Current Agriculture Research Journal Vol. **2**(1), 05-13 (2014)

Nutrient Status of Cambodian Soils, Rationalisation of Fertiliser Recommendations and the Challenges Ahead for Cambodian Soil Science

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http://dx.doi.org/10.12944/CARJ.2.1.02

(Received: February 06, 2014; Accepted: March 21, 2014)

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 need to be paid to producing profitable and reliable fertilizer and manure recommendations.

Key words: Agricultural Development, Management, South East Asia.

INTRODUCTION

Cambodia covers a wide range of climate/soil/vegetation regimes and considerable attention has been given to rice breeding, soil classification and land class assessment[1,2].The cultivated rice areas in Cambodia increased from 1.44 M ha in 1980 to 2.8 M ha in 2010[3] which included about 88% of rainfed lowland areas, and the average grain yield increased from 1.19 to 3.00 t/ha over the same period (Fig 1). This yield is relatively low compared with other rice producing countries in the region such Vietnam (5.5 t/ha)[3]. Other major crops are maize (330000 ha), cassava (1.17 mill ha) and rubber (34900 ha)[3].

MATERIALS AND METHODS

A literature search of published reports and an interrogation of the Cambodian Soils Database was undertaken to establish the situation regarding soil fertility and to establish Agricultural development in Cambodia. Observations were made of constraints to further development of soil science in Cambodia during two six week assignments in Cambodia.

In a survey of farmers in 2005[4] 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[1] and plant growth is generally limited by poor soil fertility together with fluctuating soil water regimes[10, 11,12]. 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[13, 1, 14, 15] . About half of the rice growing areas in Cambodia consist of sandy soils possessing such characteristics (e.g. Prateah Lang and Prey Khmer soil groups, Table 1).

Extension of research results and new technologies to farmers is severely hampered by a shortage of extension officers is severely and funding support for their operations. It is estimated[4] that there was only one extension officer for every 4000 households. This compares with one extension officer per 1340 households in Vietnam.

RESULTS AND DISCUSSION

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 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 (Tables 2, 3 and 4).

Research by CIAP and CARDI 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[16,12,17]. Despite the recommendations made based on this research many farmers 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[4]. 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.

Large amounts of nutrient elements are removed from the soil in crop and animal products and large inputs of nutrients are required to sustain plant production[18]. Because of this there is a need to establish a proper soil nutrient management strategy for sustainable crop production by preventing imbalanced nutrient applications, which may harm the soils and the wider environment[19, 20].

Individual nutrient responses have been identified in a large number of field and glasshouse studies detailed in annual reports of the CIAP Project, and elsewhere. An example of these studies is reported in Table 5 from an omission trial pot study[21]. This generally reflects the occurrence and severity of the deficiency in the published data.

The universal N deficiency prompted early research on N which was often carried out with insufficient knowledge of the other deficiencies constraining yield. Much of the research effort was

Table 1. Important chemical characteristics of soil groups in Cambodia

Soil group	pH	Organic C %	CEC (Cmol/kg)	Exch K (Cmol/kg) %	Olsen P (mg/kg)
Prey Khmer	5.4	0.25	0.85	0.03	1.1
Prateah Lang	5.3	0.28	1.43	0.06	1.5
Labansiek	5.3	0.94	7.14	0.09	4.0
Orung	5.1	0.80	6.02	0.14	2.5
Krakor	4.6	0.96	13.72	0.23	4.1
Bakan	5.1	0.43	3.45	0.08	1.9
Kbal Po	4.8	0.79	8.51	0.26	5.6
KeinSvay	5.7	0.92	10.36	0.22	13.7
ToulSamroung	5.2	0.78	13.00	0.17	2.6
Koktrap	5.0	1.17	4.59	0.10	3.4
KompongSiem	5.4	1.15	13.35	0.25	14.2

devoted to timing and placement of urea applications. Considerable research effort was devoted to partly replacing fertiliser N with symbiotically fixed N from *Sesbania rostrata*. This technology requires extremely high *Sesbania rostrata* seeding rates, P applications to promote rapid growth and much labour, and, as a consequence was not adopted by farmers. The development of the leaf colour chart (LCC) by IRRI should have made a significant contribution to N management in rice but lack of promotion by extension agencies has limited its contribution. The current recommendation of delaying N application until tillering and panicle initiation reduces risk associated with mid-season water deficit. The addition of LCC to this strategy

