptive Results

Distribution of ICT&SF Technology Adoption. Figure 1 presents the distribution of the ICT&SF technology adoption rates by Japanese agricultural corporations. Of the 183, 175 corporations had adopted at least one ICT&SF technology category until 2019, indicating an overall adoption rate of 95.6%. In contrast, 4.4% corporations implemented none of these technologies. Majority (82.0%) of the corporations adopted 10 or fewer technologies, and only 18.0% adopted 11 or more technologies. Moreover, the observed Japanese agricultural corporations adopted nearly 6.6 technologies on average.

Summary of the Descriptive Statistics. Table 3 depicts the summary of descriptive statistics for all variables. Majority (84.7%) of the corporations are limited and stock companies. Approximately 86.9% corporations are judicially qualified to own farmland. Nearly 24.6% corporations are located in Tohoku, 23.5% are located in

Table 1 Definition and adoption rates of ICT&SF technologies

Technology categories	Type[a]	Frequency	Adoption rate (%)
Data monitoring and collection technologies			
1. Measurement of environmental information of crops and livestock (temperature, water temperature, soil moisture, solar radiation, and so on)	ICTs applied in SF	56	30.601
2. Measurement of biological information of crops and livestock (growth status, livestock estrus, body temperature, and so on)	SFTs contained ICTs	52	28.415
3. Collection of work information from each field (recorded using a personal computer, smartphone, camera, GPS, and so on)	ICTs applied in SF	76	41.530
4. Automatic measurement of product harvest (combined with sensor and so on)	SFTs contained ICTs	14	7.650
5. Automatic measurement of product quality (livestock milk/meat quality, crop sugar content/acidity, and so on)	SFTs contained ICTs	16	8.743
6. Browsing of farming information on smartphones (weather information, crop growth status, farm work amount, and so on)	ICTs applied in SF	80	43.716
7. Measurement of crop growth using drones and artificial satellites (leaf color, pests, and so on)	ICTs applied in SF	10	5.464
Robotization technologies and autonomously operating machines			
8. Automatic detection/notification of abnormal information (temperature, humidity, soil moisture, livestock estrus, body temperature, and so on)	SFTs contained ICTs	25	13.661
9. Automation of agricultural land irrigation and water supply (paddy pipelines, open waterways, upland fields, and so on)	SFTs contained ICTs	32	17.486
10. Agricultural machinery with operation assist function (straight-ahead assist function and so on)	SFTs contained ICTs	17	9.290
11. Automatic environmental controls of greenhouses and barns (temperature, humidity, soil moisture, CO_2 concentration, and so on)	SFTs contained ICTs	40	21.858
12. Livestock feeding, manure cleaning, and milking automation and robotization	SFTs contained ICTs	19	10.383

(continued)

Table 1 (continued)

Technology categories	Type[a]	Frequency	Adoption rate (%)
13. Automation of crop cultivation machines/robots [plowing, fertilization, control (including drone), harvest, and so on]	SFTs contained ICTs	15	8.197
14. Automatic sorting of harvested products (weight/shape sorting, color sorting, sugar content sorting, and so on)	SFTs contained ICTs	41	22.404
Business management technologies			
15. Management of production record information (including data analysis such as tabulation and graphing)	ICTs applied in SF	100	54.645
16. Provision of production information to business partners and consumers (product quality, production history, and so on)	ICTs applied in SF	78	42.623
17. Sales information management (including customer management and internet sales)	ICTs applied in SF	113	61.749
18. Inventory management of materials, such as pesticides and fertilizers (recorded using a personal computer, smartphone, and so on)	ICTs applied in SF	83	45.355
19. Financial management systems, such as bookkeeping and accounting (settlement, management diagnosis, payroll, and so on)	ICTs applied in SF	154	84.153
20. Planning of business strategy and creation of business plan (simulation on a personal computer and so on)	ICTs applied in SF	72	39.344
21. Advertisement for companies and products (information on homepage and so on)	ICTs applied in SF	119	65.027

[a]Types of technology categories are tentative. ICTs and SFTs are broad concepts, they intersect with each other. With the development of each technology category, the types may be updated

Kyushu and Okinawa, and only 1.6% are located in Hokkaido. The average age of the sampled corporations is approximately 19.0 years. Regarding establishment background, approximately 47.5% are solely owned corporation, established by a farmer and 26.8% are joint corporations founded by several farmers. Regarding human capital, the number of board members is approximately 3.6 on average, and the number of regular employees is approximately 11 on average. Nearly half of the corporations have a profit margin between 1 and 10%, while 20.8% are running in financial deficit. Regarding development stage, approximately 40.4% corporations are at the "growing stage," compared with 16.4 and 6.0% corporations at the

Table 2 Definition of the variables in estimation (Nanseki, 2021)

