TABLE OF CONTENTS

List of Figures & Tables

1. Introduction

Following the first batch of soil samples collected (2002) under potato-maize based farming system from 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 a database is being built 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.

Trashigang Dzongkhag in the east is one of the major potato-maize growing Dzongkhags followed by Monggar and Pemagatshel Dzongkhags. Though potatoes are grown throughout the Dzongkhag, Kanglung geog is one of the most intensively cultivated area other than Khaling, Yangneer and Thrimshing geogs.

This report is on the soils of the major potato-maize growing areas of the Trashigang Dzongkhag, one of the important potato-maize growing districts. The National Soil Services Centre (NSSC) collected soil samples from about 81 households spread over 14 villages under Kanglung 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 81 households were selected from the initial 140 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 finding of Kanglung 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 Kanglung geog with fertilizer recommendations based on the findings for each village.

3.1 Sample households

In Kanglung geog, a total of 81 household covering 15 villages[a] were sampled. The highest number of respondents was from Bramtsang gonpa village (12.3%) followed by Naka (11.1%), Rithung gonpa, Yonphu pam, Shingchen gonpa and Yonphula villages with 10% each respondents**.** Dhopung and Tokphay wok villages had the lowest number of respondents (just 1.2% each). These figures suggest that there could be more farmers growing potatoes in Bramtsang gonpa, Naka, Rithung gonpa, Yonphu pam, Shinghcen gonpa and Yonphula villages compared to Dhopung village. 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 Kanglung geog, the majority of the plots (45%) are situated on moderately sloping areas followed by sloping (38%) and about 16% on steep slopes. The majority of the plots are north-easterly (41% of the plots) and north-westerly (28% of plots) facing aspects. More than 90% of the sampled plots are located at medium altitude range (between 2000 and 3000 m.asl) and the rest at the low altitude range (less than 2000 m.asl). The majority of the farmers (more than 80%) of the samples sites have small plot sizes (< or =1 acre). The majority of the farmers (60%) grow both the varieties (i.e. Desiree & Yusi karp), about 23% of the farmers grow Yusikarp only and about 11% of the farmers grow only Desiree. Few farmers (about 4%) grow their own local variety.

3.3 Crop 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.

As in any other village or geog in the east, potato is usually intercropped with maize. Maize is usually sown about a month after 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 Kanglung geog is 4.14 tac^{-1} and 1.25 tac^{-1} respectively. From Figure 1 it can be observed that the maximum potato yield of 5.32 tac^{-1} and maize yield of 2.67 tac^{-1} is reported from Dhurung village followed by Bramtsang gonpa and Tokphay Wok villages with 4.22 tac^{-1} and 4.2 $tac^{-1}$of potato yield. The lowest potato yield of 1.55 tac^{-1} is reported from Yonphula. These figures suggest that the potential yield level has not been attained yet and there is the possibility of increasing returns with proper management practices.

The farmers reported wild animal damage as one of the major constraints to good harvest.

[a] Villages under Kanglung geog: Yonphula, Shingchen Gonpa, Yonphu pam, Naka, Fiskang, Rithung gonpa, Dhopung, Mertsham, Dhurung, Tokphay wok, Khugonpa, Dhopung, Asham drelo, Bramtsang gonpa and Thaptsang rong.
[b] According to FAO reports

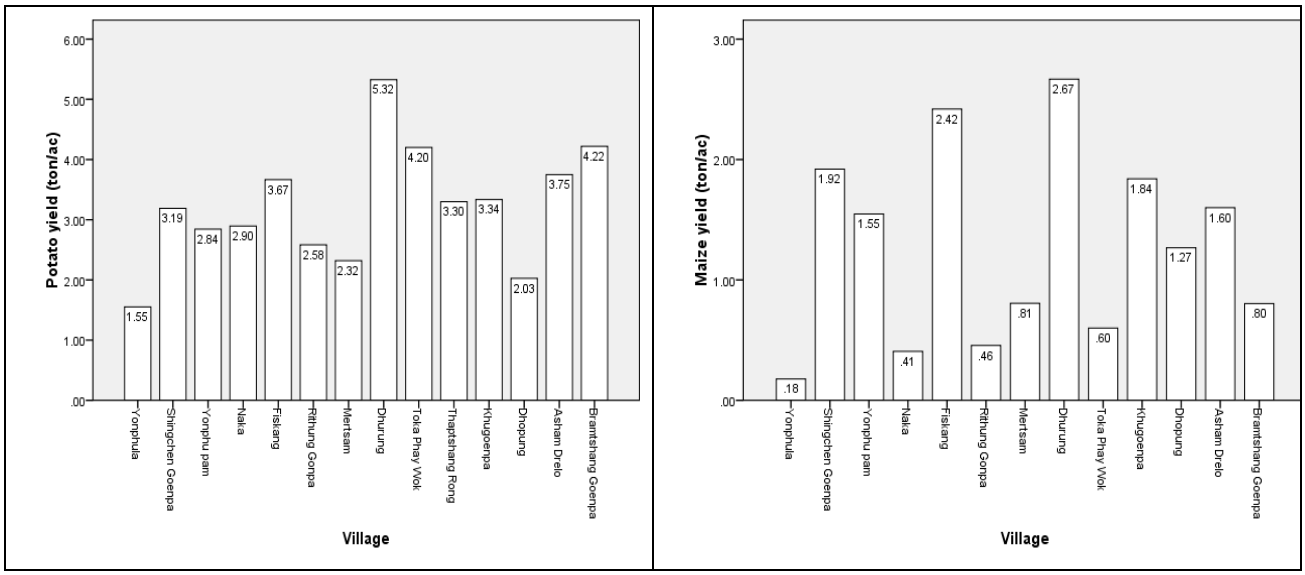


Figure 1 Average potato and maize yield (tac^{-1}) under each village

In Kanglung geog, most of the farmers (almost 75%) reported that they have not changed the potato seeds at all and this could be one important factor to consider for yield increase in addition to fertilizer inputs and other management aspects. Only about 25% reported that they have changed their seeds and from this percentage only about 15% have changed their seeds during the last 5 years while about 8% of the farmers reported having changed their seeds during the last 5-10 years.

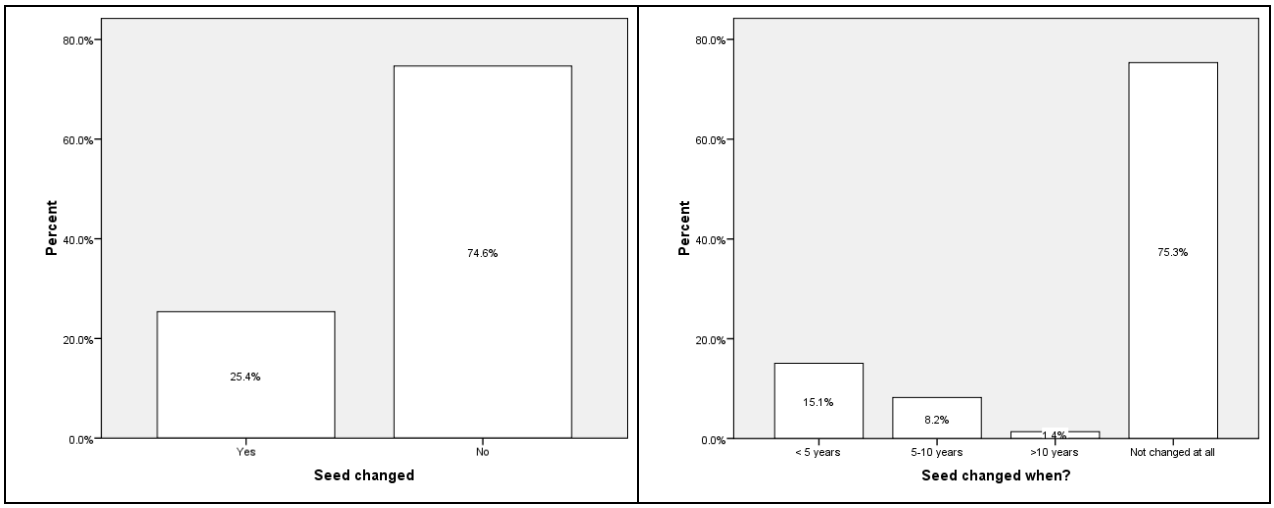


Figure 2 Potato seeds changed?

3.3.1 Soil fertility management practices

3.4.1 Farm Yard Manure (FYM)

In Kanglung geog, majority of the farmers apply FYM to their fields and only a handful (those without cattle) don't apply FYM. The average FYM application rate is 7.18 tac^{-1} (equivalent to 99.1 kg N ac^{-1}, 20.8kg P ac^{-1} and 141.45 kg K ac^{-1} and 168.7 kg Ca ac^{-1})[c]. FYM is usually broadcasted on the fields and incorporated into the soil by ploughing during land preparation. Yonphula (about 14.98 tac^{-1}, Shingchen gonpa (14.34 tac^{-1}), Rithung gonpa (11.13 tac^{-1}) and Naka (11 tac^{-1}) villages apply more FYM compared to other villages of this geog.

