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Effects of Mineral Fertilizers on Rice productivity in Wangdue-Punakha Valley

Yeshey[1], Mahesh Ghimiray, Yadunath Bajgai

Abstract

Rice is the most important food crop in Bhutan, further to cultural, traditional and religious significances. During the 10th Five Year Plan (FYP) rice self-sufficiency target was at 65%, however the self-sufficiency stands only at 51.3%. So to make up for the rice deficit, imports from India range from 50,000 to 60,000 MT every year. Currently, rice is cultivated in 59,609 acres of land with a national productivity of 1,312 kg/acre. Use of mineral fertilizers is inevitable to optimize rice production particularly for improved varieties. Though the use of mineral fertilizers in rice is widespread, the imbalanced usage (only nitrogen-fertiliser) and poor timing of applications (insufficient in critical crop growth stages) remain as the main issues. While mineral fertilizer recommendation rates existed both for local and improved varieties, adoption of the same is limited. Most farmers use lower than the recommended rates. Lack of awareness on adoption of the recommended rate among the farmers is the other issue.

Despite the limited number of farmers using recommended fertilizers, there is an increasing trend of its usage. To maintain crop productivity in the face of declining soil fertility, farmers have resorted to increased use of mineral fertilisers because farmyard manure availability has been decreasing over the years. Hence, balance and proper timing of application of the recommended mineral fertilizer rates were demonstrated to farmer at different sites. Irrespective of the sites, recommended practice out-performed the farmers' practice in both grain and straw. Recommended fertilizer rates are not only sustainable but also economically feasible. The cost benefit analysis indicated that expenditure incurred on buying fertilizers can easily generate a reasonable net benefit even with the cultivation of local rice varieties due to the incremental yield brought about by the mineral fertilisers.

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Keywords: **:** Demonstration, unbalanced, timing, cost and benefit

1. Introduction

Rice is the most important food crop in Bhutan, further to its cultural, traditional and religious significance. Rice self-sufficiency target for the 10th FYP was 65% from 51.3%. Currently, rice is cultivated in 59,609 acres of land with a national productivity of 1,312 kg/acre ((RNR Statistics, 2012). According to the Food Corporation of Bhutan (FCB) Phuntsholing, Bhutan has imported a total of 5812 MT of rice in 2010 and 5719 MT of rice in 2011. In tandem with the growing population, rice production should further be increased in the future.

Among the challenges confronting agriculture sector in meeting food demand of the country, low crop yields due to declining soil fertility is the most serious one. Generally, soil nutrient status is

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poor with low pH, nitrogen and phosphate status and imbalanced base nutrition (Norbu and Floyd, 2001). The traditional soil fertility management systems based on the use of animal manures are being undermined by socio-economic factors. Consequently, use of mineral fertilizers is inevitable to optimize rice production, particularly for improved varieties that are responsive to fertiliser application. In Punakha and Wangdue Dzongkhags, although the use of mineral fertilizers in rice is wide-spread, the productivity stood at 1920 and 1440 kg/acre respectively (RNR Statistics, 2010). This is mainly because of imbalanced fertilizer use (only nitrogen-fertilizer) and poor timing of applications (insufficient in critical crop growth stages).

Considerable amount of resources has been invested by the National Soil Services Centre (NSSC) to come up with the fertilizer recommendation rates for both local and improved rice varieties. However, according to a study report (Yeshey, 2012), none of the farmers interviewed had adopted recommended mineral fertilizer rates for rice. Most respondents used rates lower than recommended ones, while a few respondents reported using higher rates than what has been recommended. Lack of awareness on adoption of the recommended rate among the farmers is the other issue (Yeshey, 2012).

Although, farmers do not use recommended rates, the mineral fertilizer use trend is reported to be increasing by majority of them. The fertilizer distribution record from 2007 to 2012 maintained by the National Seed Centre (NSC) showed increasing trend on the use of fertilizers (Data source: National Seed Centre (NSC) Paro1) in Punakha. Use of urea is increasing followed by Suphala. Contrastingly, Single Super Phosphate (SSP) is hardly used and Muriate of potash (MoP) has never been applied during the last six years. Increased mineral fertiliser usage reported is to cope with the declining of soil fertility and decreased in farmyard manure availability in the farms. A similar study in Guma geog under Punakha Dzongkha have also found similar trends (Bajgai, 2006).

The main fertilizer use issue identified is the use of imbalanced and lower than recommended rates. With the farm labour shortage on one hand and declining soil fertility on the other, the challenge is huge to sustainably maintain the soil fertility and rice productivity with the current fertilizer application practice.

1.2 Objectives

A demonstration of recommended mineral fertilizer rates in rice was conducted with interested farmers in Punakha and Wangdue Dzongkhags with the following research objectives:

- To demonstrate the recommended rates of mineral fertilizers in rice,
- To evaluate the yield difference between recommended and farmers' practices and
- To assess the cost benefit analysis of recommended fertilizer rates in rice.

2. Materials and Method

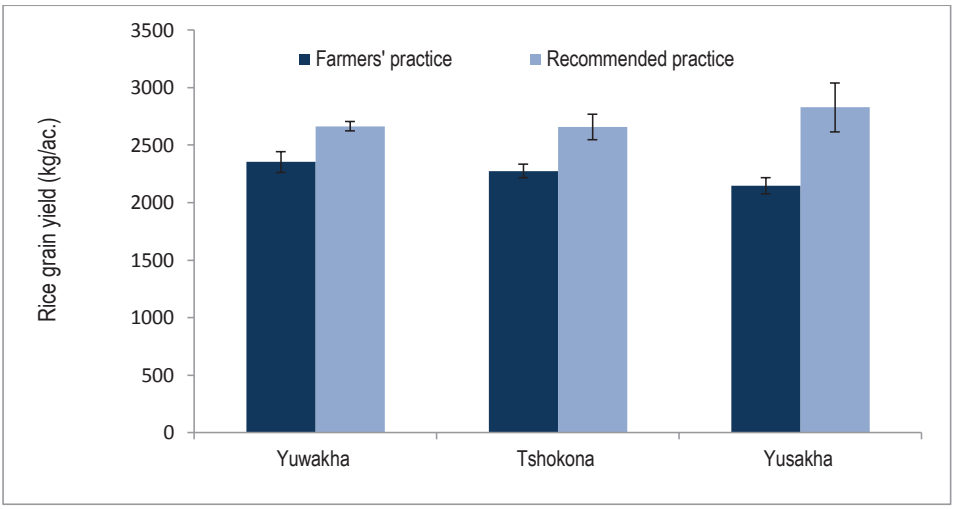
The demonstrations were carried out in Guma, Dzomi and Barp geogs of Punakha and Rubesa geog of Wangdue. In each geog there was one demonstration conducted with one interested farmer and selected farmers from each site were briefed on the aims and objectives of the demonstration. At each site, single large plots covering an area of 0.5 to 1 acre was used for the demonstration. There were only two treatments: farmers' practice and the recommended practice of fertilization. Irrigation water inlet and outlet was made separate for the demonstration plot to control fertilizer movement. Except for fertilization, other management practices were similar for both the demonstration and the farmers' practice plots. Regarding the rice variety, all farmers planted the popular IR-64, except the farmer in Rubesa who planted local variety called *Kashimer*. Recommended fertilizer rates of 28:16:16 NPK kg/ac on improved and 16:12:8 NPK kg/ac for local rice (NSSC, 2009) varieties were demonstrated, wherein all of the P and K and half of the N were applied as basal dressing with the other half N was applied as top dressing at the peak tillering stage. The selected plots were measured and the required fertilizers were supplied by the RDC Bajo at free of cost to all the collaborating farmers. For weed management, butachlor was applied by farmers themselves. While most of the management practices were similar at all sites, there was some difference in the date of transplanting which was caused mainly by irrigation water schedule.

Pre- and post- crop soil samples were collected from both demonstration and farmers' practice plots at all the sites. The samples were air-dried and sent to NSSC for nutrient analysis. At harvest, three crop cuts of 6 m^2 were taken, threshed, cleaned and weighed separately. Both grain yield and straw data were recorded. The mean of the three crop cuts was used for calculation of the final grain and straw yield. Grain moisture content was adjusted to 14%. During the harvesting time, field days were organized and yield performance was compared with the farmers' practice. Feedbacks were collected from the participating farmers.

3. Results and Discussions

3.1 Grain yield comparison

The recommended practice out-performed the farmers' practice by 13% at Yuwakha, 17% at Tshokona and 32% at Yusakha (Figure 2). All the collaborating farmers were satisfied with the yield difference and were convinced to apply the recommended practice from the next season. Of the 29 farmers who participated in the field day at Yuwakha, only two were concerned about affordability in adopting the recommended practice.



The values are mean of 3 replications and vertical bars show standard errors of means.

Figure 2: Rice (IR-64) grain yield results from Barp geog, Punakha.

The rest of the farmers mentioned that they did not apply the recommended practice until now as they were not aware about it. While there is some uncertainty with regard to the application of required amount of fertilizers per unit area, it is likely that farmers would start using balanced fertilization instead of only applying nitrogenous-fertiliser (urea). Application of balance nutrients would increase rice yield to help farmers in sustaining the crop productivity of their farms.

In Punakha, the two collaborating farmers used improved rice variety of IR-64, while in Wangdue a local variety called *Kasihmer* was grown. The effect of the recommended fertilizer rate on rice yield was very high in Dzomi geog with an increased of 50% yield difference, although the overall productivity was relatively low when compared with the productivity in Guma geog. This could be attributed to the high weed density with Shochum (*Potomogaton distinctus*). In Guma, yield difference between the recommended and farmers' practice of fertilization was about 400 kg/ac (13%), while in Rubesa the difference is only 200 kg/ac (9%).

In Rubesa, the smaller difference between the treatments could be due to none-application of urea as topdressing. As local varieties are prone to lodging, the farmer refused to apply urea top dressing. Overall, the results suggested that applying the right fertilizer dose as per recommendation, rice farmers in Punakha and Wangdue Dzongkhags can substantially increase their rice yield.

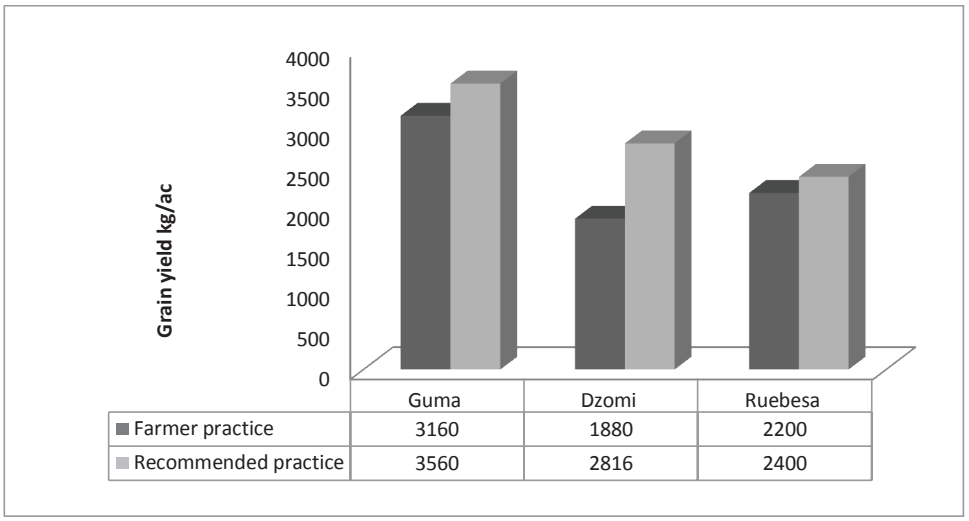


Figure 3: Rice (IR-64) grain yield results from Guma, Dzomi and Rubesa

3.2 Straw yield comparison

The weight of the straw was recorded for the final straw yield calculation for each treatment. As with the grain yield, differences in the yield of the straw are observed between the treatments across all the sites (Table 1). Since rice straw is used as cattle feed and bedding material, the quantity of straw biomass produced is also one of the criteria that farmers take into consideration while assessing technologies (Bajgai, 2006).

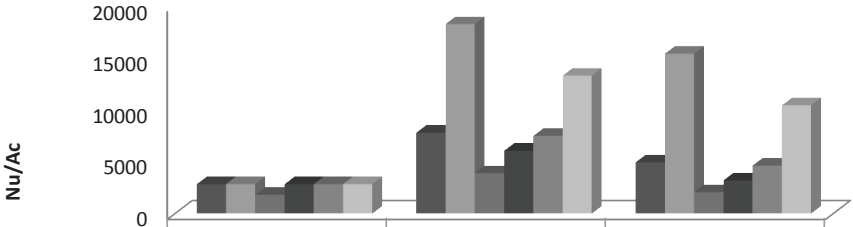
Table 1: Effect of recommended fertilizer rates on the rice straw yield

Place	Recommended (kg/ac)	Farmer practice (kg/ac)	Percent increased by recommended practice
Guma	5600	3600	56
Dzomi	8000	7933	0.85
Rubesa	6800	6000	13
Yuwakha	8173	7867	4
Tshokona	8107	8000	1.3
Yusakha	8467	6400	32.3

3.3 Cost benefit analysis

The economic analysis was done assuming a reasonable milling recovery of 65%. The market price of the milled rice was considered to be Nu.30/kg (based on local average price for milled IR-64) to calculate the total benefit accrued from using the recommended fertilizer rates. Then the cost of the required quantity of fertilizer was deducted from the total benefit, to derive the net benefit as presented in Figure 4.

The result indicates that a rice farmer using fertilizers can easily generate a net benefit even with the cultivation of local rice varieties that are generally lower yielding than the improved varieties. This increase in crop productivity per unit area of land can ultimately contribute toward achieving national goal of alleviating poverty, and also helps maintaining soil fertility, if not improving it. On one hand area devoted to rice production is decreasing due to emergence of townships, e.g. Bajothang in Wangdue and Khuruthang in Punakha, and on the other hand the demand for rice is increasing due to the rise in population. Therefore, there is a need to increase productivity per unit area of land. The productivity gains achieved may be negated by decreasing land area, and so total production may remain similar as before. Furthermore, the per capita milled rice consumption in the country is very high at 144 kg per year (PPD, 2011). With some efforts to sensitize rice farmers on the importance of application, right amount and time of fertilization in rice can make a huge contribution towards achieving rice self-sufficiency in the kingdom since Punakha and Wangdue are two important rice growing Dzongkhags both in terms of area and production.



	Total fertilizer costs (Nu/ac)	Total benefit (Nu/ac)	Net benefit (Nu/ac)
Guma	2850	7800	4950
Dzomi	2850	18252	15402
Ruebesa	1818	3900	2082
Yuwakha	2850	6060	3209
Tshokona	2850	7488	4638
Yusakha	2850	13279	10429

Figure 4: Costs benefits of recommended fertilizer rate in rice

3.4 Soil analysis results

Soil analytical results of the soil samples collected both before and after rice crop showed a poor soil fertility status. All the measured soil variables were within very low-to-low range. A study that assessed soil fertility status for Guma geog earlier found similar findings for paddy fields (Bajgai, 2006) which can somewhat validate findings of the current study. This indicates that the soil fertility status to be one of the factors contributing to the low rice productivity in the valley. The fact that there is only a slight difference between the soil variables before and after rice harvest indicated that soil nutrient input from farmyard manure supplemented with urea is not adequate and soil nutrient reserve could be depleted. It seems likely that if this practice is

continued, the risk may include the loss of soil fertility as a combination of biological, chemical and physical properties, often termed as land degradation.

Both pre- and post- rice crop soil result showed that the soil pH is between 5.3 and 5.95, which falls within the low to moderate range. Soils with pH <5.5 would be deficient in most bases like Ca, K and Mg. For both acid and alkaline soils, low temperature and organic matter content retard pH changes (Brady, 1995).

Both the cation exchange capacity (CEC) and percent base saturation (% BS) are within the low to very low range as well. The CEC gives an indication of the soil's potential to hold plant nutrients because the CEC refers to the total amount of the positively charged elements (basic cations) that a soil can hold while the percent base saturation tells what percent of the exchange sites are occupied by the basic cations.

Further, both the available phosphorus and potassium were also within the very low-to-low range. This possibly indicates the insufficient supply of mineral P and K from farmyard manure. The soil organic matter contributes to the overall chemical, physical, and biological properties of the soils and hence crop productivity. The soil organic matter percent is within the range of 2 and 4%, which indicates low soil organic matter content.

4. Conclusion

Rice is the staple food crop of the country and demand of rice is increasing with increasing population. Our production meets only about 50% of the food consumed and the rest is met through importation, mainly from neighboring India. Thus, to meet the increasing demand, we need to increase rice production. Across all the demonstration sites, the recommended practice of fertilization out-performed the farmers' practice, both in terms of the grain and straw yields.

The cost benefit analysis showed that a rice farmer can economically benefit by using the recommended fertilizer rate even after deducting the cost of fertilizers. The application of the recommended fertilizer rate not only helps in increasing productivity per unit area that ultimately contributes toward achieving national goal of alleviating poverty, but will have a huge impact on ensuring sustainable soil fertility management for rice production.

The data of soil analysis showed that the poor soil fertility status at all sites could attribute to the declining crop yields. Almost all the important soil variables are within very low-to-low range. Pre- and post- crop soil sample showed only a slight difference which indicates the depletion of soil nutrient reserve. If farmers continue using inadequate farmyard manure with single nitrogenous fertilizer there is a real danger of the loss of soil fertility and land degradation. Therefore, there is a need to build soil fertility over time to replenish the depleted nutrients in the long term, and which should be over and above the amount of nutrients removed through crop harvest.

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Monitoring of Mango Fruit Fly, *Bactrocera dorsalis* (Diptera: Tephritidae) Population Trend at Kamichu and Baychu Royal Orchards

Om Prakash Ghalley[1], Kinga Lham and Sangay Wangdi

Abstract

The monitoring of mango fruit fly (Bactrocera dorsalis) population trend was carried out in Kamichu and Baychu Royal Orchard using the pheromone trap in the year 2009, 2010, 2011 and 2012. July was found to be the peak emergence period of the fruit fly in both the study locations. The result found significant difference ($p < .05$) in seasonal fruit fly population fluctuation between months and between years at Kamichu and Baychu. In both the location, the fruit fly population started increasing from April and reached its maximum in July and after that the fly population declined dramatically until October. The findings suggested that the management strategies should be targeted from April to September with more attention during the month of June, July and August under Kamichu and Baychu environment and conditions.

