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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, Nanong geog is one of the most intensively cultivated area other than Zobel 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 70 households spread over 9 villages under Nanong 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 70 households were selected from the initial 108 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= 1350m^2). 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 Nanong 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. This is followed by soil analysis results of individual villages under Nanong geog with fertilizer recommendations based on the findings for each village.

3.1 Sample households

In Nanong geog, a total of 70 household covering 9 villages[a] are sampled. The highest number of respondents is from Womchillo village (16%) followed by Geeri (14%), Teyphu (8%), Changchung and Tokari villages (7% each). Tokari geeri village has the lowest number of respondents (just 2%). 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 Nanong geog, the majority of the plots are situated on steep slopes (67%), followed by moderately sloping areas (20%). The majority of the plots are north facing (36% of the plots) and west facing (20% of plots) and about 17% of the plots with north westerly aspects. More than 67% 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). The majority of the farmers (more than 87%) of the samples sites have small plot sizes (< or =1 acre) and only about 4.3% of the plots are more than 3 acres. In Nanong geog, more than 31% of the farmers grow only Desiree variety while about 23% of the farmers grow their local variety and very few farmers grow other varieties such as Kufri jyoti and Yusikap.

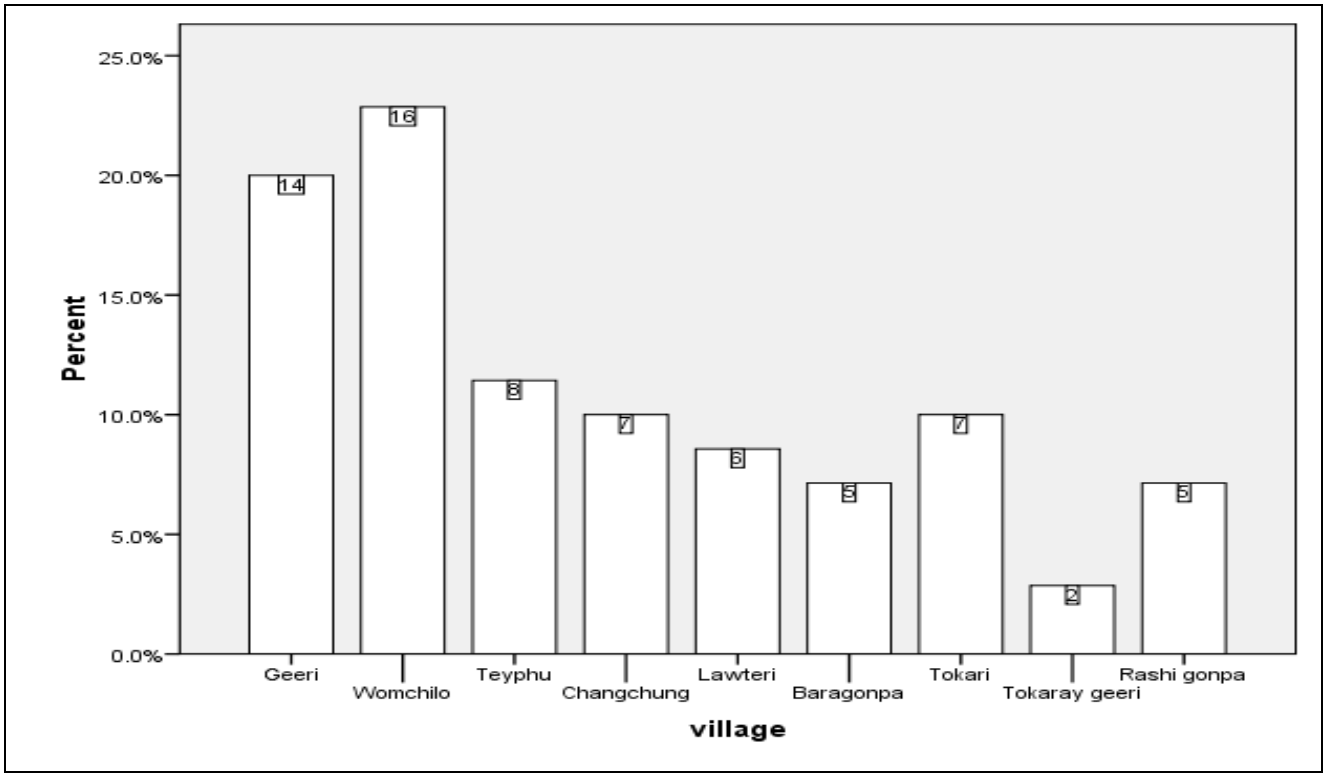

Figure 1 No. of respondents from each village under Nanong geog

[a] Villages under Nanong geog: Geeri, Womchillo, Teyphu, Changchung, Lawteri, Baragonpa, Tokari, Tokarey geeri, Rashi gonpa.

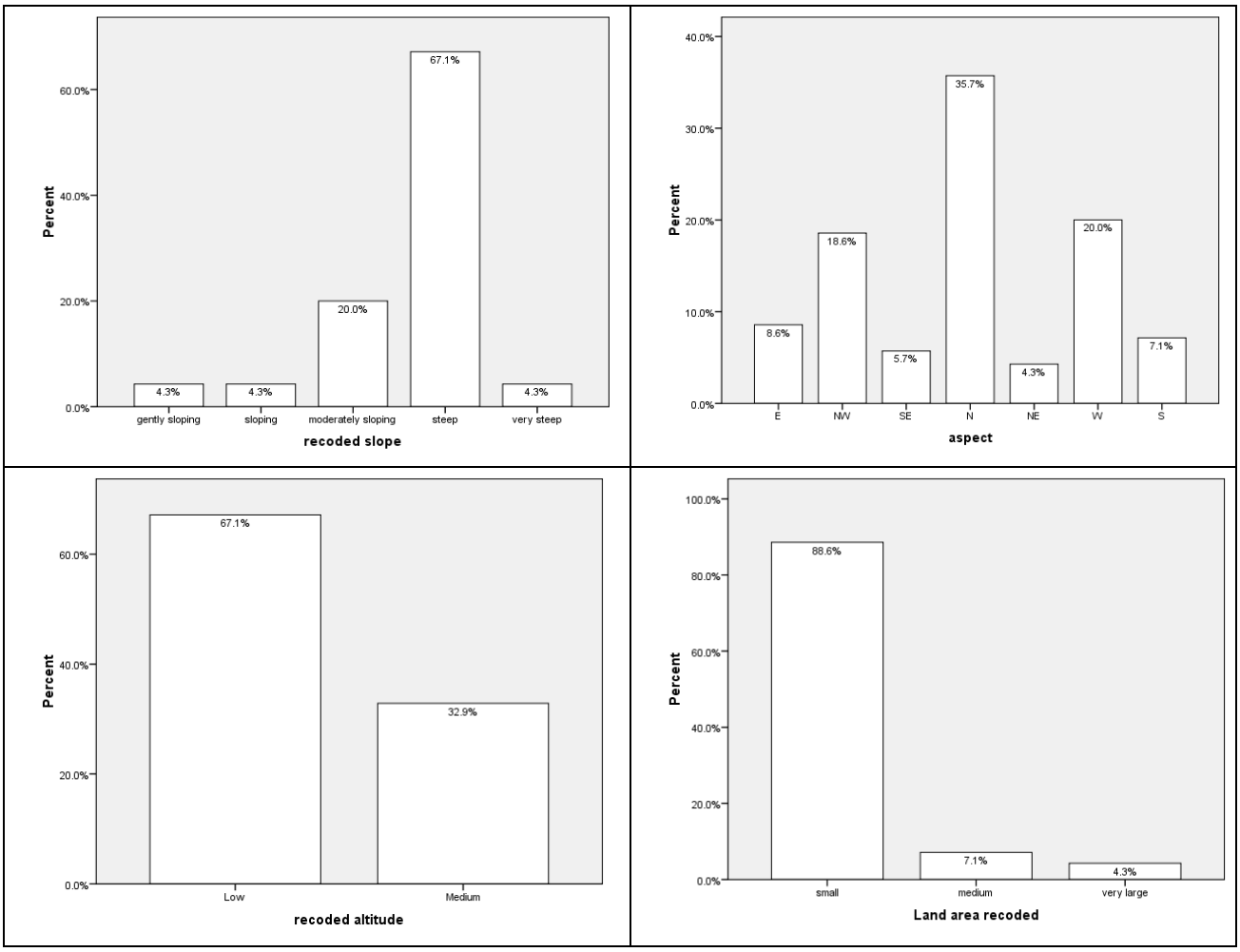

Figure 2 Slope, aspect, altitude and area of plots under potato- maize cultivation

3.3 Crop yield and other management practices.

As in other geogs of the east, potato is usually intercropped with maize in Nanong geog except for Baragonpa village, where no maize is intercropped with potato. Under favorable growing seasons, crop management and variety, the potato yield can vary from 16-20 tac^{-1}[b] though on an average, the yield is about 7-8 tac^{-1}.

