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Comparative analysis of farmers engaged in participatory research to cope with climate change versus non-participants in Northeast Thailand

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ABSTRACT
To assess the extent of improvement of rainfed rice production by using a participatory approach, we compared research project participants and non-participants (total of 206 rice-growing households) with regard to yield variability and their perspective on climate change at seven sites in Northeast Thailand. The participants were characterized by membership in local groups, an active learning attitude, and confidence in their farming. Compared to non-participants, the participants produced crops with higher yield and had more knowledge about the Intergovernmental Panel on Climate Change (IPCC) message and advanced farming technologies. Both groups had similar reactions to past climatic damage experiences, but the participants tended to have a more positive attitude about adaptation to climate change and mitigation by refraining from residual straw burning than the non-participants. The farmers' attitude about adaptation to climate change was positively associated with their active learning and close relationship with researchers. There was a large yield gap between the bottom 10 percentile farmers (0.63 t/ha) and the top 10 percentile farmers (4.05 t/ha), with an average yield of 2.18 t/ha. Yield was associated with the level of market orientation, with the market-oriented farmers attaining higher yield, including yield from broadcast seeding (2.71 t/ha), than the subsistence farmers (1.66 t/ha). Our findings suggest that technical improvement of rice production in the region by using the participatory approach could be enhanced by selecting participants who are linked with local groups, tend to be market orientated, and are willing to learn with researchers.

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Introduction

The farmer participatory research approach has been used since the 1980s (Bentley, 1994; Farrington & Martin, 1988) to improve crop production in marginal agricultural ecosystems. Only a small portion of the total farming population—a few dozens per village or a few hundred per project—are selected to participate in each project. The manner of selecting farmers affects the progress of participatory projects and the speed and magnitude of subsequent dissemination of outputs from the projects.

Before selecting the participants, researchers usually make a preliminary visit to the target region and meet with key informants such as the village chief and experienced farmers (Manzanilla et al., 2014; Paris et al., 2011). In some cases, the key informants may call particular groups of farmers, or they may try to request that almost every farmer in the region participate in the project (Courtois et al., 2001; International Crops Research Institute for the Semi-Arid Tropics, 2001). The key informants sometimes approach farmers via local groups in announcing the project (Sanginga et al. 2006). Researchers may prefer participants with diverse economic, social, and technical backgrounds (Paris et al., 2008; Paris et al., 2011). However, these processes of selecting the farmers are often not transparent (Mitchell et al., 2014; Rahman et al., 2015; Singh et al., 2014).

In addition, the characteristics of participating farmers versus those of non-participants are often unclear. Participants may be more interested in research and economically better off, but the extent to which their management, production, and income in rice farming are superior to those of non-participants is not known. Hence, the effectiveness of a participatory project across the whole target region is often unclear. If participants are technically more advanced (e.g. producing higher yields) in the total population of farmers, the adoption of project achievements by the participants can be rapid and large, but the new methods may not be readily spread and accepted by non-participants due to their different backgrounds. In contrast, if participants are representative of the whole population and

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Supplementary Material can be accessed here.

exhibit a wide diversity of characteristics, this might limit the speed of adoption of project outputs by the participants (e.g. adoption of a machine), but the transfer from participants to non-participants can be faster. Therefore, understanding the characteristics of participating and non-participating farmers is important both for technology transfer from the researchers to participants during the project as well as for possible secondary dissemination from the participants to non-participants.

Farmer participatory research traditionally covered topics such as plant protection and variety selection, but recently adaptation to climate change has been included as well, because of global concerns about the negative effects of climate change (Intergovernmental Panel on Climate Change [IPCC], 2014; Redfern et al., 2012; Wassmann et al., 2009) and the specific nature of local climatic damage that requires local farmers' knowledge and experiences for finding better solutions (Campbell et al., 2016; Lipper, 2014). In Thailand, the Rice Department (RD) of the Ministry of Agriculture and Cooperatives conducted a participatory project named 'Strengthening farmers' adaptation to climate change in the rainfed lowland rice system in the Northeast' in 2012–2015 in order to study the impact of climate change on rice production and possible adaptation by farmers and to develop a sustainable rainfed lowland rice growing system in Northeast Thailand (Bureau of Rice Research and Development, 2012). Participants learned about climate change from researchers and observed newly developed technologies (e.g. drought- or flood-tolerant varieties and a drill seeder machine) and then were prompted to test some of the technologies. As a next step, it would be helpful to clarify the perceptions of farmers in Northeast Thailand about climate change and their attitudes about alternative technologies, including the differences between participants and non-participants.

In this study, we conducted comprehensive interviews with both project participants and non-participants to assess the possible improvement of rainfed rice production to cope with climate change through participatory research in Northeast Thailand. The objectives were to clarify the farming characteristics of participating farmers compared with those of non-participants, to identify the sources of yield variability, and to determine the local perception of climate change in the project area. We hypothesized that participants would have a better learning attitude developed by associating with researchers, in turn making them more motivated to improve their techniques either for higher productivity or more resilient farming to cope with climate change or both. We expected the target population to include farmers who achieved higher yields via efficient farming practices as well as large numbers of subsistence farmers, and these group differences may create a large yield gap in Northeast Thailand. We also expected that rainfed farmers are used to being responsive to variable climate conditions and are not actively adapting to the long-term trends of climate change. Our findings expose key constraints hindering the development of rainfed rice production via participatory research and emphasize the importance of selecting farmers in participatory research projects, especially in the case of rainfed rice farmers who have diverse socioeconomic backgrounds, as seen in Northeast Thailand.

Methods

Study sites

In this study, seven sites were selected (Table 1, Figure 1). Five of these sites were selected in separate five provinces (Amnartcharoen, Sakonnakhon, Buengkan, Nongbualamphu, and Mahasarakam) with different topography and represent some out of the 16 sites of the participatory project conducted by the Thai government from 2012 to 2015, 'Strengthening farmers' adaptation to climate change in the rainfed lowland rice system in the Northeast' (Bureau of Rice Research and Development, 2012; Rice Department [RD], 2013). Sites were coded according to the district name. The Huataphan (HP) site often had flooding, the Wanonniwas (WN) and Sriwilai (SW) sites often experienced both flooding and drought, and the Naklang (NK) and Borabue (BB) sites usually experienced drought. Farmers at all five sites interacted with researchers while learning about climate change, conducting experiments on advanced varieties including evaluation of their taste, and observing demonstrations of seeder technology. Two additional sites in Ubonratchathani province were also included for comparison with the five project participation sites. At the Napo (NP) site another drill-seeder technology transfer project was conducted by the International Rice Research Institute in collaboration with the Thai government. The Donchi (DC) site is located near the Ubonratchathani Rice Research Center, with some farmers serving as laborers in the research experiments at the center. Climatic damage was less recognized by farmers at the NP and DC sites.

