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1. Introduction

To build up a database on the soil nutrient status of the major crops in the country, soil samples are being collected from the potato maize based farming system in the Eastern Region Dzongkhags, wetland farming system in Punakha-Wangdi valley, and potato based system in Bumthang Dzongkhag. Soil samples will be collected once every two to three years from the same areas. The sampled households are interviewed on their soil fertility management practices, cropping pattern and crop yields.

Pema Gatshel Dzongkhag in the east is one of the major potato growing Dzongkhags next to Trashigang and Monggar Dzongkhags. Though potatoes are grown throughout the Dzongkhag, the most intensively cultivated area is under Zobel. Between 16th November and 15th December 2002, the staff of National Soil Services Centre (NSSC) together with the staff from RNRRC-Khangma, collected soil samples from Zobel geog under Pema Gatshel Dzongkhag.

2. Method

The team collected the soil samples from the farmers' fields based on the list prepared by the Extension Agent (EA). The farmers were explained about the rationale behind collecting soils samples from their fields. Soil samples were collected from the households growing potatoes in two or more langdos (1 langdo= 1350m^2). One composite sample from a minimum of 8-10 sub samples was collected from one field though a composite sample was collected from the clustered fields. Soil samples were collected from the depth of 0-20 cm using a soil auger and put in plastic bags and sealed with a rubber band. The samples were then stored in a room with the open ends and care was taken not to contaminate the soils. These samples were then re-sealed for transportation and submitted to the Soil and Plant Analytical Laboratory (SPAL) for analysis. Aspects, slope angles, altitudes and the GPS readings of the fields were also recorded in the questionnaire form. The analysis of this survey was done using SPSS 11 for windows.

3. Results and discussions

In the first half of the report, the general observations as recorded during the survey are presented while the soil results for each village under this geog is presented in the second half of this report.

3.1 Zobel geog

3.1.1 Total sample households

In Zobel geog, a total of 94 households from 10 villages were sampled. The highest number of respondents was from Resinang village (22%) followed by Gonpa Singma and Ngamelang villages (15% each). Tshelingor man (3%) had the lowest number of respondents. These figures suggested that there were more farmers growing potatoes in Resinang, Gonpa Singma and Ngamelang compared to Tshelingor man

and Sumarthung villages. The various management practices and other site parameters in addition to the soil results are presented below.

3.1.2 Site description:

Altitudes, slopes and aspects of the fields under potato cultivation.

In Zobel geog**,** about 66% of the sampled plots are located at the low altitude range (<2000 m.asl) and the rest at the medium altitude range (between 2000 and 3000 m.asl). The plots are situated on the slopes ranging from sloping (16-25%) to steep slopes (26-50%) with the majority of them situated in the steep slopes. The majority of the plots are west (46%), north west (21%) and north (12%) facing aspects. About 94% of the households have small plot sizes (<1 acre). All the farmers own the plots under potato and there is no practice of sharing in and sharing out of plots. All the farmers (100%) of this geog grow potatoes in their fields. The farmers of this geog grow both the red (Desiree) and the white type of potatoes (Yusikap and Kufri-Jyoti). In this geog, all the farmers plant the potatoes in December and January. Maize is sown in February and March.

3.2.2 Potato and maize yield and other management practices.

The farmers assess their own plot fertility based on the yield, soil type and the slope gradient though different farmers have their own justifications for assessing their plots, which varies from village to village and from household to household.

From Figure 1 it can be observed that though the maximum yield (tons/acre) is obtained from flat areas and level areas, the majority of the plots are located in the steep and moderately sloping areas with west and north west facing aspects.

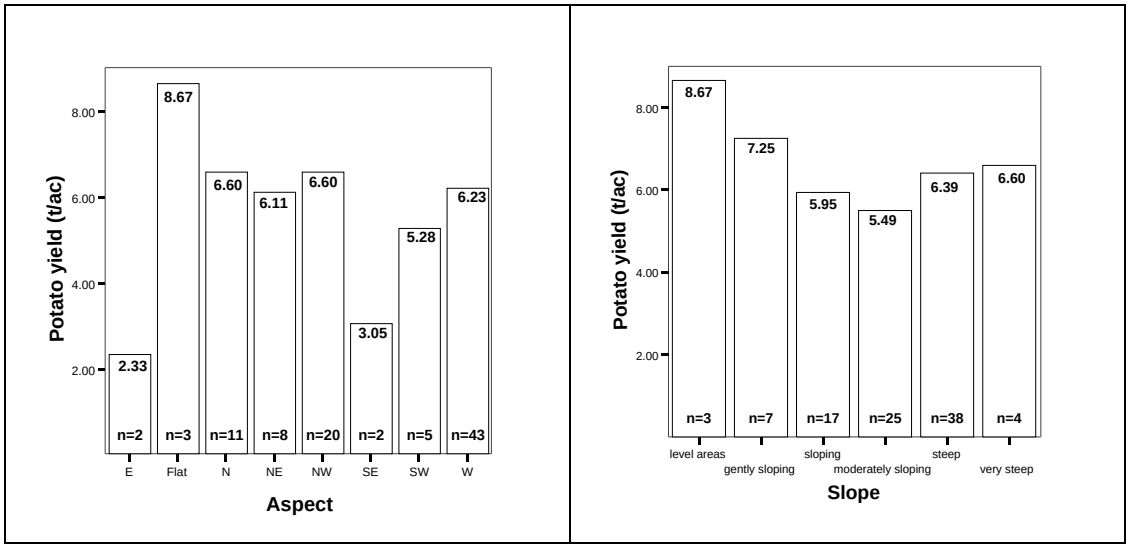

Figure 1 Potato yield in relation to aspect and slope of the plots.

