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Potato based farming system's soil management
Bumthang-Report 2006

1. Introduction

Following the first batch of soil samples collected (2002) under potato based farming system from Bumthang, a second batch of soil samples were collected from the same fields in 2005. This is to generate information on the soil nutrient status as managed by farmers; 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 soil samples will be collected after three years from the same areas.

This report is on the soils of the major potato growing areas of the Bumthang Dzongkhag, one of the important potato growing districts. The National Soil Services Centre (NSSC) collected soil samples from about 86 households spread over 28 villages within the four geogs of the Dzongkhag.

2. Method

This sampled areas covered the four geogs *viz*. Chumey, Choekor, Tang and Ura located at slightly different altitudes and with different population densities. From the original list of households (from 2002), about 50% of the total households from each geog were selected as sample households for the second batch of sampling.

Composite soil samples were collected from the fields clustered within an area. One composite sample collected from one field consisted of at least 7-8 sub samples. Depending on the size of the fields, the number of the sub samples ranged between 7 to 10. Soil samples were collected from the depth of about 0-20 cm using an auger. The samples were stored in labelled plastic bags and submitted to the Soil and Plant Analytical Laboratory (SPAL) for nutrient analysis. Aspects, slope angles and altitudes of the fields were also recorded. The information collected through interviews and the soil analytical results were analysed using the statistical programme SPSS.

The first part of this report presents the general observations as recorded during the survey and the second half reports the analytical results of the soil samples collected from the four geogs.

3. Results and discussions

3.1. Sample households

Figure 1 shows the percentage of the sample households in the four geogs. A total of 86 households covering 28 villages across the four geogs were sampled. The highest number of respondents was from Choekor (59%) followed by Ura (23%), Chumey (12%) and Tang (6%).

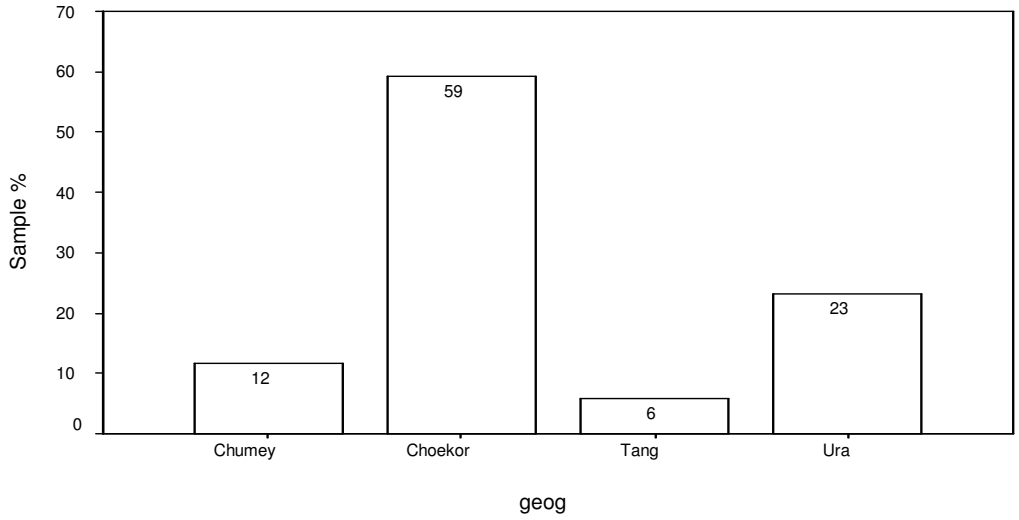


Figure 1: Percentage of sample households

Chumey:
Five villages were covered in this geog. The highest number of sampled households was in Domkhar (40%) followed by Yamthrak and Gorkhap (20%, each) and then by Nangar and Trakker (10%, each).

Choekhor:
Within the Choekhor geog, 14 villages were covered and the highest number of respondents was from Dekling and Chamkhar (12% each) followed by Norgang, Changwa, Nasfil and Jakar (10% each) and the lowest was from Jarigong (2%).

Tang:
Under Tang geog, four villages were covered and the highest number of respondents was from Phomrang (40%) followed by Jamshong, Pangshing and Pralang (20%, each).

Ura:
Within the Ura geog, five villages were sampled and the highest number of respondents was from Shingneer (35%) followed by Ura (20%) and then by Pangkhar, Samrong and Tangsibi (15%, each).

3.2. Site description: altitudes, slopes and aspects of the fields under potato cultivation

Figure 2, 3 and 4 show the altitudes, slopes and the aspects,respectively, at which the potatoes were grown. Across the four geogs, the altitudinal range has been categorised into low (<2500 m.asl), medium (2500-3000 m.asl) and high (>3000 m.asl). 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%.

Chumey:
In Chumey geog, about 90% of the sampled plots are located at the mid altitude range and the rest at the low altitude range. All the sampled plots in this geog are found on land with slope angle below 15%. About 80% of the sampled plots in this geog are situated on gently sloping

land with slope angle ranging from 4-8%, while 10% located on sloping land with slope angle of 9-15% and the rest on level area/flat land (0-3% slope angle). The majority (50%) of the plots are with SE aspect, followed by 30% facing NE and 20% facing NW.

Choekhor:
Within the Chorkhor geog, 98% of the sampled plots are found at the medium altitude range and only 2% at the low altitude range. In this geog, the sampled plots are found on lands with varying slope angles i.e. from level area to steep slopes. However, the majority (71%) of the plots are situated on level area with slope angles between 0-3% and the rest on slopes with slope angles between 4 to 50%. About 61% of the plots are with NE and 31% with SW aspects.

Tang:
All the sampled potato plots are found within the medium altitude range of 2500-3000 masl. The majority (60%) of the plots are situated on sloping land of 9-15% slope angle and the rest on moderately sloping land of 16-25% slope angle. About 40% of the plots are NE facing and 40% NW facing and the rest are with SE aspect.

Ura:
In Ura geog, 95% of the sampled plots are located at the high altitude range and only 5% at the medium altitude range. About 35% of the sampled plots are on sloping land, followed by 30% on moderately sloping land and 20% on steep slopes and the rest on level areas. The majority (45%) of the plots are with SE aspect and 40% of the plots are SW facing.

On the whole, the figures indicate that in Bumthang, the potatoes were grown mainly between an altitudinal range of 2500 to 3000 masl., on plots with varying slope gradients and with NE, NW, SE and SW aspects.

