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TECHNOLOGY CHANGE IN DRY SEASON VEGETABLE PRODUCTION: A COMPARISON OF TWO VILLAGES WITH AND WITHOUT A FARMER GROUP IN KHON KAEN PROVINCE, NORTHEAST THAILAND

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ABSTRACT

The authors reconstructed farmers' technology change over 10 years, assessed the effect of a farmer group, and identified characteristics contributing to technology change in 2017. Farmers in two villages in Khon Kaen Province, Northeast Thailand, one with a farmers' group (SS) and the other without (NSH), described technology changes in a narration format. Reasons for and benefits of changes were converted to quantitative values and analyzed statistically. The villages differed in types and numbers of technologies. SS farmers described more technologies for fertilization and pest management, while NSH farmers indicated more technologies for water management and trellising. Most pest management changes in SS involved organic pest control and cultural practices, while most in NSH involved chemical pesticides. Changes based on farmers' own ideas and interaction were 45% more numerous in SS, and SS farmers had nearly double the number of sources of information. Working off-farm increased technology changes in SS. These results suggest that farmer groups can increase farmer-to-farmer learning in using new technologies. Methods developed in this research can enable researchers to gain insights into farmer thinking using qualitative approaches and assess differences among farmers statistically.

Key words: data conversion, farmer interaction, innovation, mixed methods research (MMR), narration, pest management, water management

INTRODUCTION

During the past 20 years, emphasis has been placed on diversification of agriculture in Northeast Thailand (Isan). Vegetables are an important component of diversification. New production techniques including soil-improving organic fertilizers and alternatives to chemical pesticides have been introduced by NGOs and the agricultural extension service. Consumer awareness of the risks of excessive pesticide use on vegetables has also increased (Nguyen, 2018). The development of the East-West corridor and the elimination of tariffs on agricultural products among ASEAN countries offer new potential markets for vegetable production in Northeast Thailand (Srisathit 2017).

However, the process of change in production techniques and the reasons why farmers make changes have not been well-documented at the village level. There are many sources of information on new production techniques available to farmers. An important source is agricultural extension agents in rural districts in Thailand. Other actors providing information at the village level include projects of universities and research organizations, Royal Projects, and various NGOs. Moreover, with the spread of the internet and higher rural education levels, farmers can access information on their own. Considerable numbers of Isan people go to work for several years in other provinces or countries and then return. Some work in agriculture, and thereby learn new techniques and get new ideas that they bring back and apply on their farms (Grandstaff et al. 2008).

Recognition of the importance of farmers as innovators and researchers has increased in the past decades, beginning with observations by researchers carrying out on-farm research with farmers (Lightfoot 1987). Experiences in Latin America and Southeast Asia have supported the role of farmers' organizations involved in generating innovations (Ashby et al. 2000; Horne et al. 2002). Agricultural extension theory has moved away from technology transfer to emphasis on networks among multiple actors jointly producing innovations, termed Agricultural Knowledge and Innovation Systems, or AKIS (European Commission 2012).

In 2015, the Japan Agricultural Extension Research Society held a symposium on AKIS (Yokoyama 2015). This symposium included a presentation by an innovating farmer (Yokota 2015). Stimulated by this symposium, Caldwell and Ueda (2015, 2016, 2017) carried out research in 2015-2017 to develop new methods for reconstructing farmers' processes of technology use, change, and innovation; assessing the relative importance of farmers' own ideas and interaction compared with outside sources of information; and elucidating the benefits of different technologies for farmers.

Parallel with the above research in Japan, Caldwell and Promkhambut (2017) began research on technology change in Khon Kaen Province, Northeast Thailand. Several districts producing dry season vegetables were selected for a reconnaissance survey of vegetable production in March 2016. Based on the results of the survey, two villages were selected, one in SS District and the other in NSH District, for research on technology change. The first village was selected because it had a functioning farmers' organization. The second village did not have a farmers' organization, but had similar conditions of good water availability in the dry season.

This research sought to describe technologies and innovations over the past 10 years in two villages, compare technologies with and without the presence of a farmer group and identify factors contributing to the number of changes in technologies and revenue.

MATERIALS AND METHODS

Approach and assumptions. This research, conducted in 2017, combined qualitative and quantitative data collection, transformation of qualitative data into quantitative measures, and descriptive and inferential analysis of results. These methods developed in Japan and adapted for use in this research in Thailand seek to bridge the continuing gap in the research approaches of agricultural scientists working in the hypothetico-deductive tradition and anthropologists and other social scientists using inductive approaches. The two approaches are based on different conceptions of how one understands the world (Tashakkori et al. 2021). The hypothetic-deductive tradition is positivist in its assumptions and quantitative in its observation and analysis methods. While it recognizes that many phenomena in the biological and social realms are probabilistic rather than deterministic, it assumes that these phenomena are real and can be measured objectively. The inductive / constructivist tradition is qualitative in its observation and analysis methods. It assumes that the observer cannot anticipate all causes of phenomena in advance, so prior hypotheses may not be relevant, and places emphasis on elucidating the knowledge and perceptions of the people involved. It also assumes that knowledge of the world is constructed differently by each person, depending on their place in society and their personal and collective experiences (Kriterion 2015).

