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Potato based farming system's soil management
Bumthang-Report-1/2002

1. Introduction

In Bhutan, where farming systems are largely traditional and oriented towards food self-sufficiency, soil fertility management is considered secondary by the majority of the farming community. With only 8 percent of the total land area of the 45,000.00 sq km being cultivatable and already under cultivation, marginal lands are brought under cultivation and put under increasing pressure as farmers cultivate larger areas to maintain production and on the other hand, lands are also fragmented as a result of the land distribution among the children by the parents and these small lands are continuously cropped. Often little is done to sustain soil nutrient levels and the productivity capacity of the soil. Information covering the nutrient status of soils under farmer's management is inadequate. Such information is important to assist the farmers in crop production. Therefore, 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. Along with the soil samples, farmyard manure, cattle shed bedding materials and crop samples are also collected. Soil samples will be collected once every two to three years from the same areas.

Potato is an important cash crop besides constituting a major part of the Bhutanese diet. It is grown mainly as dry land crop and the potato based farming system is one of the major farming systems in the country. With better road networks being developed and access to markets being improved, the importance of potatoes as a major cash crop is still growing. This report is on the soils of the major potato growing areas of the Bumthang Dzongkhag, one of the important potato growing districts. Between 19th and 31st August 2002, the National Soil Services Centre (NSSC) collected soil samples from about 350 households spread over 51 villages within the four geogs of the Dzongkhag.

2. Method

This study covered the four geogs *viz*. Chumey, Choekor, Tang and Ura located at slightly different altitudes and with different population densities. Within each geog 50% of the total households were selected as sample households. Based on the lists of the sample households prepared by the geogs' extension agents (EAs), soil, FYM and cattle shed bedding materials samples were collected from the fields. Composite soil samples were collected from the fields clustered within an area. One composite sample collected from one field consisted of at least 7 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. FYM and cattle shed bedding materials were also collected. 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.

3. Results and discussions

3.1. Sample households

Figure 1 shows the percentage of the sample households in the four geogs. The maximum sample households are in Choekor geog (36%) followed by Tang (24%), Chumey (21%) and Ura has the least sample households with just about 20% of the total sample households. Almost all the villages of the Choekor geog have access to motor roads and therefore potatoes are grown widely across the geog. Motor roads have encouraged the farmers to grow potatoes. For example, Shingneer village under Ura geog did not have motor road until a couple of years back and the farmers there did not grow much potatoes then. Now with a motor road passing right through the village, farmers grow potatoes on large scales and have improved their living standards.

Ura has the least sample households mainly because the farmers of Shingkhar village depending on livestock as their main source of income and not on cash crops like potatoes. Another contributing factor for potatoes not being very popular in this village is the wild boar problem.

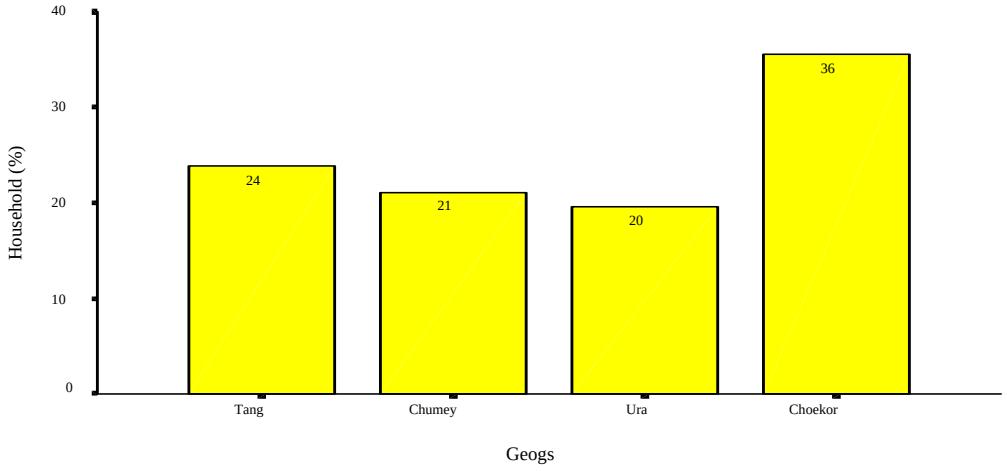


Figure 1. Percentage of sample households

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

Altitudes at which the potatoes are grown are shown in the figure 2 below. The four geogs are located approximately between 2676 m.asl. (Chumey) and 3468 masl (Ura). The altitudinal range has been categorised into low, which is less than 2500 m.asl, medium between 2500-3000 m.asl and greater than 3000 m.asl is high altitude. Most of the sample households of Chokhor, Chumey and Tang geogs fall in the mid altitude range while those in Ura are all in the higher altitudes of not less than 3000 m.asl. Only 6% of the households in Chumey, falling in low altitude (below 2500 m.asl) are growing potatoes.