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Keywords: **:** *Bactrocera dorsalis*; *Baychu; fruit fly; Kamichu; mango; methyl eugenol; population fluctuation.*

Introduction

The oriental fruit fly, *Bactrocera dorsalis* (Hendel) (synonym = *Dacus dorsalis* Hendel), is a destructive agricultural pest in many parts of the world and it attacks a wide variety of fruits, nuts, vegetables, and berries (Wright, 2003). The oriental fruit fly *Bactrocera dorsalis* (Hendel) causes devastating losses to agricultural crops worldwide and is considered to be an economically important pest (Hou *et al.,* 2014). Losses in West African commercial mango orchards due to fruit fly infestations have exceeded 50% by the middle of the crop season since 2005, resulting in considerable income loss for the growers (Vayssieres *et al.,* 2014). The oriental fruit fly, *Bactrocera dorsalis* (Hendel) induce significant economic losses through direct fruit damage, fruit drop and export limitations associated to quarantine restrictions (Wan *et al.,* 2011). Shi *et al.* (2012) reported *B. dorsalis* typically occurs in tropical areas of South, East and Southeast Asia (including Bhutan, south of mainland China, Hong-Kong, Taiwan, India, Japan, Laos, Myanmar, Nepal, Bangladesh, Sri-Lanka, Vietnam, Cambodia, Pakistan and Thailand) as well as in some Pacific islands (Hawaii, Guam, Northern Mariana, Nauru and French Polynesia). Mango and guava are two important fruit crops which are severely damaged by fruit flies (Mishra *et al.,* 2012). *Bactrocera dorsalis* is a serious pest of mangoes in India (Verghese *et al.,* 2004). *Bactrocera dorsalis* is the most destructive pest of mango occurring in homesteads of

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Kerala causing 25-50 per cent fruit loss in mango when harvested at the mature ripe stage (Rani *et al.,* 2012). In Bangalore, it was found that the loss to mango due to *B. dorsalis* in an unsprayed situation varied from 2.5 to 59% depending on the variety (Verghese *et al.,* 2002).

The infestation and fruit drop caused by the fruit fly (*Bactrocera dorsalis*) was the major problem in the orchard at Kamichu and Baychu thereby leading to reduction in mango production every year. Each year almost 30-50% of mango is lost to fruit fly infestation at Kamichu and Baychu (Wangdi, 2010). The main objective of the trial was to study the fruit fly population trend and determine the peak emergence period of the fly in the orchard and initiate further research on developing control strategies of the pest.

1.1 Limitations of the Study

The findings of the study is solely based on the fruit fly count in the traps only and other parameters like climatic factors and phenological stages are not taken into account in this study due to limited research facilities.

2. Materials and Method

The study was carried out in collaboration with the Dzongkhag Agriculture Sector, Wangdue at Kamichu and Baychu Royal Orchard for 4 consecutive years during 2009, 2010, 2011 & 2012. The altitude of Kamichu and Baychu is 625 and 670 masl respectively (M. Dorji, personal communication, February 26, 2014). The area of the mango orchard trial was about 2 acres at Kamichu and 1 acre at Baychu. All the trees in the orchard were at the economic fruit bearing age and the varieties in the orchard were mixed of *Langra* and *Dashehari*. The pheromone traps were set up to attract the male fruit fly @ 5 traps per acre as per the manufacturer's recommendations. Therefore, depending upon the size of the orchard 10 Nos. traps were installed at Kamichu and 5 Nos. at Baychu. The pheromone traps were tied to mango trees at the canopy level at a height of 1.5 - 2 m from ground depending on the architecture of the tree. The data on fruit fly were counted and recorded every week and the mean flies captured per trap per week were worked out into per month and per year population. The trapped fruit flies were removed every week after counting and recording the data. Altogether, the data for 8 months from March to October were collected every year. Since the temperature from November to February is quite low and hardly any flies can be seen in the orchard, the data were not collected during the period. Methyl eugenol (ME) lure were used to attract the fruit fly in the pheromone trap. Among the various alternate strategies available for the management of fruit flies, the use of methyl eugenol trap stands is the most outstanding alternative (Mishra *et al.,* 2012). Vargas *et al.* (2000) found that methyl eugenol (4-allyl-1,2-dimethoxybenzene-carboxylate) is highly attractive kairomone lure to oriental fruit fly, *Bactrocera dorsalis* (Hendel). Methyl eugenol traps were extremely effective to trap and kill fruit fly (Ishaq *et al*., 2004). Males, but usually not females, are attracted

to methyl eugenol, a naturally occurring plant compound (Steck, 2007). Males of the oriental fruit fly, *Bactrocera dorsalis* (Hendel), are strongly attracted to methyl eugenol (Shelly, 2001). Methyl eugenol has both olfactory as well as phagostimulatory action and is known to attract fruit flies from a distance of 800 m (Mishra *et al.,* 2012). ME lure were changed once in every two months to maintain the efficacy of the pheromone trap. The set of pheromone traps were purchased from S. B. Agency, Siliguri, India. One Way Analysis of Variance (ANOVA) was performed using the Statistical Package for Social Sciences (SPSS) version 16 for analyzing the data for month-wise and year-wise differences in the fruit fly population fluctuation. Results were considered statistically significant when the probability of their occurrence by chance was less than five percent ($p<.05$). Besides, Microsoft Excel 2007 was used for presentation of results in the form of graphs, charts and tables.

3. Result and Discussion

3.1 Seasonal fluctuation of fruit fly populations in Kamichu

The month-wise average data of four consecutive years found the highest mean fruit fly population during the month of July at Kamichu (Figure 1). In all the study years, month of July was found to be the peak period of fly population (Figure 2). Table 1 showed the highest mean fruit fly captured per trap per week in July (168.12±14.08) and the lowest in March (3.57±.51) for monthly capture. This indicated that the month of July is the peak emergence period of the fruit fly under Kamichu condition. Statistical analysis showed that the mean fruit fly captured in pheromone trap was significantly higher ($F = 42.537$, $df = 7$, $p < .001$) in July than rest of the months. Table 2 showed the highest mean fruit fly captured per trap per week in the year 2012 (104.88±9.98) and the lowest in the year 2010 (20.46±1.11) for annual capture. Statistical analysis showed the significant difference in fruit fly capture between years ($F = 31.402$, $df = 3$, $p < .001$). This indicated that the fruit fly occurrence was significantly different both between months and between years. It can be inferred that the fruit fly has distinct seasonal patterns in population fluctuation. This may be due to fruit ripening and changes in weather pattern as the peak fly emergence period (July) coincided with fruit ripening and concurrently it was also witnessed quite a hot weather and rainfall in July at Kamichu as it being the peak period for summer season. Thus, the month of July seems to be the most favorable period for the occurrence of fruit fly under Kamichu condition. The results are in agreement with Mahmood and Mishkatullah (2007) who reported that July and August as the population peak period and declined from October depending upon host fruit maturity, temperature and rainfall in Barani Agricultural Research Institute, Chakwal, Northern Punjab. Similar findings were also reported by Ye and Liu (2007) who found that the fruit fly population remained at a lower level from November to February and increased from March until it reached a peak in June or July, depending on the rainfall that year and after that the fly population declined remarkably until October in Xishuangbanna, southern Yunnan. Similar observations were reported by Patel *et al.* (2013) who claimed that the highest mango fruit infestation by *B. dorsalis* coincided with fruit

ripening cum harvest period i.e. May to July. So, the results obtained in this study are also more or less in accordance with the above reports and conforms the present findings.

The result of Kamichu demonstrated the slight increase in fruit fly population trend from the month of April to May and further increasing gradually in June until it reached a peak in July and again declining from August and decreased dramatically from September through October (Figure 1). The results from the present study showed that June, July and August as the higher fruit fly population abundance period. This indicates that the control measures of the fruit fly should be carried out from the month of April till September with the highest priority during the month of June, July and August which is a peak season for the occurrence of fruit fly. However, the flies were present in all the eight months. The fruit fly population decline from August seems to be due to harvesting of the fruit as fruit harvesting is usually completed by August under Kamichu condition. Availability of host fruits was another essential factor affecting population fluctuation (Mahmood and Mishkatullah, 2007).

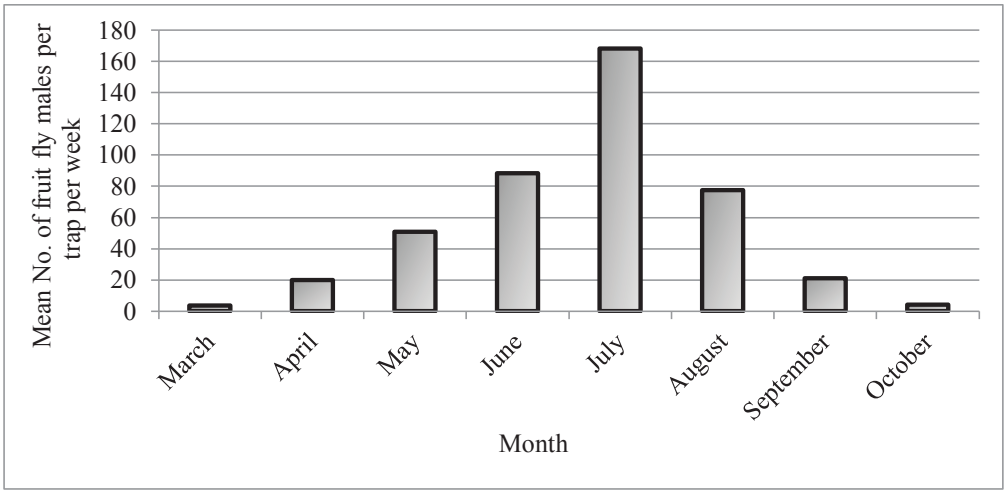

Figure 1: Month-wise mean fly capture of four consecutive years at Kamichu orchard

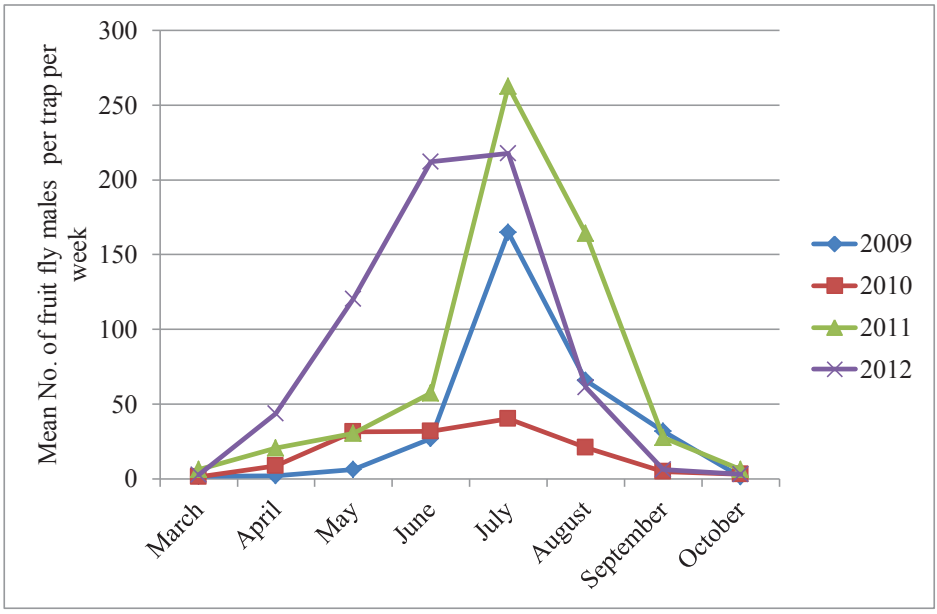

Figure 2: Seasonal fruit fly population fluctuation at Kamichu orchard in different years

Table 1: Month-wise mean (±se) fruit flies captured per trap per week in Kamichu in four study years

Months	n	Mean monthly fly capture
March	91	3.57±.51 (01-26)
April	156	19.89±2.63 (01-182)
April	156	19.89±2.63 (01-182)
May	144	50.79±6.59 (01-416)
June	174	88.28±9.62 (01-834)
July	173	168.12±14.08 (01-1238)
August	166	77.46±6.89 (01-399)
September	127	21.03±3.16 (01-227)
October	55	4.12±.83 (01-37)

The values in the parentheses are minimum and maximum number of flies captured per trap per week

Table 2: Year-wise mean (±se) fruit flies captured per trap per week in Kamichu

Year	n	Mean annual fly capture
2009	226	52.81±5.09 (01-418)
2010	295	20.46±1.11 (01-81)
2011	302	84.07±7.32 (01-1022)
2012	263	104.88±9.98 (01-1238)

The values in the parentheses are minimum and maximum number of flies captured per trap per week

3.2 Seasonal fluctuation of fruit fly populations in Baychu

Similarly, the result of Baychu orchard also found the highest mean fruit fly population during the month of July (Figure 3). The month of July was found to be the peak period of fly population in all the study years (Figure 4). Table 3 showed the highest mean fruit fly captured per trap per week in July (94.28±9.80) and the lowest in March (5.28±.72) for monthly capture. This indicated that the month of July is the peak emergence period of the fruit fly even under Baychu condition. Statistical analysis showed that the mean fruit fly captured in pheromone trap was significantly higher ($F = 22.882$, $df = 7$, $p < .001$) in July than rest of the months. Therefore, similar pattern of fruit fly population fluctuation were found at Kamichu and Baychu reaching its major peak in July than rest of the months (Figure 5). For annual capture, the highest mean fruit fly per trap per week was captured in the year 2011 (81.00±6.55) and the lowest in the year 2009 (15.27±2.21) (Table 4). Statistical analysis showed that the mean fruit fly captured in pheromone trap was significantly higher ($F = 50.480$, $df = 3$, $p < .001$) in 2011 than rest of the years. Thus, it can be concluded that the seasonal occurrence of fruit fly population are significantly different from month to month and year to year under Kamichu and Baychu condition.

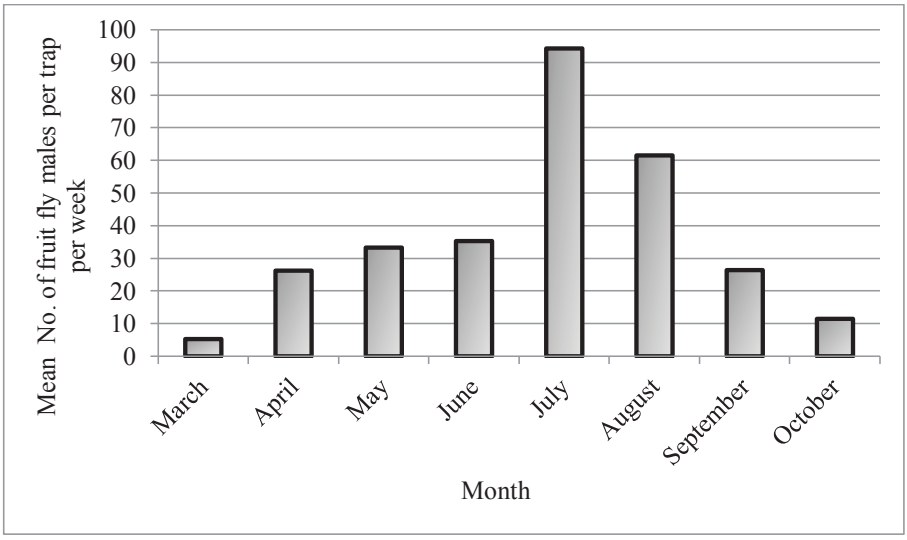

Figure 3: Month-wise mean fly capture of four consecutive years at Baychu orchard

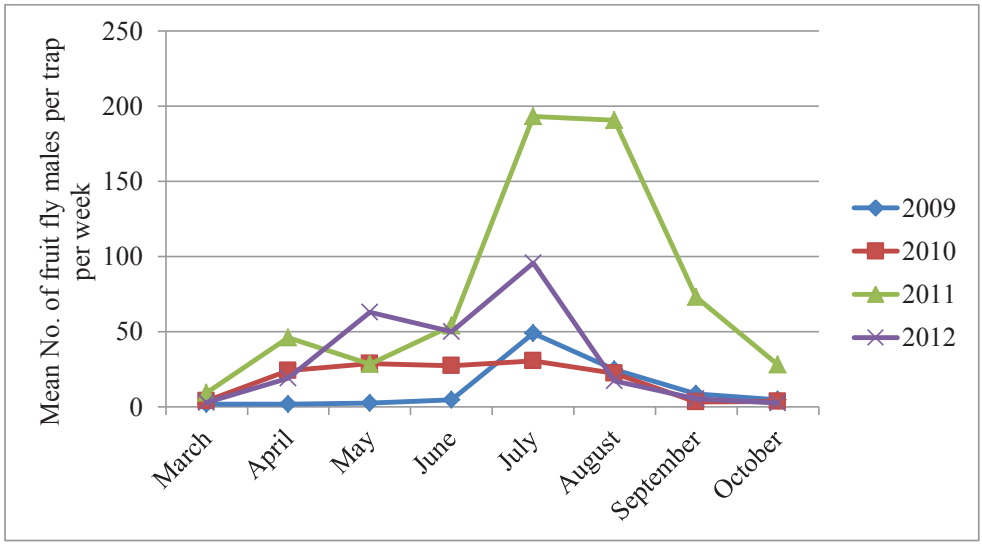

Figure 4: Seasonal fruit fly population fluctuation at Baychu orchard in different years

Table 3: Month-wise mean (±se) fruit flies captured per trap per week in Baychu in four study years

