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1. Introduction

Following the first batch of soil samples collected (2002) from the major potato-maize based farming system in the east, a second batch of soil samples were collected from the same fields in December 2008. This is to generate information on the soil nutrient status as managed by farmers and to build a database on the soils of the major crops in the country. Soil samples are collected along with the information on farmers' soil fertility management practices, cropping pattern and crop yields from the wetland farming system in Punakha-Wangdi valley, the dryland farming system in Bumthang and Eastern Dzongkhags. Next batch of soil samples would be collected after three years from the same areas.

Pema Gatshel Dzongkhag in the east is one of the major potato-maize growing Dzongkhags after Trashigang and Monggar Dzongkhags. Though potatoes are grown throughout the Dzongkhag, Zobel geog is one of the most intensively cultivated area other than Nanong geog.

This report is on the soils of the major potato-maize growing areas of Pemagatshel Dzongkhag, one of the important potato-maize growing districts in Bhutan. The National Soil Services Centre (NSSC) collected soil samples from about 66 households spread over 10 villages under Zobel geog.

2. Method

The group collected soil samples from the farmers' fields based on the list from the First Batch of samples collected in 2002. A total of 66 households were selected from the initial 94 households. The main criteria for downsizing the number of samples was based mainly on the clustered plots where a representative sample could be taken and also few scattered households were not included. Prior to sampling, 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= 1350m²). One composite soil sample from a minimum of 8-10 sub samples was collected from one field though a composite sample was collected from 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 bags were labeled properly and the samples 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 16 for windows.

3. Results and discussions

This report presents the findings of Zobel geog. The general observations as recorded during the survey are presented in the first part of the report with the average soil analysis result of the whole geog followed by soil analysis results of individual villages under Zobel geog with fertilizer recommendations based on the findings for each village.

3.1 Sample households

In Zobel geog, a total of 66 household covering 10 villages^a are sampled. The highest number of respondents is from Resinang village (21%) followed by Ngamalang (17%), Zobel (14%), Chungkhar (12%). Sumargug village has the lowest number of respondents (just 1.5%). The various management practices and other site parameters in addition to the soil results are presented below.

3.2 Site description of the fields under potato cultivation.

For potato to do well, an ideal situation is to have the fields with slopes less than 10% with either east or west facing aspects. However, it can also do moderately well on slopes ranging from 10-30% and with aspects facing either NNE-E or W to NNW. In Zobel geog, the majority of the plots are situated on sloping areas (61% of the samples), followed by moderately sloping areas (23% of the samples) and steep slopes (14%). The majority of the plots are north facing (58% of the plots) aspects. More than 84% of the sampled plots are located at low altitude range (less than 2000 m.asl) and the rest in the medium altitude range (between 2000 and 3000 m.asl). All the farmers have small plot sizes (< or =1 acre). In Zobel geog, about 39% of the farmers grow both Desiree and Kufri-jyoti varieties while about 16% of the farmers grow only Desiree and few farmers also grow their own local variety.

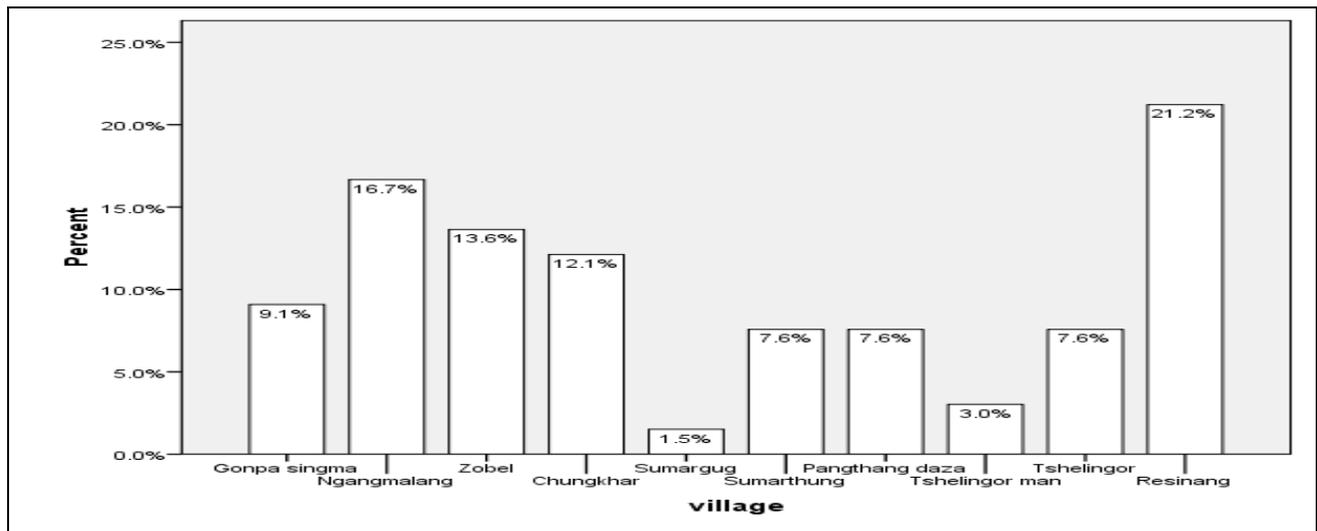


Figure 1 No. of respondents from each village under Zobel geog

^a Villages under Zobel geog: Resinang, Tshelingor, Tshelingor man, Sumargug, Sumarthung, Chungkhar, Pangthang daza, Ngamalang, Gonpa Singma, Zobel.

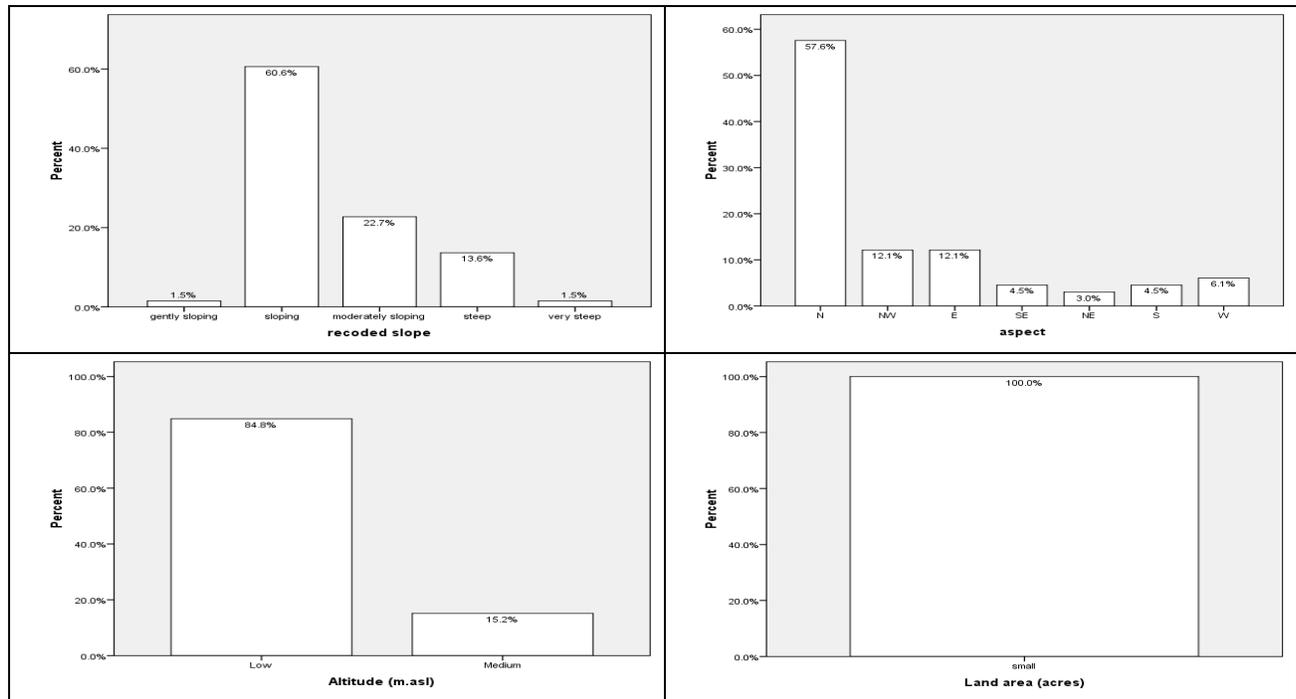


Figure 2 Slope, aspect, altitude and area of plots under potato- maize cultivation

3.3 Crop yield and other management practices.

As in other geogs of the east, potato is usually intercropped with maize in Zobel geog too. Under favorable growing seasons, crop management and variety, the potato yield can vary from 16-20 tac^{-1b} though on an average, the yield is about 7-8 tac^{-1} .

