Agricultural Systems xxx (2009) xxx–xxx

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

The early economic impact of a nutrient management decision support system (NuMaSS) on small farm households cultivating maize on acidic, upland soils in the Philippines

T. Walker [a], J. Friday [b,*], M. Casimero [c], R. Dollentas [c], A. Mataia [c], R. Acda [c], R. Yost [d]

[a] 129 Farm Lane, Fletcher, NC 28732, USA
[b] University of Hawaii Cooperative Extension Service, 875 Komohana St., Hilo, HI 96720, USA
[c] PhilRice, Muñoz, Nueva Ecija, Philippines
[d] University of Hawaii Department of Tropical Plant and Soil Science, 3190 Maile Way, Honolulu, HI 96822, USA

ARTICLE INFO

Article history:
Received 26 October 2008
Received in revised form 14 April 2009
Accepted 12 May 2009
Available online xxxx

Keywords:
Decision aid
Extension
Adoption
Lime

ABSTRACT

Maize is the most important crop in upland areas in the Philippines, but production lags behind potential in many areas, especially those with acid soils. The Nutrient Management Support System (NuMaSS), a computer based decision aid, provides soil and crop based recommendations for nutrient amendments and lime. Development and trials of the NuMaSS were carried out on upland maize farms in Isabela province in the northern Philippines from 1998 to 2006. While local practices and standardized government recommendations had included applying N, P, and K, the application of lime to correct soil acidity had not been practiced locally and lime was not commercially available in local markets. Based on data from 39 field trials on 13 different farms over four years, we calculate that liming increased maize grain yield on the average by 1.5 t/ha. A farmer purchasing and applying lime would realize a single season marginal rate of return on investment of about 160%. Because of the positive results of the on farm trials of the NuMaSS, and in particular the positive result of liming acid soils, the Philippine Department of Agriculture began a lime promotion program in four provinces in Region II in 2006. The program includes field days, farm level demonstrations, and distribution of subsidized lime to farmer cooperators. We estimate the economic value of the NuMaSS and lime promotion program to have an NPV of $8 million or an IRR of 25%. We base our calculations on the costs for the research program itself, the costs of the extension program, the costs of the subsidized inputs for the first four years, and the benefits of improved maize production over a 40 year horizon over 12,000 ha (out of a potential 90,000 ha of acid soils in maize production). Our calculations show that the NPV of the lime promotion increases with increasing adoption but the program has a positive NPV even if adoption is negligible after the initial promotional program ceases. Our results document the adoption and farm level and regional economic impact of a decision aid. As agriculture in the Philippines and other developing countries expands with increasing food prices and other demands such as bioenergy production, farmers will need better decision tools such as the NuMaSS to manage crop production on problem soils and marginal sites.

1. Introduction

Many articles in agricultural science journals underscore the importance of decision aids and expert models to enhance the productivity of well defined systems (Girard and Hubert, 1999; Welch et al., 2002; Corson et al., 2007). These tools generate information that is of potential value to targeted users ranging from policy makers to farmers.

In spite of their potential value, the literature on the practical impact of decision aids is sparse, particularly in developing country agriculture. Few studies have documented that such aids have influenced decision making to the extent that adoption has translated into impact. For example, meta analyses show that the vast majority of rate of return studies focus on what economists call embodied technological change mainly in the form of cultivars from genetic improvement programs (Alston et al., 2000 and Evenson, 2001). A recent survey of policy research in the Consultative Group for International Agricultural Research (CGIAR) highlights only three ex post impact assessments where the nexus between research, uptake, and influence was firmly established (SPIA, 2006a). Specific evidence on the ex post impact of disembodied technological change in natural resource management research was also scarce (SPIA, 2006b). Indeed, methods related

* Corresponding author. Tel.: +808 981 5199; fax: +808 981 5211.
E-mail address: jbfriday@hawaii.edu (J. Friday).

0308-521X/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.agsy.2009.05.004

contributions on how to conduct impact assessment in natural resource management research (Shiferaw et al., 2005) seem to outnumber peer reviewed accounts of success stories. Crop management research has a higher profile in ex post impact assessments (Traxler and Byerlee, 1992; Laxmi et al., 2007), but it pales in comparison to crop genetic improvement.

Multiple reasons can be given for the infrequency of ex post impact assessments on disembodied technological change in general and on decision aids in particular. Foremost among these is the problem of attribution. Showing that research led to information that in turn resulted in a changed decision making outcome is a challenging area that is itself a priority for research (SPIA, 2006a). But some attributes of informational research that are conducive for impact are well known. For example, if the research has the capacity to generate surprises, it is more likely to attract attention (Schimmelpfennig and Norton, 2003). Surprising information improves the odds not only that a recommendation will result in changed decision making but also that the adoption outcome can be attributed to the research.

In this paper, we document an application of the one decision aid the use of the Nutrient Management Support System (NuMaSS) in the Philippines that generated a 'surprise' that in turn sparked a public sector investment in one of its key recommendations: liming acidic soils in the cultivation of upland maize (*Zea mays*, L.). NuMaSS in the context of maize production in the Philippines is briefly discussed in the Section 2. The issue of attributing the regional government's lime promotion program to NuMaSS is the subject of the Section 3. The economic impact assessment of the liming recommendation and the promotion program are analyzed in Section 4. This section focuses on quantifying the yield effects of liming, estimating the expected profitability of liming to the farmer, and appraising the research and the promotion program as a project in the format of a cost benefit analysis. We review the main findings, how the research could have been structured to better accommodate ex post impact assessment, and suggest directions for future agricultural and economics research in the closing section.

2. Maize production and NuMaSS in the Philippines

Impact assessment requires knowledge of national and local livelihood contexts that shape the likely impact a specific intervention has on the population of interest. Institutional attribution of the research also needs to be documented to make the case that the research contributed substantially to the intervention that is the subject of the assessment.

2.1. Robust production growth in a net importing nation

Maize is the main upland crop grown in the Philippines. The 1980s were marked with rapid technological change in yellow maize production with the widespread acceptance of hybrids and chemical fertilizer that resulted in increased productivity accompanied by expanding area. Since the early 1980s, the average national yield has effectively doubled from about 1.0 2.0 t/ha. By 2007, national maize production was over 7 million tons, a substantial increase over the level of 3.1 million tons estimated in 1982 (FAOSTAT, 2006). Yellow maize is a major component of processed animal feed in the Philippines. In most of the northern Philippines, almost all of the maize crop is sold and processed for animal feed; maize farmers use their income to buy rice, the preferred food. The demand for maize is strong, and the Philippines position as a net importer suggests that maize producers who adopt improved technology will be the main beneficiaries of technological change because final demand is price elastic. Therefore, an increase in supply associated with lime use or other improved agricultural technologies should not result in a fall in revenues to producers as long as regional production is reasonably well integrated into the national maize market.

This study focuses on Region II, northern Luzon's Cagayan Valley, where the gross cropped area of maize is about 300,000 ha annually. The region encompasses five provinces: Nueva Viscaya, Quirino, Isabela, and Cagayan, plus the Batanes Islands. Of these Isabela Province, the center for NuMaSS testing on Luzon, is the main contributor to maize in Region II, accounting for about two thirds of growing area. While the area traditionally grew tobacco (*Nicotiana tabacum*), maize has replaced tobacco as the main upland crop. Paddy rice (*Oryza sativa*) is grown wherever irrigation is available.

2.2. The study area

The Cagayan river valley runs south to north for over 200 km and is flanked by the Sierra Madre mountains to the east and the Cordillera Central to the west. Soils are diverse with inceptisols, mollisols, alfisols developed from alluvial deposits in lowland areas and alfisols, ultisols, and oxisols developed on raised terraces and on volcanic deposits in upland areas (PhilRice, 2007; Snelder, 2001). While the center of the valley near Ilagan receives an average of 2100 mm of precipitation annually (unpub. data, Cagayan Valley Integrated Agriculture Research Center), rainfall in the region is highly seasonal. Precipitation is typically less than pan evaporation for the months of February, March, April, and May and typhoons are common.