Months	n	Mean monthly fly capture
March	57	5.28±.72 (01-27)
April	80	26.23±3.34 (01-141)
May	71	33.29±3.74 (01-141)
June	84	35.29±3.81 (01-163)
July	90	94.28±9.80 (03-505)
August	84	61.52±9.08 (04-371)
September	82	26.40±3.97 (01-145)
October	59	11.47±1.91 (01-61)

The values in the parentheses are minimum and maximum number of flies captured per trap per week

Table 4: Year-wise mean (±se) fruit flies captured per trap per week in Baychu

Year	n	Mean annual fly capture
2009	122	15.27±2.21 (01-145)
2010	158	19.67±1.27 (01-81)
2011	172	81.00±6.55 (01-505)
2012	155	34.32±3.82 (01-390)

The values in the parentheses are minimum and maximum number of flies captured per trap per week

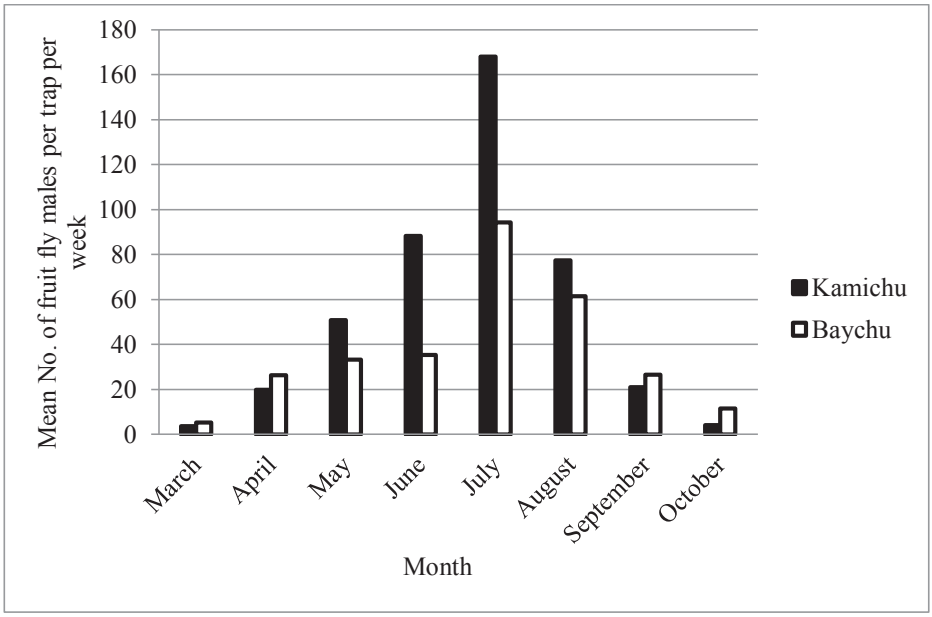

Figure 5: Month-wise mean fruit flies trapped in 4 study years in Kamichu and Baychu orchard

4. Conclusion and Recommendation

The month of July was found to be the peak season for the occurrence of mango fruit fly under Kamichu and Baychu condition. The similar pattern of fruit fly population fluctuation was found both at Kamichu and Baychu. The utmost attention should be given during the month of June, July and August for the control measures of the fruit fly. Further research is needed in future to determine the population dynamics of the fruit fly in detail in relation to other parameters like temperature, rainfall, humidity and phenological stages so as to plan and develop the specific control time of the pest organism.

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Assessing Potential of the System of Rice Intensification (SRI) Principles in Sustainable Rice Production

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Abstract

As one sustainable approach to rice production, SRI is being tried and demonstrated both on-farm and on- station at RDC Bajo. There is a need to demonstrate the yield potential of SRI system of production as part of technology promotion and to re-affirm the results. The current experiment investigated the use of young seedlings of 10-15 d old with integrated application of farm yard manure (3 t ha^{-1}) and inorganic fertilizer at 70: 40 : 30 N.P.K (kgper ha). The design of the experiment was RCBD with three replications and it was conducted at RDC Bajo, Wangdue in 2013 season. Unlike in the typical SRI experiment, weed control was achieved by two hand weedings and application of Butachlor at 1.5 kg ai ac^{-1} 3 days after transplanting. Intermittent irrigation was applied as and when required and flooding was avoided. The experiment result showed that the grain yield ranged between 4-7 t ha^{-1}, while the national average stands at 3.2 t ha^{-1}. The data on root-shoot ratio showed that there was a significant effect of seedling age with the younger seedlings exhibiting higher values of root-shoot ratio (0.174 - 0.198). The increased tillering and higher root- shoot ratio indicated higher yield potential under minimum water and proper nutrient management in SRI.

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Keywords: **:** Grain yield; intermittent irrigation; nutrient management; on-farm; on station; root-shoot ratio; tillering; young seedlings

1. Introduction

Being a number one crop for Bhutan, rice self sufficiency has become a catchphrase for the researchers, extensionists, policy makers and politicians. Due to heavy reliance on rice for food, the Department of Agriculture has identified a number of interventions for sustainable production. One such intervention is to promote system of rice intensification (SRI) techniques, modified for local conditions. The country's production of just 78,730 tons with productivity of about 3.2 t/ha (DoA, 2012) is below global average of 4.45 t/ha (FAOSTAT, 2013). Thus, there is an ample opportunity to enhance production through adaptation of improved management practices and riveting to sustainable production approaches. Dobermann (2004) mentioned that SRI is one most relevant sustainable method of rice production. A sustainable method of production is the need of the hour for a country which has strong policy and advocacy programs on conservation of environment and its natural resources. SRI is an integrated and ecologically sound approach to rice cultivation and has received global attention (Dobermann, 2004; Goud, 2008). According to Dobermann (2004), the principles of SRI include (1) raising seedlings in carefully managed nurseries, (2) use of younger seedlings (of about 8-15 d old) and transplating single seedlings at a wider spacing, (3) intermittent irrigation and avoidance of permanent flooding during the early phases of growth, (4) use of organic soil nutrients, and (5) intensive weeding regime either through mechanical weeders or manual without use of herbicides. While

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all such principles may not find applicability in the local context of Bhutan, some principles could be well integrated into our production approaches to enhance our farm sustainability and production. It has advantages over conventional production management systems in the sense that it saves water, fertilizers, seeds and overall costs of production. This sustainable production system could be well suited for Bhutan which is characterized by low land holdings and rugged mountainous terrains with rich vegetative cover to provide huge resources for organic nutrition. Since the introduction of SRI concepts in the country in 2007, many experiments were conducted and encouraging results were reported. However, there were also some reports which gave mixed results, giving more reasons to reaffirm the performance of SRI with repeated testing and promotions. Therefore, experiments and demonstrations will have to go on for few more years to provide an option for the resource poor farmers. SRI techniques, if adapted and applied widely, could enhance rice yield while taking care of agro-ecosystems for sustainable production.

Sporadic SRI experiments conducted in Madagascar and some of the Asian countries have reported mixed results. However, the proponents of SRI claimed that the farmers are usually able to harvest yield of 7-8 t ha^{-1}, and with proper management practices, yield can go beyond 15 t ha^{-1} (Uphoff, 2007). Lhendup et al (2009) reported that rice production following SRI techniques gave higher yield of up to 31% compared to the conventional system. Such increase therefore, warrants better understanding of biophysical characteristics of production management system. A critical assessment of key physiological aspects reveals that SRI is a potential approach to breaking yield barrier while taking care of crop environment from loss of soil quality and degradation. It is a healthy and sustainable production management system (Uphoff, 2009). There is a physiological basis behind the principles of SRI which contribute to optimal growing conditions enhancing tillering capacity and shortening of phyllocrons leading to accelerated growth rates (Nemoto et al., 1995). It would be interesting to relate the yield performance of rice crop following variants of SRI principles with some basic physiological mechanisms associated with the methods of production under local conditions. Plant responded positively under SRI conditions by way of enhanced tillering, enhanced crop growth rate and higher yield (Geethalakshmi et al 2008). It has a potential to raise the agronomic and economic productivity of land, labour, water and capital all at the same time and it can also enable farmers to produce more with less by mobilizing the services and benefits of soil biota (Uphoff et al., 2009). Rice is a staple diet in Bhutan, but increasing rice productivity has become a challenge for the Department of Agriculture (Chhogyel et al., 2014). Therefore, this experiment was conducted to demonstrate and promote variants of SRI principles in local production management system and to reaffirm the performance of this technique as a potential approach to yield maximization. There is a need to conduct experiments on annual basis to investigate the applicability of SRI principles and as part of technology demonstration in the face of decreasing agro-ecological resources and farm sustainability.

2. Materials and Method

A field experiment with three different seedling ages as treatments was conducted at RDC Bajo farm following SRI management techniques. The three different seedling ages were 10 d, 15 d, and 20 d old seedlings. The design of the experiment was RCBD with three replications of 20 sqm plots and the seedlings were planted at 25 x 25 cm spacing. FYM was applied at 3 t ha^{-1} and chemical fertilizer application rate followed NPK level of 70: 40: 30 kg per ha. For weed control, butachlor was applied @ 1.5 kg ai ha^{-1} and the most obnoxious weed of the rice paddies called

Shochum was weeded manually. Intermittent irrigation was given as and when required. But extra care was taken to avoid complete flooding of the field.

Basic agronomic traits and physiological parameters such as days to flowering, number of productive tillers, grain yield and root-shoot ratio were measured. The number of productive tiller was taken during the harvest and grain yield was measured at 85% maturity with moisture content adjusted to 14%. Root-shoot ratio was taken during active tillering stage (55 d after sowing) following oven drying of roots and shoots to constant weight. The data was analyzed using IBM SPSS statistical software version 20 and graphics prepared using MS excel.

3. Results and Discussion

3.1. Days to flowering

The three different seedling age groups took between 76 to 96 days to flower. Days to flowering for the 10 d old seedlings averaged at 96 while it took 87 and 76 days for 15 d and 20 d old seedlings respectively. The number of flowering days corresponded to the seedling ages with the youngest seedling taking longer (Table 1). However, the treatments did not show any significant difference ($P <$ value of 0.90) indicating that there is no effect of seedling ages on days to flower. During transplanting, rice plants receive transplanting shock which is a kind of plant stress with a potential to alter growth patterns and physiological development. Plants subjected to stress condition correspond to changes in physiological order of growth performance and respond differently leading to differing days to flower and maturity (Zaig and Zeiger, 2002). However, in the current experiment, there was no significant changes in days to flowering among the treatment groups.

3.2. Number of productive tillers per hill

In terms of number of productive tillers hill^{-1}, the three different seedling age groups did not show significant difference (Table 1). The average number of productive tillers hill^{-1} among the treatment age groups ranged between 14 to 15, which is a little higher than normally seen in the farmers' field (Chhogyel et al., 2013). Rice plants under SRI system of management produced higher number of productive tillers (Lhendup et al., 2009; Dobermann, 2004; Uphoff et al., 2002). Plant producing increasing number of productive tillers corresponds to increasing number of panicle bearing heads which are directly related to the grain yield. Yield potential in rice is often determined by the number of productive tillers (Yan et al., 2010). Hence, more number of productive tillers means higher grain yield. This is the reason why the principles of SRI approaches are geared towards enhanced production of tillers. The main attributes of SRI experiments are the production of increased number of panicle bearing tillers compared to other system of rice production (ETAG, 2009).

3.3. Root-shoot ratio

Plant root - shoot ratio taken at active tillering stage exhibited significant difference among the treatment groups (Table 1). The mean root-shoot ratio for the different seedling ages ranged between 0.128 to 0.174. Root- shoot ratio for 10 DAS and 15 DAS treatments did not differ statistically. However, there was a significant difference between 10 DAS and 20 DAS treatments indicating that there is a marked effect of seedling ages on rootability of plants. The result from the current experiment corroborated with the findings of Ginigaddara et al (2011)

who showed that younger seedlings exhibited higher values of root - shoot ratio. Thus, root system development has a larger effect on the above ground biomass production which is directly related to the overall plant performance. Higher root - shoot ratio indicated that transplanting of younger seedlings enable the plants to establish well with profuse rooting. Root shoot ratio is an index of supply - demand relationship in crops' water economy and higher root shoot ratio denoted increased ability to absorb water and nutrients efficiently. Thus the use of younger seedlings had a potential to have a better root system helping plants to cope well under stress conditions. Such plants have increased ability to mine soil nutrients more efficiently as compared to those plants planted at older age.

Rice under SRI condition avoids suffocation and degradation of plant roots which is the main reason for improved plant performance (Kar et al., 1974). Higher root shoot ratio under SRI condition is also attributed to improved soil aeration supporting growth and multiplication of soil organisms that provide multiple benefits to the plants (Randriamiharisoa et al., 2006). Uphoff et al (2002) mentioned that the emergence of tillers and root growth are biologically linked which is why the potential for yield is enhanced under SRI system. The higher root-shoot ratios for the 10 DAS treatment in the current experiment meant that the plant root development is aided by planting early. SRI experiments bank on younger seedlings to give stronger root system supporting vigorous crop growth. Higher root shoot ratio in SRI could also mean that the plants' resilience to stresses such as drought is markedly increased without much penalty on grain yield. One interesting case in point is that the rice farmers in the state of Andra Pradesh in India have positively viewed SRI as a technology to overcome drought condition (WWF-ICRISAT. 2010).

Table 1. Plant response to different seedling ages in terms of days to flowering, production of productive tillers and root-shoot ratio.

Treatment	Days to flowering	No. of productive tillers hill^{-1}	mean R/S ratio*
10 DAS	96.00	14.67	0.174 a
15 DAS	87.00	15.33	0.198ab
20 DAS	76.00	14.67	0.128c
P < value	0.90	0.88	0.028

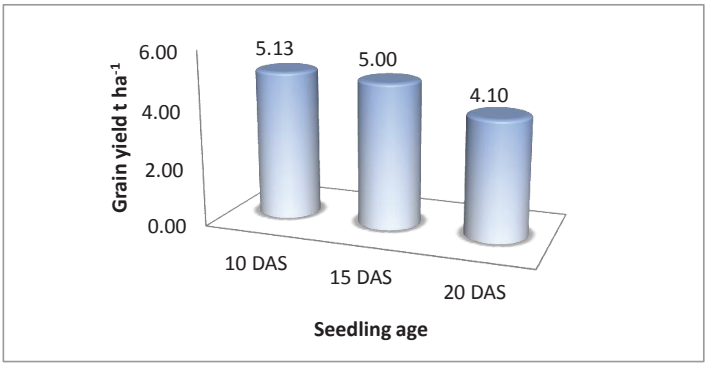
**= significant at 5% d.f*

3.4. Grain yield

The grain yield for the three different seedling ages did not show significant difference. However, the grain yield was highest for 10 DAS seedlings which was 5.13 t ha^{-1} while 20 DAS treatment showed the lowest yield of 4.10 t ha^{-1}. Figure 1 shows the levels of grain yield among the three treatments and it is interesting to note that there was a gradual decrease in grain yield with increasing seedling ages. Ginigaddara et al (2011), Uphoff (2002) and Geethalakshmi et al (2008) had also reported that use of younger seedlings gave significantly higher grain yield compared to conventional system of rice production. In the current experiment, there was a decrease in grain yield from 5.13 t ha^{-1} to 4.10 t ha^{-1}as the seedling age increased from 10 d to 20 d. This shows that the seedling age has tremendous effect on the crop performance. Even in the context of Bhutan, SRI experiments have yielded positive result with higher grain yield as

compared to the conventional management (Lhendup et al, 2008 and 2009; RNR RDC Bajo, 2012, Ghimiray et al., 2008). Increased grain yield in SRI methods of production could be attributed to a number of factors supporting plant growth environment. According to Davies et al (2010), higher grain yield in SRI system of production is related to dynamic changes in root –to-shoot signaling and physiological changes favouring optimum plant functions, growth and development.

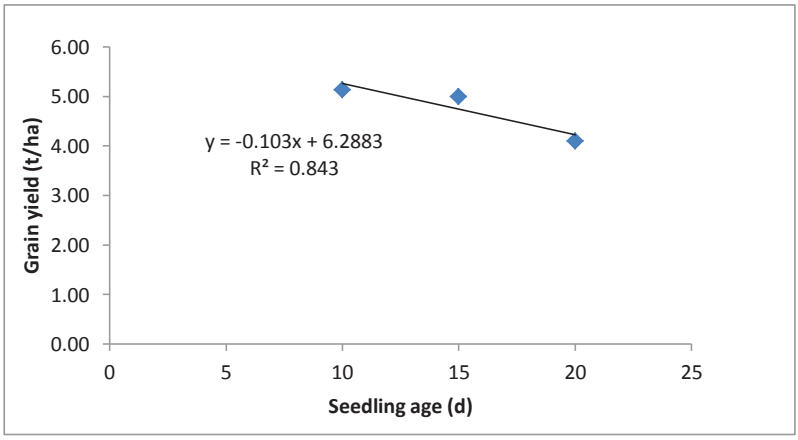
Figure 1. Grain yield among the three different seedling age groups (10 DAS, 15 DAS and 20 DAS).



3.5. Correlation between grain yield and root-shoot ratio

There was a linear correlation between the seedling age and grain yield. The seedling ages were significantly correlated to the grain yield with $R^2 = 0.843$ (Figure 2). The highest and lowest grain yields were given by the 10 d and 20 d old seedlings respectively indicating that there is a linear relationship between the two. In SRI experiments, seedling age and grain yield has always been a bone of contention and in the current experiment, when the seedling age was increased to 15 d from 10 d , there was a reduction in grain yield denoting that seedling ages are a major contributing factor in raising yield performance of rice. This relationship is very much related to the results obtained by Ginigaddara et al (2011).