Under favorable growing seasons, crop management and variety, the potato yield can vary from 16-20t/ac[1] though on an average, the yield is about 7-8 t/ac. The highest potato yield is recorded from Resinang (8.45t/ac) and Pangthang daza (8.25t/ac) villages while Zobel village (3.85t/ac) reported the least yield though the average potato yield for Zobel geog is 6.2t/ac. The highest maize yield is recorded form Pangthang daza (1.88t/ac) and Resinang (1.43t/ac) villages while the lowest yield is reported from Tshelingor man (0.53t/ac) (Figure 2). The average maize yield of this geog is about 1.2t/acre.

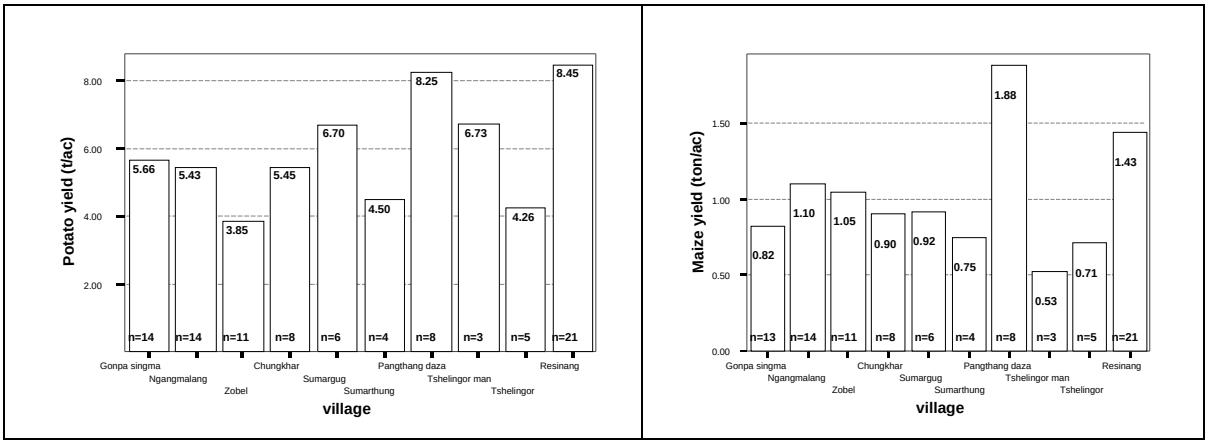

Figure 2 Average potato and maize yield (t//acre) under each village.

In Zobel geog, almost all the households (100%) apply Farm Yard Manure (FYM) to their fields with an average application rate of 11.1t/ac on fresh weight basis. This amount of FYM applied with a dry matter content of 50% (i.e. 1.38%N, 0.3%P and 1.97%K[2], the amount of FYM applied is equivalent to 5.6t/ac (which is equivalent to 77kg N/ac, 17kg P/ac and 110kg K/ac). FYM is normally broadcasted and then incorporated into the soil by ploughing during land preparation. The highest amount of FYM application (t/ac) is from Pangthang daza followed by Sumargug and Ngangmalang villages while Tshelingor man applied the least amount of FYM (figure 3). The farmers of this geog do not practice tethering of cattle in their fields. About 81% of the households burn their trash after crop harvest though no leaf litter is applied directly to the soil. The weeding frequency ranges from once (48%) to thrice (33%) and about 18% of the farmers weed twice.

[1] *According to FAO reports.*

[2] FYM Results from Lingmutey Chhu Watershed

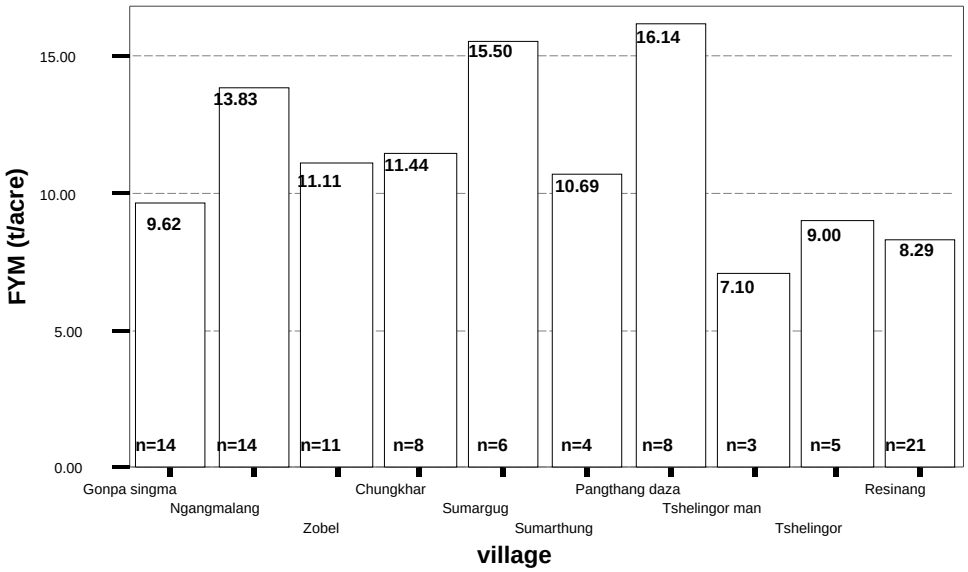

Figure 3 Amount of FYM applied (t/acre) under each village.

