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, Thrimshing geog is one of the most intensively cultivated areas other than Kanglung, Khaling and Yangneer 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 40 households covering 2 villages under this 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 Thrimshing 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 Thrimshing geog with fertilizer recommendations based on the findings for each village.

3.1 Sample households

In Thrimshing geog, a total of 40 household covering 2 villages (viz. Tsangpo and Thrimshing villages) were sampled. The number of respondents from Tsangpo village was more (75%) than Thrimshing (25%). 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 Thrimshing geog, the majority of the plots are situated on steep slopes (45%) followed by moderately sloping areas (32%) and sloping with 21%. The majority of the plots are north westerly and north easterly (43% and 23% respectively). In this geog, all the sampled plots are located at low altitude range (less than 2000 m.asl). All the farmers of this geog have small plot size (< or =1 acre) for potato cultivation. In this geog, more than 62% of the farmers grow Kufri jyoti and about 22% of them grow both Desiree and Kufri jyoti while about 14% of them grow both Desiree and Yusikap and the rest grow only Yusikap.

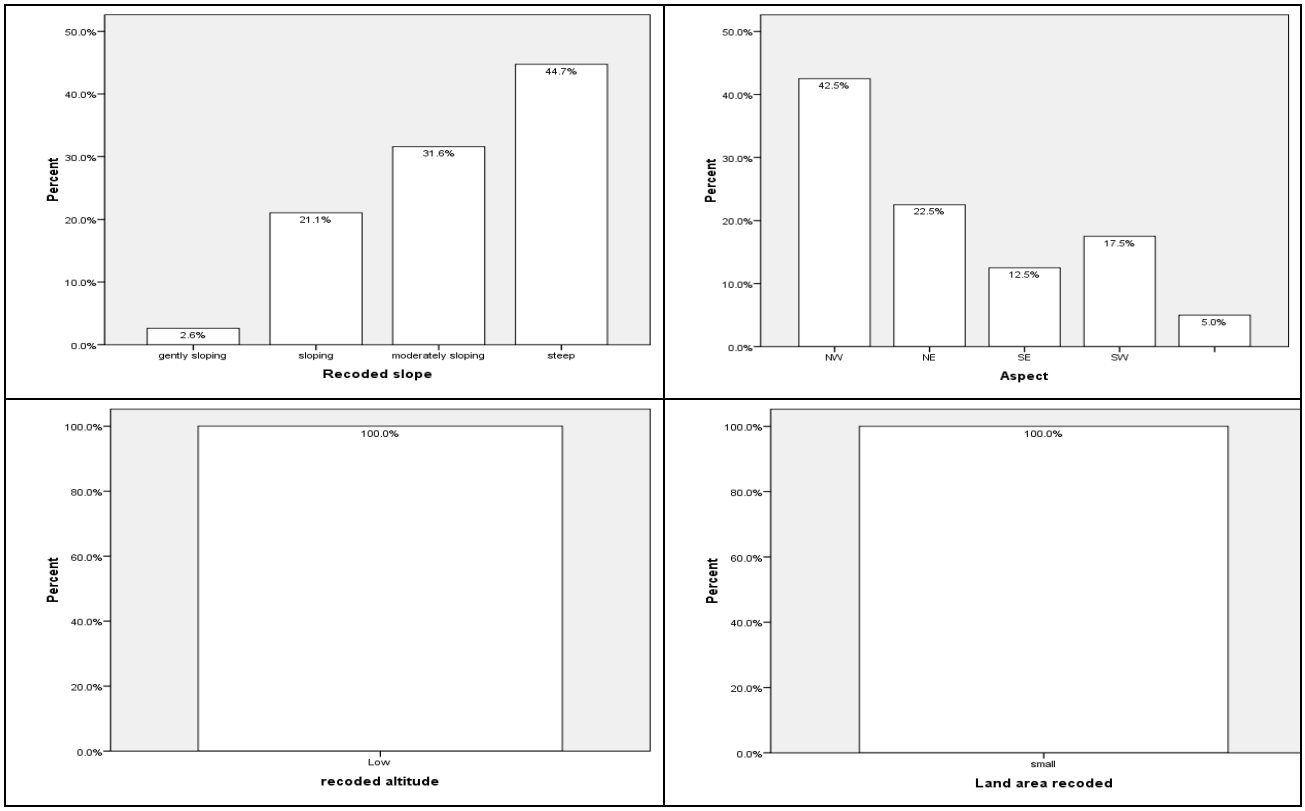

Figure 1 Slope, aspect, altitude and area of plots under potato- maize yield cultivation

3.3 Crop yield and other management practices.

In Thrimshing geog, 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}[a] though on an average, the yield is about 7-8 tac^{-1}.

The average potato and maize yield of Thrimshing geog is 2.67 tac^{-1} and 0.49 tac^{-1} respectively. From Figure 2 it can be observed that the potato yield from these two villages is almost same. The maize yield of Thrimshing village (1.15 tac^{-1}) slightly higher than Tsangpo village (0.27 tac^{-1}). These low yield figures suggest that the potential yield level in these two villages are yet to be attained and there is the possibility of increasing returns with proper management practices.