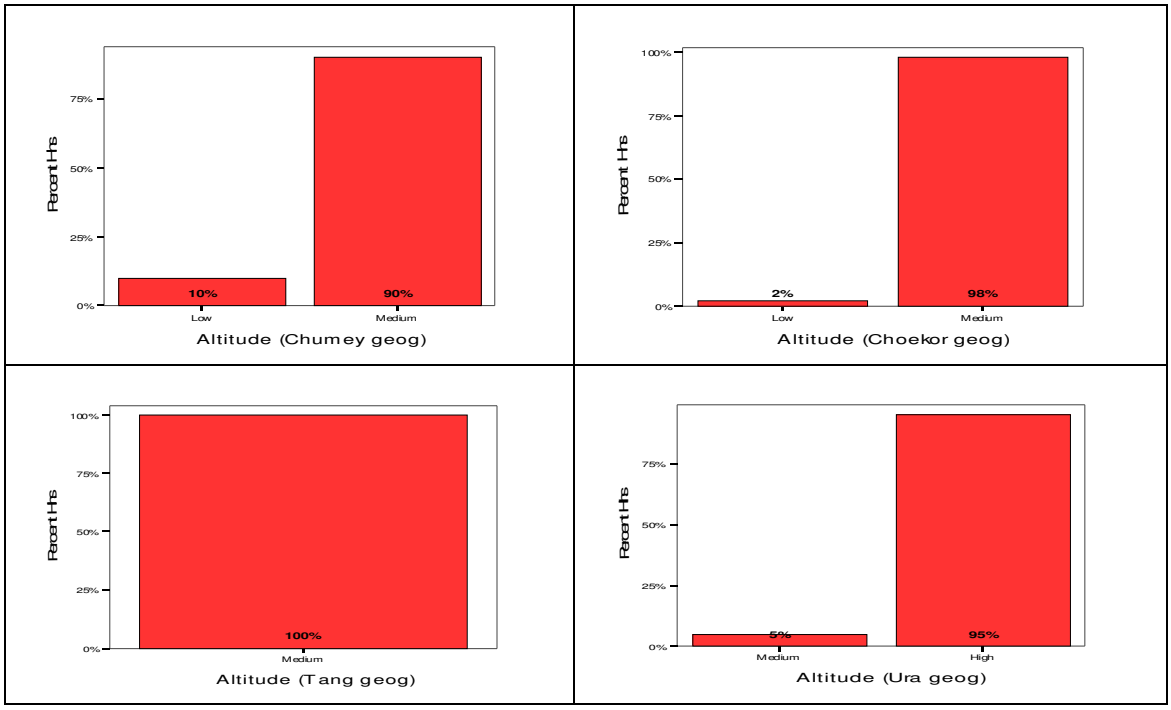


Figure 2: Altitudes at which the potatoes are grown

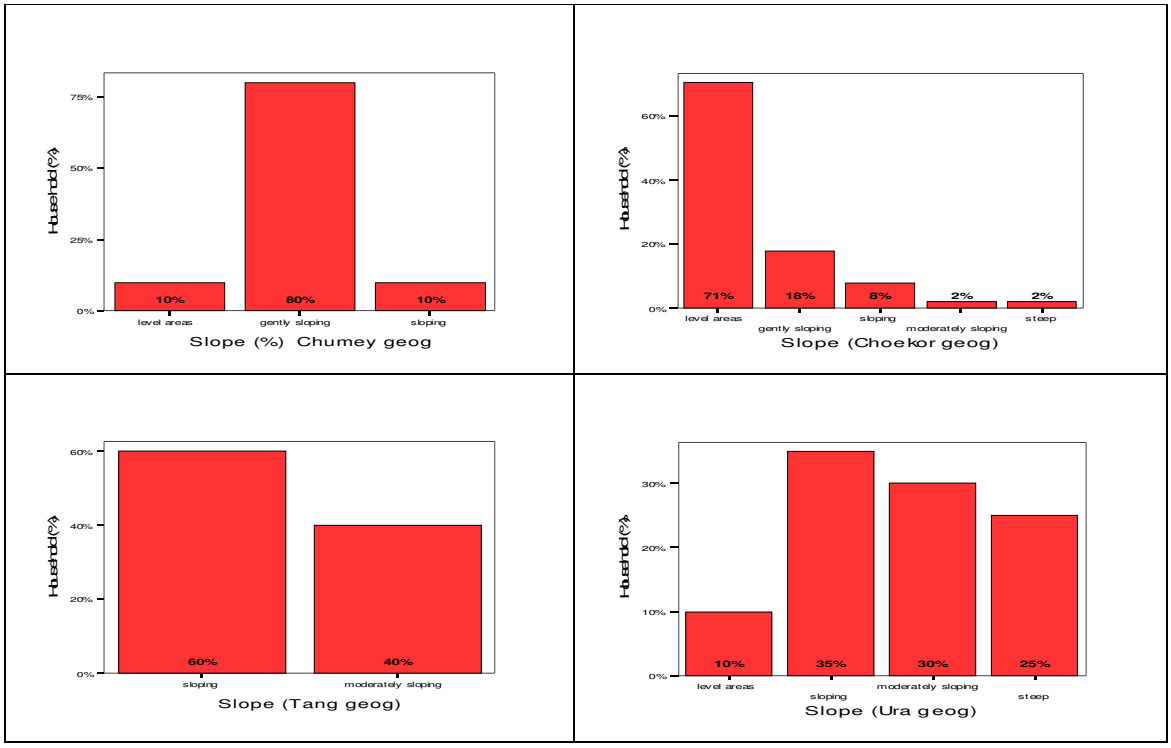


Figure 3: Slopes of the potato fields

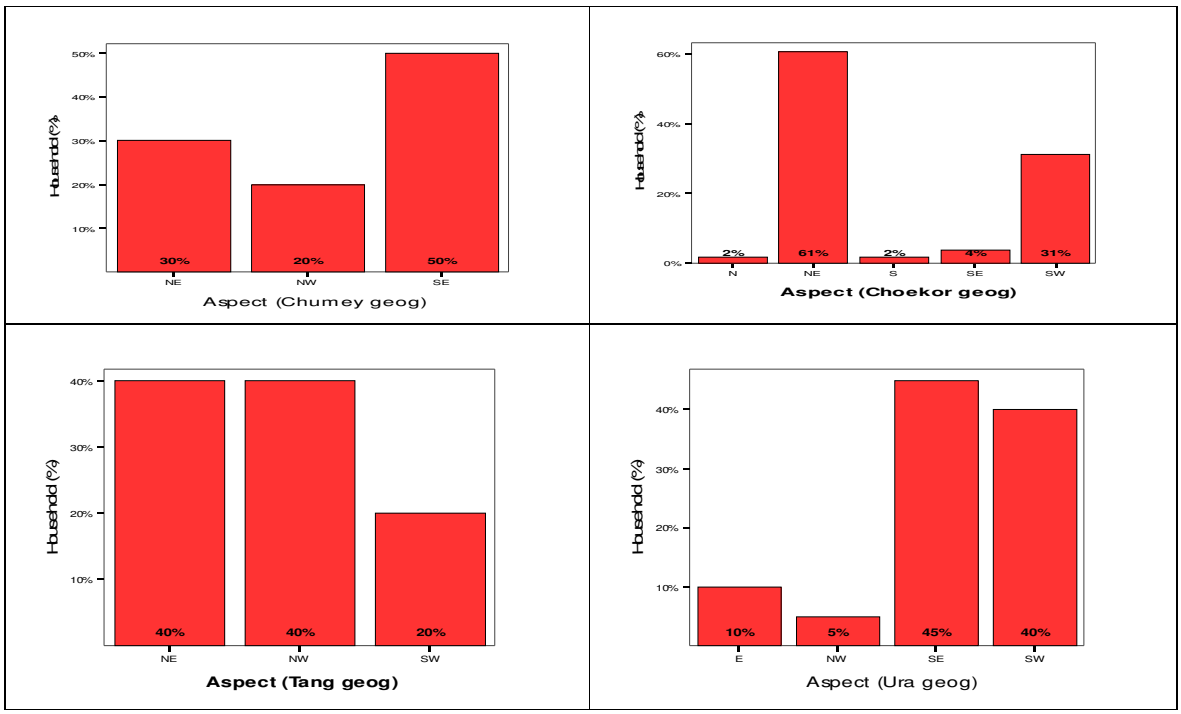


Figure 4: Aspects of the potato fields in the four geogs

3.3. Land size under potato cultivation

The areas of the potato fields are classified into four categories, small (< 1 langdos), medium (1.01-2 langdos), large (2.01-3 langdos) and very large (> 3.01 langdos). The majority of the sampled households in all the four geogs have small plots (<1 langdo).

The entire respondents of Chumey geog, has small plots (1 langdo). In Choekhor, about 59% of the respondents grew potatoes on small plots (<1 langdo), 33% on medium sized plots of 1.01-2 langdos and only about 8% on large (2.01-3 langdos) to very large plots (3.01 langdos). In Tang geog, 80% of the sampled plots are small while 20% are medium sized plots. In Ura, the majority of the sampled households grew potatoes in plots, which are small, 10% in medium, and 10% in large plots.