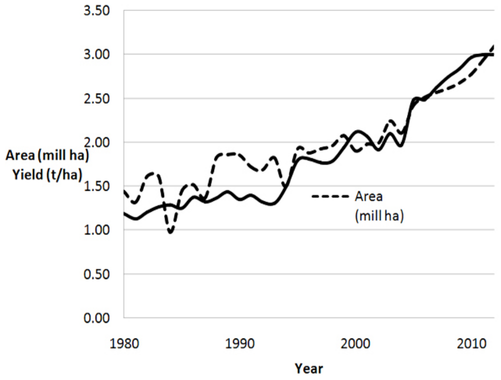

Fig. 1. Area planted to rice and average rice yields in Cambodia 1980-2010 [3]

Table 2: Classification of cation characteristics of soil samples included in the Cambodian Soils Database.

	Class	Very low	Low	Medium	High	Very High	Number of soils
CEC	Class Limit	< 6	6-12	12-25	25-40	>40	
	% of soils in class	72	13	13	2	0	299
% Base Saturation	Class Limit	0-20	20-40	40-60	60-80	>80	299
	% of soils in class	5	50	42	1	2	299
Exch. Ca	Class Limit	< 2	2-5	5-10	10-20	>20	
	% of soils in class	60	18	13	7	2	357
Exch Mg	Class Limit	< 0.3	0.3-1	1-3	3-8	>8	
	% of soils in class	60	13	12	14	2	360
Exch K	Class Limit	< 0.2	0.2-0.3	0.3-0.6	0.6-1.2	>1.2	
	% of soils in class	86	8	5	2	0	360
Exch Na	Class Limit	< 0.1	0.1-0.3	0.3-0.7	0.7-2	>2	
	% of soils in class	44	36	15	2	4	360

Source of class limits :[5]

Table 3: 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

Source of class limits : Total N[6]; Olson P[7]; OC%[8]

to estimate N rates required would likely increase yields and N use efficiency.

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 been 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.

Table 4: Classification of micronutrient concentrations of soil samples included in the Cambodian Soils Database

Nutrient	Low rating (mg/kg)	% of soils classified as low	Number of soils
Zn (DTPA)	<0.6	50	258
Mn (DTPA)	<0.3	100	28
Cu (DTPA/Amm Ac)	<0.2	11	241

Source: Tandon[9]

Table 5: Relative rice grain yields produced in omission pot trials with Cambodian soils

Soil group	Location	-N	-P	-K	-S	-Mg	-Ca	-Zn	-B-(Mn, Mo, Cu)	
		% of maximum yield								
Prey Khmer	Chhouk Sar	11	100	100	100	100	100	100	100	100
Bakan	Kap Srau	28	100	100	100	100	100	100	100	100
Bakan	Wat Chhray	29	17	41	5	100	100	100	100	77
Prateah Lang	Prateah	16	13	47	43	100	100	100	100	100
Prateah Lang	Kbal	22	32	64	12	100	100	100	100	100
Prateah Lang	Toul	12	100	100	64	75	100	100	100	100
Toul Samroung	TS	15	5	100	100	100	100	100	100	60
Koktrap	T K	21	1	25	100	100	100	100	100	100
Kbal Po	Po Village	15	18	100	100	100	100	100	100	100
KeinSvay	Dey Eth	19	100	90	100	100	100	100	100	100
% of soils responding		100	80	70	50	20	100	100	100	20
Average response (%)		80	88	61	74	61	0	0	0	30

Table 6. 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

An example of this is the study on P sorption and desorption on three lowland soils[22] where details of the starting soil properties, other than P status, are not reported.

Deficiencies of S and micronutrients have commonly been reported but little research has been conducted to delineate the areas where these problems exist, the causes of the deficiency, or their amelioration.

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[23] has been used to examine profitability using the following fertiliser and rice prices (rice $225, Urea $500, DAP $700 and KCl $700/t) following fertiliser. These calculations (Table 6) 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 $US 40/ha. Analysis by the authors of research conducted at CARDI over 6 rice crops produced similarly poor returns on investment in fertiliser and cow manure, with the poorest returns where cow manure alone was used.

