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Contrasting Considerations among Agricultural Stakeholders in Japan on Sustainable Nitrogen Management

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Abstract: Sustainable nitrogen (N) management in agriculture is one of the most important issues affecting the environmental performance of modern agriculture. It is actually well perceived that coordinated efforts and holistic approaches are required to regulate N use by farmers. The purpose of this study was to provide an initial examination of stakeholders' views in Japan regarding N use in agriculture and challenges to increase its sustainability. The analysis was based on a questionnaire study of five types of stakeholders (farmers, advisors, researchers, suppliers, policy makers). By means of multivariate analysis techniques it was revealed that consensus was lacking either in the acknowledgment of the causes and effects of unsustainable N management or in the challenges that need to be addressed. N losses from farms and the effects of N use were perceived but not conceived equally by all stakeholders. Organic farming and mandatory measures were the most controversial challenges, while those involving awareness, training and advisory were the most popular. This study cannot provide safe conclusions that can be generalized in the Japanese context, but it indicates domains where further research is required and orientations for future policy design towards more sustainable N use.

Keywords: nitrogen losses; farming practices; fertilizers; categorical principal component logistic regression

1. Introduction

A common characteristic of modern production systems is the over-exploitation of natural resources such as water and soil in order to meet the growing demand for food worldwide. At the same time, the need for environmental protection, biodiversity conservation and sustainable production is a global requirement. In the challenge of increasing crop yields while securing sustainable use of natural resources, the role of nitrogen (N) is considered very important. The overuse of N in agricultural activities and its excess in the environment serve as primary examples of the type of urgent problem of agriculture, but N is also a limiting factor in production systems, considering that gains in production of important crops are a result of increased inputs of N [1]. To face this challenge, the adoption of sustainable N management is necessary with measures at local and global scales. Indeed, agriculture is the biggest anthropogenic source of nitrate, a major pollutant of surface and groundwater, and of nitrous oxide (N_2O), a potent greenhouse gas accounting for 52% of the world anthropogenic N_2O emissions on average

from 2007 to 2016 [2] and only one of the key facts pointing toward the necessity of sustainable N management in agriculture. N loads via atmospheric deposition, runoff, and leaching to terrestrial and aquatic ecosystems cause possible eutrophication and then loss of biodiversity for sensitive species [3].

Policies and frameworks as well as technological innovations may help in achieving improvements in sustainable N management for addressing the triple challenges of food security, environmental degradation and climate change [4]. The level of success, nevertheless, of these policy measures is associated with the attitudes of different stakeholder groups towards the adoption of sustainable N practices. According to Arbuckle and Rosman [5], farmers of Iowa, USA, do not obtain enough knowledge on practices that have the highest potential for reducing the N pollution of water aquifers. The same study proved also the lack of farmers' knowledge even about the existence of such practices. According to Reimer et al. [1], farmers in four Midwestern states of the USA are aware of the environmental impact of excess N use. However, at the same time, the need to increase farm profitability through aggressive use of inputs affects their decision-making towards sustainable N management. Private advisors and consultants face challenges related to asymmetric information as a consequence of weak collaboration among key stakeholders and also emphasis on the need to improve farmers' technological skills and expertise [1]. In order to tackle such issues, numerous challenges exist including—but not restricted to—research and advisory support to farmers, collaboration and effective policy-making. Not only environmental considerations but also economic ones are important prerequisites for increasing farmers' interest in the adoption of sustainable N management [6].

The Japanese farming sector is characterized by the predominance of annual crops, as the largest area harvested was used for paddy rice production (1.54 million ha) followed by wheat (0.21 million ha), soybean (0.14 million ha), vegetables (0.12 million ha), and potatoes (0.07 million ha) in 2019 [7]. Import dependency on food and animal feed is a key feature of the Japanese food system, as self-sufficiency ratios were low at 37% for food (on a calorie basis) and 25% for animal feed (on a total digestible nutrients basis) in 2018 [8]. That is because imported agricultural products are basically cheaper than domestic ones, as Japan is generally a high-cost producer of farm products [9], thus putting pressure on Japanese agriculture and resulting in the relatively low income from farming. Indeed, the share of total farm household income derived from farming has only accounted for ca. 15% on average since 1980 [10]. The relatively low income from farming along with failures in farm succession due to the aging of farmers has led to abandonment of cultivated land since 1990s, ranging between 0.22 million ha in 1990 and 0.40 million ha in 2010 [11].

Inorganic N fertilizers are, perhaps, the most crucial inputs for the productivity of the Japanese farming sector and this, in turn, relates closely to its environmental sustainability. An integrated agri-environmental policy framework is thus in force, which emphasizes legal regulation but has paid less attention to environmental cross compliance and payments [12]. For cropland as non-point sources, direct payments are applied to promote environmentally friendly agriculture where reducing chemical N fertilizer is an aim [13]. The first direct payment in Japan was launched by Shiga Prefecture in 2004 to reduce the nutrient loads from agriculture to Lake Biwa, and the Japanese government has been implementing direct environmental payments nationwide since 2007 [12]. There are a few examples of direct payments to promote compost application, planting cover crop, living mulch, and no-tillage farming, etc., to increase soil carbon storage and of agricultural sector offsets in carbon dioxide emissions trading [12,13].

Despite these efforts, the N balance in agricultural areas in Japan showed a surplus of 152–186 kg N ha^{-1} from 2000 to 2017, and the level of N surplus was in the highest group of the OECD countries [14]. Agricultural N_2O emissions in Japan accounted for 44% on average from 2009 to 2018 of the total anthropogenic N_2O emissions in the country [15]. The engagement of multiple stakeholders in the farming sector points to the fact that each stakeholder group can represent different interests and attitudes regarding the use of N inputs in agriculture, which can somehow explain these facts [16,17]. Previous research

in Japan has examined the attitudes and preferences of specific stakeholder groups (e.g., farmers) with regards to environmentally friendly agriculture and financial incentives to support it [18–20]. So far, no case study of N management and considerations of more stakeholders has been undertaken, although N pollution is of importance in policy. Farmers' and stakeholders' attitudes with regards to N use and pollution have been examined in existing studies as part of their broader preferences for other environment-related issues. The examination of the attitudes of various stakeholders regarding the use of N in Japanese agriculture could yield important considerations for future research and policy-making.