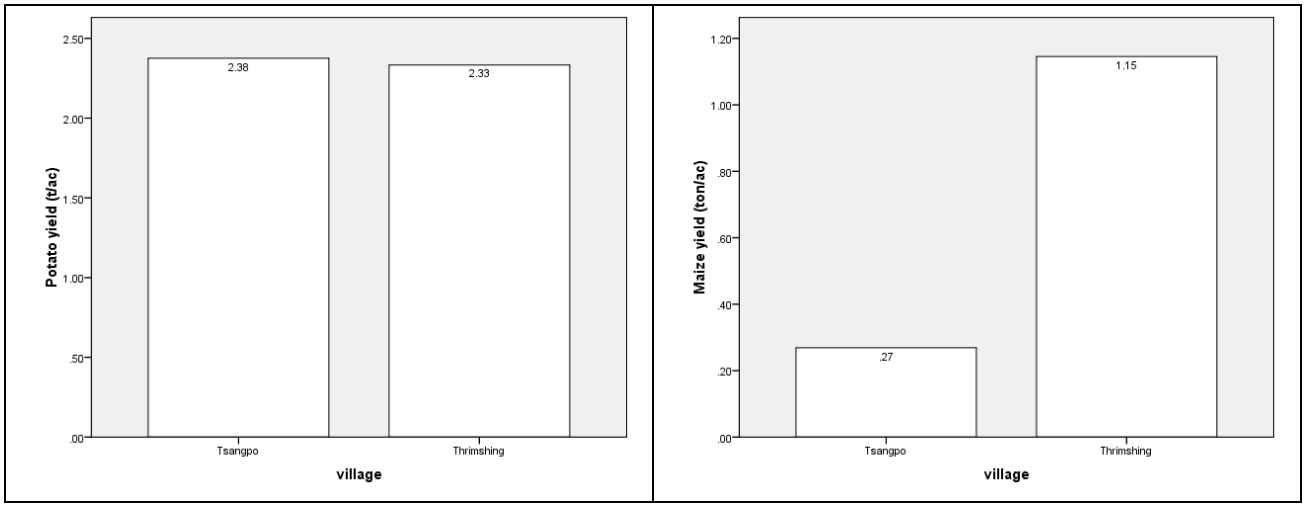

Figure 2 Average potato and maize yield (tac^{-1}) under each village

In Thrimshing geog, most of the farmers (95% of the farmers) reported that they have changed the potato seeds. However, only about 3% of them have changed the potato seeds during the last 5 years while more than 94% of them have changed the potato seeds during the last 15 years or so.

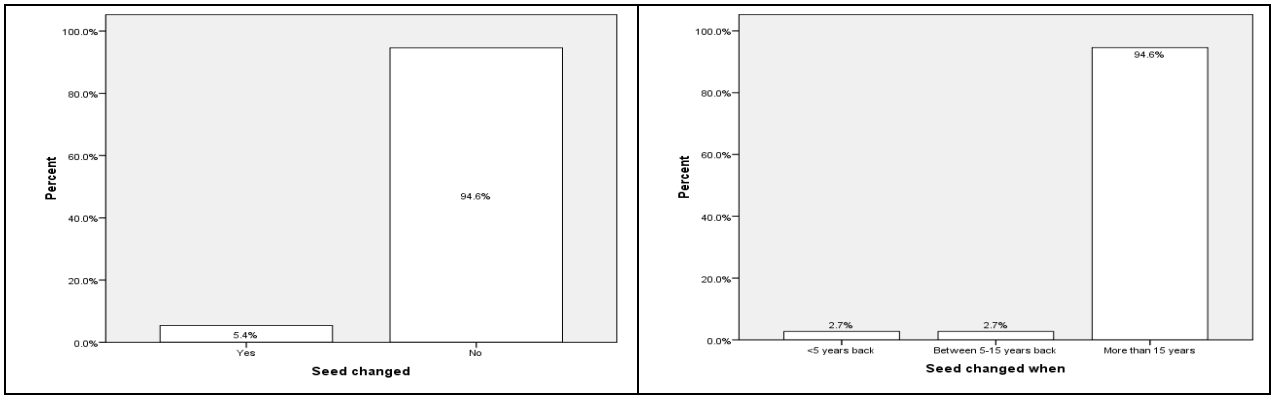

Figure 3 Potato seeds changed?

[a] According to FAO reports

3.3.1 Soil fertility management practices

3.4.1 Farm Yard Manure (FYM)

In Thrimshing geog, all the farmers apply FYM to their fields. The average FYM application rate of the geog is 2.77 tac^{-1} (equivalent to 38.23 kg N ac^{-1}, 8.03 kg P ac^{-1}, 54.57 kg K ac^{-1}, 65.1 kg Ca ac^{-1}). Tsangpo village applies more FYM to potato fields (3.25 tac^{-1}) than Thrimshing village (1.14 tac^{-1}).