The average potato and maize yield of Zobel geog is 4.42 tac^{-1} and 1.2 tac^{-1} respectively. From Figure 3 it can be observed that the maximum potato yield of 5.88 tac^{-1} is observed from Gonpa singma village while the maximum maize yield of 2.31 tac^{-1} is reported from Chungkhar village. The lowest yield of potato and maize are reported from Sumargug village (1.6 tac^{-1} and 0.64 tac^{-1} respectively). These figures suggest that the potential yield level in some of the villages has not been attained yet and there is the possibility of increasing returns with proper management practices.

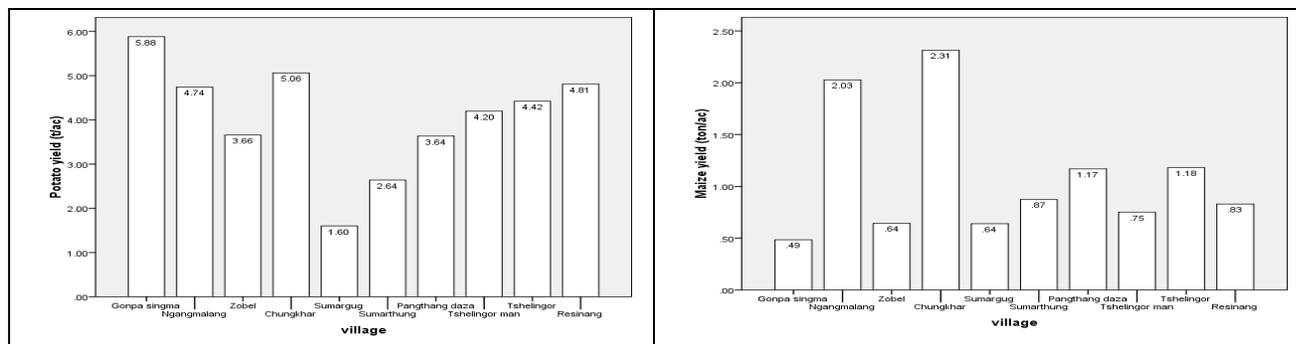


Figure 3 Average potato and maize yield (tac⁻¹) under each village

^b According to FAO reports

In this geog, all the farmers reported that they have changed the potato seeds. About 32% of them have changed the potato seeds during the last 5 years while about 55% of them have changed during the last 5-15 years and about 12% of them have changed the seeds during the last 15 years or more.

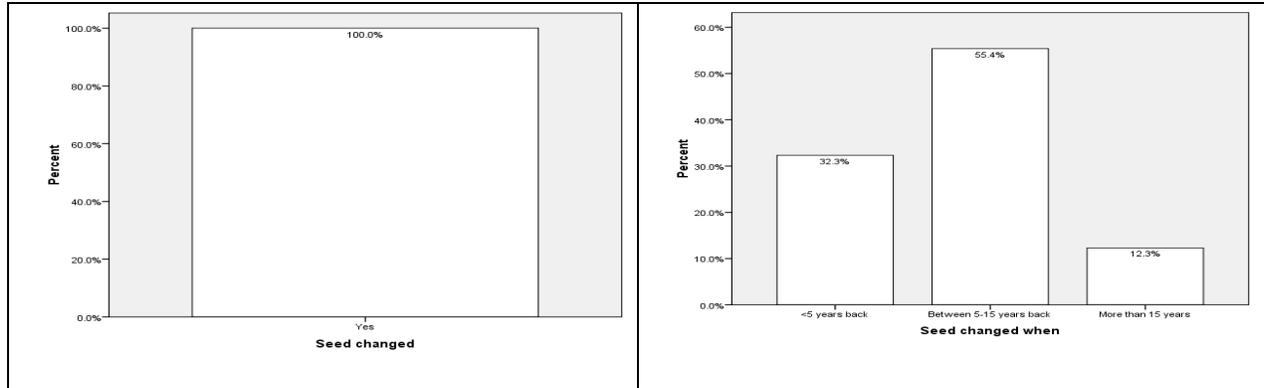


Figure 4 Potato seeds changed?

3.3.1 Soil fertility management practices

3.4.1 Farm Yard Manure (FYM)

In Zobel geog, all the farmers apply FYM to their fields. The average FYM application rate of the geog is 9.72 tac^{-1} . Sumarthung village applies the highest amount of FYM to potato fields (20 tac^{-1}) followed by Tshelingor (14.2 tac^{-1}), Gonpa singma (13.75 tac^{-1}), Tshelingor man (10.5 tac^{-1}). The lowest rates of FYM application is reported from Resinang with 4.39 tac^{-1} and Sumargug (6.0 tac^{-1}) where these low rates of Zobel geog is still higher in comparison to Trashigang Dzongkhag^c.

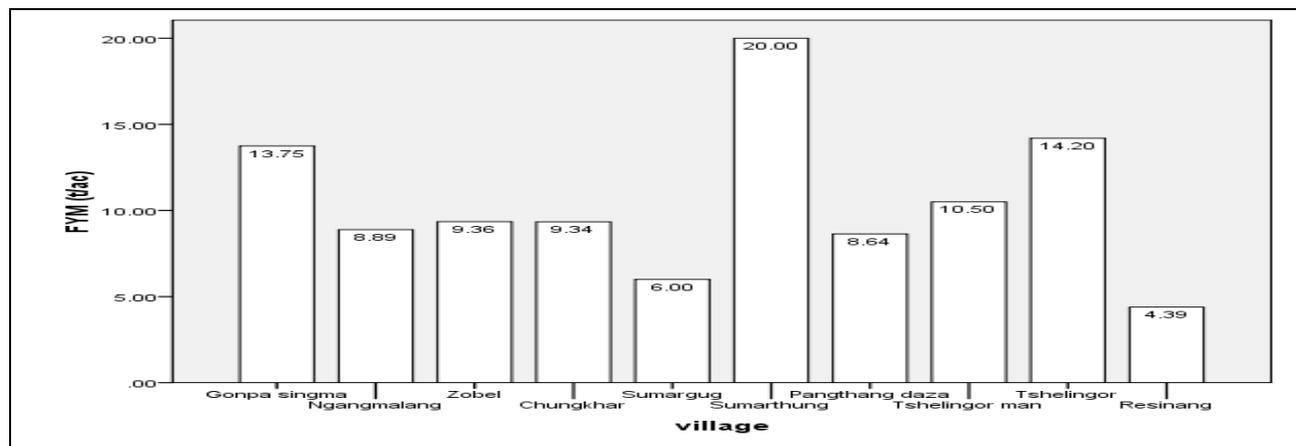


Figure 5 Amount of FYM applied (tac^{-1}) under each village.

^c These reported rates of FYM application in the geog needs to be confirmed by the Dzongkhag Agriculture staff.

3.4.2 Inorganic fertilizers

The survey findings indicate that all the farmers of this geog apply inorganic fertilizers to potato and maize. Suphala is applied to potato while urea is applied to maize and no SSP or MoP is applied in this geog. The average rates of inorganic fertilizers applied in this geog are about 97.31 kgac⁻¹ urea (applied only to maize) and about 174 kgac⁻¹ of Suphala (applied to potato) and these fertilizers amount to about 70.86 kgac⁻¹ N, 26.1 kgac⁻¹ each of P and K.

Potash and phosphorus containing fertilizers other than suphala is not applied in this geog and there could be a possibility of exploring fertilizer training program for the farmers of this village on balance nutrient application and encourage the farmers to apply potash containing fertilizers to potato. If this trend is continued there could be a possible nutrient mining due to continuous application of more N and less P and K nutrients.