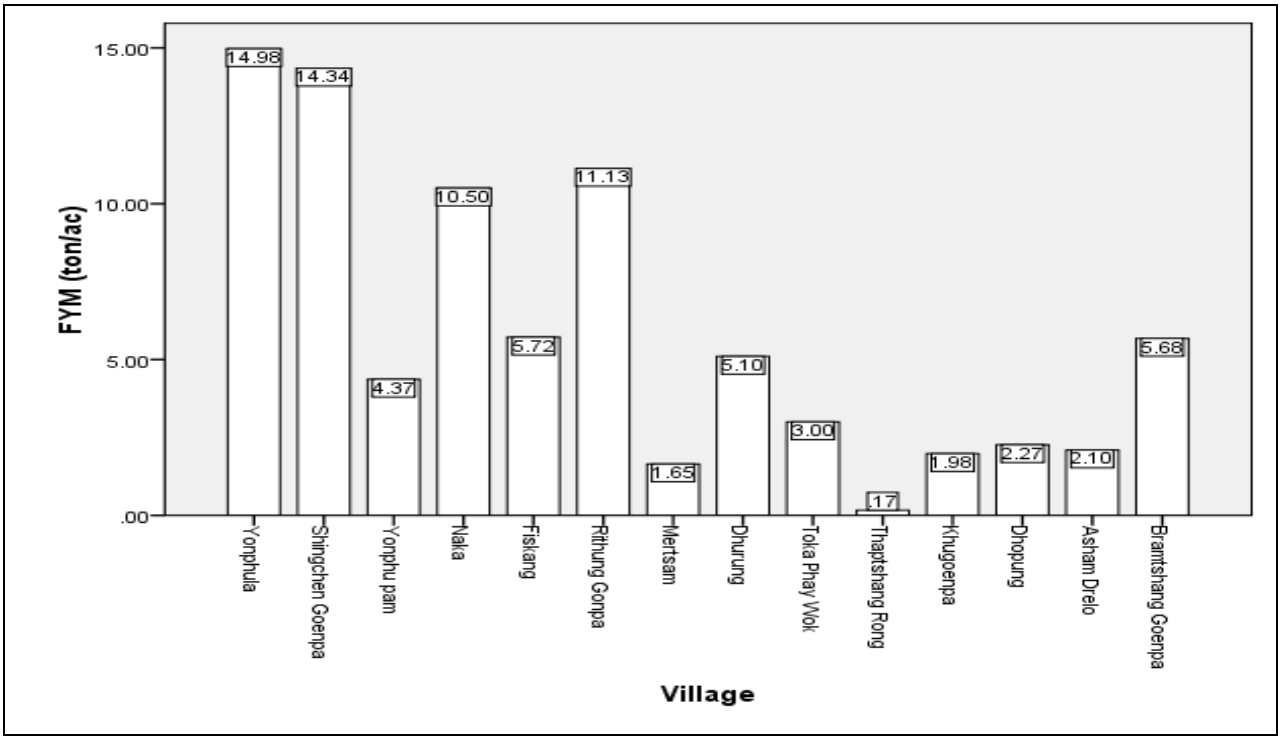


Figure 3 Amount of FYM applied (tac^{-1}) under each village.

3.4.2 Inorganic fertilizers

The survey findings indicate that all the farmers (100%) of this geog apply inorganic fertilizers to potato and maize. Suphala, Urea and SSP are applied to potato while some urea is also applied to maize as top dress during tassling stage. The farmers apply either supahala with urea or SSP with urea to potato. The farmers of Rithung gonpa still apply urea and SSP in the ratio of 1:2 as per the training they attended during the BNPP time in the late 90s. The average rates of fertilizers applied in this geog are about 197 $kgac^{-1}$ urea (inclusive of the application to potato & maize), 243 $kgac^{-1}$ SSP and 120 $kgac^{-1}$ Suphala and these amount to about 108 $kgac^{-1}$ N, 57 $kgac^{-1}$P and 18 $kgac^{-1}$ K. Most of the farmers of this geog apply suphala and urea to potato.

[c] Mean FYM dry matter nutrient content is 1.38%N, 0.29%P, 1.97%K, 2.35% Ca (Source: SSF&PNMP, 2001).

Potash 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. From the interview, the farmers reported that there is no stock of Potash fertilizers in their geog and hence MoP is not at all applied in this geog.

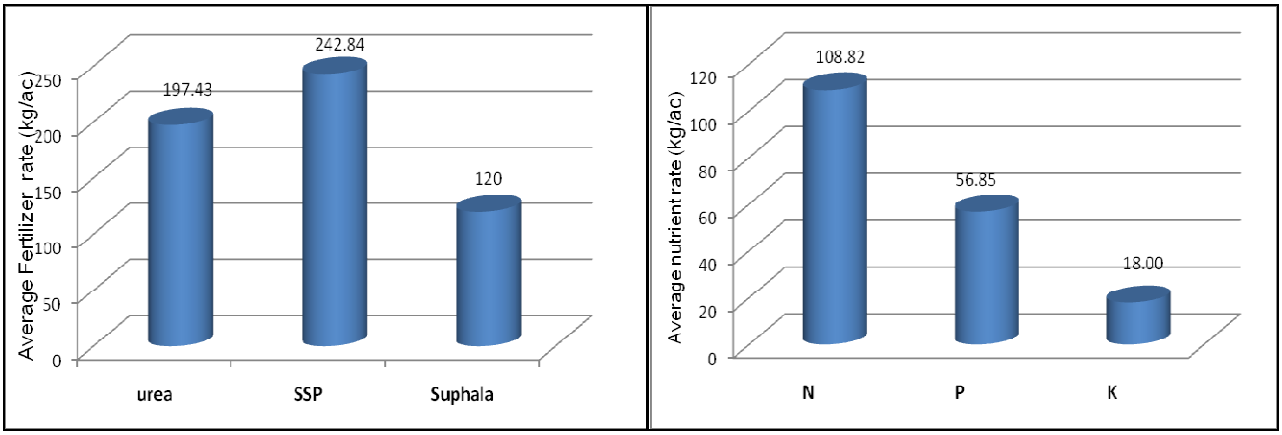


Figure 4 Average rates of fertilizer and nutrients applied ($kgac^{-1}$) in the geog.

The highest application of suphala is reported from Yonphula, Thaptsang rong, Tokphay wok and Shingchen gonpa while villages like Dhopung, Mertsham and Asham Drelo don't apply any suphala. SSP is completely not applied in Yonphula.

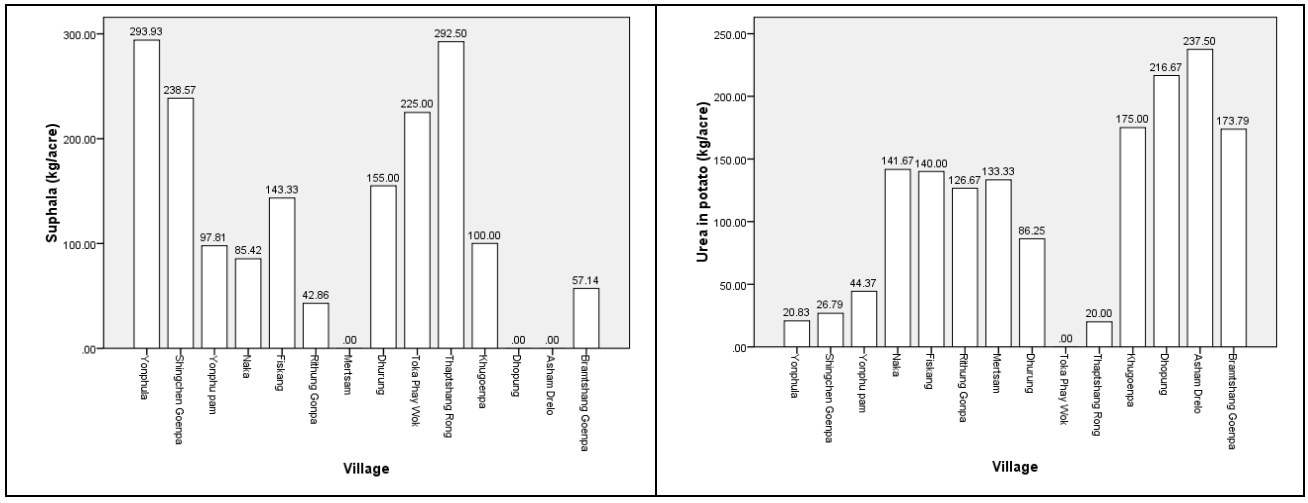


Figure 5. Amount of Suphala & urea ($kgac^{-1}$) applied to potato under each village.