The respondents classified their lands into various landuse types *viz.* kamshing, chhushing, pangshing, and pasture. Potatoes are mainly grown in kamshing. All the farmers practiced crop rotation. Buckwheat, barley, wheat and sweet buckwheat are grown in rotation with the potatoes. However, the tendency of growing potatoes year after year is high as it is more profitable than other crops. Few farmers grow potato in the same field year after year especially if the land holding is small or if the land is new.

Where the fields are clustered, farmers are very much depended upon each other on deciding what crops to be grown next and this is done mainly to prevent the crop damage from wild boars, for example, by sharing fences if the common crop is potato. Therefore, the farmers more or less follow the same pattern of crop rotation.

Some farmers, especially the big landowners, after growing potatoes continuously in a field for a certain number of years, leave their fields fallow for sometime to recuperate.

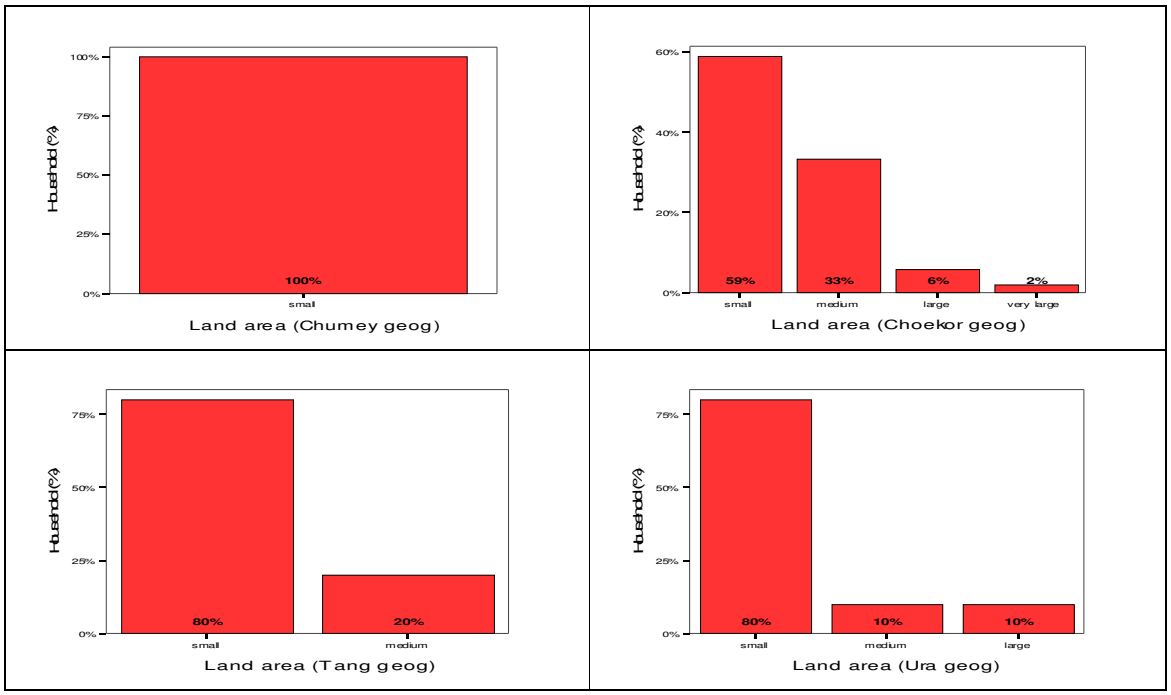


Figure 5: Land size under potatoes

Land ownership

Although the landholdings are generally small, the majority of the farmers (Chumey 100%, Choekhor 92%, Tang 100% and Ura 90%) were landowners growing crops on owned lands. Only 8% of the respondents in Choekhor and 5% in Ura were sharecropper. Mainly the landless or those with small land holding do sharecropping. In most cases, sharecroppers do not have the full authority over the land utilization; decisions as to what crops to be grown next are often made by the actual owners.

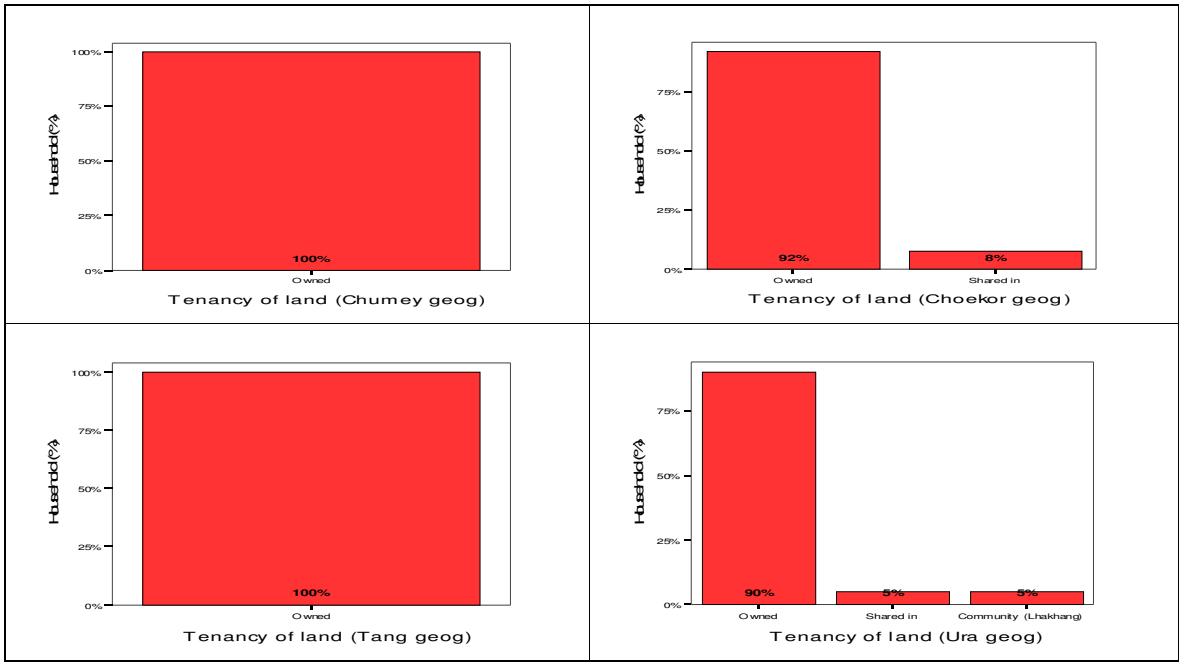


Figure 6: Land tenancy in the four geogs

3.5. Soil fertility management practices

3.5.1. Farmyard manure (FYM)

Soil fertility is maintained by applying FYM and inorganic fertilizers. Tethering is also practiced while trash burning is done only once when a new land is brought under cultivation for the first time. Leaf litters are not applied directly to the fields but as FYM by using them as cattle shed beddings. Majority of the farmers in all the four geogs apply FYM in substantial amounts (Fig. 8). On an average, Tang farmers apply about 3.8 tons/acre, Ura farmers about 2.9 tons/acre and Choeknor and Chumey apply about 0.9 and 0.8 tons/acre of FYM, respectively. There are farmers who do not apply FYM to potatoes for various reasons. For example, FYM is not applied if tethering is done on a regular basis as practiced by some farmers in Choekor geog. Some farmers in Kenchosum village in Choekor geog believe that FYM disfigures potato tubers and therefore they either apply FYM in small quantities or do not apply at all. Farmers also reported that the FYM is not applied if there is a shortage of FYM or if the fields are far from the homestead as in the case of the farmers of Rangbi, Urook and Bali villages in Chumey.