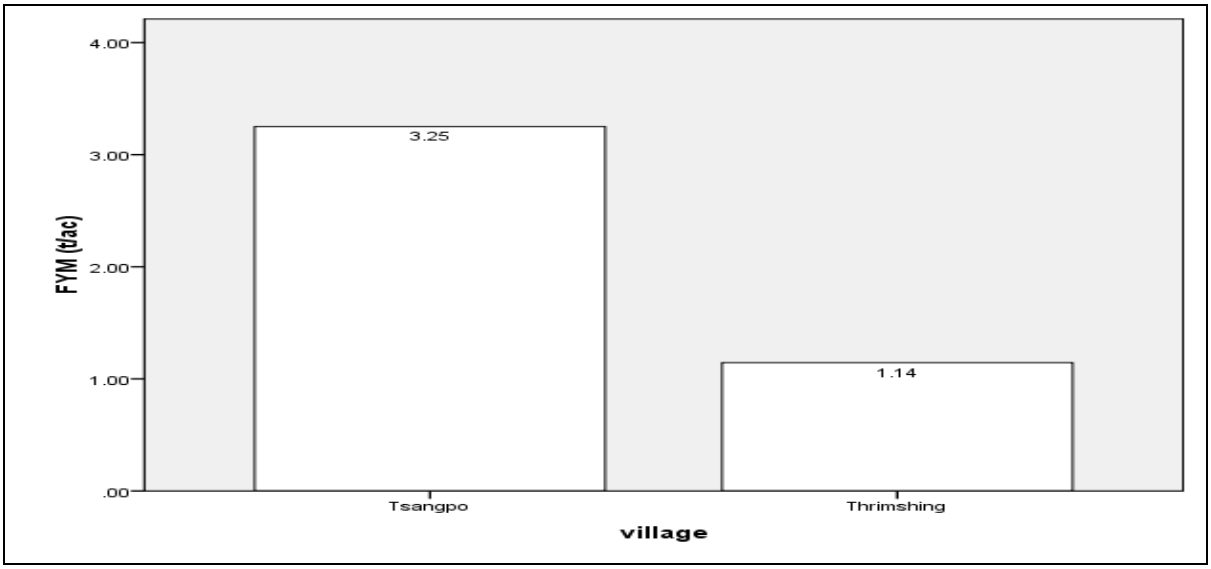

Figure 4 Average FYM (tac-1) applied under each village

3.4.2 Inorganic fertilizers

The survey findings indicate that almost all the farmers (92%) 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 at all in this geog. The average rates of fertilizers applied in this geog are about 81.06 $kgac^{-1}$ urea (applied only to maize) and about 70.07 $kgac^{-1}$ of Suphala (applied to potato) and these fertilizers amount to about 49$kgac^{-1}$ N, and about 10.51 $kgac^{-1}$ 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. On an average, the overall fertilizer rate is low for this geog.

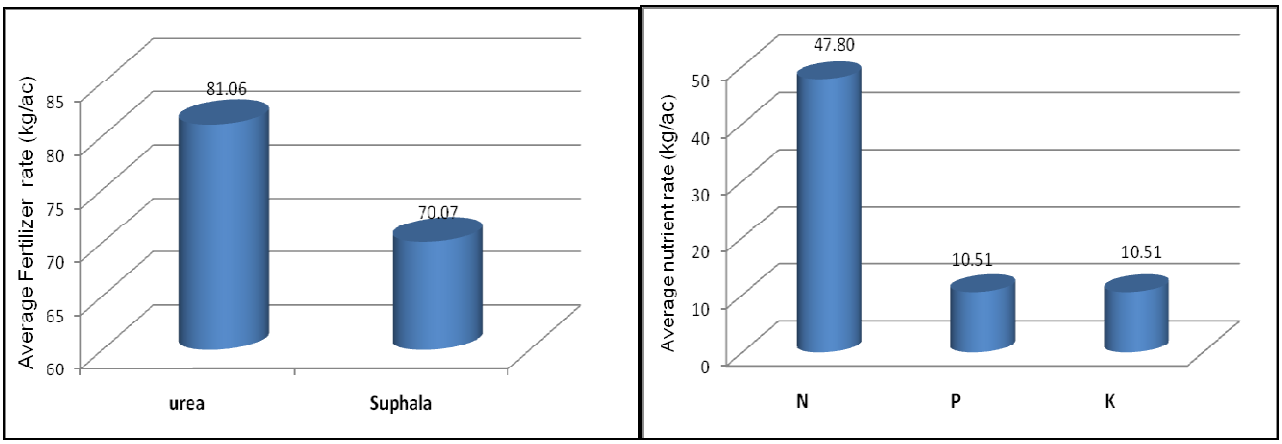

Figure 5 Average rates of fertilizer and nutrients applied (kgac-1) in Thrimshing geog.