Variables name	Definition	Unit
TECH (dependent)	Number of ICT&SF technologies adopted (Values ranging from 0 to 21)	Number
1. Corporate form (±)		
CFORM_1	1 if the corporation is limited company; 0 otherwise	Dummy
CFORM_2	1 if the corporation is stock company; 0 otherwise	
CFORM_3	1 if the corporation is agricultural cooperative corporation; 0 otherwise	
CFORM_4	1 if the corporation form is others; 0 otherwise	
2. Eligibility to own farmland (+)		
FARML	1 if the corporation is judicially qualified to own farmland; 0 otherwise	Dummy
3. Location of corporations (±)		
R_HKD	1 if the corporation located in Hokkaido; 0 otherwise	Dummy
R_TH	1 if the corporation located in Tohoku; 0 otherwise	
R_KT	1 if the corporation located in Kanto; 0 otherwise	
R_HR	1 if the corporation located in Hokuriku; 0 otherwise	
R_KKTK	1 if the corporation located in Kinki Tokai; 0 otherwise	
R_CHSK	1 if the corporation located in Chugoku and Shikoku; 0 otherwise	
R_KSON	1 if the corporation located in Kyushu and Okinawa; 0 otherwise	
4. Age of corporations (±)		
AGE_C	2019—establishment year	Year
5. Establishment background (±)		
ESTAB_1	1 if a farmer established a solely owned corporation; 0 otherwise	Dummy
ESTAB_2	1 if a farmer established a joint corporation with other members; 0 otherwise	
ESTAB_3	1 if a Farmer has established corporations in collaboration with non-farmers and companies from other industries; 0 otherwise	
ESTAB_4	1 if a non-farmer entered agriculture as individuals and established a corporation; 0 otherwise	
ESTAB_5	1 if the company's main business is non-agriculture, but they have entered agriculture as a new business; 0 otherwise	
ESTAB_6	1 if a corporation parent/main company or group company has established a new corporation and entered agriculture; 0 otherwise	
ESTAB_7	1 if the establishment background of a corporation is others; 0 otherwise	

(continued)

Table 2 (continued)

Variables name	Definition	Unit
6. Human capital (+)		
BM	Total number of board members	Persons
RE	Total number of regular employees	
7. Annual sales (+)		
SALE	Categorical variable of corporations' annual sales: 1 = <30 million yen; 2 = 30–50 million yen; 3 = 50–100 million yen; 4 = 100–300 million yen; 5 = 300–500 million yen; 6 = 500–1000 million yen; 7 = 1000–1500 million yen; 8 = 1500–2000 million yen; 9 = >2000 million yen	Category
8. Profit margin (+)		
PROF_1	1 if profit margin of a corporation is 0% (break-even); 0 otherwise	Dummy
PROF_2	1 if profit margin of a corporation is 1–5%; 0 otherwise	
PROF_3	1 if profit margin of a corporation is 5–10%; 0 otherwise	
PROF_4	1 if profit margin of a corporation is 10–15%; 0 otherwise	
PROF_5	1 if profit margin of a corporation is 15–20%; 0 otherwise	
PROF_6	1 if profit margin of a corporation is >20%; 0 otherwise	
PROF_7	1 if the deficit; 0 otherwise	
9. Development stage of the corporations (±)		
STAGE_1	1 if the development stage is "starting"; 0 otherwise	Dummy
STAGE_2	1 if the development stage is "growing"; 0 otherwise	
STAGE_3	1 if the development stage is "mature"; 0 otherwise	
STAGE_4	1 if the development stage is "recession"; 0 otherwise	
STAGE_5	1 if the development stage is the second period of "starting"; 0 otherwise	
STAGE_6	1 if the development stage is the second period of "growing"; 0 otherwise	
STAGE_7	1 if the development stage is the second period of "mature"; 0 otherwise	
STAGE_8	1 if the development stage is the second period "recession"; 0 otherwise	
STAGE_9	1 if others	
10. Sales target for the next 5 years (+)		
TSALE_1	1 if the sales target for the next 5 years is "maintain"; 0 otherwise	Dummy
TSALE_2	1 if the sales target for the next 5 years is "1.2 times"; 0 otherwise	
TSALE_3	1 if the sales target for the next 5 years is "1.5 times"; 0 otherwise	

(continued)

Table 2 (continued)

Variables name	Definition	Unit
TSALE_4	1 if the sales target for the next 5 years is "1.8 times"; 0 otherwise	
TSALE_5	1 if the sales target for the next 5 years is "2.0 times"; 0 otherwise	
TSALE_6	1 if the sales target for the next 5 years is "2.0–3.0 times"; 0 otherwise	
TSALE_7	1 if the sales target for the next 5 years is "over 3 times"; 0 otherwise	
TSALE_8	1 if the sales target for the next 5 years is "decrease"; 0 otherwise	
TSALE_9	1 if no target; 0 otherwise	
11. Profit target for the next 5 years (+)		
TPROF_1	1 if the profit target for the next 5 years is "0%"; 0 otherwise	Dummy
TPROF_2	1 if the profit target for the next 5 years is "1%–5%"; 0 otherwise	
TPROF_3	1 if the profit target for the next 5 years is "5%–10%"; 0 otherwise	
TPROF_4	1 if the profit target for the next 5 years is "10%–15%"; 0 otherwise	
TPROF_5	1 if the profit target for the next 5 years is "15%–20%"; 0 otherwise	
TPROF_6	1 if the profit target for the next 5 years is "over20%"; 0 otherwise	
TPROF_7	1 if no margin; 0 otherwise	
12. Major product[a] (±)		
PROD_1	1 if the major product is "paddy rice"; 0 otherwise	Dummy
PROD_2	1 if the major product is "wheat"; 0 otherwise	
PROD_3	1 if the major product is "beans and coarse cereals"; 0 otherwise	
PROD_4	1 if the major product is "open-ground vegetables"; 0 otherwise	
PROD_5	1 if the major product is "house vegetables"; 0 otherwise	
PROD_6	1 if the major product is "flowers and foliage plants"; 0 otherwise	
PROD_7	1 if the major product p is "fruit"; 0 otherwise	
PROD_8	1 if the major product is "mushrooms"; 0 otherwise	
PROD_9	1 if the major product is "dairy"; 0 otherwise	
PROD_10	1 if the major product is "beef cattle"; 0 otherwise	
PROD_11	1 if the major product is "swine"; 0 otherwise	