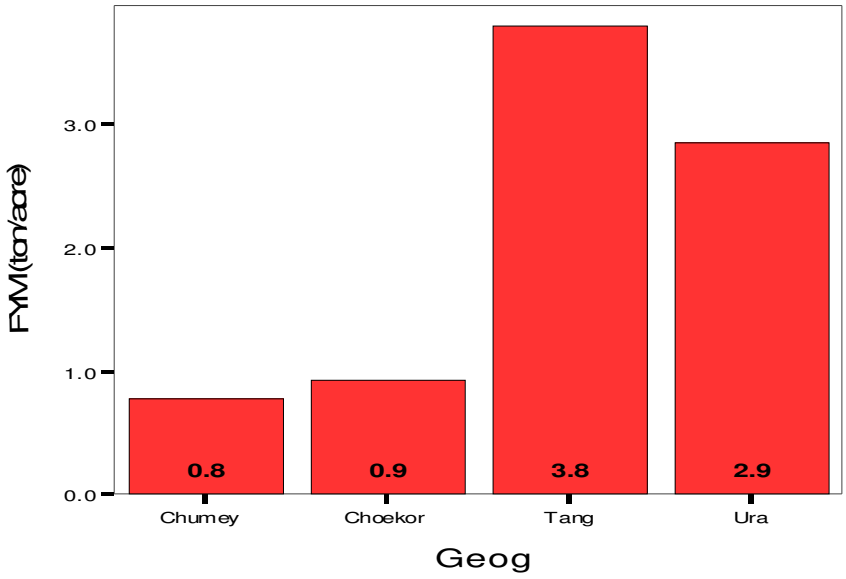


Figure 8: FYM application by the farmers of the four geogs.

3.5.2. Inorganic fertilizers

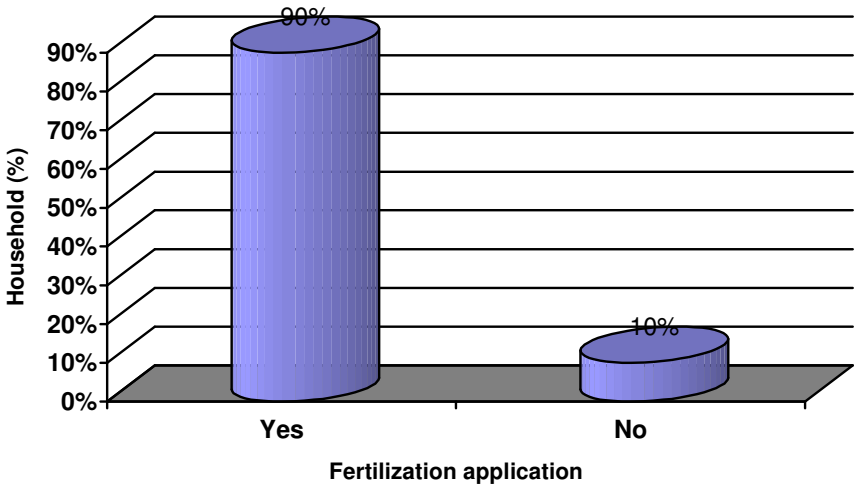


Figure 9. Percentage of households applying Inorganic fertilizers

Inorganic fertilizer application was considered to be must in potatoes and about 90% of the sampled households applied inorganic fertilizers. The most popular ones used were urea, single super phosphate (SSP) and suphala. Farmers who did not apply inorganic fertilizer at all were mostly either small landholders or sharecroppers. Some farmers with large herd sizes preferred applying FYM to inorganic fertilizers.

Table 1: Percent of the sample households in the four geogs using the three inorganic fertilizers.

Fertilizers	**Chumey (%)**		**Choekhor (%)**		**Tang (%)**		**Ura (%)**	
	Yes	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
Urea	100	0	92	8	80	20	65	35
SSP	67	33	92	8	60	40	80	20
Suphala	56	44	8	92	20	80	5	95

Table 1 shows the percentage of the sample households using the three fertilizers. Majority of the sampled households in the four geogs used urea and SSP. Suphala was not used by most mainly because it was more expensive and also the farmers were of the impression that it hardens and makes the soil difficult to work with after some years of its application. Generally, where urea and SSP combination was applied, SSP was applied in twice the amount of urea and suphala was applied in very small quantities.

Figure 10 shows the average rates of fertilizers applied in the four geogs and figure 11 shows the corresponding rates of nutrients supplied by the fertilizers applied.

Chumey:
The average rates of the fertilizers applied in this geog were 95 kg/ac urea, 190 kg/ac SSP and 164 kg/ac suphala and these amounts of fertilizers supplied 43 kg/ac N, 30 kg/ac P and 24 kg/ac NPK, respectively.

Choekhor:
In Choekhor, the average rates of fertilizer applications were 127 kg/ac urea, 300 kg/ac SSP and 146 kg/ac suphala and the rates of nutrients supplied by these amounts of fertilizers were 57 kg/ac N, 48 kg/ac P and 22 kg/ac NPK, respectively.

Tang:
In Tang geog, the average rates of fertilizers applied by the sampled households were 135 kg/ac urea, 174 kg/ac SSP and 50 kg/ac suphala and the rates of nutrients supplied to an acre of land were 61 kg/ac N, 28 kg/ac P and 7.5 kg/ac NPK, respectively.

Ura:
The average rates of fertilizers applied in the geog were as follows, 162 kg/ac urea, 336 kg/ac SSP and 60 kg/ac suphala and the corresponding rates of nutrients were of 73 kg/ac N from urea, 54 kg/ac P from SSP and 9 kg/ac NPK from suphala.

The highest rates of urea and SSP applications were in Ura and its suphala application rate was among the lowest after Tang geog. The highest rate of suphala application was in Chumey followed by Choekhor, while urea application rates in these two geogs were low.

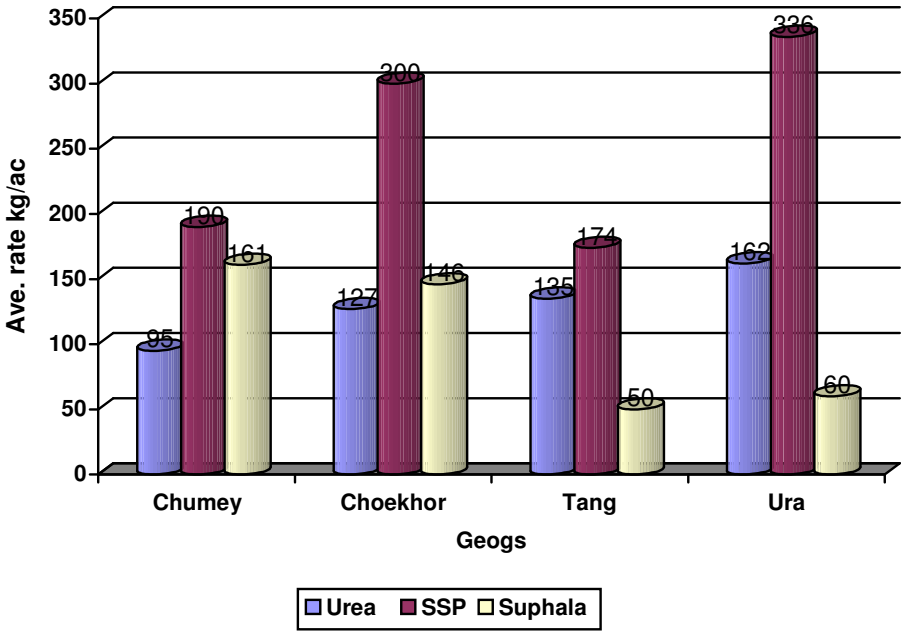


Figure 10. Average application rates of the three inorganic fertilizers

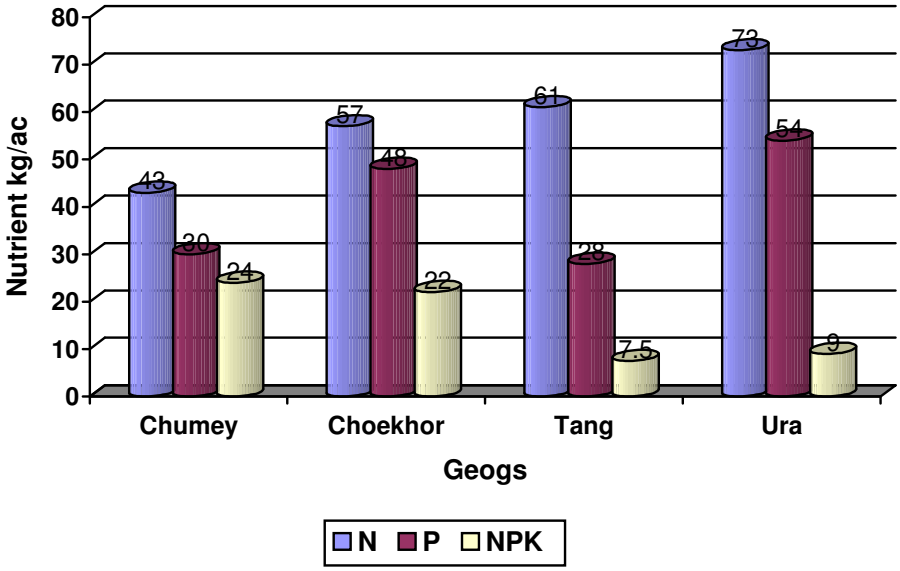


Figure 11. Average rate of nutrients supplied by the application of fertilizers.