2.3. The cropping system: rain fed, sole cropped maize in a double cropping sequence

During the first phase of the NuMaSS project in the Philippines, maize farmers in several barrios of the municipality of Ilagan in Isabela Province were surveyed in 1999 and 2001 (George et al., 1999 and Smith et al., 2001). An earlier rapid rural appraisal in 1998 had provided a foundation for these surveys that were conducted in Barrio San Antonio, Ilagan (Corton et al., 1998). A wider baseline assessment of 60 farmers in the province then was carried out in 2000 (Mataia, 2003). A final survey of 15 on farm trial cooperators and farmer leaders in 10 different barrios in several municipalities in the province who had experience with liming was carried out in January 2007.

The survey in 2007 confirmed many of the findings from the first surveys. Many respondents had small areas of lowland paddy, but most were reliant on maize for their main source of cash income.

Maize fields are usually double cropped. Sowing of the first crop starts with the initiation of the rainy season in May and can extend into early July; the second season planting regime is more staggered and can take place anytime between October and December. Maize is occasionally sequentially cropped with upland rice or is followed by a fallow in the dry season, but a maize maize double crop is the most common practice. Fertilizer dose varies considerably among farmers, but is the same for both the first and second plantings for the same farmer. Maize is never intercropped, and rotations with other field crops are rare. Rain fed, sole cropped maize in a double cropping sequence in monoculture is the norm.

For most farmers, maize gross cropped area is small, usually averaging from 0.25 3.00 ha with a median area about one hectare. Land preparation is done mechanically with tractors, but all other operations, aside from the incorporation of maize stubble, are done manually.

Farmers adopted chemical fertilizer in the 1980s contemporaneously with the introduction of hybrids. At that time, many farmers switched from planting white to yellow maize. All farmers we interviewed had adopted chemical fertilizer and maize hybrids by the mid 1990s. Many farmers also bought insecticides for the first time when they started using chemical fertilizers and maize hybrids.

Maize production in the humid tropics of northern Luzon is less prone to risk than rain fed maize production in the semi arid tropics, but rainfall is by no means assured and typhoons are a seasonal damage threat to production in Isabela Province. In particular, farmers said that 2005 was punctuated by both droughts and floods.

Several farmers had experimented with other amendments such as livestock manure and commercial organic fertilizer to enhance their soil fertility. They were quick to point out that organic fertilizer was slower acting than chemical fertilizer. Such experimentation has not resulted in sustained use. All farmers, however, benefit from the mechanical incorporation of maize residues shortly after harvest.

The respondents in the 2007 survey were selected because they had participated in the NuMaSS on farm experiments or the Department of Agriculture implemented 'techno demos' that featured the use of lime as a treatment. Prior to the project, none of the participants had used lime. They all believed that the limed plots resulted in a better crop that gave higher production than the plots that were not limed. Based on this experience, one farmer, who was by far the most educated and had recently migrated to Isabela from the city of Baguio, had purchased lime. Several others received lime from the government program that is described in the next section. But the majority still did not use lime on their own maize growing areas that were outside the experiment or the techno demo. With one exception, these farmers said that they were willing to buy lime if it was available, but they did not know where to obtain it. Overall, the survey results suggest that there exists a latent demand for lime and that the biggest problem is local availability.

Contrary to expectations, fertilizer use intensity in nitrogen (N) varied markedly among farmers and ranged from 34 to 215 kg of N/ha. In contrast, the range of application rates for phosphorus (P) was narrow, from 5 to 22 kg/ha. The mean application rate of N was about 115 kg/ha, and the mean rate for P was 15 kg/ha. To some extent, wide variation in N use was probably linked to field size with smaller fields receiving heavier applications and to liquidity constraints resulting in more extensive applications on larger fields.

Since single element fertilizer for elements other than N are not locally available, almost all farmers applied a complete fertilizer (14 14 14) basally at planting and top dressed with urea. Fertilizer use intensity has gradually increased over time. A rule of thumb farmers used in deciding how much to apply focused on maintaining a green crop that looks healthy. Some farmers said that they were applying more fertilizer now because it took more fertilizer to maintain a "healthy green looking" crop or that their soils were becoming more "sour" over time.

2.4. The development of NuMaSS and its application in the Philippines

Since the mid 1980s, nutrient management in tropical and subtropical soils has figured prominently in the Soil Management Collaborative Research Support Program (SM CRSP), a collaborative effort of several American universities (University of Hawaii, Cornell, Texas A&M, and North Carolina State University) and the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI) in the Philippines, funded by United States Agency for International Development (USAID). In addition to the Philippines, project sites in Southeast Asia included Thailand and Laos. The Nutrient Management Support System (NuMaSS) software was synthesized from modules covering acidity, phosphorus, and nitrogen. The existing ADSS (Acidity Decision Support System) software was designed and developed to transfer technology to reduce limitations to field crop productions due to acid soil conditions (Yost et al., 1986). The Phosphorus Decision Support System (PDSS) software was developed based on the ADSS experience (Yost et al., 1992), and a nitrogen module developed by T.J. Smyth based on previous experience by Osmond (1991) and Osmond et al. (2000). The NuMaSS software is comprised of the first three of the four components of the ADSS and PDSS software: 1. Diagnosis, 2. Prediction, 3. Economic Evaluation, and 4. Recommendation. Diagnosis is based on inputs from both soil and crop analysis. These four components represent different steps in the decision making process often seen in experts making fertilizer application decisions (Yost et al., 1986, 1992): the problem is identified, the biophysical options enumerated, the economic consequences of each biophysical solution is evaluated, and lastly the user selects the appropriate option to remediate the problem. The NuMaSS software guides the user through each of these three steps for the nitrogen, phosphorus, and lime components. In this way, the NuMaSS software helps users pose the same questions, come to similar conclusions based on the biophysical evidence, and reach similar economic conclusions, as would an expert in the subject. In the Philippines, the immediate users of the NuMaSS have been professional agronomists and soil scientists, who are computer literate and have access to computers and software. Farmers are the end users when recommendations from the NuMaSS are made available to them through the agricultural extension system.

The synthesized decision aid was field tested in a series of experiments established with the assistance and collaboration of PhilRice researchers and technicians in the Cagayan Valley and later on the island of Negros in the Visayan Islands and on the island of Mindanao. Adaptation and calibration experiments started in 1996 and continued through the end of the 2001 followed by on farm experiments and demonstrations from 2002 to 2007. The results reported here center on the second phase of the project, where the first phase results were made available for validation to farmers in new locations within Isabela Province. Recommendations for local farms were made by researchers using the NuMaSS and soil test data for each farm. These recommendations were then applied by local farmers in their fields through the assistance of the local agricultural extension staff.

A soil survey and classification of soils in the immediate surroundings of the original site of Barrio San Antonio in Isabela was carried out by the Philippine Bureau of Soil and Water Management (BSWM), with SM CRSP funding and support (Corton, 1998, personal communication). This soil survey was implemented just prior to the release of a major revision of the soil survey of the Philippines by the same institute (PhilRice, 2007). The revised survey of soils of the Philippines, for the first time, called attention to the 7 8 million hectares of acid soils in the heretofore unexploited uplands of the country. Most of these acid soils had been previously mapped as undifferentiated mountain and hilly soils by soil surveys designed to support paddy rice agriculture. The publication of this new survey provided additional justification and impetus to the program on soil acidity that had been developed in collaboration with PhilRice.