(continued)

Table 2 (continued)

Variables name	Definition	Unit
PROD_12	1 if the major product is “poultry (meat/eggs)”; 0 otherwise	
PROD_13	1 if the major product is “others”; 0 otherwise	
PROD_14	1 if the major product is “multiple crops”; 0 otherwise	
13. Self-evaluation of ICT utilization and information management (+)		
SELF_U	1 = weaker than others; 2 = slightly weaker than others; 3 = neither weaker nor stronger than others; 4 = slightly stronger than others; 5 = stronger than others	Likert scale
14. Perception of the FTA participation of Japan (+)		
FTA	Respondents’ perception of the FTA participation of Japan: 1 = major crisis; 2 = crisis; 3 = neutral; 4 = opportunity; 5 = great opportunity	Likert scale
15. Age of representatives (±)		
AGE_R	Value ranging from 1 to 7: 1 = 10–20 years old; 2 = 20–30 years old; 3 = 30–40 years old; 4 = 40–50 years old; 5 = 50–60 years old; 6 = 60–70 years old; 7 = over than 70 years old	Category
16. Education background of representatives (+)		
EDU_1	1 if the representative graduated from a high school; 0 otherwise	Dummy
EDU_2	1 if the representative graduated from a specialized school; 0 otherwise	
EDU_3	1 if the representative graduated from a vocational college; 0 otherwise	
EDU_4	1 if the representative graduated from a junior college; 0 otherwise	
EDU_5	1 if the representative graduated from a university; 0 otherwise	
EDU_6	1 if the representative graduated from a graduate school; 0 otherwise	
EDU_7	1 if others	
17. Non-agricultural experience of representatives (±)		
NAGRI	Values ranging from 1 to 6: 1 = none; 2 = 1–5 years; 3 = 5–10 years; 4 = 10–15 years; 5 = 15–20 years; 6 = >20 years	Category

Note Symbols in parentheses denote the expected signs of each category of independent variables
[a]Major product of an agricultural corporation is classified as a product that accounts for over 60% of that corporation’s annual sales

“mature” and “recession” stages, respectively. Regarding the operating target, the largest proportion of companies (approximately 29.5%) have set the target of 1.5 times sales growth in the next 5 years. Moreover, 83.6% corporations have set the target of 1–20% profit growth, compared with 10.4% corporations with a target of over 20% profit growth in the next 5 years. Regarding the major product, the corporations with major products as ‘paddy rice’ account for the largest proportion (18.0%),

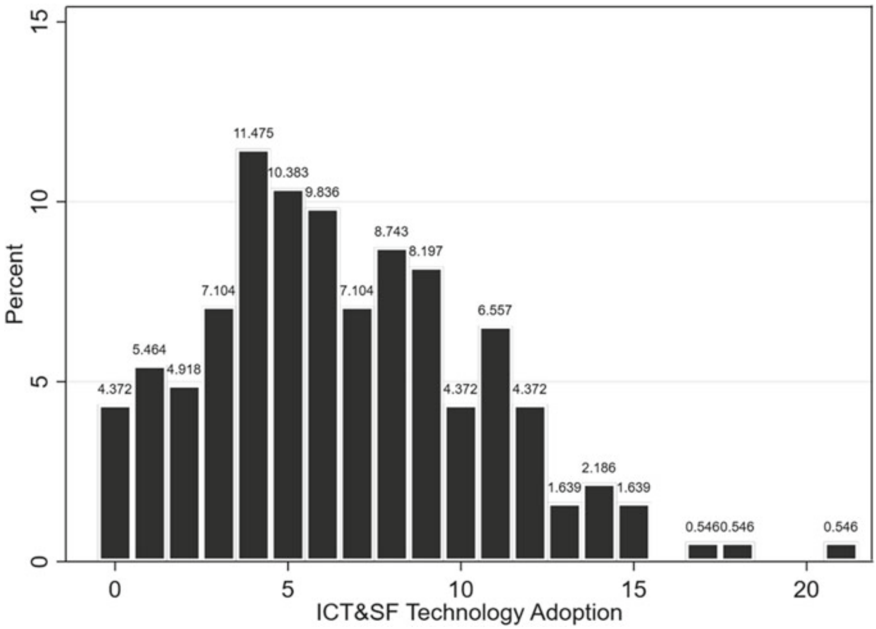

Fig 1 Distribution of technology adoption frequency of agricultural corporations ($N = 183$) (The Questionnaire Survey on Business Development and Innovation in Agricultural Corporation Management in 2019)

whereas the 'beans and coarse cereals' accounted the least, only for 1.1%. Moreover, approximately 8.7% corporations follow multiple crop farming. Regarding the profile of corporate representatives, over half of the representatives (54.6%) graduated from high schools and 36.6% from universities. Of the corporate representatives, 2.7% held a postgraduate degree.

3.2 Empirical Results

We applied a negative binomial model to identify the potential determinants of ICT&SF technologies adoption by Japanese agricultural corporations. We tested two non-nested forms of the negative binomial model denoted NB1 (which is a negative binomial model with constant dispersion) and NB2 (which is a negative binomial model with no constant dispersion) and compared their estimates according to Akaike's information criterion (AIC) and Bayesian information criterion (BIC). The results are presented in Table 4.

