Empowering Farmer Leaders to Acquire and Practice Site-Specific Nutrient Management Technology

Tasnee Attanandana
Russell Yost
Prateep Verapattananirund

ABSTRACT. Precision agriculture, using high-tech equipment and information science software, is not appropriate for the farmers of small parcels of land in the tropics. Our hypothesis, however, is that the concepts of precision agriculture and participatory action research have a similar philosophical basis and complement each other. We have adopted an approach of both empowering farmers and simplifying nutrient management technology to enable farmers to use the concepts. The simplified technology includes a visual tool to identify soil series, a soil test kit that brings the laboratory to the field, and a decision-aid that enables farmer leaders to interpret the soil test kit data in light of the soil series. The results have demonstrated increased yields with reduced fertilizer inputs over a three-year period in Central Thailand. doi:10.1300/J064v30n01_08

Tasnee Attanandana is Professor, Department of Soil Science, Kasetsart University, Bangkok, Thailand (E-mail: agrtna@yahoo.com).
Russell Yost is Professor, Department of Tropical Plants and Soil Sciences, University of Hawaii, Honolulu, HI (E-mail: rsyost@hawaii.edu).
Prateep Verapattananirund is President of Eco-Community Vigor Foundation, Bangkok, Thailand (E-mail: ecvf_prateep@hotmail.com).

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INTRODUCTION

Meeting the challenges of reducing nutrient contamination of streams, rivers, and waterways, and increasing efficiency through improved nutrient management is daunting for those producing food in the large farms of the Western hemisphere. The challenges for the small farmers of the tropics are perhaps greater and more daunting, mainly because many farms there are exceedingly small. Even Thailand, which has some of the more progressive farmers in the region, has very small farms. For example, a recent survey of over 600 farms in the maize belt of Thailand indicates that the median farm size was 1.6 ha while the maximum was 24.8 ha (Attanandana et al., 2004). Some farms were much less than one ha in size. Discounting costs of machinery and technology over such small acreages becomes nearly impossible. It is clear that much of the high-tech equipment currently promoted by vendors of Precision Agriculture in the United States, for example, is inappropriate for farmers of small parcels in the tropics. Certainly, there are cases of farmers in the tropics that are not small. Examples abound in the Cerrado region of Brazil (Lopes, 1984) where some farms are as much as 60,000 ha in size with fields of several thousand hectares. Nonetheless, the overwhelming majority of farmers in the tropics deal with land parcels that are very small. Technology developed for the large maize farms of the MidWest US is simply not feasible for farmers of such small parcels of land.

What then are the options for small parceled farmers, if any? It is our view that there are, indeed, options for small farmers through the improved use of knowledge and information science. The best of these options, in our view, builds on the farmer's knowledge and hard-gained experience. Central to this approach is the adaptation of the technology to the farmers, rather than the adaptation of the farmers to the technology, as seems to be the case in much of the technology-driven expansion and adoption of Precision Agriculture. While we report here several simplifications of technology to fit farmer needs, we also discuss increasing farmer capacity. One of the most powerful techniques of improving farmer knowledge is that of convincing the farmers that they have knowledge that is useful and that, if they use it correctly, they can change some of the critical factors of production. The techniques of capacity building are designed to encourage farmers to become aware of their potential and how to use it. We describe some approaches to farmer capacity building and then discuss how we have implemented them as we have adapted site-specific concepts to farmers of small parcels of lands in the tropics.

CAPACITY BUILDING

Capacity building of farmers and their institutions is essential for achieving a balance in economic, social, and environmental development goals. The main components of capacity building may include:

Farmer-centered development. An enabling environment was created to facilitate farmers to self-improvement. Development to us means not only improvement in farmer's knowledge and capacity but also in their morale.

