Chapter VII

Conclusions and Recommendations

7.1 Conclusions

The spatial distribution soil fertility attributes show that the soils are very poor in total N. Most of the soils are poor in available P and K and organic C soil attributes. Most of the soils are reasonable in soil pH as most of the areas lie in moderate soil pH category.

All the agricultural lands under Lakhu, Zamdongkha, Khurguma, Lakhu and most part of Pakcheykha and Wolakha are under very low levels of total N. Only some part Pacheykha and a small part of Wolakha under slightly better with low level of total N. Due to the very low or low total N levels, C:N ratios are favorable (i.e. low or very low). The available P distribution shows that the 'very low' (0.18 – 5.00 ppm) category occupies most of the land followed by 'low' (5.00 – 14.00 ppm) category. Except for some areas in Lakhu in moderate and high level, all lands are under low and very low levels of available P. Most of the wet lands of Khuruguma, Wolakha and Zamdongkha are under very low level P. Lands across all the six villages are also in low levels of available K except for some lands in Khuruguma, Zamdongkha and Lakhu that fall under moderate category. Very low available K category is only found in small area in Lakhu village. The fertility status is slightly better for available K compared to available P whose distribution shows most of lands under very low category. Spatial distribution of soil organic carbon shows that Pakcheykha and Wolakha villages have moderate level of soil organic C and rest of lands are in low level except for small areas in Khuruguma and Lakha villages with moderate levels.

Since soil nutrients statuses are determined over the geog's agricultural land, location specific fertilizer responses can be judged and fertilizer recommendations can be refined across soil types and soil conditions.

Regarding soil texture, about 35% of soils have in sandy clayey loam type (SCL), about 26% in loamy sand (LS), about 18% in sandy loam (SL), about 15% in loam (L) and the remaining 6% of the samples had clayey loam (CL) and sandy clay (SC) textures. Bulk density values in the ranges of 0.97 to 1.59 g/cm^3 with mean value of 1.28 g/cm^3, which means that the values are in non-limiting ranges for plant root penetration and porosity. But these bulk densities are low like many soils in Bhutan and that the normal correlation between soil texture and AWHC do not hold (BSS/NSSC, 2003).

The technique of scoring is a useful way to come up with some quantitative figures for both farmers' and laboratory soil fertility assessments. The commensurate numeric indices provide a way forward to make comparison between farmers' and laboratory fertility indices. Spatial distribution of soil fertility statuses by farmers' subjective assessment of soil fertility categorized 18 sites as poorly fertile, 41 sites as moderately fertile and 16 sites as highly fertile out of 75 sites assessed. From laboratory approach 14 sites, 57 sites and 11 sites were found to be in low, moderate and high fertility indices, respectively for the 75 sites covered by both farmers assessment and soil survey. For all the 97 sites, including the 22 sites not covered by household interview; 24 sites, 62 sites and 11 sites were found to be in low, moderate and high fertility indices, respectively.

The point to overlay spatial comparison shows the general correspondence of farmers' fertility indices on the surface of laboratory indices, although there are some areas of mismatch, which shows the differences between value judgment by the two knowledge systems. The two indices were statistically related at $p<0.05$ by chi-square test of significance. Percentages relatedness of soil fertility indices within laboratory index 1 to farmers' index 1 is 87.5%, laboratory index 2 to farmers' index 2 is 66.7% and laboratory index 3 to farmers' index 3 is 75%.

The practical relevance the relatedness lies in using them complementarily and benefit from the synergy of using the both for sustainable agriculture development. With the decentralization reached the *geog* level farmers are entrusted to their own development activities (Planning Commission Secretariat, 2002) and so it is essential to recognize and credit local knowledge. Development interventions aimed at improving agricultural resources management is likely to be more effective when local people have a voice in their own development (Pretty, 1995).

The findings can be used by farmers to improve soil fertility management strategies, used by extension planners and other land users for land evaluation development purposes and used by the policy makers for food security enhancement and conservation planning. The findings may not be a blue print, but can serve as a basis for commencing any soil fertility related development projects.