The combination of methods reflects the tradition of Farming Systems Research and Extension (FSRE), which began to combine qualitative and quantitative methods in multidisciplinary team-based work in applied technology development and extension in the late 1970s, and the experiences of the senior author in carrying out FSRE and similar research and extension activities in several countries since the early 1980s. In the terminology of current Mixed Methods Research (MMR), FSRE created a sequential mixed methods design (Tashakkori et al. 2021; Creswell 2022) for applied technology development, using qualitative methods for diagnosis and design of on-farm technology trials, and both quantitative and qualitative methods for assessment of technology performance in the trials.

Farming systems research and extension (FSRE) began in the late 1970s as a pragmatic response to the difficulties of Green Revolution improved technologies for rice and wheat production (Caldwell 1994; Collinson 2000). Agricultural scientists had come to recognize that farmers did not simply adopt all new technologies created by agricultural researchers, but rejected some and adapted many others depending on their conditions. The usefulness of technologies for farmers depended not only on the effects of the technologies on crops, but also on how farmers perceived the technologies and how they used them in their on-going production under varying conditions with multiple objectives of both household consumption and market sale. In response, FSRE developed team-based methods of qualitative assessment of farmer knowledge and perceptions of existing, desired, and proposed technologies, the conditions of their use, and their differing benefits and problems. Qualitative methods were seen as more effective in revealing the real experiences and perceptions of farmers than questionnaires with a pre-determined format based on the hypotheses of researchers. This knowledge became the basis for prioritization of technology development needs, followed by design, implementation, and evaluation of applied technology trials with farmers on their fields. Evaluation combined agronomic and economic quantitative data collection and analysis with farmer group-based assessment.

Nevertheless, the differing assumptions and methods of agricultural scientists and social scientists continued to create difficulties. Agricultural researchers often found the graphs, diagrams, and calendars of farmer activities to be inadequate, simply reflecting in visual, descriptive form the practices of particular farmers. Agricultural researchers were likely to consider that understanding individual farmers' experiences and perceptions was not sufficient for assessing the potential use of technologies and identifying how these might be modified to improve their usability. Extrapolation of those experiences and perceptions to a larger target area was needed.

This research sought to combine the strength of qualitative approaches in understanding farmers' experiences and perspectives, with statistical approaches for assessing the likelihood that differences among farmers were not due simply to random variation among the group of farmers. The idea of "Mixed Methods" from Tashakkori and Teddlie (2009) was used as the starting point for creating a method to link qualitative narrative data collection and quantitative data analysis. In effect a mixed methods conversion design (Tashakkori et al. 2021) was created, although this was unfamiliar terminology when work was done in 2015-2017. It was hoped that these results could provide a starting point for broader extrapolation, future technology trial design, and wider extension of improved technologies.

Data collection. Seven farmers were selected in each of two villages. In SS district, the farmers were all members of the farmers' group in the village. In NSH district, the farmers were selected in consultation with the head of the village.

Two different methods were used for data collection from the selected farmers, depending on the nature of the information sought:

(1) A large matrix recording sheet was used to record information from each farmer's narration of 10 years of change in types of vegetables and their production practices, impetuses and sources of information for each change, and benefits of each change. Columns in the matrix represented types

of vegetables and their production practices. Rows represented different points in time and types of information about each change asked through probing questions when information did not emerge in the farmer's narration. This information was recorded on post-it tags placed in the appropriate cells in the matrix. Both farmers and researchers could see how vegetable production had changed over time, based on the principle of visual sharing of data by researchers and farmers (Chambers 1993).

Fig. 1. Narration matrix

(2) Farmer personal characteristics (age, gender, education, presence or absence of off-farm income and its relative importance, farmer household labor), and types of crops and area and income from each crop were gathered using a questionnaire.

The above narration and matrix recording method was based on the method developed for technology change in "mountain potato" yam (*Dioscorea opposita*) production in Akita, Japan (Caldwell and Ueda 2015, 2016), and adapted to the research objectives and agricultural conditions of Northeast Thailand. The surveys were conducted over seven days in January 2017.

Data entry, transformation, and analysis. The information recorded on each post-it was entered into an Excel file with the same structure as the narration recording matrix. Each crop had three stages of technology use: 1)crop establishment, 2)water management, 3) pest management and other technologies. Three additional columns were inserted to the right of each technology stage column: 1) technology, 2) impetus / sources of information, 3) benefits. Information was divided vertically into four time periods: original technology more than 10 years ago; technology 10 years ago; initial innovations within the last 10 years; second innovations after an initial innovation within the last 10 years. Two files were made for classification and quantification of the technologies. The first quantification file consisted of 25 types of impetuses and sources of information that led the farmer to create or adapt a given technology. The second quantification file consisted of 20 types of benefits of using the technology.