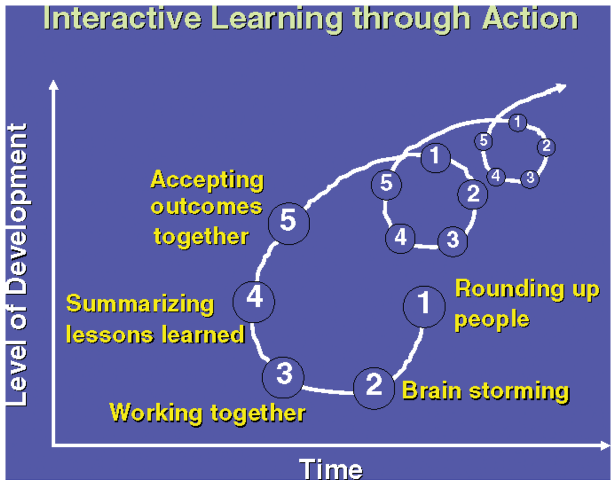
Participation of farmers. Active participation to us means that farmers assume the major role in decision making and managing their affairs. Efforts were made to build confidence in farmers so that they make decisions on how to solve the problems they have identified. Other groups such as the GOs and NGOs have supporting roles in that they provided some guidance, comments, advice, and training required for confidence building.

Participatory Learning Forum or *interactive learning,* which is a methodology developed to enable farmers to gain more control of their lives and businesses as farmers (Figure1).

Five steps of "interactive learning" are taught, often by example and by doing rather than by only giving the concepts. Steps include the following:

1. Gathering the relevant people in one place at the same time.
2. Brain-storming about problems and possible solutions.
3. Working together. Suggestions arising out of the brain-storming sessions are selected and acted upon rather than just discussed and dropped. This is an essential action step where theory and ideas are put into practice.
4. After the working sessions, some time is taken to summarize the lessons learned from the working activity and the brain-storming sessions.
5. The final step in the first iteration of the process is the acceptance of the outcomes together. This could comprise activities of realizing, accepting, and participating in the results of the group effort.

FIGURE 1. The steps of interactive learning.



The steps of "interactive learning," once taught, can be used repeatedly for problem solving. Results of *interactive learning* through action can be very empowering and can include the following:

- Farmers and growers increase their self-confidence and improve their self-management.
- Often, the farmers re-establish relationships with nature and with their community.

These outcomes stimulate self-reliance and confidence that the community can be strong. Other results of *interactive learning* may include interactive managing, improved communication and information flow, participatory technology development, and technology transfer. Taken together, these activities can lead to sustainable rural development that recognizes and respects social capital, local wisdom, and natural resources.

Focus on self-reliance: Emphasis was placed on self-reliance by mobilizing social capital, local wisdom, and natural resources for sustainable rural development. There are two fundamental concepts that serve as the philosophical basis for the technique: (1) Self-awareness and (2) Self-reliance.

Self-awareness is taught through discussions with the farmers and growers by reminding them of the capital that they possess or for which they are responsible. This change of thinking will lead to their self-reliance. Examples of farmer capital include the following:

- Morality
- Local wisdom
- Habits of saving and helping each other
- Warm family
- Values and culture
- Strong community
- Savings and assets
- Rights and freedoms
- Good health
- Environment
- Natural resources
- Forest
- Biodiversity
- Soil
- Water

Action research by farmers. Farmers were encouraged to conduct field experiments with advice from researchers. Knowledge and experiences gained from field trials by farmers and by farmer groups were exchanged.

Networking of farmer groups. Exchange and interactions between individual farmers or farmer groups include interactive learning as discussed before and participatory technology development and transfer. Farmer networks are a way of facilitating farmer-to-farmer exchange of knowledge and experiences related to agricultural practices and natural resources.

A strategic framework for local capacity building can be proposed to include the following suggestions:

1. Establish a civic group with a participatory working mechanism at the sub-district or local community level.
2. Set the farmers as the center of the problem-solving mechanism.
3. Focus on the five-step *interactive learning* process described above.
4. Arouse the local consciousness.
5. Identify the community's potential.
6. Raise issues such as local poverty as example problems.
7. Start with activities having an impact on the economy.
8. Develop a project from the ongoing activities.

We have implemented farmer capacity building in our site-specific nutrient management by selecting farmer leaders and working with them in training and disseminating improved nutrient management concepts in maize farming communities in the maize belt of Thailand (Verapattananirund, 2003, 2004).