The purpose of this study was to provide an initial quantitative examination of the opinions and attitudes of stakeholders on the use of N inputs in the Japanese farming sector. In particular, the study built on data from a questionnaire survey of a sample of key stakeholders engaged in the farming sector in Japan. By means of established methods of multivariate analysis, the paper revealed significant divergences in their opinions and attitudes regarding the actual use of N inputs, which also extended to their evaluation of challenges towards more sustainable N fertilization in Japanese farming. Since this is one of the first studies to examine this issue in a quantitative way, the results can be used as a primary step towards recognizing research and policy priorities for more sustainable N use in agriculture in the country. For this reason, the results are discussed in conjunction with previous research and findings.

2. Materials and Methods

2.1. Survey Design and Administration

Within the Towards International Nitrogen Management System (INMS) project (inms.international), a questionnaire was developed, aiming to record and analyze the attitudes, opinions, interests and aspirations of agricultural stakeholders worldwide regarding the sustainable management of N inputs in agriculture. The questionnaire was designed to accommodate the diversity of stakeholders involved in N management in agriculture (farmers; researchers/teachers; policy makers; input suppliers; practitioners/farm advisors), therefore it comprised three parts. The first part recorded the profile of the respondent (gender, age, education) as well the stakeholder group where he/she felt that he/she mostly belonged. The second part was specific to each group and varied across stakeholders, while the third was common to all survey participants. In the latter, respondents were presented with 5-point Likert-scale questions aiming to evaluate their attitudes and opinions regarding N loss from farms, the effects of N fertilizers, farming practices and sources of N pollution in the country. A separate Likert-scale question presented 17 challenges to respondents regarding the use of N fertilizers.

The survey was oriented towards the key stakeholder groups involved in sustainable N management, as identified within the INMS project. An online anonymous survey was conducted in Japan using the questionnaire translated into Japanese from 25 May 2020 to 26 August 2020, calling for expert networks (researchers and consultants) and personal networks and social media (other stakeholders). For this reason, the sample was not random and there was no control on the number of respondents from each stakeholder category. Responses were automatically recorded in a dedicated online spreadsheet, where Likert-scale variables were coded in a scale from 1 (=Not at all/Totally disagree) to 5 (=Very much/Totally agree).

2.2. Methodological Approach and Data Analysis

The methodological framework for the analysis of the categorical (ordinal) data in this paper combined (i) A descriptive analysis of responses to acquire a general view of respondents' attitudes and perceptions. The significance of differences across stakeholder groups was tested with the Kruskal–Wallis non-parametric test and with post hoc tests for pairwise comparisons, as the normality assumption for parametric tests did not stand, also due to differences in sample sizes across groups. (ii) A Categorical Principal Component Analysis (CatPCA) on categorical variables (items) describing the challenges that were

presented and evaluated by respondents, in order to reduce the number of variables and derive fewer (in number) and meaningful variables (dimensions) explaining the broader framework. (iii) Using the dimensions yielded by the CatPCA, a Multinomial Logit Model was used (Categorical Principal Component Logistic Regression—CPCRL) to examine potential differences in how each group of stakeholders regarding different dimensions of challenges (i.e., policy options).

2.2.1. Categorical Principal Component Analysis

Respondents' attitudes regarding challenges for future N use sustainability were analyzed with CatPCA in order to investigate the internal validity of specific survey variables. The method is very useful in multivariate analysis, as it reduces an original set of variables into a smaller set of uncorrelated components (dimensions) that represent most of the information (variance) found in the original variables [21]. For each variable in the original data set a correlation coefficient (factor loading) is estimated with each dimension, which is the criterion by means of which the dimension can be identified. As a rule of thumb, loadings higher than 0.7 indicate that the variable is correlated to the dimension, however in social sciences the subjective opinion of the researcher is also important for the identification task. The uncorrelated components (dimensions) are new variables that can be used in further analysis, so the researcher is able to deal with fewer variables without losing valuable information. In the application in this paper, the statistical package SPSS 24 was used for the analysis.

2.2.2. Categorical Principal Component Logistic Regression

A Multinomial Logit (MNL) model, widely applied in the social sciences literature [22,23], was employed in order to examine how different stakeholder groups evaluated challenges regarding sustainable N use. The basic Multinomial Logit Model is specified as follows:

$$P_{ij} = \frac{e^{X_i\beta_k}}{\sum_{k=1}^{J} e^{X_i\beta_k}} \ \forall j, k \in B$$

where P is the probability that outcome j occurs, X_i are independent variables and β_k the corresponding coefficients. This formulation of the logit model is estimated by the maximum likelihood estimation method. The most common goodness-of-fit measure is the McFadden pseudo-R2, which is a counterpart to R-square for linear regression. The Wald-statistic is a counterpart to the well-known t-statistic. The MNL model used in this paper is an application of CPCRL. In particular, the set of challenges presented to respondents was reduced to a smaller set of dimensions using CatPCA and then the new variables (dimensions) were used as the regressors (independent variables) in the multinomial logistic regression. The dependent variable accounted for the five stakeholder categories (farmers, consultants, researchers, policy makers, suppliers). The model was estimated using the econometric software package NLOGIT 6.0.