Sampling and data collection

The target population was farmers who have grown rice at the seven study sites, including both participants

Table 1. Administrative district and demographic information (Department of Agricultural Extension [DOAE], 2017), numbers of interviewed farmers, numbers of participants in the research projects, common climatic problems recognized by farmers, and the related research projects at the seven survey sites.

Site code	HP	WN	SW	NK	BB	DC	NP
Site name	Huataphan	Wanonniwas	Sriwilai	Naklang	Borabue	Donchi	Napo
Sub-district name	Khamphra	Kudruekam	Sriwilai and Chumpoophon	Kudkrasu	Nondaeng	Nongkhon	Kohthong
District	Huataphan	Wanonniwas	Sriwilai	Naklang	Borabue	Muang	Khuengnai
Province	Amnartchaoren	Sakonnakhon	Buengkan	Nhongbualamphu	Mahasarakham	Ubonratchathani	
Number of rice-growing households in sub-district	1,302	1,067	1,644	1,256	2,202	1,382	1,011
Rice planted area (ha) of sub-district	2,926	2,307	4,121	2,432	5,172	2,646	2,089
Number of interviewed farmers	41	40	34	29	34	11	17
Number of participants (% of total interviewees)	14 (34%)	21 (53%)	11 (32%)	12 (41%)	8 (24%)	-	8 (47%)
Climatic problems	Flood	Drought-flood	Flood	Drought	Drought	Nil	Nil
Research project	Participatory project of adaptation 'Strengthening farmers' adaptation to climate change in the rainfed lowland rice system in the Northeast' by Thai government					Some farmers provided labor for research activities at nearby Ubonratchathani Rice Research Center	Participatory project of transferring to use of drill seeder by International Rice Research Institute and Thai government

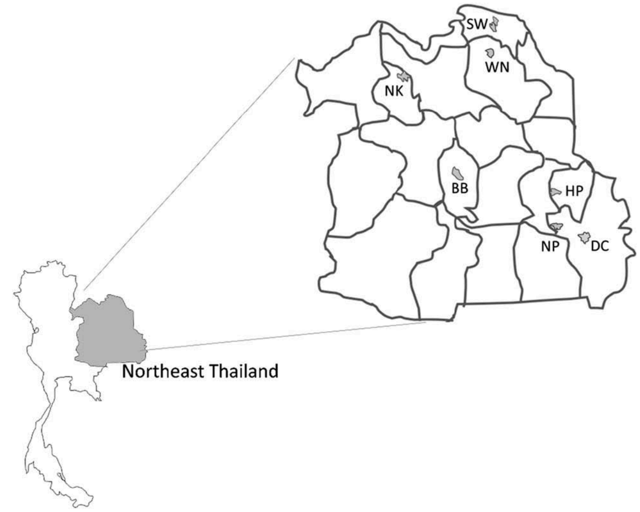

Figure 1. Location of 7 survey sites, Huataphan (HP), Wanonniwas (WN), Sriwilai (SW), Naklang (NK), Borabue (BB), Donchi (DC), Napo (NP) in 8 sub-districts (grey areas) in Northeast Thailand.

in the research projects and non-participants (except for DC). All farmers at the seven sites were called to freely attend the participatory project without registration, and several local farmers' groups were used for disseminating the project announcement (Dr. Boonrat Jongdee, personal communication). A quota sampling method was used for data collection so that the database would contain farmers who participated and those who did not participate in the research projects. However, we could not obtain an official registration record of the participating farmers in advance, and we could not select equal numbers of participants and non-participants. Finally, we collected data from 8 to 21 participants per site, with their proportion to the total interviewed farmers ranging from 24% to 53% among the sites (Table 1).

Data were collected by face-to-face interviews with a structured questionnaire, which consisted of nine parts: (1) basic household information such as age and education, (2) farming characteristics, (3) past transformation to direct seeding such as the starting year, (4) degree of engagement with researchers, (5) engagement in the current rice research project such as reasons for participation, (6) personal characteristics, (7) past climatic damages whether the farmer's fields had experienced flooding, drought, or both, (8) perception and adaptation to climate change, and (9) status of mitigation response by not burning fields. The survey was conducted from 14 to 20 January 2016, and about an hour was spent with each farmer. Twelve persons worked as interviewers and attended a training session prior to the survey, and each question was thoroughly checked during the training session.

The questionnaire was developed in English and then translated into the Thai language. The translated questionnaire was then translated back into English by a different person to confirm that the Thai version was correct. The terms used in the questionnaire and the subsequent analysis are listed in the supplementary material. Only a few farmers conducted dry season rice cropping in some years, with the majority of production coming from wet season rice. Hence, the terms 'rice yield,' 'rice cultivated area,' and 'total rice production' refer to wet season rice. In Parts 8 and 9, a summary of the fifth report of the Intergovernmental Panel on Climate Change (IPCC) about scientific findings regarding climate change was read in both standard Thai and northeastern dialect with or without additional explanation on a per case basis, since not all the farmers were literate and familiar with standard Thai.

We interviewed 211 farmers. Unclear or ambiguous recorded data were rechecked by telephoning the farmers to confirm their answers. For some questions, several farmers' answers could not be confirmed, so we had to discard these responses. In total, the data for 206 farmers were used for the analysis: 178 farmers (66 participants, 112 non-participants) at the five participatory project sites, 17 farmers (8 participants, 9 non-participants) at NP, and 11 farmers at DC.

Data analysis

In Part 2, the proportions of total rice used for home consumption and for sale (%) were calculated. A relationship score was calculated from eight questions of Part 4 (Table S1.1), ranging from 0 (least close and least interactive relationship) to 15 (closest and most interactive relationship), with scores of 0 considered as no relationship, 1–4 as a low relationship, 5–10 as a medium relationship, and 11–15 as a high relationship. Activeness in learning in general was scored from two questions of Part 6 as 0, 1, or 2, whereas activeness in learning about rice issues was scored from two other questions as 0, 1, or 2, as a simple score of farmers recent study and interest in rice farming and technology (Table S1.2). The advanced technology knowledge score was calculated from three questions of Part 6 (0 as least knowledgeable, 3 as most knowledgeable; Table S1.3) to quantify the extent to which farmers knew about technologies for coping with climate change such as stress-resistant rice genotypes and drill seeders. Confidence in farming was assessed by asking if farmers thought they could solve farming problems (=confident) or not (=not confident). The attitude of farmers regarding their willingness to adapt to climate change was quantified in Part 8, with scores of 0 (little interest to learn or to act), 1 (observation of the current situation with a conditional future action only when the climate problems get worse), 2 (intention to act in the future with possibility to learn), and 3 (readiness to act now with eagerness to learn the relevant science and technology) (Table S1.4).

We calculated three different farm-level yields: average yield of all the surveyed farmers (e.g. Van Ittersum et al., 2013), mean yield of best yielding farmers (i.e., top 10 percentile; which was considered as attainable farm yield EY_f by Stuart et al., 2016), and mean yield of lowest yielding farmers (i.e., bottom 10 percentile).