3. Attributing the public sector's extension investment in liming to NuMaSS

Before the NuMaSS related research started in the Philippines, the use of agricultural lime was virtually unheard of in Isabela Province and Region II and local and regional offices of the Department of Agriculture (DA) in general showed little awareness of the problem of acid soils. Agricultural supply houses surveyed in Ilagan, Isabela in 1998, 1999, and 2001 did not supply lime and were generally not even aware of it or its use.

In the public sector, the DA BSWM Laboratory in Ilagan analyzed soils for organic matter, P, K, and sometimes pH and made fertilizer recommendations, but in 1998 these did not include recommendations for lime. Some soil samples were brought to the laboratory by individual farmers and some soils brought there by agricultural extension technicians of behalf of the farmers. Records obtained in 1998 for results of soil pH analysis for maize and rice farms in Barrio San Antonio showed a range of 5.4 6.0 with a mean close to 6.0, close enough to neutral to require little or no lime. More strongly acid soils apparently were not sampled.

At the time, the DA made a standard, uniform recommendation for fertilizer for maize across the region that did not take the local soil properties into account. soils. Farmers surveyed in Barrio San Antonio, Ilagan, in 1998, 1999, and 2001 applied either the standard recommended rate of N, P, and K or modified it to fit their own estimates of what was needed and what they could afford, but none applied lime.

The initial field test of NuMaSS recommendations was established in Barrio San Antonio, Ilagan, Isabela in 1998. Liming was included as a treatment based on initial analysis of soil samples with pH ranging from 4.0 to 4.5. The Philippine Department of Agriculture Cagayan Valley Integrated Agriculture Research Center (DA CVIARC), PhilRice, the IRRI, and the University of Hawaii were all involved in the implementation of the experiment. By the following year, initial results of the experiment showed dramatic increases in crop production on properly limed soils. In 2001, version 1 of the NuMaSS software was released and the DA conducted the first field day for farmers at the experiment site in conjunction with a workshop for the participants in the NuMaSS program: PhilRice, the local Municipal Agriculture Office of the DA, the regional office of the DA, and the DA CVIARC. The following year the director of the CVIARC moved to the regional office of the Department of Agriculture and the Regional Technical Director attended another field day on the results of the NuMaSS field experiments which again demonstrated the usefulness of lime. By 2002, the BSWM had produced a map of acid soils which is presently available in digital form (George et al., 2003).

In 2003, the SM CRSP program began the "leave one out" element experiments that are analyzed in the next section. Results of the experiments were presented to the regional technical director of the DA by SM CRSP cooperators at the CVIARC. In 2005, the director of the CVIARC presented the results of the SM CRSP experiments to the regional research director of the DA. The DA Regional office then decided to add a liming treatment to the technology demonstrations in its region wide Farmer Led Extension Program.

The inclusion of liming in the Farmer Led Extension program was the turning point in the use of agricultural lime and management of acid soils in the Cagayan Valley. At that point, the use of lime moved from an experimental technology to one being widely disseminated and popularized. In the Farmer Led Extension program, agricultural technicians in the government work with local farmer leaders to plant demonstration plots and conduct field days. Each plants a one hectare demonstration plot, called a techno demo, so that neighboring farmers can see the effects of new technologies.

Soils were sampled in each techno demo plot before treatments are applied. The lime techno demos included treatments with agricultural lime, with dolomitic lime, and without lime. Lime was applied at three rates: 1000 kg/ha for soils of pH 4.2 5.2, 1500 2000 kg/ha for soils of pH 4.1 and below, and none for soils above pH 5.2. The DA funded the inputs for the techno demo plots and gave participating farmers an honorarium. Technology demonstration plots on lime have been established in increasing numbers since 2005 in several municipalities in four provinces of Region II in the Cagayan Valley.

Through the techno demo field days in the farmer led extension program, six to seven thousand farmers were exposed to the idea of using lime to manage soil acidity during the first crop in 2005 and the second crop in 2005 2006 (Aquino, 2006, personal communication). Farmer leaders also conducted method demonstrations on soil sampling and on the use of lime.

In contrast to pre project situation, the soils laboratory of the DA in Ilagan now provides lime recommendations when soil pH is low. Their recommendations are based on their own field liming experiments that were based on NuMaSS recommendations and corresponding soil pH values, which were much more easily determined than the more accurate but more technologically demanding percent aluminum saturation determination used by NuMaSS. They analyze soils for individual farmers as well as those involved in the Farmer Led Extension and lime distribution programs.

As a way of familiarizing more farmers with the benefits of applying lime to acid soils, the DA began a lime distribution program in 2006. As there still were no private, commercial suppliers of agricultural lime in Region II, the Department contracted with a private cooperative to supply lime. The cooperative purchased lime from central Luzon and had it shipped to Region II where it was subsequently distributed to farmer cooperators who cultivated maize. Over 29,000 bags were distributed in 2006, mainly in Cagayan and Isabela provinces.

In the 2007 survey, farmers participating in the lime distribution program recognized the benefit of applying lime. In the absence of a government program, they stated that they would be willing to purchase lime in the private market if it were available and sold at what they would perceive as a reasonable cost of about 200 PhP/50 kg bag. Farmers were generally not familiar with the idea that benefits of liming extend into subsequent cropping seasons, unlike benefits of nitrogen fertilizers.

In the first two years of the program, the government created and met a demand with the distribution program. Whether or not the subsidized government program continues, demand from farmers will likely soon outstrip the capacity of the government distribution program. Agricultural traders are poised to take advantage of the new demand and will probably begin supplying lime as they do other agricultural inputs such as fertilizers and improved seeds. One agricultural technician reported that traders are encouraging her to recommend lime, presumably to help build up the market. Farmers are only able to adopt liming or other agricultural technologies as inputs are locally available; importing inputs to the region is prohibitively expensive for the small farmer.

4. Analyzing the economic impact of NuMaSS

The economics of the NuMaSS Model is analyzed in this section that consists of three components: (1) a statistical analysis of on farm experimental data that are the raw material for identifying the productivity effects of NuMaSS treatments, (2) a partial budget of the statistically significant and economically dominant NuMaSS treatment, and (3) a project appraisal of the regional liming program that was described earlier in this paper and that was sparked by the experimental response to the NuMaSS treatments seen in the on farm fertility experiments on maize.

4.1. Quantifying the yield effects of NuMaSS information

Leave one out element experiments were carried out with 13 maize farmers in Ilagan over four years (2003 2006) and two seasons (first and second). Participating farmers were selected from locations based on the soil survey conducted in early stages of the project. Different farms were selected to represent the variation in upland soils identified in the project commissioned soil survey. Not all farmers participated in all four years and all seasons; there fore, the design is unbalanced among farmers, years, and seasons. In total, data from 39 experiments are available for analysis. In 34 of these experiments, the treatments were: (1) an unfertilized control, (2) the farmer's practice, (3) the regional recommendation, (4) the NuMaSS recommendation, (5) NuMaSS minus N, (6) Nu MaSS minus P, and (7) NuMaSS minus lime. In five of the experi ments, the treatments were a reduced set of the first four. Plots for each treatment were permanent in each season and year when the experiments were conducted (SM CRSP, 2005).

The farmer fertilizer use intensities can be compared to three treatment benchmarks in the on farm experiments: (1) the rate simulating the farmer practice, (2) the recommended regional intensity of application, and (3) the NuMaSS recommendation that depended on soil testing. The mean NuMaSS treatment for eight cropping seasons over a total of 39 on farm experiments averaged about 130 kg/ha N and 25 kg/ha P. Therefore, the NuMaSS recom mendation was marginally above the farmers' mean N application rate but was substantially higher for P showing that farmers' P application levels were low. Farmers did not perceive these differ ences because their treatment did not figure in the experimental design and because they did not remember the NuMaSS recom mendation in terms of N and P. Farmers did recall that the novelty of the NuMaSS recommendation was the use of lime (when their soils tested higher than 30% in saturated aluminum). For these rea sons, this report focuses squarely on the use of lime.