3. Results

3.1. Sample Profile and Characteristics

Table 1 presents the characteristics of the sample. Almost half of the respondents (49%) identified themselves as researchers, followed by advisors/consultants (20%). Policy makers and representatives from the supply industry were equally represented (10% each), while the remaining 16 respondents (11%) were farmers. The sample showed an over-representation of women, which exceeded the gender balance of the Japanese population. Also, almost all respondents held a Bachelor's or post-graduate degree, where, as expected, 96% of respondents categorized as "Researchers" had post-graduate studies. On the contrary, the age balance of respondents was more indicative of the population, as the majority of respondents belonged to the 31–45 (38%) and 46–60 (37%) age groups. Apart from education, there were no important deviations from the average characteristics across stakeholder groups.

In Japan farmers are categorized as follows in terms of their involvement in farming: (i) Full-time farmers have more than 50% of their income as agricultural income, are under 65 years old and have more than 60 days of agricultural work; (ii) Semi-full-time farmers have less than 50% of their total income as agricultural income and household members under the age of 65 who are engaged in self-employed farming for 60 days or more a year; (iii) Sideline farmers have no household members under the age of 65 who are engaged in self-employed farming for 60 days or more a year. Farmers in the sample were mostly full-time farmers (56%), followed by semi-full-time (25%) and sideline farmers (19%). That was largely different from the mean composition in Japan in 2020, that is, 22%, 14%, and 64%, respectively [24], which implies that farmers who participated in the study were more active and practical than the national average. Also, the sample composition of this survey differed greatly from the mean occupational population ratios in Japan, meaning that the number of stakeholders related to agriculture exhibited a small proportion in Japan. The ratio of agriculture and forestry (as industry) in the number of employed persons aged 15 or over was low and decreasing from 4.7% in 2000 to 3.5% in 2015 [25]. That ratio of scientific research, professional and technical services (including all fields not limited to agriculture) was 3.1–3.3% [25].

Table 1. Sample characteristics.

Variable	Frequency	Percentage (%)
Gender		
Male	42	28.0
Female	108	72.0
Age		
<30	16	10.7
31–45	57	38.0
46–60	56	37.3
>61	21	14.0
Education		
Primary education	0	0.0
Secondary Education	3	2.0
Technical graduate school	2	1.3
Bachelor's degree	40	26.7
Post-graduate studies	105	70.0
Stakeholder type		
Farmer	16	10.7
Consultant/Advisor	30	20.0
Researcher/Teacher	74	49.3
Policy maker	15	10.0
Industry/Supplier	15	10.0

3.2. Attitudes and Opinions Regarding the Use and Effects of N Fertilizers and N Pollution

Table 2 presents responses regarding four domains related to N use in agriculture. With regards to attitudes about N losses, most respondents were strongly in agreement with the fact that the reduction of N losses would make a difference (4.25 average score) and they were not aware of having N losses from their farm (3.61). When it came to the views of specific groups, there was general consensus that their reduction would lead to environmental benefits. Stakeholders also agreed—however, to a lesser degree—that farmers were not fully aware of such N losses in their farms and that they did not know of specific ways to reduce them, although they affected farm productivity. Contrasting views, however, were revealed regarding the extent of such N losses (between farmers, consultants and researchers) as well as the potential costs of interventions to reduce them (between consultants and researchers). In addition, suppliers supported the necessity to modernize farms in order to reduce N loss, contrary to farmers and researchers. Interestingly, diverging opinions were recorded regarding the extent to which farmers actually expected that their

behavior would make a difference, as farmers, consultants and researchers expressed neutral positions, contrary to suppliers, who confirmed disbeliefs in the actual interest that farmers had on the matter.

The environmental and economic effects of N fertilizers were generally highly acknowledged by respondents, especially with regards to adverse effects on water resources (4.23) and to the necessity to be used carefully (4.28). There was consensus with regards to consequences on productivity, water resources and soil. However, concerning air quality and climate change, farmers expressed more mediocre opinions compared to other stakeholders—especially suppliers and researchers—while significant divergence was also revealed between farmers and policy makers about effects on biodiversity. This dichotomy was also confirmed regarding the careful use of N fertilizers, as farmers were significantly less preoccupied with the issue compared to almost all other stakeholder groups.

Concerning respondents' opinions about N fertilization practices, respondents were slightly opposed to items concerning soil analysis to inform the use of N fertilizers by farmers (2.83); the availability of fertilizers as a barrier reducing their use (2.80); and the fact that their practices were oriented to the reduction of the environmental effects of N fertilizers (2.45). However, different levels of acceptability and contrasting views were expressed. There was consensus about the fact that farmers used fertilizers compatible to their machinery, which also achieved the highest mean score across all respondents, and also about the fact that farmers' choices of N quantities were not always aimed at higher economic performance. Stakeholders' opinions also converged regarding the fact that lack of accessibility was not a serious issue reducing the use of N fertilizers. Respondents also expressed agreement with the statement that "*It's not possible to be a crop farmer without using N fertilizers*", but farmers and policy makers expressed much lower levels of agreement compared to other groups—especially consultants and suppliers. Two additional significant points of divergence included environmental pressures and soil analyses. Regarding the former, farmers supported that their use of N fertilizers was low with a view to decrease environmental pressures, while all other stakeholders disagreed on that, especially researchers. Similarly, farmers reported that they performed soil analyses and adjusted their practices accordingly, but researchers and policy makers stated opposite opinions. Regarding the use of cheap fertilizers, significantly contrasting opinions were detected, but post hoc tests did not reveal specific disagreements between groups.

Chemical N fertilizers (4.06) and livestock production (3.98) were acknowledged as the most important sources of N pollution in the country, as for this item the highest mean was calculated. However, a dichotomy was detected between the views of consultants and researchers. Contrasting views were also pointed out regarding organic fertilizers (e.g., manure/compost, slurry, crop by-products), although no significant differences across groups could be reported. On the contrary, farmers did not acknowledge the transport sector as a source of N pollution, which diverged significantly from the point of view of researchers and consultants. The importance of other polluters, such as livestock production, industry, urban activities, and energy production, was also pointed out, but without significant differences across groups.