In this geog, Thrimshing village applies more inorganic fertilizers (86 kgac^{-1} suphala and 65 kgac^{-1} urea) which is equivalent to about 49.31 kgac^{-1} of N and 9.75 kgac^{-1} of P and K which is below the recommendation rate suggested by NSSC[b]. (please refer the recommendation table at the end of the report). Tsangpo applies about 26 kgac^{-1} each of suphala and urea to potato and maize, these rates are lower than the NSSC recommended rate. These values are very low for potato to do well and therefore the need to increase the fertilizer rate for all the farmers of these two villages.

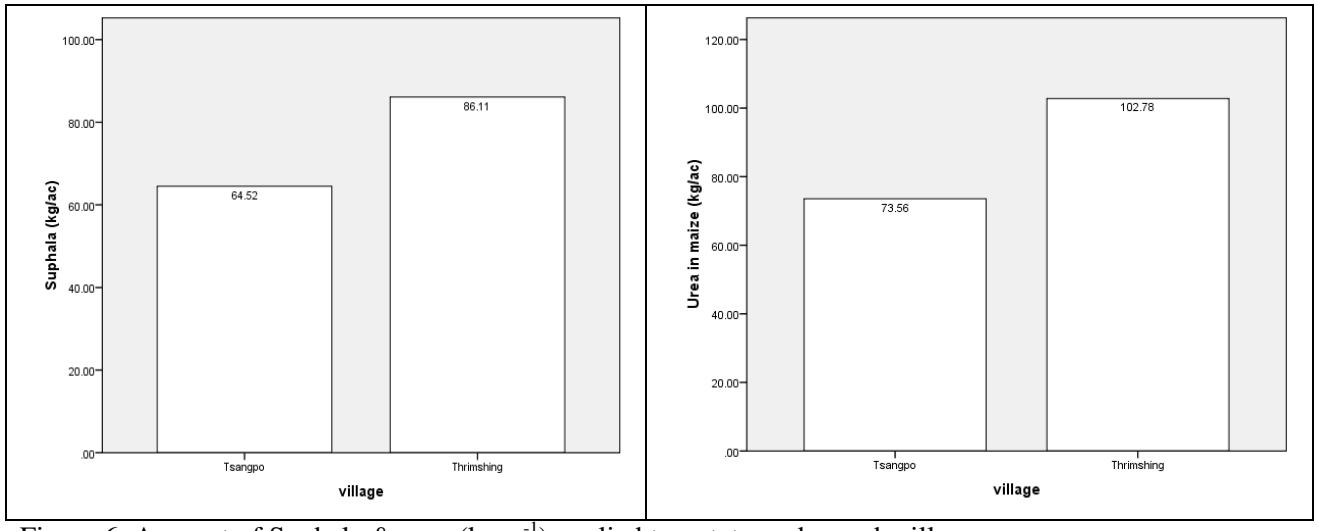

Figure 6. Amount of Suphala & urea (kgac^{-1}) applied to potato under each village.

3.3.2 Crop yield in relation to inorganic fertilizers application

From the following figure, it shows that there is no positive yield response of potato with increasing rates of suphala application though there is a positive maize yield response with increasing urea application. The maximum maize yield of 1.3tac^{-1} is reported with the maximum urea application rate of 101 – 200 kgac^{-1}.

[b] Recommended rate for potato is 40:32:32 kg ac^{-1} N,P,K.

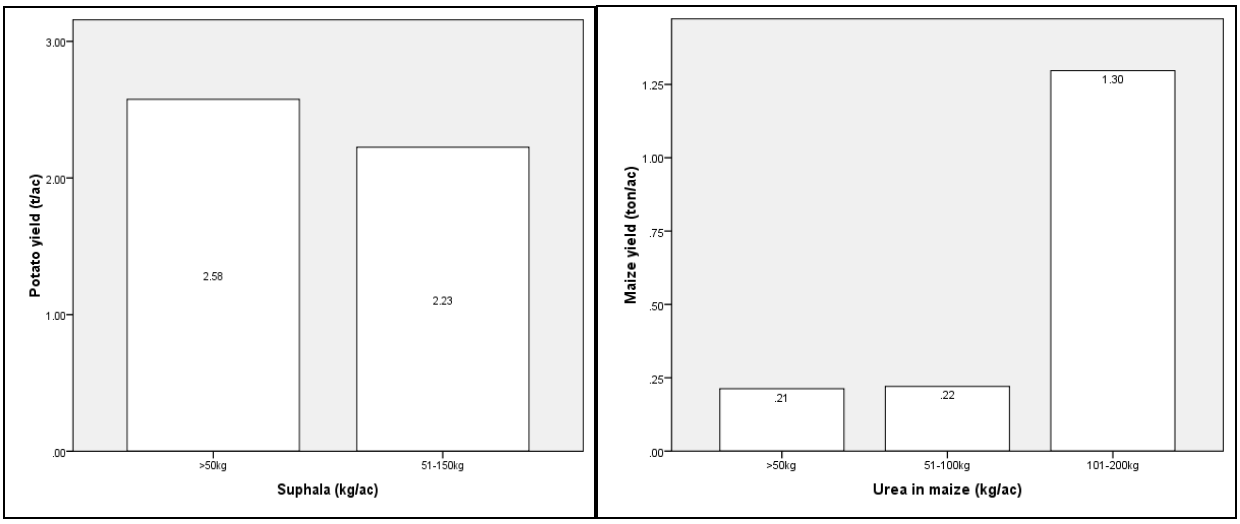

Figure 7 Potato and maize yield in relation to inorganic fertilizer applied in the geog.