The leave one out element structure of these seven treatments greatly facilitated economic analysis because the effect of each component in a composite recommendation could be readily ana lyzed. This structure permitted us to conduct a dominance analysis (CIMMYT, 1988) indicating which treatment provides the most benefit for the investment (Fig. 1) as well as an assessment of two aspects of the decision aid:

- A significant statistical test result of a treatment (e.g. a signifi cant reduction the NuMaSS N) indicates a correct diagnosis that a response to N was likely). (Recall that the purpose of the diagnostic step of the decision aid is to detect significant nutrient responsive conditions).
- Whether the amount recommended by the decision aid predic tion module did, in fact, result in an economically significant yield response.

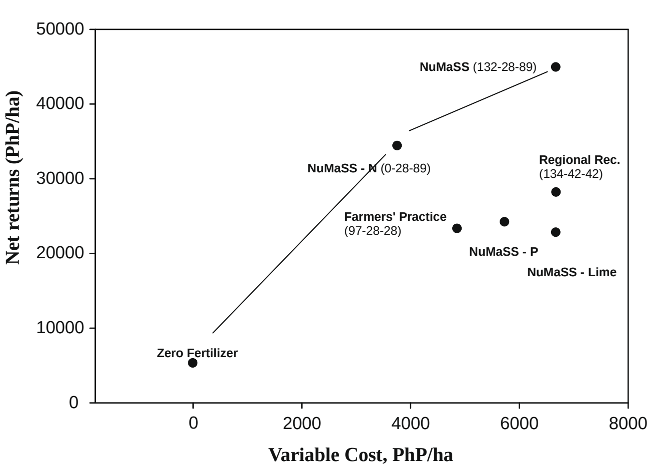

Fig. 1. Example graphical comparison of treatments using dominance analysis of data for wet season maize farms in 2004.

Notice that there was no additional variable cost associated with the full NuMaSS treatment compared to the NuMaSS lime (Fig. 1). This occurred because at the time there was no commer cially available limestone and hence no estimate of local lime cost was available. Armed with information on prospective costs, the expected profitability of lime is found to be robust across several tenancy and use scenarios in Section 4.2. With the exception of the fertilizer treatments, the level of management was the farm er's. The farmer's fertilizer practice, equivalent to the second treat ment, was not that of the individual farmer per se, but was based on the region's modal practice that was determined in an earlier rural appraisal. The NuMaSS recommendation was site specific to the field and the farmer.

Comparison with the other two benchmarks warrants some comment. The mean survey application rates were not significantly different from the farmer practice treatment that was 97 kg N/ha and 12 kg P/ha. Nor were they substantially different from the re gional recommendation which translated into 120 kg N/ha and 18 kg P/ha.

One experiment was 'lost' to drought giving no grain yield for all treatments. Because a natural hazard was the source of loss, we decided to keep this experiment in the analysis because it re flects the farmer's circumstances with respect to expected profit ability. The unfertilized control also did not produce any grain in several of the experiments.

Mean yields across the seven treatments are described in Table 1. Yields ranged from 0 to 7 t/ha. Without inorganic fertilizer, esti mated yield was only about 0.5 t/ha, which explains why almost all farmers apply this input in the form of complete fertilizer and urea. The regional recommendation gave higher yields than farmer's practice, but the NuMaSS recommendation was clearly superior in yield to all the treatments. The minus N treatment exceeded the minus P treatment by about 1 t/ha indicating the importance of P in upland maize production. This result also points to the value of NuMaSS in recommending more P relative to the regional recom mendation and the farmer's practice. The difference between Nu MaSS and NuMaSS minus lime was about 1.5 t/ha. Many farmers were surprised by the positive response to lime.

The mean estimates in Table 1 suggest that the greatest re sponse to the components of the NuMaSS recommendation was to P and then about the same response to N and the addition of lime. The main productivity effect, however, uniquely attributed to the NuMaSS recommendation was derived from the component of the model that prescribed lime application. In contrast, both the "Regional recommendation" and "Farmer's practice" included applications of N and P, as did the NuMaSS recommendation. A simple model that features additive effects in a multiple regres sion framework was estimated to quantify the effect of the liming component of the NuMaSS recommendation. This specification is given in (1); economists call this a fixed effects model

$$\text{Yield}_{ijkl} \quad \beta_0 + \sum_{i\;1}^{6} \beta_i \text{treatment}_{ijkl} + \sum_{i\;7}^{9} \beta_i \text{year}_{ijkl} + \beta_{10}\text{season}_{ijkl} + \sum_{i\;11}^{23} \beta_i \text{field}_{ijkl} + \mu_{ijkl} \tag{1}$$

One observation in (1) refers to the mean of the ith treatment in year j, season k, and field l. In each trial, replications were averaged to give an estimate of the treatment mean. Estimated mean yield is posited to be a function of treatment, year, season, and field in (1). Table 1 suggests that treatment effects were significant. Maize yield was also expected to be higher in the first crop at the onset of the wet season than in the second crop which is harvested during the dry season because all fields were rain fed. Field and year effects figure in the model to derive a more precise estimate of treatment effects.

Table 1
Summary data on maize yields by fertilizer treatment in on-farm experiments in Ilagan, Isabela Province, Philippines 2003–2006.

Fertilizer treatment	Mean yield (t/ha)	Standard deviation	Minimum	Maximum
Control (unfertilized)	0.55	0.65	0	2.58
Farmers' practice	2.47	1.14	0	5.04
Regional recommendation	2.83	1.19	0	5.53
NuMaSS recommendation	4.60	1.47	0	7.12
NuMaSS – N	3.10	1.29	0	5.53
NuMaSS – P	2.07	1.43	0	5.73
NuMaSS – lime	2.99	1.19	0	5.91

With an additive effects model, the number of estimated coefficients is (n 1) the number of categories. The 'left out' or reference variable is usually assigned arbitrarily. For our purposes, it is desirable to use the NuMaSS recommendation as the reference variable so that we can determine its statistical significance relative to the other treatments. Similarly, to determine the statistical significance of year and field effects, we make the reference point equivalent to the median yielding year and field.

The independent variables in (1) accounted for about 65% of the variation in on farm maize yield across the 258 observations (Table 2). As expected, the six treatments in Table 2 yielded significantly less than the NuMaSS recommendation. The difference between NuMaSS and farmer's practice was about 2.1 t/ha. But without the liming component of the NuMaSS recommendation, maize yield declined sharply by about 1.6 t/ha. The 95% confidence interval indicates that NuMaSS without lime was 1.1 2.0 t/ha less than NuMaSS with lime. The yields of NuMaSS without an acidity recommendation were not significantly different from NuMaSS minus N but were significantly higher than NuMaSS minus P. These significant and large results on the productivity effects of treating soil acidity in maize production show that the government's liming program was empirically well founded.

Second crop productivity was significantly lower by about 0.9 t/ha than first crop productivity. The earlier years (2003 and 2004) were somewhat higher yielding than the later years (2005 and 2006), but those differences were not statistically significant. No fields were significantly higher or lower yielding than the median field (results not shown). Differences among years and among fields do not show up in the summary model presented in Table 1 and probably account for the differences in estimates of the N, P, and lime effects shown in Tables 1 and 2.

These results on the absence of significant year and field specific results were somewhat surprising because the farmers were quick to point out bad weather events in the surveys which also showed some variation in the use of N, P, and herbicides but not in other aspects of management. One explanation for insignificant year effects is that farmers do not plant maize during some adverse weather events, e.g., mostly drought in the dry season. The loss of income is real, but it is reflected only in area variability.