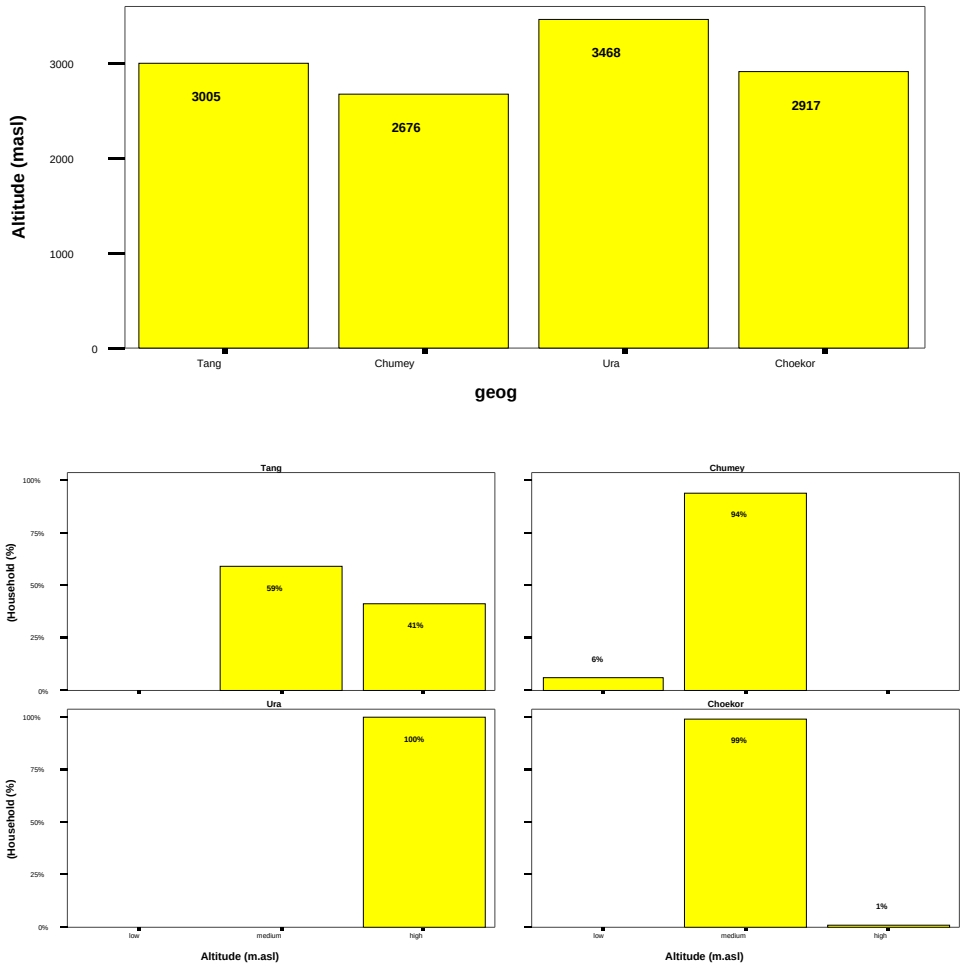


Figure 2. Altitudes at which the potatoes are grown

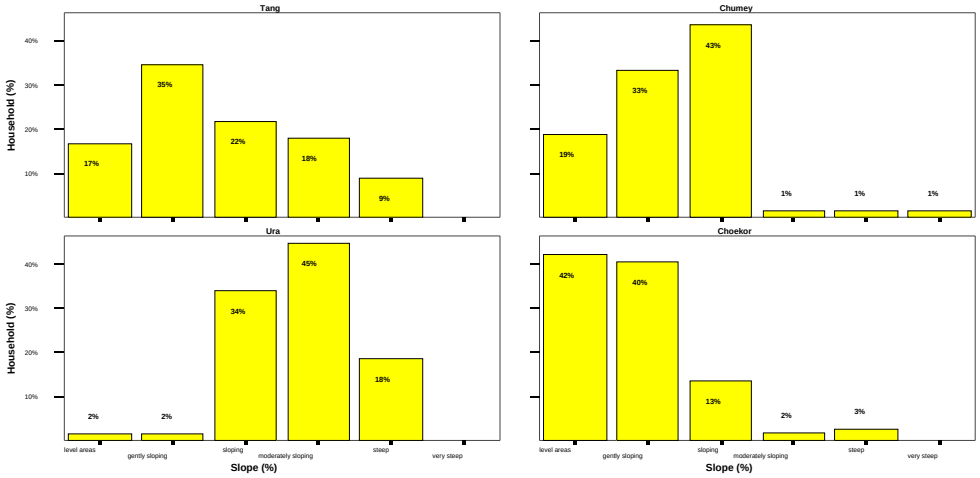


Figure 3. Slopes of the potato fields

Potatoes in Chumey geog are grown within an altitudinal range of 2250 – 2884 m.asl on relatively flat lands (0%) to sloping lands of 9 -15% gradient and most of the fields are facing either North-east (41%) or South-east (30%) directions. In Chokhor, most of the potato fields are found within the altitudinal range of 2800 and 3045 m.asl. and are mainly on level (0%) to gently sloping areas of 4% to 8%. Most of these fields face North-east (51%) direction. In Tang, potatoes are grown within the altitudinal range of 2920-3250 m.asl and mainly on gently sloping to sloping land with slope angles of 22% to 34% respectively. Most of the potato fields here face South -East (29%) and South -West (28%) directions while in Ura, potatoes are grown in higher altitude within the range of 3140 and 3670 m.asl. and on steeper slopes of 9% to 50% gradients facing south-west (45%) and South-east (34%) (Fig. 3 & 4).

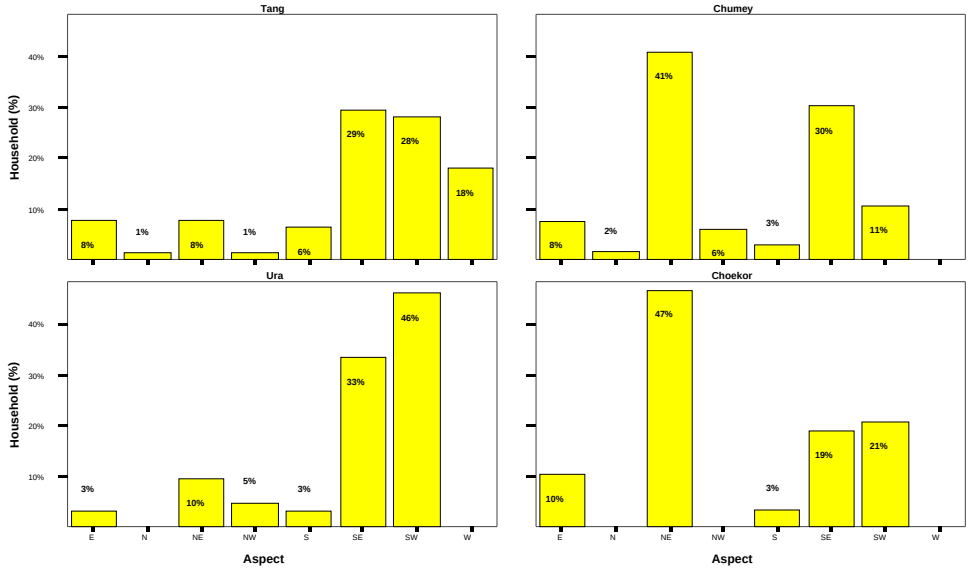


Figure 4. Aspects of the potato fields

3.3. Land size under potato cultivation

The areas of the potato fields are classified into four categories, small (< 3 langdos), medium (3-6 langdos), large (6-9 langdos) and very large (> 9 langdos). In Tang 87%, Chumey 98% and Ura 97% of the households grow potatoes in fields, which are less then 3 langdos in area while in Choekor, the majority (49%) of the farmers grow potatoes on medium sized fields (Fig. 5). Fields in Choekor geog are mostly on low-lying flat lands and the potatoes are grown on larger areas of land while in Chummey most of the fields are shared with people from other villages and therefore are fragmented into smaller plots.

Farmers classify their land into various landuse types *viz.* kamshing, chhushing (which is normally irrigated), pangshing (new land), nagshing and rishing and the potato is mainly grown in kamshing. All the farmers practice crop rotation and the sequences of crop rotation followed by the majority of the farmers are potato-sweet buckwheat-potato or potato-buckwheat-wheat-potato. However, the tendency of growing potatoes year after year is high as it is more profitable than other crops.

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

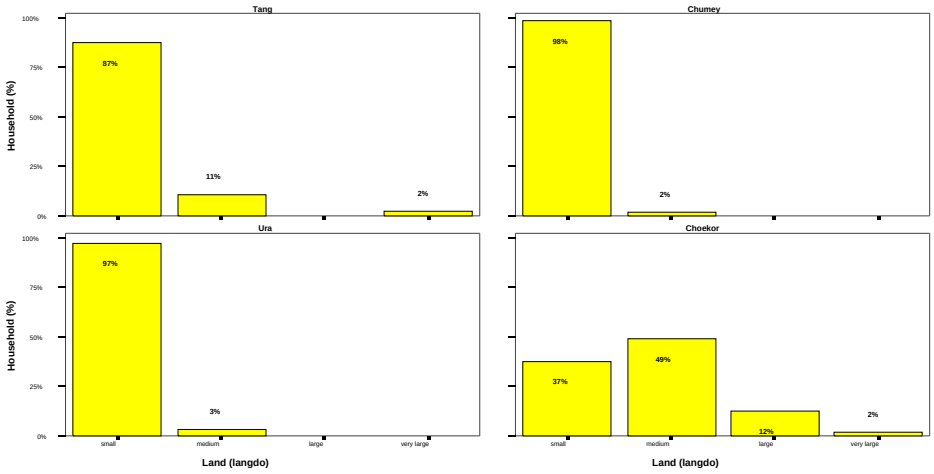


Figure 5. Land size under potato crops

Although the landholdings are generally small with an average size of about 2 langdos, the majority of the farmers (Tang 91%, Chumey 92%, Ura 94% and Choekor 86%) are landowners growing crops on owned lands and very few are sharecroppers (6%-14%). Most of these sharecroppers are found in Tang and Choekor (Pangrey village) geogs (Fig. 6) where most of the lands are still owned by big landlords. In most cases, sharecroppers do not have the full authority over the land utilization; decisions as to what crops to be grown next are partly made by the actual owners.