The average potato and maize yield of Nanong geog is 6.53 tac^{-1} and 1.81 tac^{-1} respectively. From Figure 3 it can be observed that the maximum potato yield of 18.14 tac^{-1} is observed from Changchung village while the maximum maize yield of 4.76 tac^{-1} is reported from Teyphu village. The lowest potato yield of 2.97 tac^{-1} is reported from Lawteri while the lowest maize yield is reported from Tokari with just 0.23 tac^{-1}. 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.

[b] According to FAO reports

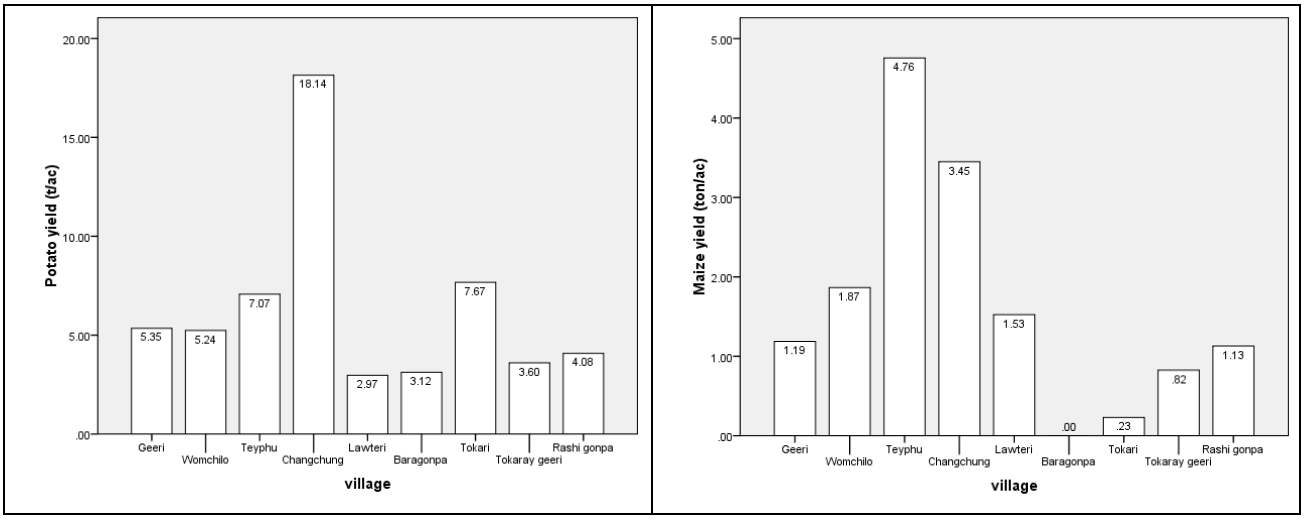

Figure 3 Average potato and maize yield (tac^{-1}) under each village

In this geog, almost all the farmers (95% of the farmers) reported that they have changed the potato seeds. About 21% of them have changed the potato seeds during the last 5 years while about 43% of them have changed during the last 5-10 years and about 35% of them have changed the seeds during the last 10 years or more while about 2% of them have not changed the seeds at all.

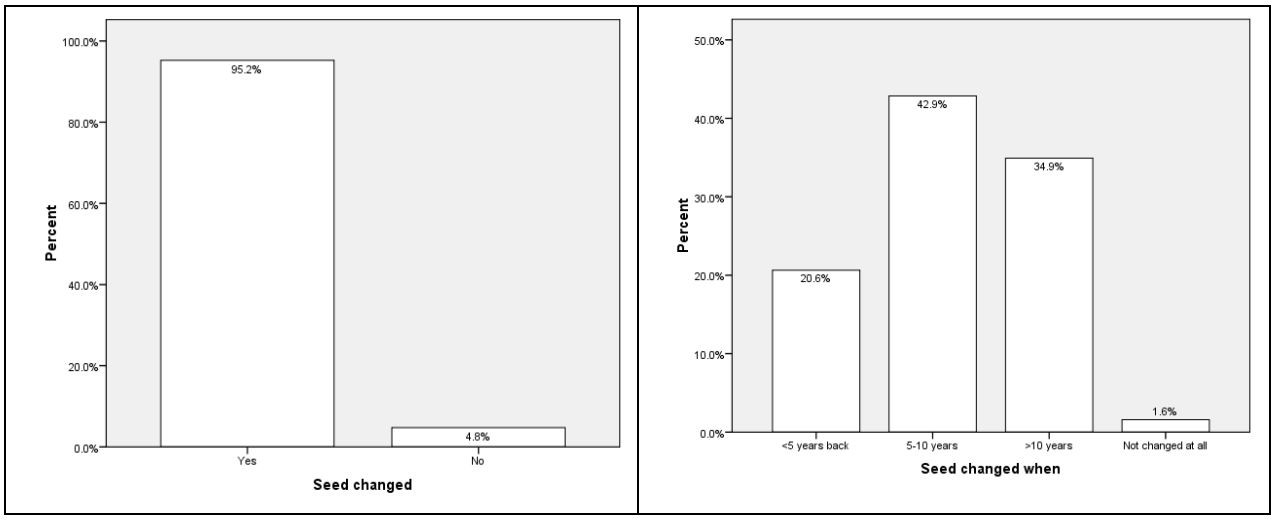

Figure 4 Potato seeds changed?

3.3.1 Soil fertility management practices

3.4.1 Farm Yard Manure (FYM)

In Nanong geog, all the farmers apply FYM to their fields. The average FYM application rate of the geog is 18.67 tac^{-1}. Baragonpa applies the highest amount of FYM to potato fields (48 tac^{-1}) followed by Rashigonpa (26 tac^{-1}), Tokari (21 tac^{-1}), Geeri (21 tac^{-1}), Womchillo (20 tac^{-1}). The lowest rate of

FYM application is reported from Teyphu with 11 tac^{-1}, which is a lot higher than the Trashigang Dzongkhag[c].