For a given technology, its impetus and/or information sources were placed in the corresponding impetus or information source category. The value 1 was placed in the cell corresponding to that category, if there was only one impetus or source. Each cell received a weighted value w calculated as the inverse of the number of impetuses or sources t, $w = (1 / t)$, if there was more than one impetus or source. The same method for quantification of each benefit was applied based on categories of the benefits. A technology change file was used to classify types of technology changes. Crop establishment and management were divided into six sub-stages: land preparation, crop and variety selection, fertilization, planting, trellising, and other. Crops were combined into five groups: yard long bean, other fruiting vegetables (pepper, various eggplants, corn), leafy crops (including heading cruciferous crops), and other crops. Changes in technologies for each production sub-stage and crop group were mapped out over the four time periods described above, and frequencies of different change patterns enumerated.

Differences in the resulting quantitative measures of types of impetus / information sources, benefits, and farm management between the two villages were assessed using Student's t. Differences in numbers of farmers in each village in different categories of impetus / information sources, benefits, and personal characteristics were assessed using the Chi-square test. Stepwise regression was used to test for contributions of farmer characteristics and three groupings of types of sources of information (farmer, research and extension, and private sector) contributing to numbers of changes in technologies and farm and vegetable revenue. All statistical analysis was done using Statistix10 (Analytical Software 2008).

RESULTS AND DISCUSSION

Farmer profile. Farmers in the two villages were similar in age, education, years farming, years off-farm experience, and household size (Table 1). All households surveyed had income only or primarily from farming. Half or more of the households in both villages had no off-farm work. Occasional off-farm work was more important in SS than in NSH. The most important difference between the districts was participation in agriculturally-related training. Over the past 10 years, farmers in SS had participated 4-5 times per year. Farmers in NSH had participated on the average only 1 time in 3 years.

Farm management. Farmers in NSH had nearly 3 times more land in rice, and overall 26% more land in agriculture compared to SS. However, land in vegetables in SS was nearly twice that of NSH. Farmers in SS had less revenue from rice than farmers in NSH, but 9 times more revenue from vegetables than NSH farmers (Table 1).

Table 1. Characteristics of farmers in two districts, Khon Kaen Province, Northeast Thailand, 2017.

Parameter	unit	SS [a]	NSH [a]	Probability [b]
Farmer characteristics [c]				
Age	year	51	50	0.79 NS
Education	year	5.4	4.0	NT
Farming experience	year	29.2	31.9	0.69 NS
Off-farm experience	year	3.2	2.9	0.90 NS
Household size	persons	4.7	4.0	0.49 NS
Training	times	45	3	0.03 *
Income sources [d]				
Only farming	%	33%	57%	0.39 NS
Farming > non-farm	%	67%	42%	
Non-farm > farming	%	0%	0%	NT
Frequency of off-farm work [d]				
None	%	50%	71%	0.43 NS
Regular or occasional	%	50%	28%	

[a] Means of 6 farmers (SS) or 7 farmers (NSH)
[b] Probability of differences, + trend at $p<0.10$, * significant at $p < 0.05$, or ** highly significant at $p < 0.01$;
NT, no statistical test .
[c] Differences between villages tested by unpaired t-test
[d] Differences between categories and villages tested by chi-square test.

Vegetables and associated crops. SS farmers planted a greater variety of vegetables and associated crops, 18 types, compared with 11 types in NSH. Both villages planted yard long bean, many kinds of leafy and heading vegetables, and several kinds of fruiting vegetables. Cruciferous crops predominated among the leafy and heading vegetables. Only five kinds of crops (yard long bean, eggplant, pepper, Chinese flowering cabbage, and coriander) were common to both villages. SS farmers also planted several kinds of fruits and herbs in the same areas where vegetables were planted (Table 2).

Table 2. Farmer crop areas and annual household agricultural revenue in two districts, Khon Kaen Province, Northeast Thailand, 2017

Crop types	Farmers		Parameter values [a]		
	SS	NSH	SS	NSH	Probability [b]
	n	n		Area (ha)	
Rice	6	7	1.33	4.40	0.01*
Other agronomic crops	2	1	3.24	1.60	NT
Other crops	2	0	0.20	0	NT
Total	5	7	4.77	6.00	0.02*
Vegetables (sum)	6	7	0.42	0.23	0.31 NS
				Revenue (bahts)	
Rice	5	7	1,120	3,200	0.18 NS
Other agronomic crops	2	1	6,000	300	NT
Other crops	2	0	1,500	0	NT
Total crops	5	7	8,620	3,500	0.82 NS
Vegetables (sum)	6	7	18,191	2,426	0.04*

[a] Means of farmers responding at each location for each parameter
[b] Probability of differences, + trend at $p<0.10$, * significant at $p < 0.05$ or ** highly significant at $p < 0.01$; NT, no test, due to small sample size or absence of variation in one or both villages.

Technologies and technology changes. Farmers described a total of 417 individual technologies, or an average of 30 technologies / farmer (Table 3). Farmers in SS described nearly twice as many more technologies than farmers in NSH. These technologies were divided into original technologies used 10 or more years ago, and technology changes made during the past 10 years. In both locations, more than half of both original and changed technologies described by farmers involved soil and planting. There were no differences between the two districts in relative proportions of different types of original technologies. However, farmers in SS described proportionally more changes (53%) than farmers in NSH (44%), and there was a highly significant difference in types of changes between the two villages. Changes in water management were more important in NSH than in SS, whereas more changes in pest management and other technologies were made in SS.