Figure 2. Correlation between grain yield and seedling age groups



4. Conclusion

SRI could be a potential production management system for a small country like Bhutan which is characterized by small land holdings and abundance of vegetation cover. As proven by a number of experiments over the years, there exists an opportunity to raise the yield ceiling of 3.2 t ha^{-1} just by adopting some principles of SRI such as planting younger seedlings and proper nutrient and water management strategies. As agriculture development continues to evolve, 21st century must be devoted to those principles and practices which takes care of agricultural productivity encompassing both the economic and environmental conditions of the entire production management systems. Although modern farming banks fully on the conventional system of production, it is of utmost importance to shift the gear towards an agro-ecologically sound concept of SRI with a specific purpose of alleviating poverty and hunger as is the case with stories from Madagascar in Africa. The SRI experiments and demonstrations in the research farms have proven to the farming communities that it is a potential technology option for enhancing yield. However, farmers have not taken a serious note of this potential production management system and only time is going to tell as to how many farmers will adopt this technology. Thus, some more efforts and continuity in demonstrations will be required to convince the farmers who are now increasingly getting aware of the implication of modern farming. In the wake of eminent climate change and global warming issues, SRI practices and principles have tremendous stake in enhancing food production without adversely affecting the environment. Therefore, there is no reason that SRI will not find takers in Bhutan given the fact that Bhutan is a resource poor country with strong policy on conservation of environment and organic farming. SRI will go a long way in enhancing crop production, environmental productivity and farm sustainability.

Recommendation

Although SRI has been viewed as a noble and sustainable approach to production, its practical field applicability warrants a thorough review. However, some of its principles could very well fit into the local management practices. For this, more demonstrations and awareness will have to be continued both on-farm and on-station. More training, demonstrations and promotional programs on SRI must be put in place to demonstrate and reaffirm it as a valuable option for the farmers.

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An Assessment of Glyphosate use and its Cost Effectiveness as a Substitute for Farm Labour on paddy terrace bunds

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Abstract

Glyphosate is a broad spectrum systemic herbicide used to control annual broadleaf and grass weeds. It was discovered in 1970s and introduced in the market under the trade name Roundup®. The herbicide is used for both agricultural and non-agricultural land. In Bhutan it is one of the registered herbicides and its use was generally restricted to managing pre-harvest in potato fields. However, recently some farmers in a few geogs under Tsirang Dzongkhag have started using the herbicide on paddy terrace bunds to control weeds to cope with the decreasing farm labour.

So far no study has been conducted to validate the general perception that some farmers use glyphosate on paddy (Oriza sativa L.) terrace bunds. This study was, therefore, an attempt to confirm the general perception, evaluate the trend, and compare the cost involved in controlling weeds on paddy terrace bunds through use of glyphosate and manually. A representative and structured household survey was conducted with 130 households covering 30% of the population from each geog.

In all the surveyed geogs of Dunglagang, Kekhorthang and Gosiling, majority of the respondents reported using glyphosate. The data of the number of farmers using glyphosate over last four years exhibited a clear increasing trend, and so was the national trend. The findings also revealed that the use of glyphosate for controlling weeds on paddy terrace bunds is comparatively cheaper than done manually. On average a farmer spends Nu. 2005/acre (excluding the cost of two meals) to clear weeds manually. However, a farmer spends only Nu. 702/acre for purchasing and spraying glyphosate to control weeds. Therefore, using glyphosate saves a farmer 65% the cost of employing farm labours. The household labour availability and the size of wetland holding did not affect the use of glyphosate, but the availability of the information did. Although glyphosate may be a short-term solution to decreasing farm labour, the potentially undesired consequences may follow in the long-term.

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Keywords: **:** Manual, trend, weed control, herbicide

1 Introduction

Glyphosate is a broad spectrum systemic herbicide used to kill both broadleaf and grass weeds. The molecular formula of the chemical is $C_3H_8NO_5$. It was discovered in 1970s and introduced in the market under the trade name Roundup®. The herbicide was quickly adopted by farmers and it became the most used herbicide in the United States agriculture sector (Mansanto, 2010). It has been used both for vegetation control in agricultural and non-agricultural land. The application is mainly done as pre-plant, pre-harvest, and post plant pre-emergence.

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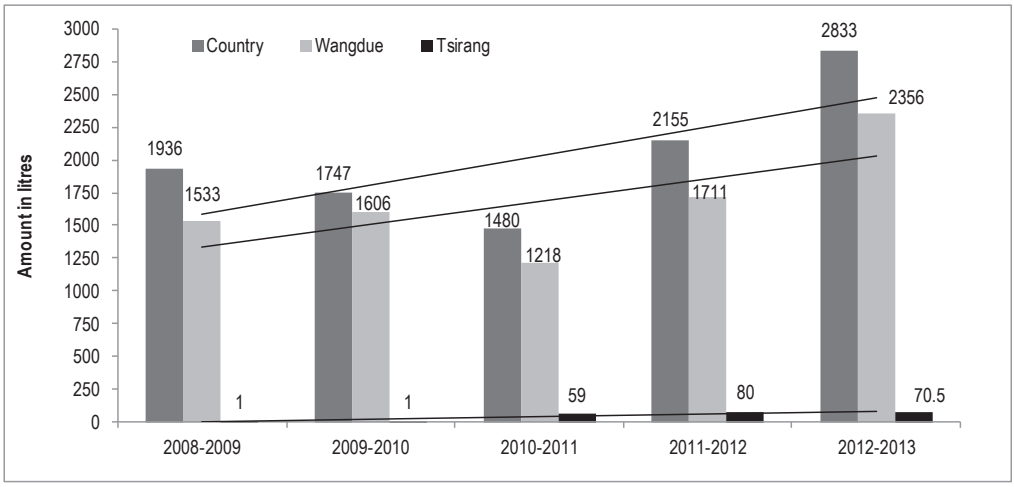
In Bhutan, its use was generally restricted to managing pre-harvest in potato fields at Phobjikha and Gangtey area in Wangdue Phodrang Dzongkhag (Yeshey et.al, 2013 in press). The total quantity imported and of which the amount used in Wangdue Phodrang and Tsirang Dzongkhags is presented in Figure 1.



Data source: National Plant Protection Centre (NPPC), Semtokha. The lines show trends for the country (top), Wangdue (middle) and Tsirang (bottom).

Figure 1: Total glyphosate import and its usage in Wangdue Phodrang and Tsirang through NPPC.

Recently some farmers in a few geogs under Tsirang Dzongkhag have started using the herbicide on paddy (*Oriza sativa* L.) terrace bunds to control weeds. The main driving force behind this move is the shortage of farm labour and availability of cheaper alternative of the glyphosate. According to a survey report (Yeshey, 2001), there is a glaring mismatch between household labour availability and requirement; the mean total full time labour availability is 3, the mean total labour requirement is 4.27. In addition, of the total 298 households interviewed during the survey, 50% reported a "decrease" in labour availability over the years (Yeshey, 2001). Rural-urban migration is the main underlying factor attributing to labour shortage. Many rural homes are left to the old people and there is simply insufficient farm labour for crop production.

Unlike cultivation of other crops, rice production requires more labour including weeds clearance on the terrace bunds. The scarcity of manual labour coupled with the drudgery required for rice production had forced farmers to seek alternatives or substitutes to farm labour. Further, high labour demand during different rice cultivation operations often adversely affects timeliness of implementation. Thus, to reduce the drudgery associated with rice cultivation, farmers have resorted to other means such as use of butachlor for controlling rice weeds and partial farm mechanization wherever feasible. As per the record maintained by the National Seed Centre (NSC), Bhutan has imported 3022 MT of butachlor from 2001 to 2012 that averages to 201.4 MT per annum. Recently, farmers have resorted to using glyphosate for controlling weeds on

terrace bunds. This study is an attempt to assess the cost effectiveness of glyphosate application on terrace bunds to control weeds with the research questions:

1. To confirm whether farmers use glyphosate on paddy terrace bunds to control weeds,
2. If used, to evaluate the trend of its usage on terrace bunds and
3. To compare the cost involved in weed clearance on the paddy terrace bunds using the herbicide and manually.

2. Materials and Method

Tsirang is one of the ten major rice growing Dzongkhags in the country and so the study was done in three geogs of this Dzongkhag. The geogs of Dunglagang, Kekhorthang and Gosiling were selected for the study because farmers in these geogs were known to use glyphosate for controlling weeds on the paddy terrace bunds. In each geog, about 30% of the total rice growing population was selected randomly and a total of 130 farmers were interviewed for the study. The formal household survey was carried out using pre-tested and structured survey questionnaire that captured gender, age group, level of education, land holding categories, means of livelihood and farm labour availability information. The questionnaire consisted of both closed and open-ended questions designed to collected both qualitative and quantitative information from the representative farmers. The data generated from the questionnaire survey was analyzed using Microsoft Excel.

A total of 38 households from Dunglagang, 66 from Kekhorthang and 36 from Gosiling were randomly selected and interviewed for the study. Majority of the respondents, 83.6% were males and only 16.4% were females. Regarding the age composition of the respondents; majority of them were adult (>18 to 60 yrs) 73.6%, while 26.4% consisted of old farmers (>60 yrs). Irrespective of age and gender, the occupation of all respondents was farming. Regarding the level of education, 31% attended high school, 28% dropped from primary while 41% never went to school.

Almost all the respondents own both dryland and wet land at varying sizes. However for the purpose of this study, the focus has been on the wet land as the study aims to investigate the usage, trend and the cost effectiveness of glyphosate for controlling weeds on the paddy terrace bunds. Respondents were categorized into three wet land holding groups of small (0 - 2 ac.), medium (2.1 – 4 ac.) and large (>4 ac.). Of the total 130 respondents interviewed, majority of 52.5% fell under small, 41% medium and the rest 6.5% fell under large land holding group. The average wet land holding of the respondents is 1.55 acre with 6 acres as the highest and 0.25 acre as the least wet land holding.

Irrespective of geogs, the main means of livelihood is cultivation of crops. The second important source of livelihood is the rearing of livestock which include poultry, piggery and dairy. Other important supplementary livelihood avenues are small businesses, off-farm activities and remittances.

The number of household members was categorized into three groups such as large, medium and small. A respondent with a family member ranging from 1- 4 is categorized as "small", 5 – 8 was grouped as "medium" and more than 9 members was identified as "large". This was done mainly to see how many respondents fall under each category in terms of household size. Of the total 130 respondents, 24.4% fell under the small category, 57.4% were in the medium category and the rest (8.2%) fell under the large category.

3. Results and Discussion

3.1 Source of glyphosate

According to the findings of this study, there are only two sources from where respondents have been purchasing glyphosate. While 37.5% respondents mentioned to be purchasing glyphosate from the National Plant Protection Centre (NPPC) Simtokha, majority (62.5%) respondents go as far as Datgari (near Gelephu) in India to purchase the herbicide. There is a slight difference in the cost of the herbicide and that could be the reason why most farmers bought the herbicide from Datgari. A liter of glyphosate 41 EC cost a farmer Nu. 350 from Datgari and Nu. 420 once transported to Tsirang. From NPPC, 500 ml glyphosate 41 EC cost a farmer Nu. 158, however once the herbicide is transported to Tsirang a farmer has to pay Nu. 250 for 500 ml.

3.2 Household labour availability

To assess the availability of farm household labour in relation to the uses of glyphosate, the households were further divided into two groups such as those who stay on-farm and do farming and those who do not stay on-farm. A household that falls under the high household member category does not necessarily fall under the high labour availability category. Labour availability of a respondent is also grouped as low, medium and high. A household with farm labour ranging from 1 – 2 is categorized as "low", 3 – 4 as "medium" and more than 4 as "high". Unlike household member population, majority (54.1%) of the respondents fall under the low labour availability group, 39.4% in medium labour availability category and only 6.6% in high labour availability category. Majority of the respondents have only 1 - 2 farm labours for farming to support the main source of livelihood.

3.2 History of glyphosate usage and trend

Of the total 130 respondents, 66% reported to be using glyphosate and the rest were not applying it. The main reasons for not using the herbicide were "Never heard about it" and "Not easily available". Among the users majority of 75% respondents had heard about the herbicide from friends and the remaining 25% from the RNR staff irrespective of where they access the herbicide. Nearly half of the respondents have come to know about the herbicide since 2009. Although the respondents came to learn about the herbicide in the very recent past, the number of farmers using it to control weeds in the paddy terrace bunds is perceived to be increasing.
Among the respondents who were using glyphosate, the number of years of usage differs and the maximum number of years respondents have been using the herbicide is four as shown in Figure 2.

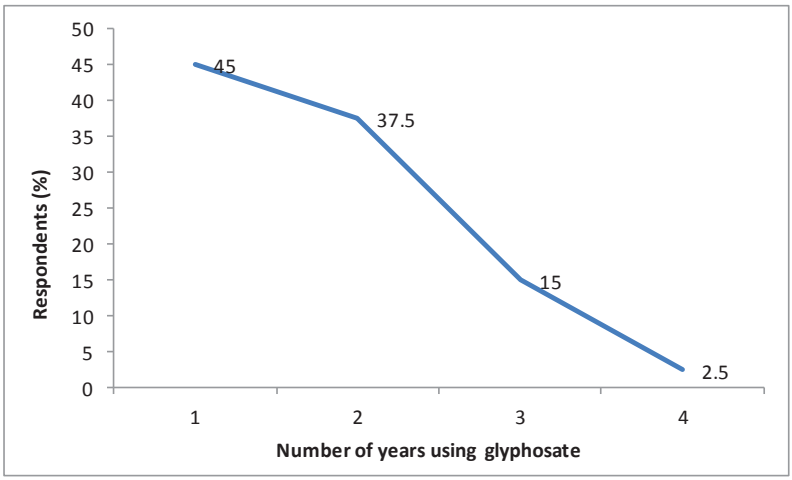


Figure 2: Percent of respondents using glyphosate for various periods

The result not only shows the percent of respondents and the number of years they have been using glyphosate, but also clearly indicates that the number of respondents using glyphosate is increasing. Four years ago, of the total 130 respondents, only 2.5% mentioned to be using glyphosate. However in the following year percent respondents using glyphosate has increased to 15% which has further increased to more than double in the third year after the introduction. As of 2013 when the study was done, percent respondents using glyphosate has increased from 2.5% four years ago to 45%. The increasing trend of glyphosate usage found by this study can be validated by the secondary data presented in Figure 1 that demonstrated a clear increasing trend in Tsirang, Wangdue or nationally. The household labour availability and the size of wetland holding did not affect the use of glyphosate, but the availability of the information did.

With the decreasing farm labour availability, it seems that the number of farm households using glyphosate is increasing over the years. Although only some Bhutanese farmers are using the glyphosate annually for pre-harvest potato field (Yeshey et.al, 2013 in press) and recently in paddy terrace bunds in some geogs under Tsirang; the usage can potentially affect Rupee reserved as its ultimate source is India. The increasing trend of glyphosate usage in Tsirang Dzongkhag suggests the effectiveness of the herbicide in managing weeds in paddy terrace bunds and the trend also suggests that more farmers are likely to switch into using it, which would negatively impact on the Bhutanese policy of going organic and potentially harm agro-ecosystem in the long term (Powles, 2008 and Shaner et. al, 2011)..

3.3 Time and frequency of glyphosate application

Irrespective of geog, the frequency of glyphosate application is reported to be only once in one rice season. However, the time of application differs among the respondents.

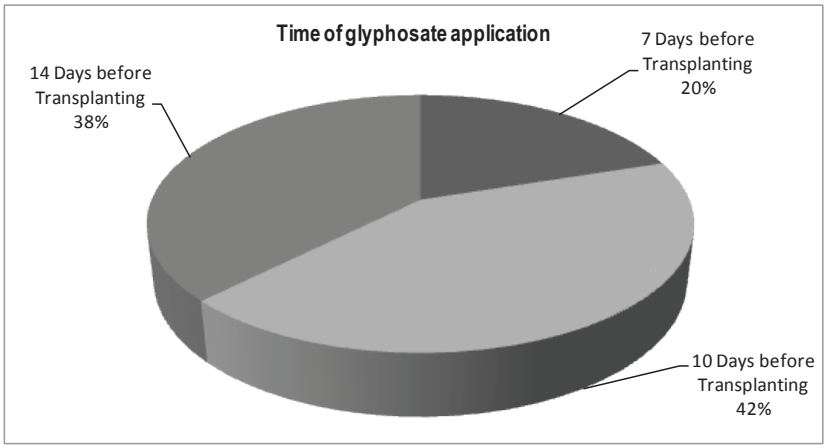


Figure 3: Percent respondents and time of glyphosate application

Amongst the respondents using glyphosate, majority 42.5% apply the herbicide on terrace bunds 10 days before of rice transplanting, 37.5% apply 14 days before of rice transplanting and the rest 20% apply 7 days before of rice transplanting. However, we do not know the reasons behind different times of application and their associated effectiveness in controlling the weeds on the paddy terrace bunds. Despite the difference in application time, all respondent observed that the new vegetation comes back nearly after one and half months of application with completely new weed composition. They mentioned that the herbicide eradicates a bladey grass (*Seru in Lhotshamkha*) species which was commonly used as roofing material. This is an indication of a negative consequence like biodiversity loss the herbicide is likely to bring about. Few respondents who have been using the herbicide for more than three years observed that with repeated application of the herbicide, they said that the stability of the bunds weakens as there are no more grass roots to hold the soil together. Furthermore, some respondents are also concern about declining soil fertility from repeated application of the herbicide. They said that if they do not use the herbicide, the grasses and other weeds whatever is scrapped off the bunds are incorporated into the soil and adds soil fertility. With the application of the herbicide, this practice no more there.

Glyphosate is the global herbicide of choice for weed control in a wide variety of environmental uses in different areas (Powles, 2008). Glyphosate is subject to microbial degradation, which reduces the risk of accumulation (Borggaard and Gimsing, 2008) and thus it seems safe for the rice-ecosystem to apply glyphosate on paddy terrace bunds. However, while one application of glyphosate is said to be effective in controlling perennial weeds for many years (Mansanto, 2010), it would be also important to study how long the weeds take to grow back after the application of glyphosate on paddy terrace bunds. More serious consequence from regular application is the likelihood of emergence of glyphosate resistant weeds as such impacts have been reported elsewhere (Powles, 2008 and Shaner et. al, 2011).