About 99% of farmers apply inorganic fertilizers viz. urea and suphala. Supahala is applied to potato as a basal dose (95%) while urea is applied as both basal (34%) and top dress (31%). The average amount of suphala applied by the farmers of Gonpa singma vilage is more than the rest of the other villages while Chungkhar applied the least (Figure 4). On an average, the farmers of this geog apply 152.3kg/ac suphala, which is 23kg N per acre, 23kg P per acre and 23kg K per acre**.** The farmers apply 98kg/ac urea, which is 46.5kg N per acre as basal to potato while about 67 kg per acre of urea is also applied to maize as top dress. The basal fertilizer is applied in a band while the top dress applied in a single top dress is broadcasted near the plants.

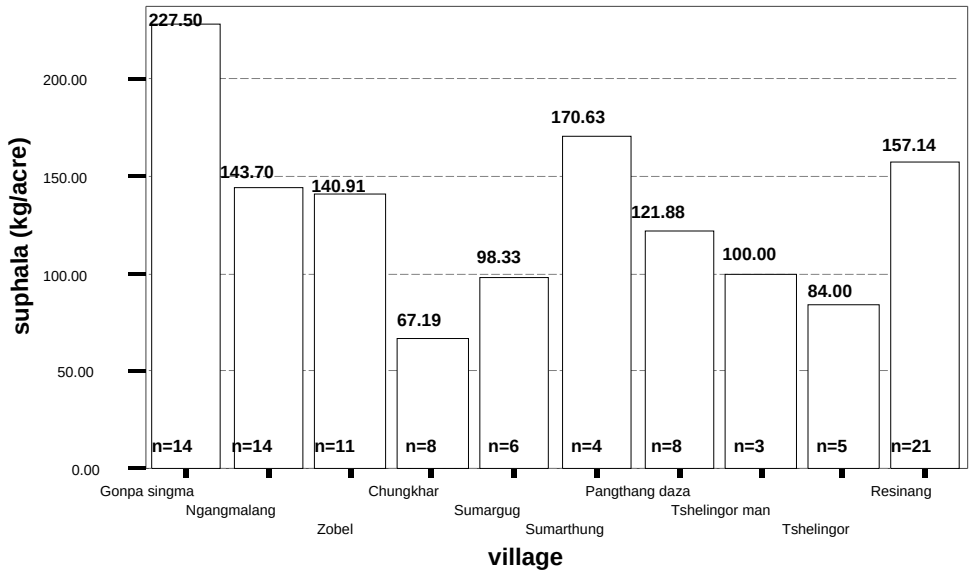

Figure 4 Amount of Suphala (kg/acre) applied under each village.

3.2.3 Soil results of Zobel geog

In the soil analysis result, with the exception of soil pH, the classifications are normally categorized as very low, low, moderate, high, and very high. For fertility factors (N, P, K, micronutrients) very low and low classifications indicate a high probability for obtaining a fertilizer response; moderate classifications indicate a fertilizer response may or may not occur; high and very high classifications indicate a fertilizer response is not likely to occur. Crops need all the essential nutrients but not in equal quantities and supplying of only one nutrient i.e. unbalanced nutrient such as urea leads to rapid depletion of soil reserves of other nutrients.

Potato can be grown in most soil types where though its greatest productivity is from a deep, loose, crumbly and well-aerated soil. It does well in slightly acidic soils (pH range of 5.0-5.8) while it is not suitable if the soil pH is either <4.5 or is >7.0. Alkaline soil conditions can adversely affect skin quality and high alkaline soils can also induce micronutrient deficiencies. The soil results of each village under Zobel geog is summarised as follows.

i. Soil result of Gonpa singma village (see figure 5).

The pH of the soils of this village is mostly within the low (pH <5) to medium (pH 5.5-6.5) range. As any other crops, potatoes also require adequate amount of N, P and K for optimum crop yield although its N and K requirements are high. Potatoes are efficient removers of K.

About 57% of the available K is in the low range (40-99mg/kg) while another 21% are within the very low range (<40mg/kg). More than 50% of these soils have low available P (5-15mg/kg). These figures suggest that there is a need to apply P and K containing fertilizers to improve the nutrient status of these soils. More than 90% of these soils have high matter contents (> 5%) and more than 70% these soils have high to very high C:N ratio (>12).

More than 90% of these soils have medium CEC range (15-25 meq/100g) and in such soils with low CEC values, all the major macro and micronutrients may be required to attain adequate growth and thereby yields. The BS% range of these soils is evenly distributed from very low to very high range. Coarse-textured soils lack both nutrient and water holding capacities while fine-textured soils often have structural and infiltration problems. The major soil type is silty clay loam (figure15). This soil type is of medium textured soils containing less than 40% clay content. However, for light textured soils, a split application of inorganic fertilizers especially urea is advisable.