Table 3. Individual technologies used by farmers in vegetable production 10 or more years ago and technology changes made during the past 10 years in two districts, Khon Kaen Province, Northeast Thailand, 2017.

Technology categories	SS		NHS			All	
	No.	%	No.	%	Signif. [a]	No.	%
Individual technologies	271		146			417	
Original technologies [b]							
Soil and planting [c]	72	56%	48	59%		120	57%
Water management [c]	27	21%	17	21%	NS	44	21%
Pest mgt. and other [c]	29	23%	17	21%		46	22%

Technology categories	SS		NHS			All	
	No.	%	No.	%	Signif. [a]	No.	%
Technology changes [e]							
Soil and planting [c]	84	59%	35	55%		119	57%
Water management [c]	11	8%	17	27%	<0.01**	28	14%
Pest mgt. and other [c]	48	34%	12	19%		60	29%
Totals [d]							
Original technologies [b]	128	47%	82	56%	0.08+	210	50%
Technology changes [e]	143	53%	64	44%		207	50%

[a] Probability of differences in technologies tested by chi-square test,
** highly significant at $p < 0.01$, + trend at $p<0.10$, or * NS not significant at $p\geq0.10$.
[b] Technologies used 10 or more years ago
[c] Percentage of original technologies or technology changes
[d] Percentage of all individual technologies
[e] Technologies changed in the past 10 years

The 417 individual technologies were grouped into 83 technology types. Each type grouped several individual technologies described using similar words by different farmers. Approximately one third of the technology types were common to both villages, while two thirds were specific to one or the other village.

There were significant differences between the two villages in numbers and types of technology changes. In SS, nearly half of all technology changes involved leafy vegetables, while in NSH, more than half involved yard long bean. Differences among vegetables and types of technology changes were significant in NSH but not in SS, where pest management changes were most important for leafy vegetables. In NSH, pest management changes were most important for yard long bean (Table 4).

Farmers did not make technology changes in the same way or sequence (Table 5). Changes in fertilization involved all types of fertilizers: chemical, organic, and mixed. Water management changes tended to move from hand and hose to systems using pumps, and in some cases then changing from furrow to trickle or sprinkler irrigation, especially in NSH. Some farmers changed water sources from ponds to underground, while others improved ponds. Adding ponds was more important in SS than in NSH. There were significantly more pest management changes involving organic pest control products, cultural practices, or IPM techniques in SS, while most changes in pest management in NSH involved changes in types of chemical pesticides.

Table 4. Types of technology changes of different vegetable types in two districts, Khon Kaen Province, 2017

Technology change	Vegetable type				
	Yard long Bean	Other fruiting	Leafy	Other	All
			SS		
Crop and variety	3	4	11	10	28
Fertilization	5	5	11	1	22
Trellising	5	0	0	0	5
Water management	0	0	4	1	5
Pest management	2	5	15	4	26
All changes	15	14	41	16	86
Probability of differences [a]					

Technology change	**Vegetable type**				
	Yard long Bean	**Other fruiting**	**Leafy**	**Other**	**All**
All crops, SS [b]			0.12 NS		
			NSH		
Crop and variety	3	6	2	1	12
Fertilization	4	1	3	0	8
Trellising	3	0	0	0	3
Water management	4	1	2	0	7
Pest management	10	1	3	0	14
All changes	24	9	10	1	44
Probability of differences [a]					
All crops, NSH[c]			0.03*		
SS vs. NSH, all changes [d]			<0.01**		

[a] Probability of differences in technologies tested by chi-square, ** highly significant at $p < 0.01$, * significant at $p<0.05$, or * NS not significant at $p\geq0.05$.
[b] Probability of differences between vegetables x technology changes within SS; trellising and water management not included due to small numbers.
[c] Probability of differences between vegetables x technology changes within NS; other vegetables and fertilization, trellising and water management not included due to small numbers.
[d] Probability of differences between districts and vegetable types.

Table 5. Sequences of technology changes in two districts, Khon Kaen Province, 2017

Technology Groups	**Technology change**	**SS**		**NSH**	
		Changes	**Types**	**Changes**	**Types**
Crop and variety	variety	13	28	7	12
	add or change crop	15		5	
Fertilization	chemical→ organic	1	22	2	8
	change within chemical	9		2	
	change within mixed	5		3	
	change within organic	7		1	
Trellising	none→ string	0	5	1	3
	stakes→ wire and string	0		1	
	change pole type	0		1	
	net, other	5		0	
Water management	hand→ hose	0	5	1	7
	hose→ pump→ trickle	0		2	
	water source→ trickle	0		1	
	hose→ pump, source	1		1	
	pump: petrol→ electric	1		1	
	bucket→ pump→ sprinkler	0		1	
	ponds	3		0	
Pest management	change to or add organic	4	26	1	14
	cultural practices	8		3	
	IPM	3		0	
	change within chemical	8		10	
	mixed, other	3		0	

Technology Groups	Technology change	SS Changes	SS Types	NSH Changes	NSH Types
Total	all technology changes		86		44
Probability of differences [a]					
X^2 test, districts x all technology groups [b]		0.28 NS			
X^2 test, districts x non-chemical vs. chemical pest management [c]			0.03*		

[a] Probability of differences tested by Chi-square, * significant at p< 0.05, or NS not significant.
[b] Trellising not included due to small numbers.
[c] Non-chemical pest management is the sum of change to or add organic, cultural practices, and IPM vs. change within chemical; mixed not included due to small numbers.