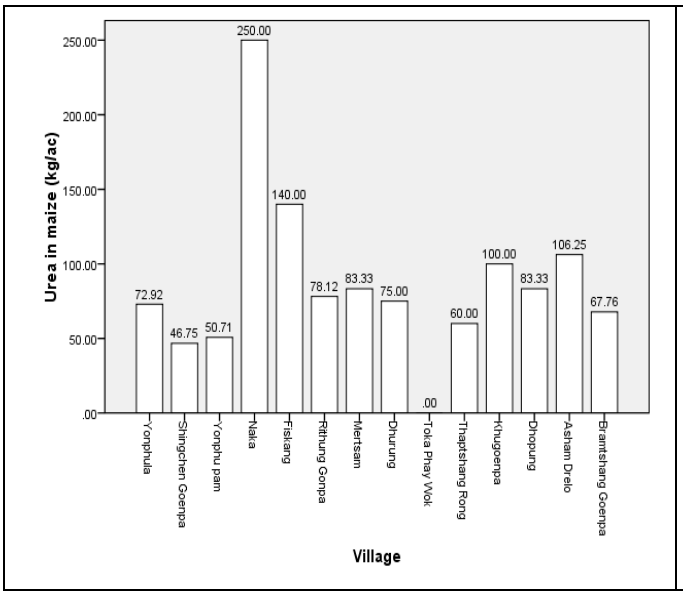


Figure 6a. Amount of urea applied ($kgac^{-1}$) under each village

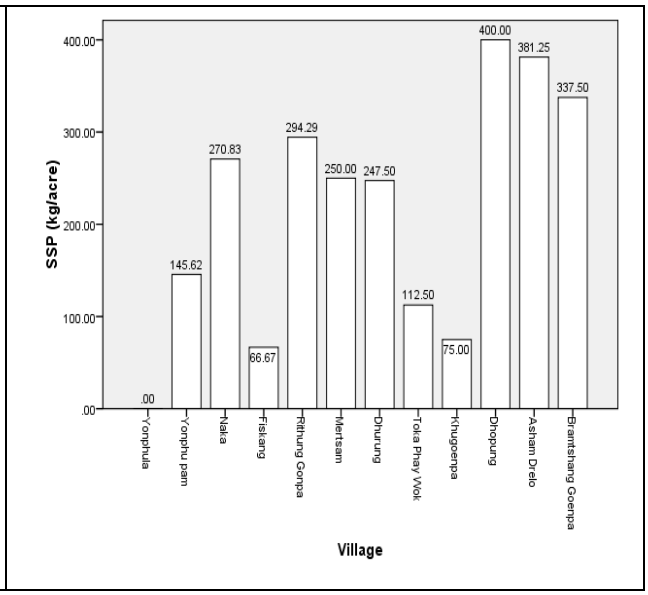
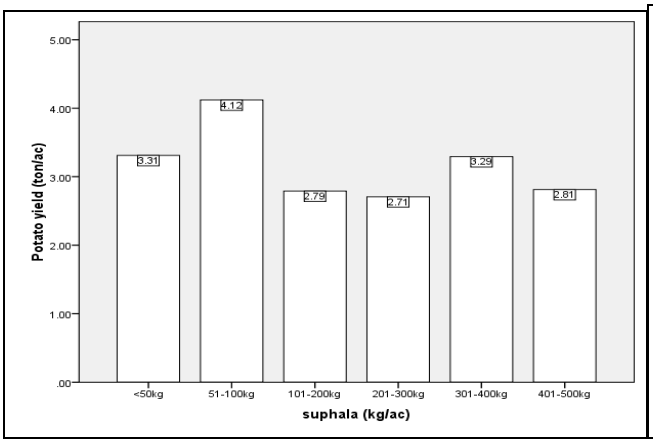
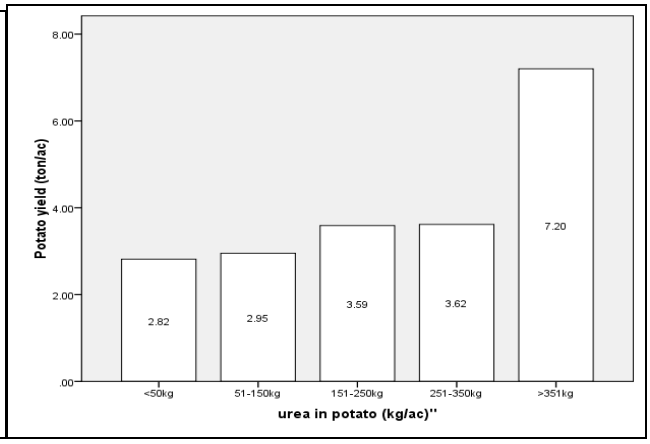


Figure 6b. Maize yield vs Urea applied

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 urea application to potato. The maximum potato yield was about 7 tac^{-1} when urea application rate was more than 350 $kgac^{-1}$ though not much difference is observed with increasing rate of suphala application. There was no positive response of maize yield with urea application rates.





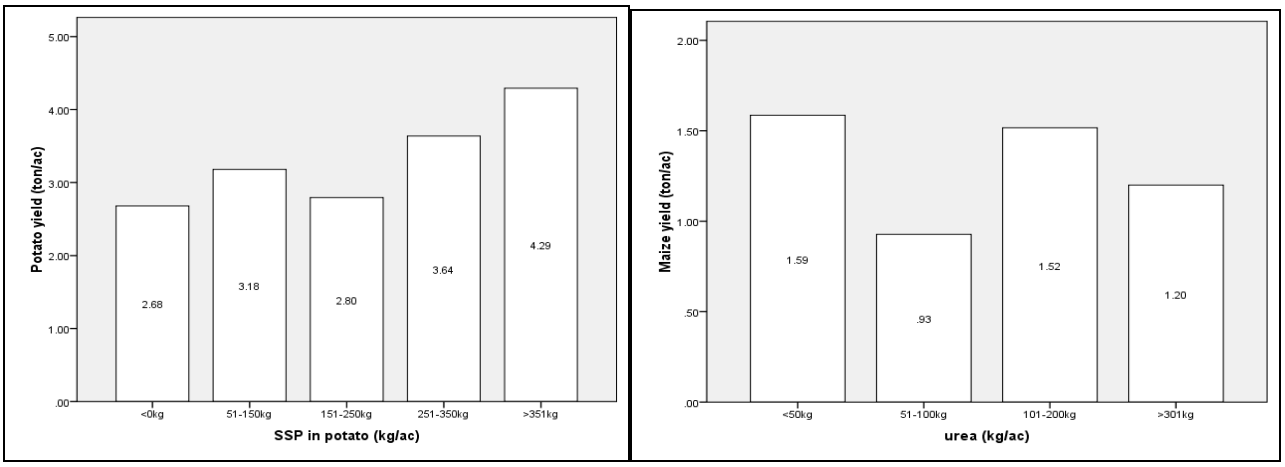


Figure 3 Potato and maize yield in relation to inorganic fertilizer applied in the geog.

Potatoes respond well to moisture, however, irrigation at tuber initiation can affect the skin quality of daughter tubers by influencing phytopathogens, either favourably 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 Kanglung 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 high (>7.5), high (6.5 to 7.5), medium (5.5 to 6.5), low (5.0 to 5.5) and very low (<5.0).

The majority (more than 55%) 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 growth is 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 range. Usually the organic matter content of the soils can be increased by incorporating farm yard manure and other organic materials into the soil.

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 56% of the samples have low to very low available P while about 19% is within the medium range and only about 24% is within 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 Yonphula, Shingchen gonpa, Dhopung, Dhurung, Bramtsang gonpa, Tokphay wok and Thaptsang rong 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).

3.5.4 Available potassium (K)

As 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 58% of the samples have low to very low available K and about 25% within the medium range and only about 17% within the high range. In general, the K content of these soils is poor and the farmers of Yonphu pam, Fiskang, Dhopung, Dhurung, Mertsham and Rithung gonpa need to apply K containing fertilizers such as MoP.

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 low. 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 within the low to medium range indicating a fairly poor soil fertility status.

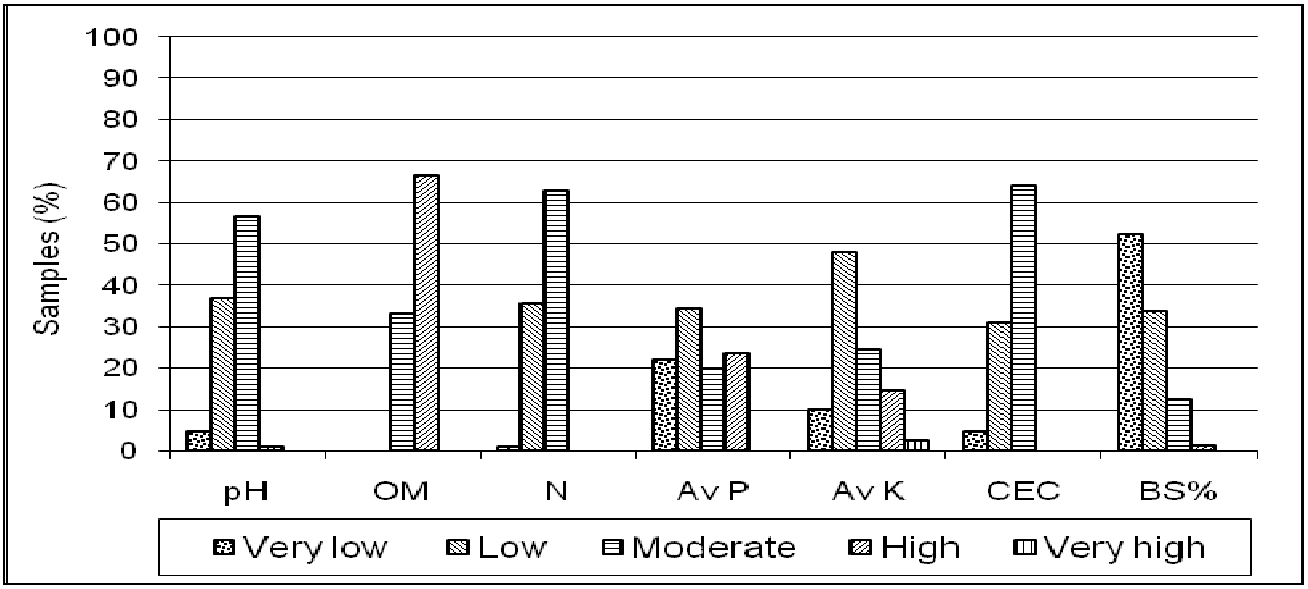


Figure 7. Soil parameters of potato fields under Kanglung geog.

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 loam (SL) which is a fine textured soil and Sandy clay loam (SCL) which is a medium textured soil are the two dominant soil textures of this geog (48% and 17% respectively).

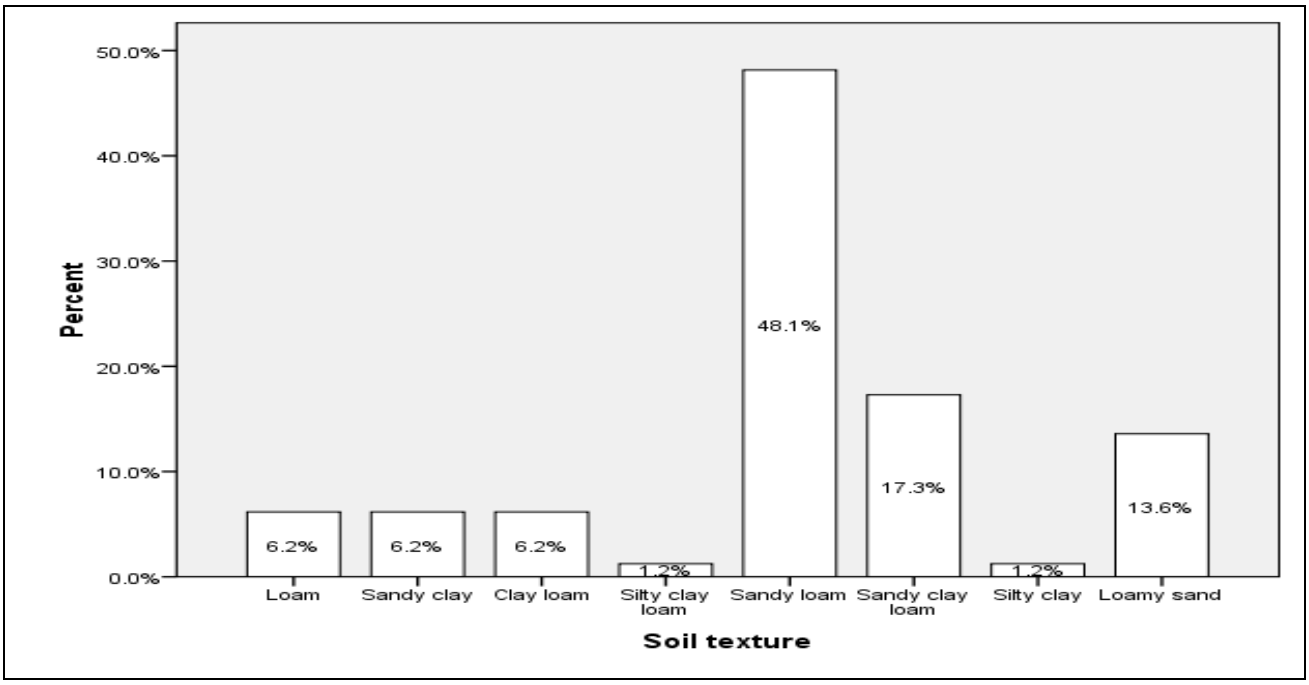


Figure 8 Soil texture of potato fields under Kanglung geog (average of all villages)

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

3.6 Soil analytical result of individual village under Kanglung geog

3.6.1 Soil result of Yonphula village

The pH of the soils of this village is mostly within the low range while it is very low for two farmers (viz Kunzangla & Lhadip Lobzang) with pH value of 4.84. Research has shown that once the pH drops below 4.8, growth is impaired and therefore the soil may need to be corrected. However, another round of sample could be collected from these two sites for further confirmation. The organic matter content of Yonphula village is mostly within the high range (more than 85% of the samples). The nitrogen content is mostly within the medium range. ***About 50% of these soils have low P and K values and therefore the need to apply P and K containing fertilizers such as SSP such as MoP respectively.*** Only about 10% have high P values while about 38% have medium P values. The CEC values are mostly within the medium to high range though the BS% range of these soils is very low.