4.2. Estimating the expected profitability of liming at the farm level

Showing that the technology of interest is profitable at the farm level is central to any impact assessment because expected profitability in a cash crop drives adoption. In the previous sub section, we estimated about a 1.5 t/ha yield gain with the addition of lime in the NuMaSS recommendation. We assume that this 1.5 t/ha increase will also prevail with the farmer's present fertilizer use intensity because NuMaSS and the mean farmer's application rate were not significantly different although NuMaSS, in general, prescribed less N and more P than farmers were applying.

Farm level profitability depends on economic context. From 2004 to 2006, producers sold their maize at a nominal price of about 8.5 Philippine Pesos (PhP) per kg. This price is equivalent to a value of USD 212.50 per metric ton. Because the Philippines is a net importer of maize, its price to domestic producers depends on global supply and demand.

Both seasonal and intertemporal price risk seem low in maize production in the Philippines. Based on de trended data from 1988 to 2006, the seasonal low price in September, the peak harvest month, is only 17% below the monthly average price and the seasonal high price in April is only 5% above the same benchmark. Participation in the international market also dampens price seasonality within years and contributes to price stability across years. All farmers sell at harvest in both seasons. Limited price seasonality suggests that returns to storage are low and no farmers reported storing maize.

Responses of the trial cooperators and techno demo farmers in the final evaluation survey support the hypothesis that increased production from lime use will not result in a fall in price that

Table 2
Determinants of maize yield in the on-farm experiments in Ilagan, Isabela Province, 2003–2006.

Determinant[a]	Estimated coefficient	Standard error	*t*	[95% confidence interval]	
Control (unfertilized)	−4.06	0.23	−17.84	−4.50	−3.61
Farmers' practices	−2.14	0.23	−9.39	−2.58	−1.69
Regional recommendation	−1.77	0.23	−7.78	−2.22	−1.32
NuMaSS – N	−1.46	0.24	−6.15	−1.93	−0.99
NuMaSS – P	−2.50	0.24	−10.51	−2.97	−2.02
NuMaSS – lime	−1.58	0.24	−6.65	−2.04	−1.11
Second crop (dry season)	−0.88	0.14	−6.34	−1.15	−0.61
Year 2003	0.74	0.43	1.72	−0.11	1.58
Year 2004	0.43	0.27	1.62	−0.09	0.96
Year 2005	−0.31	0.27	−1.15	−0.84	0.22
Constant	4.72	0.66	7.20	3.43	6.01

Number of observations = 258.
$F(22, 235) = 21.62$.
Adjusted R-squared = 0.64.
Root MSE = 1.00.
[a] Reference variables are the NuMaSS Recommendation, first crop year 2006 and Field 13.

Please cite this article in press as: Walker, T., et al. The early economic impact of a nutrient management decision support system (NuMaSS) on small farm households cultivating maize on acidic, upland soils in the Philippines. Agr. Syst. (2009), doi:10.1016/j.agsy.2009.05.004

compromises gains to producers from this technological change. Most farmers could not recall a season when heavy regional harvests resulted in abnormally low prices. Farmers' recollection of low prices stem from quality damage from continuous rain during harvest.

Farmers finance production from their own equity and many also borrow from either the owners of input supply stores or maize traders. Input dealers and maize traders charged the equivalent of 20 30% interest during the cropping season. They supplied funds not only for hybrid seed and chemicals deployed in maize production but also gave loans in the form of cash for school fees and cash operating expenses such as the hiring of casual labor. Farmers who relied on private sector credit usually formed a long term association with the lender. For farmers who borrowed, several said that they had received funds from the same lender for from 10 to 15 years. Borrowers believed that they could persuade lenders to include lime in their credit 'package' for maize production.

Tenancy is also common among the maize farmers in Isabela. The prevailing arrangement seems to be quarter share tenancy. The landowner receives one fourth of the harvest as a payment for the use of the land. Like the tied credit transactions, tenancy transactions were characterized by longer term relationships often lasting longer than ten years. The long duration of tenancy relationships suggest that it is both in the interest of the sharecropper and the landlord to apply lime as the relationship endures much longer than the persistence of the carry over effects of applying lime.

This background information on economic context suggests that output price risk is not a major concern in conditioning the expected profitability of liming and that expected profitability should be addressed from several perspectives because of double cropping, sharecropping, and carry over effects. Multiple cropping, dynamic response and institutional scenarios are addressed. The liming dose in the NuMaSS recommendation was mostly 1.0 t/ha. This application rate was equivalent to twenty 50 kg bags of lime per hectare. Each bag of lime costs about 225 PhP. Additionally, we add four labor days per hectare as a cost of acquiring and spreading lime which is equivalent to increasing the cost of each bag by about 10%. We did not add any additional costs in harvesting the increased crop. Therefore, the investment in lime comes to 4884 PhP or about US$100/ha at an exchange rate of 48 PhP equal to US$1 in 2006. The additional production of 1.5 t/ha is worth about 12,750 PhP and results in a single season marginal rate of return on investment of about 160%. This level of expected profitability satisfies the conventional rule of thumb that the marginal rate of return should be superior to 100% for adoption to occur (CIMMYT, 1988). The investment in lime is also attractive from the point of view of the informal credit market conditions that now prevail in northern Luzon. Demonstrating that liming can pay in the first cropping season is important because smallholder agriculture is characterized by a marked positive time preference that leads to the rejection of technology that does not generate benefits in the near term.

Ten scenarios on expected profitability are given in Table 3. The first six examine the robustness of lime's expected profitability by varying assumptions on cropping intensity, carry over effects, and tenancy. The latter four address the issue of expected profitability from the perspective of an investment where the farmer buys lime in year 0 but does not use it until the next year. Scenarios 3, 6, 8, and 10 illustrate the incorporation of carry over effects in the calculation. We assume that lime productivity declines by 50% in the second year and to 25% in year 3. In carry over scenarios 3 and 6, we also assume that farmers strongly prefer the present to the future by discounting future outcomes by 50% which is the modal interest rate across the two seasons. Justification for linking the farmer's discount rate to interest rates is given in Pender (1996).

In five of the first six scenarios where lime more than pays for itself in the first year, its expected profitability is higher than a marginal rate of return of 100% (Table 3). For the sharecropper, lime's profitability is questionable if the sharecropper believes that its effects are confined to one season. For a marginal rate of return (MRR) of 100% to obtain, the price of lime could vary from a high of over 900 PhP/bag in scenario 3 that is perceived by the farmer to be the most productive outcome and to a low of just under 240 PhP/bag in the tenant, single season scenario 4. A comparable break even price for scenario 1 to guarantee a 100% rate of return from a season's production is 317 PhP/bag.

The average productivity of a kg of lime varies from 4.33 kg maize in scenario 3 with double cropping and carry over effects to 1.12 kg maize in scenario 4 with single season sharecropping. For a farmer to attain a 100% MRR, the average productivity of lime needs to exceed 1.15 kg maize per kg lime applied. This level of productivity refers to the summed response over cropping seasons and years when a response is forthcoming from a single application.

Scenarios 7 10 represent situations where the farmer purchased lime initially but did not use it or because of drought or typhoon did not plant or harvest maize. In spite of these adverse assumptions, internal rates of return on investment are still high and exceed seasonal interest rates of 25 30%. If the owner operator only reaped the residual productivity effects of lime in the second and third year, the internal rate of return on investment would still exceed 200%.

The illustrative calculations in Table 3 do not bring out two of the positive features about lime as an input in the Region II context. Firstly, lime, although expensive for farmers, is likely to be associated with less production risk than equally priced inputs because of the scope for residual effects that function as a productivity option or form of insurance. Lime is also a divisible input as farmers can apply as few or as many bags as they desire and can afford. An expected scenario consistent with the diffusion literature (Rogers, 1995) is a first application consisting of a few bags to determine response before more bags are purchased. The real risk in applying lime is not production risk per se but rather the

Table 3
The expected profitability of liming by scenario and criterion.