The result of NB1 revealed corporate form, eligibility to own farmland, sales targets, profit target, major product, self-evaluation of ICT utilization and information

Table 3 Result of descriptive statistics

Variables	Mean	SD	Min	Max	Obs.	Variables	Mean	SD	Min	Max	Obs.
TECH (dependent)	6.623	3.988	0	21	–	10. Sales target for the next 5 years					
1. Corporate form						*TSALE_1*	0.126	0.332	0	1	23
CFORM_1	0.410	0.493	0	1	75	*TSALE_2*	0.284	0.452	0	1	52
CFORM_2	0.437	0.497	0	1	80	*TSALE_3*	0.295	0.457	0	1	54
CFORM_3	0.137	0.344	0	1	25	*TSALE_4*	0.038	0.192	0	1	7
CFORM_4	0.016	0.127	0	1	3	*TSALE_5*	0.137	0.344	0	1	25
2. Eligibility to own farmland						*TSALE_6*	0.060	0.238	0	1	11
FARML	0.869	0.338	0	1	–	*TSALE_7*	0.055	0.228	0	1	10
3. Location of corporation						*TSALE_8*	0.005	0.074	0	1	1
R_HKD	0.016	0.127	0	1	3	*TSALE_9*	0.000	0.000	0	0	0
R_TH	0.246	0.432	0	1	45	11. Profit target for the next 5 years					
R_KT	0.137	0.344	0	1	25	*TPROF_1*	0.038	0.192	0	1	7
R_HR	0.087	0.283	0	1	16	*TPROF_2*	0.213	0.411	0	1	39
R_KKTK	0.137	0.344	0	1	25	*TPROF_3*	0.350	0.478	0	1	64
R_CHSK	0.142	0.350	0	1	26	*TPROF_4*	0.158	0.366	0	1	29
R_KSON	0.235	0.425	0	1	43	*TPROF_5*	0.115	0.320	0	1	21
4. Age of corporation						*TPROF_6*	0.104	0.306	0	1	19
AGE_C	19.071	12.516	2	76	–	*TPROF_7*	0.022	0.147	0	1	4
5. Establishment background						12. Major product					
ESTAB_1	0.475	0.501	0	1	87	*PROD_1*	0.180	0.386	0	1	33
ESTAB_2	0.268	0.444	0	1	49	*PROD_2*	0.000	0.000	0	0	0
ESTAB_3	0.044	0.205	0	1	8	*PROD_3*	0.011	0.104	0	1	2
ESTAB_4	0.055	0.228	0	1	10	*PROD_4*	0.077	0.267	0	1	14
ESTAB_5	0.044	0.205	0	1	8	*PROD_5*	0.115	0.320	0	1	21
ESTAB_6	0.060	0.238	0	1	11	*PROD_6*	0.038	0.192	0	1	7
ESTAB_7	0.060	0.238	0	1	11	*PROD_7*	0.137	0.344	0	1	25
6. Human capital						*PROD_8*	0.033	0.179	0	1	6
BM	3.552	2.394	1	20	–	*PROD_9*	0.022	0.147	0	1	4
RE	11.055	21.956	0	238	–	*PROD_10*	0.049	0.217	0	1	9
7. Annual sales						*PROD_11*	0.044	0.205	0	1	8
SALE	3.760	1.741	1	9	–	*PROD_12*	0.049	0.217	0	1	9
8. Profit margin						*PROD_13*	0.158	0.366	0	1	29
PROF_1	0.087	0.283	0	1	16	*PROD_14*	0.087	0.283	0	1	16
PROF_2	0.322	0.469	0	1	59	13. Self-evaluation of ICT utilization and information management					
PROF_3	0.191	0.394	0	1	35	*SELF_U*	2.628	0.985	1	5	–

(continued)

Table 3 (continued)

Variables	Mean	SD	Min	Max	Obs.	Variables	Mean	SD	Min	Max	Obs.
PROF_4	0.098	0.299	0	1	18	14. Perception of the FTA participation of Japan					
PROF_5	0.071	0.258	0	1	13	*FTA*	2.891	1.010	1	5	–
PROF_6	0.022	0.147	0	1	4	15. Age of representatives					
PROF_7	0.208	0.407	0	1	38	*AGE_R*	5.098	1.158	2	7	–
9. Development stage of the corporation						16. Educational background of representatives					
STAGE_1	0.066	0.248	0	1	12	*EDU_1*	0.546	0.499	0	1	100
STAGE_2	0.404	0.492	0	1	74	*EDU_2*	0.077	0.267	0	1	14
STAGE_3	0.164	0.371	0	1	30	*EDU_3*	0.142	0.350	0	1	26
STAGE_4	0.060	0.238	0	1	11	*EDU_4*	0.055	0.228	0	1	10
STAGE_5	0.169	0.376	0	1	31	*EDU_5*	0.366	0.483	0	1	67
STAGE_6	0.104	0.306	0	1	19	*EDU_6*	0.027	0.163	0	1	5
STAGE_7	0.027	0.163	0	1	5	*EDU_7*	0.027	0.163	0	1	5
STAGE_8	0.000	0.000	0	0	0	17. Non-agricultural experience of representatives					
STAGE_9	0.005	0.074	0	1	1	*NAGRI*	3.186	1.980	1	6	–