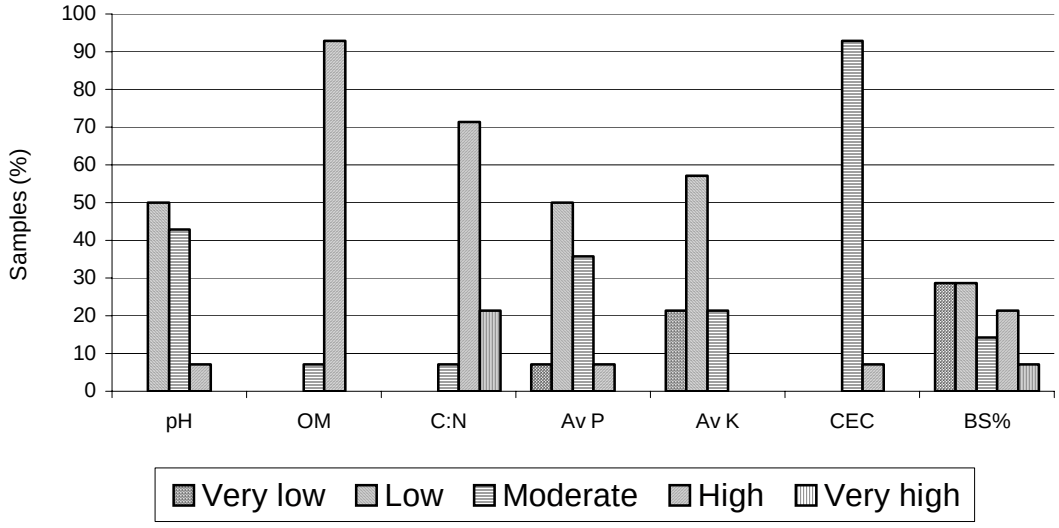

Figure 5 Soil parameters of potato fields in Gonpa singma village.

ii. Soil result of Ngangmalung village (see figure 6).

In this village, the soil pH is mostly within the low to medium range while the organic matter content of these soils is mostly within the moderate to high ranges. The C:N ratios of these soils is high while the CEC is moderate. The available K of these soils is generally very low and the available P is also all in the low to very low ranges. These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% is evenly distributed from very low to high ranges though more than 30% of these soils are

within the very low range. Silty clay loam is the predominant soil type in this village (figure 15). This soil type is of medium textured soils containing less than 40% clay content and for such light textured soils, a split application of inorganic fertilizers especially urea is advisable.

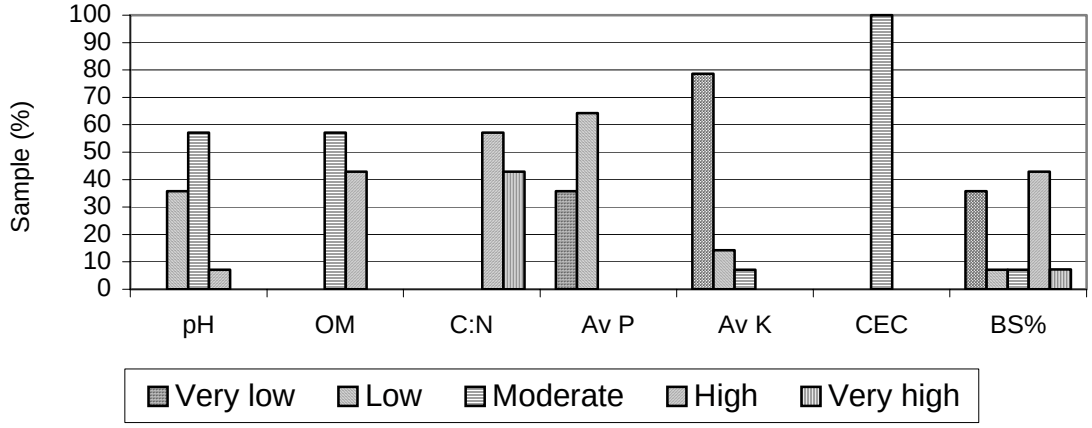

Figure 6 Soil parameters of potato fields in Ngangmalang village.

iii. Soil result of Zobel village (see figure 7).

In this village, the soil pH is mostly within the low to medium range while the organic matter content of these soils is mostly within the moderate to high ranges. The C:N ratios of these soils is high while the CEC is moderate to high. The available K and P of these soils are generally very low to low. These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% is evenly distributed from very low to high ranges though more than 30% of these soils are within the very low range. Silty clay, silty loam and silty clay loam are the major soil types in this village (figure 15). This soil type is of medium textured soils containing less than 40% clay content. However, for light textured soils, split application of inorganic fertilizers especially urea is advisable.

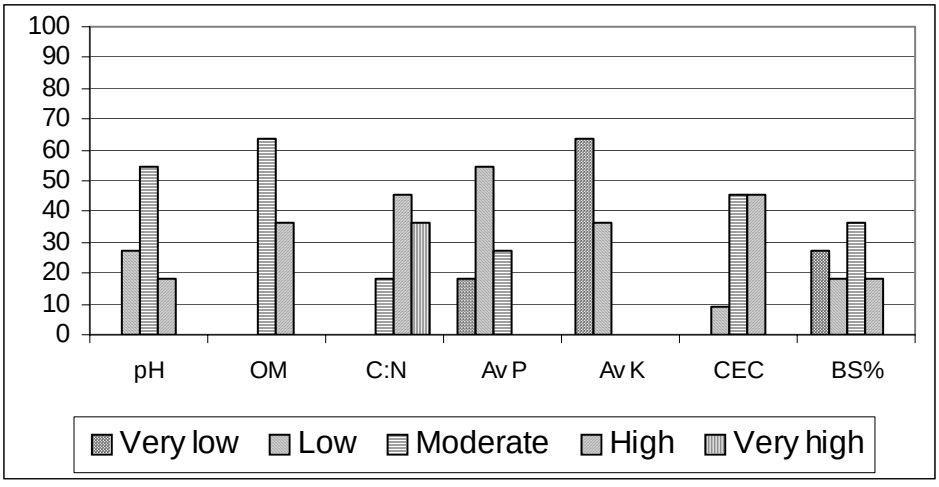

Figure 7 Soil parameters of potato fields in Zobel village.

iv. Soil result of Chungkhar village (see figure 8).

In this village, about 75% of the soil pH is mostly within the medium range though about 25% are within the high range. The organic matter content of these soils is high. The C:N ratios of these soils is also high while the CEC is moderate to high. The available K and P of these soils are generally low to very low. These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% is evenly distributed from very low to high ranges though about 38% each of these soils are within the high to very high range. The major soil type is silty clay loam (figure 15). This soil type is of medium textured soils containing less than 40% clay content. Normally for light textured soils, split application of inorganic fertilizers especially urea is advisable.