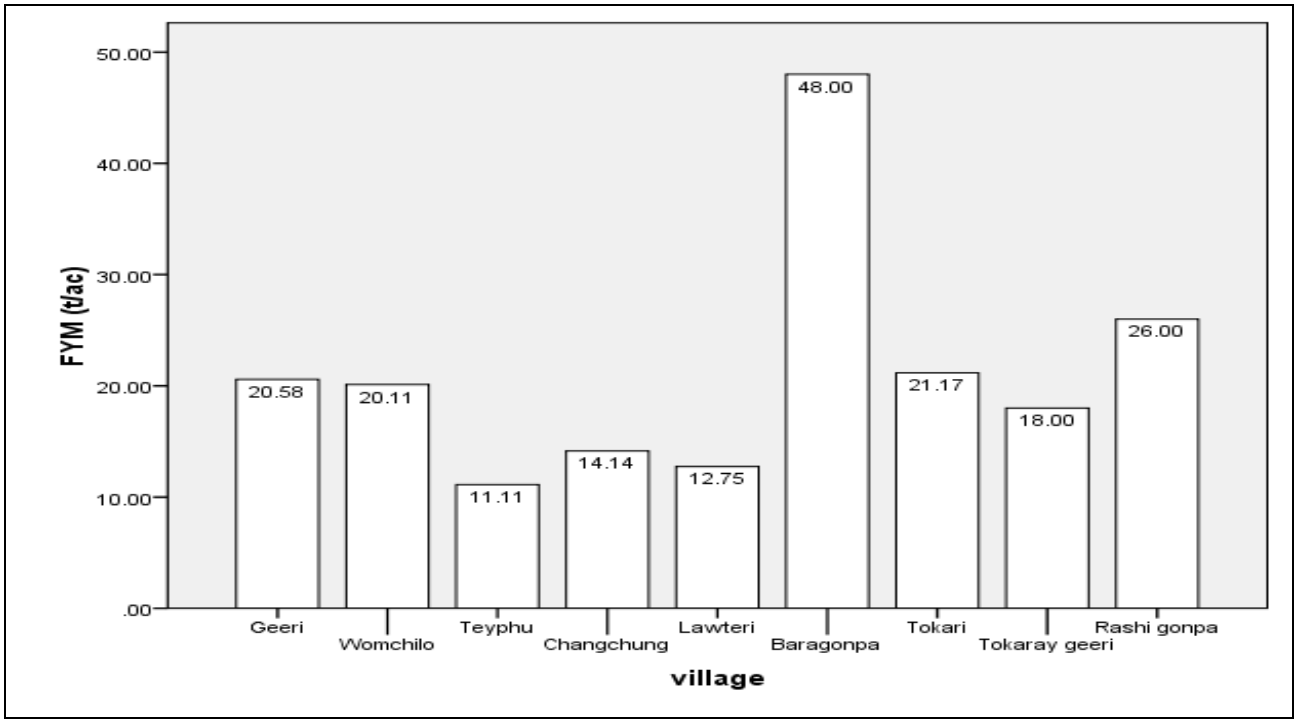

Figure 5 Amount of FYM applied (tac^{-1}) under each village.

3.4.2 Inorganic fertilizers

The survey findings indicate that most of the farmers (about 81%) apply inorganic fertilizers to potato and maize while the rest of them don't apply (few farmers of Lawteri and Womchlillo villages). 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 fertilizers applied in this geog are about 61 $kgac^{-1}$ urea (applied only to maize) and about 120 $kgac^{-1}$ of Suphala (applied to potato) and these fertilizers amount to about 46 $kgac^{-1}$ N, 18 $kgac^{-1}$ 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.

[c] These reported rates of FYM application from Nanong geog needs to be cross checked by the Dzongkhag Agriculture staff.

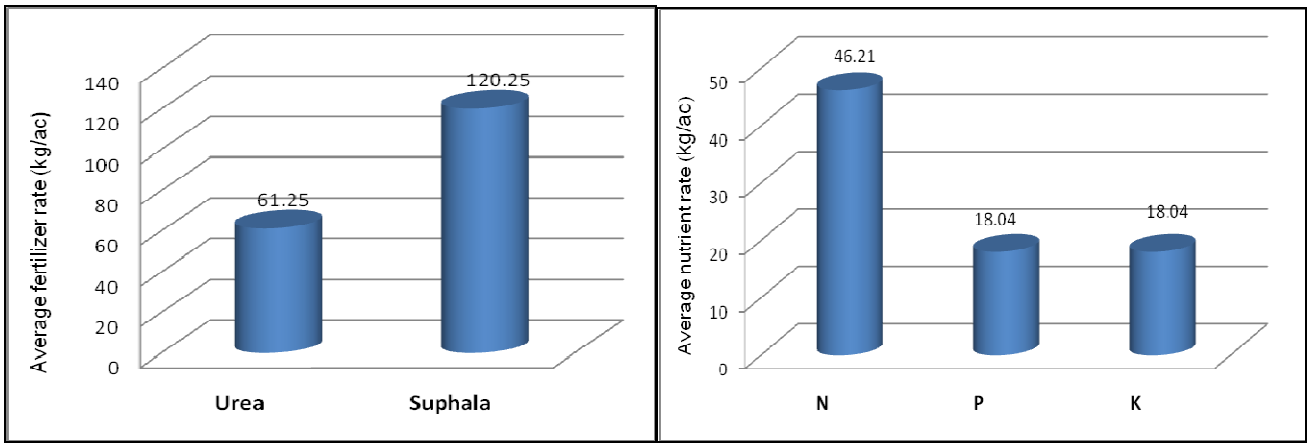

Figure 6 Average rates of fertilizer and nutrients applied (kgac^{-1}) in Nanong geog.

The highest application of suphala is reported from Teyphu (239 kgac^{-1}) which is equivalent to about 36 kgac^{-1} of N, P and K which is quite comparable to the recommendation rate 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). Baragonpa applies about 180 kgac^{-1} of suphala which is slightly lower than the recommended rate. Lawteri applies the lowest rate of suphala (about 46 kgac^{-1}) which is equivalent to about 7 kgac^{-1} of N, P and K and this could be the reason for low potato yield (the lowest potato yield is also reported from Lawteri). These values are very low for potato to do well and therefore the need to increase the fertilizer rate for most of the villages.

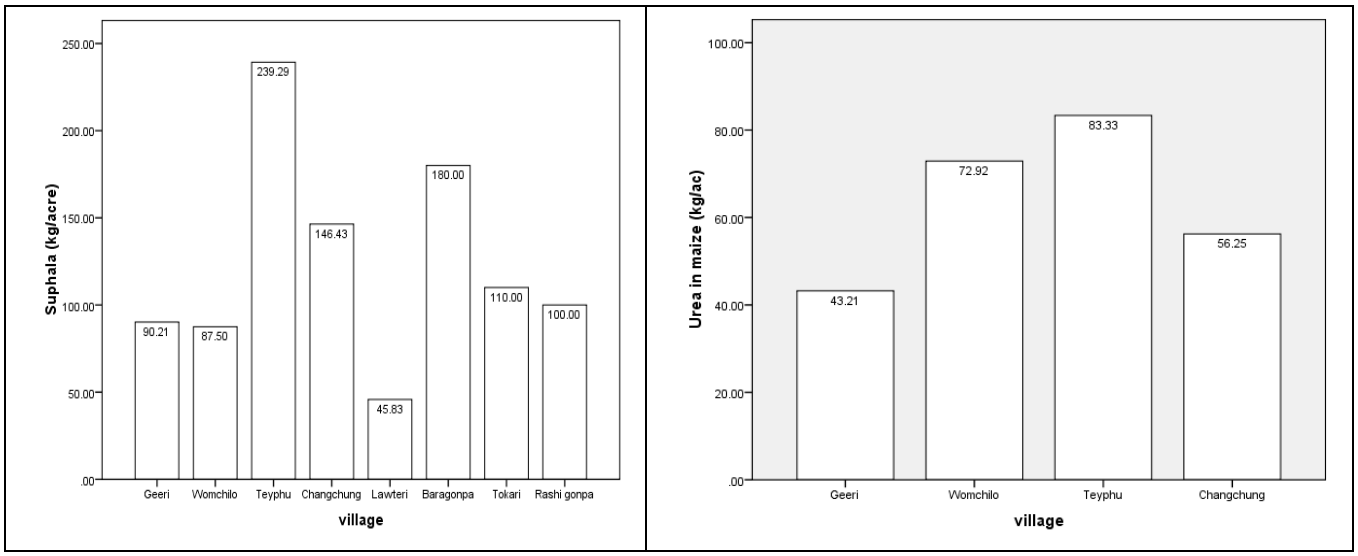

Figure 7 Amount of suphala & urea (kgac^{-1}) applied to potato and maize under each village.

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 suphala application to potato or urea application to maize. The maximum potato yield of about 12 tac^{-1} is reported when suphala application rate of 201-300 kgac^{-1} and another when the rate is more

than 500 kgac^{-1}. The maximum maize yield of 2.7 tac^{-1} is reported with the urea application of 100-200 kgac^{-1}.