Inorganic fertilizers are generally applied only once as basal application at the time of land preparation. Few farmers go for urea topdressing especially if the crop growth is poor at the initial stages. To prevent lodging, inorganic fertilizers are not applied to the subsequent crops such as wheat and barley. The residual effect of the fertilizers applied to the preceding potato crop is considered to be adequate for the following cereal crops. A small amount of urea is top dressed only if the crop growth is poor.

3.6. Crop yield

Crop yield has been categorised into very low (<1 tac^{-1}), low (1-5 tac^{-1}), medium (5-10 tac^{-1}), high (>10 tac^{-1}) yields.

Chumey:
About 44% of the total sampled households in Chumey geog reported to have low yield and 33% had medium yield.

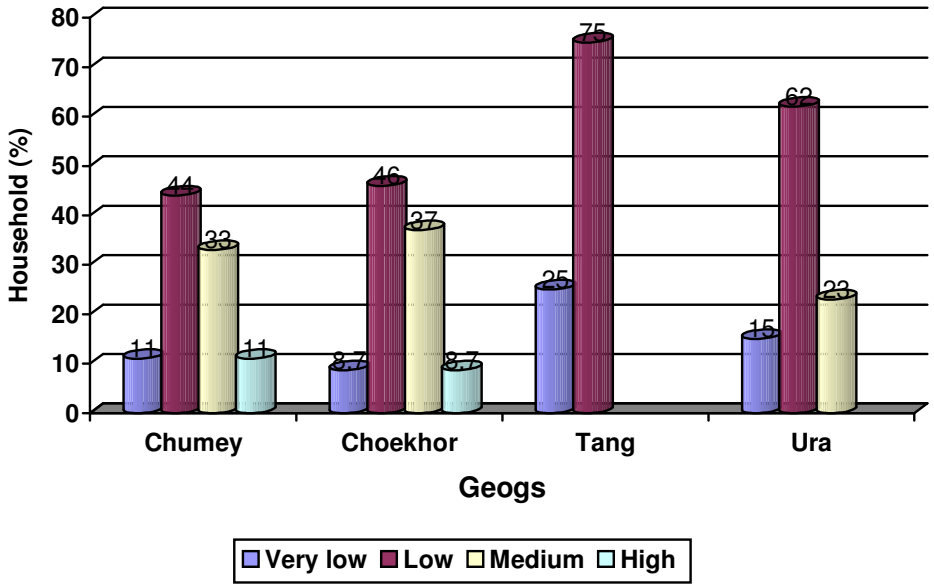
Choekhor:
In Choekhor geog, 46% of the sampled households had low potato yield and 37% of them had medium yield.

Tang:
In Tang geog, 75% of the households had low yield while 25% of them reported to have very low yield.

Ura:
About 62% of the sampled households had low yields, while 25% of them had medium yield.

Only few households, 11% in Chumey and 8.7% in Choekhor reported to have high yields of more than 10 tac-1. On average, the crop yield per acre was highest in Choekhor with almost 6 ac^{-1} followed by Chumey, Ura and Tang with 5, 3.5 and 3 tons per acre respectively (Fig. 12). These figures indicate that the average crop yields within the four geogs were below the national estimated yield of 5 – 8 tac^{-1} (FAO TCP/RAS/4554, 1997) obtained in farmers' fields under farmer management.

The crop yield appears to be related to the doses of fertilizers applied by the farmers. Ura, where higher doses of SSP and urea are applied has the highest crop yield per acre followed by Chumey where suphala is applied in higher dose as compared to Tang and Choekor geogs.



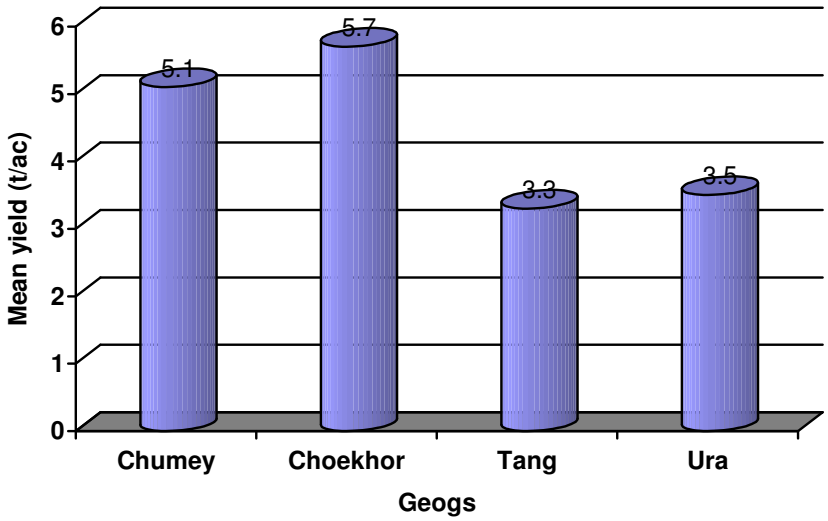
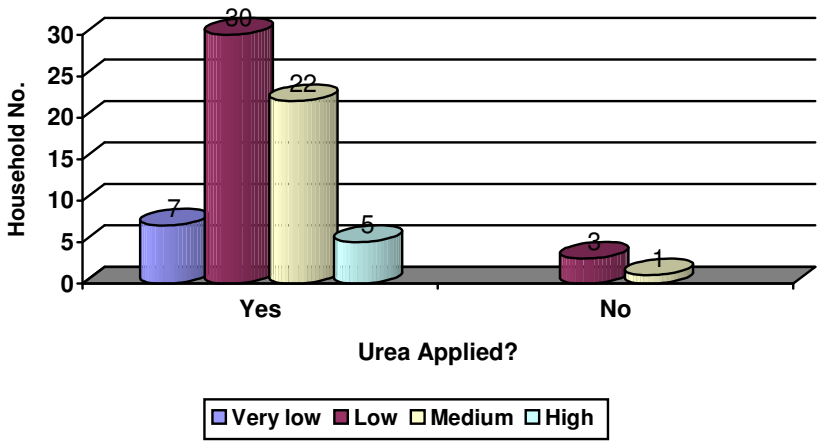


Figure 12: Mean potato yield in the four geogs

Potato yields in relation to inorganic fertilizer application is shown in figure 14. There were more households who applied urea and SSP and reported higher yields than those who did not apply these fertilizers. Since urea and SSP are applied in combination, the number of households who reported on the yields with these two fertilizers is similar. On the other hand, only a few households applied suphala and the crop yields that they got were similar to many who did not apply suphala. This probably could be due to the low application rate of suphala by those using it. On the whole, the crop yield was definitely greater with than without inorganic fertilizer application, especially in the case of urea and SSP.