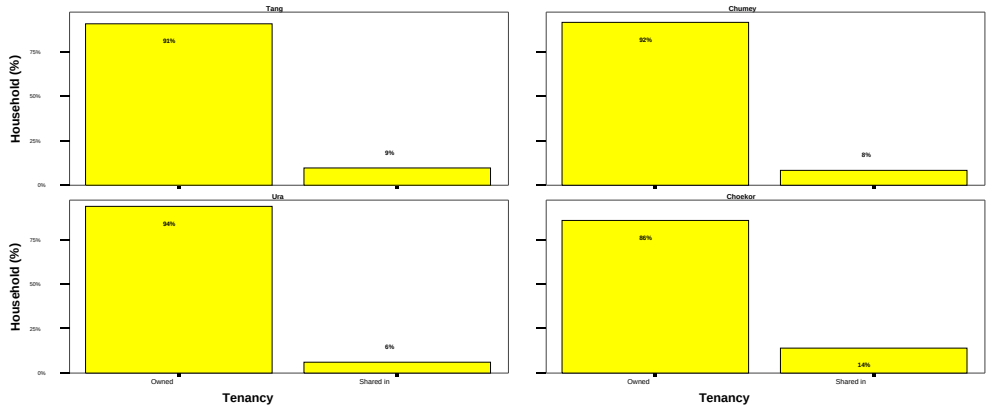


Figure 6. Land tenancy

3.4. Farmers perception of their soil fertility status

Soil fertility status according to the farmers of the four geogs is shown in figure 7. The majority of the farmers in all the four geogs rated the fertility status of their fields either as good or medium. In Tang (44%), Chumey (53%), Ura (31%) and Choekor 51% of the farmers rated their fields as highly fertile while 53%, 39%, 57% and 48% of the farmers in Tang, Chumey, Ura and Choekor respectively considered their fields to be moderately fertile. Few farmers, mostly in Ura (12%), rated their soils to be infertile (Fig. 7). Farmers rated the soil fertility status based on the soil texture, colour and drainage. Marshy soils are considered as either moderately fertile or poor and light textured and light coloured soils as poor soils. New lands that are brought under cultivation recently are considered to be very fertile and farmers grow potato on these lands continuously for sometime without applying much fertilizer.

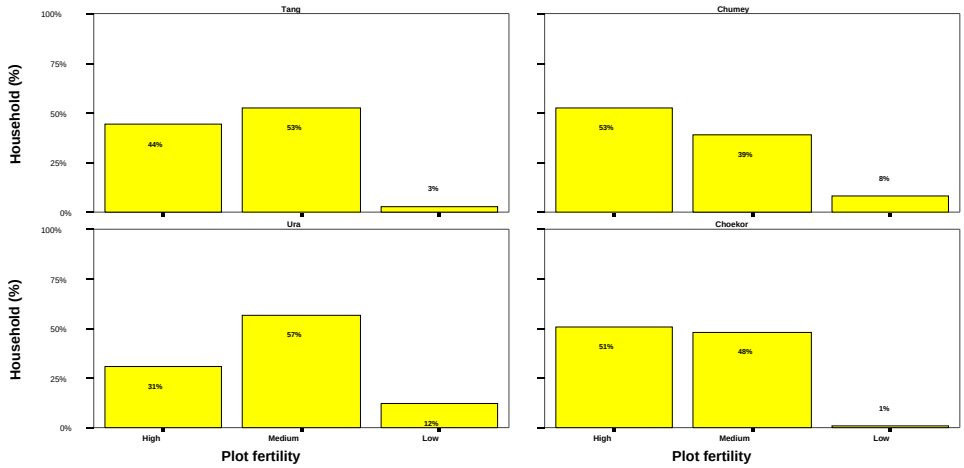


Figure 7. Soil fertility status

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). In Tang, all the households apply FYM while in Chumey, Ura and Choekor, 73%, 84% and 55% respectively of the total households apply FYM. On an average, with 5.0 tons/acre, Ura farmers apply a greater amount of FYM in an acre of land followed by Choekhor with 4.6 tons, Tang with 3.2 tons and finally 2.8 tons per acre in Chumey.

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 the 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.

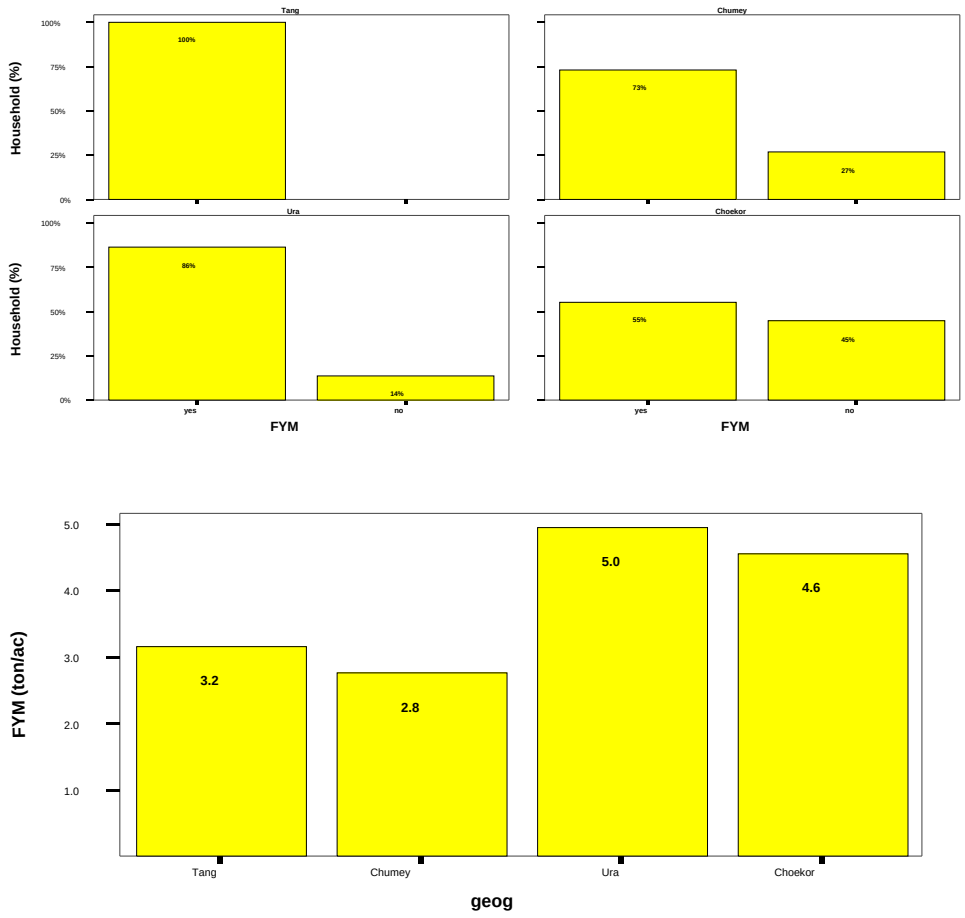


Figure 8. FYM application.

3.5.2. Inorganic fertilizers

Inorganic fertilizer application is considered to be must in potatoes and the most popular ones used are urea, single super phosphate (SSP) and suphala Table 1. However, suphala is not as popular as SSP and urea as it is more expensive and also because some farmers believe that it hardens the soil and makes it difficult to work with after some years of its application. Where urea and SSP combination is applied, most farmers apply SSP in twice the amount of urea. Among the four geogs, Tang uses the least amount of urea with 66% households followed by Chumey (81%) and then by Ura (85%). With 93% of the households using urea, Choekor geog on the whole, uses a lot of urea in potatoes. On an average, however, Ura farmers are using a greater dose of urea in an acre (169 $kgac^{-1}$) and Tang uses the least with 77 kg urea ac^{-1}. Choekor and Ura where urea is being used the most also use a great deal of SSP. Choekor has the highest percentage of households using SSP (90%) followed by Ura (75%) but again, on average, the farmers of Ura are using more SSP in an acre (380 $kgac^{-1}$) than the farmers of Chumey using 230 $kgac^{-1}$. Chumey and Tang geogs use more of suphala than urea and SSP. In Chumey 64% and Tang 60% of the household are using suphala and on average greater doses of suphala per acre is applied in Chumey with 218 $kgac^{-1}$ while Tang, Ura and Choekor apply 118 kg, 98 kg and 70 kg of suphala per acre respectively (Fig. 10). Figure 11 shows the rates of nutrients supplied by the amount of fertilizers shown in Figure 10.