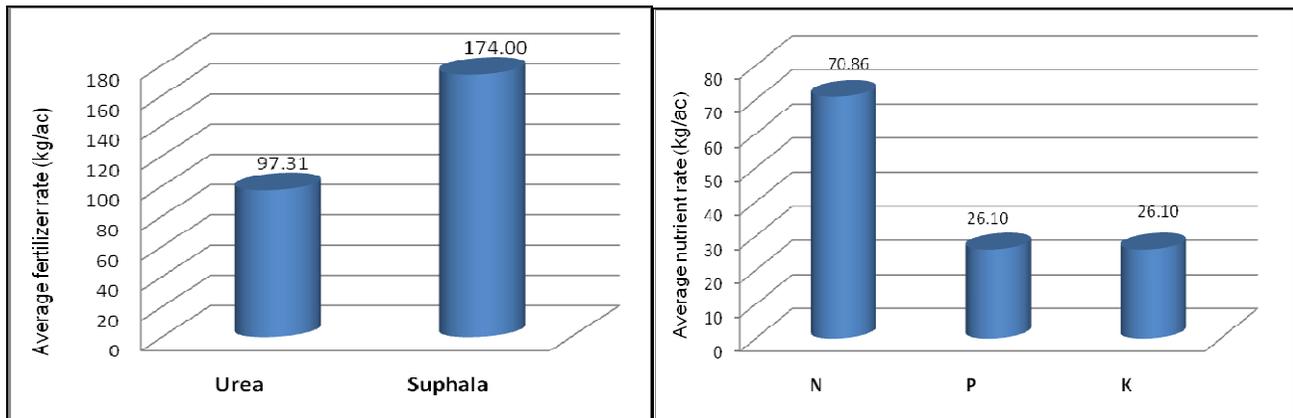


Figure 6 Average rates of fertilizer and nutrients applied (kgac⁻¹) in Zobel geog.

The highest application of suphala is reported from Gonpa singma (229 kgac⁻¹) which is equivalent to about 34.4 kgac⁻¹ of N, P and K which is quite comparable to the recommendation rate (of P, K) suggested by NSSC, though there is the need to top dress N with some urea (please refer the recommendation table at the end of the report). Tselingor man applies the lowest rate of suphala i.e. about 75 kgac⁻¹ of suphala (equivalent to only about 11 kgac⁻¹ of N,P,K) which is lower than the recommended rate. These fertilizer rates are very low for the potato to do well and therefore the need to increase the fertilizer rate for most of the villages in this geog.

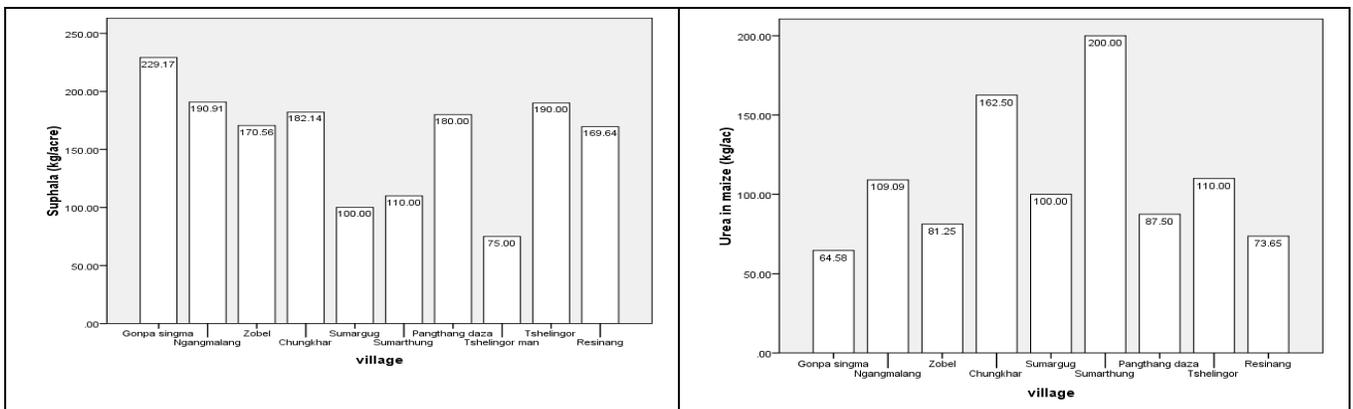


Figure 7 Amount of suphala & urea (kgac⁻¹) applied to potato and maize under each village.

3.3.2 Crop yield in relation to inorganic fertilizers application

From the following figures, it shows that there is a positive yield response with increasing rates of either sulphala application to potato or urea application to maize. The maximum potato yield of 7.2 tac^{-1} is reported when sulphala application rate is highest (201-300 kgac^{-1}). The maximum maize yield of 2.04 tac^{-1} is reported with the urea application rate is 100-200 kgac^{-1} and above this rate the yield drops.

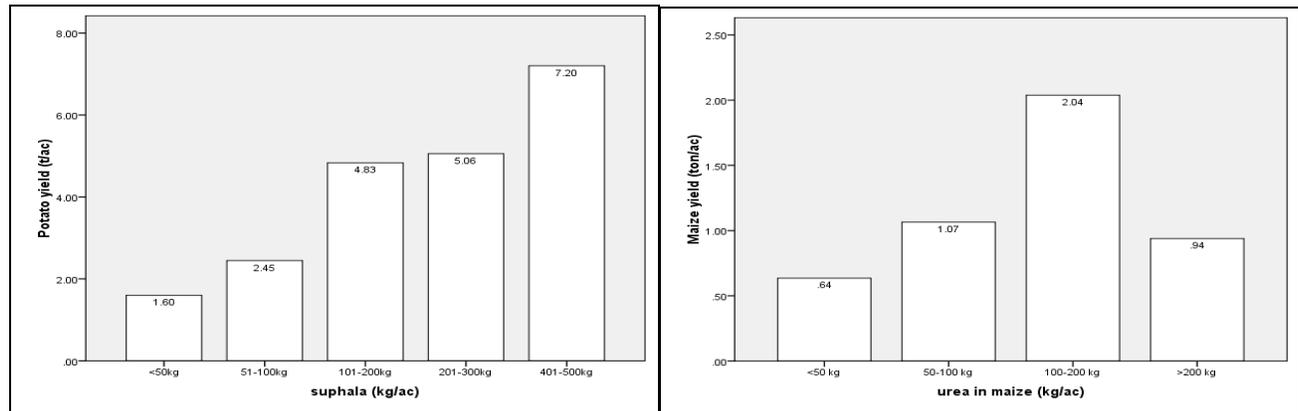


Figure 8 Potato and maize yield in relation to inorganic fertilizer applied in the geog.

It is reported from literature that potatoes respond well to moisture, however, irrigation at tuber initiation can affect the skin quality of daughter tubers by influencing phytopathogens, either favorably or adversely according to conditions, and amount of moisture present. However, in this geog, no irrigation is done and is completely rain fed.

3.5 Soil analytical results of Zobel geog.

In the soil analysis result, with the exception of soil pH, the classifications are categorized as very low, low, moderate, high, and very high. For fertility factors (N, P, K and micronutrients) very low and low classifications indicate a high probability for obtaining a good fertilizer response; moderate classifications indicate a fertilizer response may or may not occur while a high to a very high classifications indicate that 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 applying only urea leads to rapid depletion of soil reserves of other nutrients such as P and K etc.

3.5.1 Soil pH

The following figure 7 shows the soil parameters of the geog. The soil pH is generally categorized into five categories viz. very low (<5.0), low (5.0 to 5.5), medium (5.5 to 6.5), high (6.5 to 7.5) and very high (>7.5).

The majority (more than 70%) of the plots have moderate/medium pH range and about 26% of the samples have low values and two farmers of Ngamalang (viz. Phuntsho and Tshering Wangpo) have very low pH values (pH of 4.85 and 4.95). Therefore, the pH of these two soils could be rechecked^d. Potatoes are grown on organic as well as mineral soils. For potatoes, the minimum soil pH

^d If the concerned EA could kindly collect the soil samples from these fields and submit to NSSC

requirement is 5.5 and below about pH 4.8 growths are impaired. Alkaline conditions (pH above 7.0) can adversely affect skin quality and highly alkaline conditions can induce micronutrient deficiencies.

3.5.2 Organic Matter content (OM%)

Organic matter serves as a reservoir of nutrients and water in the soil, aids in reducing compaction and surface crusting, and increases water infiltration into the soil. The organic matter content of the soils in this geog is within the moderate to high ranges. This could be due to the heavy application of FYM to the fields.