Impetuses and sources of information of technologies. Comparison of impetus and information sources between the two villages showed important differences between the two districts (Table 6).

Impetuses based on farmers' own ideas and interaction were 45% more numerous in SS than in NSH. Farmers' own ideas and farmers' own trials were more common in SS, while farmers' reasons for adaptive use of technology and talking among themselves were more important in NSH.

Farmers in SS obtained significantly more information from public extension and research sources, approximately 7 times more than in NSH. These included training programs and university visits that were not present in NSH. Farmers in both villages obtained similar amounts of information from the private sector and other outside sources. Information from input stores and companies was the most important private sector source. Farmers in SS also obtained considerably more information from printed publications and the internet, and from markets. In contrast, more farmers in NSH had off-farm experience that contributed information. These included farmers who had worked in Israel and Taiwan.

Overall, farmers in SS had significantly more types of sources of information, and nearly double the number of sources of information. The first measure, types of sources, indicates more diverse sources of information. The second measure, number of sources, reflects the greater number of technologies in SS. While not all individual impetus and source type comparisons were statistically significant, they provide insight into reasons why differences in total types and numbers of sources of information were significant.

Table 6. Impetus and sources of information of technologies used in vegetable production in two districts, Khon Kaen Province, Northeast Thailand, 2017

Impetuses and sources	SS [a]	NSH [a]	Probability [b]
Farmers' ideas and interaction			
Farmer's own idea	3.14	1.50	0.28
Farmers' reason for adaptive use	0.07	0.19	0.33
Family	0.71	0.00	No test
Farmers talking	0.14	1.64	0.12
Farmer organization	0.36	0.00	No test
Observing another farmer	0.83	0.68	0.69
Farmer's own trial	1.19	0.44	0.27
Farmers' ideas and interaction sum	6.45	4.45	0.22
Research and extension			
Extension information	1.50	0.55	0.23
Training program	0.68	0.00	No test

Impetuses and sources	SS [a]	NSH [a]	Probability [b]
University visit	0.94	0.00	No test
On-farm collaborative trial	0.00	0.00	No test
Research station information	0.00	0.00	No test
Other organization	0.39	0.00	No test
Research and extension sum	3.51	0.55	0.01 **
	Private sector and other sources		
Store or company	2.07	2.34	0.78
Printed publication or internet	0.57	0.08	0.03 *
Private collaborative trial	0.00	0.00	No test
Market	1.39	0.57	0.16
Infrastructure	0.00	0.14	No test
Overseas experience	0.00	0.00	No test
Off-farm work experience	0.00	0.57	No test
Private sector and others sum	4.03	3.71	0.81
Number of types of sources	7.71	5.57	0.03 *
Sum of sources	14.00	8.71	0.003 **
Independence quotient[c]	0.44	0.52	0.52

[a] Mans of 7 farmers / location.
[b] Probability of differences, * significant at $p < 0.05$ or ** highly significant at $p < 0.01$; no test, one or both averages zero.
[c] Proportion of all sources comprised by farmers' ideas and interaction.

Benefits of technologies. Farmers in SS and NSH differed in benefits obtained from technologies (Table 7). Farmers in SS cited twice as many benefits as did NSH farmers. This partially reflected the 38% greater number of impetuses and sources of information in SS seen in Table 6. It also reflected more benefits per technology in SS.

Crop production and environmental benefits comprised 63% of the benefits of technologies in SS, while those benefits comprised 45% of the benefits of technologies in NSH. Economic benefits comprised only 29% of the benefits in SS, but 46% of benefits in NSH. Crop production and environmental benefits were thus relatively more important in SS, and conversely the economic quotient (proportion of all benefits) was greater in NSH. Social and individual benefits comprised less than 10% of the benefits cited in both villages.

Within the crop production and environmental benefits group, benefits for insect and disease management were the most important type of benefit in SS, cited 5 times more than in NSH. Soil fertility and fertilization benefits were second in importance in SS, while cited only occasionally in NSH. Water management benefits were also significantly more important in SS. Crop growth benefits were the most important type of benefit within NSH.

Economic benefits were cited 32% more often in SS than in NSH, but this difference was not significant. Marketability was cited 78% more often in SS. This trend might become significant if a larger number of farmers were compared in each village.