The crop yield is also affected by the location of the fields in which the potatoes are grown. Although, the farmers on flat lands (e.g. Choekhor & Chumey) get good crop yield, much of it cannot be accounted for due crop damage caused by the waterlogging problem in wet season.



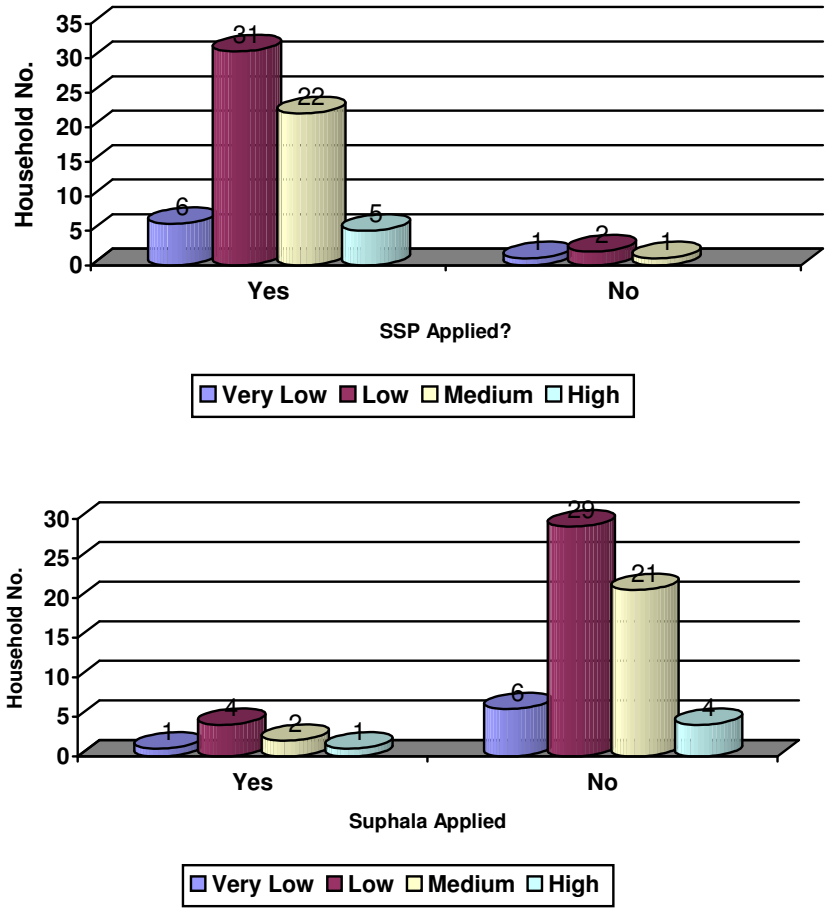


Figure 14: Potato yield in relation to inorganic fertilizer applications

3.7. Soil analytical results

3.7.1. Soil

pH

Figure 15 shows the pH of the soils in the four geogs. The soil pH has been categorised into five categories i.e. very high (>7.51), high (>6.51 and <7.5), medium (>5.51 and <6.5), low (>5.01 and <5.5) and very low (<5.0). Most of the samples from Chumey and Choekhor had low to medium pH while those from Tang and Ura had medium to high pH. Potatoes are tolerant of a wide pH range but grow best on slightly to moderately acid soils. The optimum pH for potato is between 5.0 -6.0. The pH of some soil samples in Choekor was very low i.e. less than 5. In soils with very low pH, the availability of many nutrients such as phosphorus, potassium, calcium, magnesium etc. could be low while that of iron, aluminium and manganese could be high resulting in the deficiency and toxicity of various nutrients, poor growth, low biological activity and reduced yield levels.

In Tang and Ura, some samples were found to have high pH range of 6.51 to 7.5. This probably could be due to the prolonged usage of soil acidifying fertilizers such as urea. In soil

with high pH, certain constraints such as low or unbalanced soil nutrient availability could hamper the crop growth and yield.

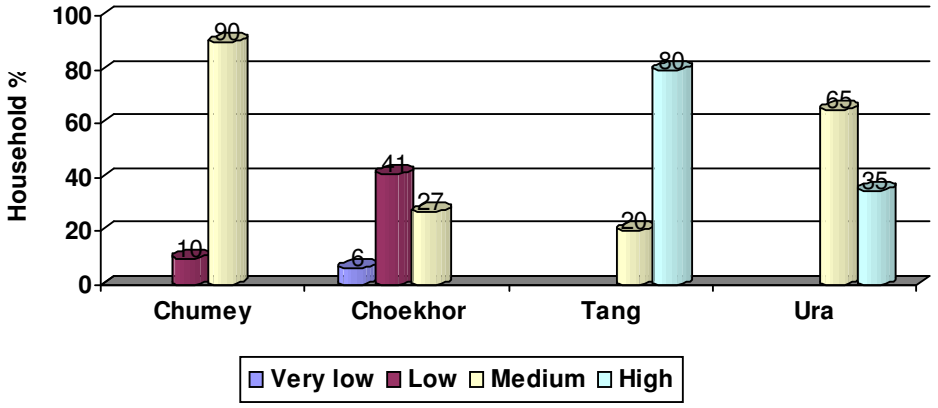


Figure 15: pH of the soils of the four geogs

CEC

The cation exchange capacity (CEC) is used to assess the fertility potential of a soil or the measure of the capacity of the soil to hold exchangeable cations (nutrients). The CEC has been categorised into five categories i.e. very high (>40.01), high (>25.01 and <40), medium (>15.01 and <25), low (>5.01 and <15) and very low (<5.0). The CEC of the most samples was within the low range of 5.01 to 15 me/100g. All the soil samples from Chumey, Tang and Ura and 90% from Choekhor had low CEC. Soils with low CEC are often associated with either light soil texture or high degree of degradation and therefore with low soil fertility. Where the fertilizer application per acre is low, the low CEC could contribute to the low crop yield.

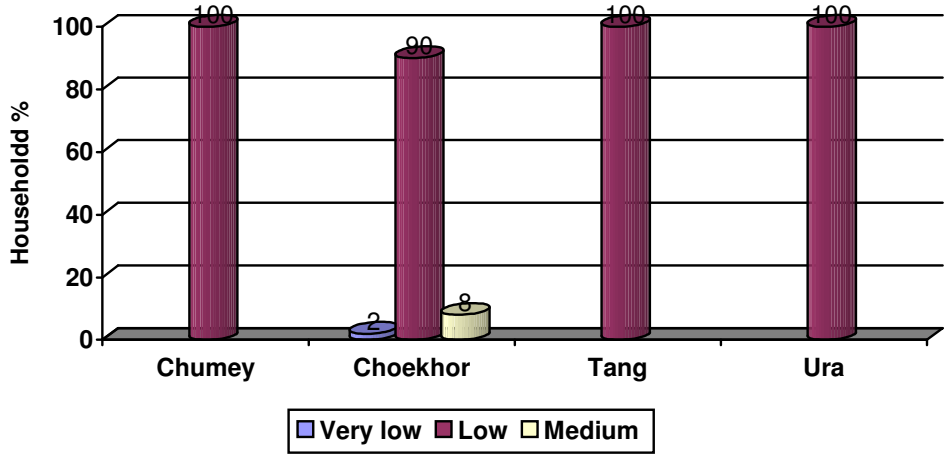
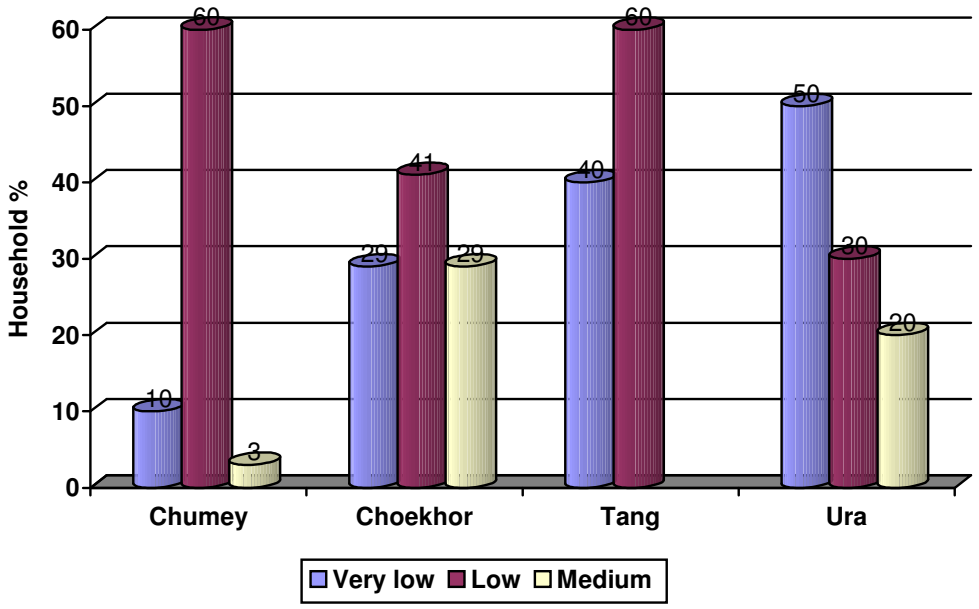