The major soil type of this village is sandy clay, is a fine textured soil and loamy sand, a moderately coarse textured soil (Figure 23).

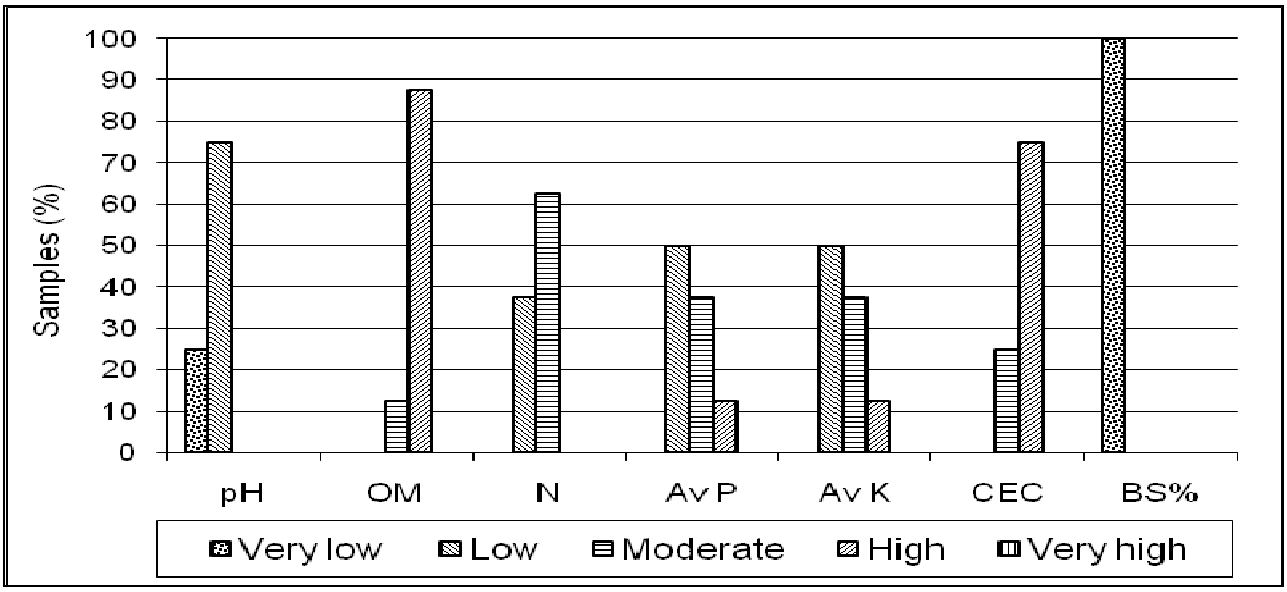


Figure 9 Soil parameters of potato fields in Yonphula village.

3.6.2 Soil result of Shingchen Gonpa village

The pH of the soils of this village is mostly within the medium range which is ideal for growing almost all crops. The soil organic matter content is high and this could be due to the application of FYM (about 14 tac^{-1}) to their fields. The N content is within the medium range. The **available P content of these soils is *very low*** (more than 87% of samples) and only about 12% of the samples is within the medium range. Therefore, to get a good yield, there is ***a need to apply P containing fertilizers such as SSP*** in this village. The available K is mostly within the high range and only ***two farmers have low K values (viz. Aum Dechen & Karma)*** and as potatoes are good extractors of K, there is a ***need to apply K containing fertilizers such as MoP for these two farmers only***. The CEC of these soils is high which could indicate a fairly good soil fertility status. The base saturation is distributed within the very low to medium ranges. Sandy loam and loamy sand are the two types of soils in this village (Figure 23).

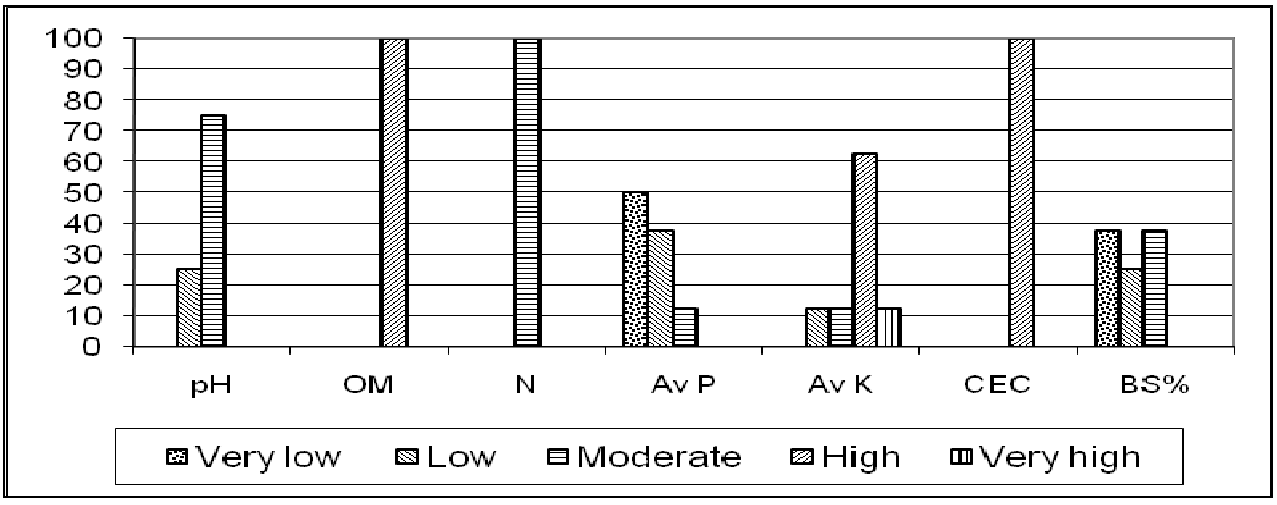


Figure 10 Soil parameters of potato fields in Shingchen Gonpa village.

3.6.3 Soil result of Thaptsang Rong village

About 60% of these soils are within the medium pH ranges and the rest within the low ranges. The organic matter content of these soils is mostly high. The ***available P of these soils is mostly within the low to very low ranges (more than 80%)*** indicating the need to **apply P containing fertilizers such as *SSP or TSP***. The available K content of these soils are mostly within the low to medium ranges (about 80% of these soils) and therefore need to ***apply K containing fertilizers such as MoP*** to improve the nutrient status of these soils. The CEC of these soils is mostly within the medium to high range while the BS% range of these soils is within the very low to low ranges. The soil type of this village is sandy loam which is of moderately coarse textured soils containing less than 20% clay content (Figure 23). In such soils, usually a split application of N is advisable.

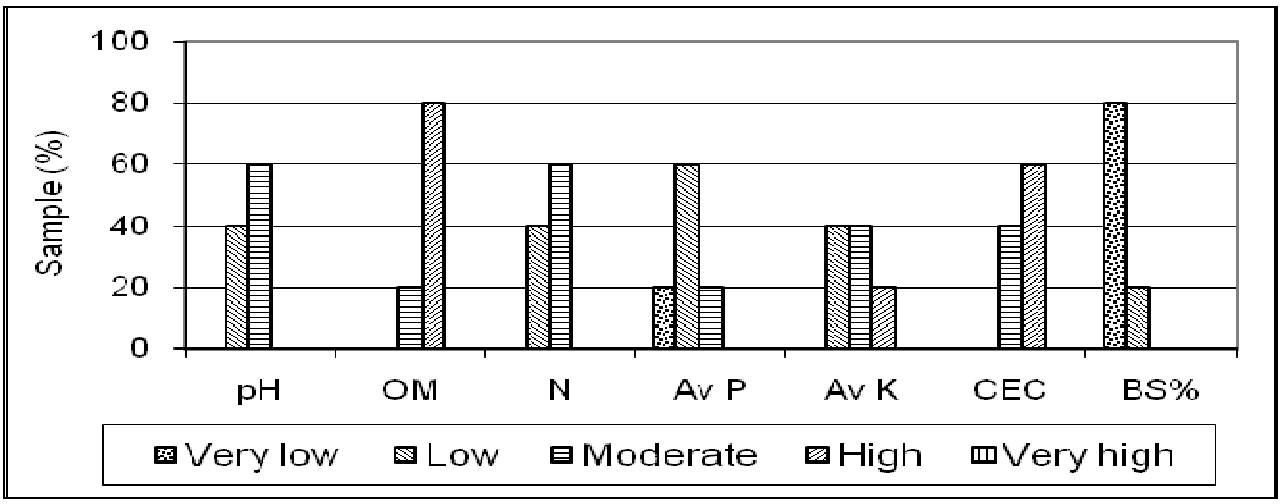


Figure 11 Soil parameters of potato fields in Thaptsang Rong village.

3.6.4 Soil result of Yonphu Pam village

The pH of the soils of this village is mostly within the medium range (almost 90% of these samples). The organic matter content of these soils is within the medium range. The N content of these soils is mostly within the low range. The available P of these soils is distributed from very low to high ranges, with 50% of these samples within the high ranges and only about 25% within the ***very low to low ranges (viz. Sonam Tobgay and Kinzang Dema)*** and for these two farmers with low to very low 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 also mostly in the medium range (50% of the samples) while about ***37***% are within the low range and therefore the ***need to apply K containing fertilizers such as MoP (viz. all the farmers except Sonam Tobgay).*** 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 to high ranges. The BS% range of these soils is evenly distributed from very low to very high ranges. Sandy loam, a moderately coarse to medium textured soil is the dominant soil types of this village and therefore a split application of N is advisable (Figure 23).