$N = 183$

management, and educational background of representatives as the potential determinants of ICT&SF technologies adoption by Japanese agricultural corporations. Here we mainly discuss these indicators with parameters at 1 and 5% significance levels. First, the marginal effect of *CFORM_3* on ICT&SF technology adoption was −2.431 at 5% significance level, indicating that cooperative agricultural corporations tend to adopt fewer technologies than limited companies. Second, the coefficient of *FARML* was positive and statistically significant at 5% level, indicating that corporations eligible to own farmland were likely to adopt two more technologies. Third, the self-evaluation of ICT utilization and information management significantly and positively affected technology adoption ($p < 0.01$). It demonstrated that corporations with a higher self-evaluation of ICT utilization and information management tended to use more ICT&SF technologies. Finally, the marginal effects of *EDU_2* and *EDU_3* are both positive statistically significant at 5% level, indicating the representatives who graduated from specialized schools and vocational colleges were more likely to adopt ICT&SF technologies. These results differ from the finding of Carrer et al. (2017), who demonstrated that university-level education positively affected the likelihood of technology adoption in farm management. This discrepancy may be explained by the fact that representatives who graduate from specialized schools and vocational colleges have more opportunities to receive specific agricultural knowledge and training lessons on farming skills and are, therefore, more willing to adopt technologies.

Table 4 Result of negative binomial regression model

	NB2		NB1	
	Parameter	Marginal effect	Parameter	Marginal effect
1. Corporate form (benchmark: *CFORM_1*, limited company)				
CFORM_2	−0.046	−0.306	−0.049	−0.323
CFORM_3	−0.361**	−2.391**	−0.367**	−2.431**
CFORM_4	−0.273	−1.805	−0.290	−1.923
2. Eligibility to own farmland				
FARML	0.246**	1.627**	0.257**	1.700**
3. Location of corporation (benchmark: *R_HKD*, Hokkaido)				
R_TH	−0.032	−0.209	−0.021	−0.141
R_KT	−0.040	−0.265	−0.031	−0.204
R_HR	0.030	0.201	0.036	0.240
R_KKTK	0.380	2.516	0.395	2.616
R_CHSK	−0.083	−0.547	−0.078	−0.516
R_KSON	−0.088	−0.581	−0.080	−0.532
4. Age of corporation				
AGE_C	0.001	0.009	0.001	0.008
5. Establishment background (benchmark: *ESTAB_1*, a farmer established a solely owned corporation)				
ESTAB_2	0.014	0.091	0.020	0.131
ESTAB_3	0.218	1.442	0.219	1.453
ESTAB_4	0.029	0.193	0.046	0.305
ESTAB_5	0.115	0.764	0.127	0.842
ESTAB_6	0.107	0.707	0.115	0.764
ESTAB_7	−0.179	−1.184	−0.166	−1.097
6. Human capital				
BM	0.038*	0.249*	0.038	0.252
RE	0.000	−0.002	0.000	−0.002
7. Annual sales				
SALE	−0.016	−0.107	−0.017	−0.110
8. Profit margin (benchmark: *PROF_1,* 0%)				
PROF_2	0.012	0.078	0.011	0.075
PROF_3	−0.136	−0.900	−0.138	−0.916
PROF_4	0.041	0.271	0.053	0.354
PROF_5	−0.139	−0.921	−0.129	−0.855
PROF_6	−0.267	−1.770	−0.251	−1.665
PROF_7	0.073	0.486	0.075	0.495

(continued)

Table 4 (continued)

	NB2		NB1	
	Parameter	Marginal effect	Parameter	Marginal effect
9. Development stage of the corporation (benchmark: *STAGE_1*, starting)				
STAGE_2	0.079	0.522	0.096	0.634
STAGE_3	0.186	1.233	0.205	1.358
STAGE_4	−0.029	−0.193	−0.004	−0.025
STAGE_5	0.186	1.234	0.212	1.403
STAGE_6	0.313	2.075	0.331	2.195
STAGE_7	0.165	1.095	0.160	1.059
STAGE_8	(omitted)	0.000	(omitted)	0.000
STAGE_9	−0.245	−1.620	−0.203	−1.342
10. Sales target for the next 5 years (benchmark: *TSALE_1*, maintain)				
TSALE_2	0.241*	1.595*	0.247*	1.637*
TSALE_3	0.110	0.728	0.114	0.753
TSALE_4	0.318	2.105	0.340	2.249
TSALE_5	−0.020	−0.135	−0.011	−0.076
TSALE_6	0.107	0.711	0.124	0.818
TSALE_7	0.114	0.754	0.125	0.826
TSALE_8	0.042	0.280	0.090	0.595
TSALE_9	(omitted)	0.000	(omitted)	0.000
11. Profit target for the next 5 years (benchmark: *TPROF_1*, 0%)				
TPROF_2	0.262	1.736	0.268	1.776
TPROF_3	0.419*	2.778*	0.414	2.739
TPROF_4	0.319	2.111	0.314	2.079
TPROF_5	0.528**	3.494**	0.520*	3.443*
TPROF_6	0.475*	3.149*	0.469	3.104
TPROF_7	−0.724	−4.795	−0.731	−4.844
12. Major product (benchmark: *PROD_1*, paddy rice)				
PROD_2	(omitted)	0.000	(omitted)	0.000
PROD_3	−0.031	−0.206	−0.048	−0.317
PROD_4	0.030	0.201	0.038	0.255
PROD_5	0.042	0.275	0.036	0.241
PROD_6	−0.452**	−2.996**	−0.475*	−3.144*
PROD_7	−0.072	−0.474	−0.064	−0.425
PROD_8	−0.253	−1.675	−0.240	−1.587
PROD_9	−0.026	−0.169	−0.022	−0.145

(continued)

Table 4 (continued)