Table 2. Stakeholders' contrasting preferences regarding N use in agriculture in Japan.

	n = 150		Farmers (n = 16)		Consultants (n = 30)		Researchers (n = 74)		Policy makers (n = 15)		Suppliers (n = 15)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Attitudes regarding N losses												
Measures to reduce them are expensive	3.26 *	0.96	3.38 [ab]	0.72	3.63 [b]	1.03	3.09 [a]	0.94	3.20 [ab]	0.77	3.27 [ab]	1.16
Measures to reduce them will make a difference in environment	4.25	0.70	3.94	0.57	4.27	0.58	4.27	0.73	4.33	0.72	4.33	0.90
Measures/Technologies to reduce N losses are difficult to implement	3.21	1.01	3.19	1.05	3.30	0.99	3.20	1.03	3.20	0.86	3.13	1.13
Measures to reduce N losses affect productivity	3.53	0.95	3.19	0.98	3.80	0.85	3.46	0.98	3.53	0.64	3.73	1.16
Farmers are not aware of having N losses from their farm	3.61	1.00	3.44	1.03	3.63	1.10	3.54	0.97	3.93	0.88	3.80	1.01
Farmers do not know how to reduce N losses	3.42	0.98	3.13	0.96	3.33	0.99	3.42	0.99	3.80	0.86	3.53	0.99
Farmers think they won't make a difference, so they do not care	3.41 ***	0.98	3.06 [a]	0.57	3.27 [a]	0.87	3.34 [a]	1.05	3.73 [ab]	1.03	4.13 [b]	0.74
Farms need to be modernized in order to reduce N losses	3.28 ***	0.93	2.94 [a]	0.85	3.63 [ab]	0.89	3.15 [a]	0.92	3.00 [ab]	0.93	3.87 [b]	0.83
Investments to reduce N losses will not pay back	3.17	1.08	2.88	0.89	3.40	1.16	3.18	1.06	3.20	1.08	2.93	1.16
Farmers don't have N losses from their storage facilities	2.76 ***	0.96	3.56 [a]	1.03	3.13 [a]	0.97	2.49 [b]	0.83	2.67 [ab]	0.82	2.60 [ab]	0.99
Effects of N fertilizers												
Bad for water resources	4.23	0.77	4.06	0.77	4.27	0.69	4.19	0.81	4.40	0.83	4.33	0.72
Bad for air quality	3.83 ***	0.85	3.38 [a]	0.81	4.00 [ab]	0.64	3.85 [ab]	0.86	3.47 [a]	0.83	4.27 [b]	1.03
Accelerate climate change	3.83 ***	0.93	3.25 [a]	0.86	3.80 [ab]	0.92	3.93 [b]	0.85	3.60 [ab]	0.99	4.27 [b]	1.10
Bad for biodiversity	3.95 **	0.93	3.44 [a]	0.89	3.80 [ab]	0.81	4.08 [ab]	0.84	4.27 [b]	1.10	3.87 [ab]	1.25
Bad for soil quality	3.73	0.92	3.31	0.87	3.83	0.87	3.74	0.83	3.93	1.10	3.73	1.22
Increase productivity	3.89	0.78	3.75	0.45	3.87	0.78	3.85	0.77	3.80	1.08	4.33	0.72
Need to be used carefully	4.28 **	0.80	3.75 [a]	0.68	4.33 [b]	0.66	4.38 [b]	0.68	4.40 [b]	1.12	4.13 [ab]	1.13

Table 2. *Cont.*

	n = 150		Farmers (n = 16)		Consultants (n = 30)		Researchers (n = 74)		Policy makers (n = 15)		Suppliers (n = 15)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Farming practices regarding N fertilizers												
Farmers minimize N use to reduce environmental pressures	2.45 ***	0.92	3.50 [a]	0.82	2.77 [ac]	0.68	2.03 [b]	0.74	2.40 [bc]	0.91	2.80 [ac]	1.08
Farmers use N quantities which lead to highest economic performance	3.33	0.97	3.50	1.03	3.33	0.96	3.20	0.89	3.67	0.90	3.47	1.36
Farmers do soil analysis and use N accordingly	2.83 ***	0.97	3.50 [a]	1.03	3.13 [ab]	1.01	2.59 [b]	0.84	2.47 [b]	0.83	3.07 [ab]	1.03
Farmers use the cheapest N fertilizers	3.16 *	0.90	2.63	0.89	3.03	1.10	3.27	0.82	3.40	0.63	3.20	0.94
Farmers use fertilizers compatible to their machinery	3.69	0.85	3.25	1.13	3.60	0.93	3.73	0.76	3.80	0.86	4.00	0.65
If they had access to more fertilizers, farmers would use more	2.80	1.11	2.44	1.21	2.67	1.15	2.92	0.99	3.20	0.86	2.47	1.55
It's not possible to be a crop farmer without using N fertilizers	3.61 ***	1.00	3.00 [a]	1.10	3.87 [bc]	0.90	3.61 [abc]	0.96	3.20 [ac]	0.77	4.13 [b]	1.06
Importance of sources of pollution in the country												
Inorganic/mineral/synthetic/manufactured nitrogen fertilizers	4.06 **	0.91	3.63 [ab]	1.26	3.70 [a]	0.92	4.24 [b]	0.74	4.13 [ab]	0.99	4.27 [ab]	0.88
Organic fertilizers/manure/slurry/composts/other organic materials	3.69 *	1.09	3.25	0.77	3.93	1.01	3.73	1.02	3.20	1.42	3.93	1.28
Industry	3.77	0.92	3.38	1.20	4.03	0.56	3.76	0.90	3.80	0.94	3.67	1.11
Transports	3.51 **	1.05	2.75 [a]	1.06	3.80 [b]	0.96	3.55 [b]	1.00	3.33 [ab]	1.23	3.73 [ab]	0.96
Urban sources	3.70	0.93	3.38	1.09	3.97	0.72	3.61	0.92	3.67	1.05	4.00	1.00
Livestock production	3.98	0.91	3.56	1.09	3.83	0.87	4.16	0.81	3.93	0.88	3.87	1.13
Energy production	3.55	0.97	3.38	0.96	3.67	0.92	3.55	0.95	3.40	0.99	3.67	1.23

* *p*-value < 0.1; ** *p*-value < 0.05; *** *p*-value < 0.01 using the Kruskal–Wallis test; Significant differences between groups are denoted by different superscripts.