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 it is completely rain fed.

3.5 Soil analytical results of Thrimshing 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 80%) of the soils have moderate/medium pH range which is ideal for growing most of the agronomic crops. 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 mostly within the moderate range (more than 67% of the samples). 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 47% of the samples have low to very low available P and only about 15% is within the medium range. Only about 37% of the samples are 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. Available P for Tsangpo village is mostly low except for 11 farmers. All the farmers of Thrimshing village (except for 3 farmers) have very low to low P contents in their soils and therefore the need to apply P containing fertilizers such as SSP or TSP (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 $mgkg^{-1}$).

In this geog, about 63% of the samples have available K in the medium range and the rest falls within the low to very low ranges. In general, the K content of these soils is poor and the farmers of both the villages need to apply K containing fertilizers such as MoP (details under individual soil report).

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.

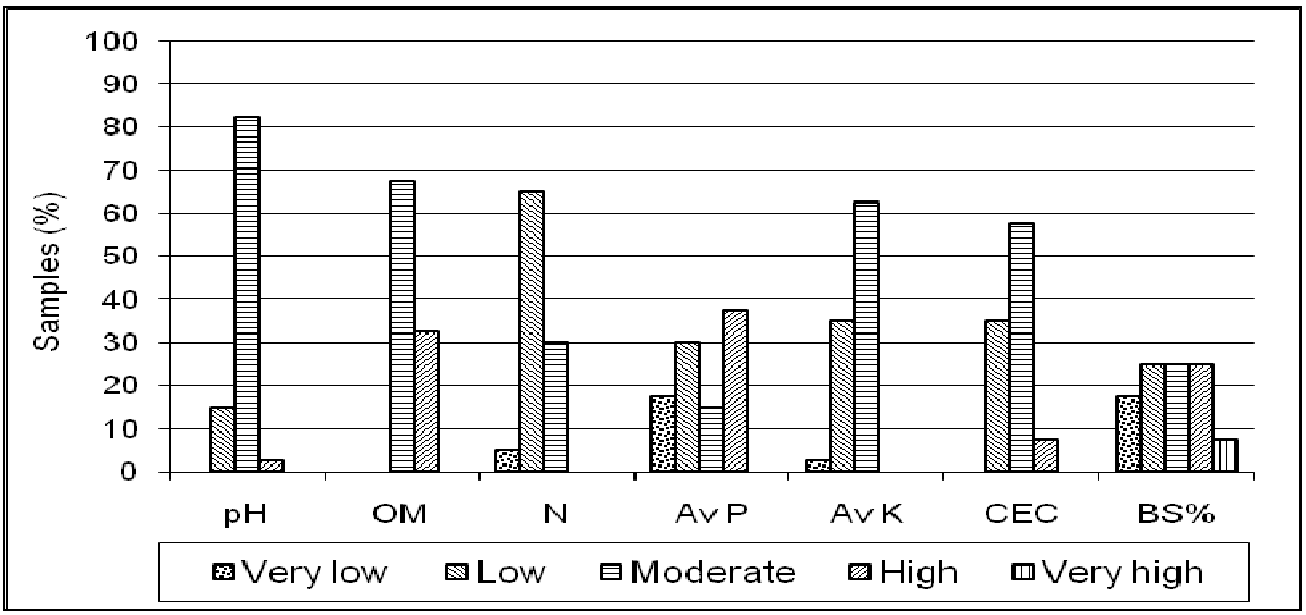

Figure 8 Soil parameters of potato fields under Thrimshing geog.

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 50% sand and about 35% clay particles) is the dominant soil type of this geog.