SCREENING OF THE FARMER LEADERS

Farmer leader selection was initially difficult and our initial attempts through the existing extension service personnel were not effective. We then adopted the following approach to identify and select farmer leaders to work with the development and adaptation of site-specific nutrient management. The selection of farmer leaders was conducted during the Participatory Learning Forum in which those attending the initial meeting were given some relatively easy tasks in preparation for a second meeting. The tasks assigned to all those attending the initial meeting were the following:

1. Identify the leaders in the community.
2. Identify the best and most knowledgeable maize farmers in the community.
3. Estimate the area and yield of maize in the local community.
4. Determine price of maize, cost of fertilizer, and investment opportunities in the local community.

Farmers who completed this work and satisfactorily presented their responses were selected for further contact and eventually for training in site-specific nutrient management technology. Many farmers responded to the opportunity to present their information. Some took the initiative to form their own network.

SIMPLIFYING NUTRIENT MANAGEMENT TECHNOLOGIES TO FIT FARMERS' NEEDS

In addition to increasing farmer capacity, we adopted traditional nutrient management technology so that the farmers could learn and use the technology and the new information it provides. There were three components of the technology that were simplified and which, after simplification and use by the farmer, become technologies that support site-specific nutrient management. These simplified technologies include:

- Simplifying soil identification by using a graphical, visual decision-aid that helps the farmers learn the names and major characteristics of their soils. These names serve as a basis for discussion and sharing experiences among farmers, districts, and provinces. It becomes a tool that facilitates the transfer of knowledge and sharing of information among the farmers.

- Simplifying the testing of soil is another technique that became an empowering technology. Traditional soil testing presents a nearly insurmountable problem for small farmers. How can they afford to sample a field of a hectare or less and send the sample to a distant laboratory for analysis? How are they to interpret and understand the analytical results? The answer is already clear–most farmers do not avail themselves of soil test results. Currently less than 5% of soybean growers in some states of the United States obtain soil tests of their fields every year (Snyder et al., 1995).
- Simplifying the interpretation of the soil test kit results. Rather than use sophisticated simulation models to predict the fertilizer quantities, simple decision-aids were developed to assist farmers and growers to use the information. The current NPK fertilizer recommendations for most crops are obtained from field experiments and the recommendations could not be transferred to other environments where the climate, soil type, and crop variety, and management are different (Attanandana and Yost, 2003).

Simplification of Soil Taxonomy

One of the deficiencies in the classification and grouping of soil information has been the lack of user friendliness of the results of applying Soil Taxonomy. Although systems such as Soil Taxonomy (Soil Survey Staff, 1975) have been invaluable to soil scientists and those with the interest and time to learn the terminology, it has been too complicated, non-intuitive, and difficult to use by non-experts such as farmers and growers. Those who can benefit from a language to describe soil properties and use, have seldom been able to use it because of this complexity. An example with Thai farmers illustrates the benefit of a simple language. Nearly all farmers who have participated in the site-specific nutrient management training can tell you which soil series they farm as well as which soil series comprise their farms. They have learned not only the names of their soil, but how to determine the names of other soils. They use the soil series names to share their experiences, successes, and even failures with other farmers with similar soils. In this way, a simple visual tool that farmers can use becomes an information transfer tool for farmers, enabling them to share their knowledge and experience with each other. The soil series identification tool is based on a decision-tree concept whereby five factors have been found to be sufficient to identify the major maize-producing soils.

1. Soil color (Black/dark brown, Brown/yellowish brown, Red/Reddish brown, Light gray/Pinkish white).
2. Soil texture (Loam/Sandy loam, Gravelly loam, Clay, Gravelly clay, Sand).
3. Coarse fragments (None, Rock fragments, Limestone nodules, Lateritic nodules).
4. Soil pH (4.5-5.5, 5.5-6.5, 6.5-8.0) (using the pH solution of the soil test kit).
5. Soil depth (Shallow, Moderate, Deep).

The soil series is used to identify or index the soil parameters, potential yields, climatic data, and other information needed by the decision-aids to reason to a prediction and recommendation. An example of this visual aid is shown in Figure 2.

Soil Test Kits

A second simplification tool in the site-specific nutrient management for small farms is the soil test kit (Figure 3). Typical soil testing laboratories

FIGURE 2. Soil series identification guidebook.