Farmers who do not apply inorganic fertilizer at all are mostly either small landholders or sharecroppers. Some farmers who have large herd sizes prefer applying FYM to inorganic fertilizers.

Table 1.Percentage of the households using inorganic fertilizers

Fertilizers	Chumey (%)		Choekhor (%)		Tang (%)		Ura (%)	
	Yes	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
Urea	81	19	93	7	66	34	89	11
SSP	51	49	90	10	50	50	75	25
Suphala	64	36	17	83	60	40	23	77

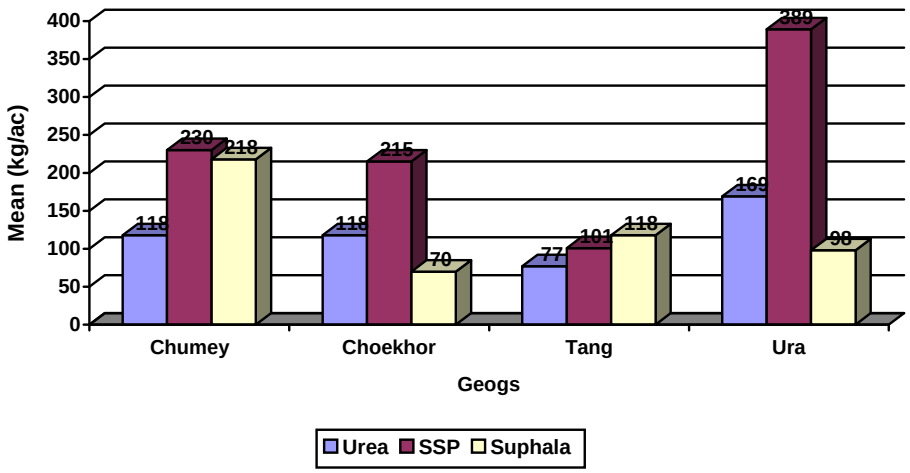


Figure 9. Average application rates of the inorganic fertilizers

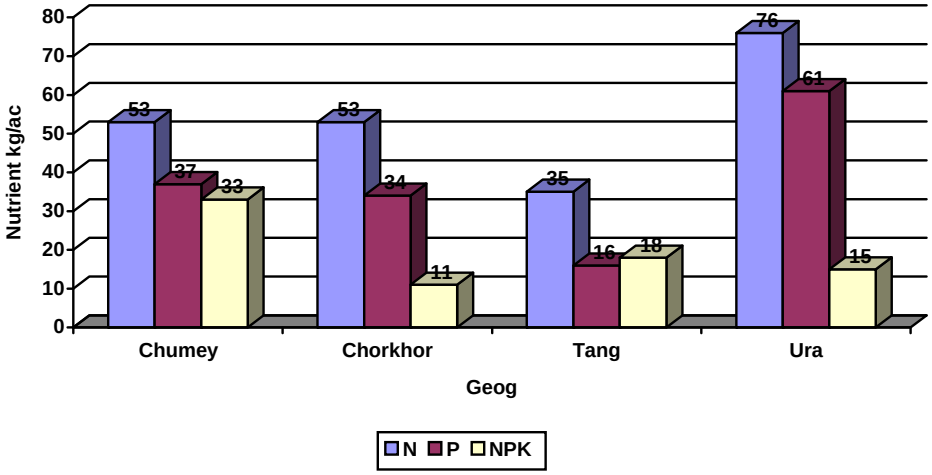


Figure 10. Average rate of nutrient supplied through fertilizer application

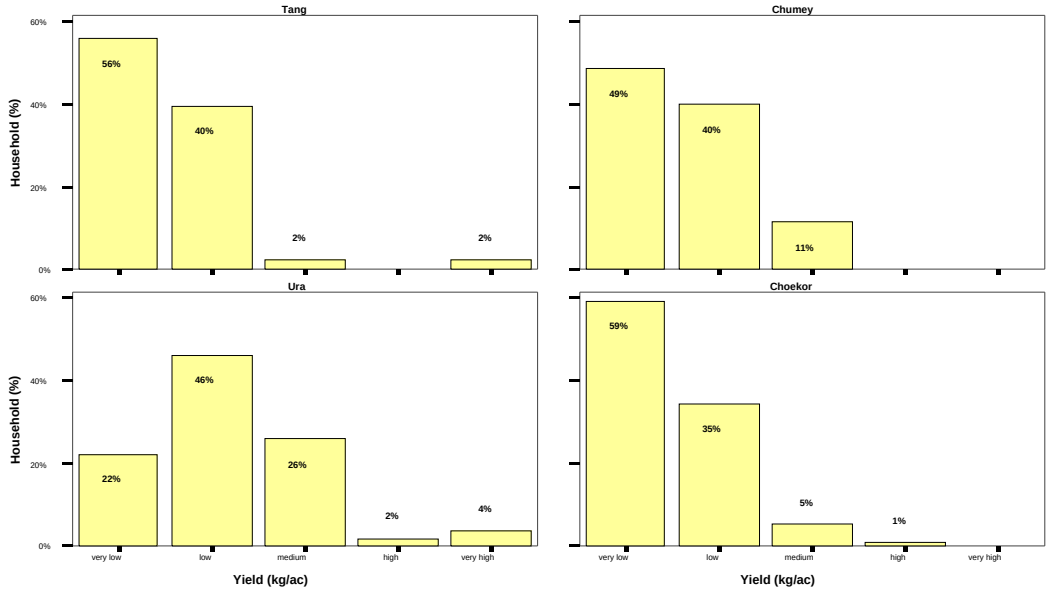
Inorganic fertilizers are generally applied only once as basal application at the time of land preparation. Few farmers go for urea topdressing especially if the crop growth is poor at the

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 (<4000 kgac^{-1}), low (4000-8000 kgac^{-1}), medium (8000-12000 kgac^{-1}), high (12000-16000 kgac^{-1}) and very high (>16000 kgac^{-1}) yields. The majority of the farmers in all the four geogs (96% in Tang, 94% in Chokhor, 89% in Chumey and 68% in Ura) reported that they have very low to low crop yields. Only a few households (7%) said that they have high to very high crop yields and some of them even harvesting as much as 30,000 kgac^{-1}. On average, the crop yield per acre is highest in Ura with almost 7,000 kgac^{-1} followed by Chumey, Choekor and Tang with 4,863 kg, 4,136 kg and 3764 kg per acre respectively (Fig. 12). These figures indicate that the average crop yield within the Bumthang Dzongkhag is below the estimated yield of 5,000 – 8,000 kgac^{-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.