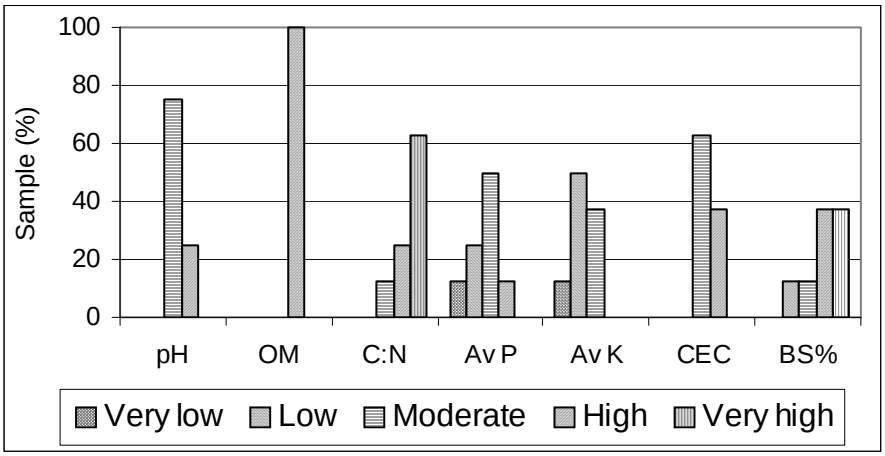

Figure 8 Soil parameters of potato fields in Chungkhar village.

v. Soil result of Sumargug village (see figure 9).

In this village, more 65% of the soil pH is mostly within the medium range though about 15% each are within the low and high range. The organic matter content of these soils is within the moderate to high range. The C:N ratios of these soils is mostly within to moderate to high ranges and the CEC is also mostly within moderate to high ranges though about 35% are within the low range. The available K and P of these soils are generally low to very low. These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% is evenly distributed from low to high ranges though about 50% of these soils are within moderate range. The major soil type is silty loam (figure 15). This soil type is of medium textured soils containing less than 40% clay content and for light textured soils, split application of inorganic fertilizers especially urea is advisable.

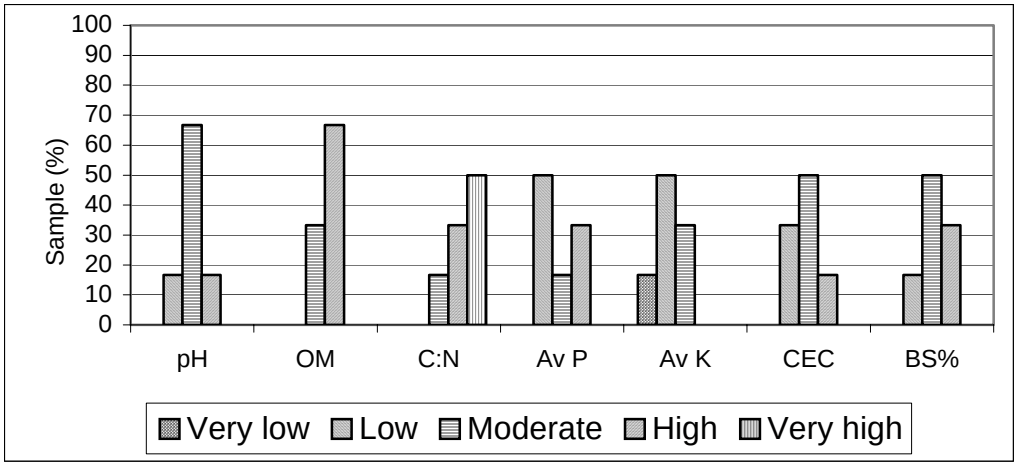

Figure 9 Soil parameters of potato fields in Sumargug village.

vi. Soil result of Sumarthug village (see figure 10).

The soil pH of the soils in this village is of medium range while more than 75% of these soils have high organic matter content. The C:N ratios of these soils is mostly within high to very high ranges and the CEC is also mostly within moderate to low ranges. The available K of these soils is low (100%) while the available P of these soils are also generally low to very low with more than 50% within the very low range. These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% is equally distributed between low to moderate range (50% each). The soil type of this village is silty clay **(**figure 15). This soil type is of medium textured soils containing less than 40% clay content. However, for light textured soils, a split application of inorganic fertilizers especially urea is advisable.

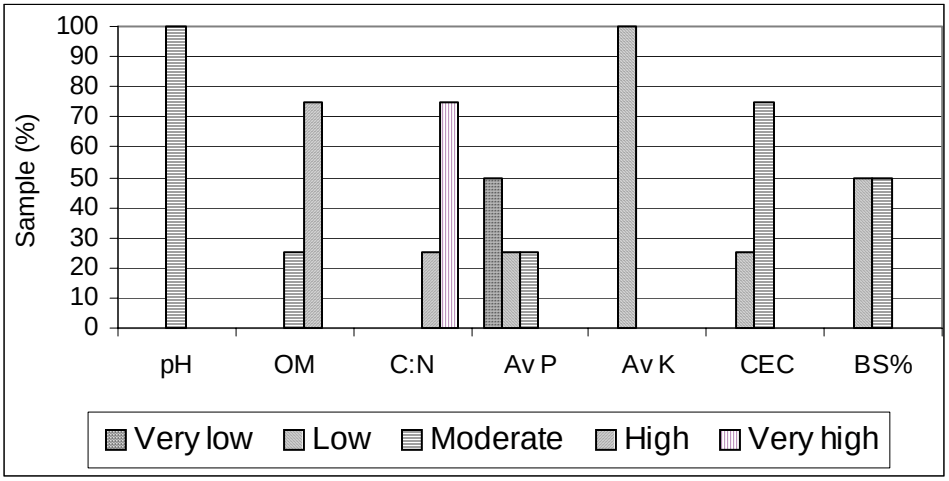

Figure 10 Soil parameters of potato fields in Sumarthug village.

vii. Soil result of Pangthang daza village (see figure 11).