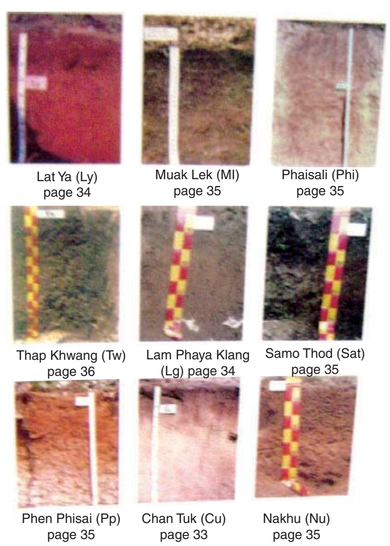


FIGURE 3. KU soil test kit.

often do not even exist in most developing countries of the tropics, let alone do farmers have the funds for the cost of analysis. In addition, there often are delays that can occur between the time of a sample collection and when the recommendation is received by the grower. The soil test kit is a simplification of the standard laboratory soil analysis to enable agricultural officers and farmer leaders to analyze the soil themselves, on site, and without delay. Actually it is not intended to serve as a replacement for standard soil testing, rather as an extension of it. A typical problem with standard laboratories is that the time when a sample is collected and the fertilization decision is made, is separated by long periods of time. It is the unusual farmer manager who anticipates the fertilization decision and sends in a soil sample in preparation for the decision.

The soil test kit can produce the results of soil pH, nitrate and ammonium, phosphorus, and potassium within about 30 to 45 minutes, which can short-circuit the lengthy delays typical of soil testing. Many soil scientists disbelieve the results from soil test kits, sometimes with good reason. Seldom is training given together with existing commercial soil test kits. Seldom are users given information about which steps of the determination are critical and which are not. Farmer leaders in Thailand, for example, identified through the Participatory Learning Forum, have been very successfully taught to use soil test kits as part of site-specific nutrient management for small parceled farmers. It is important to point out that from a diagnostic point of view, it is most important to identify the cases of extreme nutrient deficiency or excess. That is, the fields that are extremely excessive or deficient are the ones the most critical to diagnose. In other words, a high degree of precision is not needed to identify the most serious problem cases. With training we have found that soil test kits can even be quantitative and, thus, when used with simplified decision-aids, can be used to estimate the amounts of nutrient needed to restore nutrient status to an adequate level. Soil test kits also contribute a strong component of farmer empowerment. If farmers learn to sample the soil and obtain a reliable analysis in such a short time and in their own fields, it has a strong empowering effect. This aspect of enabling farmers and growers to obtain the information on the status of their soils and fields relates closely to the principle of the Participatory Learning Forum–that of self-reliance in diagnosing and solving one's own problems.

Decision-Aids

The third simplification that is introduced is that of the decision-aid, which takes the soil series information, once the soil series is identified, and the soil test kit results to form the diagnosis, prediction, economic evaluation, and presents the results to the grower. The purpose of the decision-aid is to take this information and develop a prediction of fertilizer requirement necessary to resolve the deficiency identified during the diagnosis by soil test kit. The components of the decision-aid are as follows: (1) Diagnosis of existing deficiencies/excesses, (2) Prediction of the fertilizer requirement or recommendation to change crops (in acidity module), (3) Economic analysis showing the benefits and costs of the recommended fertilizer, and (4) Presentation of the results in farmer-friendly form and manner. There are three nutrient calculation algorithms embedded in the software, one each for nitrogen, phosphorus, and potassium. The N algorithm is based on the DSSAT 3.5 simulation model, which has been adopted to accept soil test kit nitrate as the current N status of the field. The P algorithm is based on a simple P algorithm developed for soil test results as PDSS software (Yost et al., 1992). Potassium fertilizer requirements are based on a Mitscherlich-Bray equation in the original software. Currently, a revised algorithm is being used to predict K requirements. These algorithms were implemented in both desktop and handheld computers in both Thai and English versions. The software is used by extension officers, farmer leaders, and other interested people. The fertilizer recommendations were summarized in a fertilizer handbook and given to farmers of the respective province (Figure 4).

RESULTS OF DISSEMINATION OF SITE-SPECIFIC NUTRIENT MANAGEMENT FOR SMALL FARMS IN 2002

The site-specific nutrient management approach described earlier has been developed by Kasetsart University and applied in various national and international projects over the last several years (Attanandana et al.,

FIGURE 4. NPK fertilizer recommendation manual.