Table 7. Benefits of technologies used in vegetable production in two districts, Khon Kaen Province, Northeast Thailand, 2017

Impetuses and sources	SS [a]	NSH [a]	Probability b
Crop production and environmental benefits			
Soil fertility and fertilization	2.50	0.29	0.05 +
Water management	1.21	0.21	0.04 *
Environment	0.57	0.43	0.70
Compatibility with other technologies	0.14	0.00	No test
Weed management	1.14	0.07	0.14
Insect and disease management	5.03	1.07	0.003**
Crop growth	2.21	1.60	0.52
Product quality	0.37	0.79	0.31
Subtotal, production and envir. benefits	13.18	4.45	0.03*
Economic benefits			
Yield	1.80	1.07	0.37
Crop planted area	0.14	0.26	0.51
Production costs	0.50	0.62	0.74
Returns	0.43	0.57	0.60
Marketability	1.65	0.93	0.08+
Labor quantity, efficiency	0.58	0.33	0.41
Compatibility with other crops	0.07	0.00	No test
Ease of input obtainability	0.71	0.69	0.96
Input quality	0.21	0.14	0.74
Subtotal, economic benefits	6.11	4.62	0.20
Social and individual benefits			
Recommendation of other farmers	0.00	0.14	0.78
Recommendation by extension, etc.	0.00	0.14	No test
Farmer organization	0.17	0.00	No test
Easy, fast, etc.	1.10	0.71	0.36
Policy	0.00	0.07	No test
Others (health, home use)	0.36	0.00	No test
Subtotal, social and individual benefits	1.64	0.93	0.27
Number of types of benefits	11.57	8.71	0.09 +
Sum of benefits	20.93	10.00	0.02 *
Benefits / source	1.5	1.1	No test
Economic quotient [c]	0.32	0.45	0.099+

[a] Means of 7 farmers / location
[b] Probability of differences, + trend at p<0.10, * significant at p < 0.05 or
** highly significant at p < 0.01;
no test, one or both averages zero
[c] Proportion of all benefits comprised by economic benefits

Factors contributing to changes in technologies and revenue. Table 8 summarizes the results of stepwise regression analysis of factors hypothesized to affect the number of changes in technologies and revenue. Effects of several farmer characteristics were seen on all four dependent variables overall (both villages combined) and in SS, but only on total revenue in NSH.

Overall, greater age increased both the number of changes in technologies due to farmer ideas and interaction and the total number of changes in technologies. More years working off-farm increased both farmer-initiated changes and the total number of changes in SS but not in NSH.

Overall, more years in farming increased farm revenue. Greater farm area increased revenue in SS, while more years working off-farm increased revenue in NSH. Family size and training increased vegetable revenue. In SS, greater farm area increased vegetable revenue, but none of the hypothesized variables contributed to vegetable revenue in NSH.

Table 8. Results of stepwise regression of effects of selected farmer characteristics on numbers of technology changes and revenue in two districts, Khon Kaen Province, Northeast Thailand, 2017

Dependent variables	Independent variables [a] in model, significance [b], and model R^2		
	All	SS	NSH
Changes due to farmer ideas and interaction	Mean 5.5 Age * +0.3 Years farming * +0.18 72%	Mean 6.5 Years off-farm * 0.6 84%	Mean 4.5 All variables NS No model
Total number of changes	Mean 11.4 Age * +0.07 48%	Mean 14.0 Years off-farm * 0.1 84%	Mean 8.7 All variables NS No model
Farm Revenue (baht)	Mean 66,154 Yrs farming** +6,124 60%	Mean 60.833 Total area* +1,860 89%	Mean 70,714 Yrs off-farm* +18,164 72%
Vegetable revenue (baht)	Mean 242,551 Family size* +70,991 Training** +1,421 67%	Mean 454,778 Farm area -7,311 97%	Mean 60,643 All variables NS No model

[a] Farmer and farm characteristics hypothesized as contributing to all dependent variables: age, number of years of education, number of years farming, number of years engaged in off-farm work, total farm area, number of times participated in training.
Impetuses and information sources hypothesized as contributing to revenue:
weighted number of technology changes due to farmer ideas and interaction, information from extension or research, or information from the private sector, and
total number of technology changes,

[b] Significance of dependent variables remaining the final model:
NS non-significant at $p \geq 0.05$, * significant at $p < 0.05$, or ** highly significant at $p < 0.01$;
+ indicates positive effect, - indicates negative effect.

Origins of technology changes. The above results show that farmers in the village with a farmers' organization, SS, are using a greater variety of technologies and have made more technology changes than the farmers in the village without a farmers' organization, NSH. Moreover, farmers in SS made more changes based on their own ideas and interaction than in NSH. At the same time, they also accessed outside information more than farmers in NSH.

In the oral interviews, farmers in SS described how an early training program by public extension and universities starting from 1994 had helped them organize themselves into a group and work together to produce for the market. As farmer 6 stated, "Middlemen set the price on the day of sale. There was no assurance of price. Training gave us knowledge on how to form a group. As the group became stronger, it became able to market on its own." The above quantitative analysis shows that SS farmers became more active innovators, taking information from public and private sources, combining it with their own ideas (such as making sticky traps from local materials), testing innovations in their own trials, and making more technology changes in their production. For example, farmer 5 stated that he changed the variety of *kana* (Chinese kale, a popular leafy vegetable) "because he observed that another farmer in the group found this variety sold well." Farmer 7 stated that she changed her watering method "based on observing the vegetables and following a friend in the group." In contrast, farmers in NSH had plentiful informal interaction, but overall made fewer technology changes than in SS. These comparisons suggest that the farmers' group had a stimulating effect on technology change and innovation.