Glyphosate is widely use in the world mainly because of its efficacious and economical benefits and it has found a range of uses in agricultural, urban and natural ecosystems. As it is a non-selective herbicide that controls a very wide range of plant species, it is used for broad-spectrum

weed control. At the study sites, irrespective of the different time of application, the effectiveness of glyphosate in controlling weeds has been rated as "highly effective" by majority 67.5% of the respondents. The other 32.5% of respondents mentioned its efficacy as "moderately effective". This indicates that glyphosate is effective in controlling weeds on paddy terrace bunds.

3.4 Comparison of cost of using glyphosate and manual clearance of weeds

One of the main objectives of this study was to find out the economics of controlling weeds on paddy terrace bunds in an acre of wetland using glyphosate and through manual clearance. Of the 130 respondents, about 41.7% reported that they would need 10 people to clean weeds on terrace bunds in an acre of land. Similarly 31.3% mentioned that minimum 12 people are required to clean weeds on terrace bunds in an acre of land. The highest number of people needed to clean weeds on terrace bunds in an acre of land is 15 as stated by 27% respondents. The little variation in number of people requires cleaning weeds on terrace bunds in an acre of land could be because of the difference in size of the bunds and the efficiency of workers.

The daily wages for people cleaning terrace bunds range from Nu. 150 to 200 per day with two meals. The difference in the daily wage rate could be because of the difference in local wage rates in different geogs. On an average, a farm household has to expend Nu. 2005 for cleaning terrace bunds manually in an acre of land. This amount does not include the cost of the two meals. While most respondents reported to use wage labourers, there are some respondents who use their own household labours for cleaning terrace bunds. Irrespective of wage or household labour, the study results showed that an acre of wet land requires 10-15 labourers for cleaning vegetation on terrace bunds.

On the other hand, a farmer spends about Nu. 702 for purchasing and spraying the herbicide for controlling weeds while using the herbicide, on an average. On an acre of wet land a farmer has to spend Nu. 502 for buying the herbicide and Nu. 200 per person as wage to spray on the bunds. The expenditure in purchasing glyphosate for an acre of land ranged between Nu. 600 to 300 and wage rate for spraying the herbicide ranged between Nu. 150 – 200 with one meal. The difference in the total amount of money spend suggests the differences in solution concentration while mixing glyphosate with water for spraying. This difference could also possibly be due to the difference in dosages sprays of the prepared solution. Some respondents may be applying higher dose while others use lower concentration.

Despite the difference in amount of money spent in purchasing glyphosate for an acre of land among the respondents, the use of glyphosate is still much cheaper by 65% than controlling weeds manually on the paddy terrace bunds. This could be the reason why the number of farmers using glyphosate is increasing over the years.

4. Conclusion

In Bhutan glyphosate use was generally restricted managing pre-harvest in potato fields of Gangtey and Phobjikga geogs of Wangduephodrang. Recently some farmers in a few geogs under Tsirang Dzongkhag have started using the herbicide on paddy terrace bunds to control weeds to cope with the decreasing farm labour. A majority (66%) of respondents from 130 households surveyed use glyphosate and some of these households have been using it since

2009. The herbicide is applied once in one rice season and is applied within 7 – 14 days before rice transplanting. Most respondents purchase glyphosate across the border from Gelephu with a few buying from the NPPC in Semtokka.

Number of farmers using the herbicide has shown an increasing trend over last four the years with only 2.5% of the respondent using in 2009 have increased to 45% in 2013, and the findings agree with the secondary data in terms of usage in Tsirang, Wangdue and nationally. On average, a farmer spends Nu. 2005/acre to clear weeds manually compared with Nu. 702/acre using glyphosate. The increased number of the users over the years indicates the efficacy of the herbicide coupled by cheaper herbicide alternative. Hence, the findings confirm that farmers use glyphosate as a substitute for farm labour.

Weed clearance on the paddy terrace bund is one of the key operations involved in paddy cultivation. Decreasing farm labour has led farmers to resort using glyphosate as an alternative. However, there is a need to disseminate associated side effects on paddy ecosystems in particular and environment in general.

Acknowledgement

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LIVESTOCK

Producation and Compositional Dynamics of High Altitude Grasslands in Western Bhutan

Tshering Gyeltshen[1], Yonten, Harilal Nirola, Krishna Kumar Rai, Nidup Tshering

Abstract

A study was carried out to assess and monitor the dry matter production and botanical composition of natural grasslands at Soeyaksa, situated above 4000 meters above sea level (masl). The study was conducted on three locations at two sites representing plain and slope areas. Eight metal cages measuring 0.49m^2 were installed at each site. Transect method was used to estimate the botanical composition and vegetation cover prior to every harvest. The nine year observations revealed three major categories of broad leaf herbs, grasses, and sedges although their abundance varied between sites. The number of individuals were 33 broadleaf, 7 grass and 3 sedge species.Dry matter production between two grassland types differed significantly. The highest usable DM yield inside the cage was 1.1t ha^{-1} for "lax" grassland type and 0.8t ha^{-1} DM for "very short" grassland type. In open area without cage, the highest DM yield was 0.6t ha^{-1} for "lax" grassland type and 0.01t ha^{-1} for "very short" grassland type. There was no significant difference in DM yield between sites selected on slopes and plain area except at Thombu. On "lax" grassland, the average plant height was 22.6 cm (inside cage) and 14.4 cm (open area). On "very short" grassland type, the plant height was 12.4 cm (inside iron cage) and 2.6cm (open area).The crude protein (CP) content was 11.5 % and 8.80 % for "very short" and "lax" grassland types, respectively. Ash content of the herbage was slightly higher in the open area (6.7 %) compared to inside iron cage (5.7 %).The soil was highly acidic for "very short" grassland type. The soil available P and exchangeable K were low for all sites with no significant difference between soil depths in the levels of P and K. However the organic matter content (C/N ratio) at 0-10 cm was medium, whereas the content at 10-20cm and 20 – 40 cm soil depth was low.About 65 % of different plant species are yet to be identified; therefore, taxonomical enumeration of vegetation needs to be addressed.

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Keywords: **: :** Botanical composition; Carrying capacity; dry matter; grassland; meadow

1. Introduction

In Bhutan, the estimated area of 155,300 ha comprises natural grasslands, pastures, meadows and other grazing areas (LUPP, 1995). According to Gyamtsho (1996), the alpine rangelands of Bhutan (3300-5000m) include 400,600ha of permanent snow cover; 345,600 ha of barren and exposed areas; 295,600 ha of fir forests; 74,800 ha of alpine meadows and 191,800 ha of alpine scrubs. The total area of alpine rangelands is about 1,308,400 ha, which is over 32% of the country's total land cover, excluding substantial portions of water spreads and mixed coniferous forests in the high altitude zone. Apart from providing forage for livestock, high altitude rangelands are the sources of many major rivers that are harnessed for hydropower generation

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and also serve as critical habitat for numerous endangered plant and wildlife species of national and global importance (Chophyel, 2009).

A number of efforts have been made in the past two decades to improve low productivity of these native pastures by introducing exotic plant species. Attempts were initiated to make an inventory of the natural grasslands in eastern Bhutan during the tenure of the then ADB assisted Highland Livestock Development Project. Some works have been carried out in western Bhutan on highland altitude rangeland and description of development possibilities by then FAO TCP project. However, to date, there are no clear and consolidated evidence of what are the plant components contributing to the diet of grazing animals and wildlife. Thus, it is important that further attempts are made to assess and describe native pastures, identify the species and monitor trends in production, estimate carrying capacity of different grassland types, change in soil properties, population composition, and their nutritive qualities of alpine grasslands.

Therefore, a study was conducted with two sets of objectives. The short term objectives were to describe the natural grasslands, identify fodder species and establish herbarium for native fodder species. The long term objectives were to monitor trends in forage production, soil quality, population composition and nutritive qualities of alpine grasslands.

2. Materials and Methods

2.1 Site description

The study site was selected in Soeyaksa area under ParoDzongkhag. Soeyaksa community depends on yak husbandry for their livelihood. Yaks are mainly raised for milk and meat. The three sites (grasslands) selected for study were grazing ground for autumn, winter, spring and summer. The selected sites were predominantly under natural condition without the influence/presences of exotic fodder species between the ranges of 4000-4300masl. Broadly, the grasslands at Soeyaksa area can be categorized into two different types of grasslandsthat very short grassland (sedge species dominated grasslands) and mixed vegetation grassland comprising of broadleaf herbs, grasses, and sedge species. Harris (1987) had clearly described these grasslands into two categories as "*lax*" and "*very short*" grasslands. The "very short" grasslands are spread above 4100masl and face high grazing pressure during summer and the "lax" grasslands type (<4100m) face much lower grazing pressure during summer. The details of study sites are explained in Table 1.

Table 1: Details of study sites

Site	*Altitude (m)*	*Slope (%)*	*Aspect*	*GPS position*	*Owner of grazing land*
Lamilakha, slope	4200	35	S, SE	N 270 42.396'; E 0890 18.857'	NiduZam
Lamilakha, plain	4060	12	S,SW	N 270 42.250'; E 0890 19.111'	NiduZam
Kamgung, slope	4130	30	SW	N 270 42.258'; E 0890 20.592'	Tshomo
Kamgung, plain	4100	12	NE	N 270 42.258'; E 0890 20.592'	Tshomo
Thombu, slope	4300	30	S, SW	N 270 39.203'; E 0890 18.945'	Dago
Thombu, plain	4200	5	S,SW	N 270 39.200'; E 0890 18.947'	Dago

2.2 Study design

A total of 3 locations × 2 sites were selected with special attention given to aspects to get an indication of the different vegetation types at different altitude and slope percentage. Each site had 45m^2 of circular area with a radius of 12m^2. An iron peg was driven in the center of the circle to enable re-location of the area for follow up during the trial monitoring. The geographical positions were noted down with help of GPS prior to the trial establishment. The trial plots were laid out under snow accompanied by icy wind. The study was conducted from 1999 -2007.

i) Botanical composition and vegetation cover

In our study, the transect method was used for vegetation analyses. A transect of 1.5 m was laid down and 30 points were enumerated along this transect at an interval of 5 cm. The first plant that the dissection pin touched was noted down on to the standard transect sheet. A total of 12 transects at each site were recorded prior to every biomass harvest.

ii) Herbage yield assessment

Eight metal cages measuring 0.49m^2 with a base of 70cm × 70cm, top dimension of 40cm × 40cm and height of 0.6m were installed at each site for recording herbage production. Although the growing season extends from May to October, significant herbage production doesn't occur until the beginning of the rain, usually in June. Therefore, forage was harvested once in a year due to short growing season. Each year fodder was harvested in early October before the yak herds arrived for winter grazing. After every harvest, the iron cages were rotated avoiding previously harvested areas that were 12 m radius within the trial area. The herbage was cut to a stubble height of 1-2cm using serrated sickle and grass clippers (using hand clipping method). Fresh yield (FY) was recorded at the site after the samples were bulked together using reliable weighing scale. The sub-samples dried in hot air oven for 24 hours at 60^oC to determine DM yields.

iii) Collection and processing of soil samples

Fifty sub-samples each from depths of 0-10; 10-20 and 20-40cm were collected at the time of trial establishment and after every five years. Soil samples were air dried at ambient temperature and the dried samples were sent to National Soil Service Centre (NSSC), Simtokha to estimate organic C and N exchangeable P, K and soil pH.

2.3 Data analysis

Descriptive statistics were used to estimate and compare dry matter production and species composition between sites. Data were analyzed with the statistical software SPSS 13.

3. Results and Discussions

3.1 Botanical Composition and Vegetation Cover

The compiled average botanical composition and vegetation cover over the period of nine years is presented in Table 2.The plant communities illustrating the open grassland consisted of three major species of broadleaf herbs, grasses and sedges although their existence varied from site to site. Under these three broad plant diversity categories, 33 different broadleaf species, 7 grass species and 3 sedge species were recorded from the "lax" grassland type. Bennie et al (2006) reported that the proportions of broadleaf and grass differ significantly between sites, which is probably due to variations in microclimate that influence many grassland species.

The study also revealed that ground covered by other plant species such as ferns, Junipers, dung, stone etc. is negligible. Bare land percentage reported is mainly due to the trampling effect by the grazing animals. More grass species are found in "lax" grassland type than "very short" grassland type. "Very short" grassland type is dominated by sedge species and plant composition did not change significantly over the period of 9 years (Fig. 2). However, in the "lax" grassland type, the plant composition changed within the period of 9 years. The grass component increased by 5% while broadleaf species reduced by 8% and the sedges reduced by 32%.

Table 2: Average botanical composition & vegetation cover in percentage

Site	Grass sp.	Sedge sp.	B.leaf sp.	Mosses (MS)	Fern	Bare land (BL)	Stone	Juniper sp.	Dung (D)
Lamilakha, slope	14.15	41.9	32.4	4.65	0.9	5.6	0.15	-	-
Lamilakha, plain	13.05	15.9	63.0	3.7	1.1	2.7	0.06	-	0.4
Kamgung, slope	5.34	43.9	33.3	13.0	0.1	3.54	0.2	-	1.0
Kamgung, plain	9.22	37.2	38.8	12.0	0.06	1.91	0.1	0.6	-
Thombu, slope	2.87	55.8	12.8	21.0	-	5.82	0.6	1.0	-
Thombu, plain	2.94	59.5	21.5	13.0	0.3	0.57	0.2	0.3	-

A list of native grass, sedge and broadleaf species recorded in the two grassland types above 4000 m are presented in Table 3. Occurrence of similar species was also reported by Harris (1987) in Soeyaksa grazing areas.

Table 3. Native grass, sedge and broadleaf herbs

Sl no.	Broadleaf/shrub sp.	Grass/sedge
1	*Saussurea spp.*	*Kobresia sp.*
2	*Texaxacum spp.*	*Festucasp*
3	*Epilobium spp.*	Brachypodium sylvaticum
4	*Ranunculus spp.*	Calamagrostis lahulesis
5	*Potentillaspp*	Agrostis pilosula
6	*Gentianaprolata*	Trisetum himalaicum
7	*Rubus fragariodes*	*Denthonia spp.*
8	*Thermopsis barbuta*	*Carex hamatostoma*
9	*Leontopodium jacotianum (Anaphalis sp.)*	*Bromus himalaicus*
10	*Onosma hookeri*	*Elymus dahuvicus*
11	*Cyananthus labotus*	*Danthonis cumminsii*
12	*Polygonatum hookeri*	*Poasp*
13	*Geranium polyanthes*	*Calamagrostics cabrescens*
14	*Ligularia sp.*	*Elymus nutans*
15	*Geranium nakoanium*	*Stipa sp.*
16	*Anemane sp.*	
17	*Pedicularis sp.*	
18	*Inular hizocephala*	
19	*Pterocephalus hookeri*	
20	*Rhodiola sp.*	
21	*Sarifraga purunassifolia*	
22	*Aster faleeneri*	
23	*Allium wallichii*	
24	*Rhododendron anthopogen*	
25	*Rhododendron setosum*	
26	*Rhododendron aeruginosum*	
27	*Aconogonum sp.*	
28	*Heracleum obtusifolium(Dhum*)	

3.2 Dry Matter Production

Annual DM production varied from year to year and this could be attributed to time and distribution of annual rainfall and period of snowfall for the particular year. Other factors contributing to the yearly DM production variations could be the time of harvest. If the harvest is done in mid or late October, standing biomass is affected by the cold weather and frost. Dry matter production between two grassland types differed significantly. The highest usable DM yield inside cage was recorded as 1.1 t ha^{-1} from "lax" grassland type and 0.8 t ha^{-1} DM was

recorded from "very short" grassland type (Table 5). The yield of both grassland types, are higher than the DM yield of 0.29 t ha^{-1}previously estimated for high altitude grassland (Roder et al., 2001).The yield of "lax" grassland type is almost at par with DM production of 1.03 t ha^{-1}reported by Wangchuk et al (2013). Similarly, Pariyar(1995)also reported an average forage DM yield of 0.5 – 1.54 t $ha^{-1}$for alpinesteppe Himalayan rangelands of Nepal. In the alpine steppe Himalayan rangelands of India, dry matter yield reported was 0.7- 1.0 t ha^{-1}(Singh, 1995).

DM yield recorded from outside cage or in open area, was 0.6t $ha^{-1}$from "lax" grassland type and DM yield of 0.01 t $ha^{-1}$from "very short" grassland type. It should be noted that without cage or open area was grazed by horses and wild ungulates (Blue sheep) in "lax" grassland type and whereas the trial site at "very short" grassland type was grazed throughout the growing season by yaks.

Without calculation of utilizable yield considering that some yield losses during harvest,actualforage DM yieldare shown below (Table 4 and Fig.3).

Table 4: Average DM production of 9 years

Site	Inside cage (tha^{-1})	Open area (tha^{-1})
Lamilakha, slope	1.50	0.88
Lamilakha, plain	1.53	0.82
Kamgung, slope	1.29	0.27
Kamgung, plain	1.35	0.29
Thombu, slope	0.64	0.12
Thombu, plain	1.09	0.14

The average forage DM production over the period of nine years have been calculated to utilizable yield considering that some yield losses (10-15%) occurred during harvest and its associated factors. Utilization factors ranging from 0.6 -0.9 were used while calculating usable yield (Harvey, 1990). Table 5 and 6 show yield of DM converted to usable yield.

Table 5: Average dry matter yield converted to usable yield (inside iron cage).

Site	Experimental plot yield (t ha^{-1} DM)	Field factor	Commercial * field yield (t ha^{-1} DM)	Utilization factor	Utilizable ** yield (DM t ha^{-1})
Lamilakha, slope	1.50	0.8	1.20	0.90	1.10
Lamilakha, plain	1.53	0.8	1.53	0.90	1.10
Kamgung, slope	1.30	0.8	1.04	0.90	0.94
Kamgung	1.35	0.8	1.08	0.90	0.97
Thombu, slope	0.64	0.8	0.51	0.90	0.46
Thombu, plain	1.09	0.8	0.87	0.90	0.80

Table 6: Yield of DM converted to usable yield (open area without cage)

Site	Experimental plot yield (t ha^{-1} DM)	Field factor	Commercial * field yield (t ha^{-1} DM)	Utilization factor	Utilizable ** yield (DM t ha^{-1})
Lamilakha, slope	0.88	0.8	0.7	0.90	0.63
Lamilakha, plain	0.82	0.8	0.66	0.90	0.60
Kamgung, slope	0.27	0.8	0.22	0.90	0.20
Kamgung	0.29	0.8	0.23	0.90	0.21
Thombu, slope	0.12	0.8	0.1	0.90	0.09
Thombu, plain	0.14	0.8	0.11	0.90	0.01

One - Sample Kolmogorov Smirnov Test showed that there is no significant difference in dry matter production recorded inside the cage area in all locations (Table 7). However the DM yield outside the cages was significantly higher (p=0.002). The significant difference may be due to the grazing pressure from the seasonal yak migration and continuous grazing by blue sheep and horses in most trial sites. Amongst all the sites, Thombu site is severely affected due to over stock and grazing resources is shared by seven herders' families.