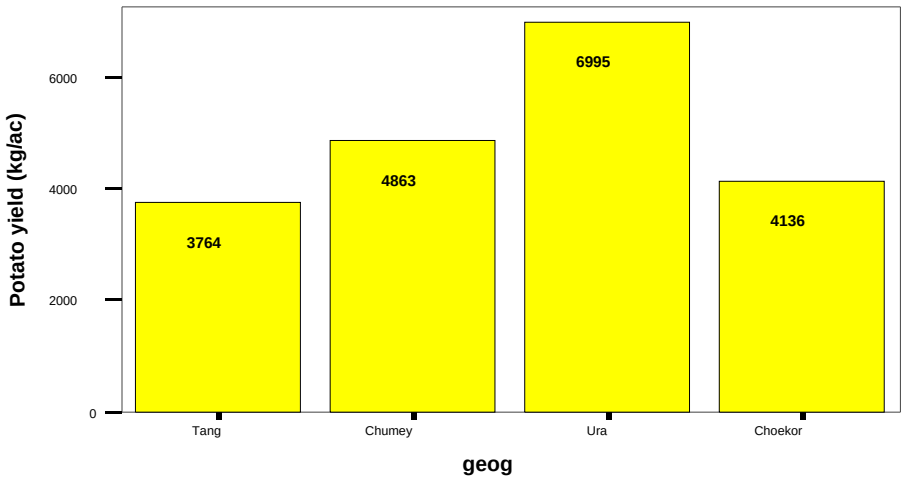


Figure 11. Potato yield

There seems to be a relation between the crop yield and farmers' opinion of their plot fertility. Farmers who considered their plots to be of medium to high fertility have greater crop yields compared to those who said that they have poor soil quality (Fig. 13).

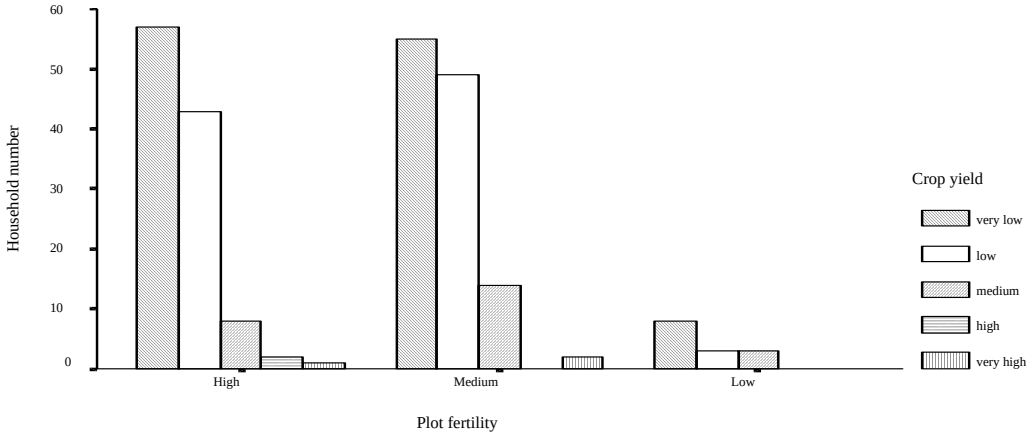


Figure 12. Potato yield in relation to farmers' perception of plot fertility

The crop yield in relation to inorganic fertilizer application is shown in figure 14. Farmers applying SSP and Urea have greater yields compared to those applying only suphala and the yield is definitely greater with inorganic fertilizer application than without inorganic fertilizer except in the case of suphala where yield is better off without suphala than with suphala. The crop yield is also affected by the location of the fields in which the potatoes are grown. Many farmers in Choekor and Chumey where the land is fairly flat reported that though they get good potato yield, much of it cannot be sold due to the damage (rotting) caused by the waterlogging problem in the wet season.

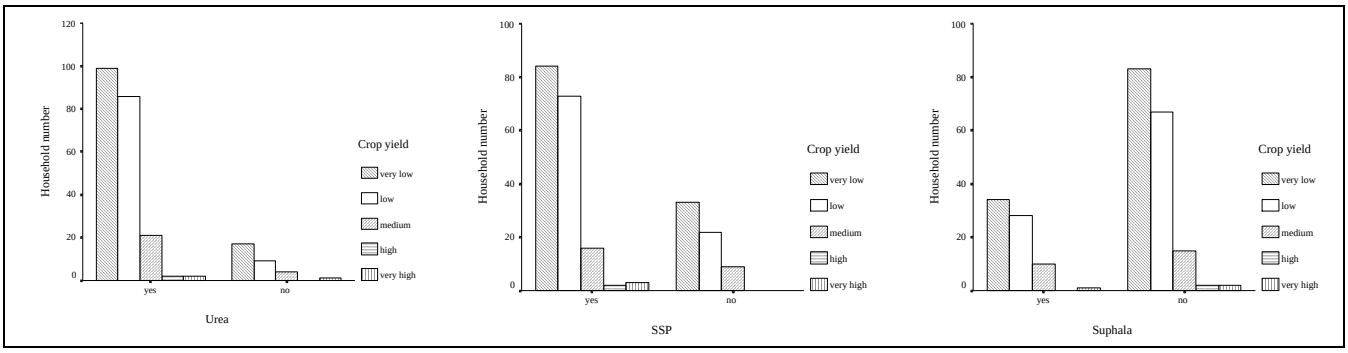


Figure 13. Potato yield in relation to inorganic fertilizer application

3.7. Soil analytical results

3.7.1. Farm Yard Manure (FYM)

The nutrient content of the FYM samples collected from the four geogs is 1.8% Nitrogen (N), 0.35% Phosphorous (P), 2.14% Potassium (K), 1.44% Calcium (Ca), and 0.30% Magnesium (Mg) at 45% dry matter while the nutrient content of the cattle shed bedding materials only is 1.42% N, 0.11% P, 1.1% K, 1.08% Ca, and 0.14% Mg at 58% dry matter. If these figures are converted into the nutrient kg ha^{-1} the FYM manure would supply about 18 kg N, 3.5 kg P and 21.4 kg Kha^{-1} (or 7.4 kg N ac^{-1}, 1.4 kg P ac^{-1}, and 8.6 kg K ac^{-1}) while the cattle shed bedding materials composed mainly of ferns, shajurshing (Dz) and pine needles would supply 14 kg N, 1.1 kg P and 11 kg Kha^{-1} (or 6 kg N ac^{-1}, 0.4 kg P ac^{-1} and 4.4 kg K ac^{-1}). These figures indicate that the leaf litters have lower nutrient contents than the FYM and therefore the farmers are better off applying the leaf litter to the fields after using it as cattle shed bedding and therefore mixed with dung and urine (as FYM) than using it directly on its own.

The amount of nutrients supplied through the application of: 2.8 tac^{-1} FYM in Chumey would be 21 kg N, 4 kg P and 24 kg K per acre, 4.6 tac^{-1} FYM in Choekhor would be 34 kg N, 6 kg P and 40 kg K per acre, 3.2 tac^{-1} FYM in Tang would be 24 kg N, 5 kg P and 28 kg K per acre and finally 5 tac^{-1} FYM in Ura would be 37 kg N, 7 kg P and 43 kg K per acre.

3.7.2. Soil

pH

Figure 15 shows the pH of the soils in the four geogs. The soil pH has been categorised into four categories i.e. very high (>7.5), high (>6.5 and <7.5), medium (>5.5 and <6.5), low (>5.0 and <5.5) and very low (<5.0). Most of the soil samples have pH within the low to medium range, but still suitable for potatoes. 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. The pH of some soils in Chumey and Choekor is less than 5 and therefore in these soils the availability of phosphorus, calcium and magnesium could be low while that of iron, aluminium and manganese could be high resulting in the deficiencies and toxicities of various nutrients, poor growth, low biological activity and reduced yield levels. Soils with pH above 7 found in Tang and Ura, could have constraints such as low or unbalanced soil nutrient availability.