1999). The technology has been effectively disseminated in the maize-producing provinces in recent years. The results of dissemination for the most recent two years, 2000-2002, are presented here. In these cases, the farmers have applied the technology in comparison with the inputs, yields, and profits of their neighboring farmers.

Yield of Corn and Profit Obtained by the Farmers

The results obtained during the past three years have indicated that the yield and profit were higher with the use of site-specific nutrient management as compared with the farmers' practice (Figures 5 and 6). It is interesting to note that the rainfall amount and distribution was more favorable in 2000. Nonetheless, yields and profit were higher in 2002 with the use of site-specific nutrient management.

Economic Analysis

The fertilizer efficiency, calculated as maize yield in kg per fertilizer cost in US dollars, was compared among three soil series in 2000 and 2002.

FIGURE 5. Comparative maize yield of the farmers in four primary maize-producing provinces before (2000) and after (2002) using the developed fertilizer recommendation.

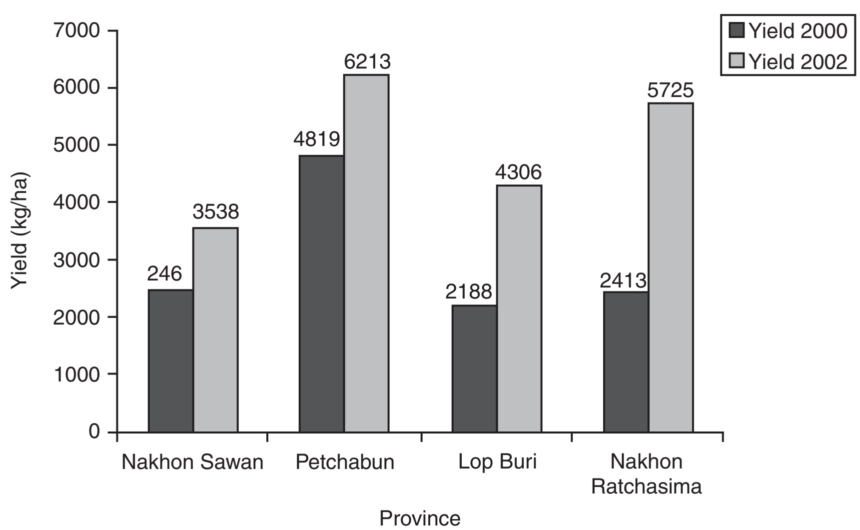
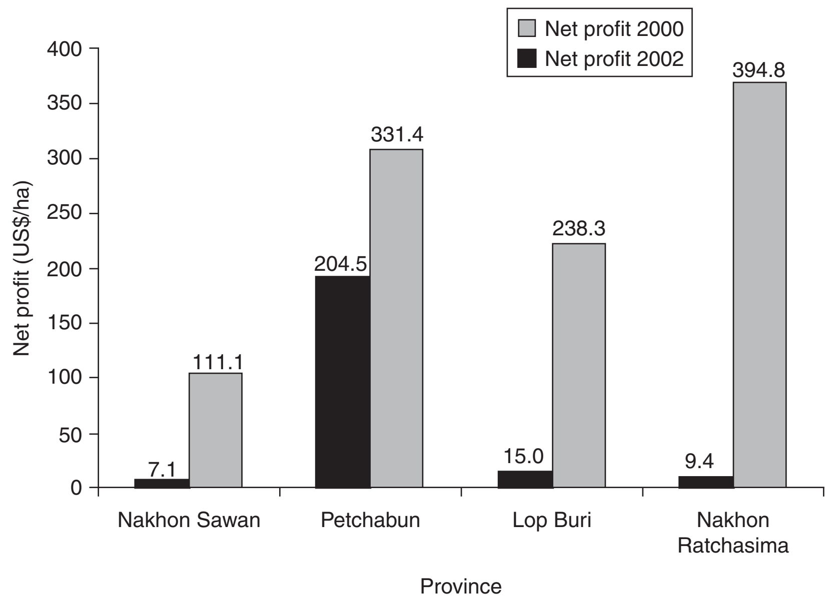


FIGURE 6. Comparative net profit of the farmers in four maize-producing provinces before (2000) and after (2002) using site-specific nutrient management fertilizer recommendations.