Figure 16: CEC of the soils of the four geogs

Nitrogen (N)

Nitrogen is an important nutrient for potatoes. Its deficiency reduces plant growth and crop yield besides accentuating certain diseases such as early blight and *Verticillium* wilt. On the other hand excess nitrogen may delay the onset of tuber growth, increase knobby potatoes, and promote excess vine growth.

The total soil nitrogen has been made into five categories: very low (<0.1%), low (0.1-0.19%), medium (0.2-0.49%), high (0.5-0.99%) and very high (>1%). In all the four geogs, most of the soil samples had very low to low total nitrogen percentage. Geogs that applied higher rates of urea per acre and lower rates of suphala had most of their samples with very low soil nitrogen. This probably indicates either the loss of nitrogen from the soil through leaching and/or volatilisation due to factors such as improper application method and timing or inadequate application of nitrogen containing fertilizers.



Available phosphorus (P)

Potato plants need phosphorus (P) for plant growth and will respond to P fertilizer if the soil test concentration is low.

The available P has been categorised into five ranges, very low (<5 $mgkg^{-1}$), low (5 – 15.01 $mgkg^{-1}$), medium (15.01 – 30 $mgkg^{-1}$), high (30.01 - 34 $mgkg^{-1}$) and very high (>34.01 $mgkg^{-1}$). Some soil samples from Chumey (20%) and Choekhor (61%) had very high available P of 34.01 $mgkg^{-1}$ or more. In these geogs, high available P was probably due to the application of suphala besides applying SSP in abundance by some farmers. On an average for every bag of urea, two bags of SSP are applied every year, which would obviously result in the build up of soil P. Other factors that could contribute to high P in the soil would be the shallow root system of potato plants not being able to utilize the less available P forms easily and the immobilization of phosphorus fertilizers in the soils with low pH.

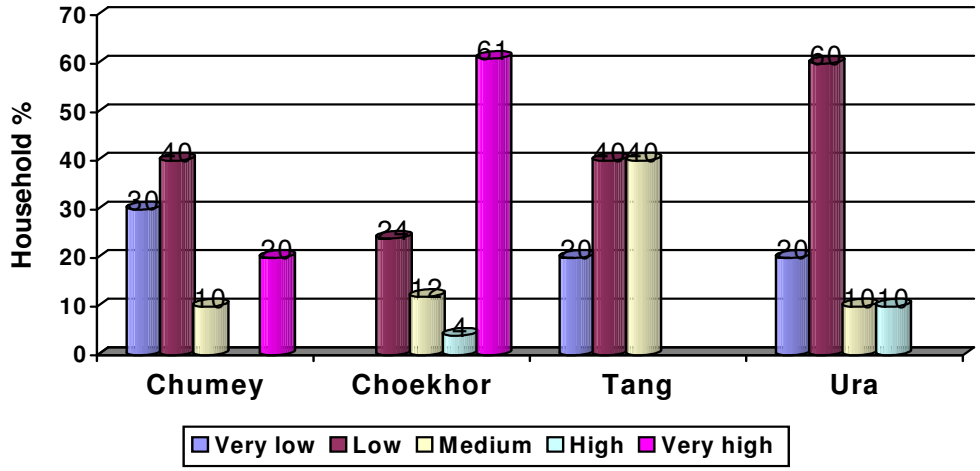


Figure 17: Available P

Available Potassium (k)

Potatoes require high levels of available soil potassium (K) as it plays an important role in photosynthesis and starch production by the potato crop.

The available K range has been classified as very low (<40 $mgkg^{-1}$), low (>40.01 and < 99 $mgkg^{-1}$), medium (>99.01 and <199 $mgkg^{-1}$), high (>199.01 and <299 $mgkg^{-1}$) and very high (>299.01 $mgkg^{-1}$). In all the four geogs, most of the soil samples had either low or medium available K and only about 5% of the sample in Ura had very high available K. For soils that were, in most cases, not supplied with mineral K fertilizer, these figures indicate a good status of K in the soils.

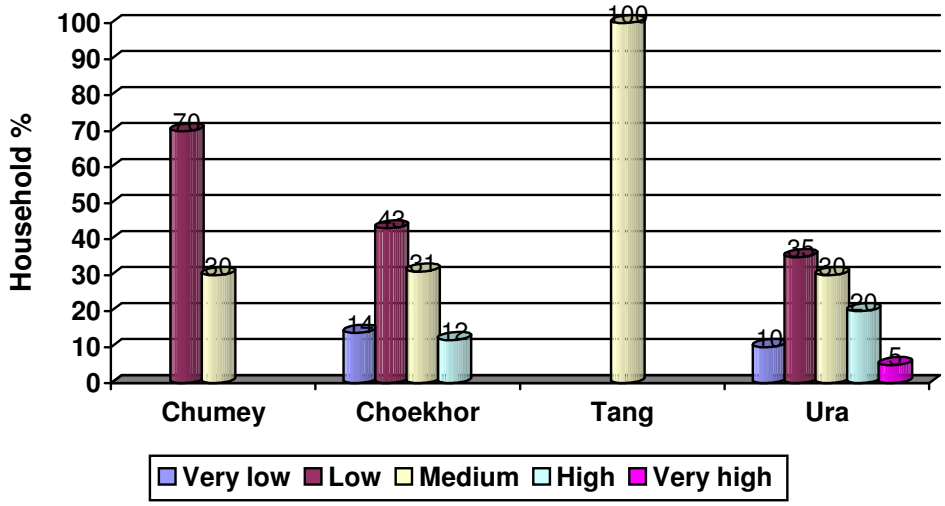


Figure 17: Available K

Carbon:Nitrogen (C:N)ratios

The C;N ratios are indicators of the type of organic matter present in the soil and, in particular, the degree of humification. C:N ratios are lower in tropics and higher in temperate

places. Crop residues such as rice straw would increase C:N ratios while others such as legume residues decrease C;N ratio.

Carbon:Nitrogen ratio has been categorised into five ranges: very low (<6), low (6.01-8), medium (8.01-10), high (10.01-12) and very high (12.01>). The figure shows a clear relationship between the C:N ratio and the altitudes of the four geogs. The percentage of the samples with very high pH increased with increasing altitude. Ura had the highest percentages of samples (85%) with very high C:N ratios followed by Tang with 80%, Choekhor with 71% and Chumey had the least percentage of samples with very high C:N ratios.

Tang and Ura being on slightly higher altitudes than Chumey and Choekor, would have lower temperature and the rate of decomposition of organic matters would be lower compared to that in Chumey and Chorkor with higher temperature.