	NB2		NB1	
	Parameter	Marginal effect	Parameter	Marginal effect
PROD_10	−0.139	−0.922	−0.133	−0.882
PROD_11	0.343	2.269	0.365	2.415
PROD_12	0.364*	2.413*	0.376*	2.493*
PROD_13	−0.045	−0.296	−0.051	−0.341
PROD_14	0.003	0.017	0.014	0.092
13. Self-evaluation of ICT utilization and information management				
SELF_U	0.344***	2.279***	0.345***	2.287***
14. Perception of the FTA participation of Japan				
FTA	0.058	0.386	0.059	0.394
15. Age of representatives				
AGE_R	−0.035	−0.232	−0.036	−0.237
16. Educational background of representatives				
EDU_2	0.287**	1.901**	0.293**	1.939**
EDU_3	0.287**	1.900**	0.289**	1.913**
EDU_4	−0.179	−1.188	−0.198	−1.309
EDU_5	−0.027	−0.177	−0.033	−0.217
EDU_6	−0.153	−1.012	−0.156	−1.031
EDU_7	−0.010	−0.068	−0.002	−0.017
17. Non-agricultural experience of representatives				
NAGRI	0.020	0.135	0.021	0.142
_cons	−0.045		−0.092	
N	183		183	
Pseudo-R^2	0.145		0.146	
Log likelihood	−433.160		−432.347	
Lnalpha	−15.603			
Lndelta			−1.882**	
AIC	1006.319		1004.694	
BIC	1230.983		1229.358	

Note ***, **, * denote statistically significance level of 1%, 5%, 10% respectively; The parameter here can be interpreted as semi-elasticity, and marginal effect is calculated at the mean of the dependent variable (Paxton et al., 2011)

With regard to the empirical results at 10% significance level, first, the marginal effect of *TSALE_2* was 1.637, indicating that corporations targeting 1.2 times sales growth in the next 5 years were likely to use two more technologies than corporations aiming to maintain the current sales. Second, the marginal effect of *TPROF_5* was 3.443, indicating that corporations targeting 15–20% profit growth in the next 5 years were likely to use three more technologies than corporations that aimed to maintain the profit. Finally, the marginal effects of *PROD_6* and *PROD_12* were −3.144 and 2.493, respectively. Compared with the benchmark major product "paddy rice", corporations operating "flowers and foliage plants" were likely to use three less technologies, whereas corporations operating "poultry" were likely to use two more technologies.

In particular, indicators with estimated parameters at 10% significance level were slightly different from the previous results, which based on 193 samples (see Table 5 in Appendix). Some variables with 10% significance level in the previous version, such as the number of board members and representatives' age, were altered. As shown in Table 14.4, the number of board members promoted ICT&SF technologies adoption even the marginal effect is not significant. Similarly, the coefficient of *AGE_R* was insignificant as well, but still, it revealed a negative sign. This is also consistent with a previously reported finding from the adoption literature, which demonstrated a negative association between the age of decision-makers and technology adoption (Simmons et al., 2005).

4 Conclusion

Through a national questionnaire survey of "Business Development and Innovation in Agricultural Corporation Management", this study identified the determinants of ICT&SF technology adoption by Japanese agricultural corporations. Negative binomial models were employed to examine the relevant corporate attributes and representative characteristics potentially affecting the technology adoption by agricultural corporations.

The results revealed that, of the 183 sampled corporations, 175 had adopted at least one ICT&SF technology until 2019, indicating an overall adoption rate of 95.6%. Among the 21 ICT&SF technologies, the most frequently adopted component was financial management systems, such as bookkeeping and accounting, with an adoption rate of 84.2%, whereas the least frequently adopted technology was the measurement of crop growth using drones and artificial satellites, with an adoption rate of 5.5%. Regarding the attributes of sampled corporations, majority (84.7%) of the corporations were limited and stock companies and 86.9% were qualified to own farmlands. In addition, 18.0% corporations operated paddy rice as major product and only 1.1% mainly operated beans and coarse cereals. Regarding the profile of corporate representatives, over half of the representatives (54.6%) graduated from high schools and 36.6% from universities.

The results of empirical models revealed corporate form, eligibility to own farmland, sales target, profit target, major product, self-evaluation of ICT utilization and information management, and educational background of representatives as the potential determinants of technologies adoption by Japanese agricultural corporations. Specifically, regarding corporate form, cooperative agricultural corporations tended to adopt fewer technologies than limited companies. Moreover, corporations eligible to own farmland were likely to adopt two more technologies. Regarding sales and profit targets, corporations aiming to increase their sales by 1.2 times the current value or raise their profits by 15–20% of the current margin in the next 5 years were likely to adopt more technologies than those aiming to maintain the current status. Compared with corporations operating paddy rice as the major product, those mainly operating flowers and foliage plants were likely to use less technologies, whereas those targeting poultry were likely to adopt more technologies. Moreover, the self-valuation of ICT utilization and information management positively affected technology implementation. Finally, in terms of corporate representatives' characteristics, those who graduated from specialized schools and vocational colleges were more likely to adopt the technologies.

Appendix

See Table 5.