3.3. Challenges for More Sustainable N Management in Agriculture

Table 3 presents the results of the CatPCA on the set of 17 variables (items) describing challenges for sustainable N use in agriculture. The analysis yielded five principal components (Dimensions) with eigenvalues higher than 1, which accounted for 67.7% of total variance. These dimensions were kept for the analysis. Each one of them was named/characterized by the variables that had the higher loadings and were thus highly correlated with the specific dimension, as follows.

- *Dimension 1 "Targeted measures, research and training/advisory"*. The highest loadings were found for variables describing environmentally friendly techniques, targeted measures and research needs, as well as education, training and awareness requirements for farmers (including simple and understandable information and proposal of voluntary measures) and the general public (also communication).
- *Dimension 2 "Mandatory measures"* included two items that described compulsory measures and critical thresholds to decrease the use of N.
- *Dimension 3 "Organic production"* described challenges relating to organic practices, especially regarding the use of organic fertilizers and the further adoption of organic production in general.
- *Dimension 4 "Measures to control fertilization costs"* involved challenges to reduce costs and increase efficiency of N fertilizers, including collective provision, price regulation and more effective practices.
- *Dimension 5 "Top-down approaches"* encompassed policy-driven measures to regulate the use of N fertilizers, which involved subsidies to increase N use and a "top-down" shift to crops requiring less N (crop restructuring).

Table 3. Rotated CatPCA Table—Component loadings per dimension.

	Dimensions Component Loadings *				
	1	**2**	**3**	**4**	**5**
Mandatory measures with penalties to decrease use N fertilizers	0.079	**0.897**	0.006	0.024	0.030
More incentives to increase use of N fertilizers (subsidies)	−0.071	−0.210	−0.325	0.193	**0.706**
Establish critical thresholds by law/Mandatory regulations	0.315	**0.820**	0.032	0.081	−0.106
More free technical/advisory support from the public sector	**0.543**	0.266	0.067	0.400	−0.104
Better technology (more efficient fertilizers and practices)	0.462	0.070	0.193	**0.518**	−0.254
More widespread use of organic fertilizers	0.131	−0.076	**0.798**	0.380	0.073
More rational prices of fertilizers (relative to the economic outcome)	0.055	0.051	0.156	**0.793**	0.190
More incentives to decrease (voluntary policy measures)	**0.508**	0.426	0.122	0.214	−0.110
More training and communication about policies and measures	**0.696**	0.346	0.242	0.152	−0.015
Innovations to assist more widespread organic production	0.378	0.137	**0.752**	0.033	0.071
Environmentally friendly techniques for efficient fertilization	**0.691**	0.102	0.387	0.108	−0.140
Policies and measures tailor-made for specific regions (non-generic)	**0.732**	−0.086	−0.060	0.247	−0.088
Shift to crops requiring less N fertilizers	−0.047	−0.027	0.342	−0.103	**0.792**
Increased awareness and education for the general public	**0.692**	0.181	0.251	−0.242	0.076
More research regarding the effects of N fertilizers	**0.801**	0.125	0.032	0.018	0.061
Encourage collective provision of fertilizers (e.g., cooperatives)	0.195	0.265	0.137	**0.486**	0.560
Availability of simple and understandable information for farmers	**0.673**	0.204	0.220	0.092	0.161
Cronbach's-α	0.867	0.742	0.732	0.677	0.451
Eigenvalue	4.198	2.105	1.850	1.703	1.648
% of variance explained	24.69	12.38	10.88	10.02	9.70
% of variance explained (Total)			67.67		

* Varimax method with Kaiser Transformation. Component loadings in bold are the highest and most important in each dimension.

Table 4 presents the results of the CPCRL. According to the partial effects, there were not many dimensions that interpreted attitudes and pursuits of stakeholder groups significantly. For farmers, Dimensions 2 and 3 seemed to have a significant effect, showing that higher interest in challenges relating to mandatory measures and organic production affected the probability that one respondent belonged to this group. On the contrary, researchers expressed significant interest in mandatory measures and so did policy makers. Suppliers were mostly interested in issues categorized in Dimension 5, relating to top-down approaches to reduce N losses and increase efficiency. It should be noted that, for consultants, none of the five dimensions was found to be significant in explaining probability of categorization, while challenges in Dimension 1 and 4 were not significant explanatory variables for any of the five stakeholder categories.

Table 4. Results of Categorical Principal Component Logistic Regression (CPCRL)—Significant dimensions of challenges by stakeholder group.