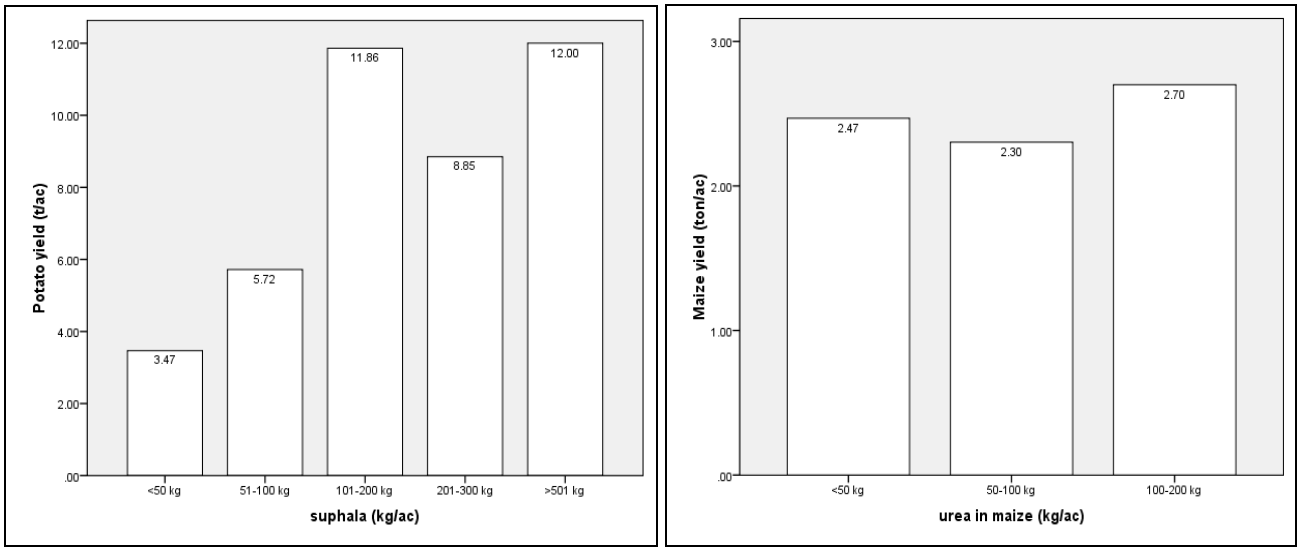

Figure 8 Potato and maize yield in relation to inorganic fertilizer applied in the geog.

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 Nanong 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 of 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 90%) of the soils have moderate/medium pH range. Potatoes are grown on organic as well as mineral soils. For potatoes, the minimum soil pH 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 high range (83% of the plots) while about 14% of the plots are in the moderate range and only about 3% in the low range. 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 $mgkg^{-1}$), low (5-15 $mgkg^{-1}$), medium (15-30 $mgkg^{-1}$), high (30-35 $mgkg^{-1}$) and very high (>35 $mgkg^{-1}$).

More than ***57% of the samples in this geog have low to very low available P*** while about 7% of the samples are within the medium range and about 36% 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 Tokari, Tokari geeri, Lawteri and Changchung 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, few selected farmers need to apply P containing fertilizers to their fields (details under individual village report and for individual name list, please refer 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 $mgkg^{-1}$), low (40- 100 $mgkg^{-1}$), medium (100-200 $mgkg^{-1}$), high (200-300 $mgkg^{-1}$) and very high (>300 $mgkg^{-1}$).

About ***33% of the samples have low to very low available K*** and about *54% are within the medium range* and only about 13% within the high range. In general, the K content of these soils is very poor and the farmers of Tokari, Tokari geeri, Baragonpa need to apply K containing fertilizers such as MoP while in other villages, 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). However, the farmers of Teyphu and Changchung need not worry about applying more K for this season as the K status of these soils is quite high.

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/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 medium to high range indicating a fairly medium soil fertility status though the BS% is widely distributed from very low to medium to high ranges.

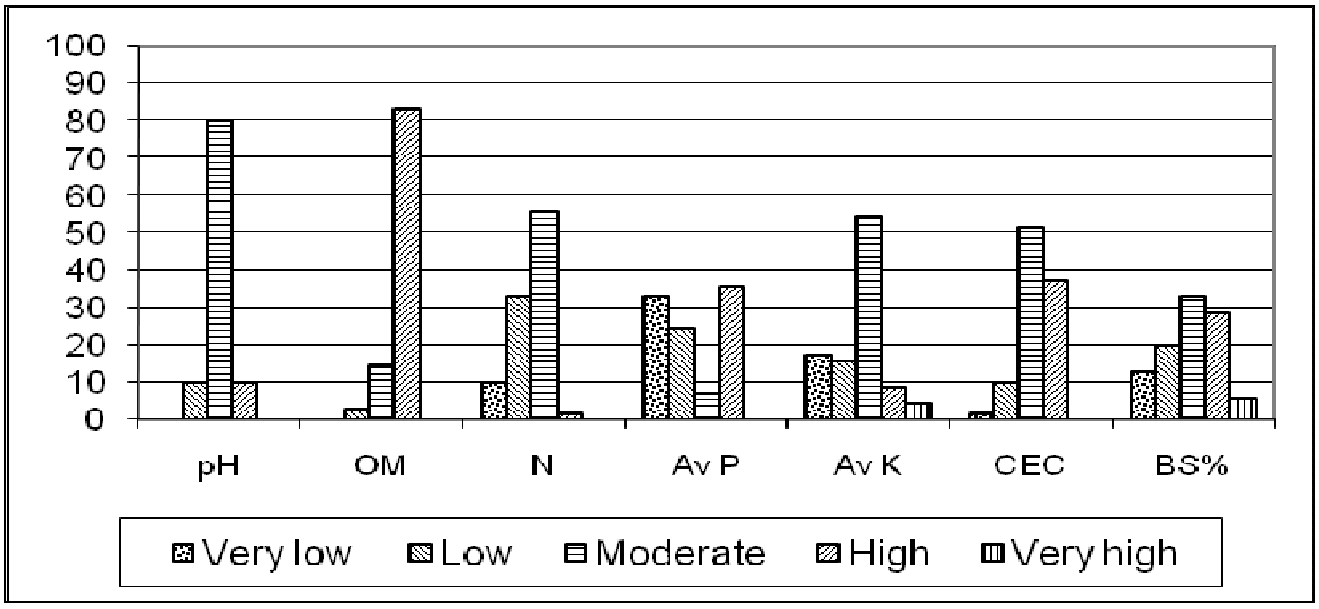

Figure 9 Soil parameters of potato fields under Nanong geog.

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); Sandy loam (SL) which is a medium textured soil (containing more than

50% sand and about 20% 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 three dominant soil textures of this geog (42%, 27% and 26% respectively).

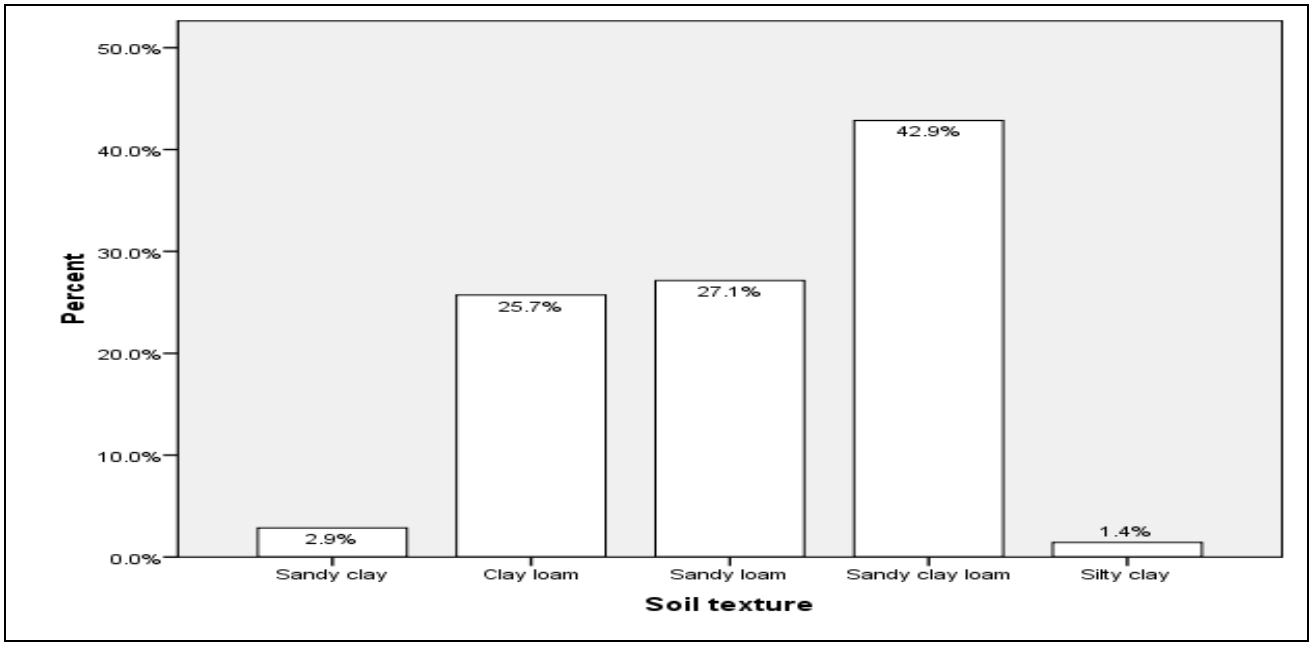

Figure 10 Soil texture of potato fields under Nanong geog (average of all villages)

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

3.6 Soil analytical result of individual village under Nanong geog

3.6.1 Soil result of Rashi gonpa village

The pH of the soils in this village is within the medium range. The organic matter content of this village is within the medium to high range. The nitrogen content is mostly within the medium range. More than ***60% of these soils have low P values*** and for these soils there is the ***need to apply P containing fertilizers such as SSP or TSP.*** While the rest of the samples (40% of the samples) have high available P contents. About 60% of the samples have ***medium available K*** ranges and only about 20% each in the **low and high** ranges. 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 range though the BS% range of these soils is widely distributed from very low to high ranges.