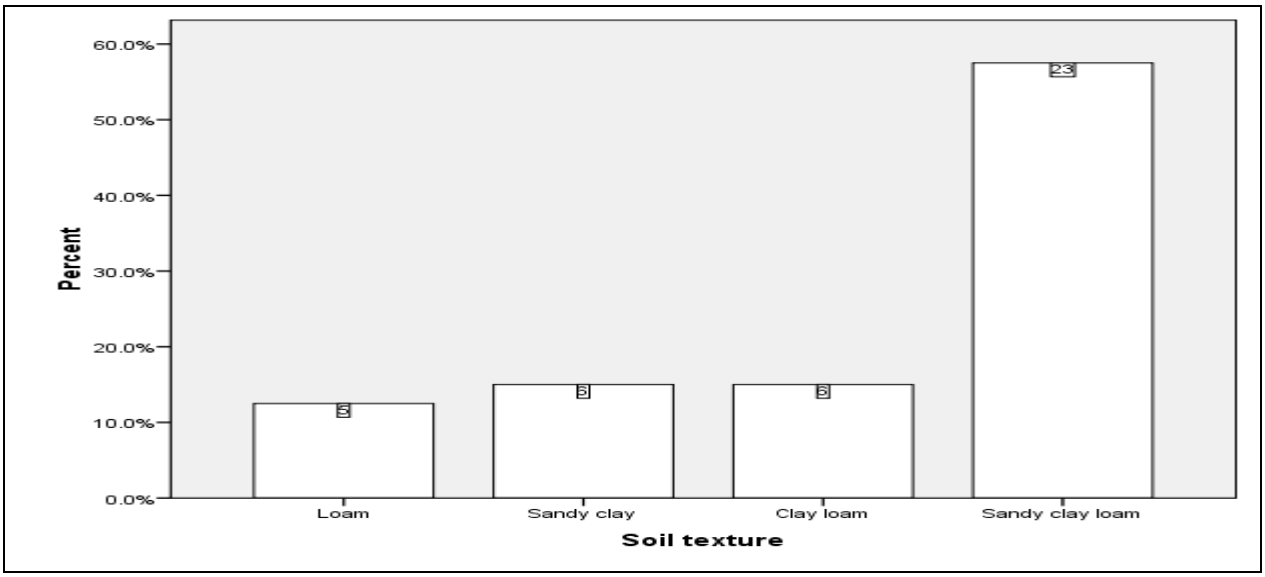

Figure 9 Soil texture of potato fields under Thrimshing geog (average of all villages)

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

3.6 Soil analytical result of individual village under Thrimshing geog

3.6.1 Soil result of Tsangpo village

The pH of the soils of this village is mostly within the medium range (more than 80% of the samples). The organic matter content of Tsangpo village is mostly within the medium to high ranges. The nitrogen content is mostly within the very low to low ranges (more than 63% of the samples) and only about 37% within the medium range. More than ***46%*** of these soils have ***low to very low P*** values and for these soils there is the ***need to apply P and K containing fertilizers such as SSP.*** About 40% of these samples have high P (i.e. the 11 farmers of Tsangpo viz. Phuba, Rinzin Dorji, Lamzang, Kota, Dema, Yangdon, Balha, Sakten Tshering, Ngajay, Sangay and Cheten Tshering) with high available P.

More than 43% of these samples have ***low to very low K values*** and the rest of the samples are within the medium range. These low to medium values indicate the need to apply ***K containing fertilizers such as MoP.*** The CEC values are mostly within the medium range (more than 63% of the samples) and only about 3% within the high range and the rest in the low range. The BS% range of these soils is distributed from very low to high ranges.

Sandy clay loam and clay loam are the two major soil types of this village (Figure 12).