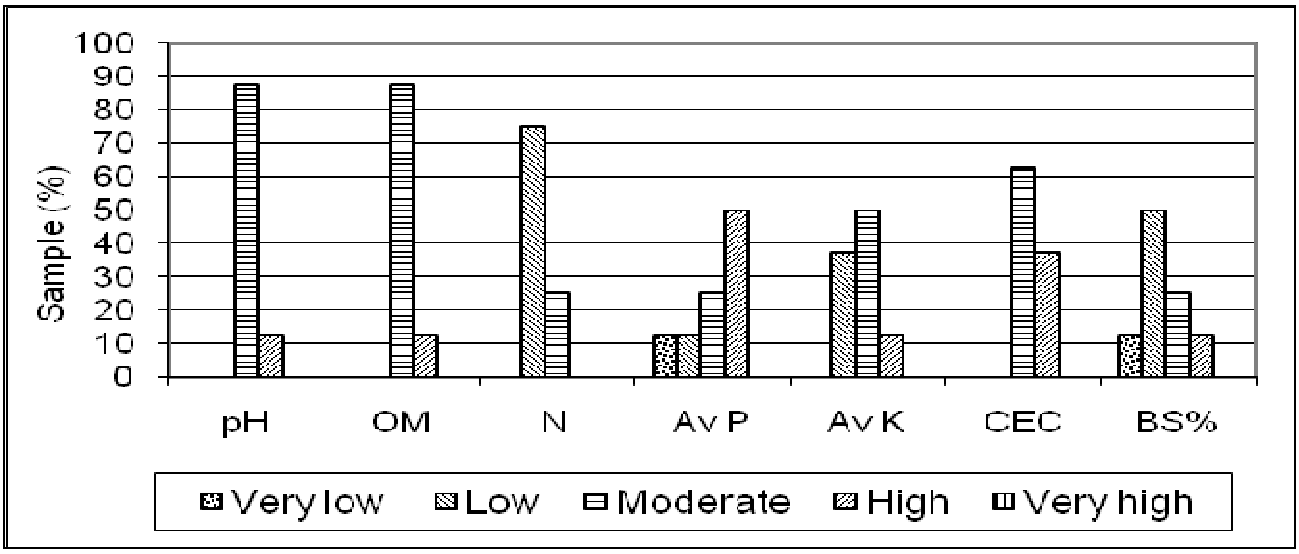


Figure 12 Soil parameters of potato fields in Yonphu Pam village.

3.6.5 Soil result of Naka village

The pH of these soils is within the medium range. The organic matter content of the soils in Naka village is within the medium to high range. The N content of these soils is within the low to medium range. More than **40% of these soils have low available P** contents and about 11% within the medium range while about 45% are within the high range. ***For those with low to medium P values, there is the need to apply P containing fertilizer such as SSP or TSP*** (refer Table 1 for name list). The available K is all in the very low to low ranges and therefore the **need to *apply K containing fertilizers such as MoP.*** The CEC is mostly within the medium range. The BS% range of these soils is within the very low to low ranges. The major soil type is sandy loam (Figure 23), which is moderately coarse to medium textured soil containing less than 30% clay content. (Name list of low P values, please refer Table 1)

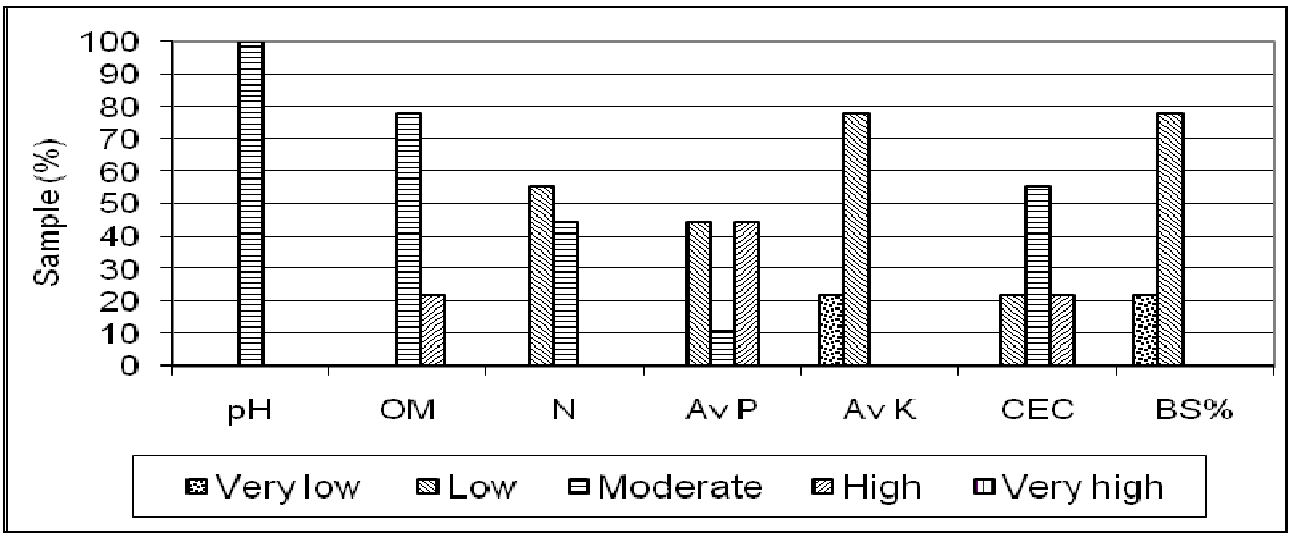


Figure 13 Soil parameters of potato fields in Naka village.

3.6.6 Soil result of Fiskang village

The pH and the organic matter content of the soils of this village are all within the medium range. The nitrogen is low. About 33% each of the samples have low, medium and high P values and therefore those with ***low to medium values, there is the need to apply P containing fertilizers such as SSP or TSP***. The available K content is mostly within the ***medium range*** (about 67% of the samples) and the rest in the ***low range***. As potatoes are good extractors of K, there is the ***need to apply K containing fertilizers such as MoP to this village.*** The CEC of these soils is mostly within the low to medium ranges and in 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, a moderately fine textured soil containing more than 35% clay content is the prominent soil type of this village (Figure 23).

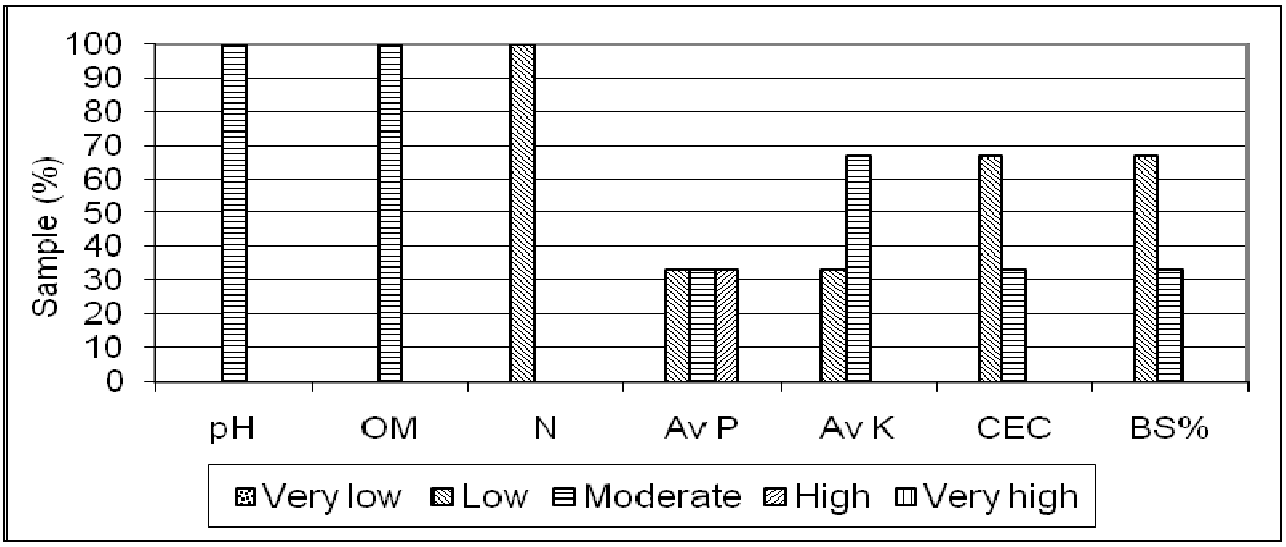


Figure 14 Soil parameters of potato fields in Fiskang village.

3.6.7 Soil result of Rithung Gonpa village

The pH of the soils of this village is mostly within the low to medium ranges and only one farmer within the very low range (pH of 4.89) and for this farmer (Sonam Choden) no FYM is applied to the fields as she have any cattle. The organic matter content of the soils in this village is mostly within the high range. About **50% of these soils have very low to low available P** (See Table 1 for the name list) and therefore the need to ***apply P containing fertilizers such as SSP or TSP*** while the other 50% of these soils have high P status. ***The available K*** content of these soils is ***within the very low to low ranges and therefore the need to add K containing fertilizers such as MoP.*** The CEC of these soils is in the medium to high range with BS% distributed from very low to medium ranges. Sandy loam (more than 60% of these samples) and loam (about 40% of the samples) are the major soil types in this village (Figure 23).