3.5.3 Available phosphorus (P)

As in all plants, potatoes also need phosphorus for good growth and yield and do respond well to P fertilizer application if the soil test results show low P values.

The available P has been categorized into five ranges, viz. very low ($<5 \text{ mgkg}^{-1}$), low (5-15 mgkg^{-1}), medium (15-30 mgkg^{-1}), high (30-35 mgkg^{-1}) and very high ($>35 \text{ mgkg}^{-1}$).

More than **64%** of the samples in this geog have **low to very low available P** and about 34% in the medium range and only about 5% in the high range. Usually for available P values with low to medium range, there is a possibility of a good yield response with P application. All the farmers of Ngamalang, Gonpa singma, Resinang, Tselingor, Tsleingor man, Sumargug, Sumarhung and Zobel have very low to low P contents in their soils and therefore the need to apply P containing fertilizers such as SSP or TSP while in the other villages (Chungkhar and Pangthang daza) only few selected farmers need to apply P containing fertilizers to their fields (details under individual village report and individual name list under Table 1).

3.5.4 Available potassium (K)

As in any other crops, potatoes also require adequate amounts of N,P,K for optimum crop yield. Potatoes require large amounts of K as it plays an important role in photosynthesis and starch production. Potatoes are efficient extractors of K and therefore the need to apply more K to the soil especially if the soil test results show low values.

Available K is also categorized into five ranges viz. very low ($<40 \text{ mgkg}^{-1}$), low (40- 100 mgkg^{-1}), medium (100-200 mgkg^{-1}), high (200-300 mgkg^{-1}) and very high ($>300 \text{ mgkg}^{-1}$).

In Zobel geog, about **36%** of the samples have **low to very low available K** and about **57% in the medium range** and only about 7% within the high range. In general, the K content of these soils is very poor and the farmers of Pangthang daza, Ngamalang and Sumargug, need to apply K containing fertilizers such as MoP while in other villages (i.e. Gonpa singma, Zobel, Resinang, Tshelingor, Tselingor man and Sumarhung) only few selected farmers with low K values also need to apply K containing fertilizers to improve the crop yields (details under individual village report and refer Table 1 for name list).

3.5.5 Nitrogen (N)

Potatoes require high amounts of nitrogen during a short period of time and potatoes also use large amounts of N, frequently more than the total applied as fertilizer (Anderson & Hewgill, 1978). Nitrogen is important for potato and its deficiency induces poor plant growth and crop yield besides

accentuating certain diseases such as early blight and *Verticillium* wilt. On the other hand, excess N can delay the onset of tuber growth, increase knobby potatoes and promote excess vine growth.

On an average, the nitrogen content of the soils in this geog is within the low to medium range. This could probably indicate the loss of nitrogen from the soil through leaching, volatilization due to improper application method and/or timing or inadequate application of nitrogen containing fertilizers.

3.5.6 Cation Exchange Capacity (CEC)

The CEC is the measure of the capacity of the soil to hold exchangeable cations (nutrients) and is used to assess the overall fertility potential of the soil. The CEC has been categorized into five ranges, viz. very low (<5 meq100g⁻¹), low (5-15 meq100g⁻¹), medium (15-25 meq100g⁻¹), high (25-40 meq100g⁻¹), very high (>40 meq100g⁻¹). Usually, a soil with a high CEC value (>25 meq/100g) is a good indicator that a soil has high clay and/or organic matter content and can hold lots of cations while a soil with a low CEC value (<5meq/100g) is a good indication that a soil is sandy with little or no organic matter that cannot hold many cations. Normally a soil with high CEC values is considered more fertile than the ones with low values.

On an average, the CEC of this geog falls mostly within the high range (79% of the samples) and the rest in the medium range. This medium to high CEC could indicate fairly medium soil fertility or alternatively there could be high clay content in the soils. The BS% is widely distributed from very low to medium to high ranges.

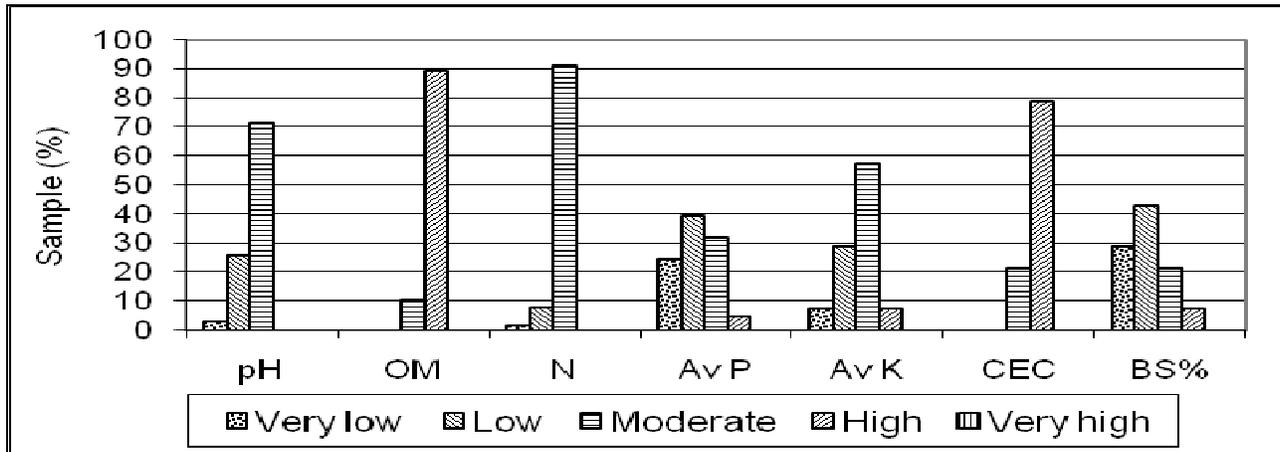


Figure 9 Soil parameters of potato fields under Zobel geog.

3.5.7 Soil Texture

Potatoes can be grown in most soil types though the greatest productivity is from a deep, loose, crumbly and well-aerated soil. Potatoes have low tolerance to water logging and do not do well in heavy clayey soils. Coarse-textured soils lack both nutrient and water holding capacities while fine-textured soils often have structural and infiltration problems.

Sandy clay loam (SCL) which is a moderately fine textured soil (containing more than 45% sand and about 35% clay separates) and clay loam (CL) which is also a moderately fine textured soil (containing about 50% sand and about 40% clay separates) are the dominant soil types of this geog.

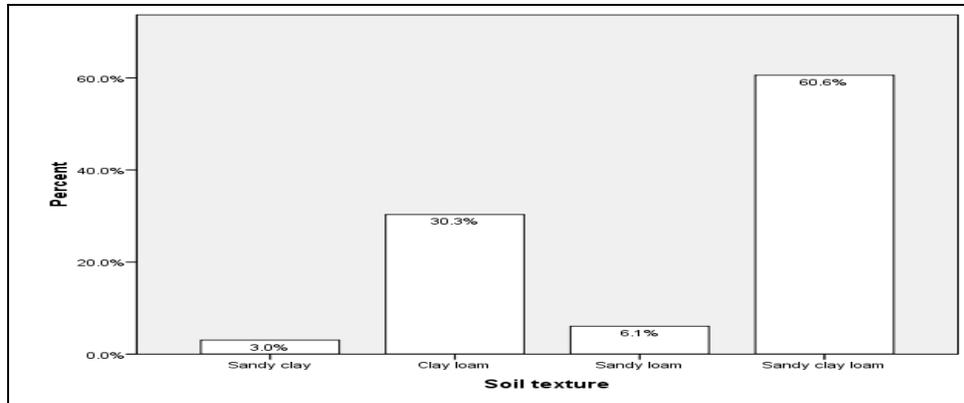


Figure 10 Soil texture of potato fields under Zobel geog (average of all villages)

The soil results of individual village under Zobel geog are summarized as follows.

3.6 Soil analytical result of individual village under Zobel geog

3.6.1 Soil result of Resinang village

The pH of the soils in this village is within the low to medium ranges. The OM content of this village is high. The nitrogen content is within the medium range. More than **93% of these soils have low P values** and for these soils there is the **need to apply P containing fertilizers such as SSP/TSP**. The rest of the samples (7% of the samples) have medium P values. About **36% of the samples have very low to low available K** and only about 57% of the samples have medium K values and only about 7% have high values. For those samples with low to medium K ranges, there is the need to apply **K containing fertilizers such as MoP** (please refer Table 1 for individual name list with low P and K values). The CEC values are mostly within the medium to high range though the BS% range of these soils is widely distributed from very low to high ranges.