Scenario	Purchase date	Cropping intensity	Carry-over effects	Tenancy	Criterion[a] MRR/IRR(%)
1	Same year	Single	No	Owner	160
2	Same year	Double	No	Owner	420
3	Same year	Double	Yes	Owner	650
4	Same year	Single	No	Sharecropper	95
5	Same year	Double	No	Sharecropper	290
6	Same year	Double	Yes	Sharecropper	463
7	Year before	Single	No	Owner	160
8	Year before	Double	Yes	Owner	469
9	Year before	Single	No	Sharecropper	95
10	Year before	Double	Yes	Sharecropper	143

[a] MRR = Marginal Rate of Return; IRR = Internal Rate of Return.

risk of using it on soils that are unresponsive. Testing soil pH would be a quick way to determine which soils are likely to be responsive to liming, and acid soils in the region have been shown to be uniformly response to liming. Field trials, combined with farmer experience and with testing of Al saturation levels, would be necessary in other regions where crop yield has not been shown to improve with liming on some acid soils.

Secondly, the adoption of lime could contribute significantly to absolute income poverty alleviation among the poorer maize producing households, particularly those who rely heavily on maize as a cash crop. The poverty related benefits from liming could be large to these poorer households with few outside sources of income. *Ceteris paribus*, technological change in specialized commodity production from households with few income sources is likely to be associated with more favorable poverty consequences than comparable innovation in unspecialized households with diverse income sources. This intervention that increases the supply of maize may not score high marks in reducing consumption poverty, as maize is sold for processing into livestock feed not eaten, but its potential to alleviate income poverty seems ample.

4.3. The rate of return on NuMaSS research and the attributed lime promotion program

The analysis in the previous two sub sections has set the stage for assessing the impact of NuMaSS and the related lime promotion program as a research and extension project. This project appraisal takes the form of a conventional cost benefit analysis where net benefits (NB_t) over time are described in (2):

$$NB_t = \left(p\sum_{i=1}^{3} a_i y_i - cx_t\right)_t - R_t - E_t \qquad (2)$$

where p = the price of maize per kg, a_i = maize area limed in year i, y_i = the yield increment from liming in year i in kg, c = the price of lime per bag, x_t = the number of bags of lime applied in year t, R_t = research expenditures in year t in 2006 prices, and E_t = extension expenditures on the lime promotion program mainly subsidies on lime and staff salaries.

The net benefit specification in (2) is typical of a rate of return study of technological change with one significant departure. Carry over consequences are allowed for over a three year period in the appraisal so that the productivity effects of liming are composed of three sources: (1) a 'full' yield increment in the year lime was purchased, (2) a partial yield increment from yields limed for the first time in year $t-1$, and (3) and a partial but smaller yield increment in fields initially limed in year $t-2$. Once lime is adopted, it is assumed that it will be re purchased every three years.

The cost benefit analysis of liming is based on the assumptions described in Table 4. The project appraisal is viewed from the point of view of the Philippines, and it starts in 1996 when the NuMaSS collaboration initiated in the country. In principle, it would be possible to trace back the costs of the intervention to the time that research first started in the Soil Management CRSP on NuMaSS and proportionally assign a small portion of those costs to research in the Philippines (Manalo and Ramon, 2007). But adoption of this perspective would doom the project to low or even negative rates of return as the gestation period between the initiation of research on NuMaSS and first adoption in the Philippines would be about 25 years. Implicitly, we regard those earlier modeling expenditures as sunk costs.

We assume a relatively long project life of 40 years because lime is a bulky commodity that requires both public and private sector investment to make it available to farmers. Ensuring availability will take time and most likely will be a gradual but sustained process. The speed of diffusion is unlikely to approach levels characterized by varietal change. For that reason, it will take some time to arrive at a ceiling level of adoption.

Table 4
Assumptions used in appraising the NuMaSS research and related lime promotion program as a research-extension project by category and description.

Category	Description
Timing	
Project duration	40 years
Research start	1996
Lime promotion program duration	4 years
Non-program adoption start	2010
Costs	
Research	US$60,000 per year
Lime promotion program	
Bags of lime per year	28,800
Price per bag (PhP)	225
Number of technicians	38
Salary per technician US$/yr	2000
Proportion time on lime program	0.67
Benefits	
Adoption	
Size of the recommendation domain (ha)	90,000
Ceiling rate of adoption (%)	13.3
Lime program coverage – First year (ha)	3,000
Lime program coverage – Second year (ha)	4,000
Seasonal productivity increase per ton of lime (kg/ha)	
First year	750
Second year	375
Third year	187.5
Price of maize (PhP/kg)	8.46
Real rate of social discount	.05

The lime promotion program is assumed to last for five years from 2006 to 2010. Private adoption without access to the subsidized program is scheduled to begin in 2011 (15 years after the initiation of research). Adoption reaches its ceiling level in 2035 at a level significantly less than 100%.

Suppositions on program coverage were 3000 ha in the first year and 4000 ha in subsequent years. The rate of application was specified at 500 kg/ha in the first year and 1000 kg/ha in subsequent years. After that, we assumed that the benefit of liming would become apparent to the private sector and that lime would be applied to 15,000 ha of acid upland soils.

To calculate annual costs of the lime distribution program, for each year of the program (2006 through 2010) we added the cost of the lime and the cost of the local agricultural staff dedicated to the project (Table 4). The cost of the lime promotion program totaled about $400,000 annually in 2006 prices. Expenditures on the research program were about $60,000 annually including costs borne in the Philippines and a proportional allocation of time to the Philippines of one of the principal investigators of NuMaSS in the SM CRSP. These annual research costs were adjusted for past inflation based on estimates from a Consumer Price Index in the Philippines. We assume that future inflation will be at the same rate for benefits and costs. Once the government program of free lime distribution ended and the private program was assumed to begin, the cost of the lime itself was included in the calculation, but no government staff costs were assumed.

The project appraisal was conducted for Region II (Cagayan Valley) provinces of Nueva Viscaya, Quirino, Isabela, and Cagayan. Production estimates from the Department of Agriculture, 2006, indicate that approximately 120,000 ha of maize were harvested in each season from Isabela Province. We made conservative assumptions of the extent of the adoption of the liming technology. Although there are approximately 90,000 ha of net cropped area planted to maize with acid soils in Region II, we only assumed that 5000 ha per year would receive lime each year after the promotion program stopped, that is, at any point in time after year 2013 there would be 15,000 ha contributing to project benefits because of the potential for dynamic effects from liming.

The potential impact of the liming and soil acidity management program can be far greater than the project appraisal suggests. Inspection of soil maps from the Philippine Bureau of Soils and Water Management shows that the area of six soil series characterized as acid in Region II with a pH from 4.8 to 5.6 exceeds 600,000 ha.

Based on the earlier analysis in this section, we estimated that maize yield would increase by 1 kg/ha for every kg/ha lime applied if soil acidity were a problem. Lime was assumed to have residual effects of 50% in the second and 25% in the third year, after it was initially purchased (Table 4). These assumptions on carry over effects are conservative; commonly, lime effects last several years.

For our baseline conservative scenario of 5000 ha limed each year following the closure of the lime promotion program in 2010, the estimated Net Present Value (NPV) is over 8 million dollars and the IRR is a healthy 25%. Adoption is one of the key determinants in influencing the NPV and IRR of any impact assessment of technological change (Walker and Crissman, 1996). A sensitivity analysis of the results shows that estimates of the financial parameters increase linearly area limed per year to the maximum participation level of 30,000 ha per year (Fig. 2). NPV increases linearly with increasing area limed until it reaches a value approaching US$45 million at full adoption which occurs at 30,000 ha assuming carry over effects. IRR increases asymptotically to a maximum of about 35%.