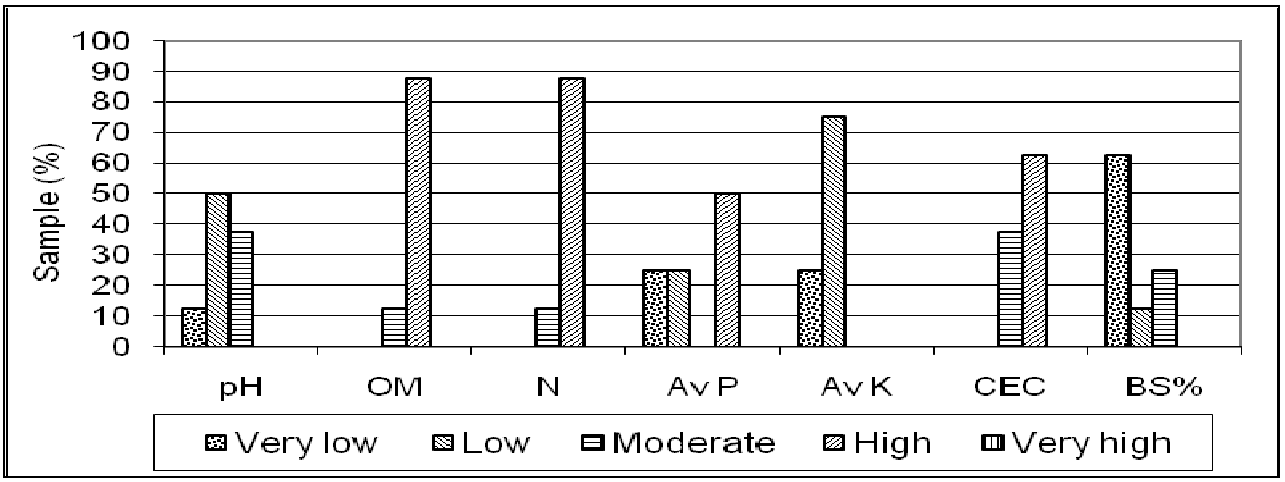


Figure 15 Soil parameters of potato fields in Rithung Gonpa village.

3.6.8 Soil result of Khugonpa village

The pH and the N content of these soils are within the medium range. The organic matter content (OM%) is within the medium to high range. ***The available P is mostly in the low range*** (60% of the samples) and therefore **the need to apply P containing fertilizers such as SSP or TSP** (See Table 1 for name list). The ***available K is within the very low to low to medium ranges*** and since potatoes are good extractors of K, there is th***e need to apply K containing fertilizers such as MoP*** (refer Table 1 for name list). The CEC of these soils is mostly within the high range while the BS% is fairly distributed from very low to medium ranges. Clay loam, a moderately fine textured soil containing about 40% clay separates with less than 45% sand content is the dominant soil type of this village. The other soil types found in this village are sandy clay loam and loam (Figure 23).

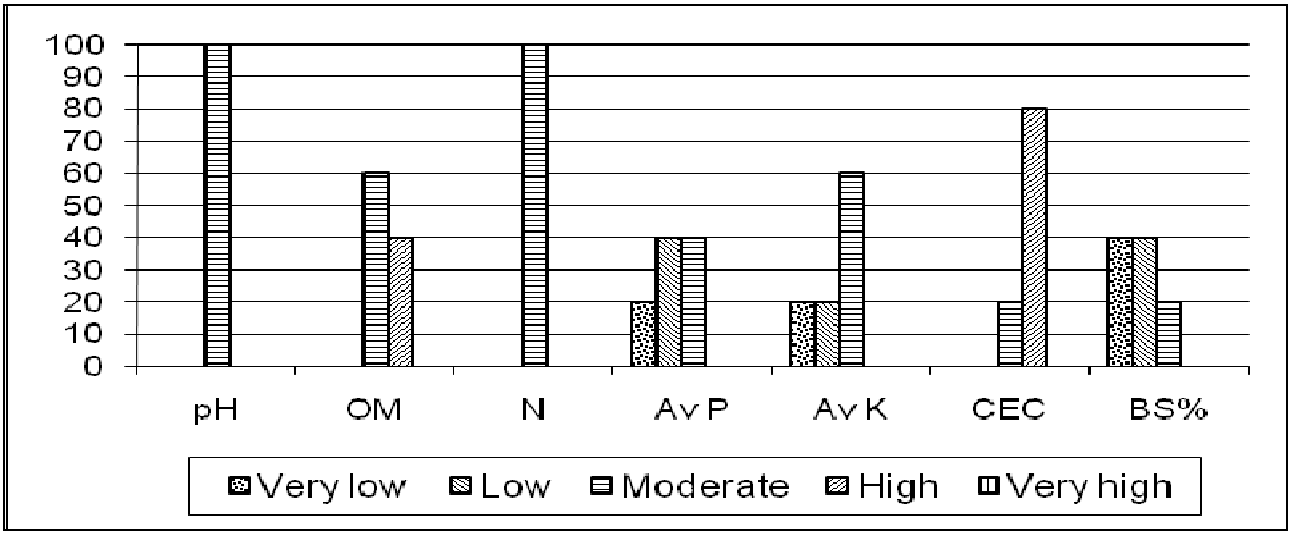


Figure 16 Soil parameters of potato fields in Khugonpa village.

3.6.9 Soil result of Dhopung village

The pH of the soils of this village is mostly within the low to medium ranges. The organic matter content of these soils is high. The N content is within the medium range. ***The available P is very low***

for all the soils. The ***available K is also mostly within the low range*** and very few in the medium range. Therefore, for this village there is ***the need to apply both the P and K containing fertilizers such as SSP/ TSP and MoP*** respectively (refer Table 1). The CEC is high for the soils in this village though the BS% is very low. Sandy loam and sandy clay loam are the two dominant soil types of this village (Figure 23).

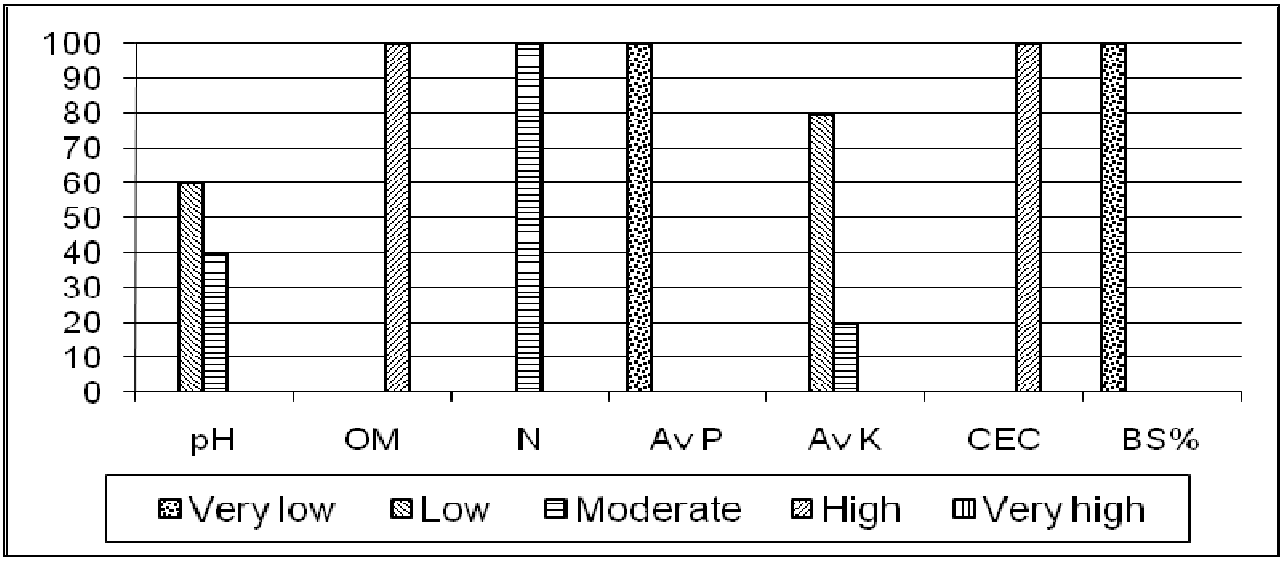


Figure 17 Soil parameters of potato fields in Dhopung village.

3.6.10 Soil result of Mertsham village

The pH of the soils of this village is mostly within the low to medium ranges while the organic matter content is high. The N content of these soils is mostly within the medium range. For this village, the ***available P is either very low or low*** (66% of the sample, See table 1 for name list) and therefore the need to ***apply P containing fertilizers such as SSP or TSP***. The ***available K is low for all the soils*** in this village and so the ***need to apply K containing fertilizers such as MoP*** (refer Table 1). The CEC of these soils is mostly within the medium to high range while the BS% is within the very low to low ranges. Sandy clay loam (moderately fine textured soil with more than 50% sand content with less than 40% clay content) and loamy sand (coarse textured soil containing less than 15% clay separates with more than 80% sand content) are the two major soil types of this village (Figure 23). For those soils with light/coarse textured soils, split application of N is advisable.

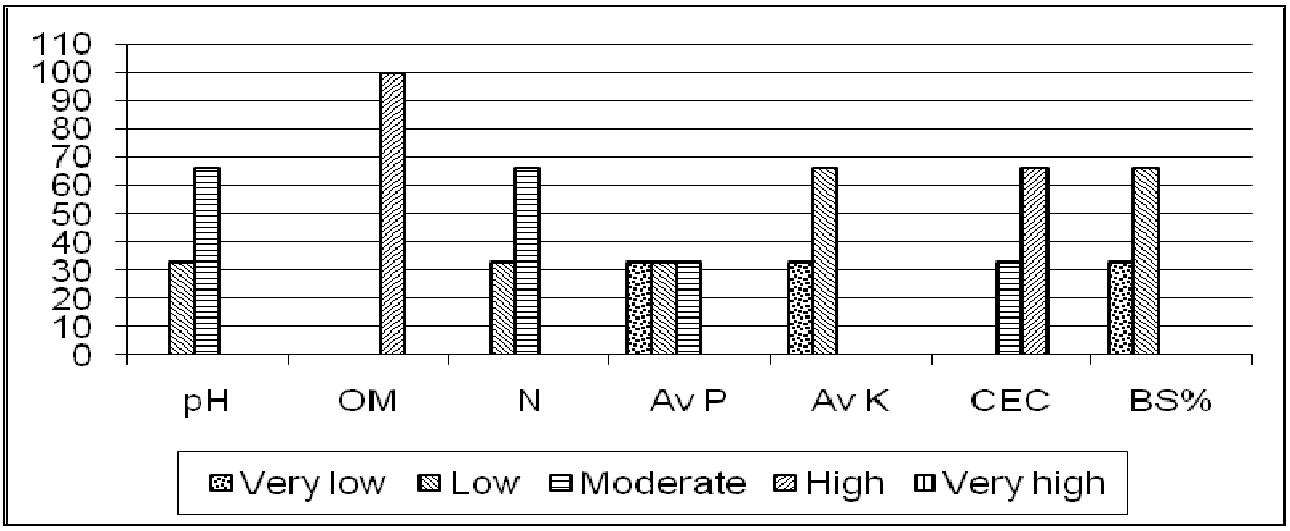


Figure 18 Soil parameters of potato fields in Mertsham village.

