Soil fertility constraints and limitations to fertilizer recommendations in Cambodia

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Abstract
Soils of Cambodia are low in fertility and conventional rice cultivation destroys any structure that they have. Usage of inorganic fertilizers is low and farmers are encouraged to use animal manure. Much of the research conducted on crop responses to manure is based on trials where unrealistically high application rates have been used so the farmers are given false hopes as to what they might achieve through its use. Little response curve data exists on which to base fertilizer rate recommendations and general recommendations have been formulated for the different soil groups. An economic analysis comparing the general recommendation with site specific nutrient management (SSNM) recommendations has been made on the results of a published experiment and shown substantial increases in both profitability and benefit/cost ratio in using the SSNM recommendations on four soil types. Cambodian farmers, like many in the developing world, have to be careful with their limited cash resources in purchasing plant nutrients and more attention needs to be paid to producing profitable and reliable fertilizer and manure recommendations.

Key Words
Rice productivity, phosphorus, nitrogen, potassium, manure, cost benefit ratio

Introduction
The cultivated rice areas in Cambodia increased from 1.44 M ha in 1980 to 2.54 M ha in 2007 (FAOSTAT) which included about 88% of rainfed lowland areas, and the substantially increased profits and cost/benefit average grain yield increased from 1.19 to 2.36 t/ha over the same period. This yield is relatively low compared with other rice producing countries in the region such as Thailand (2.6 t/ha) and Vietnam (4.9 t/ha) (EIC 2006). Other major crops are maize (11000 ha), cassava (96000 ha) and rubber (21999 ha). In a survey of farmers in 2005 (EIC 2006) farmers were asked to identify production constraints. Skills constraint was identified by 4%, land by 5%, fertilisers by 18%, tools by 29% and water by 84%. Most soils in the rainfed lowlands of Cambodia are infertile (White *et al*. 1997) and plant growth is generally limited by poor soil fertility together with fluctuating soil water regimes (Seng *et al*. 2004). The low fertility results from strong weathering, low cation exchange capacity, low organic matter content, strong soil acidity, strong phosphate sorption capacity, and strong nutrient leaching or nutrient imbalances (Asher *et al*. 2002). About half of the rice growing areas in Cambodia consist of sandy soils possessing such characteristics (eg. Prateah Lang and Prey Khmer soil groups).

The current situation
Considerable efforts have been made in land classification, mapping and fertiliser response trials over a number of years. A major, and significant, output from this phase of soils research was the development of the practical Cambodian Soil Classification system. This has enabled good communication between research, extension, farmer and policy players involved in agriculture. A considerable amount of soil analysis data has been entered into a Cambodian Agricultural Research and Development Institute (CARDI) database which currently holds over 3000 individual data items. An analysis of this database confirms the contention that most of Cambodian agriculture is practiced on soils with low chemical fertility (Table 1). Research has shown that the growth and yield of rice in rainfed lowland soils in most areas of Cambodia is restricted by inadequate supplies of N, P and K (Seng *et al*. 2001). Despite the recommendations made based on this research many farmer have insufficient money to buy fertiliser or think that the coming season will be an average one and that the recommended fertiliser application rate is too high. An additional problem faced by farmers is that an estimated 70% of fertilisers sold in the market are adulterated (EIC 2006). Given the diversity and uncertainty in the rainfed rice growing environment in Cambodia it is very difficult to accurately predict optimum fertiliser rates for all conditions.

Table 1. Classification of N, P and C characteristics of soil samples included in the Cambodian Soils Database.

Class	Very Low	Low	Medium	High	Very High
Total N	<0.05	0.05-0.15	0.15-0.25	0.25-0.50	>0.5
% of soils in class	63	34	3	0	0
Olson P		0-7	7-15	>15	
% of soils in class		88	5	7	
OC%	<0.06	0.60-1.00	1.00-1.8	1.8-3.0	>3
% of soils in class	1	86	11	2	0

Individual nutrient responses have been identified in a large number of field and glasshouse studies and many thousands of combined N, P and K field experiments have been conducted in Cambodia but there have been few trials reported where the response curve to one nutrient has been established in the presence of adequate levels of the other nutrients. Rarely has soil test data reported for the soils being studied so it is still not possible to use soil test results to extrapolate the trial result to farmer's fields in other areas of the same soil type. A relatively recent example of this is the study on P sorption and desorption on three lowland soils reported by Pveav *et al*. (2002) where details of the starting soil properties, other than P status, are reported. This large body of research results has been blended with experience to establish a general set of fertiliser recommendations for the individual soil groups. The question arises as to the profitability to farmers of applying the recommended rates of application given the generally low yields obtained. Data on rice yield response to recommended fertiliser reported by Olk *et al*.(2008) has been used to examine profitability using 2008 fertiliser and rice prices (rice $225, Urea $500, DAP $700 and KCl $700/t). Although prices of both fertilisers and rice have increased sharply in recent times the relativity between them is expected to remain. These calculations (Table 2) show that poor return, both in terms of $US/ha and value/cost ratio, would have been obtained at 3 of the 4 sites. At the Bakan site the farmer would have lost $US40/ha. Research undertaken at CARDI conducted over 6 rice crops produced similarly poor returns on investment in fertiliser and cow manure, with the poorest returns where cow manure was used.