Most of the comparative analysis of participants versus non-participants was conducted at the five sites of the participatory research project, as well as at the drill seeder project site (NP). Descriptive and inferential statistics were used in this study. Student's *t*-test, Tukey–Kramer and Games–Howell were conducted to assess the significance of differences in continuous variables or parameters for two or more groups, such as differences between participants and non-participants. For nonparametric tests, we used the Kruskal–Wallis test, Mann–Whitney *U*-test, and cross tabulation using the chi-squared test to check for associations between nominal or ordinal variables. Pearson correlation analysis was used to test the significance of the relationship between two parameters. The statistical analysis function in Microsoft Office (Excel) and SPSS software version 24.0 were used, and a p value < 0.05 was considered to represent a significant difference. To identify socio-economic and farming factors contributing to farmer participation in the climate change project (for more details, see Table S2), we carried out logistic regression analysis (Peng et al., 2002) with the binary dependent variable of participation (1, participate; 0, not participate).

Results

Differences between participants and non-participants

Participants generally had similar ages (~ 53 years) and years of education (up to primary school) as those of non-participants (Table 2). Participants produced significantly larger amounts of rice in the wet season than non-participants. Participants sold more than 4 t of rice, whereas non-participants sold less than 3 t ($p < 0.05$), and the difference was clearer in NK (data not shown). The yield of participants (mean ± SD, 2.43 ± 0.97 t/ha) was significantly higher than that of non-participants (1.99 ± 0.98 t/ha), and the difference was clearer in SW and NK (data not shown).

Table 2. Characteristics of participants in the research project across the five sites (HP, WN, SW, NK, BB) in comparison with those of non-participants. Mean (SD) values are given.

Characteristic	Participant	Non-Participant	*p* value
Basic background			
Age	53 (9)	54 (10)	0.425
Education (years)	6.8 (3)	5.9 (2.81)	0.055
Rice farming characteristics			
Rice cultivated area (ha)	2.84 (1.46)	2.55 (1.64)	0.234
Total rice production (kg)	6560 (3543)	5,024 (4356)	0.016
Rice yield (t/ha)	2.43 (0.97)	1.99 (0.96)	0.004
Rice sale amount (kg)	4156 (3434)	2943 (4132)	0.046
Rice sale (%) from total rice	55 (29)	43 (31)	0.011
Rice income (baht/year)	45,283 (45,139)	37,497 (72,403)	0.432
Proportion of farmers who had target when designing farming (%)	85%	68%	0.012
Proportion of farmers who had confidence in farming (%)	18%	8%	0.043
Household economic characteristics			
Total income score	1.26 (0.81)	0.78 (0.85)	0.001
0 = < 50,000, 1 = 50,001–100,000, 2 = > 100,000 (baht/year)			
Sufficiency of income for livelihood	1.02 (0.77)	0.92 (0.65)	0.051
0 = not enough at all			
1 = not enough but could survive			
2 = enough for well being			
Social relationships			
Relationship score with researchers	6.06 (3.96)	0.54 (1.11)	<0.001
Recognition of researcher status (% of farmers who could differentiate researcher from extension officer)	49%	29%	0.007
Membership in rice-related groups in village (% of farmers)	96%	7%	<0.001
Willingness to talk and work with other farmers	97%	88%	0.033
Willingness to talk and work with persons in other jobs	96%	62%	<0.001
Learning activeness			
Activeness in learning general issues (score)	1.76 (0.53)	1.38 (0.81)	0.001
Activeness in learning rice issues (score)	1.71 (0.46)	1.03 (0.63)	<0.001

On average, 77% of the farmers had explicit targets in their farming, such as yield level or organic farming model. Participants, however, more commonly had the target of developing rice farming ($p = 0.01$) and higher confidence in farming ($p = 0.04$) as compared to non-participants (Table 2). Participant farmers tended to have more years of education ($p = 0.055$) and a stronger relationship with researchers ($p = 0.001$). Although participants had higher income, no difference between participants and non-participants was observed regarding sufficiency of their income for their livelihood. Participants had a close relationship with researchers and could better recognize the status of researchers, and they tended to like to interact with people in other jobs more so than non-participants. Among farmers, 11% had worked as research project coordinators, and they had more education than the other farmers ($p < 0.002$) (data not shown). On average 40% of the farmers were members of rice-farming groups in their villages; most participants were members, whereas non-participants were not. Among those farmers who wanted to contribute to improve the rice farming community, 67% were members of local farming groups with a higher relationship score with researchers (5.3), whereas 86% of those who wanted to minimize their relationship with the community did not belong to any local farming groups and had a lower relationship score (0.7). Participants had significantly higher active learning scores. Farmers with more years of education than primary school had a higher activeness in learning score (1.85) than those who had fewer years of education (1.45; $p = 0.001$). The score for activeness in learning about rice issues was higher in farmers with targets (1.43) than that of farmers who had no target (1.04; $p < 0.001$).

Farmers participated in the research projects because they needed either general or specific technical advice for their farming (data not shown). Non-participants did not attend because they never heard about the project (21%), they heard but they were not interested in it (16%), or they heard but they were unable to participate (38%) (data not shown).

Among the 36 candidate variables, three factors were selected as significantly influencing farmers' participation: (I) membership in rice-related groups in the village, (II) activeness in learning about rice issues, and (III) confidence in farming (Table 3). Model prediction accuracy was 94%, with Nagelkerke's R^2 of 0.876. Those who were members had a greater likelihood of participating in the research project than non-members. Farmers who were active in learning about rice and had confidence in their ability to solve problems in rice farming had a higher likelihood of participating in the project.

Yield variability and farming characteristics

Two-thirds of the surveyed farmers had additional water sources, such as canals to a river (46%) and on-

Table 3. Results of logistic regression with likelihood ratio forward stepwise variable selection for factors that influence participation in the research project.

Explanatory variables	Coefficient (*B*)	SE	Exponential *B*/ Odds ratio	*p* value
(I) Membership in rice-related groups in village	6.934	1.227	1026.45	<0.001
(II) Activeness in learning rice issues	2.593	0.790	13.365	0.001
(III) Confidence in farming	3.306	1.342	27.275	0.014
Constant	−8.459	1.755	0.00	<0.001
−2 log likelihood	52.07			
Model chi-squared	182.666 (p value < 0.001)			
Model prediction accuracy (%)	94.4%			
Nagelkerke's R^2	0.876			
N = 178				

farm ponds (21%; data not shown). Percentages of farmers without additional water sources reached more than 40% in SW, NK, and BB, while the values were only 12 and 23% in HP and NP, respectively. Eighty-seven percent of the surveyed farmers grew rice only during the wet season (data not shown).