The major soil type of this village is clay loam (CL), which is a moderately fine textured soil (containing about 50% sand and about 40% clay separates), followed by sandy clay loam (SCL) which is a moderately fine textured soil (containing more than 45% sand and about 35% clay separates) and sandy clay (SC) which is a fine textured soil (containing more than 50% sand and more than 55% clay) (Figure 19).

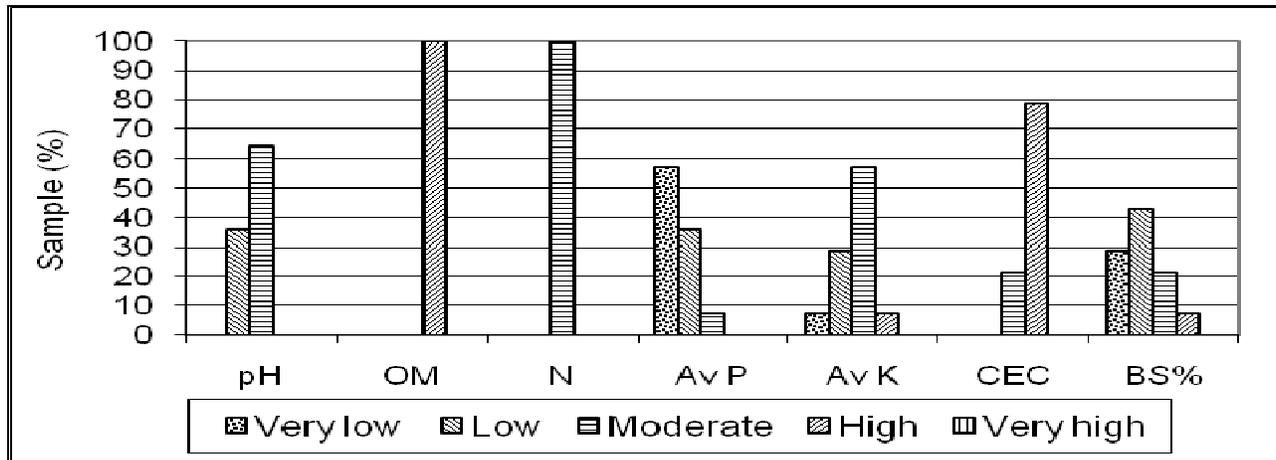


Figure 11 Soil parameters of potato fields in Resinang village.

3.6.2 Soil result of Tselingor & Tselingor man villages

The soil pH value of these villages is within the low to medium ranges, which is ideal for growing almost all agronomic crops. The soil organic matter content is high for all the plots. The N content is within the medium range. **The available P content** of these soils is mostly within the **very low to low ranges** (about 86% of the plots) and therefore in this village, there is the need to **apply P containing fertilizers such as SSP/TSP** for most of the farmers of this village. The **available K** content is mostly within the **medium range** (about 57% of the samples) while about 14% are in the low range and about 29% of the plots are in the high range. Therefore, to get a good yield, there is a need to apply **K containing fertilizers such as MoP** to improve the soil K status, thereby increasing the yields (please refer Table 1 for individual name list with low P and K values). The CEC of these soils is mostly within the medium to high range while the BS% is low.

Sandy clay loam (SCL) which is a moderately fine textured soil (containing more than 45% sand and about 35% clay separates) is the dominant soil type in Tselingor and Tselingor man villages (Figure 19).

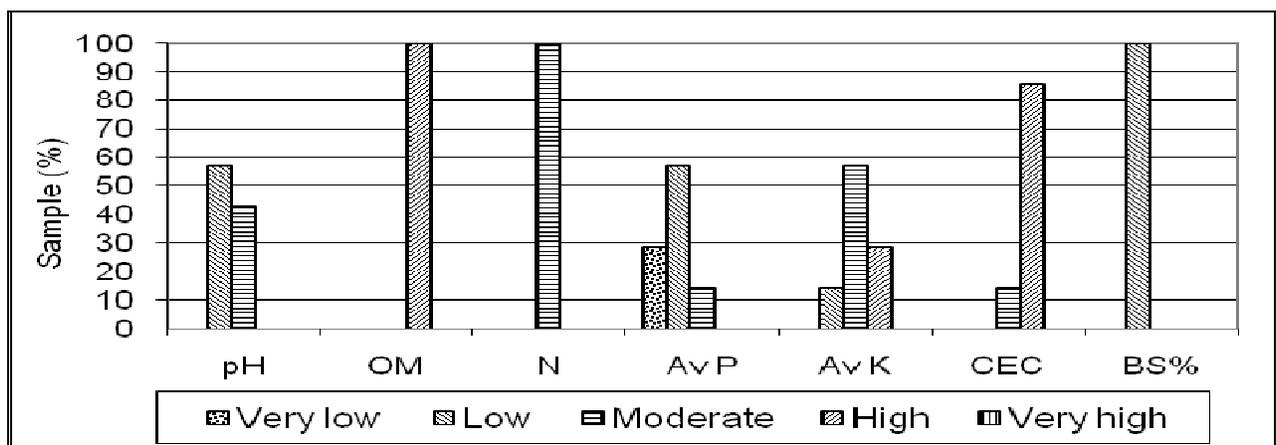


Figure 12 Soil parameters of potato fields in Tselingor & Tselingor man villages.

3.6.3 Soil result of Sumargug & Sumarthing villages

The soil pH of this village is mostly within the medium range while the organic matter content of these soils is high. The N content is of medium range. **The available P** content of this village is **very low** and this low values indicate the need to **apply P containing fertilizers such as SSP or TSP**. The **available K content** of these soils is mostly within the **medium** range (**67% of the samples**) and about 17% of the samples have low and high values. These low to medium values indicate the need to **apply K containing fertilizers such as MoP** to improve the nutrient status of these soils (refer Table 1 for name list). The CEC of these soils is mostly within the high range while the BS% is mostly in the medium to high ranges.

Sandy clay loam (SCL) which is a moderately fine textured soil (containing more than 45% sand and about 35% clay separates) and Sandy loam (SL) which is a moderately coarse textured soil, containing more than 50% sand and about 20% clay separates and are the two soil types of this village (Figure 19).

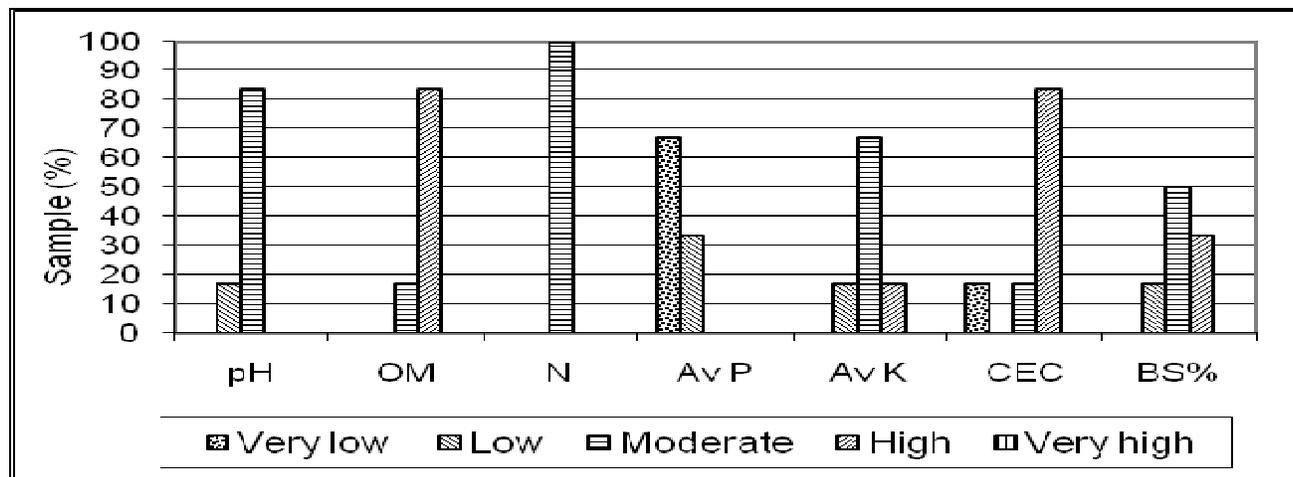


Figure 13 Soil parameters of potato fields in Sumargug & Sumarthing villages.