Unless the productivity and profitability of rice farmers can be substantially improved poverty alleviation programs will increasingly be needed as population increases and the drift of rural youth to cities will increases resulting in less human production capacity on farm and likely social problems in cities.

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 by Government and campaigns by well meaning NGO's has promoted, 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 3.5 mill cattle in Cambodia in 2010[3] and assuming a daily intake of 8 kg DM with a digestibility of 50% some 1.40 t of manure is produced /animal/year. This amounts to 4.9 mill t for the whole country. Given a collection rate of 50% and a rice area of 3.0 mill hectares this amounts to a possible application rate of approximately 0.82 t/ha. Both the availability and the time taken to apply such large amounts is a major impediment to their use.

Ways to moderate the need for inputs of inorganic fertilisers have been a major driver to the use of the System of Rice Intensification (SRI).

Research on soil physical constraints has not been a priority to date because crop production has concentrated on flooded rice where considerable effort is put into destroying soil structure by puddling. As more attention is paid to crops following rice and upland cropping this area of soils investigation will need to be expanded (see under "the challenges ahead).

Cambodian Government and overseas agencies have been very active in training in soil science with the emphasis mostly on post-graduate training. This has increased the pool of soils researchers but their capacity to contribute their knowledge and experience to Cambodia is often hampered by lack of funds for research, opportunities for career advancement and poor salaries. In addition the lack of well trained technical staff to support the research is a major limiter on their output.

The development of teaching and research in universities has been neglected resulting in graduates studying with insufficient lecturing and learning resources. The relatively small pool of soils researchers and their location in a number of agencies restricts interchange of ideas and experiences. In a resource limited situation, such as exists in Cambodia, institutions tend not to share physical and human resources and thisresults in a reduction in scientific advancement. this results can also occur within institutions.

Although considerable effort has been put into research policy and forward planning a considerable amount of research undertaken appears to be driven by donor desires rather than what are the top national priorities.

The challenges ahead

The major 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 challenges ahead for soil science can be divided into the following categories

1. Human capital development and deployment.
2. Resource accumulation and use.
3. Improvements in fertiliser and soil management.
4. How to increase involvement in the sustainable development of upland areas.
5. How to improve the linkage between research and extension.

Human capital development and deployment

As the challenges facing development of upland soils, and the need to produce more food crops and forages for livestock in lowland areas, increases more soil scientists and their technical and administrative support will be needed. Lack of financial inducement in government service will result in movement to the private sector as this develops. This is not necessarily bad, provided the pool of trained people is large enough to support both groups.

As indicated earlier, the imbalance between trained post-graduates and technicians must be overcome if the increased capacity of the scientists is to be captured. Training of technicians is best carried out by a mix of group training at a well developed facility, and on-the job training. The group training can introduce new skills but these often cannot be implemented because of the lack of capacity to adapt them to the local equipment and field resources available at their home base.

Soil science, by its nature, requires access to relevant field sites and mobility. The lack of education opportunities away from major cities restricts the placement of scientists and technicians in rural areas where they can be close to the problems they are investigating. This means that reliable and timely transport arrangements must be possible so they can get to the field when required.

Without significant inputs into the University education sector the attractiveness of agricultural study, and supply of graduates into agriculture, will be restricted. Increasingly people entering agriculture will have had less direct contact with the land. This means that their training in agriculture will need to have a stronger practical component. A major restriction to agricultural training will emerge as overseas post-graduate training opportunities decrease unless there is a concomitant increase in university post-graduate research and teaching capacity.

Resource accumulation and use

Sometimes items of equipment are requested in projects which already exist in another section within the institution, or in a nearby institute. This problem needs to be addressed to increase the effectiveness of the research funds and reduce the need for maintenance of the equipment.

Major items of equipment located in research institutions need to be made available to universities and technical colleges to train students. Such a scheme exists at the University of New England where students from the Technical and Further Education (TAFE) College participate in practical classes at the University to familiarize them with equipment.

Significant amounts of laboratory and field equipment have been amassed in institutions but when these malfunction the capacity to repair them is most often absent. Repair and maintenance technicians need to be trained, or arrangements made with equipment suppliers to overcome this problem

Improvements in fertiliser and soil Management

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.