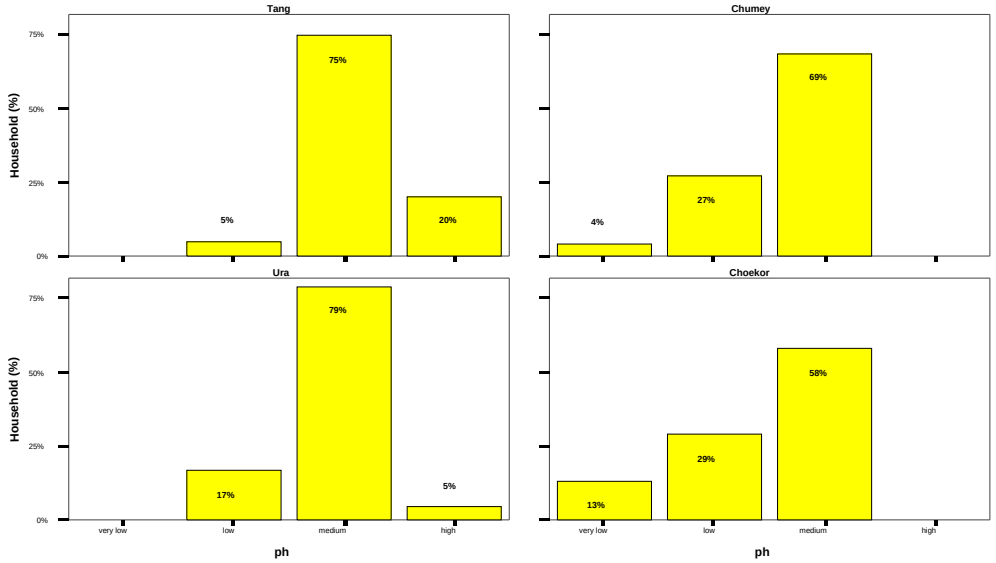


Figure 14. pH of the soils

CEC

The cation exchange capacity (CEC) is used to assess the fertility potential of a soil. The CEC (Fig.16) of the samples is within the low to medium range of 5 to 25 me/100g. This range is within the satisfactory range for an agricultural land if the soil fertility is managed properly. Among the four geogs, most of the soil samples from Ura (92%) have low CEC followed by those of Choekor (88%) indicating that the soils of these two geogs are either more degraded or are lighter textured soils as compared to the soils with higher CEC of Tang and Chumey. Although the CEC of most of the soils in Ura is low, the average crop yield per acre is high and this probably is due to the higher doses of fertilizers applied per acre in Ura. Choekor, where the fertilizer application per acre is low, the low CEC could contribute to the low crop yield.

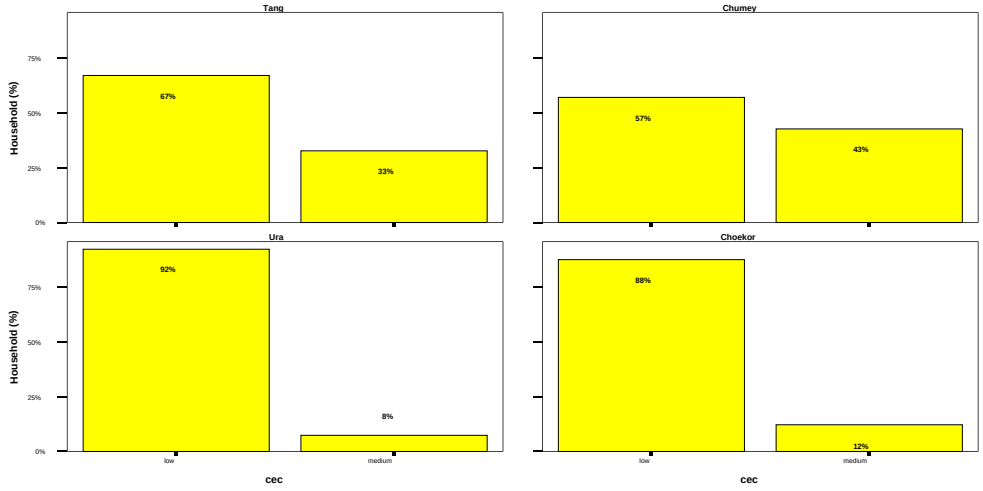


Figure 15. CEC of the soils

Available Phosphorus (P)

The available P has been categorised into four ranges, very low (<5 mgkg^{-1}), low (>5 – 14.9 mgkg^{-1}), medium (15 – 29.9 mgkg^{-1}), and high (>30 mgkg^{-1}). Most of the soil samples from Chokhor and Chumey have higher (>30 mgkg^{-1}) available P as compared to those from Tang and Ura (Fig. 17). In these geogs, higher available P is probably contributed by SSP being applied in abundance by some farmers. On an average for every bag of urea, two bags of SSP are applied every year, which would 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.

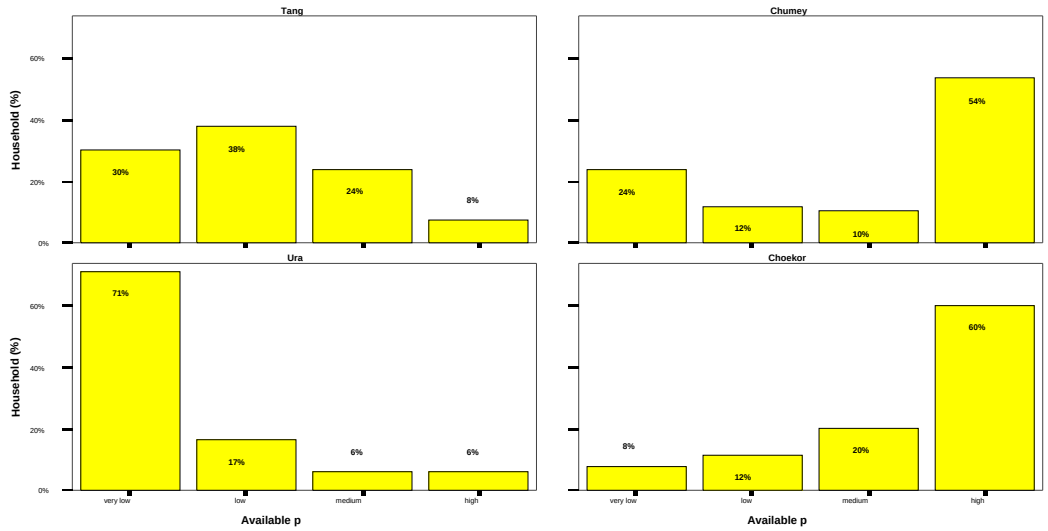


Figure 16. Available phosphorous

Available Potassium (K)

The available K range has been classified as very low (<40 mgkg^{-1}), low (>40 and < 99 mgkg^{-1}), medium (>100 and <199 mgkg^{-1}), high (>200 and <299 mgkg^{-1}) and very high (>300 mgkg^{-1}). The available K of most soil samples range from low to medium (40-199 mgkg^{-1}) while some soils even have high to very high (>200 mgkg^{-1}) K content. For soils that are, in most cases, not supplied with mineral K fertilizer, these figures indicate a good status of K in the soils. Potatoes require high K supply as it plays an important role in photosynthesis and starch production by the potato crop.