Olk *et al*. (2008) suggested that there is limited opportunity for soil testing in irrigated rice in Asia based on a large number of nutrient omission trials where Dobermann *et al*. (2003) found little correlation between soil test values and plant N, P or K uptake measured in on-farm nutrient omission trials. Based on experience elsewhere the situation is likely to be different for crops grown after rice, and in upland areas. Calibration of soil tests requires on-farm trials and in these maximum achievable yields need to be established. An alternative site specific nutrient management (SSNM) approach to making fertiliser recommendations has been proposed. In this fertiliser N, P and K requirements are calculated based on the difference between yields under on-farm nutrient limited conditions and target, not necessarily maximum, yields (Dobermann, White 1999). The nutrient needs for this increased yield are estimated from plant analysis tables and fertiliser requirements per I t of yield increase which are estimated at 40-50 kg N/ha, 7-12 kg P/ha and 22-41 kg K/ha. Results from the trials conducted by Olk *et al*. (2008) using this approach is reported in Table 2. In each situation profit would have been higher using the SSNM recommendation rather than standard one. This procedure for making fertiliser recommendations needs serious consideration. This recommendation is not new and a similar approach was advocated by Bell *et al*. (2001).

Table 2. Economics of fertiliser application using recommended rates and rates based on Site Specific Nutrient Management.

Soil type	Recommended fertiliser rate (N-P-K kg/ha)	Average yield increase (t/ha)	National Fertiliser Recommendation		Site Specific Nutrient Management	
			Profit (+) or loss (-) ($US/ha)	Value/Cost ratio	Profit (+) or loss (-) ($US/ha)	Value/Cost ratio
Toul Samrong	86-30-10	0.83	+48	1.4	+116	2.2
Prey Khmer	19-12-26	0.56	+62	2.0	+97	2.0
Bakan	73-64-20	0.59	-40	0.8	+97	2.0
Prateah Lang	67-24-16	0.77	+55	1.5	+204	3.0

In poor agricultural communities the cost of inorganic fertilisers is a major constraint to their use and this prompts promotion of animal manures. Policy pushes and campaigns by well meaning NGO's has promoted the use of manures and continues to discourage inorganic fertiliser use. As a result much research has been conducted on the use of mulches and cattle manure in rice cropping. This has generally shown responses to their application, but in most experiments reported the rates of application used (generally around 5 t/ha) are far higher than a farmer could access. There were an estimated 3.3 mill cattle in Cambodia in 2006 and assuming a daily intake of 8 kg DM with a digestibility of 50% some 1.32 t of manure is produced /animal/year. This amounts to 4.9 million t for the whole country. Given a collection rate of 50% and a rice area of 2.5 million hectares this amounts to a possible maximum application rate of approximately 1.2 t/ha. Both the availability and the time taken to apply such large amounts is a major impediment to their use.

The challenges ahead

The challenge ahead is to be able to increase productivity in a sustainable way on both old and new lands in order to feed the ever increasing population, which is growing at an estimated 1.75%/year in Cambodia. The profitability of farmers must be increased if they, and their children, are to stay on the land. An aging farmer population and lack of attraction of farming to young people in Cambodia will inevitably lead to the introduction of mechanization, as it has done in Thailand. This will require new research into fertiliser placement and management, and in crop residue management. Moves to mechanical harvesting and direct sowing of crops will open up more opportunities for crop residue management which will have significant effects on nutrient and water requirements, particularly in upland areas. Rice and other crop yields have steadily increased over the past decades and changes in fertiliser and rice prices have changed and there is a need to reassess fertiliser recommendations. Calibration of soil tests, particularly for P and K are urgently needed to assist in tailoring recommendations to particular farms. The need for other nutrients in this more productive environment also needs to be investigated. A significant limitation to increased productivity and input research is that the maximum production capacity of the soil groups in Cambodia is not known. This is essential if new technologies are to be introduced to narrow the gap between present on-farm production and what is achievable.

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