7.2 Recommendations

Findings of this study show that soils are generally poor in plant nutrients and there are spatial variations of different levels. To support agricultural production the sites with low nutrients are to be applied with scientifically adjusted quantity fertilizers and manures. The areas that are poor in N should be applied with scientifically adjusted quantity of urea fertilizer, but should be restricted cultivable lands and orchards may be applied with other less soluble N-providing fertilizers like *suphala*. The areas that are poor in K and P can be applied with Muriate of potash and single super phosphate fertilizers respectively, and the areas that poor in both available P and K nutrients can be applied with a mixture of two fertilizers supplying the required nutrients. The areas that are poor in NPK can be applied with *suphala* fertilizer, which can be obtained in either 15:15:15 or 17:17:17 formulations. All fertilizer application should also consider the expected yield of a concerned crop in a particular location. Most of the soils are reasonable in soil pH but the areas with low soil pH can be applied with lime. More cost-effective fertilizers of single super phosphate or triple super phosphate as the P source and Muriate of potash as the K source are suggested rather than more expensive *suphala* for better economic returns (DRDS, 2001).

Since soil organic matter is the key indicator of soil fertility, which controls physical, chemical and biological properties of soil, it is of essential to improve it. The areas under very low and low categories of organic C must be applied with appropriate rate of organic manures like compost and farmyard manure to improve crop productivity. This study found the decreasing trend of FYM availability and increasing trend of use of chemical fertilizers in Guma *geog*, which is in agreement with the findings of Norbu and Floyd (2004) at the national level. However, recommending application of organic manure in one thing but having access to adequate supply of it another, which warrants policy interventions.

Farmers' assessments are significantly related to chemical analysis results at soil fertility indices level. Although farmers have no idea about individual nutrients they have knowledge through experiences about soil fertility as one can further confirm from general correspondence of farmers' fertility indices over the surface of laboratory indices. The practical relevance the relatedness lies in using them complementarily and benefit from the synergy of using the both for sustainable agriculture development.

7.3 Implications and future directions

7.3.1 Extension

Since the soil fertility status is poor, availability of FYM has decreased and the use of chemical has increased; the farmers will increasingly resort to using more fertilizers in a bid to maintain their crops yields. Extension has an important role to play by disseminating and educating the mass on basic principles of plant nutrition to enable balance fertilizer use both in terms of economic returns and environmental perspectives.

Promotion of leguminous crop and plant species to fix atmospheric Nitrogen is another area. Livestock fodder plant species should be promoted and enhanced to support livestock production so as to increase supply of FYM.

7.3.2 Policy

Soil organic matter is poor and its usual supply from the farms as FYM has decreased over the last five to 10 years. Policy interventions are needed to boost livestock rearing to provide more environmentally benign organic manures.

Organic farming, the relatively new concept should have a strong policy support. Since it is a less productive and more profitable farming as long as the niche markets exist. Organic farming will have higher incentive to take up than the conventional farming and it will have its in-built mechanism to stimulate intensive livestock production for FYM.

Withdrawal of the Government subsidy on chemical fertilizers may discourage the use of fertilizers and encourage using organic manures. However, this may have some negative repercussions on national food security and food self-sufficiency goals. A balance between food security strategies and conservation is needed.

7.3.3 Research

Location specific fertilizer recommendations can be refined through such study that provides soil fertility maps as outputs. Soil maps are very useful tools for farmers and extension workers and so further research is needed to produce soil fertility maps at *geog* and *dzongkhag* levels.

There is a need to find out the intensity of fertilizer usage. Percentage households using chemical fertilizer should be further examined for crop specific rates and number of times applied.

Farmers' assessment of soil fertility needs to be further carried out based on their indicators of soil fertility and compare it with chemical analysis results to determine the meeting point between the two knowledge systems. This meeting point could be materialized for sustainable agricultural development.

7.3.4 Future issues and directions

In this study CEC, BS and mineral nutrients like Ca, Mg, etc. were not included and this makes detail analysis impossible. To be more comprehensive and holistic these aspects of soil fertility should be included in future works.

One of the other weaknesses of this study was that it did not include crop yield in the geo-referenced sites as village wise crops yields for 2004/2005 was obtained from the secondary data source. Since yield is the main indicator (49.1% by weight) of soil fertility used by 100 percent of farmers. Further yield trends of each crop over the years could be serve as a basis for soil fertility trend.

There is general correspondence between the two types of soil fertility indices and the correspondence suggests that they may be used complementarily. If we can link the two assessment systems, we may only need fewer samples for chemical analysis complemented by farmers' assessment. The process, if proven, could save time and money to generate utilitarian soil fertility maps.