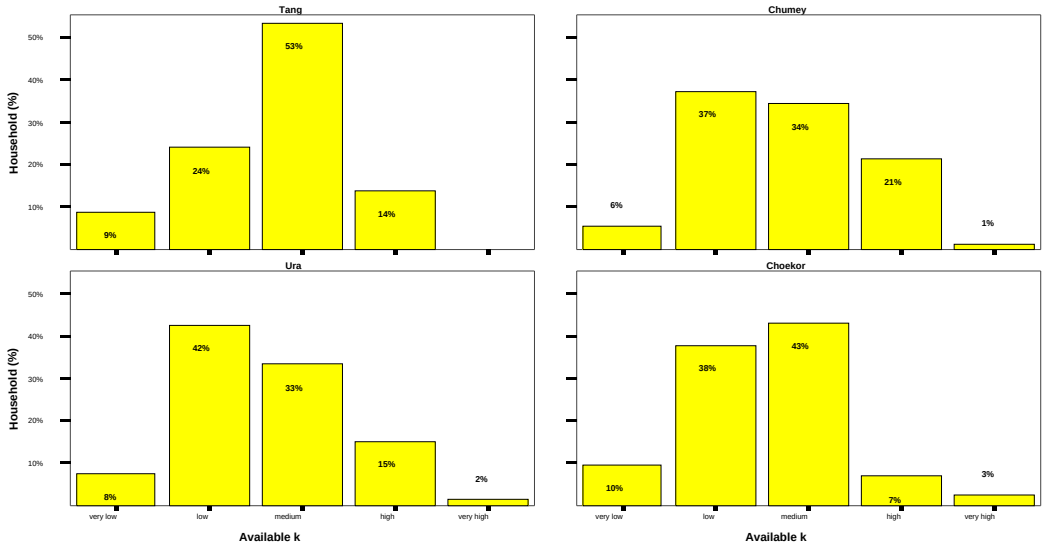
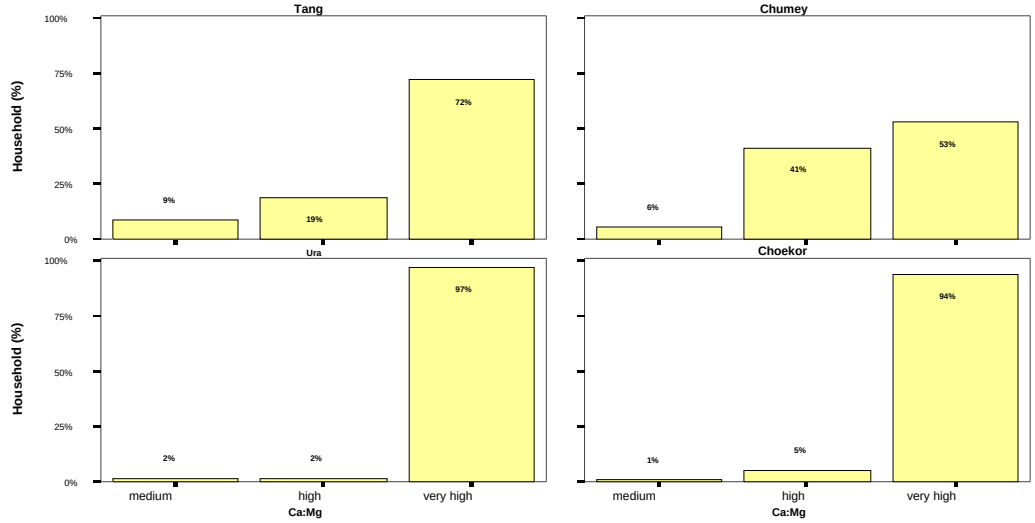


Figure 17. Available potassium

Ca:Mg ratio

Figure 18 shows the ratios of the exchangeable bases. Most of the soils of all the four geogs have very high (>7) Ca:Mg ratio indicating either low Mg content in the soil or the presence of large amounts of other cations, particularly Ca and K. Although soils can remain fertile over a wide range of Ca:Mg ratios, with increasing Ca:Mg ratios above 5:1, the Mg may become progressively less available to plants. In the soils with high Ca:Mg ratio, there would be P inhibition as well and therefore restricted availability to plants.



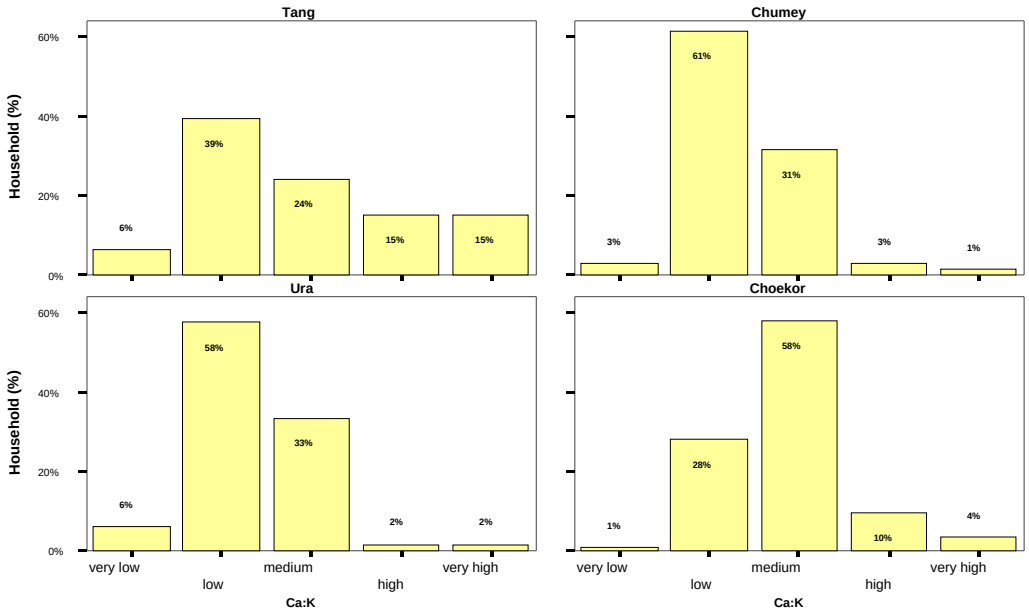


Figure 18. Ca:Mg and Ca:K ratios

Organic matter

The percent organic matter obtained is considered to be low, medium and high if <2%, >2 and <5% and >5% respectively. The percent organic matter of the soil samples is within the low (<2%) to high (>5%) ranges. On agricultural land, the organic matter content of the soil is very much depended upon the supply of farmyard manure, compost, green manure etc. The difference in soil organic matter content may have been due to the difference in altitudes of the places. 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.

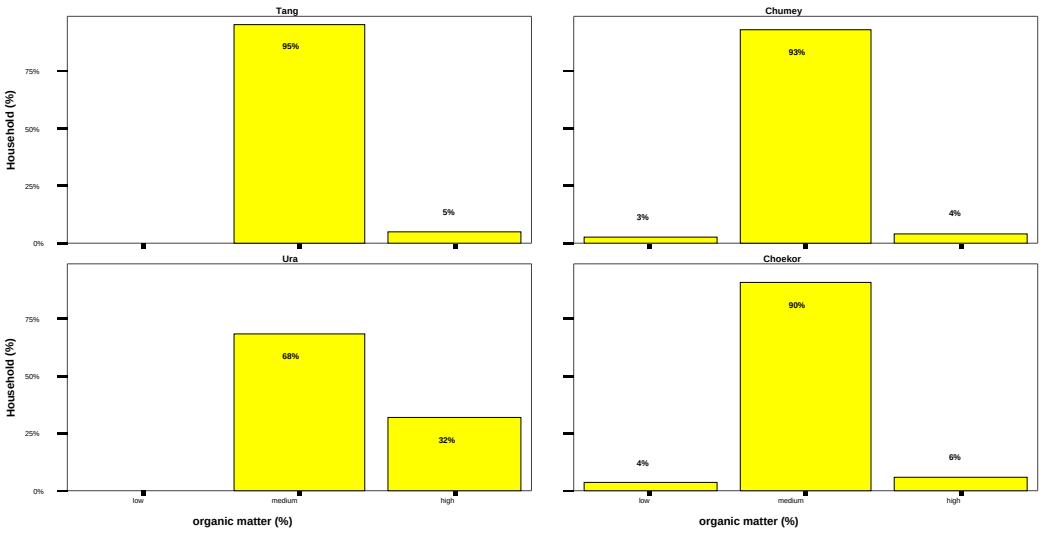


Figure 19. Organic matter

C:N Ratio

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 C:N ratio of the samples ranged from medium to very high. Most of the samples from all the four geogs had high to very high C:N ratio (i.e. between 10.2 to 12). This indicates that, in breaking down organic matter, microbes would need more nitrogen than is in the organic matter and would take it from the soil. Microbes are more efficient than crops in obtaining nitrogen from the soil. If there is not enough nitrogen for both the microbes and the crop, the crop would not be able to obtain what it needs and suffer from nitrogen deficiencies.