The average yield of the surveyed farmers was 2.18 t/ha, with the best yielding farmers (i.e., top 10 percentile) and the lowest yielding farmers (i.e., bottom 10 percentile) having yields of 4.05 and 0.63 t/ha, respectively (Table 4). The yield gap between the best yielding farmers and the average farmers was 1.88 t/ha, whereas that between the best yielding and lowest yielding farmers was 3.42 t/ha. All surveyed farmers grew rice at a similar scale (mean ± SD, 2.60 ± 1.54 ha). The total amount of rice produced per household was 5.5 t on average, ranging from 1.6 to 8.2 t. Households consumed 2.2 t of paddy rice on average, but the value was only 1.2 t for the lowest yielding farmers.

Rice sold at market was 3.4 t or 61% of total production on average, ranging from 5.9 t (72%) to only 0.4 t (26%). The most popular varieties were RD6 (49%) and KDML105 (38%), and the others were improved varieties such as RD15 and local traditional varieties. On average 85% of RD6 was for home consumption, but the values were higher (96%) for the lowest yielding farmers and smaller (58%) for the best yielding farmers. On average 77% of KDML105 was sold at market, but the value was lower (31%) for the lowest yielding farmers. Average annual rice income was about 40,000 baht, which was more than double for the best yielding farmers and about only 10% of that value for the lowest yielding farmers. The lowest yielding farmers also had low total income (< 50,000 baht/year).

The proportion of area planted by broadcasting (BC) was 73% on average, which was lower for the best yielding farmers (60%) and higher for the lowest yielding farmers (80%). BC yield was slightly lower than transplanted (TP) yield, and there were yield gaps of about 1.8 t/ha between the best yielding farmers and average farmers for both planting methods. Seed rate of the lowest yielding farmers was lower (85 kg/ha) compared with the average (111 kg/ha) and the best yielding (119 kg/ha) farmers (data not shown). The yield gaps for RD6 and KDML105 were 1.7 and 1.4 t/ha, respectively. Active learning scores were higher for the best yielding farmers than the average and lowest yielding farmers (data not shown).

When considering differences among sites, farmers at WN, DC, and NP had a higher percentage of area favorable for growing rice (around 70% on average)

Table 4. Rice yield, rice cultivated area, total rice production, water source score, amounts and proportion of rice for home consumption or sale, rice income, proportion of broadcast (BC) area, yield by transplanting (TP) or BC methods, and yield by varieties for farmers in the top 10 percentile of yield, those in the bottom 10 percentile of yield, and average data of all the farmers. The *p* values are for differences between the best and lowest yielding farmers.

	Best yielding farmer (*N* = 20)	Average farmer (*N* = 206)	Lowest yielding farmer (*N* = 21)	*p* value (*t*-test or chi-squared)
Rice yield (t/ha)	4.05	2.18	0.63	<0.001
Rice cultivated area (ha)	1.98	2.6	2.42	0.324
Total rice production (kg)	8,205	5,536	1,630	<0.001
Water source score (0 = rainfed, 1 = pond, 2 = river)	1.15	1.12	0.76	0.366
Home rice consumption amount (kg)	2316	2184	1205	0.008
Home rice consumption proportion (%)	33%	52%	83%	<0.001
Rice sale amount (kg)	5924	3362	425	<0.001
Rice sale proportion (%)	67%	48%	17%	<0.001
Rice income (baht/year)	81,434	40,811	4056	0.010
BC area (%)	60	73	80	0.144
TP yield (t/ha)*	4.41 (9)	2.58 (65)	0.71 (4)	<0.001
BC yield (t/ha)*	3.85 (13)	2.08 (165)	0.66 (18)	<0.001
Yield of cv. RD6 (t/ha)*	4.18 (18)	2.46 (176)	0.85 (17)	<0.001
Yield of cv. KDML105 (t/ha)*	3.63 (15)	2.20 (148)	0.63 (7)	<0.001

*The values in parentheses indicate actual numbers (N) used for the calculation of the means.

according to their perception. Farmers at HP had a higher proportion of flood-prone area (35%), and those at BB and NK had a higher proportion of drought-prone area (40–45%). Yields of rice at HP, BB and NP were higher than those at other sites, whereas NK and SW yields were lowest (Figure 2(a)). HP had the highest total amount of rice produced and a larger rice cultivation area (Figure 2(b,c)). Median rice income was less than 10,000 baht or close to zero at BB and NK and highest at HP, WN and NP (Figure 2(d)). Farmers at NK and BB produced the least rice for sale, whereas those at HP and NP produced the most (Figure 2(e)).

At HP, NK, BB, and SW, more than 80% of rice fields were planted by BC, whereas DC and NP had the highest proportion of TP (Table 5). At NP, 30% of rice fields were planted by using a drill seeder machine. HP had higher BC yield and higher RD6 yield than other sites (data not shown). NP had the largest proportion of cultivation area by TP and by drill seeder. At each site, TP yield was generally higher than that of BC. Yield produced by using the drill seeder introduced by researchers tended to be higher than BC yield, but not significantly so ($p > 0.05$). SW and NK had the lowest BC yield and lowest RD6 yield. The yield of RD6 varied more among the seven sites than that of KDML105 (data not shown).

When categorizing farmers by level of rice marketing, farmers who sold less than 25% of their yield had