Table 7: Comparison of DM yield between inside and outside iron cages

		DM Inside cage	DM Open area
Normal Parameters(a,b)	Mean	1280.487	429.8063
	Std. Deviation	546.8759	472.0893
Kolmogorov-Smirnov Z		0.778	1.879
Asymp. Sig. (2-tailed)		0.581	0.002
[a]Test distribution is Normal [b]Calculated from data			

3.3 Herbage growth

Plant height was recorded prior to every harvest time and the average plant height recorded in "lax" grassland was 22.6 cm (inside iron cage) and 14.4 cm in open area. As for the "very short" grassland type it was 12.4 cm (inside iron cage) and 2.6 cm in open area. The difference in plant height also indicates the yield variations of the herbage between the two distinct grassland types.

3.4 Nutritional quality

Nutritional quality parameters of the native forage wereanalyzed at National Soil Service Centre (NSSC), Simtokha. Forage nutrient analysis included moisture content, ash and crude protein (CP). In case of "very short" grassland type, CP content is higher (11.5%) compared to "lax" grassland type (8.8%). The reasons could be that vegetation cover of "very short" grassland type is dominated by Cyperaceae (sedges) and whereas vegetation cover of "lax" grassland type is of a more heterogeneous composition. Ash content of the herbage is slightly higher in open area (6.7%) compared to inside cage (5.7%).

3.5 Soil nutrient

Soil analysis results of highland altitude grasslands indicated that the soils are generally acidic (pH 4.2 – 5.6). Soil acidity is severe at "very short" grassland type, Thombu. Soil analysis results also revealed low level of Phosphate and Potassium across all sites.But the organic matter content (C/N ratio) at 0-10cm depth was found to be medium and the organic matter content at 10-20cm and 20-40cm soil depth was low. However, the soil analysis results indicate that there was no significant difference of available P and K at various soil depths.

4 Conclusion

Grazing of high altitude grasslands/rangelands is a major land use in yak husbandry system in Bhutan.Nine years study on grassland production monitoring revealed that DM production differed significantly between two grasslands types.Botanical composition and vegetation cover varied between two grassland types. Over the nine years study period, the plant composition remained more or less same in "very short" grassland typewhereas species composition changed in "lax" grassland type. An increase in grass species and decrease in broadleaf species was observed. In general, it can be concluded that the herbage quality of native grassland above 4000 m is low to moderate. No legume species were recorded within the experiment period. The soil nutrient status is acidic and with low available P and K. This would have implications on choice of forage species for improvement of the native grasslands in near future. Other observation on signs of soil disturbance (micro erosion) within transect were also recorded and over the study period, no significant soil disturbances were found within the trial area as well as outside trial areas. The most common soil disturbance noted was yak bull pits which are common throughout the yak rearing zone.

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Evaluation of Maize Varieties as Winter Fodder and Feasibility for Making Portable Plastic Bag Silage

Dorjila[1] and Penjor

Abstract

Field experiment was conducted at Agriculture farm, College of Natural Resources from 4th September 2013 to 9th November 2013. The objective of study was to evaluate maize varieties both late and early maturing varieties as winter fodder and to assess its feasibility for making portable plastic bag silage. The Experiment was laid out in Randomized Complete Block Design (RCBD) with three replications measuring 12 m^2 per plot and maize varieties used were Talo Dasum (TD), Gelephu Local White (GLW), Yangtsepa Red (YR) and Arun-2 (A-2). The parameters such as plant height, number of leaves, stem diameters and CP content of fresh maize fodder were highly significant in late maturing variety while DM content was higher in early maturing variety. In case of silage quality and palatability test there was no significant differences among the four maize varieties but differed significantly in nutrient contents. The Ash content in both fresh and silage forage did not differ significantly but there was significant difference in silage pH. However, after ensiled there was decreased in DM content and increased in CP content in all maize varieties

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Keywords: **:** *Ash, Crude protein, Dry matter, No. of leaves, Plant height, pH and Stem diameter.*

1 Introduction

Dairy farming is one of the most important components of traditional farming system in Bhutan. They are mainly kept for manure, draught power and cash and home consumption (Wangdi, 2006). Besides, it has been focused as a core developmental plans and projects in rural areasPhanchung *et al.* (2002) and similarly,Thinlay (2012) reported that during the 10th five Year plan 112 dairy farmers group were formed and established 35 milk processing units across the country.

However, shortage of feed and fodder during the winter season is a major limiting factor and mostly fed with agricultural by-products which are of very poor quality (Roder, n.d). On other hand, Roder (2004) and Tamang and Perkins (2005) reported that the availability and quality of fodder during dry months is considered a major constraints on large ruminant production and use seasonal migration to reduce the impact of fodder shortage during the winter season. In order to address these issues, various technologies were recommended. However, adoptions among farmers were very low due to lack of appropriateness and labour intensiveness. Chaudhary *et al.*(2012) reported,for dairying to be successful there must be a year round fodder supply and green maize are excellent amongst the non-legume cultivated foddersin terms of nutritional quality and biomass. But maize cultivation are practiced only for subsistence and never used as winter fodder in Bhutan. In addition, growing of maize crops as winter fodder and technology of producing maize silage in portable plastic bags havebeen neverdemonstratedalthough there is

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huge potential to adopt maize as a winter fodder and ease in making silage in portable plastic bags.The common maize varieties grown are varied but these maize varieties were never tested and used as winter fodder in our dairy production system because little attention has been paid by owners and due to poor technical know-how on this particular technology.

Therefore, considering the aforementioned points this experiment was being undertaken with objectives to evaluate potential of late and early maturing maize varietiesas winter fodder and to assess its feasibility of making portable plastic bagsilage which could providean alternative fresh green fodder for lactating cows to maintain their optimum level of milk production and efficiency of reproductive cycle during the dry winter season.

2 Materials and Methods

The study was conducted in the fields of College of Natural Resources (CNR) agricultural farm from 4th September to 9th November 2013. It lies at an altitude of 1440 masl and falls under dry subtropical climatic region. The experimental design usedwas Randomized Complete Block Design (RCBD) and replicated three times.Maize varietiesused were Yangtsepa Red (YR), Talo Dasum (TD), Arun-2 (A-2) and Gelephu Local White (GLW). The seeds were sown in drilledholes at distance of 45 cm row to row and 30 cm plant to plant. During sowing, a7.5 kg of FYM per plot was applied asbasal and 130 gm of urea as top dressing at knee height.

Data recording were done on Plant height, number of leaves and stem diameter in centimeter. At 70 days, three samples measuring $1m^2$ quadrant was cut from each plots and measured for total average biomass. Then, leaves and stems were separated and weighed separately as Green Stem Fodder (GSF) and Green Leaf Fodder (GLF).A 250 gm. of mixed stem and leaf was sampled from each replication for chemical analysis (DM, CP and Ash) in laboratory of CNR. The samples were dried in hot air oven at 70^0C for 24 hours, cooled, weighed and expressed in gramsand percentage.

$$\text{DM \%} = \frac{\text{Dry weight}}{\text{Fresh weight}} \text{X } 100$$

The samples were further groundfor CP and ash analysis. The CP was analyzed using Kjeldahal methods (N % × 6.25) and Ash with muffle furnace.

$$\text{Ash \%} = \frac{(W3 - W1)}{(W2 - W1)} \text{ X } 100$$

Where
W1 = Crucible weight,
W2 = Crucible + sample weight
W3 = Crucible + Ash weight.
CP % = (N % × 6.25)

$$\text{N \%} = \frac{14 \text{ x (normality of acid (0.1N)) x (Titration value) x100}}{\text{Sample wt. x 1000}}$$

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After biomass analysis, whole experimental plots of maize were harvested and pooled together by variety. The harvested maize plants were wilted till late afternoon and were chopped variety wise at the length of 2-3 cm with the help of electrical mortar machine for ensiling.A 20 kg of chopped maize fodder was weighed and filled into the plastic bags. After filling, an electrically operated Vacuum Cleaner Machine (230 V) was used to remove the air from plastic bags and fodder materials. The ensiling of silage was done variety wise in this manner and in total there were 12 bags ensiled.The ensiled bags were put into another ploythene sacks and closed with cotton threads and stored in a dark enclosure at room temperature.At 6 weeks,Bags were opened and physical evaluation such as colour, smell, touch, taste and pH were done. Thereafter, a 250 gm of silage was sampled from each bagfor chemical analysis and pH determination. A 100 gm of each fresh silage sample was used for pH determination and rest is used for chemical analysis. The methods and procedures were explained under fresh fodder in above lines.Finally, a palatability test was undertaken on CNR farm through feeding of four cows. Cows were fed from 1 to 12 days and while feeding they were rotated every after 3 days to new maize silage varietywith increase in 1 kg quantity. The initial quantity of silage fed was 3 kg per cow and final quantity was increased to 6 kg per cow by 4^{th} rotation. The assigned silage quantity was fed during evening and next morning leftover silage in manger was collected and expressed palatability test in percentage.

$$\text{Palatability \%} = \frac{S2}{S1} \text{ X } 100$$

Where:
S1 = Weight of silage fed in evening,
S2 = Weight of leftover silage in morning.

The data were analyzed using SPSS 16.0. It includes descriptive,ANOVA andpaired sample *t*-tests and Microsoft Excel2010 for graph and tables.

3 Results and Discussion

i) Plant height, Number of leaf and stem diameter

Therewas significant difference on plant height amongfour maize varieties, $p < .05$, (Table 1). The tallest height was TD (134.28 cm) and shortest GLW (74.92 cm). The study suggests that among four maize varietiesTD was taller but not significantly different with Arun-2. This could be due to their early maturating ability. At 70days, tassel and silk gets fully emerged in both TD and A-2, whereas GLW and YR were under vegetative stage. Similarly, Hoopen and Maiga (2012) argued, even at same location with identical temperature certain maize varieties mature earlier due to their early growth pattern.

There was significant difference on number of leaves borne among four maize varieties, $p < .05$. The highest was in YR (11.00 ± .00) and lowest TD (9.00 ± .00). The result was similar to the findings of Ibrahim *et al.* (2006) and Khaliq *et al.* (2012) who also reported differences in numbers of leaves among maize varieties. Further, Tripathi *et al.*(2011) and Islam *et al.* (2010) argued that the general growth and development of all maize varieties will be same but the total number of leaves will vary according to genotype, seasons, time of planting and location. The stem diameter varied significantly among four maize varieties. The highest stem diameter was

observed in YR (2.30 ± .18) and lowest in TD (1.55 ± .11). The resultsshowed that stem diameter was larger in improve and late maturing variety and it was close agreement with the results obtained by Karasahim (2013) who also reported similar stem diameter from two different hybried maize varieties. The significant differences could be due to genetic potential.

Table 1. Mean comparison of plant height, number of leaves and stem diameter.

Paramteters	Maize varieties			
	TD	GLW	YR	A-2
Plant height (cm)	134.28 ± 17.90^{a}	74.92 ± 12.13^{b}	88.42 ± 14.76^{b}	109.94 ± 13.46^{ab}
Number of leaves	$9.00 \pm .00^{b}$	$9.67 \pm .58^{b}$	$11.00 \pm .00^{a}$	$9.67 \pm .58^{b}$
Stem Diameter (cm)	$1.55 \pm .11^{b}$	$2.03 \pm .12^{a}$	$2.30 \pm .18^{a}$	$1.94 \pm .06^{a}$

Means within the rows with different superscripts differ significantly ($p< .05$)

Biomass yield

The biomass yield in respective to GSF, GLF and TGFY were shown in table 2. There was no significant difference in GSF and TGFY among four maize varieties $p> .05$,(Table 2). However, data showed GSF yield was higher in YR (3.90 ± 1.80) and lowest in TD (2.95 ± 1.10). Similarly, the TGFY produced by each maize variety were within the range of 16.24 - 26.15 MT/Ac, which is in agreement with the findings of Ahmad *et al.* (2012), Islam *et al.* (2010), Awan *et al.* (2001) and Pandy & Roy (2011) who also reported simialr TGFY in maize fodder.The non-significant could be could be due to differences in plant height, number of leaves and stem diameter.

However, GLF yield among four maize varieties differed significantly, $p< .05$. The highest was in YR(2.60 ± .80) and lowest in TD (1.10 ± .37). These difference in GLF yield is attributed to number of leaves borne among maize varieties. Ahmad *et al*(2012) and Islam *et al*(2010)also argued that Biomass yield is an effect of genetic as well as environmental factors which plays a vital role in plant growth and development. It also depends on factors such as plant height, number of leaves, leaf area and on stem circumference.

Table 2. Mean comparison of stem and leaf biomass among Maize varieties in kg/m^2

Paramteters	Maize varieties			
	TD	GLW	YR	A-2
GSF (kg)	2.95 ± 1.10^{a}	3.81 ± 1.43^{a}	3.90 ± 1.80^{a}	3.73 ± 1.82^{a}
GLF (kg)	$1.10 \pm .37^{a}$	$2.20 \pm .80^{b}$	$2.60 \pm .80^{b}$	$1.95 \pm .75^{ab}$
TGFY (kg)	$4.01 \pm .1.33^{a}$	$6.00 \pm .2.12^{a}$	6.50 ± 2.50^{a}	5.70 ± 1.80^{a}

Means within the rows with different superscripts differ significantly ($p< .05$)

ii) Chemical composition of fresh maize fodder

Dry matter, Crude Protein and Ash

There was significant difference in DM content among four maize varieties, $p < .05$, (Table 3).The DM content of fresh maize fodder was highest in TD (30.99 ± 1.00) and lowest in GLW (19.39 ± 1.98). The results indicated, there was association between DM content and crop maturity and therefore DM content was seen to be higherin TD. *Abid et al.* (2001) also reported similar views and findings on DM conent of maize fodder. Besides, the results were also in line with findings of Mussadiq (2012) who reported significant and positive correlation between the DM content and plant maturity. The results were also in line with findings of Islam *et al.* (2010) andNaikwade *et al.* (2012) who reported DM content within the range of current study. However, Islam *et al.* (2010) argued that the dry matter content is an indicator of fodder quality and it can vary according to season, climatic conditions, temperature, soil topography, variety and stage of crop maturity.

Similarly, there was significant difference on CP content among maize varieties, $p < .05$. The CP was highest in YR (5.69 %) followed by GLW (4.53), A-2 (4.43) and TD (3.99). The CP content of maize was seen to be highest when plants were at vegetative stage and in late maturing varieties contains highest. The finding was in line with the findings of Abid *et al.* (2001) who also reported highest CP in maize fodder at vegetative stage. Liu *et al.* (2011) also found that CP content of local maize varieties was within the range of this study. However, the CP content was lower when compared to ideal range but this could be explained by the views of Omoregie (1991) who argued that CP level of maize varies according to seasons of cultivation and it will be higher during wet season when compared to dry seasons. Therefore, low CP content in current study may be because of the cultivation during winter season. In case of Ash, there was no significant difference among the four maize varieties, $p > .05$. However, GLW had maximum ash (11.13 ± 2.22 %) when compared to A-2 (10.67 ± .46), YR (10.45 ± .92) and TD (10.28 ± 1.36). The result of this study was in accordance with the findings of Rahman *et al.,* (2008)who also reported ash content similar to this findings from maize fodder using different dosages of cattle slurry. Further, the study conducted by Islam*et al.*(2010)also rported similar ash content from maize fodder production experiment using different levels of biogas slurry.

Table 3. Mean comparison of nutrients among Maize varieties

Paramteters	Maize varieties			
	TD	GLW	YR	A-2
DM %	30.98 ± 1.00^{a}	19.39 ± 1.98^{b}	21.72 ± 2.58^{b}	27.64 ± 3.02^{a}
CP %	$4.00 \pm .71^{b}$	$4.53 \pm .64^{b}$	$5.54 \pm .29^{a}$	$4.43 \pm .02^{ba}$
Ash %	10.28 ± 1.36^{a}	11.13 ± 2.22^{a}	$10.45 \pm .92^{a}$	$10.67 \pm .46^{a}$

Means within the rows with different superscripts differ significantly ($p < .05$)

iii) Silage

Physical quality of silage

The color of silage was pale–yellow, bright greenish yellow, sweet-sour pleasantsmell, sour taste and free of molds. When felt, it was soft and moist and when tightly held in hands the silage formed ball mass for few minutes. The result showed that there was no difference on physical properties of silage among four maize varieties. The Silage quality was good which could be due to complete compaction by electric vacuum suction force and by the stable anaerobic fermentation in the plastic bags. The findings were similar to the findings of Hamza *et al.* (2009) who also reported similar physical qualities from the evaulated whole corn silage and from two kinds of palm residues silage. On contray, Lemcke and Cameron(2003) argued that the quality of silage is determined by the factor such as material used, treatment of cut materials before ensiling and storage condition. The good silage is the one obtained from well compacted and effective sealing of stored materials. It will be always moist but not wet, has a clean sweet acid smell which enhances palatability.

pH of Silage

The pH varied significantly among the silage of maize varieties. The highest pH was in GLW (3.81) followed by A-2 (3.75), YR (3.56) and TD (3.48), (Figure 1). The possible factor for high and low pH could be due to plant maturity and sugar content in the plants which favors proper fermentation leading to low pH (acidic). The results was in line with the findings of Stekar *et al.* (1991) who also reported similar pH range from seven ensiled hybrid maize varieties. Further, results were also supported by the findings of Juracek *et al.*(2012) who had recorded similar findings from different maize silage. Besides, Heinrichs and Virginia(1914) explained that ensiling fodder at right pH is very important and it helps to determine the type of fermentation that has taken in ensiled fodder and helps to evaulate the fodder quality. Thus, it can be concluded that PPBS can maintain ideal pH and can produce good quality silage for Dairy cows.