The major soil types of this village are sandy loam (SL) which is a moderately coarse textured soil (containing more than 50% sand and about 20% clay separates) and clay loam (CL) which is a moderately fine textured soil (containing about 50% sand and about 40% clay separates, Figure 20).

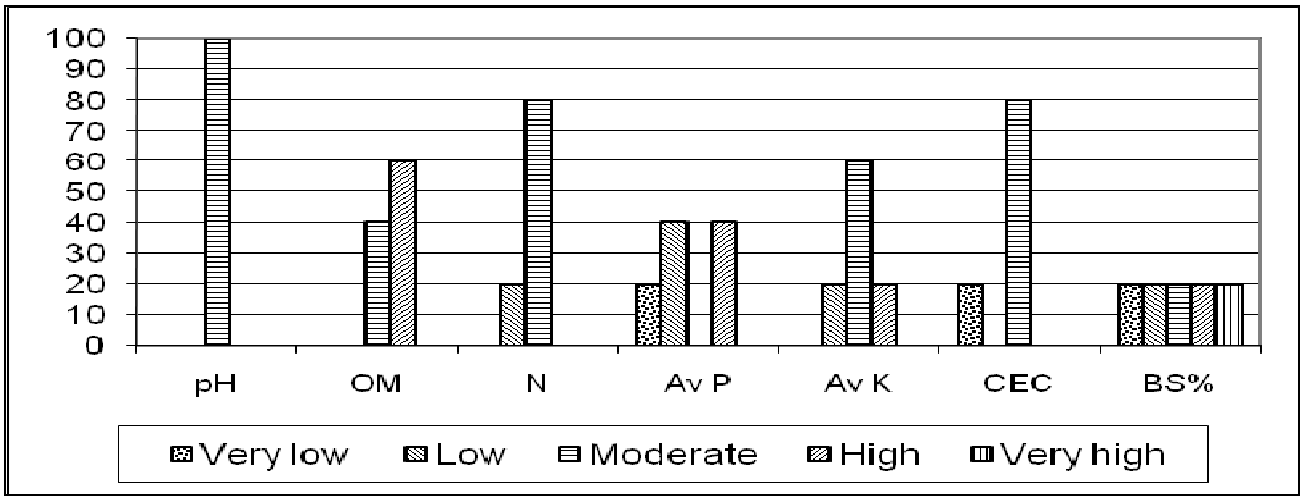

Figure 11 Soil parameters of potato fields in Rashi gonpa village.

3.6.2 Soil result of Tokari village

The majority of the sampled plots of this village have medium pH values, which is ideal for growing almost all agronomic crops. The soil organic matter content is high for most of the plots. The N content is within the low to medium ranges. ***The available P content*** of these soils is all within the ***very low to low*** ranges and therefore in this village, there is the need to ***apply P containing fertilizers such as SSP for all the farmers***. The ***available K*** content is also within ***the low to medium ranges.*** Therefore, to get a good yield, there is a need to ***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 range.

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

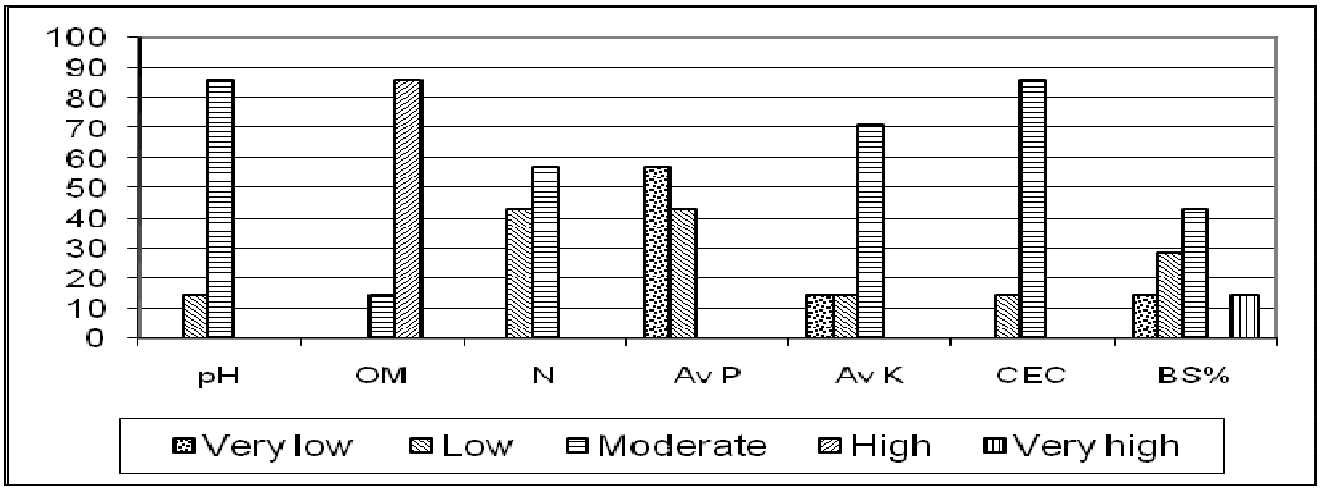

Figure 12 Soil parameters of potato fields in Tokari village.

3.6.3 Soil result of Tokari Geeri village

The soil pH of this village is in the medium ranges while the organic matter content of these soils is high. The N content is distributed equally between very low and medium ranges. ***About 50%*** of the samples have ***very low available P*** while the rest of the samples are in the medium range. These low to medium values indicating the need to ***apply P containing fertilizers such as SSP or TSP***. The available K content of these soils is within the ***low to medium*** range (50% each of the samples) and 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). The CEC and the BS% of these soils are mostly within the low to medium ranges.

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

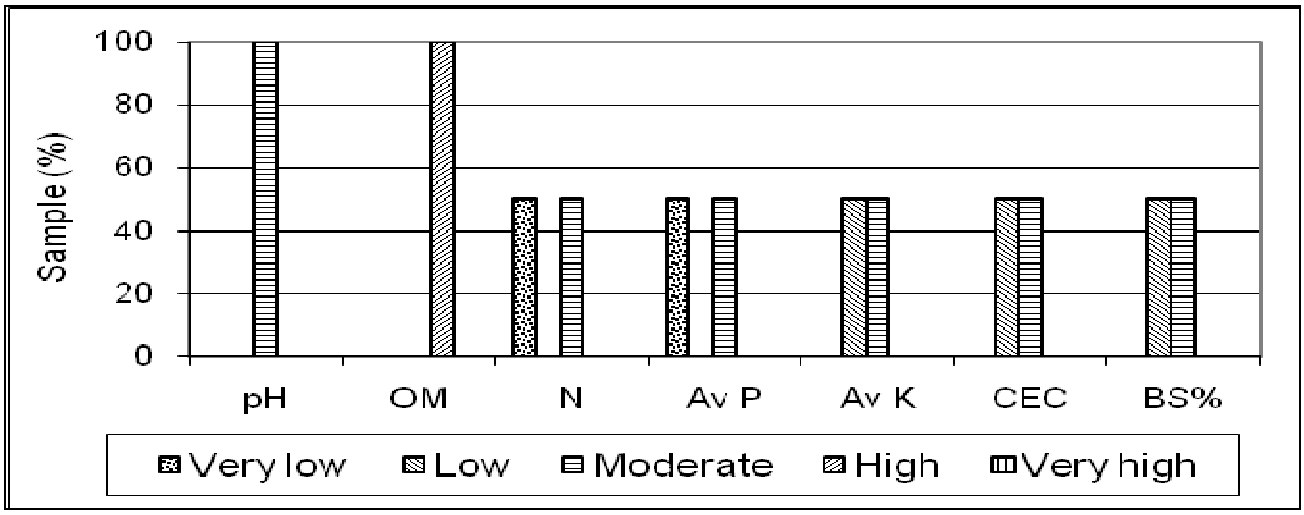

Figure 13 Soil parameters of potato fields in Tokari Geeri village.