More than 85% of the soils have moderate pH while the organic matter content of these soils is within the moderate to high ranges. The C:N ratios of these soils is evenly distributed within the moderate to high ranges. More than 60% of these soils have low CEC values. The available K of these soils is very low (100%) while the available P of these soils ranges from low to high values with 50% of these soils in the low range. These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% is equally distributed from very low till very high ranges. Silty clay and silty loam are the two major soil types found in this village (figure 15). These soil types are of medium textured soils containing less than 40% clay content and for light textured soils, split application of inorganic fertilizers especially urea is advisable.

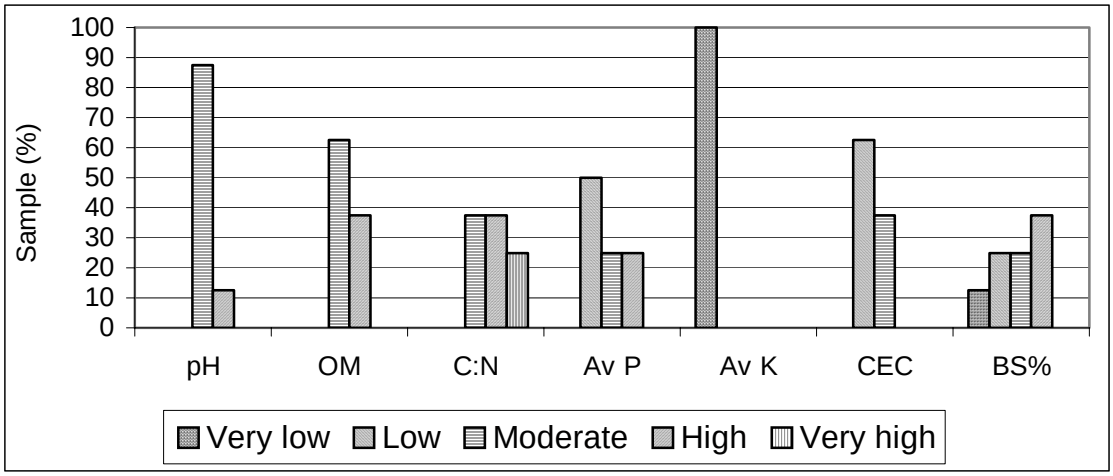

Figure 11 Soil parameters of potato fields in Pangthang daza village.

viii. Soil result of Tshelingor man village (see figure 12).

The soil pH in this village is of moderate range (100%) and the organic matter content of these soils is also high. The C:N ratios of these soils is within the high to very high ranges and the CEC of these oils is also low (100%). The available K of these soils is within the low to moderate range with more than 30% in the low range. The available P of these soils is within the very low to low range. These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% is high (100%). Silty clay loam is the soil type found in this village (figure 15). This soil type is of medium textured soils containing less than 40% clay content and usually for light textured soils, a split application of inorganic fertilizers especially urea is advisable.

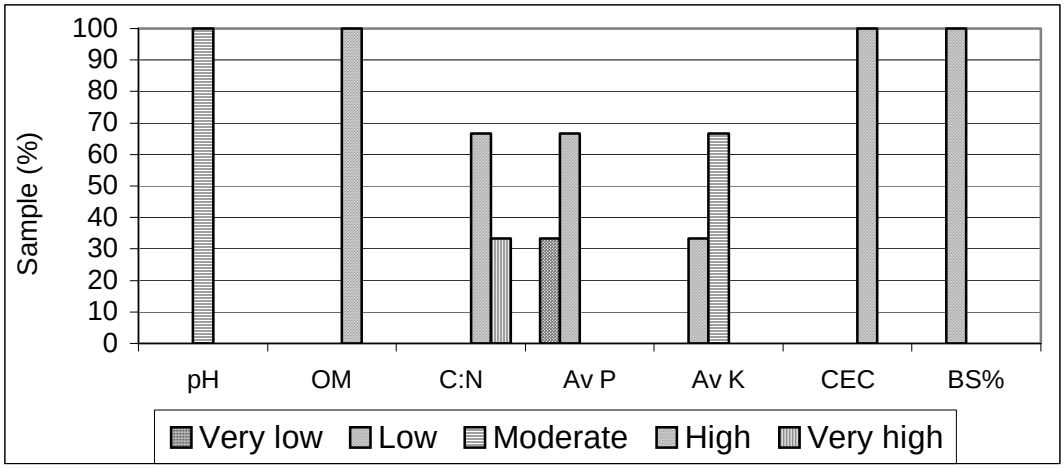

Figure 12 Soil parameters of potato fields in Tshelingor man village.

ix. Soil result of Resinang village (see figure 13).

More than 85% of these soils have moderate pH values while more than 95% of these soils have high organic matter content. The C:N ratios of these soils is distributed between the moderate to high ranges and the CEC of these soils is also within the moderate to high range with more than 80% in the high range. The available K of these soils is mostly within the low to very low range and the available P of these soils is also mostly within the very low to low ranges with more than 55% in the very low range. These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% is evenly distributed from very low to moderate range. Silty clay loam is the most predominant soil type found in this village (figure 15). This soil type is of medium textured soils containing less than 40% clay content and a split application of inorganic fertilizers especially urea is advisable.