	Partial Effects	Elasticity	z (Wald-Statistic)
Group 1. Farmers			
Dimension 1 "Targeted measures"	−0.03563	0.8348×10^{-4}	−1.56
Dimension 2 "Mandatory measures"	−0.05734 *	$−0.4478 \times 10^{-4}$	−1.79
Dimension 3 "Organic"	−0.03066 *	0.1994×10^{-17}	−1.75
Dimension 4 "Cost reduction"	0.01799	0.1405×10^{-4}	0.74
Dimension 5 "Top-down approaches"	−0.01214	0.2845×10^{-4}	−0.48
Group 2. Consultants			
Dimension 1 "Targeted measures"	0.00937	$−0.9016 \times 10^{-5}$	0.27
Dimension 2 "Mandatory measures"	−0.04843	$−0.1554 \times 10^{-4}$	−1.22
Dimension 3 "Organic"	−0.01439	0.3846×10^{-18}	−0.35
Dimension 4 "Cost reduction"	−0.00183	$−0.5880 \times 10^{-6}$	−0.05
Dimension 5 "Top-down approaches"	−0.04131	0.3976×10^{-4}	−1.10
Group 3. Researchers			
Dimension 1 "Targeted measures"	0.04494	$−0.1683 \times 10^{-4}$	1.08
Dimension 2 "Mandatory measures"	0.07518 *	0.9383×10^{-5}	1.67
Dimension 3 "Organic"	0.00577	$−0.5998 \times 10^{-19}$	0.10
Dimension 4 "Cost reduction"	−0.00912	$−0.1138 \times 10^{-5}$	−0.22
Dimension 5 "Top-down approaches"	−0.01741	0.6519×10^{-5}	−0.40
Group 4. Policy makers			
Dimension 1 "Targeted measures"	−0.01625	0.3333×10^{-4}	−0.67
Dimension 2 "Mandatory measures"	0.03690 *	0.2523×10^{-4}	1.77
Dimension 3 "Organic"	−0.01206	0.6865×10^{-18}	−0.41
Dimension 4 "Cost reduction"	0.02206	0.1508×10^{-4}	0.96
Dimension 5 "Top-down approaches"	0.01904	$−0.3905 \times 10^{-4}$	0.83
Group 5. Suppliers			
Dimension 1 "Targeted measures"	−0.00242	0.6445×10^{-5}	−0.12
Dimension 2 "Mandatory measures"	−0.00631	$−0.5590 \times 10^{-5}$	−0.28
Dimension 3 "Organic"	0.05134	$−0.3788 \times 10^{-7}$	1.21
Dimension 4 "Cost reduction"	−0.02911	$−0.2579 \times 10^{-4}$	−1.47
Dimension 5 "Top-down approaches"	0.05182 ***	−0.00014	2.89

* denotes significance at $p < 0.1$; *** denotes significance at $p < 0.01$.

Table 5 presents the specific challenges that were categorized in the five dimensions, along with the average score of responses for each one of them per stakeholder category. It is obvious that measures grouped in Dimension 1 achieved the highest averages, which showed that challenges relating to innovation and training/advisory were the most relevant to sustainable N management. Combined with CPCRL analysis, respondents' opinions did not diverge significantly and were relatively high for all items in this dimension. Challenges including organic production and cost reduction—grouped in Dimensions 3 and 4—also received high levels of acceptance overall—especially among farmers—except

for the importance of the role of cooperatives. On the other hand, the least preferred challenges were those relating to top-down approaches and mandatory measures. In particular, mandatory measures to regulate N use—either to increase or decrease it—were the least favorite options and this also applied to crop restructuring, if it was "imposed" top-down. The establishment of critical thresholds by law was more acceptable than other challenges grouped in these two dimensions—however, it was the least preferred by consultants and farmers.

Table 5. Evaluation of the five dimensions of challenges toward sustainable N management in agriculture by different stakeholder groups.

	Sample n = 150		Farmers (n = 16)		Consultants (n = 30)		Researchers (n = 74)		Policy makers (n = 15)		Suppliers (n = 15)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Dimension 1. Targeted measures, research and training/advisory												
More free technical/advisory support from the public sector	4.06	0.88	4.13	0.96	3.70	1.06	4.16	0.64	4.00	0.93	4.27	1.22
More training and communication about policies and measures	4.04	0.71	3.94	0.85	3.97	0.67	4.03	0.68	4.00	0.85	4.40	0.63
Environmentally friendly techniques for efficient fertilization	4.26	0.66	4.25	0.77	4.20	0.61	4.20	0.68	4.40	0.63	4.53	0.52
Policies and measures tailor-made for specific regions	4.21	0.65	4.13	0.89	4.20	0.66	4.15	0.59	4.27	0.70	4.60	0.51
Increased awareness and education for the general public	4.13	0.75	3.94	1.12	3.87	0.86	4.22	0.63	4.33	0.72	4.20	0.56
More research regarding the effects of N fertilizers	4.28	0.68	4.19	0.83	4.13	0.63	4.32	0.62	4.27	0.88	4.47	0.64
Availability of simple and understandable information for farmers	4.33	0.63	4.25	1.06	4.30	0.53	4.35	0.53	4.13	0.74	4.53	0.52
More incentives to decrease (voluntary policy measures)	4.25	0.69	4.00	0.82	4.33	0.55	4.27	0.67	4.20	0.77	4.27	0.88
Dimension 2. Mandatory measures												
Mandatory policy measures with penalties to encourage decreases in N fertilizers	3.15	0.97	**2.94**	1.06	2.67	0.88	**3.22**	0.82	**3.53**	0.92	3.67	1.35
Establish critical thresholds by law/Mandatory regulations	3.63	0.97	**3.13**	1.02	3.37	1.10	**3.68**	0.83	**4.13**	0.83	3.93	1.10
Dimension 3. Organic production												
More widespread use of organic fertilizers	3.92	0.85	**4.00**	0.63	3.60	1.07	4.08	0.72	3.87	0.99	3.73	0.88
Innovations to assist more widespread organic production	3.93	0.86	**4.06**	0.85	3.67	0.92	3.96	0.77	4.00	1.13	4.13	0.92
Dimension 4. Measures to control costs of fertilization												
More rational prices of fertilizers (relative to economic outcome)	3.91	0.87	4.06	0.93	4.13	0.78	3.86	0.83	3.73	0.96	3.73	1.10
Better technology (more efficient fertilizers and practices)	4.36	0.64	4.25	0.86	4.17	0.70	4.39	0.57	4.40	0.63	4.67	0.49
Encourage collective provision of fertilizers (e.g., cooperatives)	3.43	0.91	3.63	0.96	3.20	0.89	3.46	0.88	3.07	0.88	3.93	0.88
Dimension 5. Top-down solutions and practices												
More incentives to increase use of N fertilizers (subsidies)	3.01	1.23	2.63	1.09	3.00	1.23	3.08	1.20	2.87	1.30	**3.20**	1.47
Shift to crops requiring less N fertilizers	3.23	0.91	3.06	0.85	2.97	0.93	3.49	0.81	2.87	0.99	**3.00**	1.07

Numbers in bold denote significance in the CPCRL.