3.6.4 Soil result of Chungkhar village

The pH and the N content of these soils are in the medium range. The OM% of these soils is high. About **38% each** of the samples have **low and medium P** values while about 25% of these samples have high P values. For those soils with low to medium P values, there is the need to **apply P containing fertilizers such as SSP and TSP** to increase the P content of the soils for better crop yield. **The available K** of these soils is within the **medium to high range**. As discussed earlier, potatoes are good extractors of K and therefore the need to apply K containing fertilizers to the soil to get the maximum returns, especially for those soils with low to medium K values. The CEC of these soils is mostly within the medium to high ranges while the BS% of these soils is distributed from very low to medium to high ranges.

The major soil type of this village is sandy clay loam (SCL) which is a moderately fine textured soil (containing more than 45% sand and about 35% clay separates) followed by clay loam (CL) which is a moderately fine textured soil (containing about 50% sand and about 40% clay separates). (Figure 19).

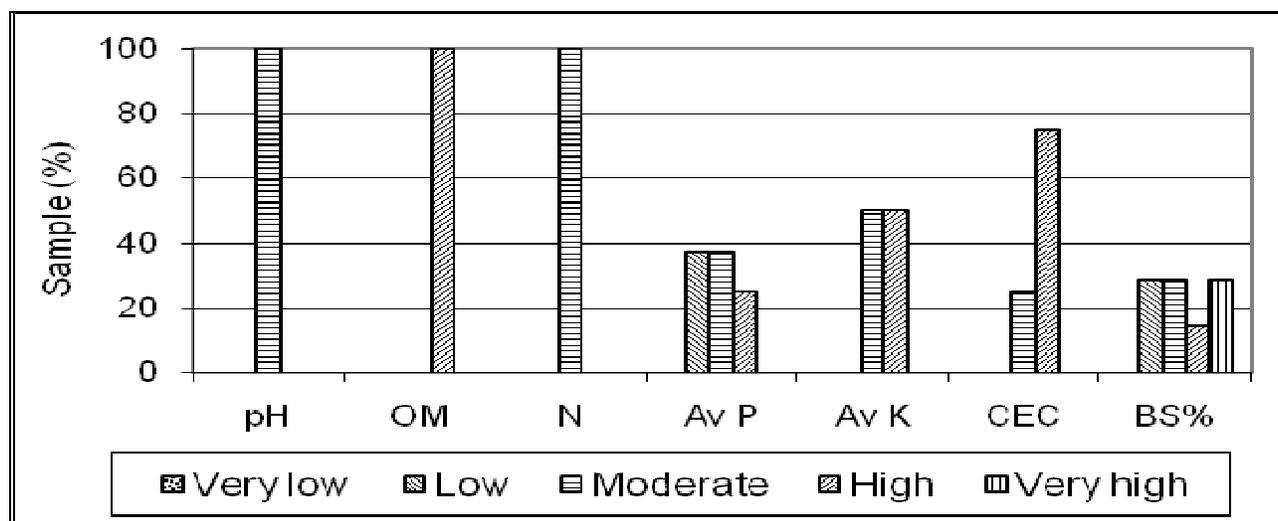


Figure 14 Soil parameters of potato fields in Chungkhar village.

3.6.5 Soil result of Pangthang daza village

The soil pH and the N content of these soils are mostly within the medium range. The OM% content of these soils is mostly high. About **40% of the samples have low available P** while about **20% of the samples have medium P** values and the rest 40% of the samples have high P values. These low to medium P values indicate the need to **apply P containing fertilizers such as SSP/TSP**. The **available K is all in the very low to low** range and this low value indicates the need to **apply K containing fertilizers such as MoP** (refer Table 1 for name list). The CEC is mostly within the low to medium ranges while the BS% is distributed from low to medium to high ranges.

The soil type of this village is Sandy clay loam (SCL) which is moderately fine textured soil containing more than 45% sand and about 35% clay separates (Figure 20).

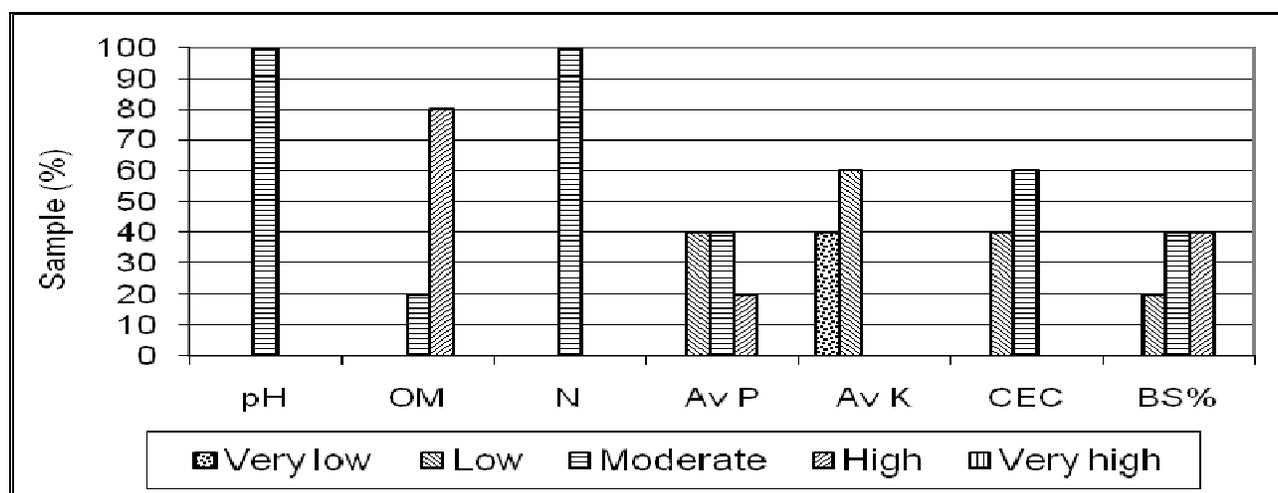


Figure 15 Soil parameters of potato fields in Pangthang daza village.

3.6.6 Soil result of Ngangmalang village

The pH value of the soils in this village is mostly in the low to medium range. The OM% is mostly in the high range and only about 18% in the medium range. Nitrogen content of these soils is also mostly within the high range. The *available P of these soils* is mostly in the *very low to low ranges* (about 72% of the samples) and therefore the need to *apply P* containing fertilizers such as *SSP or TSP*. The *available K content of all the plots in this village is in the very low to low ranges* and therefore the need to *apply K containing fertilizers such as MoP* (refer Table 1 for name list). The CEC of these soils is within the low to medium ranges while the BS% range of these soils is distributed from very low to medium to very high ranges.

Clay loam (CL) which is a moderately fine textured soil (containing about 50% sand and about 40% clay separates) is the dominant soil type of this village (more than 80% of the samples) followed by Sandy clay loam (SCL) which is moderately fine textured soil containing more than 45% sand and about 35% clay separates (Figure 19).

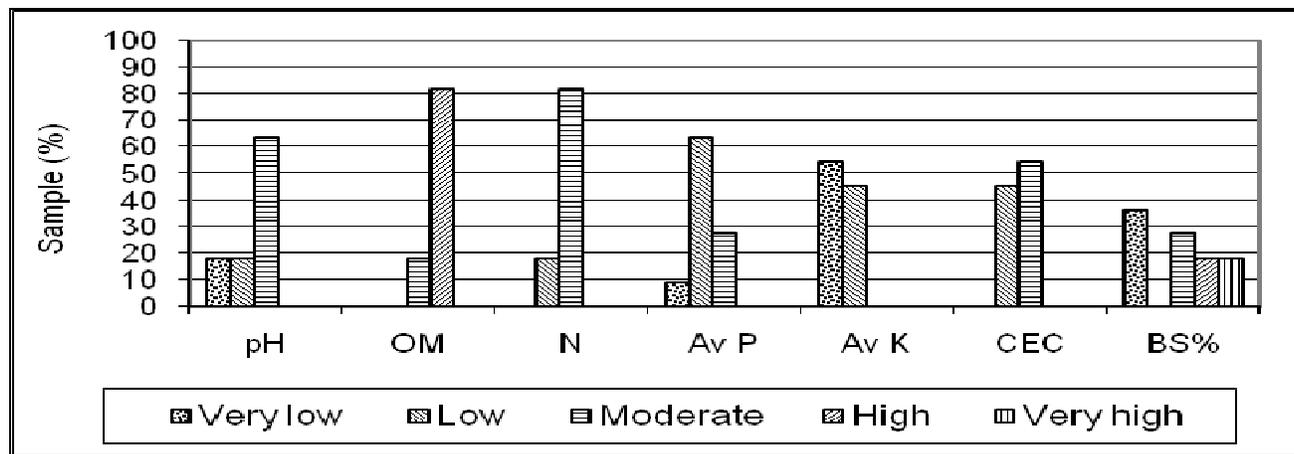


Figure 16 Soil parameters of potato fields in Ngangmalang village.