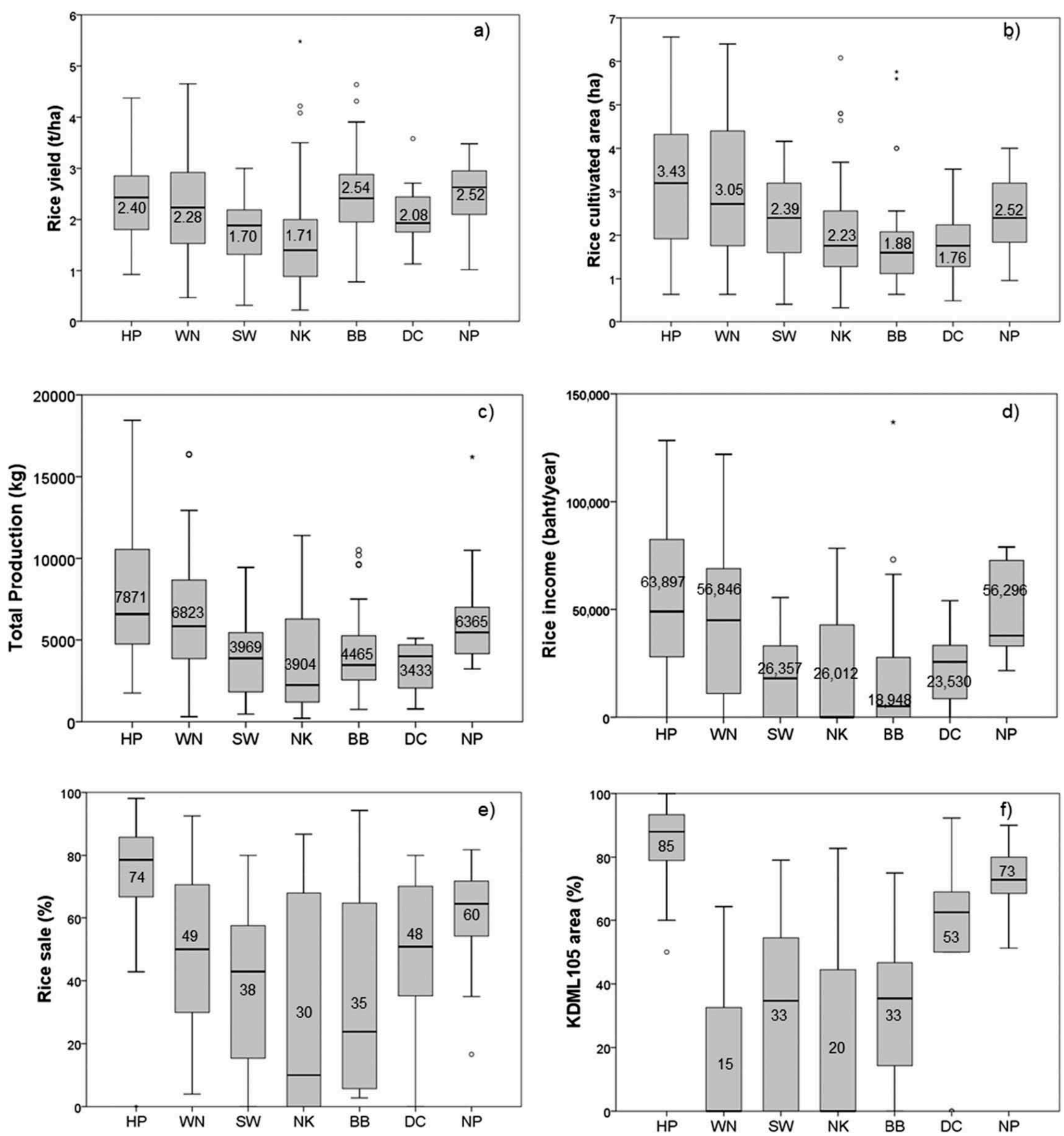

Figure 2. Boxplot of (a) rice yield, (b) rice cultivated area, (c) total rice production, (d) rice income, (e) proportion of rice sale from total rice production, and (f) proportion of KDML105 planted area for seven sites (HP, WN, SW, NK, BB, DC, NP) in Northeast Thailand. Maximum (top whisker), third quartile (top of box), median (thick line), first quartile (bottom of box), and minimum (bottom whisker) are shown as well as the average values (numbers).

Table 5. Percentage of area and yield by transplanting (TP) or broadcasting (BC) methods and drill seeder yield across the seven sites in Northeast Thailand.

Site	TP area (%)	BC area (%)	TP yield (t/ha)	BC yield (t/ha)	Yield by drill seeder (t/ha)
HP	6	94	3.26*	2.29	-
WN	42	55	2.54	1.97	-
SW	18	82	1.62*	1.84	-
NK	15	85	2.41*	1.72	-
BB	17	83	3.24*	2.37	-
DC	54	43	2.17*	2.39*	-
NP#	48	22	2.79*	2.04*	2.47
Average	24	73	2.58	2.08	2.47
N	205	205	65	165	10

*Number of samples used for calculation was less than 10.
NP had 30% area cultivated by drill seeder.

smaller rice cultivation areas, less total production, and lower yield (1.66 ± 0.80 t/ha) compared to market-oriented farmers (2.71 ± 0.85 t/ha) (Table 6).

The yields of TP and BC were also higher for farmers who sold a greater percentage of their production (Table 6). Market-oriented farmers had more years of direct seeding experience (i.e., 9 years) with a higher seed rate (136 kg/ha) than those of home consumption–oriented farmers (5 years and 95 kg/ha). The seed rate of the drill seeder method was 57 ± 30 kg/ha (N = 10), nearly half that of BC. Yields of RD6, KDML105, and other varieties all tended to be higher in market-oriented farmers than home consumption–oriented farmers, and the difference was significant for RD6 ($p < 0.001$). Farmers who sold less than 25% of their rice yielded 1.85 and 1.91 t/ha for RD6 and KDML105, respectively, whereas those who sold more than 75% yielded 3.11 and 2.50 t/ha, respectively. Higher yield in the group with higher proportion sold was clearly observed at HP, WN, and NK (Table 6). The

Table 6. General farming characteristics, growing method, varieties, activeness of learning, and mean yield of each site categorized by proportion of rice sale (0–25%, 26–50%, 51–75%, 76–100%).

	0–25% of production sold (*N* = 57)	26–50% of production sold (*N* = 37)	51–75% of production sold (*N* = 59)	76–100% of production sold (*N* = 53)	ANOVA *p* value
General farming characteristics					
Rice yield (SD) (t/ha)	1.66 (0.80) a	1.98 (0.82) *ab*	2.33 (0.98) bc	2.71 (0.85) c	<0.001*
Rice cultivated area (ha)	1.71 a	2.66 b	2.75 b	3.38 b	<0.001**
Total rice production (kg)	2,699 a	4,991 b	5,909 b	8,574 c	<0.001**
Home consumption amount (kg)	2,458 b	3,089 b	2,176 b	1,282 a	<0.001**
Seed production (kg) (% from total rice production)	102 a (4.1%)+	208 b (5.3%)	213 b (4.5%)	340 b (3.8%)	<0.001**
Sale amount (kg)	238 a	1897 b	3759 c	7308 d	<0.001**
Growing method†#					
TP area (%)	17	32	28	24	0.243
BC area (%)	83	68	65##	75##	0.170
TP yield (t/ha)	1.81 a (11)	2.17 *ab* (15)	2.74 *ab* (20)	3.17 b (19)	0.016*
BC yield (t/ha)	1.70 a (50)	1.82 a (30)	2.21 *ab* (39)	2.56 b (46)	<0.001*
BC seed rate (kg/ha)	95 a (50)	97 a (32)	111 *ab* (46)	136 b (47)	0.005**
Estimated year of starting BC	5.3 (51)	5.9 (32)	8.3 (50)	9.2 (48)	0.06***
Rice varieties#					
RD6 area (%)	69 c	48 bc	43 b (57)	28 a	<0.001*
KDML105 area (%)	20 a	42 b	46 b (57)	64 c	<0.001**
RD6 yield (t/ha)	1.85 a (51)	2.30 *ab* (31)	2.61 bc (48)	3.11 c (46)	<0.001*
KDML105 yield (t/ha)	1.91 (29)	1.95 (29)	2.23 (43)	2.50 (47)	0.079
RD6 home consumption (%) from total rice production	53 b	42 *ab*	33 a	18 a	<0.001**
RD6 for sale (%) from total rice production	2 a	5 *ab*	10 b	11 b	<0.004**
KDML105 for sale (%) from total rice production	1 a	24 b	41 c	63 d	<0.001**
Learning activeness					
Active in learning rice issues score	1.07 a	1.38 *ab*	1.44 b	1.49 b	0.003*
Rice yield by site (proportion of farmers in the sale category)					
HP	1.47 (2%)	2.06 (7%)	2.37 (32%)	2.49 (59%)	-
WN	1.45 (20%)	2.03 (28%)	2.43 (30%)	3.12 (23%)	-
SW	1.53 (29%)	1.78 (29%)	1.77 (32%)	1.77 (9%)	-
NK	1.07 (55%)	2.23 (10%)	2.29 (24%)	3.22 (10%)	-
BB	2.27 (56%)	1.80 (12%)	3.52 (12%)	3.12 (21%)	-
DC	1.76 (18%)	1.94 (27%)	2.24 (27%)	2.27 (27%)	-
NP	2.26 (6%)	2.45 (18%)	2.37 (53%)	2.99 (24%)	-