One of the looming crises for Cambodian agriculture is the availability and price of phosphate. Research conducted in the CIAP project demonstrated the value of local rock phosphate. In most lowland situations Cambodian rock was shown to be equal to, or superior to soluble phosphorus as contained in triple superphosphate and ammonium phosphates. Problems with spreading the powdered rock phosphate and product quality resulted in this P source not being accepted by farmers. There is a need to reassess this resource as at present it is being sold out of the country, made into soluble fertiliser and sold back into Cambodia. New developments in granulation and compaction should be investigated to see if this resource can be better and more profitably utilized in Cambodia.

A significant limitation to increased productivity and input research is that the maximum production capacity of the soil groups 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.

It has been suggested[23] that there is limited opportunity for soil testing in irrigated rice in Asia. Little correlation has been found between soil test values and plant N, P or K uptake measured in a large number of on-farm nutrient omission trials conducted in Cambodia[24]. 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 approach to making fertiliser recommendations is referred to as site specific nutrient management (SSNM) where 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[2]. The nutrient needs for this increased yield are estimated from plant analysis tables and fertiliser requirements per 1 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 using this approach is reported in Table 6. 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 has been advocated earlier[25].

Puddling of the soil for rice production destroys soil structure and makes the growing of post-rice crops difficult. Straw management, direct sowing into the straw mulch and water management in these crops requires study. Significant effort has been, and is being put into growing legumes after rice. The choice of crop, legume or non-legume needs to be reconsidered as all the data to date shows very low yields from the major crops investigated so far namely, mungbean, soybean and peanut. The judicious use of herbicides and insecticides in these crops also requires investigation. .

One constraint to growing second crops after rice has been poor seedling emergence as a result of surface hard setting of the previously puddled soils. Research on the impacts of different straw management regimes, the use of straw mulch and different surface water management strategies are needed to try and overcome this problem. A further constraint to crop growth is the hard pan layer at around 25-30 cm depth that is often found following the rice crop. This can impose restrictions on root growth limiting the available rooting area for exploration of both water and nutrients. As mechanization becomes more prevalent in rice production in Cambodia this problem will be further exacerbated. There is only limited knowledge of irrigation scheduling for dry season crops following rice and this area also requires further study.

How to increase involvement in the sustainable development of upland areas

The upland areas in Cambodia, which need to be developed, are located far from Phnom Penh so attracting staff to work there will be a major challenge. New skills in conservation agriculture will have to be developed as most soil scientists have been involved with lowland rice soils. This will require a greater knowledge of agronomy as good soil conservation in upland areas is primarily good agronomy.

Crop residues are a major source of animal feed in upland areas and competition exists between this use and their value in providing soil cover to avoid erosion. Maintenance of ground cover is essential in these areas to prevent soil loss and ground cover/crop production/erosion relationships need to be established to assess the value of crop residue retention compared to animal feeding. Production of specific forages to be able to leave the crop residues *in situ* may be a more sustainable alternative.

How to improve the linkage between research and extension

The present dearth of extension workers must be rapidly overcome. In the short term these will most likely have to be farmers with training in extension. Over time, the training of students completing high school and those trained in technical colleges will increasingly support extension.

The old model of researcher producing results and the extension worker adapting and communicating them to farmers has not worked well in most countries. Increasingly research and extension agencies are being co-located to improve opportunities for two way communication, identifying, planning and implementing research projects. This model needs to be investigated for Cambodia. In the recent past farmer participatory research has been in vogue but the results and outputs have often been well below expectations.

The experience in other countries has been that as private sector investment in agriculture increases more of the extension is handled by this group. In many instances a private company will provide a complete package of production and marketing advice and the products required to achieve the desired results. This is already occurring with contract maize production in North West Cambodia and is likely to spread

A similar situation is likely to develop as vertical integration occurs in the plantation sector. This development changed the emphasis of government extension agencies from providing direct advice to farmers to providing extension material to company agronomists and soil technicians.

ACKNOWLEDGEMENTS

This paper was prepared whilst the authors were on a mentoring assignment to CARDI. The visit was initiated and supported by the Australian Academy of Technical Sciences and Engineering Crawford Fund. The authors wish to thank the staff of the Soil and Water Division of CARDI for providing access to the CARDI Soils Database and for their hospitality and cooperation.

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