3.6.7 Soil result of Gonpasingma village

The pH of these soils is within the low to medium range. The OM content of these soils is high. The nitrogen is mostly within the medium range. The *available P is in the low to medium range* and therefore, for those with low to medium values, there is the need to *apply P containing fertilizers such as SSP or TSP*. The available K is also mostly in the low to medium range and only about 17% in the high range. As potatoes are good extractors of K and also for those soils with low to medium K values, there is the need to *apply K containing fertilizers such as MoP* (refer Table 1 for individual name list). The CEC of these soils is in the medium range while the BS% range of these soils is distributed from very low to medium to high ranges.

Sandy clay loam (SCL) which is a moderately fine textured soil (containing more than 45% sand and about 35% clay separates) is the only soil type in this village (Figure 19).

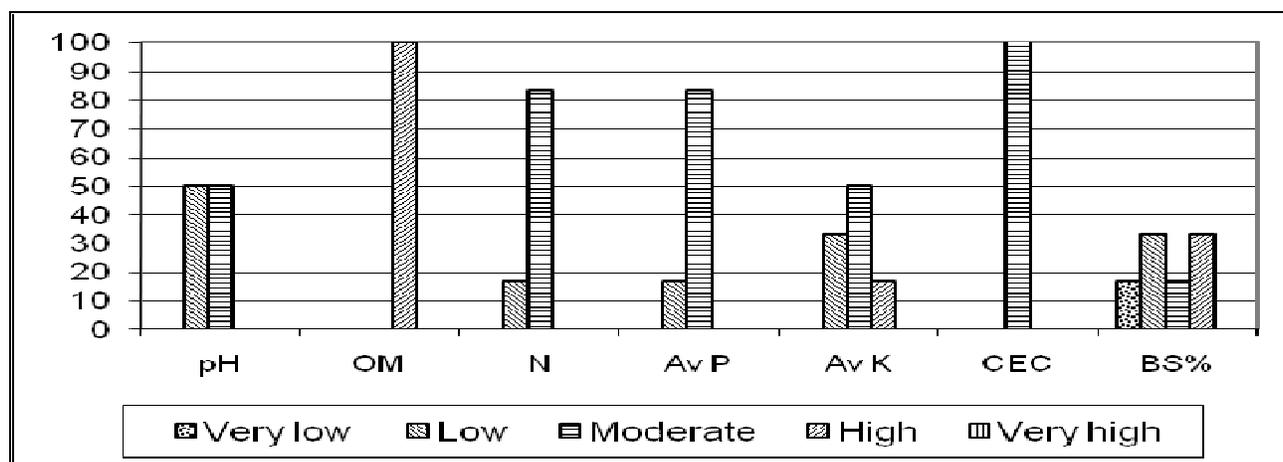


Figure 17 Soil parameters of potato fields in Gonpasingma village.

3.6.8 Soil result of Zobel village

The pH of the soils is mostly within the medium range. About 67% of these samples have medium OM% values while about 33% of the samples have low OM % contents. About **33% of the samples have very low to low P** values and about **67% of the samples have medium P values**. Therefore, in this village, there is the need to **apply P containing fertilizers such as SSP or TSP**. About **22% of the samples have low K** values while about **56% of the samples have medium K** values and only about 22% of them have high values. Therefore, in this village there is the need to apply **K containing fertilizers such as MoP** especially for those farmers with low to medium K values (refer Table 1 for individual name list). The CEC and the BS% of these are mostly in the low to medium ranges. In soils with low CEC values, all major macro and micronutrients may be required to attain adequate growth and thereby yield.

Sandy clay loam (SCL) which is moderately fine textured soil (containing more than 45% sand and about 35% clay separates) is the predominant soil type followed by clay loam (CL) which is also moderately fine textured soil (containing about 50% sand and about 40% clay separates) and sandy loam (SL) which is moderately coarse textured soil, containing about more than 50% sand and about 20% clay separates (Figure 19).

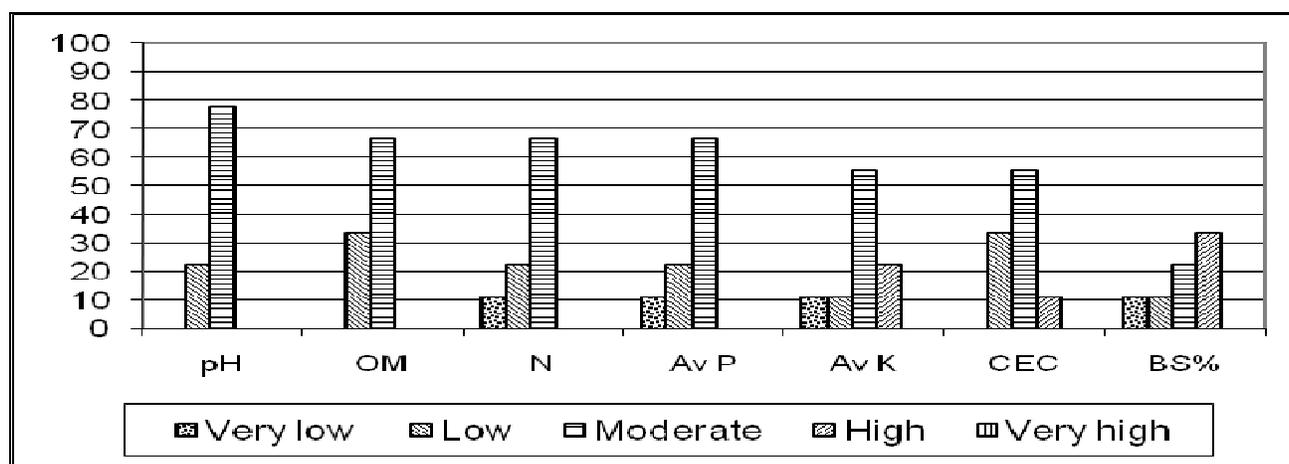


Figure 18 Soil parameters of potato fields in Zobel village.

3.7 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.

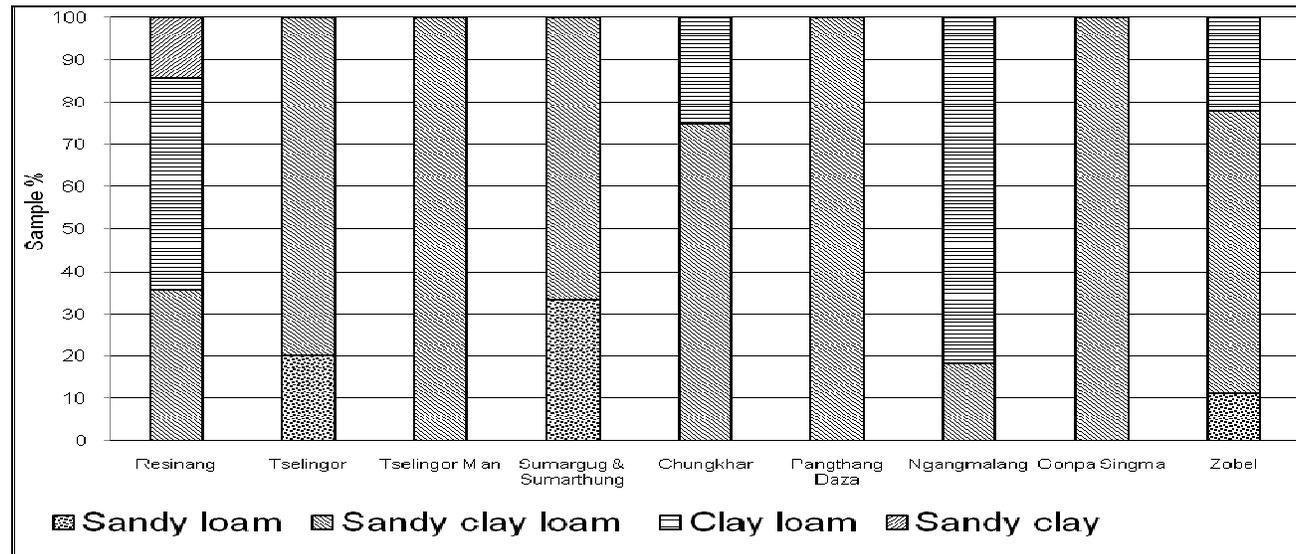


Figure 19 Soil textures of potato fields in different villages under Zobel geog

4. Conclusions

In Zobel geog, the survey findings indicate that the majority of the sampled plots are located at low altitude range of (<2000 m.asl). It also shows that most of the plots are situated on sloping areas with north facing aspects. All the farmers of this geog have small plot size for potato plantation (i.e. less than 1 acre). Desiree is the most preferred potato variety grown by the farmers.