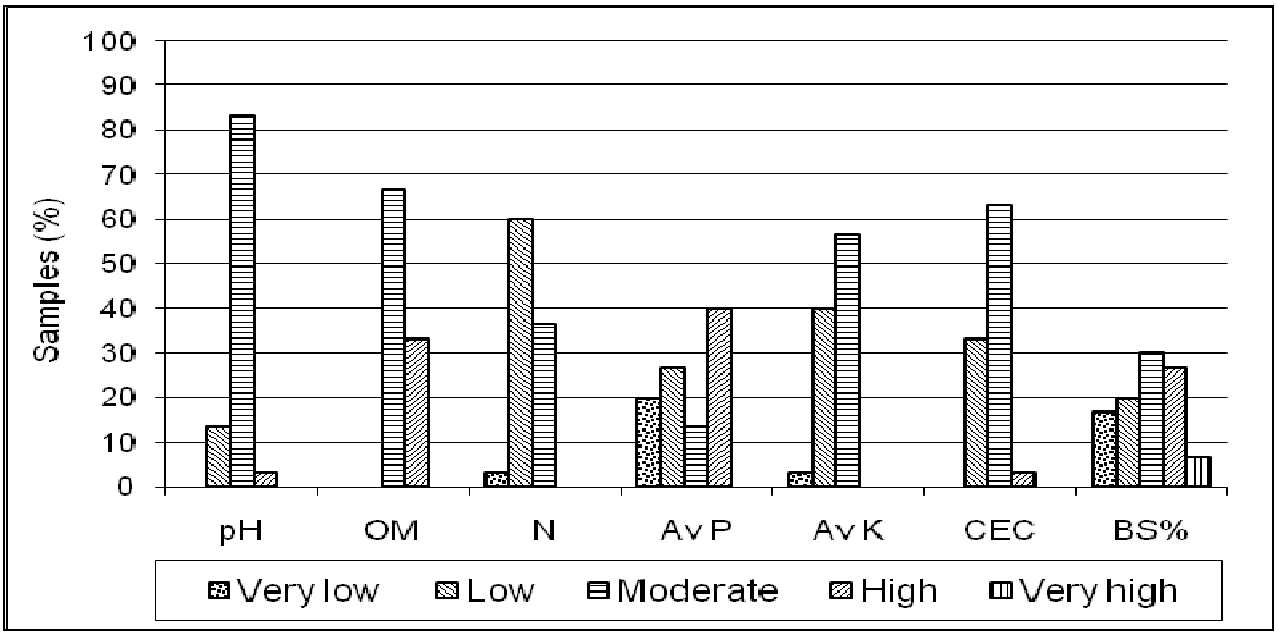

Figure 10 Soil parameters of potato fields in Tsangpo village.

3.6.2 Soil result of Thrimshing village

The pH of the soils of this village is mostly within the medium to low range which is ideal for growing almost all crops. The soil organic matter content is also within the medium to high range. The N content is mostly within the low range. About 50% of the samples ***have low to very low available P*** and 20% of the samples have medium values and about 30% of the samples within the high 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 all within ***low to medium*** range and therefore, all the farmers of this village need to ***apply K containing fertilizers such as MoP.*** Potatoes are good extractors of K, and therefore the need to apply K into the soil for better crop yields. About 40% each of the samples have low and medium CEC values while only about 20% of the samples have high CEc values. The base saturation is distributed within the very low to high ranges. Sandy clay loam is the dominant soil type of this village, followed by clay loam and loam (Figure 12).

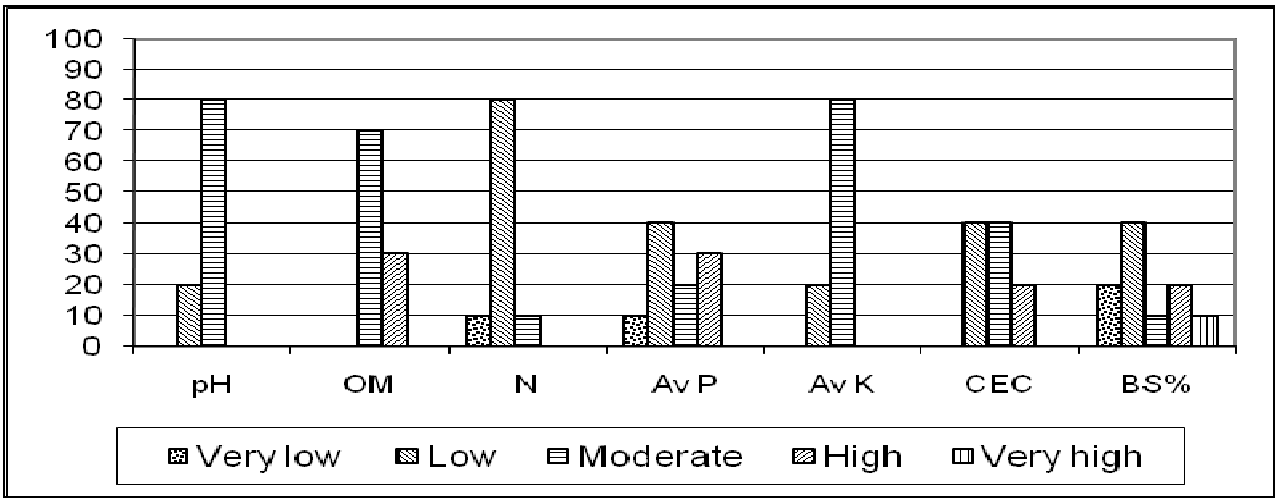

Figure 11 Soil parameters of potato fields in Thrimshing village.