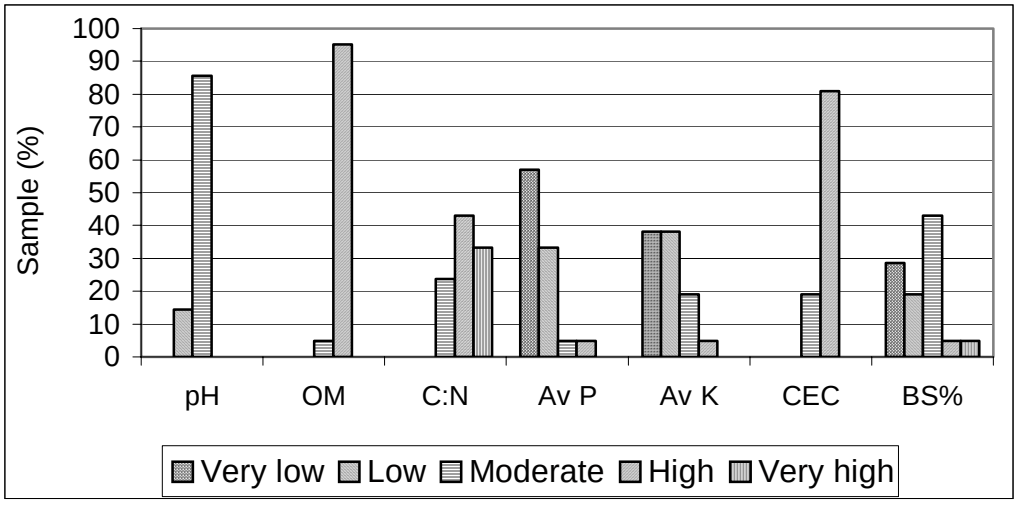

Figure 13 Soil parameters of potato fields in Resinang village.

x. Soil result of Tshelingor village (see figure 14).

The soil pH in this village is of moderate range (100%) and the organic matter content of these soils is also high (100%). The C:N ratios of these soils is within the high to very high ranges and the CEC of these oils within the moderate to high range. The available K of these soils is within the very low to low ranges with 60% in the very low range. The available P of these soils is within the very low to moderate range with 20% each in low and very low ranges. **.** These figures suggest that there is the need to apply P and K containing fertilizers to improve the nutrient status of the soil and thereby yield. The BS% of these oils is within the low to high range with almost 60% in the high range. Silty clay loam is the soil type found in this village (figure 15). This soil type is of medium textured soils containing less than 40% clay content. However, for light textured soils, split application of inorganic fertilizers especially urea is advisable.

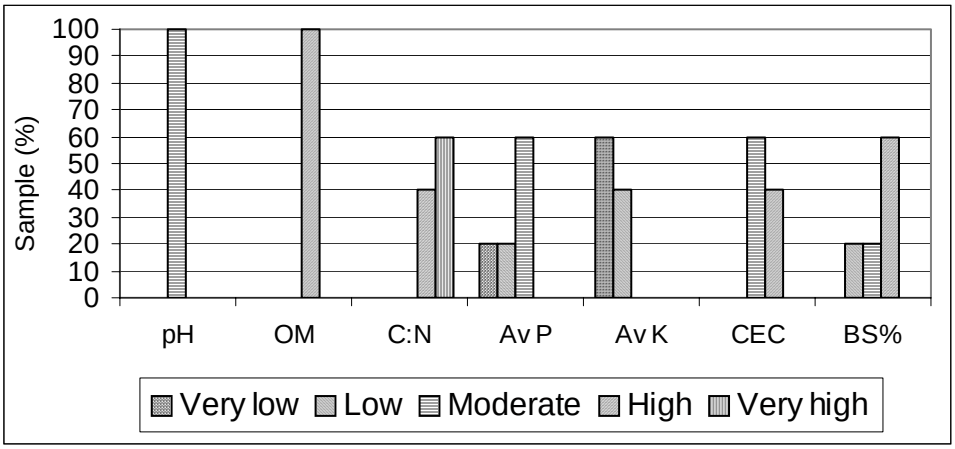

Figure 14 Soil parameters of potato fields in Tshelingor village.

x. Soil Texture of different villages under Zobel geog.

The different soil textures found in each village under Zobel geog is presented in the following figure.