Aside from the marked sensitivity of the results to adoption, Fig. 2 also demonstrates that the lime promotion program has paid for itself even if negligible adoption takes place after its closure. Estimates of both NPV and IRR are both positive even though no adoption is assumed to occur after the program closes. In other words, the program was sufficiently large and productive to more than compensate for its own cost and the earlier expenditures on research. Nevertheless, Fig. 2 amply demonstrates that the economic performance of the NuMaSS related research and the lime promotion program hinges on adoption in the post program period. Negligible adoption following the termination of this subsidized fertilizer program would be a major disappointment because the use of lime needs to be sustainable in an unsubsidized setting.

The baseline scenario assumes a low ceiling rate of adoption. Lime is bulky, and it will take time to popularize its use in an upland small holder setting where poor road transport erodes its

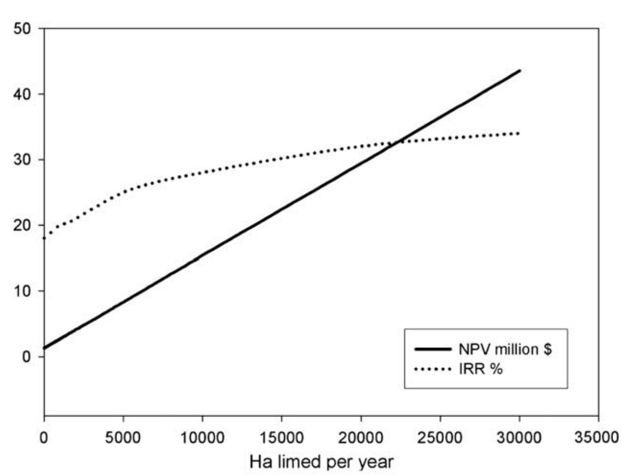

Fig. 2. The sensitivity of financial estimates to assumptions on adoption of liming in Region II after the lime promotion ends in 2010.

profitability in more remote regions. We do not expect lime's speed of diffusion and ceiling level of adoption to be as rapid and as high as the uptake of inorganic fertilizer and hybrid varieties of maize in the 1980s and early 1990s. But the baseline scenario is conservative not only for its assumptions on adoption but also because possible spill over effects are not incorporated on other maize growing regions that are also partially characterized by acidic soils where lime use could be profitable. As discussed, NuMaSS is also being tested in those regions.

In spite of its conservative emphasis, the base case is a status quo counterfactual. In the evaluation of policy change that is attributed to research, a typical counterfactual is a scenario that says without the research the policy change would have eventually happened but it would have occurred at a later date (Walker et al., 2008a). Determining when the policy would eventually have been implemented is often highly speculative, and this 'sooner than later' counterfactual warrants more scrutiny in the impact assessment literature (Walker et al., 2008b).

It is likely that lime would have eventually been adopted by smallholder maize producers in acidic, upland soils in the Philippines in the absence of this research. But it is highly unlikely that adoption would have occurred in the absence of response research that showed that applying lime was an economically robust practice in well defined maize growing conditions. Nor is adoption likely to have occurred without a targeted extension and public sector distribution program to make lime more widely available to hasten initial diffusion. Buying, transporting, and applying twenty 50 kg bags of lime per hectare every three years can be a major undertaking for a small upland maize grower. Therefore, a reasonable 'sooner than later' counterfactual would be to suppose that a similar research program to NuMaSS would have occurred ten years later than it did and that this program would also have resulted in a subsidized public sector distribution program in Region II. Sooner than ten years seems highly unlikely.

With this 'ten years later' counterfactual, net present value is halved to about 4.3 million US dollars but the rate of return on investment only declines from 25% to 24%. A sharp decline in the estimated NPV and only a small decrease in the estimated IRR is typical of sooner than later counterfactuals because benefits in the later years of the project appraisal are eliminated and benefits in the early years do not change that much.

5. Conclusions and directions for future research

The context of this assessment research was generic in two important aspects. Firstly, we addressed the issue of attributing practical impact from information generated with the deployment of a decision aid. That the use of a decision aid in developing country agriculture has the potential to result in farm level impact is unquestioned, but well documented success stories are not numerous. Secondly, the recent surge in maize prices partially driven by the crop's potential as a biofuel means that the area cultivated to maize in Southeast and South Asia will most likely expand markedly above historical trends. Much of this prospective area for planting is situated on upland, highly acidic soils. Thus, liming is increasingly accorded a high priority in enhancing productivity under such adverse environments.

We have documented a concrete case where applied research in the framework of a decision aid has translated into practical impact and has the potential to generate favorable consequences on a much wider scale. The element of surprise figured prominently in creating conditions that stimulated public sector investment in a lime promotion program. The highly productive response of the NuMaSS treatment in the simple, but highly effective on farm research experiments made a favorable impression on research

Please cite this article in press as: Walker, T., et al. The early economic impact of a nutrient management decision support system (NuMaSS) on small farm households cultivating maize on acidic, upland soils in the Philippines. Agr. Syst. (2009), doi:10.1016/j.agsy.2009.05.004

and extension administrators alike; so much so, that a decision was taken to invest regional government funds in the lime promotion program.

Substantially positive rates of return were estimated for applying lime on acid, upland soils both at the farm and project levels. The economic returns to the use of liming as an input could result in tens of millions of dollars in NPV in Region II alone. Experimental results suggest that lime could also be a profitable investment in maize cultivation on Mindanao and Negros although liming may not be as economically attractive as in the Cagayan Valley. Therefore, the consequences of Region II's lime promotion program is of potential interest to other maize producing regions of the Philippines.

The case of NuMaSS and liming maize in the Philippines also highlights several issues that warrant more research. Our assessment was cast from the perspective of ex post analysis. However, much of the impact assessment was ex ante as adoption has only taken place in the setting of a government subsidized fertilizer program. Such government interventions have fallen out of favor with market liberalization and globalization initiatives over the past 30 years (World Bank, 2007). But there still appears to be a time and a place for such programs and conducting research on their experience in making highly desirable inputs more widely available is a priority.

Likewise, a greater investment in soils research is essential to maintain and build on gains in productivity in the fragile, upland maize growing environments in Southeast and South Asia. Economic conditions that increasingly make rain fed maize monoculture more attractive pose several taxing challenges to soil scientists, entomologists, and pathologists in their quest to mitigate threats to the sustainability of a cropping system that may not be the most ecologically desirable.

A more subtle area for research centers on the structuring of applied and adaptive research so that the information from a decision aid can be readily valued if indeed its use results in changed behavior. Although the NuMaSS experiments were highly effective in drawing everyone's attention to the utility of lime, a novel input, differences between the NuMaSS recommendations on N and P were not widely perceived by farmers because the farmer treatment was not set at their individual level but was specified from the central tendency of earlier survey data. Whatever the case, farmers were not clear on the difference between the NuMaSS recommendations on N and P and their own application rates. Lack of clarity leads to fuzzy evaluation and for that reason we could not attribute any changes in application rates in N and P to the extent that there were changes to NuMaSS. With hindsight, it could have been more informative to tailor the farmer treatment to their own highly specific application levels so as to instill in them an appreciation for differences between what they were doing and what NuMaSS was recommending. Liming quickly became the focus of their attention; any other differences in treatments faded into the background. Once lime becomes a non novel input, farmers could receive feedback for the need for more lime as well as for nutrients through ongoing soil testing. The generation and comparative use of information related to non novel inputs calls for careful consideration in the formative stages of adaptive research so that assessment can become a reality if new information results in changed behavior.

In closing, major limitations of this analysis warrant discussion. This study is limited by the relatively small number of soil types and on farm trials on which the response research is based and by the ex ante character of the analysis which takes place only 3 4 years after initial adoption. This work sets the stage for a follow up study in 5 10 years time that compares initial and projected benefits with a historical picture on lime use in smallholder maize production in Region II in particular and the Philippines in general to address several of the key issues that are posed in this paper. Confronting early results and projections with updated results from later ex post analyses is a neglected theme in the economic impact assessment of prospective technological change.