+*N* = 56, with 1 missing data.
† TP, transplanting; BC, broadcasting.
# Total *N* of data in rows below is < 206 farmers because not all farmers used these planting methods and varieties Value in parentheses is *N* of each cell.
Sum of percentage of TP and BC is not equal to 100% because a few farmers planted with a seeder machine.
*, ** Multiple comparison by Tukey–Kramer and Games–Howell, respectively. Different letters indicate difference in mean proportion of rice sale among the four categories.
*** Chi-squared test by the Kruskal–Wallis method.

difference in yield among groups was very small at SW, and the groups with less market proportion maintained relatively high yield at BB and NP (>2.2 t/ha). Market-oriented farmers had higher active learning scores about rice issues than home consumption–oriented farmers. The group that sold less than 25% of rice yield depended on non-rice sources of income for their household livelihood, had low total household income (<100,000 baht), and had the lowest relationship score with researchers (i.e., 2.0 of 15). Market-oriented farmers and subsistence farmers had similar years of education and social positions within their villages (data not shown).

Farmers' perceptions and attitudes toward climate change

Eighty percent of the surveyed farmers had experienced severe climatic damage to rice production by drought and/or flooding (Figure 3). Drought was experienced at every site and its overall average percentage was large (~ 42%), although the percentage of farmers who experienced flooding was also as large or larger at HP, SW, and NP. There were no differences between participants and non-participants in their exposure to climatic damage.

We found no difference between participants and non-participants in their perception of the climate trend based on their childhood (Table 7). Almost all the surveyed farmers perceived that climate had changed since their childhood, noting less frequent cold days and cold nights, more frequent hot days and hot nights, more frequent and severe heavy rainfall, and more severe and prolonged drought.

When a brief description of climate change from the IPCC report was explained to farmers, 57% of participants said they understood the contents, whereas only 31% of non-participants did so (p = 0.005). The level of farmers' understanding was affected by years of education (p = 0.001), activeness in learning about rice issues ($p < 0.001$), membership in local rice-farming groups (p = 0.005), and relationship score with researchers ($p < 0.001$). Participants knew slightly more about advanced technology for coping with climate change (Table 7).

Despite nearly all farmers perceiving a change of climate, only 49% had ever thought to deal with adverse effects from these changes and only 27% actually took action (e.g. obtaining supplementary water resources by digging underground, building ponds, or installing pumps). Participants and non-participants did not differ in these responses (Table 7). Those farmers who had thought to deal with climate effects had more education (p = 0.063), clearer farming targets (p = 0.024), and active learning attitudes (p = 0.010). The farmers who took action tended to have additional water sources available (p = 0.016) such as a pond or river, however, climatic damage experience was not found to affect the decision to take action (p = 0.715).

Participants tended to burn less rice straw than non-participants (Table 7), and they were more likely than non-participants to agree that burning caused negative effects (p = 0.038) and that farmers should stop it (p = 0.058) (data not shown). Eighty-two percent of the farmers did not burn the rice straw because the

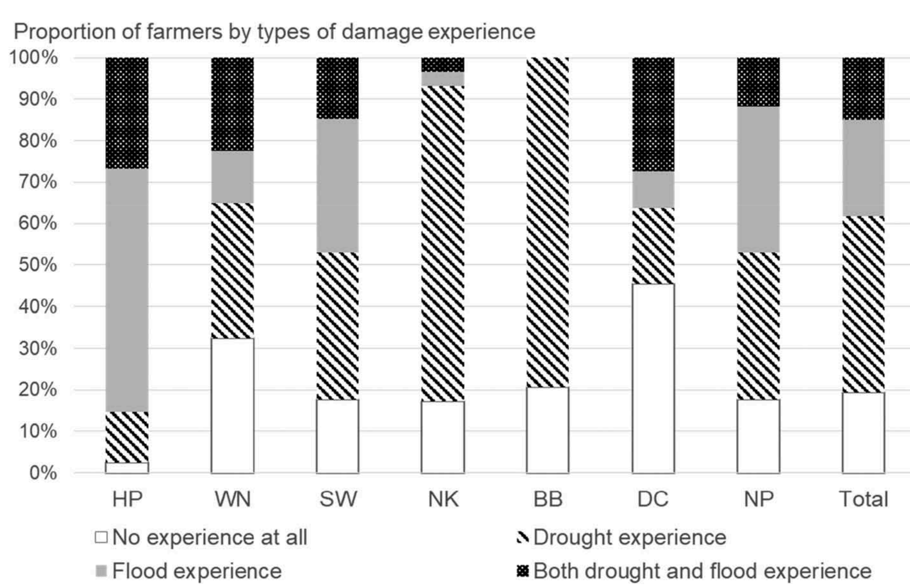

Figure 3. Proportion of farmers' experiences of damages by extreme climatic incidents for seven sites (Total N = 206).

Table 7. Comparisons between participants and non-participants regarding perceptions of climate trend, understanding of IPCC message, advanced technology knowledge score, previous experiences with climate change both in thinking and action, farmer's attitude score about adaption to climate change, rice straw burning.

Farmers' perceptions and actions toward climate change	Participants (N = 66)	Non-participants (N = 112)	p value	Effect of participation
1. Perception of climate trend based on farmer's childhood	Hotter, more drought	Hotter, more drought	>0.05	No
2. Understanding of IPCC message (% of farmers)	57%	31%	0.005	Substantial
3. Advanced technology knowledge score (e.g. resistant varieties)	1.86	0.92	<0.001	Substantial
4. Previous experience of thinking to deal with effects from climate change (% of farmers)	50%	47%	0.730	No
5. Previous experience of actions to deal with effects from climate change (% of farmer in No.4)	47% (N = 32)	63% (N = 53)	0.170	No
6. Farmer's attitude score about adaption to climate change	2.30	2.04	0.061	Small
7. Rice straw burning (% of farmers)	14%	25%	0.071	Small

land preparation option of using four-wheel tractors was readily available, while the other farmers found it difficult to prepare land without burning. Sixty-eight percent of the farmers understood that straw burning caused greenhouse gas (i.e., CO_2) emission. A stronger relationship with researchers and more years of education were significantly associated with less residue burning (p = 0.029 and p = 0.070, respectively). Practicing both dry and wet season cropping tended to enhance burning activities, although the trend was not significant; 40% of those who practiced dry season rice cropping burnt straw, whereas 19% of those who grew only the wet season crop did so.