3.6.11 Soil result of Asham Drelo village

The pH of these soils is within the medium range while the organic matter content is within the medium to high ranges. The nitrogen content is within the low to medium ranges for these soils. About 25% of these samples have ***low P values indicating the need to apply P containing fertilisers such as SSP or TSP to improve the P content of these soils*** (Refer Table 1 for name list). In this village, only about ***25% of the samples have low K values*** and therefore the need to ***apply K containing fertilizers such as MoP for those with low K values*** (refer Table 1 for name list), while about 75% of the samples have high to very high K values. The CEC of these soils is mostly within the medium to high ranges while the BS% is within the low to medium ranges. Sandy clay loam (moderately fine textured soil with more than 50% sand content with less than 40% clay content) and clay loam (moderately fine textured soils) are the two dominant soil types of this village (Figure 23)

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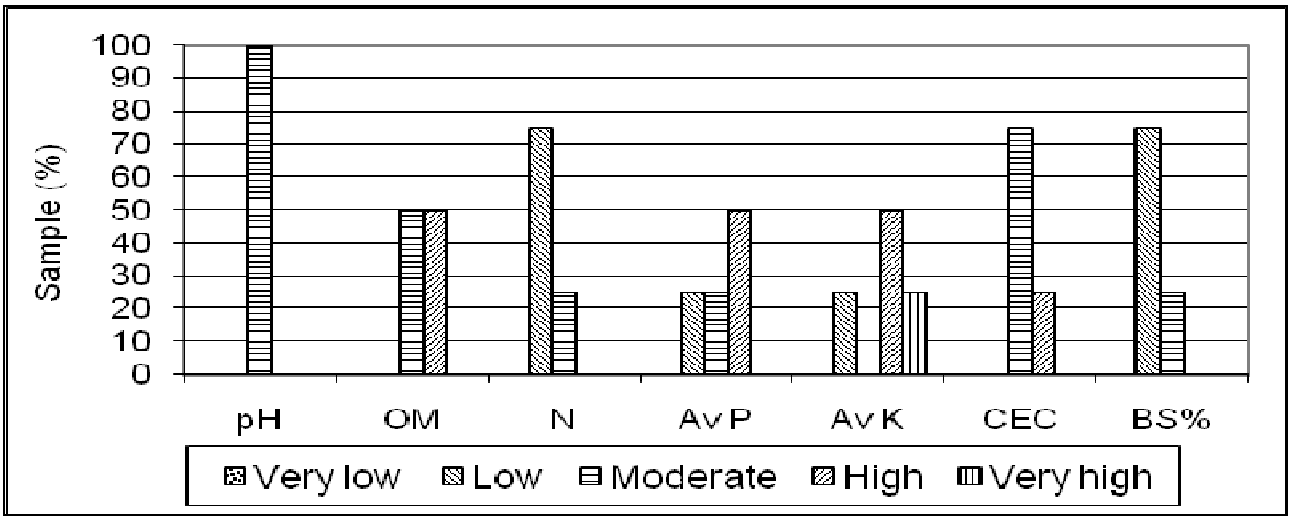

Figure 19 Soil parameters of potato fields in Asham Drelo village.

2.6.12 Soil result of Dhurung village

The pH of these soils is within the low range while the organic matter content is within the medium to high ranges. The nitrogen content is mostly in the very low to low ranges and about 25% in the medium range. **The available *P*** of these soils is mostly in ***the low range*** (more than 75% of the samples) and about 25% in the medium range and ***these low values indicate the need to apply P containing fertilisers such as SSP or TSP*** to improve the P content of these soils (Refer Table 1 for name list). ***The available K values is also within the low to medium range*** and therefore the need to ***apply K containing fertilizers such as MoP.*** (refer Table 1 for name list). The CEC of these soils is mostly within the medium to high ranges while the BS% is within the low range. Sandy clay loam (moderately fine textured soil with more than 50% sand content with less than 40% clay content) and clay loam (moderately fine textured soils) are the two dominant soil types of this village (Figure 23)

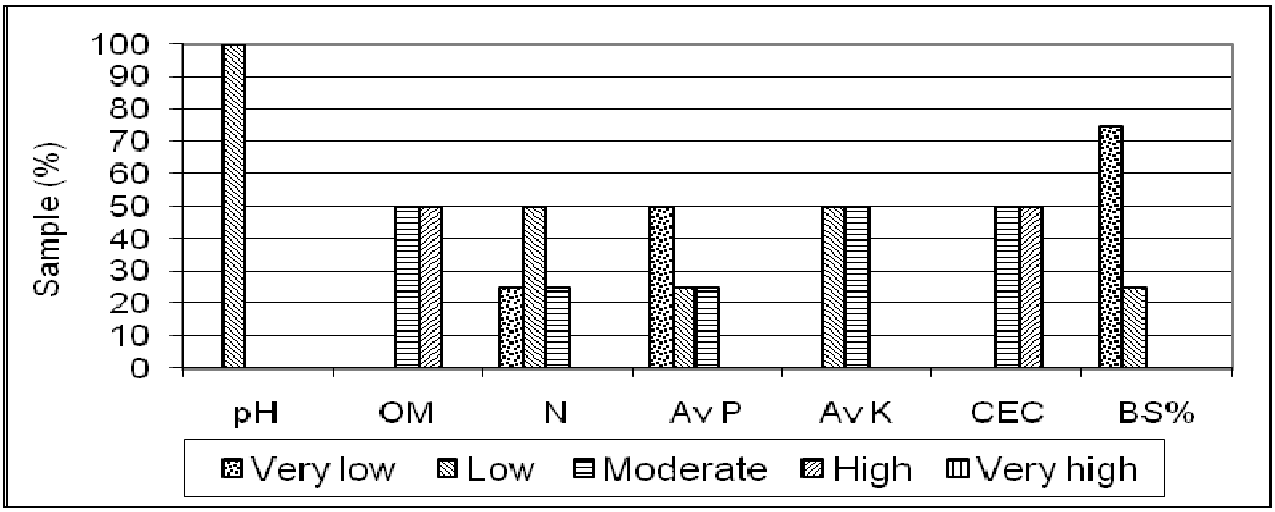

Figure 20 Soil parameters of potato fields in Dhurung village.

2.6.13 Soil result of Tokphay Wok village

The pH of these soils is within the medium range while the organic matter content is within the medium to high ranges. The nitrogen content is within the low to medium ranges for these soils. About 25% of these samples have ***low P values indicating the need to apply P containing fertilisers such as SSP or TSP*** (Refer Table 1 for name list). In this village, only about ***25% of the samples have low K values*** and therefore the need to ***apply K containing fertilizers such as MoP*** (refer Table 1 for name list), while about 75% of the samples have high to very high K values. The CEC of these soils is mostly within the medium to high ranges while the BS% is within the low to medium ranges. Sandy clay loam (moderately fine textured soil with more than 50% sand content with less than 40% clay content), sandy loam (moderately coarse to medium textured soil containing less than 20% clay and about 70% sand), silty clay loam (moderately fine textured soil with 40% clay and 20% sand separates) and silty clay (a moderately fine textured soil with 60% clay and 20% sand separates) are the dominant soil types of this village (Figure 23).

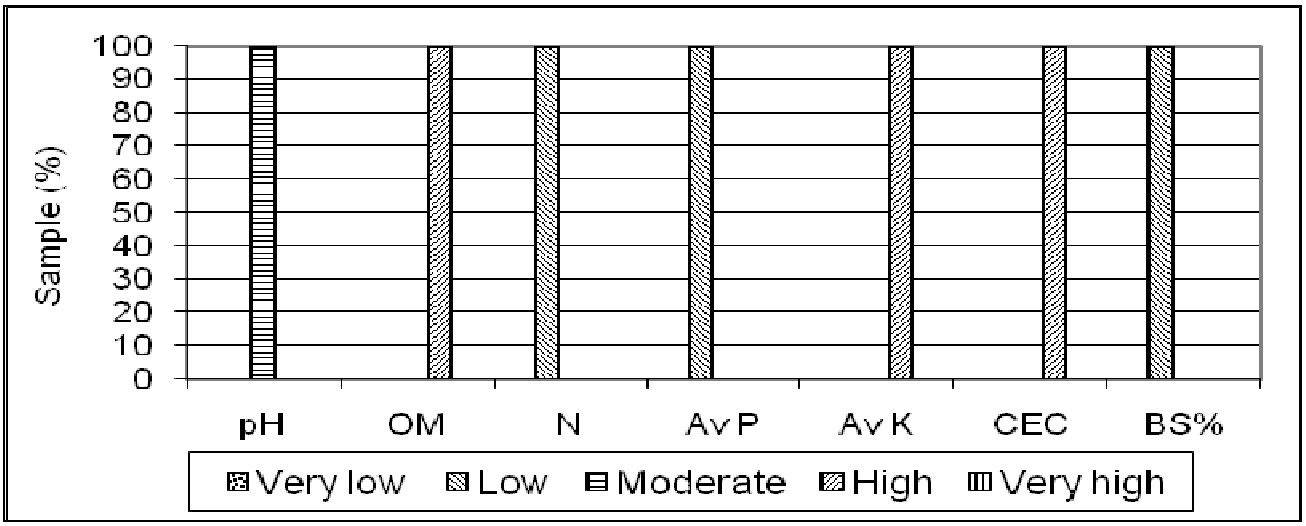

Figure 21 Soil parameters of potato fields in Tokphay Wok village.