Table 5 Comparison of NB1 results with different sample sizes

	$N = 195$		$N = 183$	
	Parameter	Marginal effect	Parameter	Marginal effect
1. Corporate form (benchmark: *CFORM_1*, limited company)				
CFORM_2	−0.001	−0.004	−0.049	−0.323
CFORM_3 (agricultural cooperative corporations)	−0.334**	−2.184 **	−0.367**	−2.431**
CFORM_4	−0.249	−1.627	−0.290	−1.923
2. Eligibility to own farmland				
FARML	0.195	1.274	0.257**	1.700**
3. Location of corporation (benchmark: *R_HKD*, Hokkaido)				
R_TH	−0.292	−1.908	−0.021	−0.141
R_KT	−0.263	−1.721	−0.031	−0.204
R_HR	−0.203	−1.328	0.036	0.240
R_KKTK	0.108	0.704	0.395	2.616
R_CHSK	−0.276	−1.808	−0.078	−0.516
R_KSON	−0.276	−1.808	−0.080	−0.532
4. Age of corporation				
AGE_C	0.003	0.017	0.001	0.008
5. Establishment background (benchmark: *ESTAB_1*, a farmer established a solely owned corporation)				
ESTAB_2	0.025	0.161	0.020	0.131
ESTAB_3	0.182	1.193	0.219	1.453

(continued)

Table 5 (continued)

	$N = 195$		$N = 183$	
	Parameter	Marginal effect	Parameter	Marginal effect
ESTAB_4	0.2	1.309	0.046	0.305
ESTAB_5	0.162	1.063	0.127	0.842
ESTAB_6	0.146	0.953	0.115	0.764
ESTAB_7	−0.189	−1.239	−0.166	−1.097
6. Human capital				
BM (number of board members)	0.041*	0.270*	0.038	0.252
RE	0.000	−0.003	0.000	−0.002
7. Annual sales				
SALE	−0.024	−0.157	−0.017	−0.110
8. Profit margin (benchmark: *PROF_1*, 0%)				
PROF_2	0.084	0.547	0.011	0.075
PROF_3	−0.010	−0.065	−0.138	−0.916
PROF_4	0.129	0.842	0.053	0.354
PROF_5	−0.011	−0.075	−0.129	−0.855
PROF_6	−0.168	−1.098	−0.251	−1.665
PROF_7	0.130	0.849	0.075	0.495
9. Development stage of the corporation (benchmark: *STAGE_1*, starting)				
STAGE_2	0.202	1.321	0.096	0.634
STAGE_3	0.261	1.710	0.205	1.358
STAGE_4	0.042	0.274	−0.004	−0.025
STAGE_5	0.252	1.648	0.212	1.403
STAGE_6	0.331	2.166	0.331	2.195
STAGE_7	0.215	1.407	0.160	1.059
STAGE_8	−14.031	−91.810	(omitted)	0.000
STAGE_9	−0.065	−0.427	−0.203	−1.342
10. Sales target for the next 5 years (benchmark: *TSALE_1*, maintain)				
TSALE_2 (1.2 times)	0.149	0.978	0.247*	1.637*
TSALE_3	0.046	0.298	0.114	0.753
TSALE_4	0.313	2.045	0.340	2.249
TSALE_5	−0.043	−0.281	−0.011	−0.076
TSALE_6	0.042	0.275	0.124	0.818
TSALE_7	0.126	0.823	0.125	0.826
TSALE_8	−0.101	−0.659	0.090	0.595
TSALE_9	(omitted)	0.000	(omitted)	0.000

(continued)

Table 5 (continued)

	$N = 195$		$N = 183$	
	Parameter	Marginal effect	Parameter	Marginal effect
11. Profit target for the next 5 years (benchmark: *TPROF_1*, 0%)				
TPROF_2	0.095	0.622	0.268	1.776
TPROF_3	0.203	1.328	0.414	2.739
TPROF_4	0.092	0.603	0.314	2.079
TPROF_5 (10–15%)	0.279	1.828	0.520*	3.443*
TPROF_6	0.192	1.257	0.469	3.104
TPROF_7 (no target)	−0.926*	−6.060*	−0.731	−4.844
12. Major product (benchmark: *PROD_1*, paddy rice)				
PROD_2	(omitted)	0.000	(omitted)	0.000
PROD_3	−0.034	−0.220	−0.048	−0.317
PROD_4	−0.012	−0.080	0.038	0.255
PROD_5	−0.065	−0.428	0.036	0.241
PROD_6 (flowers and foliage plants)	−0.499**	−3.265**	−0.475*	−3.144*
PROD_7	−0.155	−1.011	−0.064	−0.425
PROD_8	−0.279	−1.825	−0.240	−1.587
PROD_9	−0.140	−0.916	−0.022	−0.145
PROD_10	−0.240	−1.572	−0.133	−0.882
PROD_11	0.257	1.681	0.365	2.415
PROD_12 (poultry)	0.218	1.425	0.376*	2.493*
PROD_13	−0.214	−1.397	−0.051	−0.341
PROD_14	−0.058	−0.380	0.014	0.092
13. Self-evaluation of ICT utilization and information management				
SELF_U	0.328***	2.146***	0.345***	2.287***
14. Perception of the FTA participation of Japan				
FTA	0.045	0.293	0.059	0.394
15. Age of representatives				
AGE_R	−0.065*	−0.425*	−0.036	−0.237
16. Educational background of representatives				
EDU_2 (specialized schools)	0.298**	1.950**	0.293**	1.939**
EDU_3 (vocational colleges)	0.246*	1.613*	0.289**	1.913**
EDU_4	−0.214	−1.401	−0.198	−1.309
EDU_5	−0.029	−0.188	−0.033	−0.217

(continued)

Table 5 (continued)

	N = 195		*N* = 183	
	Parameter	Marginal effect	Parameter	Marginal effect
EDU_6	−0.240	−1.567	−0.156	−1.031
EDU_7	0.075	0.492	−0.002	−0.017
17. Non-agricultural experience of representatives				
NAGRI	0.006	0.038	0.021	0.142
_cons	0.641		−0.092	
N	195			183
Pseudo-R^2	0.148		0.146	
Log likelihood	−459.061		−432.847	
Lndelta	−1.716**		−1.882**	
AIC	1060.122		1004.694	
BIC	1292.505		1229.358	

Note ***, **, * denote statistically significance level of 1%, 5%, 10% respectively

References

Bucci, G., Bentivoglio, D., & Finco, A. (2019). Factors affecting ict adoption in agriculture: A case study in italy. *Quality—Access to Success, 20*(S2), 122–129.