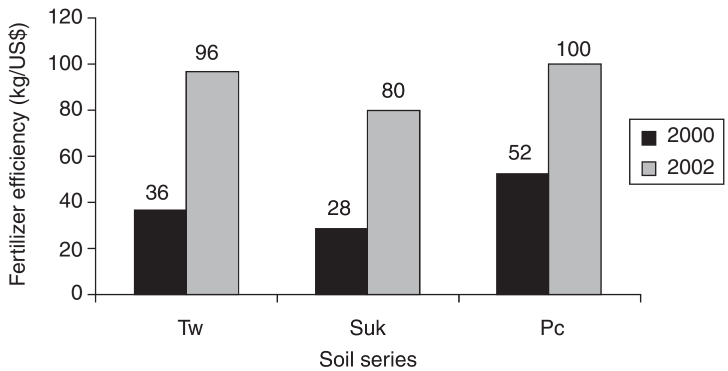
The efficiency values of 2000 indicate efficiency before the introduction of site-specific nutrient management, while the results of 2002 reflect the impact of the technology. The result revealed that fertilizer efficiency of the three soils increased dramatically from 36 to 96, 28 to 80, and 52 to 100 kg per one US dollar for Tab Kwang, Satuk, and Pak Chong soil series, respectively (Figure 7). Site-specific nutrient management dramatically increased the yield, profit, and fertilizer efficiency compared with the current practice of the farmers.

DISSEMINATION OF THE TECHNOLOGY IN 2003

Yield and Amounts of NPK Fertilizer Used by the Farmers

In effort to compare the technology during the same seasonal growing environment, the comparison in 2003 were made between the site-specific nutrient management and neighboring fields that did not use

FIGURE 7. Comparative fertilizer efficiency (calculated as maize yield in kg/ha per fertilizer cost in US$/ha) of maize production on three soil series (Tw = Tabkwang, Suk = Stuk, Pc = Pak Chong) in 2000 and 2002, respectively.



the improved technology. Yields and fertilization of these fields were tabulated and compared. While timing, crop variety, and other management may have been slightly different, we tried to find identical conditions as much as possible. With these caveats in mind, we present the following results for 2003.

The field-to-field comparisons for 2003 revealed that the yield of maize on plots of site-specific nutrient recommendations were nearly always higher than in the adjacent farmers' fields where conventional fertilization was used. The higher K and lower N applications appear to be the main factors associated with the higher yields of the site-specific nutrient management when compared with the farmers' plots in Nakhon Ratchasima and Petchabun provinces while the higher K application appears to be a factor in the higher yields in Lop Buri province. This indicates the importance of balanced nutrients in maize production. The 2003 results further indicate that the yields where site-specific nutrient recommendations were applied in Nakhon Ratchasima province were markedly higher than the other provinces (Table 1).

A comparison of maize yields between site-specific nutrient management and current farmer practice points out that site-specific nutrient management resulted in significantly higher yields in all provinces but Nakhon Sawan (Table 2). An analysis of the data from Nakhon Sawan suggests that the technology was not accurately applied in that province.

TABLE 1. Comparison of yields and amounts of N, P, and K fertilizers applied by site-specific nutrient management methodology and neighboring farmers for four provinces.

Province	No. of com-pari-sons	Yield ($kg\ ha^{-1}$)		Amount N ($kg\ ha^{-1}$)		Amount P ($kg\ ha^{-1}$)		Amount K ($kg\ ha^{-1}$)	
		Farmer[1/]	Site[2/] Specific	Farmer[1/]	Site[2/] Specific	Farmer[1/]	Site[2/] Specific	Farmer[1/]	Site[2/] Specific
Nakhon Ratchasima	150	4,792 a[3/]	7,488 a	121.0 a	81.7 a	48.9 a	30.5 a	13.6 a	41.9 a
Nakhon Sawan	14	4,836 a	4,901 b	73.7 c	105.0 a	27.5 a	30.8 a	0.0 b	41.1 a
Lop Buri	104	3,978 a	5,479 b	96.6 b	95.2 a	28.5 a	27.6 a	16.6 a	27.6 b
Petchabun	70	3,912 b	4,744 c	98.0 b	90.6 a	32.2 a	32.4 a	2.2 b	46.4 a

Notes: [1/] Neighboring farmers not using site-specific nutrient management.
[2/] Site-specific nutrient management.
[3/] Letters report the statistical comparisons between yields and nutrient applications among provinces. Similar letters indicate no difference between provinces at the 99% significance level.