2.6.14 Soil result of Bramtsang Gonpa village

The pH of these soils is mostly within the medium range while the organic matter content is high. The nitrogen content is mostly within the medium ranges for these soils. In this village, about 80% of these samples ***have very low to low P values*** indicating ***the need to apply P containing fertilisers such as SSP or TSP*** to improve the P content of these soils (Refer Table 1 for name list). The available K content of these soils is also low (70% of the samples) and another 20% within the medium range. For these siols with low to medium K ranges, there is the need to ***apply K containing fertilizers such as MoP*** (refer Table 1 for name list). The CEC of these soils is high while the BS% is low. Sandy clay loam (moderately fine textured soil with more than 45% sand content with and clay content less than 40%) and sandy loam (moderately coarse to medium textured soils) are the two dominant soil types of this village (Figure 23)

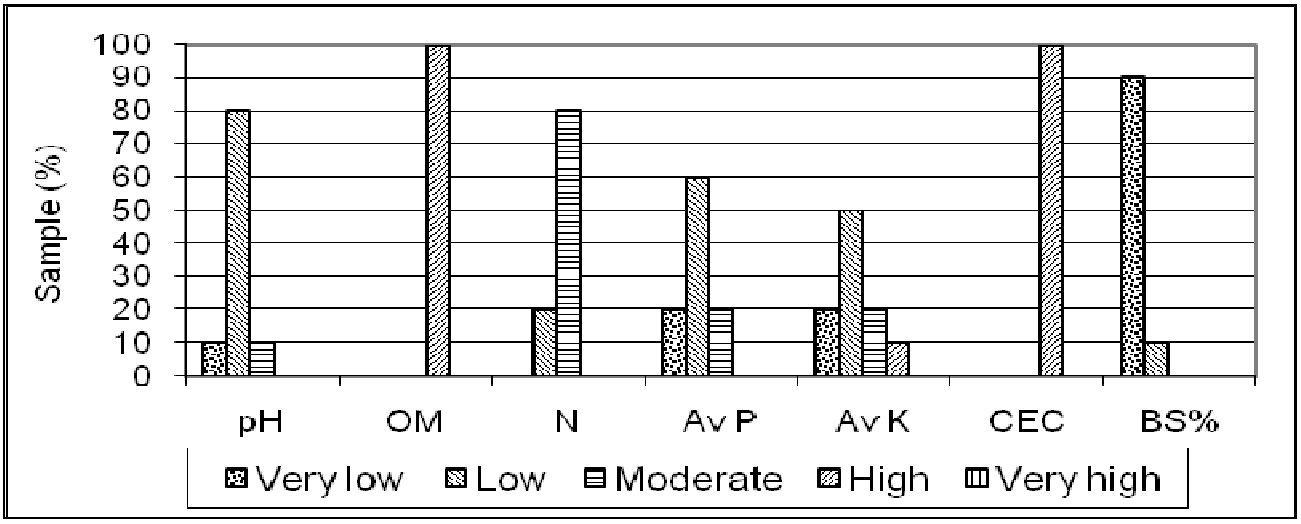

Figure 22 Soil parameters of potato fields in Bramtsang Gonpa village.

3.7 Soil texture of different villages under Kanglung geog

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

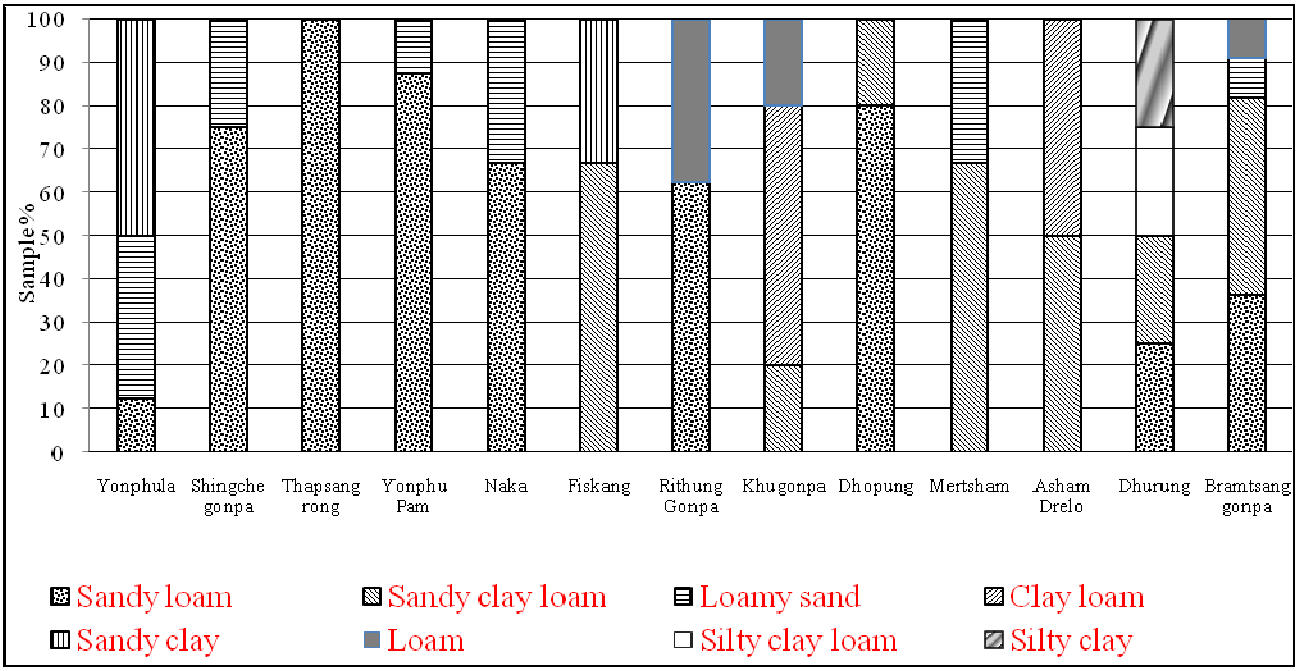

Figure 23 Soil textures of potato fields in different villages under Kanglung geog.

4. Conclusions

In Kanglung geog, potato is the major cash crop grown while maize planted a month later is mostly used for consumption. The survey findings indicate that more than 90% of the sampled plots are located at medium altitude range of 2000 and 2500 m.asl. The majority of the plots are situated on moderately sloping areas followed by sloping areas. The majority of the plots are north-easterly facing aspects. The average field size for potato plantation is less than 1 acre. Desiree and Yusikarp are the most preferred potato varieties grown by the farmers, which is planted in the month of November -December.

Almost all the farmers of this village apply FYM and some chemical fertilizers as part of the soil fertility management practices. On an average, the farmers apply about 7.18 tac^{-1} of FYM and about 197 $kgac^{-1}$ urea, 243 $kgac^{-1}$ SSP and 120 $kgac^{-1}$ Suphala to potato. Urea is applied to both potato and also to maize as a top dress.

The average yield of potato and maize in Kanglung geog is 4.14 tac^{-1} and 1.25 tac^{-1} respectively[d]. Dhurung village reported the highest yield of potato and maize (5.32 tac^{-1} and 2.67 tac^{-1} respectively). The potato yield figure is lesser than the FAO yield estimate for Bhutan (FAO yield estimate for farmer field is about 6.5 tac^{-1}) indicating the potential for increasing yield with better

[d] The potato yield figure is less than the figures of 2002 (i.e. potato=6.4 tac^{-1}) and maize =0.8 tac^{-1}).

inputs and management practices. Majority of the farmers reported that they have not been changed the potato seeds for the last 5-10 years. This could be one contributing factor for low yield in addition to the low and unbalanced nutrient inputs. The farmers also reported the wild animal damage to the crops as one of the major constraint to bounty harvest.

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 also within the medium to high range indicating a fairly good status of OM in these soils. The available P and K are mostly within the low to medium range though few villages have fairly good P status. The CEC of these soils in the geog are mostly within the low to medium range indicating a fairly medium soil fertility status. The major soil types of this geog are sandy loam and sandy clay loam.

5. Recommendations

- The average nutrient input through inorganic fertilizers to potato was 51 $kgac^{-1}$ N from urea, 39 $kgac^{-1}$ P from SSP and 18 $kgac^{-1}$ NPK from suphala (i.e 111 $kgac^{-1}$ of urea, 243 $kgac^{-1}$ of SSP and 120 $kgac^{-1}$ suphala). With the limited use of balanced mineral fertilizer, especially P and K, 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 result indicate a fairly low to medium P and K status The farmers' nutrient application rate of about 69:39:18 kg NPK ac^{-1} is much lower for K, though high 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) 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 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 low to medium range and therefore there is also the need to improve its nutrient content as all the major macronutrients are required to obtain an adequate yield 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 Kanglung geog

VERY LOW – LOW P	VERY LOW – LOW K
SONAM CHODEN (RITHUNG GONPA)	TSHERING GYELMO (YONPHULA)
UGYEN (RITHUNG GONPA)	KUNZANGLA (YONPHULA)
DRIVER SAMDRUP (RITHUNG GONPA)	LHADIP LOBZANG (YONPHULA)
NGAWANG CHODEN (NAKA)	PEM CHODEN (YONPHULA)
AUM TSHERING (NAKA)	AUM DECHEN (SHINGCHEN GONPA)
SONAM ZANGMO (NAKA)	KARMA (SHINGCHEN GONPA)
AUM BAKI (NAKA)	AM SANGAY (THAPTSANG RONG)
UGYEN DORJI (NAKA)	AP DORJI (THAPTSANG RONG)
TSHERING CHODEN (FISKANG)	NYERPA WANGDI (THAPTSANG RONG)
SONAM TOBGAY (YONPHU PAM)	TSHEWANG ZANGMO (THAPTSANG RONG)
KINZANG DEMA (YONPHU PAM)	NGONDO & THINLEY (ASHAM DRELO)
SONAM (MERTSHAM)	SANGAYMO (BRAMTSANG GONPA)
KINZANG DORJI (MERTSHAM)	PEM CHEZOM (B/GONPA)
NGONDO & THINLEY (ASHAM DRELO)	AP SONAM (BRAMTSANG GONPA)
UGYEN LHAMO (ASHAM DRELO)	WANGMO (BRAMTSANG GONPA)
TSHERING DORJI (KHUGONPA)	JANGCHUK (BRAMTSANG GONPA)
GOMCHEN UGYEN (KHUGONPA)	PEM YUDEN (BRAMTSANG GONPA)
DENDUP (KHUGONPA)	NGAWANG CHODEN (NAKA)
	AUM TSHERING (NAKA)
	SONAM ZANGMO (NAKA)
	UGYEN DORJI (NAKA)
	BAKI (NAKA)
IN ADDITION, ALL THE FARMERS OF YONPHULA, SHINGCHEN GONPA, THAPTSANG RONG, DHOPUNG, DHURUNG AND TKPHAY WOK & BRAMTSANG GONPA	IN ADDITION, ALL THE FARMERS OF YONPHU PAM, FISKANG, KHUGONPA, DHOPUNG, DHURUNG & RITHUNG GONPA