Farmers with more education knew significantly more about advanced technologies than those who had only completed primary school (Table 8). Farmers with high scores for knowledge of advanced technology were more active learners, had stronger relationships with researchers, and were members of local farming groups. Those with more years of education, targets in their farming, and activeness in learning in general and on rice issues had significantly higher attitude scores about adaptation to climate change (Table 8). Farmers with high relationship scores also had higher attitude scores. Those who thought to deal with adverse climatic effects based on past incidents had higher attitude scores about adaptation to climate change. Those who were active learners and had higher technology knowledge scores also had higher attitude scores.

Discussion

Characteristics of farmers participating in research projects

We hypothesized that participant farmers would have a better learning attitude developed by associating with researchers, in turn making them more motivated to improve their farming, which was generally confirmed by our survey. Compared to non-participants, the participants had higher relationship scores, which serve as a comprehensive indicator of farmers' relationship with researchers. The participants were more active learners with confidence about not only rice farming but also general matters (despite having similar ages and levels of education as non-participants) and worked toward farming targets such as yield level or organic farming. The participants produced 22% higher yield than the non-participants (Table 2). A previous study in Africa also showed that farmers participating in research groups were more interested in innovation to improve their farms and more frequently contacted agricultural extension staff (Sanginga et al., 2006).

Although these personal characteristics of the participants led to higher yields, the differences in perception of climate change between participants and non-participants were much smaller. The mindset and actions of participants made them slightly more prepared to cope with climate change; this may be a positive result of the participatory project on adaptation to climate change, or it may reflect a bias that farmers who were already more aware participated in the research project. However, because the research focused on long-term changes of climate patterns in the future, which are less familiar to local farmers and less linked with their immediate economic benefits, our survey did not detect any large differences between the participants and non-participants after the 3-year research project.

Although the research project was open to all farmers at the sites, most participants belonged to local farming groups, such as rice seed production groups and organic rice groups, in their communities. This finding reflects the strength and importance of local group networks for participatory research and for subsequent technology dissemination in Northeast Thailand. Leaders might have

Table 8. Advanced technology knowledge score and farmer's attitude score about adaption to climate change by education, rice sale (%) from total rice production, targets in designing farming, confidence in farming, activeness in learning in general and rice issue, relationship with researcher, membership in local farming groups, and previous experience of thinking to deal with effects from climate change.

		Advanced technology knowledge score	*p* value	Farmer's attitude score about adaption to climate change	*p* value
Education length	≤6 years (*N* = 153)	1.15 a	0.034	2.06 a	0.008
	>6 years (*N* = 52)	1.58 b		2.37 b	
Rice sale (%)	<25% of production for sale (*N* = 57)	1.11	Ns	2.21	Ns
	25–50% of production for sale (*N* = 37)	1.35		2.05	
	51–75% of production for sale (*N* = 58)	1.22		2.21	
	>75% is for sale (*N* = 53)	1.41		2.04	
Targets in designing farming	No (*N* = 47)	1.12	Ns	1.70 a	<0.001
	Yes (*N* = 158)	1.30		2.27 b	
Confidence in farming	No (*N* = 177)	1.2	0.060	2.08	0.038
	Yes (*N* = 28)	1.62		2.46	
Activeness in learning in general	Low (*N* = 29)	0.79 a	0.010	1.66 a	<0.001
	Medium (*N* = 35)	1.29 b		1.89 *ab*	
	High (*N* = 141)	1.35 b		2.30 b	
Activeness in learning rice issues	Low (*N* = 22)	0.50 a	<0.001	1.82	0.054
	Medium (*N* = 92)	1.11 b		2.07	
	High (*N* = 91)	1.60 c		2.29	
Relationship with researchers	No (*N* = 90)	0.84 a	<0.001	1.99 a	0.025
	Low (*N* = 58)	1.20 a		2.12 a	
	Medium (*N* = 45)	1.91 b		2.29 *ab*	
	High (*N* = 12)	2.25 b		2.75 b	
Membership in farmer groups	No (*N* = 71)	0.91 a	<0.001	2.03 a	0.08
	Yes (*N* = 107)	1.74 b		2.26 b	
Previous experience of thinking to deal with effects of climate change	No (*N* = 105)	1.22	Ns	1.88	<0.001
	Yes (*N* = 98)	1.30		2.42	
Advanced technology knowledge score	<1 (*N* = 48)	-	-	1.90 a	0.022
	1–2 (*N* = 78)	-		2.13 *ab*	
	>2–3 (*N* = 52)	-		2.38 b	

*Different letters show statistical difference by ANOVA multiple comparison by Tukey–Kramer or Games–Howell test at 0.05; ns, not significant with $p > 0.1$.

influenced other group members to join the research project. Those who have targets while developing their farming, such as higher yield to allow for more rice to be sold, may have joined local groups to gain the knowledge and skills necessary to attain their target, and they likely joined the participatory project for similar reasons.

About 18% of the participants joined the project not to learn new rice technologies to solve problems derived from climate hazards, but because of their relationships with neighbors and/or leaders (data not shown). Relationship scores varied widely among participants (cf. large standard deviation in Table 6), indicating the heterogeneity and broad levels of individual farmer's interactions with researchers. Some participants were very motivated in learning research findings and testing new technologies, whereas others were more passive and affected by the behavior of other farmers (data not shown). Although the presence of a few leading farmers was expected, the presence of an inactive group of participants is not uncommon. This variation in quality of participants should be understood by researchers as a factor influencing the effectiveness of participatory projects.

Our results imply the superiority of participants to non-participants with regard to rice yield and household economics (although we did not collect detailed economic indicators such as income), but the differences between these groups were not large in some basic characteristics, such as size of landholdings and education. In a participatory wheat breeding project in the United States, large-scale farmers who grew many varieties at specific locations to attain higher quality were more willing to participate in the program (Dawson & Goldberger, 2008). On the other hand, a participatory rice variety selection project in India included farmers with broad economic statuses and with different landholding sizes (Paris et al., 2008). In Africa, both wealthier and poor farmers participated equally in research activities in a program aimed at increasing capacity of small-scale farmers (Sanginga et al., 2006) and for the development of IPM (Togbé et al., 2015). The surveyed project in northeastern Thailand focused on the testing and adoption of new rice varieties, which could be considered as scale-independent, allowing participation of farmers with different size landholdings.