TABLE 2. Statistical comparison of maize yields using farmer practice or site-specific nutrient management for 2003.

Province	Methodology	
	Farmer practice	Site-Specific
	Yield ($kg\ ha^{-1}$)	
Nakhon Ratchasima	4792 b[1/]	7488 a
Nakhon Sawan	4836 b	4901 b
Lop Buri	3978 b	5479 a
Petchabun	3912 b	4744 a

Note: [1/] Letters report the statistical comparisons between site-specific nutrient management and farmer practice (no site-specific recommendation) for each province. Similar letters indicate no difference between the two methods at the 99% significance level.

Economic Analysis

The economic analysis of the yield, investment cost, and profit of the two methods of fertilizer management revealed that overall, the investment in fertilizer was not different, but yields and profits were significantly higher at the 99% level on plots receiving site-specific nutrient recommendations for 248 comparisons (Table 3). When considering

TABLE 3. Economic analysis of the yield, investment, and profit of the site-specific nutrient and farmers' plots in the four provinces (comparison of fertilizer management methods).

Province	No. of comparisons	Yield (kg ha^{-1})		Investment (US$ ha^{-1})		Profit (US$ ha^{-1})	
		Farmer[1/]	Site[2/] Specific	Farmer[1/]	Site[2/] Specific	Farmer[1/]	Site[2/] Specific
Average	248	4,679 b	6,327 a	65.4 a	64.6 a	425.4 b	602.3 a
Nakhon Ratchasima	89	5,071 b	7,192 a	76.4 a	55.1 b	480.0 b	733.9 a
Nakhon Sawan	6	4,732 b	4,626 b	39.6 b	63.5 a	450.4 b	416.3 b
Lop Buri	101	4,263 b	5,877 a	60.9 a	65.0 a	413.8 b	588.8 a
Petchabun	52	4,809 b	5,917 a	58.4 b	80.2 a	351.6 b	424.9 a

Notes: [1/] Neighboring farmers not using site-specific nutrient management.
[2/] Site-specific nutrient management plot.
[3/] Letters report the statistical comparisons between site-specific nutrient management and farmer practice (no site-specific recommendation). Similar letters indicate no difference between the two methods at the 99% significance level.

each province, we can see that in Nakhon Ratchasima province, the yield was higher and the investment cost was less in site-specific nutrient management plots, resulting in higher profit at a 99% level of confidence. In Lop Buri province, the yield was higher. Although there was no difference in the investment costs of the two methods, the profit was higher in the site-specific nutrient plot at a 99% level of confidence. In Petchabun province, the yield was higher, the investment was also higher, but the profit was higher at a 99% level of confidence. In the case of Nakhon Sawan province, there was no difference in yield, investment, and profit between the two methods, however, with only six comparisons (Table 3).

SUMMARY AND CONCLUSIONS

We have adapted precision agriculture concepts to small farmers of the tropics by both increasing farmer capacity and by simplifying the site-specific technology so that it is easily learned by farmers and producers. Simultaneously, we have worked with the farmers to increase their knowledge and skill to manage the simplified technologies. Site-specific nutrient management with the components of the Participatory

Learning Forum and Empowerment of the Farmers, simplified soil identification, simplified soil testing, and simplified decision-aids has been an effective technique for increasing production and profit for these farmers. The identifying of farmer leaders and encouraging them to understand their local wisdom and the power of the local network in their lives and agricultural production has been a crucial component of the technology. The 67 trained farmer leaders have disseminated the technology to their 629 network members, 338 of whom have planted maize using the site-specific nutrient management technology. The results indicate higher yield and profit from the site-specific nutrient management plots compared with the current practice of the farmers. Six farmers obtained no difference between the site-specific nutrient management and the current practice of neighboring farmers. This might be attributed to the incorrect management of their field. The support and guidance of the extension officers is still needed. One of the challenges that remain is the transferring of these concepts to farmers and different farming systems in other regions of the tropics with different social, political, as well as agronomic environments.

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