3.6.4 Soil result of Baragonpa village

The pH of these soils is within the low to medium range. The OM% of these soils is mostly within the high range while the N content of these soils is within the low to medium range. ***The available P*** of these soils is ***very low*** and for such soils with low P, 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 of ***medium 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. The CEC of these soils is mostly within the medium range while the BS% of these soils is low.

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 about more than 50% sand and about 20% clay separates) and are the two soil types of this village (Figure 20).

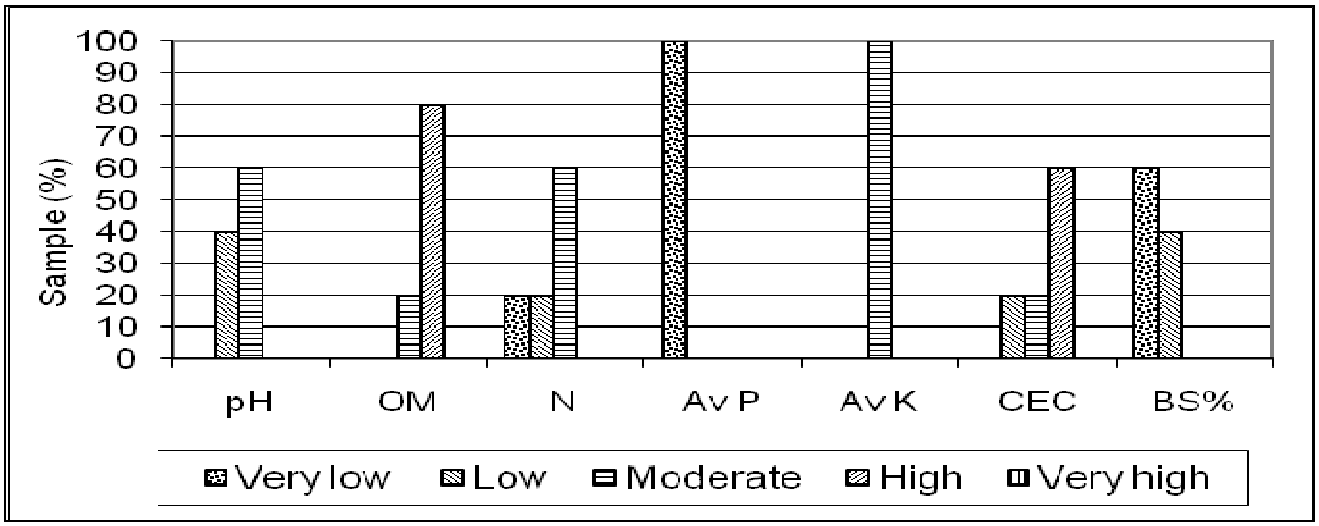

Figure 14 Soil parameters of potato fields in Baragonpa village.

3.6.5 Soil result of Geeri village

The pH of these soils is mostly within the medium to high range. The OM content of these soils is mostly high. The N content of these soils is distributed from very low to medium ranges. The ***available P content of these soils is high for this village***. The ***available K*** is distributed from very ***low to high*** ranges though the majority of the soils have medium K values. These ***low to medium*** values indicate the need to ***apply K containing fertilizers such as MoP*** (refer Table 1 for name list). The CEC is mostly within the medium to high ranges while the BS% is distributed from very low to medium to high ranges.

The major soil types of this village are 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 a moderately fine textured soil (containing about 50% sand and about 40% clay separates) and Sandy loam (SL) which is a moderately coarse textured soil (containing about more than 50% sand and about 20% clay separates, Figure 20).

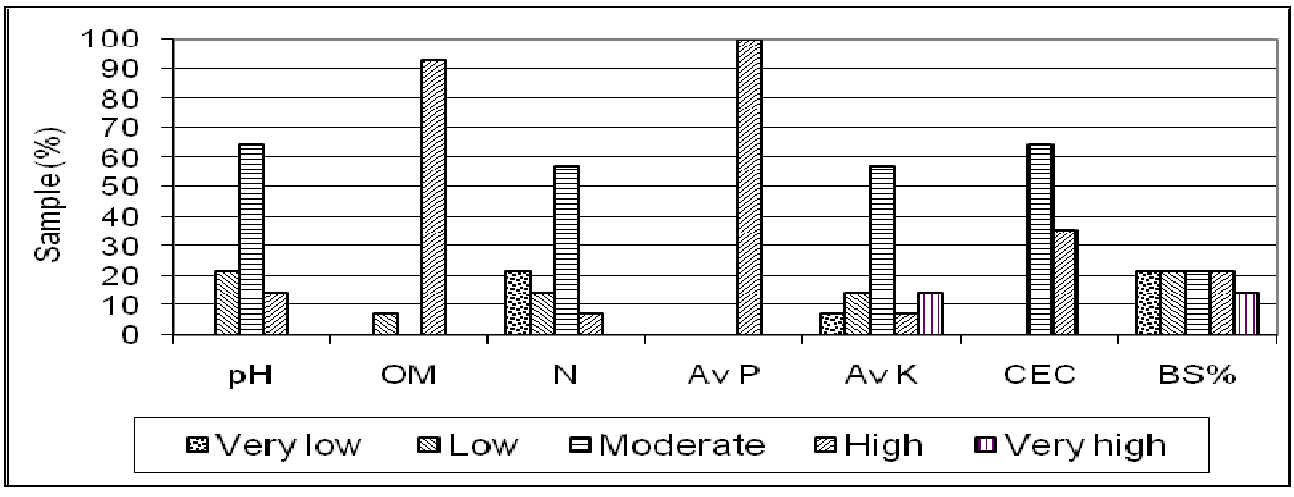

Figure 15 Soil parameters of potato fields in Geeri village.

3.6.6 Soil result of Lawteri village

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

Sandy loam (SL) which is a moderately coarse textured soil (containing about more than 50% sand and about 20% clay separates) and Sandy clay (SC) which is a fine textured soil (containing more than 50% sand and more than 55% clay) and Silty clay (ZC) which is also a fine textured soil (containing about 20% sand and about 60% clay with about 40-60% silt separates) are the three soil types of this village (Figure 20). In general, the major soil type of this village is slightly heavy.

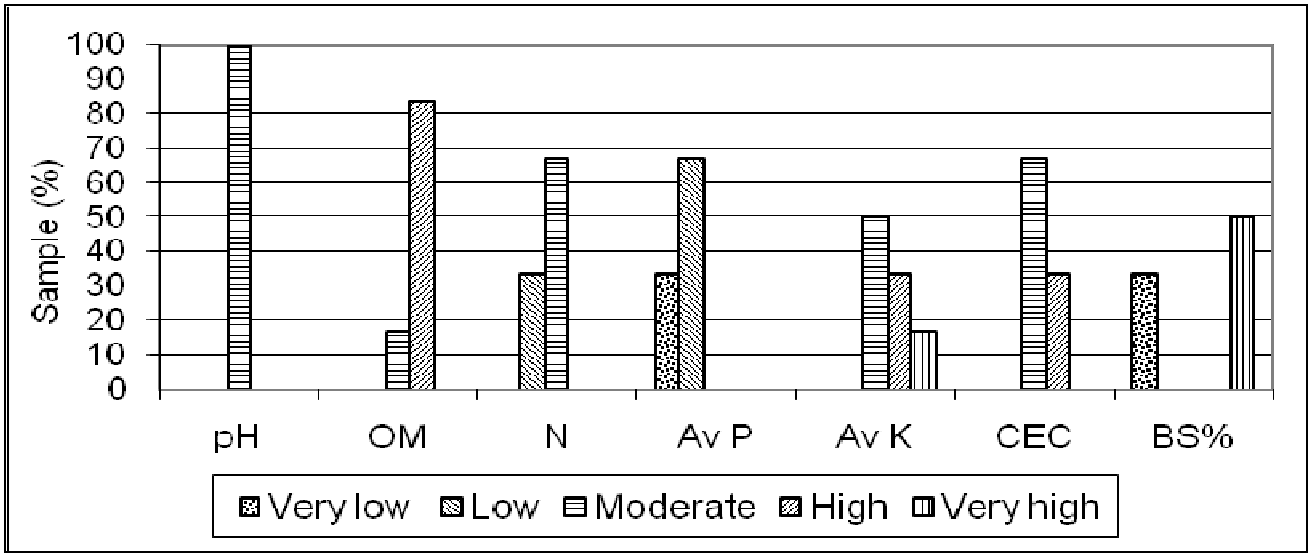

Figure 16 Soil parameters of potato fields in Lawteri village.