Analysis of farmer perceptions of benefits suggests that the technologies used in SS are successfully addressing more types of environmental and production problems than in NSH. SS farmers are also deriving marketability benefits more often from technologies.

Value, types, and origins of farmer organizations. These results overall support the value of farmer organizations in stimulating technology change and innovation. Extension agents, university and research institute researchers carrying out field-based, farmer-oriented applied research, and private sector actors working with farmers can support the formation and functioning of farmer organizations with the expectation that it will provide environmental, agronomic, and economic benefits to farmers. The effect of farmer organizations in increasing the use of organic and reduced chemical technologies can also result in better quality agricultural products for consumers.

In this case, the farmer group in SS consisted of 10 farmers in one village, all producing vegetables. The group formed naturally among relatives. The leader is a respected person in their kinship network and was formerly head of the village. The group has a market stall in the city where they sell products together. This selling platform is therefore one of the locations ("ba") for sharing knowledge among members. The word "ba" means "place" in ordinary Japanese usage, but Yokoyama (2015) proposed using this word as a term to refer to the location of interaction among actors involved in agricultural extension and development. Caldwell (2021) has explained "ba" as a "theater of action" for agricultural extension and development activities, both spontaneous and of external origin, and introduced this term in international agricultural extension training conducted by the Japan International Cooperation Agency (JICA).

Shigetomi (2006) divided community organizations into four types, based on field work in both Northeast Thailand and the Philippines. Organizations were classified based on their function (addressing a specific objective vs. mediating social relations) and origin (spontaneous within the village vs. from outside the village). This farmer group begin from a kinship network, but had a specific objective, to sell products together. Moreover, the farmers sought out assistance from both extension and the regional agricultural university. So in effect, they evolved from Type III (spontaneous mediating social relations) to Type I (spontaneous with a specific objective), seeking out and taking advantage of information from outside sources, similar to Type II. The authors term this a hybrid "collaboration" type. The Agricultural Extension Research Society of Japan has made the word "collaboration" the central focus of an expanded understanding of agricultural extension (Sato et al. 2020), wherein agricultural extension workers facilitate and support spontaneous development effects of farmers and communities. The word in Japanese is a combination of the characters for "cooperating" and "working."

More information on the formation of farmer groups is needed to identify the conditions for successful formation and operation of farmer groups. This information should include what stimulated formation of the group, characteristics of the location of the group (including water access, soils, and access to markets), characteristics of members of the groups (type of farming, kinship and social relationships, market access), and frequency of both formal meetings and informal interaction.

One example of the impetus to group formation can be seen in the response quoted above of farmer 6 in SS who stated in his narration that, "Training gave us knowledge on how to form a group. Because we had the problem of middlemen fixing prices." This indicates that farmers wanted to form a group to gain the power to set their own prices. In other words, economics was the impetus to group formation.

Effects of technology changes. In contrast with results in Akita (Caldwell and Ueda 2017), greater numbers of technology changes due to farmers' own ideas and initiatives did not show a linear effect on farm or vegetable revenue. Years farming and family size had more effect on revenue than technology changes. In Akita, a major innovation stimulated other technology changes for a single crop that was the flagship brand crop of the area of study. On the other hand, in Northeast Thailand, small technology changes were spread across many types of vegetables, so the effect on overall farm and vegetable revenue of each change was likely to be small. Young farmers without other family members to help with intensive vegetable production and marketing could benefit from support in targeting production to markets to obtain meaningful economic benefits from making technology changes.

The sample size for modelling of 12 in this study was approximately half only the sample size of 23 obtained in Akita. With a larger sample size, a significant effect on farm and vegetable revenue of technology changes due to farmers' own ideas and initiatives might have been found in this study in Northeast Thailand. A larger sample size also allows for more independent variables to enter into models (Hair et al. 2010), such as in Akita, where three factors (potato planted area positively, total planted area and years of off-farm experience negatively) were found to contribute to the number of technology changes (Caldwell and Ueda 2017). Models with several variables can provide more insights for designing support programs targeting farmers most likely to obtain economic benefits from technology change.

Factors affecting technology changes. The role of off-farm employment in stimulating agricultural technology change for vegetables is in accordance with off-farm employment's positive effect on rice technology change (Grandstaff et al. 2008). Future research could trace the types of information brought back from overseas and the interactions of returning farmers with other farmers.

In a study of constraints to organic production in the same area but with different farmers, insufficient understanding of the principles of organic production and lack of training in organic production were the two greatest constraints of vegetable farmers in that area, followed by lack of organic pesticides, difficulties with organic soil management, and lack of cooperation among farmers (Mondal et al. 2014). The results presented here suggest that farmer organization can help address technical difficulties through sharing of knowledge among member farmers.