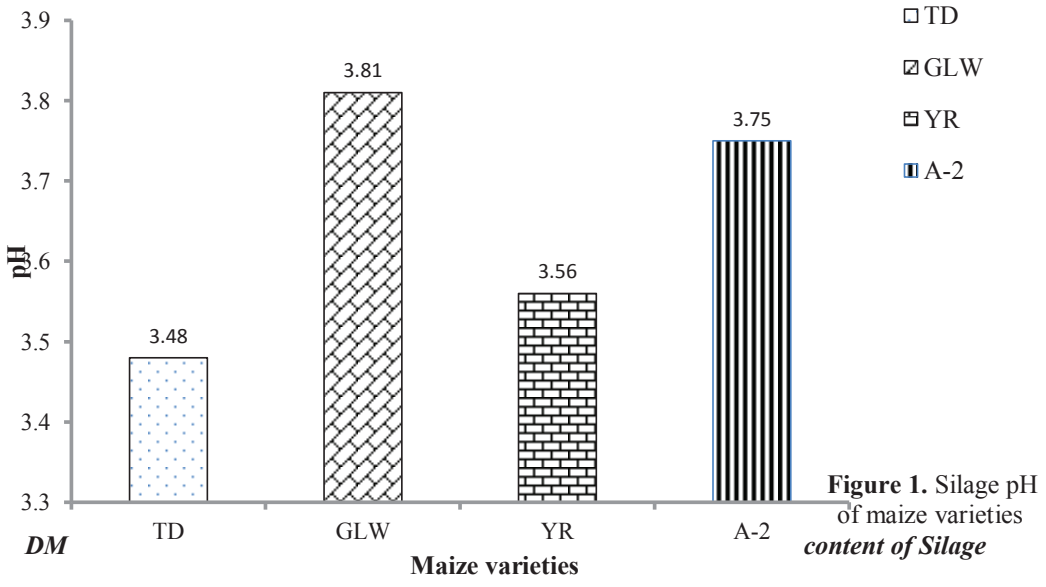

Figure 1. Silage pH of maize varieties

DM content of Silage

There was significant difference on DM content of silage among four maize varieties, $p < .05$. The highest was in TD (29.37 ± 1.23)and lowest was in GLW (17.90 ± 2.30), (Table 4). Higher DM content in TD could be due to plant maturity as TD was seen to mature earlier than other varieties. Therefore, the results of current study was similar to Abid *et al.* (2001) who explained that DM content is related with plant maturity. However, the DM content was low when compared to other reports but this could be explained by the views of (Chase, 2013) who argued thatCompared to matured corn silage immature corn silage will usually vary in both nutrient composition and dry matter content.

Ash conten of Silage

There was no significant differenceon Ash content among four maize varieties, $p > .05$. The highest Ash content was seen in A-2 (10.44 ± .38) and lowest in TD (9.10 ± 1.36), (Table 4). However, the average range of Ash % recorded from this study was slightly higher than that of different reports but agrees with the views of Hoffman (2005) who argued that the Ash % of maize silage can vary up to 10 % at the maximum depending on location, soil, weather and the equipment used while harvesting and sample preparation. Therefore, the higher ash % could be due to these different factors.

CP contentof silage

There was no significant difference on CP content among the four maize varieties, $p> .05$. This could be due to microbial proteins developed during the process of fermention. The result of findings was similar to the findings of Subramani and Loper (2011) who also reported similar CP from hybrid maize silage. However, when data were compared among four varieties the CP content was recorded slightly higher in YR (7.74 ± .99) followed by GLW (6.89 ± .82), A-2 (5.73 ± 1.25) and TD (5.60 ± .70), (Table 4). These results indicated, CP content of silage was slightly higher in late maturing variety than early maturing variety. This could be due to its highest CP content before ensilage and being at vegetative stage when crops are harvested. As, Chase(2013) reported that the immature corn silage contain higher CP when compared to normal silage. The result was also similar to Wang *et al.*(2010) who also reported CP content within the range of current study.

Table 4.Mean comparison of silage nutrients among Maize varieties

Paramteters	Maize varieties			
	TD	GLW	YR	A-2
DM %	29.37 ± 1.23[a]	17.90 ± 2.30[b]	19.63 ± 3.12[b]	26.35 ± 2.18[a]
CP %	5.60 ± .70[a]	6.89 ± .82[a]	7.74 ± .99[a]	5.73 ± 1.25[a]
Ash %	9.10 ± 1.36[a]	10.43 ± .75[a]	9.11 ± 1.01[a]	10.44 ± .38[a]

Means within the rows with different superscripts differ significantly ($p< .05$)

iv) Nutrients comparison before and after ensilage

DM content before and after Ensilage

There was significant different in DM content between fresh fodder and silage ($p< .05$). The DM content found in fresh fodder was 24.93 ± 5.19 % and after making silge was 23.32 ± 5.30 %. The results showed, there was decresed in DM content of fresh green maize fodder after making silage. The reasons could be due to acting of microbes on organic matter present in the plant and by processes of fermentation. The findings were also similar to Rahman and Aneela (2004) also reported decreased in DM content of fresh maize fodder(local variety) after making silage. Turk *et al.* (2012) also recorded similar results on sole maize fodder.

CP content before and after Ensilage

The CP content of fresh green fodder was (5.62 ± .72) and silage was (6.49 ± 1.23)varied significantly($p< .05$), (Table 5.). The results indicated, there was increased in CP content of fresh green fodder after making silage. This increased in CP content could be due to the effect of microbial proteins present in silage. The results of this study was similar to the findings of Rahman and Aneela (2004) who also recorded high CP content in maize fodder after making silage. Therefore, maize fodder feeding as silage has higher protein value than feeding fresh green fodder.

Table 5. Paired sample *t*-tests on CP and DM content before and after ensiling

Source	*Mean*	*Std. deviation*	*df*	*t value*	*p value*
DM % before ensiling	24.50	5.24	11	7.99	.000*
DM % after ensiling	23.32	5.30	11		
CP before ensiling	5.62	.72	11	-7.71	.000*
CP after ensiling	6.48	1.23	11		

*Significant at the .05 levels

v) Palatability test

There was preferential act demonstrated by each cows against each variety of maize silage. The animals accepted the silage and there was no wastage. The reason may be due to good quality silage produced from PPBS with fresh green aroma, taste and smell. Besides, PPBS allows silage to be stored without exposure to the air that helped maintaining quality and no deterioration, and therefore the acceptability of silage by animals was very good. Thus, it can be concluded that all four maize varieties in the form of PPBS when feed to cows as silage has high palatability.

4 Conclusion and Recommendation

The study concluded that the CP content, number of leaf, stem diameter and biomass were highly significant with late maturing variety (YR) while DM content and plant height among maize varieties were highly associated with early maturing variety (TD). However, when biomass and DM yield per acre were compared YR was found to be highest in both biomass and DM yield. Besides, Silage DM content was highly related in early maturing variety when compared to late maturing variety but no significant difference in CP, Ash, silage quality and palatability test.

Therefore, the overall results of the study suggest that variety YR was the best to adopt as winter fodder crops for dairy production since it revealed highest in maximum parameters, Biomass and DM yield per Acre. Besides, PPBS technology can be applied successfully under maize growing areas. However, due to lack of laboratory facilities the complete feed nutrient analysis were not done and further study may be continued in future.

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Pricing Assessment of Domestic Milk and Milk Products in Bhutan

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Abstract

The Bhutanese dairy farmers had produced annual domestic milk and milk products worth about Nu. 1816.66 million in 2012. More than 90% of total milk produced annually are processed and consumed in the form of milk products mainly butter and cottage cheese. There are no standards of milk pricing and it was marketed on volume and weight basis with a little or no emphasis on compositional quality. This study undertaken to document the pricing of domestic milk and milk products showed that prices of milk and dairy products differ from one Agro-Ecological Zone (AEZ) to another. The highest price of milk and milk products was observed at the higher altitude AEZs. In average , milk producer receives farm gate price of Nu. 26.83/kg of raw fresh milk and the same were sold at Nu. 33/kg in the markets. The skimmed milk was sold at Nu. 24.12/kg in the markets. The average price of butter was Nu. 285.6/kg; cottage cheese was Nu. 270/kg; hard cheese (chugo) was Nu. 896.20/kg and fermented cheese (yetpa) was Nu. 383.33/kg. Considering huge potential for the development of dairy industry , a need to adopt a standard pricing scheme to ensure just payment to milk producers, is recommended.

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Keywords: *pricing, domestic milk and milk products, farm gate price, AEZ*

1 Introduction

Milk in Bhutan is produced by cows, yaks and buffaloes. Cow's milk dominates the total milk production followed by the yak and buffalo. Milk is the major dietary source of protein for the Bhutanese people. Milk produced is mostly consumed in the form of cottage cheese and butter. Other milk products consumed are yogurt, skim milk, ice cream, Gouda cheese, hard cheese (*chugo*), fermented cheese (*yetpa*), paneer, philu and telep.

At present milk is seldom consumed in the form of fresh raw milk. However, the consumption of fresh raw milk is expected to grow with ever increasing population and increasing awareness on importance of consuming dairy products in relation to nutritional intake and human health. Consequently, the milk producers will have to increase milk

2.2 Limitation of the study

Most of the data were gathered from accessible areas, i.e. towns, MPUs, MCCs, individual milk producers from peri-urban areas, members of farmers' groups, middlemen, EAs, DLOs, Sunday markets, agriculture sale counters and vendors along the highways. Thus, probably the rural milk pricing might have been overlooked in this study.

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Milk components particularly fat and solid not fat (SNF) plays important role in pricing of fresh raw milk. For instance, pro-rata fat basis and either % fat and % SNF alone or combination of two components, i.e., two-Axis basis are adopted as milk payment scheme in other countries. Such system assures minimum pay prices for the milk and milk components according to end products produced. However, in Bhutan there are no legal standard for pricing of domestic milk. As such, market forces determined the milk prices, leading to unfair milk payment particularly to the milk producers.

The pricing of domestic milk and milk products are not documented in the country, so far. Therefore the study was undertaken to document and understand the packing, utilization and pricing of milk and milk products

2 Materials and Method

2.1 Data collection

The data were gathered from different locations across twenty dzongkhags (Bumthang, Paro, Haa, Thimphu, Trongsa, Zhemgang, Sarpang, Tsirang, Mongar, Trashigang, Samdrup Jongkhar, Pemagatshel, Wangdue Phodrang, Punakha, Samtse, Chukha Lhuentse, Gasa, Dagana and Tashiyangtse) personally through informal discussions with shopkeepers in the towns/vegetable markets or sale counters, vendors along the highways, individual milk producers, middlemen or milk hauler, herders, extension agents (EAs), Dzongkhag Livestock Officers (DLOs), members of the farmers' groups and technicians/individual working in milk processing units (MPUs) and milk collection centres (MCCs) using a simple checklists through the month of September to December 2012. The locations mapped using GPS, model etrex 30.from where data were gathered were also

The cottage cheese (*datshi*) ball ranging from 3 to 22 in numbers were weighed using spring balance (d=10g) and thereafter, an average weight of cottage cheese/ball was determined. Simultaneously, the farm gate and market price of fresh raw milk, and the prices of major milk products such as cottage cheese, butter, skimmed milk, hard cheese (*chugo*), and other minor milk products, i.e. ghee, ice cream, yoghurt, Gouda cheese, fermented cheese (*yetpa*) were gathered.

2.2 Limitation of the study

Most of the data were gathered from accessible areas, i.e. towns, MPUs, MCCs, individual milk producers from peri-urban areas, members of farmers' groups, middlemen, EAs, DLOs, Sunday markets, agriculture sale counters and vendors along the highways. Thus, probably the rural milk pricing might have been overlooked in this study.

2.3 Data analysis

The data gathered were entered in the spreadsheet and analyzed descriptively using Microsoft Excel 2007.

3 Results and Discussion

3.1 Packaging, storage and utilization

In general, fresh raw milk produced are found stored in containers, i.e. plastic buckets, jerry-can, chillers, aluminum can and plastic (PET) bottles of various volume. In the past, butter and cottage cheese were wrapped in tree leaves and now they are found packed in plastics. Butter produced by the farmers groups at MPUs level are packed in butter papers. In most MPUs and MCCs butter and cottage cheese are stored in deep freezers or in cool boxes, whereas at the village level it is usually kept in open cool areas.

Cow milk dominates the milk production followed by yaks and buffaloes respectively. Of the total milk produced, more than 90% of milk are processed into milk products mainly cottage cheese and butter. The remaining are either consumed as raw fresh milk or in the form of processed minor milk products, i.e. yoghurt, skimmed milk, fermented cheese (*yetpa*), ice cream, philu, hard cheese (*chugo*), soft and hard cheese, etc.

3.2 Markets for domestic milk and milk products

There is a niche market for milk and milk products in Bhutan. Urban dwellers are the major consumers of domestic milk and milk products. Thus the milk producers or the middlemen always bring their products to weekend markets to sell. Milk and milk products produced are marketed through established MPUs, MCCs and sale counters. It is also marketed along the highways to travellers.

Most milk and milk products produced are consumed within the dzongkhag, with exception to summer months when there are surplus milk production. The surplus milk products are transported to other dzongkhags, either by milk producer themselves or by middlemen to sell. Thimphu is considered as an ultimate market for any surplus milk products produced across the country. For instance, milk products are transported to Thimphu to sell from various dzongkhags, i.e. Trashigang, Wangdue Phodrang, Haa, Tsirang, Paro, Bumthang and Punakha.

3.2.1 Pricing of domestic milk and milk products

i) Liquid based milk products

Figure 1 shows an average price of liquid based milk products consumed in Bhutan. Raw milk and skimmed milk dominate the markets amongst other liquid milk products. It was mostly sold through middlemen or from MPUs or MCCs after the delivery of milk by

individual producers. Milk pricing was generally based on volume (litre) or weight (kilogram) basis with a little or no emphasis on the compositional quality.

Two milk prices were observed in most dzongkhags, i.e. a farm gate and market price. The milk producers in average get a farm gate price of Nu.26.83/kg (n=40) of fresh raw milk. The middlemen then sell it to urban dwellers at Nu. 33/Kg (n=38) in the markets, earning a gross profit margin of Nu.6/Kg of milk with little investments on transports and labor.

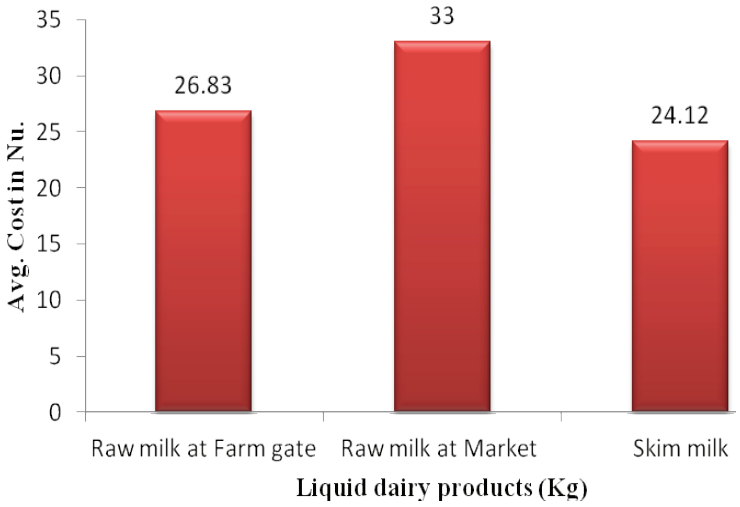

Figure 1. Average price (Nu.) of liquid milk products in Bhutan

The skimmed milk fetches an average price of Nu. 24.12/kg (n=64), almost equivalent to farm gate price of fresh raw milk. The skimmed milk was generally marketed on volume basis (PET bottle) and occasionally on weight basis along the highways, weekend markets, MPUs and hotels.

Others liquid dairy products consumed were butter milk, whey and yoghurt. The average price of butter milk and yoghurt was Nu. 16.67/Kg (n=2) and 125/kg (n=1), respectively. Whey produced at individual household level was either consumed by human or fed to animals, whereas the whey produced in MPUs are mostly discarded.

ii) SNF based Products

Figure 2 shows average prices of different SNF based domestic products consumed. The domestic SNF based products widely consumed were cottage cheese (*datshi*), hard cheese (*chugo*) and fermented cheese (*yetpa*).

The cottage cheeses are usually marketed in ball of different sizes, shapes and weight. The cottage cheese in average weighs 99.44 gm and priced Nu. 24.38 per ball (n=67). The average market prices of hard cheese (*chugo)* and fermented cheese (*yetpa)* were Nu. 896.20/Kg (n=10) and 383.33/kg (n=3), respectively (Figure 2). Hard cheese (chugo) was

mostly produced from yaks' milk by herders at high altitude areas; however, now chugos are also made from cows' milk and it is getting popular particularly with the farmers' of Bumthang dzongkhag.