3.6.7 Soil result of Womchillo village

The pH of these soils is mostly within the medium range. The OM content of these soils is mostly in the high range. The nitrogen is within the low to medium ranges. About ***44% of the samples have very low to low P*** values and ***19% of the samples*** within the ***medium range*** while about ***44% of the samples have high P*** values. Therefore, for those with low to medium values, there is the need to ***apply P containing fertilizers such as SSP or TSP***. About ***44% of the samples have very low to low K*** values, while about ***50% of them have medium K*** values and only about ***6% 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 mostly within the low to medium ranges. For those soils with low CEC values, all major macro and micronutrients may be required to attain adequate growth and thereby yield. The BS% range of these soils is within the low to medium ranges.

Sandy clay loam (SCL) which is a 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 a moderately fine textured soil (containing about 50% sand and about 40% clay separates) and to a lesser extent, sandy loam (SL) which is a moderately coarse textured soil, containing about more than 50% sand and about 20% clay separates (Figure 20).

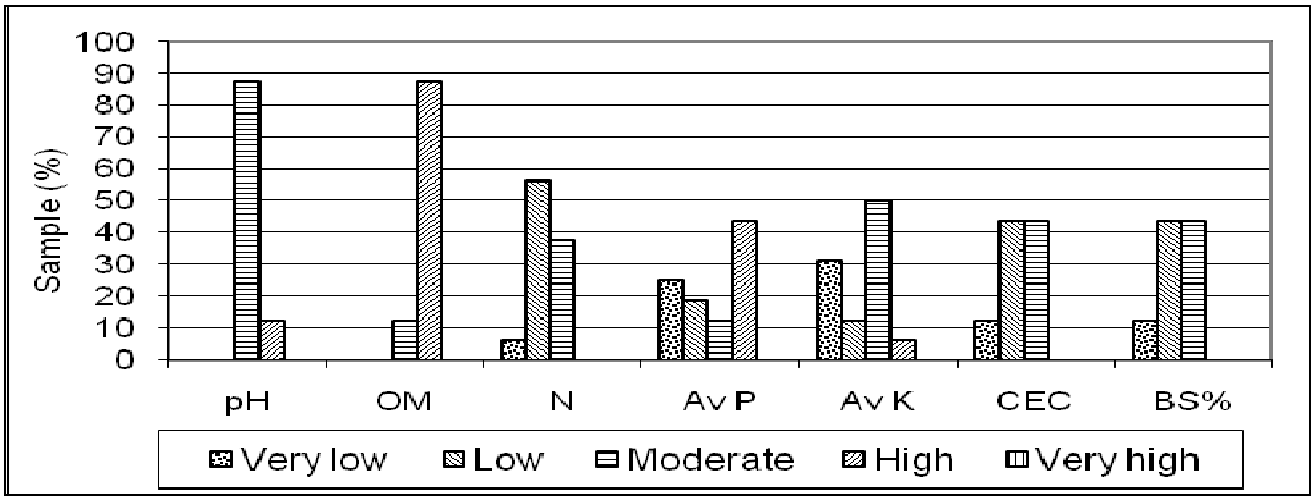

Figure 17 Soil parameters of potato fields in Womchillo village.

3.6.8 Soil result of Teyphu village

The pH of the soils is mostly within the medium range. About 50% of these samples have high OM% while about 38% of the samples have medium OM % and only about 13% in the low range. About ***50% of the samples have very low to low P*** values and about 25% of the samples are within the medium range and the rest in the high range. Therefore, for those with low to medium P values, there is the need to ***apply P containing fertilizers such as SSP or TSP***. About ***88% of the samples have very low to low K values*** and only about 12% have high K values. Therefore, in this village there is the need to apply ***K containing fertilizers such as MoP*** especially for those farmers with low K values. The CEC and the BS% of these soils are distributed from low to medium to high 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 a moderately fine textured soil (containing more than 45% sand and about 35% clay separates) is the predominant soil type followed by Sandy loam (SL) which is a moderately coarse textured soil (containing about more than 50% sand and about 20% clay separates) and clay loam (CL) which is a moderately fine textured soil (containing about 50% sand and about 40% clay separates) are the three major soil types of this village (Figure 20).

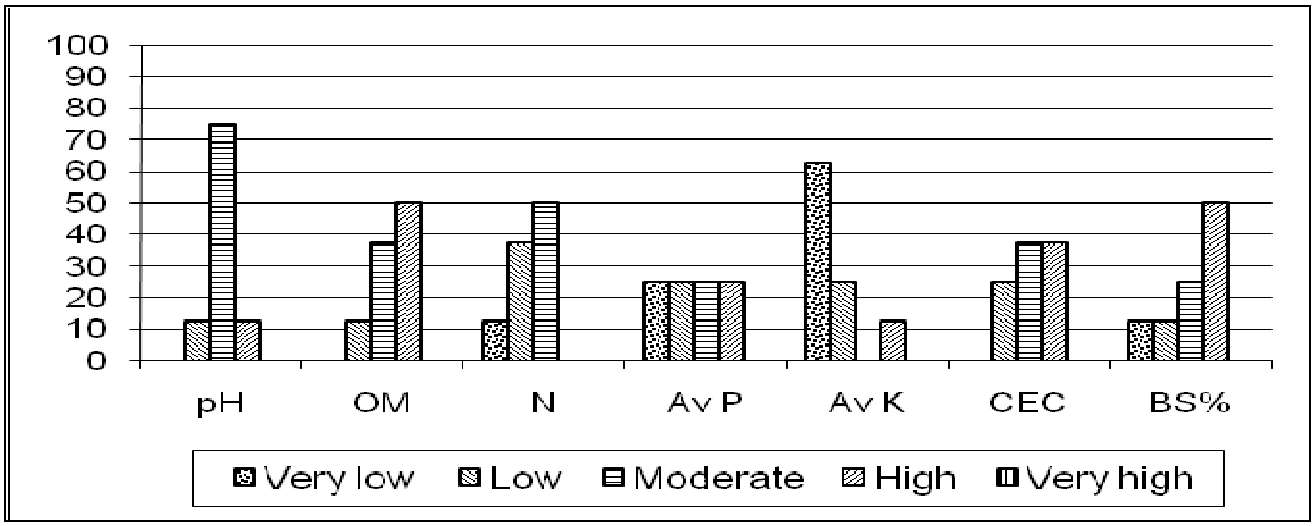

Figure 18 Soil parameters of potato fields in Teyphu village.

3.6.9 Soil result of Changchung village

The pH of the soils in this village is mostly within the medium to high range which is within the ideal pH range for growing most agronomic crops. The OM% of this village is high. The N content of these soils is mostly within the low to medium ranges. The ***available P is low for all the samples in this village*** and therefore, the need to ***apply P containing fertilizers such as SSP or TSP to whole village.*** The ***available K content of these soils is also within the low to medium ranges***. Therefore, in this village there is the need to apply ***K containing fertilizers such as MoP*** for all the farmers. The CEC is mostly within the high range while the BS% of these soils is within the medium to high ranges.

In this village about 86% of the samples have clay loam (CL) which is a moderately fine textured soil (containing about 50% sand and about 40% clay separates) and about 14% of these samples have Sandy clay loam (SCL) which is a moderately fine textured soil containing more than 45% sand and about 35% clay separates (Figure 20).