A key issue to consider in future research is the question of the effects of market type, size, and access on innovation. Farmers in SS had access to an urban market with more demand for reduced pesticide and organic vegetables, while demand in the smaller market in NSH was almost exclusively for conventionally-produced vegetables. These results suggested marketability to be a factor in technology use and change in SS, and marketability may be an underlying motivational factor in the difference between the two villages. Analysis of farmers' motivation through self-determination analysis can help farmers understand better the importance of market access, and thereby increase motivation for market-oriented technology change and innovation. This approach has been successfully applied with small-scale farmers in Kenya (Sayanagi et al. 2016).

Potential for future uses of MMR in agricultural extension and development research. The methods used in this study linked qualitative narration as a source of information about technology change and quantitative analysis to assess to what extent there were differences between the two villages, as a first step towards extrapolation. From the perspective of Mixed Methods Research (MMR), research questions 2 and 3 required integration using the conversion design the authors created to address these two questions. Mixed Methods Research (MMR) is defined by Tashakkori et al. (2021, p. 401) as "research that collects/analyzes QUAN [quantitative] and QUAL [qualitative] data and integrates the findings and makes meta-inferences based on both types of findings." This research meets the standard of the first part of this definition, but it did not set out to conduct a separate qualitative analysis to make meta-inferences from both qualitative and quantitative types of analysis. It does, however, meet the older, broader definition of Johnson et al. (2007) quoted by Tashakkori et al. (2021, p. 47): "Mixed methods research is the type of research in which a researcher or a team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the purpose of breadth of understanding or corroboration."

To add an explicitly qualitative analysis for making meta-inferences in a convergent design (Creswell 2022; Creswell and Plano Clark 2022) would require a preparatory study to determine which qualitative analysis method would be most useful for the objectives of agricultural extension and development, and for identifying key farmer responses for qualitative analysis and inclusion in joint displays. The life pathways method of Aquino (2021) could be a useful method to determine how spontaneous farmer groups form. A range of qualitative methods and their uses with examples are presented Corbin and Strauss (2015), which could be used as a reference in considering the use of MMR to address research questions in agricultural extension and development.

The data conversion process, in which each key element of the narration is read one-by-one and assessed for quantification, provides context for interpreting the quantitative analysis that follows in a conversion design, but it is very time consuming. Discussion with several MMR researchers at the 2018 Symposium of the Japan Mixed Methods Research Society did not lead to a conclusion as to how computer technology might be used to speed up the conversion process without losing the qualitative understanding gained by the researcher's reading of each response for qualitative analysis and interpretation.

MMR uses joint displays as one method (Creswell 2022; Creswell and Plano Clark 2022; Fetters et al. 2013) for presenting the results of both types of analysis for meta-inference. This should be considered at the beginning of planning research that aims for meta-inference from both QUAL and QUAN analyses. The overall time requirements for the different steps in MMR need to be considered carefully and planned for in advance, as explained in more detail in Creswell and Plano Clark (2022).

The original responses of the farmers were used to identify examples of key results revealed by the quantitative analysis. This was like re-entering a forest and looking at all the individual trees one-by-one. The individual trees provide context, but one cannot see a whole forest from examination of each tree. Quantification is a tool that enables one to reduce this complexity and see the overall contours and characteristics of the forest of farmer technology change revealed in the qualitative narration by individual farmers. This is a benefit of the combination of quantitative and qualitative methods.

The integration of formal MMR methods into agricultural research on farmer technology change would need to address the above issues. This could be a topic for a graduate student interested in using qualitative and quantitative methods for understanding farmer technology change, and thereby developing better methods of farmer-centered and farmer-led collaboration in agricultural extension and development.

CONCLUSION

Overall, farmers in this study made on the average 30 technology changes over the 10 years that they described technology changes in their narrations. These technology changes differed both in content and in number between the village with a farmer group, SS, and the village without a farmer group, NSH.

The mixed methods research (MMR) conversion design developed for this study provided quantitative measures of frequency of key words in the narrations. Statistical comparisons of the villages showed that the village with a farmer group, SS, made twice as many technology changes overall, with proportionally more technology changes in pest management. More pest management changes in SS involved organic pest control, cultural practices, and IPM. The farmers in SS were then able to gain access to a market for organic and reduced chemical vegetables.. These changes reflected more training and other support programs, greater use of public extension and research information, and greater farmer interaction in SS. Increased training had a positive impact on vegetable revenue in both villages considered together.

These results overall indicate that farmer groups can have a positive effect on technology change. In order to stimulate and support farmer group formation, more research is needed to identify the conditions that lead to the successful formation and operation of farmer groups. Life path history of farmers both belonging to and not belonging to a farmer group could reveal these conditions. This research should include identification of information brought back from off-farm work experience and patterns of sharing that information among farmers. More research on types of markets and farmer motivation in seeking new market access is also needed. The key factors identified through such qualitative research could then be tested using a similar MMR conversion model with a larger number of farmers to increase the power of statistical testing for extrapolation. Results from both qualitative and quantitative analysis could then form the basis for guidelines for agricultural extension and other collaborators in rural development to use in developing farmer-centered and farmer-led collaboration in agricultural extension and development.

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