Cameron, A. C., & Trivedi, P. K. (1986). Econometric models based on count data: Comparisons and applications of some estimators and tests. *Journal of Applied Econometrics, 1*(1), 29–53. https://doi.org/10.1002/jae.3950010104

Carrer, M. J., de Souza Filho, H. M., & Batalha, M. O. (2017). Factors influencing the adoption of Farm Management Information Systems (FMIS) by Brazilian citrus farmers. *Computers and Electronics in Agriculture, 138*, 11–19. https://doi.org/10.1016/j.compag.2017.04.004

Ehiakpor, D. S., Danso-Abbeam, G., & Mubashiru, Y. (2021). Adoption of interrelated sustainable agricultural practices among smallholder farmers in Ghana. *Land Use Policy*, *101*(November 2020), 105142. https://doi.org/10.1016/j.landusepol.2020.105142

EU-JAPAN CENTRE FOR INDUSTRIAL COOPERATION ECOS GmbH. (2021). *Smart farming technology in Japan and opportunities for EU companies*. ECOS. https://www.ecos.eu/files/content/downloads/publikationen/REPORT_Smart_Farming.pdf

Fountas, S., Carli, G., Sørensen, C. G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J., & Tisserye, B. (2015). Farm management information systems: Current situation and future perspectives. *Computers and Electronics in Agriculture, 115*, 40–50. https://doi.org/10.1016/j.compag.2015.05.011

Isgin, T., Bilgic, A., Forster, D. L., & Batte, M. T. (2008). Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption. *Computers and Electronics in Agriculture, 62*(2), 231–242. https://doi.org/10.1016/j.compag.2008.01.004

Knierim, A., Kernecker, M., Erdle, K., Kraus, T., Borges, F., & Wurbs, A. (2019). Smart farming technology innovations—Insights and reflections from the German Smart-AKIS hub. *NJAS—Wageningen Journal of Life Sciences, 90–91*(October), 100314. https://doi.org/10.1016/j.njas.2019.100314

Knowler, D., & Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy, 32*(1), 25–48. https://doi.org/10.1016/j.foodpol.2006.01.003

MAFF (Ministry of Agriculture Forestry and Fisheries). (2020). *Agriculture and Forestry Census in 2020 (in Japanese).*

MAFF (Ministry of Agriculture Forestry and Fisheries). (2022). *Smart agriculture (in Japanese).* https://www.maff.go.jp/j/kanbo/smart/attach/pdf/index-69.pdf

Mi, J., Nanseki, T., Chomei, Y., Uenishi Y., & Nguyen, T. L. (2021). Determinants of ICT and smart farming technology adoption by agricultural corporations in Japan. In *The 10th The Asian Society of Agricultural Economists International Conference.* http://www.asae2020.pku.edu.cn/index.htm

Nanseki, T. (2019). *Smart agriculture practice in rice-farming and perspective of farm in next-generation (in Japanese).* (T. Nanseki, Ed.). Yokendo, Tokyo, Japan.

Nanseki, T. (2021). *Agricultural corporations as seen from fact data: Profile, business operation, strategy and innovation (in Japanese).* Agriculture and Forestry Statistics Publishing Inc.

Nanseki, T., Chomei, Y., & Matsue, Y. (2016). *Rice farm management innovation and smart agriculture in TPP era: Farming technology package and ICT applications (in Japanese).* (T. Nanseki, Y. Chomei, & Y. Matsue, Eds.). Yokendo, Tokyo, Japan.

Ogata, Y., Nanseki, T., & Chomei, Y. (2019). Factor analysis of agricultural corporation managers' consciousness of ICT cost-effectiveness (in Japanese). *Agricultural Information Research, 28*(1), 1–12. https://doi.org/10.3173/air.28.1

Paxton, K. W., Mishra, A. K., Chintawar, S., Roberts, R. K., Larson, J. A., English, B. C., Lambert, D. M., Marra, M. C., Larkin, S. L., Reeves, J. M., & Martin, S. W. (2011). Intensity of precision agriculture technology adoption by cotton producers. *Agricultural and Resource Economics Review, 40*(1), 133–144. https://doi.org/10.1017/S1068280500004561

Rahelizatovo, N. C., & Gillespie, J. M. (2004). The adoption of best-management practices by Louisiana Dairy Producers. *Journal of Agricultural and Applied Economics, 36*(1), 229–240. https://doi.org/10.1017/s1074070800021970

Simmons, P., Winters, P., & Patrick, I. (2005). An analysis of contract farming in East Java, Bali, and Lombok, Indonesia. *Agricultural Economics, 33*(SUPPL 3), 513–525. https://doi.org/10.1111/j.1574-0864.2005.00096.x

Zhang, S., Sun, Z., Ma, W., & Valentinov, V. (2020). The effect of cooperative membership on agricultural technology adoption in Sichuan, China. *China Economic Review, 62*(August 2019), 101334. https://doi.org/10.1016/j.chieco.2019.101334