All the farmers of this geog apply FYM and some chemical fertilizers as part of the soil fertility management practices. On an average, the farmers apply about 9.72 tac^{-1} of FYM. The farmers also apply about 97 kgac^{-1} urea to maize and about 174 kgac^{-1} Suphala to potato. Other fertilizers such as SSP and MoP are not applied at all.

The average potato yield in this geog is 4.42 tac^{-1} and the average maize yield is 1.2 tac^{-1} . Gonpa singma village reported the highest yield of potato (5.88 tac^{-1}) and highest maize yield of 2.31 tac^{-1} is reported from Chungkhar village. The potato yield figure from this village is less than those of FAO yield estimate for Bhutan (FAO yield estimate for farmer field is about 6.5 tac^{-1}). The lowest yield of potato (1.6 tac^{-1}) is reported from Sumargug village and this figure suggests that the potential yield in some of the villages is yet to be attained. About 32% of the farmers reported that they have changed the potato seeds during the last 5 years and about 55% of them during the last 5-15 years.

On an average, the soil pH of most of the plots is within the suitable range for growing potatoes and maize. The organic matter content of these soils is mostly within the medium to high range. The available P is mostly within the low range though few farmers in the geog have fairly good P status. The available K content of most of these soils is in the low to medium ranges and very few in the high range. The CEC of these soils in Nanong geog are mostly in the high range indicating a fairly

^e The potato yield figure is slightly less than the figures of 2002 (i.e. potato= 6.2 tac^{-1} and maize =1.2 tac^{-1}).

good soil fertility status and this could also be due to fairly good clay content in the soils. The major soil types of this geog are sandy clay loam and clay loam.

5. Recommendations

- The average nutrient input through inorganic fertilizers to potato and maize is 71 kgac^{-1} N, 26 kgac^{-1} P and K from suphala and urea (i.e 97 kgac^{-1} of urea and 174 kgac^{-1} suphala). With the limited use of balanced mineral fertilizer, especially P and K for most of the villages, the soil P and K status could deteriorate with time. The farmers of this geog should increase the fertilizer application rates and could include P and K fertilization to get a good yield and also to prevent nutrient mining of their soils (Please refer Table 1 for the farmer list with low P and K values).
- For this geog, the soil analytical results indicate a fairly low to medium P and K status for most of the villages. The farmers' nutrient application rate of about **71:26:26 kg NPK ac^{-1}** is much lower for K and P, though higher for N than the NSSC recommendation of **40:32:32 kg NPK ac^{-1}** . However, at the individual village level there are farmers with much lower rate of application and therefore the list in Table 1 should be included for following the recommended rate.

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 3.5 and 3.6) the following recommendations are suggested to improve the soil nutrient status in this geog.

- ☞ The available P content of these soils in most of the villages is low and this could be improved by applying P containing fertilizer such as SSP together with urea as a basal dose (refer Table 1 for name list).
- ☞ The available K content of these soils is mostly within the low to medium range (except for few farmers) and there is the need to apply K containing fertilizer such as MoP to replenish the K content of these soils as potatoes are efficient removers of K (refer Table 1 for name list).

The CEC of these soils is within the medium to high range. There is also the need to improve the nutrient content and hence an application of balanced nutrients with proper recommended rate needs to be encouraged (i.e. the rate of $40:32:32 \text{ kgac}^{-1}$ of NPK is recommended based on the soil results).

The P and K values need to be increased for these soils based on the NSSC and FAO recommended rate, as these values from the soil analysis report are low while the rate of N is decreased slightly as the farmers apply plenty of FYM and urea. 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 $40:32:32 \text{ kgac}^{-1}$ of NPK:**

5.1 Using Suphala, urea and MoP (in one acre):

- In order to supply the nutrients at the recommended rates, apply about 213 kgac⁻¹ of Suphala as basal dose during land preparation (i.e. about 4 bags of Suphala @50 kg bag⁻¹ ac⁻¹).
- Followed by one application of 17 kgac⁻¹ of urea once either at the time of flowering of potato or when the maize plants are of knee high stage if intercropped with maize (or two split application of urea @ 8.5 kg each when the plants are knee high and the other at pre tassling stage).

5.2 Using SSP, MoP and Urea (in one acre)^f:

- Apply 44 kgac⁻¹ of Urea as basal dose during land preparation (i.e. about 1 bag of urea @50 kg bag⁻¹ ac⁻¹).
 - Apply 200 kgac⁻¹ of SSP as basal dose during land preparation (i.e. 4 bags of SSP @ 50 kg bag⁻¹ ac⁻¹).
 - Apply about 54 kgac⁻¹ of MoP as basal dose during land preparation (i.e. about 1 bag of MoP @ 50 kg bag⁻¹ ac⁻¹).
 - Followed by urea application as two split top dressings, i.e about 22kg ac⁻¹ of urea top dressed when the maize plants are of knee high stage and another 22 kg ac⁻¹ of urea at pre-tassling stage.
- ☞ In addition to this, where ever there is a moderately coarse to medium textured soil type, a split application of urea is even more advisable for better utilisation of the N nutrient.
- ☞ The timing of fertilizer application with adequate soil moisture is crucial for obtaining good yield and therefore, application of fertilizers on a completely dry soil is not encouraged.
- ☞ The above recommended rate would be applicable for those farmers' soils with low P and K values as suggested in Table 1 for easy reference.

^f If the farmers are willing, this second type (5.2) of application is more advisable than the first type as the SSP contains additional nutrient (sulphur), which helps in better production of yield.

Table 1. Name list of farmers with low P and K values under Zobel geog

VERY LOW – LOW P	VERY LOW – LOW K
ALL THE FARMERS OF NGAMALANG	KARMA GYELSTHEN (CHUNGKHAR)
ALL THE FARMERS OF GONPA SINGMA	PENJOR (CHUNGKHAR)
ALL THE FARMERS OF RESINANG	SANGAY PHUNTSO (CHUNGKHAR)
ALL THE FARMERS OF TSELINGOR & TSELINGOR MAN	KOLAY (CHUNGKHAR)
ALL THE FARMERS OF SUMARGUG	ALL THE FARMERS OF PANGTHANG DAZA
ALL THE FARMERS OF SUMARTHUNG	ALL THE FARMERS OF NGAMALANG
ALL THE FARMERS OF ZOBEL VILLAGE	ALL THE FARMERS OF SUMARGUG
ALL THE FARMERS OF CHUNGKHAR (<i>EXCEPT KARMA GYELTSHEN</i>)	ALL THE FARMERS OF GONPASINGMA (<i>EXCEPT TSHERING DUBA</i>)
ALL THE FARMERS OF PANGTHANG DAZA (<i>EXCEPT NYRA</i>)	ALL THE FARMERS OF ZOBEL VILLAGE (<i>EXCEPT DORJI GYELTSHEN</i>)
	ALL THE FARMERS OF RESINANG (<i>EXCEPT DORJI</i>)
	ALL THE FARMERS OF TSHELINGOR & TSHELINGOR MAN (<i>EXCEPT THINLEY WANGDI, JAMTSO</i>)
	ALL THE FARMERS OF SUMARTHUNG (<i>EXCEPT PEMA TSHERU</i>)