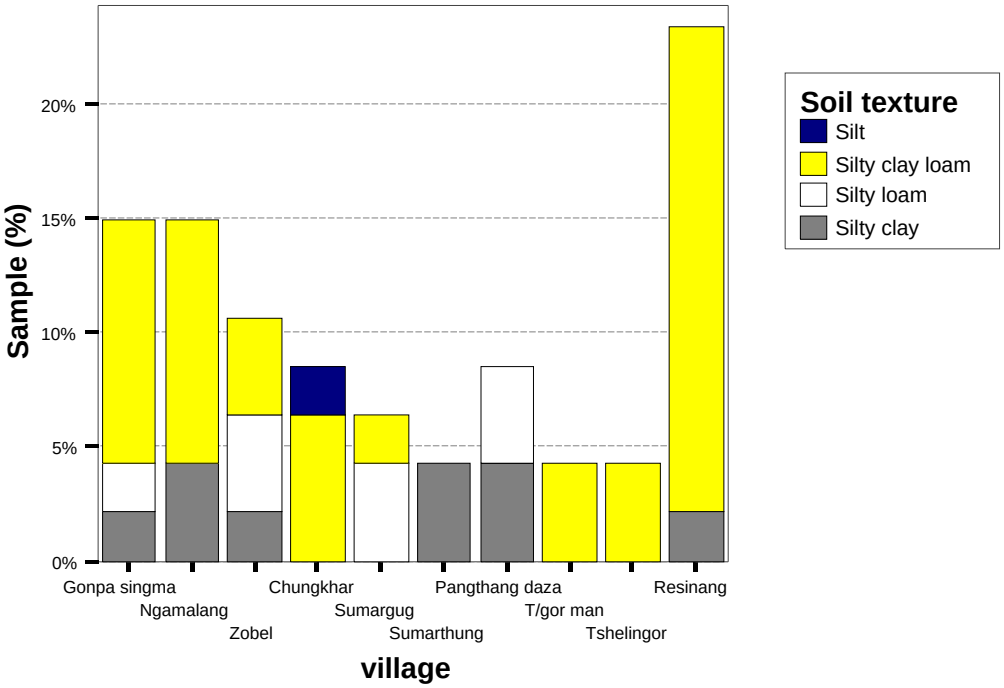

Figure 15 Soil texture of potato fields in different villages under Zobel geog.

4. Conclusions

In Zobel geog the potato fields are mostly located at the medium and low altitude ranges with most of the plots on steep slopes with aspects facing mostly west and northwest with small land holdings. The farmers grow all the three varieties of potatoes, which are planted in the months of December and January. Potato is intercropped with maize, which is sown in February and March by all the farmers. In this geog, the majority of the farmers apply FYM to the fields at the rate 11.1t/ac. FYM is usually broadcasted prior to ploughing. The farmers do not practice tethering. The average yield of potato and maize is 6.2t/ac and 1.2t/acre respectively. All the farmers burn the crop residues prior to land preparation. Weeding frequency ranges from once to thrice.

Inorganic fertilizers like suphala and urea are applied to potato and maize while SSP is not at all applied. Suphala is applied in trenches while urea in maize is applied as a single top dress. The rate as reported by the farmers is a bit lesser than the recommended rate of 100:80:60 kg/ha (i.e. 40:32:24 kg/acre of NPK from SSF&PNM[3]) of N, P and K respectively. How ever for this geog the N rate could be decreased from recommended rate of 40 to 36 (since the farmers of this geog apply plenty of FYM which contributes about 75kg N/ac) while the K level could be slightly

[3] SSF&PNM based on FAO recommendations (K rate has been increased as the K in these soils are very low while the N level has been decreased).

increased from 24 to 32 as the soil results show that the K levels are low in these soils and in addition potatoes are efficient removers of K and hence the need to replenish it).

In general, the soil pH is mostly within the high range, which could be due to the addition of rich base materials like FYM and the ash from trash burning. The available K and available P of these soils are mostly in the low range. The available P content of these soils could be improved by using P rich sources such as the SSP together with urea. The organic matter content of these soils are within the moderate to high ranges while the majority of these soils have very high C:N ratio. Most of the soils have low CEC content while the BS% range is equally distributed. Silty clay loam is the dominant soil type in this geog.

5. Recommendations

For a precise fertilizer recommendation, yield and management history, sources of plant nutrient applied in the past in particular are required in addition to the soil information. Given the above soil results (Section 3.2.3) the following recommendations are suggested to improve the soil nutrient status in this geog.

- The available P content of these soils in all the villages is low and this could be improved by applying P containing fertilizer such as SSP together with urea as a basal dose.

- The available K content of these soils is also low and therefore, there is a need to apply K containing fertilizer such as MoP to improve the K content of these soils.

- The low CEC of these soils also indicate that almost all the major macronutrients are required to obtain adequate yield and hence application of balanced nutrients with proper recommended rate needs to be encouraged. (i.e. the rate of 90:80:80 kg/ha or 36:32:32 kg/acre of N,P,K is recommended based on the soil result with modifications from the previously recommended rate of 100:80:60 kg/ha of N,P,K or 40:32:24 kg/acre of N,P,K). The P and K values are slightly increased from the FAO recommended rate, as these values from the soil analysis report are low in this geog. From the above mentioned soil information, the following recommendations are suggested to improve the soil nutrient management program: What, when, how and why are answered below.

  - **Thus the recommended rate of 90:80:80 kg/ha of N,P,K:**

  1. <u>Using Suphala is as follows:</u>

  - Apply about 216 kg/acre of Suphala as basal dose during land preparation (i.e. about 4 bags of suphala @50 kg per bag per acre).

- Followed by one application of 9 kg of urea once either when the plants are of 15-20 cm high (30-45 days after planting) or at the time of flowering (i.e. maize plants are of knee high stage).

2. <u>Using SSP, MoP and Urea is as follows:</u>

- Apply 69kg/acre of Urea as basal dose during land preparation (i.e. about 1 bags of Urea @50 kg per bag per acre).

- Apply 202kg/acre of SSP as basal dose during land preparation (i.e. 4 bags of SSP @ 50 kg per bag per acre).

- Apply about 54kg/acre of MoP as basal dose during land preparation (i.e. about 1 bag of MoP @ 50 kg per bag per acre).

- Followed by about 9kg of urea as top dress either when the plants are of 15-20 cm high (after 30-45 days of planting) or at the time of flowering (i.e. maize plants are of knee high stage).

- In addition to this the major soil type is of medium textured and so a split application of urea is even more advisable for better utilisation of the N nutrient.

- In addition, the timing of fertilizer application with adequate soil moisture is crucial for obtaining good yield and therefore, application of fertilizers on dry soil is not encouraged.