4. Discussion

The findings of this study pinpointed that advisory and training for farmers constitute key challenges that should be considered toward sustainable N use. The Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan, promotes organic farming to save the natural functions in the agricultural biosphere [26], providing supports to farmers, especially to increase new farmers [27]. MAFF created a web portal to support agricultural corporations and new agricultural applicants to increase new farmers. Apart from training and advisory for farmers, this study also revealed that public awareness was deemed an important challenge for increasing the sustainability of N use in Japanese agriculture. Sasaki [19] showed that there were positive relations of cause and effect between agri-environmental knowledge and consciousness of the environment based on a questionnaire survey in Shiga Prefecture, Japan.

The analysis in this paper revealed that voluntary policy measures were among the most preferred options to increase the sustainability of N use in agriculture. This was in line with the research presented by Kuriyama et al. [18], who deployed an experimental economic analysis for farmers and found that a subsidy for conservation has continuous effects on conservation behavior, while the conservation effects depend on the amount of subsidy. This system has been found effective in other areas—such as the European Union—in the form of Payments for Ecosystem Services, where farmers receive policy support contingent upon the provision of environmental services [28]. On the contrary, a non-monetary support system has a significant effect on conservation behavior only in its early stage, thereafter, financial incentives are needed to sustain the effect [18].

Awareness raising for the general public also received high score in this study, in line with Uetake and Sasaki [20]. In their study, farmers' profits would increase by means of an environmental payment to reduce chemical fertilizer use if the selling price of fertilizer-reduced crops was higher than that of conventional crops—which relates to consumer awareness. The same study also reported that direct environmental payments were effective to increase rice production and to improve environmental quality by enhancing crop N uptake and carbon storage. A 100% reduction of chemical fertilizers was not necessarily good compared to a 50% reduction since ammonia loss from manure might increase. Therefore, the finding of this study that N management measures would achieve environmental benefits coincided with the study by Uetake and Sasaki [20], which also applied to the fact that this study revealed a very high support for environmentally friendly techniques for efficient fertilization. This also applied to the finding of this study that input suppliers were in favor of modernizing the sector in order to increase sustainability of N use.

The results of the analysis demonstrated that two issues were the most contradictory. The first was the imposition of mandatory issues and top-down solutions. The low acceptability of a shift to crops with less N requirements showed that crop restructuring as an induced policy option is not acceptable. Mandatory measures were highly appreciated by policy makers, but received considerably lower scores from other stakeholders, which showed the disparity of preferences and their conflicting attitudes. Farmers and consultants, actual implementers of measures, particularly expressed much lower acceptability for such the measures. On the other hand, researchers supported a shift toward less N-demanding crops relatively more than other stakeholders. A survey conducted in Denmark by Case et al. [29] showed the importance of policies to a higher adoption of better N management measures. In their study, most farmers agreed that the restrictions imposed by national and supranational policies (e.g., Nitrate Directives, The Clean Water Act) was a key factor in enhancing N efficiency from manure application/use.

In addition, as expected, suppliers welcomed—more than others—measures to subsidize the use of N fertilizers, as in the example of developing countries in East Africa. However, the survey conducted by Rakshit [30] from 2015–2016—to evaluate the effects of the 2010 fertilizer subsidy measure—showed that this was not the best solution to promote agriculture productivity or the reduction of fertilizer losses. This finding was interesting, when considered alongside the low acceptability of measures relating to collective pro-

vision. Japan has a long history of agricultural cooperatives, that is, Japan Agricultural Cooperatives (JA), which was enacted in 1947 with the Agricultural Cooperative Law but can be traced back to the traditional cooperatives in the Edo era (1603–1868) [31,32]. The current JA movement is comprehensive, covering almost all needs of both the farming and non-farming communities including credit, mutual insurance, purchasing, processing, marketing, and welfare [31]. In fact, 74% of the fertilizer sales to farmers can be traced back to JA while the National Federation of Agricultural Cooperative Associations (ZEN-NOH) contributed to 50% of the procurement of raw fertilizer materials and 55% of the distribution of fertilizers in 2013 [33]. Although no significant discrepancies were detected across stakeholders in this study, the low score of this measure could reflect the fact that stakeholders did not consider that encouragement was required to enforce the role of JA in fertilizer procurement. In addition, the integration of cooperatives in the country, which led to a decrease from 3591 in 1990 to 719 in 2010, largely aimed to strengthen the purchasing and sales business of JA [34]. In addition, this situation partially explained why suppliers were strongly in favor of a further reinforcement of the procurement and distribution system already established by JA and their associations, as they obviously preferred to sell to cooperatives and thus to reduce uncertainty and transaction costs.

The second contradictory issue was organic production. In order to adopt organic practices, the positive attitude of farmers toward new measures and innovations to support organic production was proposed by this study and respondents were found to be in favor. There is significant evidence that certain practices relating to organic production, such as the use of composts, can be advantageous to promote residues treatment and nutrients recycling, besides the advantage of organic matter addition to soils. Benefits include reduction of mass, volume, and water content compared with fresh manure, which in turn reduces transportation requirements. Concomitant benefits also involve elimination of pathogens, parasites, weed seeds and odor emissions on land application via the fermentation process. Compost also enhances soil physical and biological properties and has a disease suppression effect [35,36]. However, the lack of synchrony between crop needs and nutrient release from composts may, in turn, increase ammonia and nitrate loss and, depending on the source of the material composted, there is an associated risk of undesired element build-up in soils. This leads to the necessity of taking close care about organic practices to avoid trade-offs and pollution swapping.