Acknowledgment

This report was made possible through support provided by the Offices of Agriculture and Natural Resources Management, Bureau for Economic Growth, Agriculture and Trade, U.S. Agency for International Development, under the terms of Award No. LAG G 00 97 00002 00. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Agency for International Development.

References

Alston, J.M., Chan-Kang, C., Marra, M.C., Pardey, P.G., Wyatt, T.J., 2000. A meta-analysis of rates of return to agricultural R&D, *Ex Pede Herculem*? IFPRI Research Report 113, International Food Policy Research Institute, Washington, DC.

CIMMYT (International Maize and Wheat Improvement Centre), 1988. From Agronomic Data to Farmer Recommendations: Economic Training Manual. Revised edition. CIMMYT, Mexico City.

Corson, M.S., Rotz, C.A., Skinner, R.H., Sanderson, M.A., 2007. Adaptation and evaluation of the integrated farm system model to simulate temperate multiple-species pastures. Agri. Sys. 94, 502–508.

Corton, T., Friday, J.B., George, T., Tanzo, I., 1998. Exploratory Rapid Appraisal of Barangay Centro San Antonio, Ilagan, Isabela, Philippines. Unpublished Report, University of Hawaii, Honolulu, HI.

Evenson, R.E., 2001. Economic impacts of agricultural research and extension. In: Gardener, B., Rausser, G. (Eds.), Handbook of Agricultural Economics, vol. 1a. Elsevier Science, pp. 573–628 (chapter 11).

FAOSTAT, 2006. FAO, Rome.

George, T., Friday, J.B., Smith, F.J., 1999. Unpublished report on trip to the Philippines. SM-CRSP Project Decision Aids for Integrated Nutrient Management. University of Hawaii, Honolulu, HI.

George, T., Lasquite, J.B., Corton, T.M., Escabarte, R.S., Asuncion, Q.L., Macarubbo, B.C., Quiton, J., Yost, R.S., 2003. Extensive evaluation of NuMaSS diagnosis and predictions of N, P, and lime requirements in the Philippines. In: Casimero, M.C., Publico, S.Ma., Yost, R.S., Aragon, M.L. (Eds.), Field testing of the Integrated Nutrient Management Decision Support System (NuMaSS) in Southeast Asia. Philippine Rice Research Institute, PhilRice Maligaya, Muñoz, Nueva Ecija, Philippines, pp. 90–103.

Girard, N., Hubert, B., 1999. Modeling expert knowledge with knowledge-based systems to design decision aids: the example of a knowledge-based model on grazing management. Agri. Sys. 59, 123–144.

Laxmi, V., Erenstein, O., Gupta, R.K., 2007. CIMMYT. Assessing the impact of natural resource management research: the case of zero tillage in India's rice-wheat systems. In: Waibel, H., Zilberman, D. (Eds.), International Research on Natural Resource Management: Advances in Impact Assessment. CABI, Oxfordshire, UK, pp. 68–90.

Manalo, A.J., Ramon, G.P., 2007. The cost of product development of Bt corn event MON810 in the Philippines. AgBioForum 10 (1), 19–32.

Mataia, A.B., 2003. Baseline assessment of farm households in upland areas. Field testing of the Integrated Nutrient Management Support System (NuMaSS). In: Casimero, M.C., Publico, S.Ma., Yost, R.S., Aragon, M.L. (Eds.), Field testing of the Integrated Nutrient Management Decision Support System (NuMaSS) in Southeast Asia. Philippine Rice Research Institute, PhilRice Maligaya, Muñoz, Nueva Ecija, Philippines, pp. 104–120.

Osmond, D.L., 1991. Nitrogen Fertilizer Recommendations for Corn Produced in the Tropics: Comparison of Three Computer-based Models. PhD Dissertation, Cornell University.

Osmond, D.L., Corton, T., Smyth, T.J., Yost, R.S., Reid, W.S. (Eds.), 2000. In: Proceedings of the Workshop on Decision Processes for Determining Diagnostic and Predictive Criteria for Soil Nutrient Management, September 6-10, 1999, PhilRice, Muñoz, Nueva Ecija, Philippines.

Pender, J.L., 1996. Discount rates and credit markets: theory and evidence from rural India. J. Dev. Econ. 50 (2), 257–296.

PhilRice, 2007. Simplified Keys to Soil Series, Isabela Province. PhilRice, Muñoz, Nueva Ecija, Philippines.

Rogers, E.M., 1995. Diffusion of Innovations, fourth ed. The Free Press, New York.

Schimmelpfennig, D., Norton, G., 2003. What is the value of agricultural economics research? Am. J. Agr. Econ. 85, 81–94.

Shiferaw, B., Freeman, H.A., Swinton, S.M. (Eds.), 2005. Natural Resource Management in Agriculture: Methods for Assessing Economic and Environmental Impacts. CABI Publishing, Wallingford, UK.

SM-CRSP, 2005. Annual Report (2003–2004). <http://tpss.hawaii.edu/sm-crsp/pubs/index.html> (accessed May 17, 2008).

Smith, F.J., George, T., Friday, J.B., 2001. Unpublished Report on Trip to the Philippines. University of Hawaii, Honolulu, HI.

Snelder, D.J., 2001. Soil properties of *Imperata* grasslands and prospects for tree-based farming systems in Northeast Luzon, The Philippines. Agrofor. Sys. 52, 27–40.

SPIA, 2006a. State of the Art in Impact Assessment of Policy-oriented Research in the CGIAR: A Scoping Study Report. Science Council Secretariat, Rome.

SPIA, 2006b. Natural Resources Management Research Impacts: Evidence from the CGIAR. Science Council Secretariat, Rome.

Traxler, G., Byerlee, D., 1992. Economic returns to crop management research in a post-revolution setting. American Journal of Agricultural Economics 74 (3), 573–582.

Walker, T., Crissman, C., 1996. Case Studies of the Economic Impact of CIP-Related Technologies. International Potato Center, Lima, Peru.

Walker, T., Maredia, M, Kelley, T., La Rovre, R., Templeton, D., Thiele, G., Douthwaite, B., 2008a. Strategic Guidance for *Ex Post* Impact Assessment of Agricultural Research. Report prepared for the Standing Panel on Impact Assessment, CGIAR Science Council Secretariat: Rome, Italy.

Walker, T.S., Ryan, J.G., Kelley, T.G. 2008b. Synthesis. In: Impact Assessment of Policy-Oriented Research in the CGIAR: Evidence and Insights from Case Studies. A study commissioned by the Science Council Standing Panel on Impact Assessment. CGIAR Science Council Secretariat, Rome, Italy.

Welch, S.M., Jones, J.W., Brennan, M.W., Reeder, G., Jacobson, B.M., 2002. PCYield: Model-based decision support for soybean production. Agri. Sys. 74, 79–98.

World Bank, 2007. World Development Report: Agriculture for Development. The World Bank, Washington, DC.

Yost, R.S., Uehara, G., Wade, M., Sudjadi, M., Widjaja-adhi, IP.G., Li, Z., 1986. Expert systems in Agriculture: Determining lime Recommendations for Soils of the Humid Tropics. Research Extension Series 089. University of Hawaii, Honolulu, HI.

Yost, R., Onken, A.B., Cox, F., Reid, S., 1992. The diagnosis of phosphorus deficiency and predicting phosphorus requirement. In: Balas, S. (Ed.), Proceedings of the Tropical Phosphorus Decision Support System Workshop, College Station, TX, March 11–12, 1992. TropSoils Bulletin 92–01. University of Hawaii, Honolulu, HI.

Please cite this article in press as: Walker, T., et al. The early economic impact of a nutrient management decision support system (NuMaSS) on small farm households cultivating maize on acidic, upland soils in the Philippines. Agr. Syst. (2009), doi:10.1016/j.agsy.2009.05.004