Variation in farm-level rice yield

We recorded large yield variation among the 206 farms at the seven target sites in rainfed lowland rice ecosystems with different climate problems in Northeast Thailand. The overall average yield of the seven sites (2.18 t/ha) was similar to the regional statistical yield (2.24 t/ha; Office of Agricultural Economics, 2017) and the sampled yield values of the sites in the project (RD, 2013, 2014). The large variation of yield, ranging from 0.63 to 4.05 t/ha between the bottom and top 10 percentile of farmers, revealed the presence of not only low-yielding subsistence farmers but also a small number of high-yielding farmers who can attain more than 4 t/ha even under rainfed cultivation. Supporting evidence of higher yield attained in Northeast Thailand is available from a field survey conducted at some lower toposequence positions (e.g. Kamoshita et al., 2009) as well as from some on-station agronomic experiments, for example, with a high nitrogen fertilizer application rate in lower toposequential fields (Haefele et al., 2010; Hayashi et al., 2007). In our study, the yield gap between the best yielding farmers and average farmers was 1.88 t/ha (85% higher), which is slightly higher than the yield gaps of 1.2 t/ha (6.2 vs. 5.0 t/ha) and 1.4 t/ha (6.2 vs. 4.8 t/ha) reported by Laborte et al. (2012) and Stuart et al. (2016), respectively, under irrigated cultivation in central Thailand. Our method for calculation of yield gap differed slightly from theirs, so these figures should be compared with caution, but we have demonstrated a substantial yield gap in rainfed lowland rice ecosystems in Northeast Thailand, as seen in irrigated rice in central Thailand, including information on the yield gap for each planting method and each major variety.

The major reason for the large yield gap was the difference in the purpose of rice production among farmers, that is, whether for sale or for home consumption. Market-oriented rice farmers had higher yields than those of subsistence farmers (Table 6). Market orientation could promote higher yield as a means for higher income. The highest, average, and lowest yields were 4.1, 2.2, and 0.6 t/ha, those of rice sale percentages were 67%, 48%, and 17%, and those of amounts sold were 5.9, 3.4, and 0.4 t (Table 4). The sites with more rice sold (e.g. HP and NP) had higher yield with small yield variability, whereas sites with less rice sold (e.g. NK) had lower yield and larger yield variability because farmers' income sources were diverse (Figure 2(a,d,e)). Market-oriented farmers seem to have been equipped with more supplementary irrigation water, judging from the tendency for them to have more available water sources (e.g. on-farm ponds, canals connecting to a river), which allowed them to achieve higher yield, as in the case of lower toposequence fields in previous studies (e.g. Kamoshita et al., 2009; Naklang et al., 1996). Several studies also showed that market-oriented farmers produced rice more efficiently (Ebers et al., 2017; Piya et al., 2012). Saisema and Pagdee (2015) also reported that many farmers in Northeast Thailand grow rice for self-consumption as a cultural norm even under severely constrained farming conditions, which were less efficient and lower yielding. The presence of many such subsistence farmers lowered the regional yield level in the national statistic record, despite some farmers with high yields.

Direct seeding by broadcasting has recently become the most prevalent planting method at the surveyed sites (e.g. higher proportion than regional average value of 47%; Office of Agricultural Economics, 2017) in spite of the slightly lower yield than traditional transplanting, because of its cost and labor savings. Market-oriented farmers had a higher yield than subsistence farmers when using broadcasting, with a slightly higher seed rate (136 vs. 95 kg/ha) and with a longer period (9 vs. 5 years) since changing to the direct seeding method. Market-oriented farmers are applying a higher seed rate than the standard rate recommended by the government (94–125 kg/ha; Pongsrihadulchai, 2013), which can be seen as a means of securing plant establishment to avoid yield reduction from abiotic stress. Subsistence farmers tended to use a lower seed rate even though their yield was reduced. Use of a seed rate above 95 kg/ha resulted in a yield increase of 21 kg/ha per kilogram of seed by broadcasting. Use of a drill seeder can reduce the seed rate, with an average of 57 kg/ha, without yield reduction (2.5 kg/ha at NP). The development of drill seeding technology that saves seeds without yield penalty would likely be attractive to subsistence farmers as well if use of the devices could be shared within farmers' groups.

Farmers' perceptions and actions toward climate change

Our study revealed the perspectives of northeastern Thai farmers about climate: (1) in general, drought is more recognized than flooding at the seven sites, and (2) the climate of the region has become hotter and drier since their childhood (i.e., the 1970s). In fact, the records of the Meteorological Department of Thailand from 1970 to 2009 showed temperature has increased by around 0.2 ℃ per decade in the northeastern region (Limjirakan & Limsakul, 2012) in accordance with the IPCC report (IPCC, 2013). Limsakul and Singhruck (2016) also reported long-term trends of less frequent precipitation events from 1955 to 2014 across most regions in

Thailand, which seems to support the farmers' perceptions. The differences between participants and non-participants were generally small with regard to these perceptions. A brief summary of the IPCC report was understood by 41% of farmers, and the percentage was higher for participants than non-participants, suggesting that participants gained knowledge about climate change from researchers during the project.

Despite the common perception of long-term climate changes by northeastern Thai farmers, they have not yet seriously responded or prepared to deal with these changes. Some farmers performed some responsive actions after climatic damage to their crops, but these tended to be short-term reactions, such as water pumping during drought, rather than long-term strategic adaptation, such as adopting new rice varieties better adapted to variable climate conditions (Deressa et al., 2009; Harmer & Rahman, 2014). Some of the long-term climate adaptations that would require changes in the farming system might not be easy for farmers in Northeast Thailand to accomplish, because they are costly and labor intensive.

However, the willingness to learn new technologies, prepare for adaptation, and refrain from residual straw burning were more marked in the participants than in the non-participants (Table 7). The participants appear to have learned about and better understood climate change and its risks, which is a prerequisite for subsequent actions for long-term adaptation (Dang et al., 2014; Esham & Garforth, 2013; Saguye, 2017). The relationship score was also positively correlated with the advanced technology knowledge score and attitude about adaptation to climate change (Table 8). Therefore, if researchers continue to help farmers understand the local changes in climate conditions and the potential risks to rice production, they should become more ready to change their traditional farming methods and adopt technologies resilient to climate hazards with improved yield level and stability (Campbell et al., 2016; Chandra et al., 2017; Manzanilla et al., 2011). Several rice farming technologies for adaptation to climate change have been developed, with a strong emphasis on farm-level demonstration, such as breeding for submergence resistance (Mackill et al., 2006; Manzanilla et al., 2017) and for drought resistance (Kumar et al., 2014), planting adapted varieties (Mitchell et al., 2014), and managing crop nutrients (Jairin et al., 2017; Kato et al., 2016).

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