3.7 Soil texture of different villages under Thrimshing geog

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

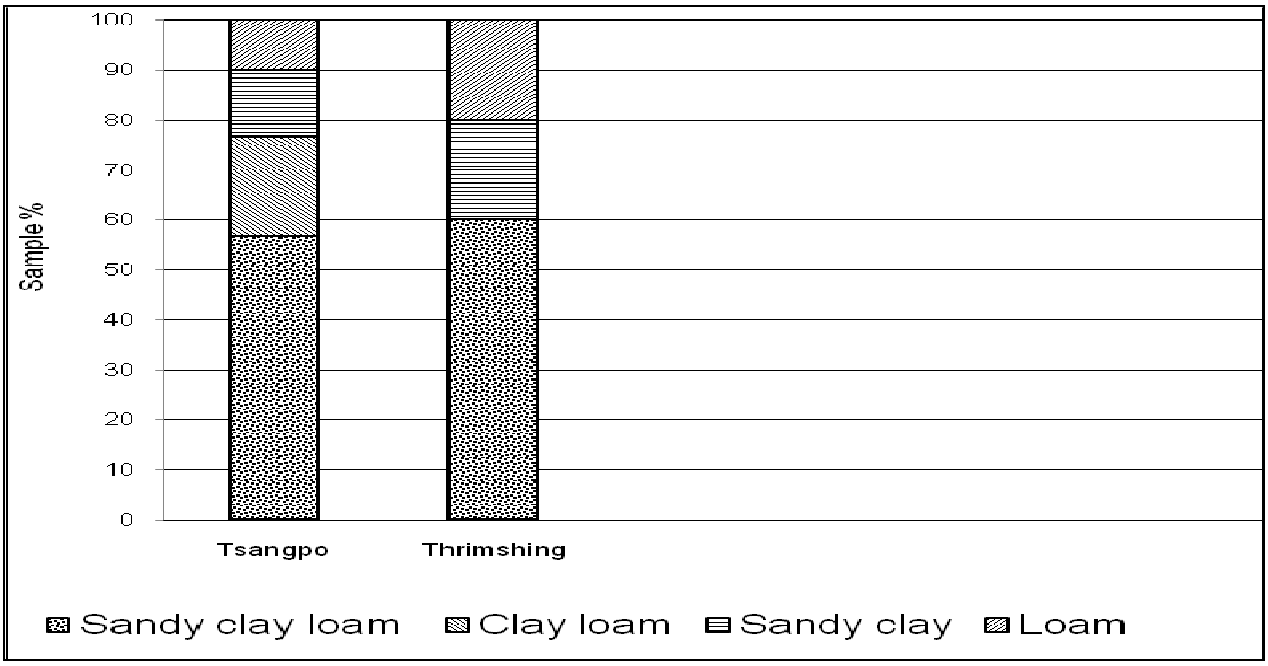

Figure 12 Soil textures of potato fields in different villages under Thrimshing geog.

4. Conclusions

In Thrimshing geog, the survey findings indicate that the sampled plots are located at low altitude range of (<2000 m.asl). The majority of the plots are situated on steep areas followed by moderately sloping areas. The majority of the plots are north-easterly and north westerly facing aspects. The average field size for potato plantation is less than 1 acre. Kufrijyoti is grown by most of the farmers though Desiree and Yusikarp are also grown by farmers of this geog but to a lesser extent.

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 of this geog apply about 2.77 tac^{-1} of FYM and about 81 $kgac^{-1}$ urea and about 70 $kgac^{-1}$ Suphala to potato and maize. Urea is applied only to maize as a top dress while suphala is applied to potato. Neither SSP nor MoP is applied in this geog.

The average yield of potato and maize in Thrimshing geog is 2.67 tac^{-1} and 0.49 tac^{-1} respectively[c] and the yield of both potato and maize has remained almost constant over the years. The potato yield figure is very low compared to 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 inputs and management practices. Majority of the farmers reported that they have not been changed the potato

[c] The potato yield figures of 2002 (i.e. potato=2.9 tac^{-1} and maize =0.97 tac^{-1}).

seeds for the last 5-15 years or more. This could be one contributing factor for low yield in addition to the low and unbalanced nutrient inputs.

On an average, the soil pH of most of the plots is within the medium range and this range 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. However, the OM content of the soils could be increased by adding more FYM and other organic plant residues into the soil. The available P content of most of these plots are within the very low to medium ranges and only few farmers of Tsangpo village have high P values while all the farems of Thrimshing have low P values. All the farmers of Tsangpo and Thrimshing villages have low available K contents and therefore there is the need to improve the K content of these soils to get better crop yields. The CEC of these soils in the geog are mostly within the low to medium range indicating a fairly low to medium soil fertility status. The major soil types of this geog is sandy clay loam.

5. Recommendations

- The average nutrient input through inorganic fertilizers to potato was 49 $kgac^{-1}$ N from urea and suphala; 10.51 $kgac^{-1}$ each of P & K from suphala. (i.e about 81.06 $kgac^{-1}$ of urea and 70.07 $kgac^{-1}$ of 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 low K status The farmers' nutrient application rate of about 49:11:11 kg NPK ac^{-1} is much lower for P and K, though it is 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 very low to low ranges 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 very 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 nutrients at the recommended rates, apply about 213 kgac^{-1} of Suphala as **basal dose** during land preparation (i.e. about 4 bags and 13 kgs 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) [d]:

- 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}).

- 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 (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}).

- 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.

[d] 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 Thrimshing geog

VERY LOW – LOW P	VERY LOW – LOW K
• ALL THE FARMERS OF TSANGPO (EXCEPT FOR PHURBA, RINZIN DORJI, LAMZANG, KOTA, DEMA, YANGDON, BALHA, SAKTEN, TSHERING, NGAJAY, SANGAY, CHETEN TSHERING). • ALL THE FARMERS OF THRIMSHING (**EXCEPT** KARCHUNG, JAMTSHO, TASHI PHUNTSHO)	• ALL THE FARMERS OF TSANGPO • ALL THE FARMERS OF THRIMSHING