MAFF promotes organic farming in Japan based on the Act on the Promotion of Organic Agriculture enacted in 2006. However, the area for organic farming is still very small, only less than 0.6% of the total cropland area of Japan [33]. In addition, as explained in Miyake and Kohsaka [37], organic production in Japan is in need of better contextualization and definition. Therefore, the findings of this study could set a good starting point to discuss and design policies targeted to the needs of farmers. However, positive attitudes about organic farming by farmers in this study could be partially due to the over-representation of full-time farmers in the sample, who are generally more active and expected to be more inclined toward organic production and environmental protection through practices that include minimal use of N fertilizers and performance of soil analyses to adjust their practices accordingly. Thus, the policies to support farmers' eagerness to adopt new measures and innovations for organic production, instead of mandatory requirements, could be more feasible to start the discussion. In this domain, the role of agricultural cooperatives should be considered because of their current orientation toward bulk provision of chemical fertilizers.

Among the public goods treated by Japanese agri-environmental policy, that is, landscapes, biodiversity, water quality, soil quality and protection, climate change, air quality, and resilience to natural disaster [10], water quality and climate change are closely related to the agricultural N use. With respect to N management, Japanese agri-environmental policy treats water quality as the most important public good [10]. Livestock wastewater and runoff and leaching of N from croplands as non-point sources have caused water pollution [38]. That was reflected well in the survey, in the high agreement with "Bad

for water resources" (Table 2). Water quality is regulated by relevant laws, which focus on achievement of the environmental standards (i.e., nitrate and total N concentrations in water) and regulate discharge from livestock farming. Water quality is linked to both human health as drinking water and ecosystem health via eutrophication. Concentrations of nitrate and total N in terrestrial water have been improved since the beginning of the 2000s, whereas the environmental standards of water pollution have often been violated in groundwater for nitrate and in lake water for total N [39,40]. The mean ratio of agricultural areas that exceeded drinking water limits for nitrate in groundwater was 5% in 2000 and the level of exceedance was 17th out of 23 countries [41]. However, the groundwater nitrate pollution tends to be persistent as shown in that exceedance of the nitrate standard was 17.3% in the survey of the areas adjacent to polluted wells and 42.6% in the monitoring survey of polluted wells in 2018 [40]. A general improvement in water quality regarding nitrate concentrations is usually accompanied by the existence of contamination/pollution hotspots due to agricultural activities, as demonstrated by [42,43]. This means that a closer look must be given to local and regional aspects of N losses, and all actors must be involved in the development of sustainable N management.

The highest agreement of policy makers with "Bad for biodiversity" was also interesting compared to the existing situation in the country, because the Japanese agri-environmental policy does not directly relate the N issue to biodiversity conservation (rather relating agrochemicals and invading species intendedly or unintendedly introduced with agricultural practices to biodiversity conservation). Note that the biodiversity aspect of the Japanese agri-environmental policy is to conserve farm areas including surrounding areas as agro-ecosystems. In the same context, opinions regarding N use and soil quality were not contrasting and the average was lower than for other natural resources, although soil quality is also subject to agricultural N use since a long-term or heavy use of N fertilizer can acidify cropland soil without soil amendments to neutralize, like lime [44].

5. Conclusions

The analysis of survey data in this study provided some initial support to the argument that agricultural stakeholders in Japan recognize the importance of agricultural N effects and of related N loss from farms. In addition, average responses regarding the adoption of sustainable N management practices showed that significant room for improvement is deemed. However, stakeholders' views diverged in several statements in all domains under examination in this study, including the challenges that need to be addressed toward sustainable N use.

The main conclusion that can be derived from this study is that the different views of stakeholders in key issues could be one of the causes of N surplus in the country, as consensus was lacking either in the acknowledgment of the causes and effects of unsustainable N management or in the challenges that need to be addressed. Thus, the present study demonstrated that it is worth taking a step forward to elucidate the awareness in Japan of sustainable agriculture from the viewpoint of N management, including information on the potential co-benefits and drawbacks of N losses. Among the most important findings that could be considered in policy design is that there was a significant positive attitude of farmers toward new measures and innovations to support organic production. This could be a good starting point to discuss policies targeted to the needs of farmers, also providing a hopeful future for sustainable agriculture in Japan.

The basic limitation of this study is that the sample is too small and not representative of key agricultural stakeholders in Japan. For this reason, by no means could the results reported here be used directly in policy-making. However, this is one of the first studies tackling attitudes and opinions about sustainable N management in Japan and the first one revealing contrasting considerations among agricultural stakeholders. The study results converging with previous research show that these findings could provide the basis to initiate policy debates and more widespread research in the field, with the examination of larger representative samples of respondents nationwide or in particular areas with high

levels of N use in agriculture. Such future studies could be supported and understood better through dedicated stakeholder analyses to grasp how each group perceives the role of other groups, but also their particular interests and perceptions regarding other environmental issues, cultural and societal values. Indeed, stakeholders' communication was found to be necessary and beneficial to better N management behaviors. Also, more research regarding the role of consumer-driven change in N management is required, as in the example described by Parker [45], who discussed an alternative form to enhance consumer-citizenship to have a say in what and how produce is grown and how the land is managed. Assessments of the roles and opinions of the general public are required toward this end, as in the study by Sasaki [19], according to which there were negative relations of cause and effect between food safety consciousness and consumers' evaluation of agri-environmental policy.

Institutional Review Board Statement: Not applicable.

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