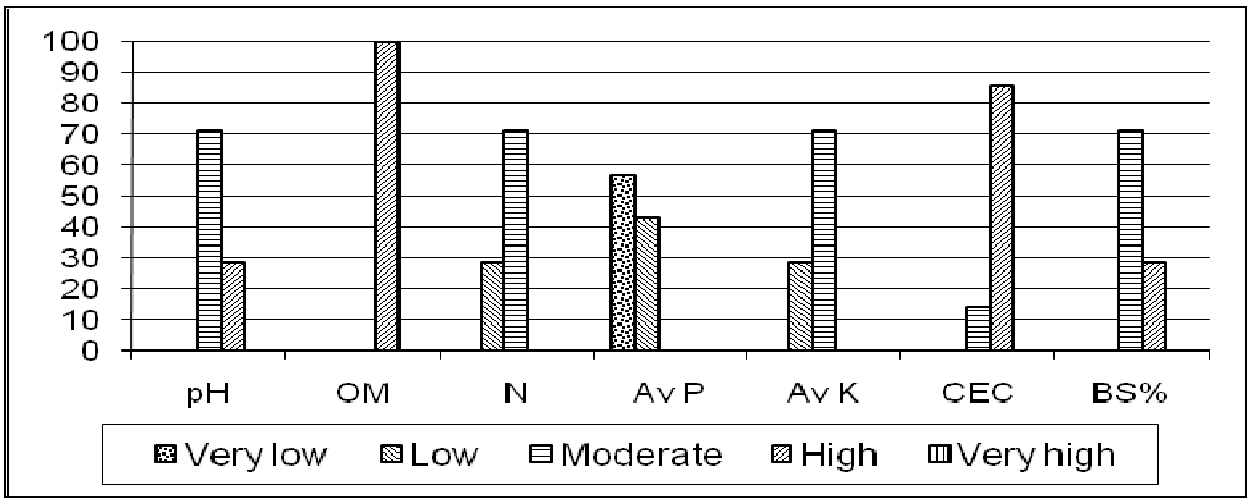

Figure 19 Soil parameters of potato fields in Changchung village.

3.7 Soil texture of different villages under Nanong geog

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

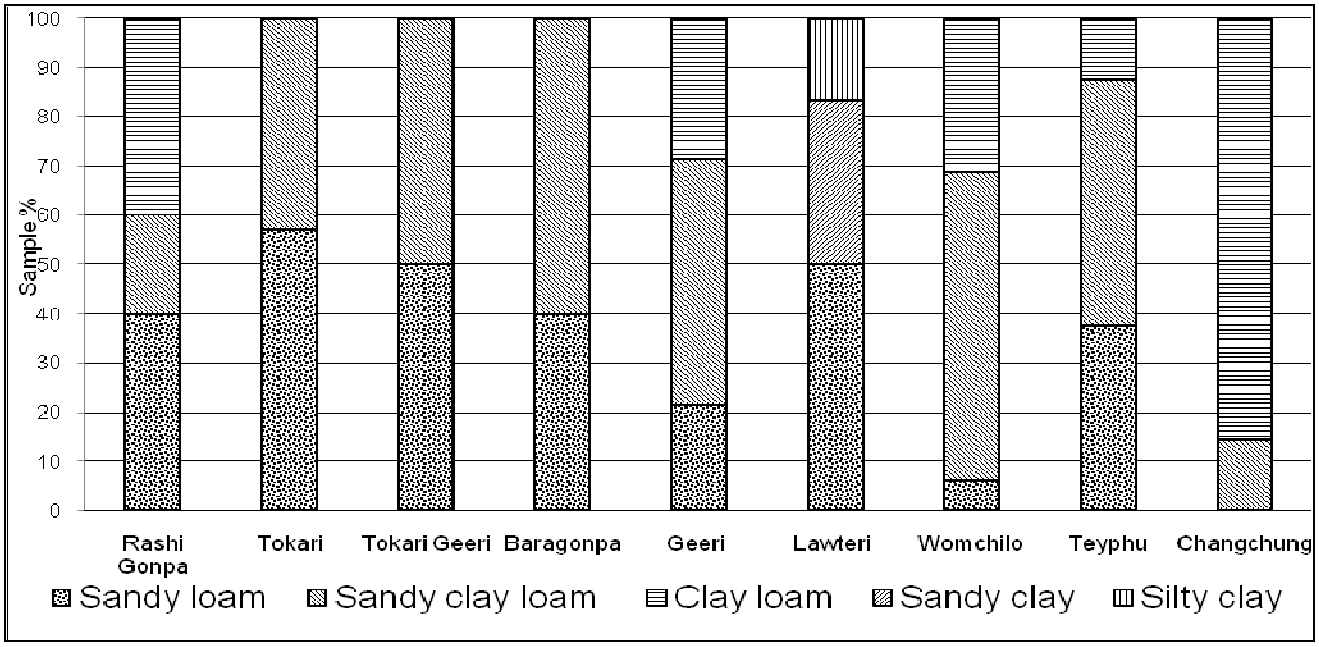

Figure 20 Soil textures of potato fields in different villages under Nanong geog.

4. Conclusions

In Nanong geog, the survey findings indicate that more than 67% of the sampled plots are located at low altitude range of (<2000 m.asl) and the majority of the plots are situated on steep slopes, followed by moderately sloping areas. Most of the sampled plots are north facing aspects followed by west facing aspects. The average field size for potato plantation is less than 1 acre. Desiree is the most preferred potato variety grown by the farmers, followed by the local variety.

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 18.67 tac^{-1} of FYM, which is quite high in comparison to Trashigang Dzongkhag. The farmers also apply about 61 $kgac^{-1}$ urea to maize and about 120 $kgac^{-1}$ Suphala to potato. Other fertilizers such as SSP and MoP are not applied at all.

The average yield of potato and maize in Nanong geog is 6.53 tac^{-1} and 1.81 tac^{-1} respectively[d]. Changchung village reported the highest yield of potato (18.14 tac^{-1}) and highest maize yield of 4.76 tac^{-1} is reported from Teyphu village. The average potato yield figure from this geog is more or less at par to those of FAO yield estimate for Bhutan (FAO yield estimate for farmer field is about 6.5 tac^{-1}). The lowest yield of potato (2.97 tac^{-1}) is reported from Lawteri village and this figure suggests that the potential yield in some of the villages is yet to be attained. About 21% of the farmers reported that they have changed the potato seeds during the last 5 years and about 43% of them during the last 5-10 years.

[d] The potato yield figure is slightly less than the figures of 2002 (i.e. potato= 8.5 tac^{-1} and maize =1.4 tac^{-1}).

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 high range. The available P is mostly within the low range though few villages 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 within the medium to high range indicating a fairly medium 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, sandy loam and clay loam.

5. Recommendations

- The average nutrient input through inorganic fertilizers to potato and maize is 46 $kgac^{-1}$ N, 18 $kgac^{-1}$ P and K from suphala and urea (i.e 61 $kgac^{-1}$ of urea and 120 $kgac^{-1}$ 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 **46:18:18 kg NPK ac^{-1}** is much lower for K and P, though slightly 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 Teyphu and Changchung villages) 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 $kgac^{-1}$ 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 kgac^{-1} of NPK:**

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

- In order to supply the nutriens 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) [e]:

- 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.

[e] 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 Nanong geog

VERY LOW – LOW P	VERY LOW – LOW K
YANGZOM (RASHI GONPA)	ALL THE FARMERS OF RASHI GONPA VILLAGE ***(EXCEPT NORBU)***
NORBU (RASHI GONPA)	ALL THE FARMERS OF TOKARI
KOTA & LEKZOM (RASHI GONPA)	ALL THE FARMERS OF TOKARI GEERI
ALL THE FARMERS OF TOKARI	ALL THE FARMERS OF BARAGONPA
ALL THE FARMERS OF TOKARI GEERI	ALL THE FAREMRS OF GEERI ***(EXCEPT KEZANG, SONAM, CHETEN WANGDI)***
ALL THE FARMERS OF BARAGONPA	ALL THE FARMERS OF LAWTERI ***(EXCEPT SHERAB, TSHERING WANGDI, JIGME)***
ALL THE FARMERS OF LAWTERI	ALL THE FARMERS OF WOMCHILLO ***(EXCEPT CHHEDON, TSHEWANG)***
ALL THE FARMERS OF CHANGCHUNG	
ALL THE FARMERS OF WOMCHILLO ***(EXCEPT KOTA, BU DORJI, SHEL DEMA, TSHOMO, TEMPA, SONAM, CHHEDON)***	
ALL THE FARMERS OF TEYPHU ***(EXCEPT RINCHEN, ZANGTU/ZAMTO, WANGDI)***	