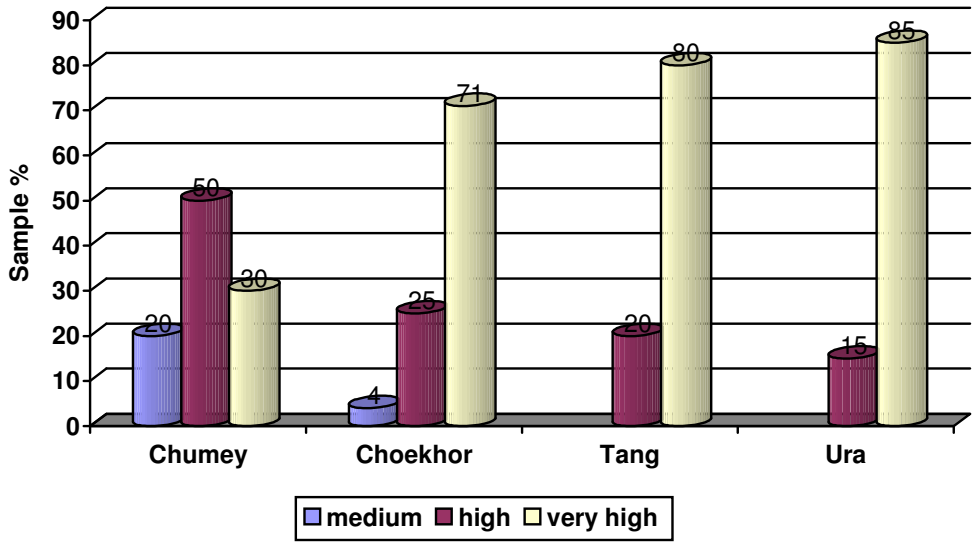


Figure 19:Carbon:Nitrogen ratio

Soil texture

The major soil textures are loam (L), sandy loam (SL), silty clay loam (ZCL) and silty loam (ZL). Tang soils (61%) are mainly loamy soils followed by that of Choekor (41%) and Ura (28%) while Chumey soils are either sandy loam (33%) or silty clay loam (33%) (Fig.20). Since the soils are of medium to light texture, the soils of all the four geogs are suitable for growing potatoes. Potatoes require medium to coarse textured soils, which are well drained, aerated and porous as potatoes have low tolerance to waterlogged conditions.

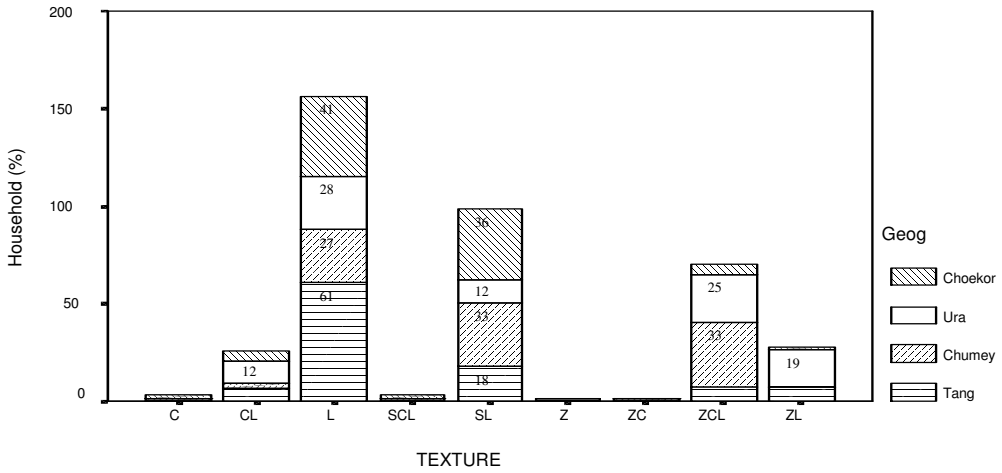


Figure 20: Soil texture of the soils of the four geogs

4. Conclusion

Potato is the major cash crop grown in all the four geogs of the Dzongkhag. Its importance as the cash crop has been heightened over the years by the improvement in the road network and access to market. In Bumthang Dzongkhag, potatoes are grown within an altitudinal range of 2250 – 3670 m.asl. on relatively flat lands (0%) to slopes as steep as 50% slope angle. The majority of the farmers are small landholders with the average landholding size of about 2 langdos however, most of them are landowners growing crops on owned lands and very few are sharecroppers.

Since the potato being the most important cash crop, farmers do not hesitate investing in soil fertility maintenance. In order to maximize their crop yields, farmers are applying inorganic fertilizers like urea, SSP and suphala besides following other practices such as applying FYM, leaf litter, trash burning and tethering. On an average, farmers are applying 49 kg N and 29 kg P in an acre from the use of urea and SSP and only about 7 kg NPK per acre by those using suphala. About 54 kg N, 10.5 kg P and 64.2 kg K per acre are supplied through the application of 3 t ac^{-1} on average by the geogs.

The average yield per acre is highest in Ura (7,000 kg ac^{-1}), where higher doses of inorganic fertilizers and FYM are applied in an acre and Choekor, which has the lowest average yield (4,136 kg ac^{-1}), has the lowest rate of both organic and inorganic fertilizer application per acre. According to the FAO, the potato yield at farmers' fields in Bhutan is about 6,500 kg ac^{-1} while yields under optimal conditions, at research stations are as high as 15,000 kg ac^{-1} to 25,000 kg ac^{-1}. This indicates that there is a potential to increase potato yield at farmer's field level with improved management including the soil fertility management aspects.

Laboratory analysis results show the nutrient content of the FYM samples to be 1.8% N, 0.35% P and 2.14% K which is equivalent to 18 kg N ha^{-1}, 3.5 kg P ha^{-1} and 21.4 kg K ha^{-1}. Most of the soils had pH and CEC within the low to medium ranges, suitable for growing potatoes. Available P was abnormally high in some cases probably due to the application of high doses of SSP fertilizer. Generally, for every bag of urea two bags of SSP are applied in potatoes. Despite not applying mineral K fertilizer by most farmers, the available K status in the soil was fairly good, probably due to a good soil's natural reserve of K and also the

contribution from FYM. The organic matter content was higher in the soils of Tang and Ura, which are on higher altitudes than Chumey and Choekor.

5. Recommendations

⌘ Urea and SSP are the two main fertilizers applied in potatoes by the farmers and the plants requirement for the third important nutrient K is often not taken care of. Such imbalanced nutrient use has been shown to stagnate crop yield levels in other countries besides influencing the quality of the potatoes. Excess nitrogen fertilizer can reduce tuber dry matter and cooking quality while potassium deficiency can cause blackening of the tubers. Farmers should be educated on the use of balanced soil nutrients.

⌘ Farmers should know the importance of the soil analysis to find out their soil nutrient status and to base their fertilizer applications on the results of the analysis.

⌘ On average, the nutrient input through inorganic fertilizer is fairly low with 49 kg ac^{-1} N from urea, 29 kg ac^{-1} P from SSP. Mineral K is supplied mainly through FYM application. Nutrients supplied through FYM application are minimal. FAO recommends at least 70 kg N, 80 kg P and 35 kg K per acre for Bumthang area. See the improvement in the crop yield using this rate.

Fertilizer recommendations for nutrient rate of 70-80-35 kg NPK ac^{-1}.

(1) From Suphala, SSP and Urea (in once acre)
Apply 219 kg of Suphala and 281 kg of SSP at the time of land preparation as basal application. Apply 76 kg of urea soon after the first weeding.

(2) From Urea, SSP and MOP (in one acre)
Divide 152 kg urea in two equal doses and apply the first dose as basal at the time of planting and apply the second dose soon after the first weeding. Apply 500 kg SSP and 58 kg MOP as basal at the time of land preparation.

⌘ Soils with very high available P and K may not require regular application of these two minerals fertilizers at least for few years.

⌘ Since the soils are light textured soils, apply urea and potassium in at least two split doses to reduce losses through leaching and runoff.