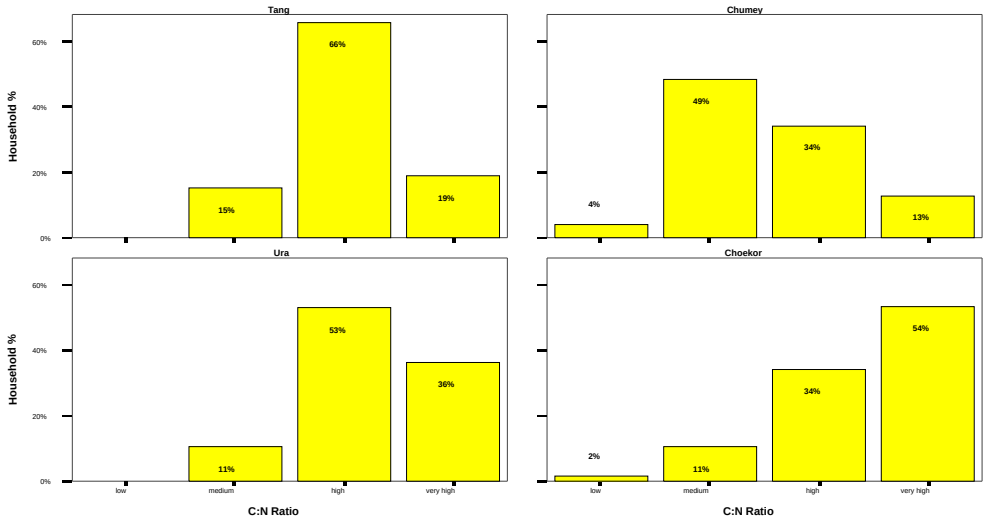


Figure 20. C:N ratio

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.

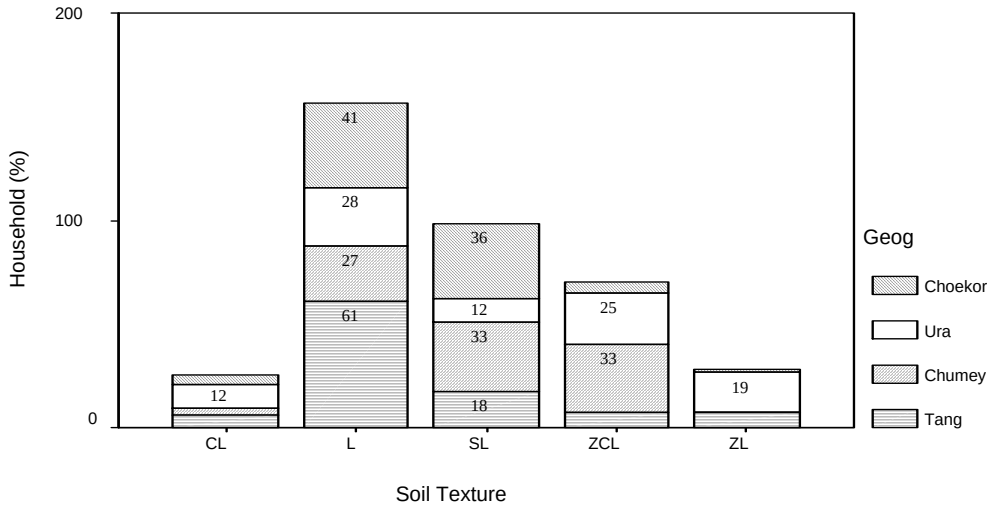


Figure 21. Soil texture

4. Conclusion

Potato is the major cash crop grown in all the four geogs of the Dzongkhag. Its importance as the cash crop has increased 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 53 kg N and 37 kg P and 33 kg K per acre in Chumey; 53 kg N, 34 kg P and 11 kg K per acre in Choekhor; 35 kg N, 16 kg P and 18 kg K per acre in Tang and 76 kg N, 61 kg P and 15 kg K per acre in Ura through the use of inorganic fertilizers.

Additional 21 kg N, 4 kg P and 24 kg K per acre are added through the use of 2.8 tac^{-1} FYM in Chumey; 34 kg N, 6 kg P and 40 kg K per acre with the application of 4.6 tac^{-1} FYM in Choekhor, 24 kg N, 5 kg P and 28 kg K per acre from 3.2 tac^{-1} FYM in Tang and finally 37 kg N, 7 kg P and 43 kg K per acre are added by 5 tac^{-1} FYM applied in Ura.

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 7.2 kg N ac^{-1}, 1.4 kg P ac^{-1} and 8.6 kg K ac^{-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. Most of the samples from all the four geogs had medium organic matter and high to very high C:N ratios.

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 soil analysis to find out their soil nutrient status and to base their fertilizer applications on the results of the analysis.

- FAO recommends at least 70 kg N, 80 kg P and 35 kg K per hectare or 28 kg N, 32 kg P and 14 kg K per acre for Bumthang area. However, based on the soil nutrient analysis results, different nutrient rates are recommended for different geogs.

5.1. Recommendation for Chumey & Choekhor Geogs: 50:25:30 kg NPK ac^{-1}

For Chumey and Choekhor, where the available P is high for most of the samples, a lower rate of P has been recommended.

5.1.1. From Suphala, Urea and MoP:

In order to supply the above recommended rates of nutrients using suphala, urea and MoP, 167 kg of suphala, 54 kg urea and 8 kg MoP are needed to be applied in an acre of land.

Apply the entire dose of suphala and MoP at the time of land preparation as basal dose. Divide 54 kg urea into two equal quantities and apply first half of urea when the plants are of 15-20 cm high (i.e. 30-45 days after planting) and the second half at the time of potato flowering.

5.1.2. From Urea, SSP and MoP:

If single nutrient fertilizers are used, then 109 kg urea, 156 kg SSP and 50 kg MoP are required to be applied in an acre of land.

Split urea application into three and MoP into two applications. Apply the entire dose of SSP along with 36 kg urea and 25 kg MoP as basal dose at the time of land preparation. Apply another 36 kg urea along with the remaining 25 kg MoP when the plants are of 15-20 cm high (i.e. 30-45 days after planting) and finally use the remaining 36 kg urea at the time of potato flowering.

5.2. Recommendation for Tang & Ura Geogs: 60:50:30 kg NPK ac^{-1}

For Tang and Ura, where the available P is fairly low for most of the samples, a higher rate of P had been recommended.

5.2.1. From suphala, urea and SSP

For the recommended rates of nutrients, apply 200 kg suphala, 65 kg urea and 125 kg SSP in an acre of land.

Apply the entire dose of suphala and SSP at the time of land preparation and apply urea in two split doses i.e. first half of urea when the plants are of 15-20 cm high (i.e. 30-45 days after planting) and the second half at the time of potato flowering.

5.2.2. From urea, SSP and MoP

Using single nutrient fertilizers would require the application of 130 kg urea, 313 kg SSP and 50 kg MoP in an acre of land.

Split urea application into three and MoP into two applications. Apply the entire dose of SSP along with 43 kg urea and 25 kg MoP as basal dose at the time of land preparation. Apply another 43 kg urea along with the remaining 25 kg MoP when the plants are of 15-20 cm high (i.e. 30-45 days after planting) and finally use the remaining 43 kg urea at the time of potato flowering.

- 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.