Developing Sustainable Soil Fertility in Southern Shan State of Myanmar

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Soil Science at Massey University Palmerston North New Zealand.

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TO WHOM IT MAY CONCERN

This is to state the research carried out for the PhD thesis entitled "Developing Sustainable Soil Fertility in Southern Shan State of Myanmar" was done by Tin Maung Aye in the Institute of Natural Resources, Massey University, Turitea Campus, New Zealand. The thesis material has not been used for any other degree.

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This is also to certify that the thesis material has not been used for any other degree.

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ABSTRACT

Literature review and a farm survey results indicated that the productive capacity of the Red Earths and Yellow Earths (Acrisols in FAO/UNESCO system) in Southern Shan State, Myanmar, continues to decline as poor, near-subsistence, farmers usually fallow-crop these soils and are unable, for economic reasons, to provide the necessary fertilisers and crop management strategies that could improve and maintain soil fertility.

This thesis reports on investigations undertaken to determine ways in which the fertility of these soils can be improved in an economical and sustainable manner.

A preliminary soil survey confirmed that soils of the Southern Shan State study area had low soil P status, low pH, low SOM (low reserves of N, P and S) and low base saturation, which are likely constraints to crop production on these marginal soils.

A farmers' survey indicated farmers were aware of the P availability and soil acidity problems, however, they use low levels of N, P, K fertilisers, green manure and liming material because their economic margins were insufficient to buy expensive P fertilisers and liming materials.

Preliminary glasshouse trials were conducted to establish the key soil fertility constraints. These trials included testing the P responsiveness of crops (pigeon pea (*Cajanus cajan*), rice bean (*Vigna umbellata*) and upland rice (*Oryza sativa* L)), the influence of liming materials on legume growth (black gram (*Vigna mungo*), cowpea (*Vigna unguriculata*), kidney bean (*Phaseolus vulgaris*), lentil bean (*Culinaris lentil*), pigeon pea, soybean (*Glycine max*), stylosanthes (*Stylosanthes quyanensis*)), and the effectiveness of green manures for building SOM and P reserves in the Red Earths and Yellow Earths.

The glasshouse trials confirmed that low P status is the factor most limiting to crops particularly legumes grown in the Yellow Earths. Upland rice, however, did not respond to added P suggesting that upland rice may not be a suitable test plant for evaluating the relative P effectiveness of fertilisers in the Red Earths and Yellow Earths. This pot experiment with the upland rice trial also demonstrated that indigenous Myanmar phosphate rock (MPR) and Farmyard manure (FYM) were ineffective P sources for raising soil plant-available P in the short-term. Local dolomite, however, was an effective liming material and when added with P enhanced the nodule formation of pigeon pea.

Laboratory incubation studies showed that incorporating organic amendments (FYM, pigeon pea and upland rice residues) into the Red Earths and Yellow Earths significantly increased soil organic C, improved soil pH buffering, increased the total P content and increased labile-P fractions that could be used for plant growth. The Walkley and Black organic C determination can be used as a suitable 'low tech', portable method for the determination of organic C to monitor soil organic matter levels.

Based on the results from the preliminary glasshouse trials, field trials were designed to establish relationships between P fertiliser form, application rate and soil P test levels for maize (*Zea mays*) and legumes (rice bean and black gram) grown in a Yellow Earth. In soils with initial Olsen-P values of approximately 8 kg P kg^{-1} soil, two maize field trials consistently indicated that near maximum yield (90%) of maize can be obtained by application of water-soluble P fertiliser (Triple superphosphate, TSP) at 40 to 50 kg P ha^{-1} in year one and reapplication of TSP at 25 kg P ha^{-1} in year two. Phosphate supplied as FYM, *Tithonia diversifolia*, Chinese partially acidulated phosphate rock (CPAPR) and Sechura reactive phosphate rock (SPR) were agronomically less effective as short-term P sources for maize than TSP, with TSP substitution ratio of 0.1, 0.17, 0.61 and 0.07 respectively at an application of 40 kg P ha^{-1} rate. A legume-wheat rotation field trial showed that rice bean (the legume) yield was significantly increased by the application of TSP at 40 kg P ha^{-1} plus local dolomite. Subsequently, rice bean plots fertilised with 40 kg P ha^{-1} as TSP produced the largest wheat grain yields in the Yellow Earth.

In all trials the Olsen-P test was a suitable soil P test for providing an index of plant-available P. Olsen-P values at which optimum crop growth occurred (90% maximum yield) ranged between 30 to 40 mg P kg^{-1} in the Red Earths and Yellow Earths, depending on the season, plant age when harvested and crop grown.

Use of the sulphuric acid acidulated CPAPR and elemental S (S°) with SPR confirmed that plant growth in the Yellow Earths was very responsive to sulphur application. Chinese PAPR can be used as a cost-effective P and S fertiliser to increase the crop yield in these Red Earths and Yellow Earths, particularly where S is also deficient. Use of local dolomite (2.5 t ha^{-1}) in the field trials caused significant increases in soil pH in the first season and in the legume-wheat trials resulted in increases in legume yield.

The research findings on soil P testing, alternative P sources and liming materials presented in this thesis are discussed in terms of the role they might have in the establishment of sustainable agriculture practice in Southern Shan State, Myanmar. Future research directions that should be taken to realise the productivity of these soils and farming systems are also discussed.

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