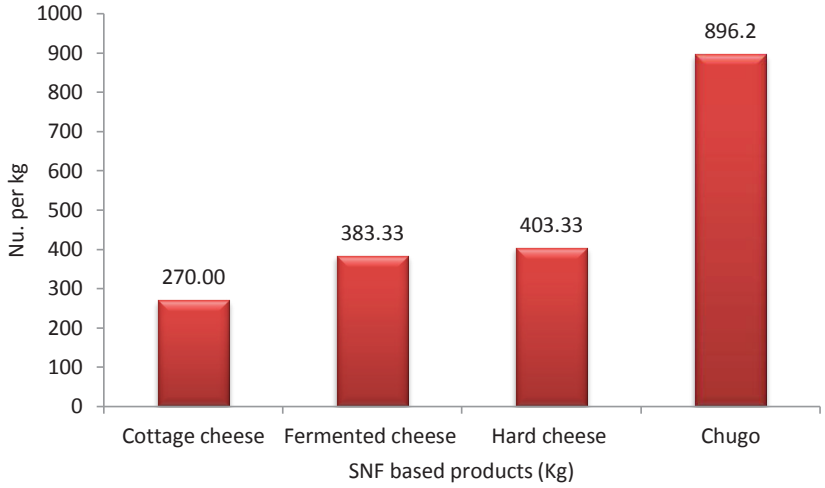

Figure 2. Average cost (Nu) of SNF based domestic milk products

This study found that the average price of cottage cheese in Bhutan was Nu. 270/kg. The price of cottage cheese was comparatively low as compared to the imported AMUL cheese (Nu. 360/kg). However, the price of cottage cheese was found much higher in some dzongkhags i.e., Thimphu, Haa, Tshirang, Punakha, Wangdue Phodrang and Samdrup Jongkhar as compared to the price of AMUL cheese. The smaller size of cottage cheese with higher prices/ball, coupled by high demand for the cottage cheese in the markets with low supply could have attributed to higher price.

Other SNF based domestic milk products consumed were Gouda cheese, soft cheese, telep, and paneer. These new SNF based products are getting popular among the rising middle class of Bhutanese populace.

iii) Fat based products

The average prices for the domestically consumed fat based milk products are illustrated in Figure 3. Butter dominates the choice of consumers for the fat based milk products followed by ghee and cream. Ghee is mostly consumed in southern districts and creams produced by MPUs are sold to high-end international hotels based in Bhutan, i.e. Aman Kora, Bhutan Tourism Corporation Ltd (BTCL) and Uma, for the preparation of desserts as reported.

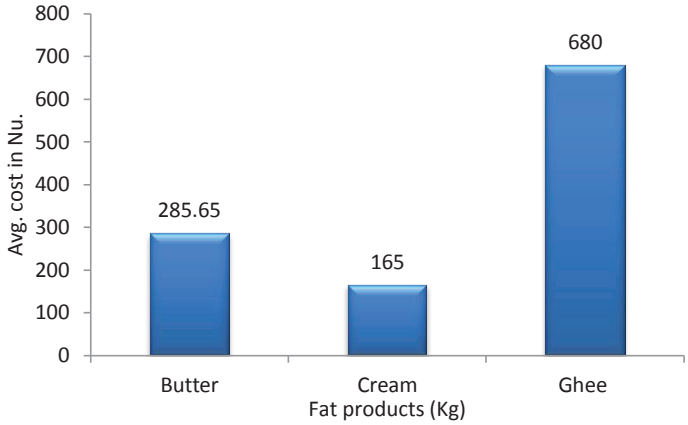

Figure 3. Average price (Nu) of fat based milk products

Butter are marketed in kilogram and phog basis (1phog = 1.67 Kg). Among the fat products, the average price for the ghee was observed highest at Nu.680/kg (n=2) followed by butter and then cream at Nu. 285.65/kg (n=65) and Nu. 165/Kg (n=2), respectively. Other domestically fat based products, i.e. Ice cream and philu are produced consumed in small scale at household level.

3.3 Pricing of major milk production by different AEZs

The average prices of major liquid milk products were compared based on three defined agro-ecological zones (AEZs); <1200 masl as low altitude areas, between 1201 to 1800 masl as mid altitude areas and >1800 masl as high altitude areas for this study. Figure 4 and 5 illustrates pricing of milk and major milk products for the three different AEZs as designated above. The average prices of raw fresh milk at market and farm gate were Nu. 37.36/Kg, 31.67/kg, 30.20/kg and 26.6/kg, 25.82/kg, 30.23/kg for the low, mid and high altitude areas, respectively.

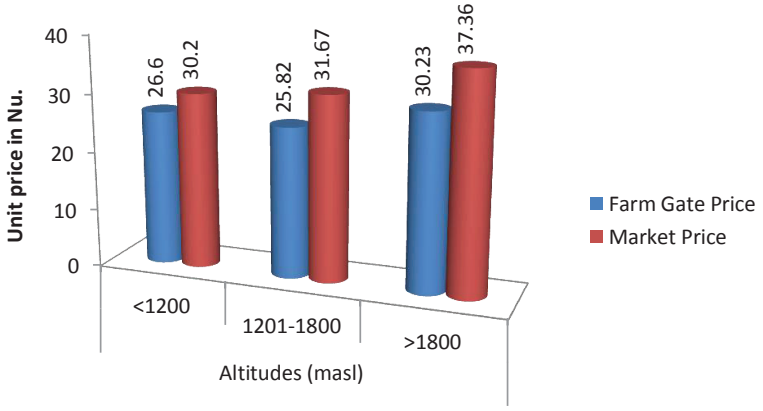

Figure 4. Average farm gate and market price of fresh raw milk by different altitudes

The average prices of domestic butter and cottage cheese were Nu. 292.86/kg, Nu. 269.06/kg, Nu.303.65/kg and Nu. 235.21/kg, Nu. 225.65/kg, Nu. 327.21/kg for the low, mid and high altitude areas, respectively.

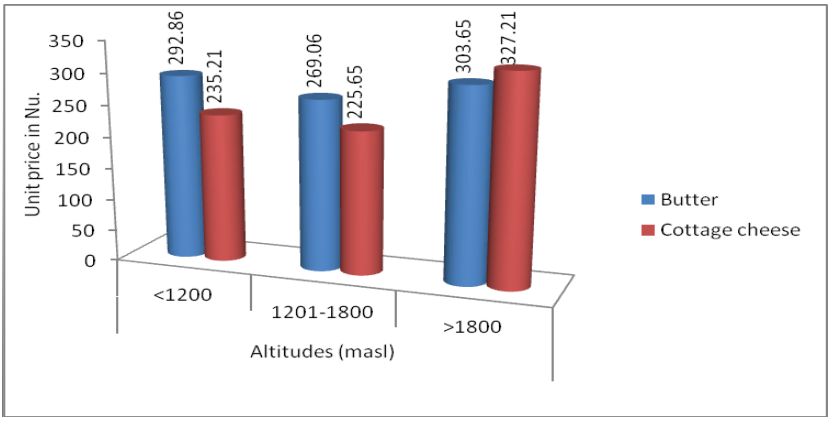

Figure 5. Average price of butter and cottage cheese by areas defined based on altitudes

The average prices of milk and milk products were observed highest at the higher altitude areas (Figure 4&5). The price differences for different AEZs could be attributed to high concentration of urban population at higher altitude areas particularly for dzongkhags like Thimphu, Paro and Bumthang, which in turn demand more milk and milk products resulting to higher price. It could also be attributed to a higher inputs cost required at higher altitude areas for the production of equivalent unit of milk and milk products as compared to lower altitude areas.

3.4 Milk pricing in Bhutan

Different milk pricing schemes are adopted in different countries. Some of the pricing schemes are pricing on pro-rata fat basis, two-Axis basis and equivalent fat unit basis. However, in Bhutan none of these pricing schemes were adopted nor do we have legal standard milk pricing scheme in place. Thus pricing of milk and milk products is mostly driven by the market force.

The formulas adopted for the milk pricing are:

1. Pro-rata fat basis: **Milk price = litres of milk x (fat % x fat price)/100**
2. Equivalent-Fat-Units (e.f.u) basis : **Milk price = (e.f.u x rate per e.f.u)**
3. Two-Axis basis:

Milk price = litres of milk x {(fat % x fat price)/100 + (SNF % x SNF price)/100}

Table 1 below shows derived milk price/kg of fresh raw milk for twenty dzongkhags using two pricing schemes, i.e. two-axis pricing schemes and pro-rata fat basis, assuming that the milk in Bhutan contains 4 & 5% fat and 8.25% SNF in average.

Table 1 Milk price (Nu/kg) derived based on different pricing schemes for twenty dzongkhags

Dzongkhag	Existing milk price (Nu./Kg)	Two-axis basis		Pro-rata fat basis	
		4% Fat	5% Fat	4% Fat	5% Fat
Bumthang	25.67	27.87	30.73	11.43	14.29
Monggar	26.25	25.43	27.58	8.60	10.75
Trashigang	22	27.18	29.70	10.06	12.57
Samdrup Jongkhar	19.33	39.22	41.28	8.27	10.33
Sarpang	31.67	31.89	35.01	12.50	15.63
Tshirang	23.13	37.02	40.29	13.10	16.37
Punakha	30	45.49	48.49	12.00	15.00
Wangdue Phodrang	40	46.70	49.70	12.00	15.00
Paro	27.50	31.56	34.81	13.00	16.25
Trongsa	24.17	24.11	26.76	10.60	13.25
Haa	27	41.49	44.79	13.20	16.50
Samtse	20	19.51	21.81	9.20	11.50
Thimphu	29.36	49.67	53.07	13.60	17.00
Lhuentse	35	27.98	31.48	14.00	17.50
Dagana	31	21.34	23.84	10.00	12.50
Tashiyangtse	22.5	19.71	22.06	9.40	11.75
Gasa	35.00	32.63	35.63	12.00	15.00
Zhemgang	20	29.33	32.33	12.00	15.00
Pemagatshel	20	20.23	22.68	9.80	12.25
Chukha	26.99	31.21	34.48	13.07	16.33
Total Average	**26.83**	**31.48**	**34.33**	**11.39**	**14.24**

Adopting two-axis pricing scheme in Bhutan the milk producers should get minimum average price of Nu. 31.48/kg of raw fresh milk containing average 4 % fat content and 8.25% SNF. The average fat and SNF price of Nu. 285.65/kg and Nu. 270/kg, respectively derived from this study was used. However, present milk price of Nu. 26.83/kg of fresh raw milk received by the milk producers was observed comparatively low. It will require further assessment of prices for milk and milk products prior to the adoption of any pricing scheme for the dzongkhags with unreasonably low and higher milk prices derived above (Table 1). The average milk price determined using pro-rata fat basis pricing scheme was much lower than the existing milk price for all dzongkhags. Thus the pro-rata fat basis pricing scheme will not be applicable or acceptable to milk producers in Bhutanese. There is an urgent need to adopt legal standard milk pricing schemes to ensure fair milk payment to milk producers in Bhutan.

3.5 Estimated annual monetary valuation of domestic milk and milk product

The dairy farmers in year 2012 produced estimated annual domestic milk and milk products worth about Nu. 1816.66 million. It was estimated from annual milk and milk products production data (Livestock statistics, 2012) using prices of milk and milk products generated in this study. The details of monetary valuation are presented below in Table 2.

Table 2 Monetary valuation of milk and major milk products

Products	Annual Production (mt)	Estimated value In Nu. (million)
Milk	29624.99	184.91
Butter	1207.48	344.91
Cottage cheese	2300.44	621.12
Chugo	742.81	665.72
Total Nu.		**1816.66**

The monetary value of domestic milk and milk products will be much higher, if annual production of other minor milk products, i.e. Gouda cheese, yoghurt, fermented cheese (*yetpa)*, ice cream, paneer etc., were accounted. However, it couldn't be accounted due to lack of record or information on annual production data of other minor domestic milk products produced.

4 Conclusion

Milk in Bhutan is produced by cows, yaks and buffaloes. More than 90 % of domestically produced milk are processed and consumed in the form of butter and cottage cheese. The pricing of domestic milk and milk products vary from individual to individual and place to place. The average farm gate price of raw milk was Nu.26.83/kg and market price was Nu. 33/Kg. The average price of butter was Nu. 285.6/kg; cottage cheese was Nu. 270/kg; hard cheese (chugo) was Nu. 896.20/kg and fermented cheese (yetpa) was Nu. 383.33/kg in Bhutan. The prices of milk and milk products differ by AEZs. Increasing trend in the prices of milk and milk products was observed as you move up to the higher AEZs region.

There are no legal standard milk payment schemes in place. Milk pricing was generally based on volume or weight with a little or no emphasis on the compositional quality. Thus, the pricing of milk and milk products were mainly determined by market forces. As result, in Bhutan the milk producers have had not received fair milk payment, so far. In order to ensure fair milk payment to milk producers based on the compositional quality, it warrants adoption of legal standard milk pricing schemes. The two-Axis pricing scheme will be appropriate for the country as majority of milk products consumed are fat and SNF based, besides fat and SNF are equally valued in Bhutan. An adoption of fat % or the pro-rata fat based pricing will not be acceptable to the milk producers in the country.

Consumption of domestic milk and milk products are expected to grow with the increasing population and increasing disposal income in Bhutan. An increasing awareness on importance of nutritional intake and public health concern will ultimately demand for more quality and superior milk products. In order to produce abundant, hygienic and quality milk the government must frame a definite enabling policy environment with sufficient supports on packaging and storing facilities to increase shelf life of milk products. The usage of plastics for packaging of milk products across the country is increasing, which should be of concern to the government keeping in line with maintaining of clean and green environment or plastic free- Bhutan.

The government must also initiate or institute standardization of milk and milk products to ensure public health safety and for the delivery of standard quality products to consumers across the country.

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Assessment of Nutrient Content and Biomass Yield of Oat Cultivated Using Different Manure

Jigme Chophel[1] and Phub Dorji

Abstract

A study on oat cultivation applying different manures either alone or in combination was conducted with the objective to assess the nutrient content (Dry matter, Ash, Crude Protein) and herbage yield (Height and Biomass). Four treatments consisting of cow dung (CD), poultry litter (PL), poultry litter combined with cow dung (PLCD) and control was assigned to four plots measuring 2 x 2m with four replicates in a completely randomized design (CRD). The quantity of manures applied were 6.8 kg, 2.6 kg, and 4.08: 1.04 kg for CD, PL and PLCD respectively while control did not receive any manure. PL promoted the maximum height and BM yield in both the cuts followed by PLCD, CD and control. Although, PL performed the best in terms of plant height and BM yield, the performance of PL was found to be lower in terms of DM, P and ash.

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Keywords: **:** Fodder oat of Bhutan, Manure, Nutrient content, Oat yield

1 Introduction

Dairying is a vital component of the global food system especially with the role it plays in sustainable rural livelihood(International Dairy Federation, 2013)**.**Livestock are an integral part of the Bhutanese farming system, the value of which extends beyond the immediate benefits of milk, meat, and fiber production and of late has transcended as an important source of cash for the rural poor (Phangchung *et al*., 2001) contributing about 4.3% of the country's GDP (Department of Livestock (DOL), 2013).

However, the major constraint in dairy production has been the inadequate feeding during long dry periods, low availability and poor quality feeds which are almost devoid of nutrients important for increased rumen and microbial fermentation necessary for maintaining production (Davendra, 2001; Lanyasunya*et al*., 2006).In Bhutan, open grazing continues to be the main source of fodder for the majority of livestock since both improved pastures and stall feeding remain limited (Phanchung*et al*., 2001)and contributes over 70% of the total feed requirements (Roder*et al*., 2001).In the absence of a reliable winter fodder, it is very important that we look into solving fodder shortages through introduction of promising fodder species with the required nutrient as well as yield.

Oats (*Avena sativa*) are an important winter fodder resources which was introduced in Bhutan either from India or Japan in the early seventies (Gyaltsen *et al.,* 2002). It can be easily cultivated in areas lying at a height of 1000 to 2700 meters above sea level (masl), with temperature range of 4 to 20 ℃ and a rainfall of 737.18 mm(Wangchuk *et al*., 2008). Oats can be best grown in loam to clay loam soils with adequate drainage while satisfactory yields can be obtained from

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heavy or light soils (Panday & Roy, 2011). Different cultivation methods are practiced depending on the variety and agro ecological location (Panday & Roy, 2011). Oat cultivation in Bhutanese condition, Wangchuk *et al* (2008) observes is similar to wheat. The recommended seed rate is 50 kg per acre while fertilization is done at sowing time followed by top dressing after every cut. Compared to wheat and barley, Dost (1995) claims that oats provide multiple cuts, tiller profusely, yield more and are of higher nutritional value. Oats can provide green fodder after 60-70 days as an emergency feed to fight over the scarcity period and after 90-100 days to obtain larger quantity of fodder. It is high in TDN, protein, fat, vitamin B1 and minerals such as phosphorus and iron (Iqbal *et al.*, 2009). Shingoethe (1982) maintains that feeding high protein oats can eliminate the need for supplementary protein diets such as corn or soya bean.

While there is limited research works on oat cultivated using mixture of poultry litter and cow dung, available literature indicate the usefulness of livestock manure especially in combinations. This study was therefore conducted to assess the growth, yield and nutrient content of oat in different stages of cuts using different manures either separately or in combination.

2 Materials and Methods

2.1 Materials

The oat variety used for this experiment was Fodder Oat of Bhutan (FOB). The seeds were collected from Livestock Extension Center Lingmukha, Punakha, produced under farmers' management condition. Cow dung (Solid manure) was collected from the colleges' dairy farm and poultry litter from a layer farm in the same area. The land was thoroughly tilled using a power tiller.

The experiment was conducted at the agricultural farm of the CNR, Lobesa. The site agro ecologically falls under dry subtropical zone, lying at an elevation of 1440 meters above sea level, and receiving a mean annual rainfall of 830 mm with temperature range of 13 to 35°C according to the meteorological records maintained by the RNR RDC, Bajo, Wangdi Phodrang. The status of the soil of the experimental site was analyzed by the CNR laboratory for chemical composition which indicated a reddish clay soil which is slightly acidic with low nitrogen. In a report prepared by Dorji (2008) the nutrient status of the soils of Bhutan were revealed to be generally poor. The major concerns according to the analytical tests conducted are rather low pH and nitrogen content, phosphate status and imbalanced base nutrients. The findings also indicated soil nutrients to be favorable in warm temperate and dry subtropical soils than wet subtropical soils.

2.1 Method

i) Seed bed preparation and Experimental Design

Sixteen beds were prepared after thoroughly ploughing the land with a power tiller. Four treatments consisting of Cow Dung (CD), Poultry Litter (PL), Poultry Litter mixed with Cow Dung (PLCD) and control were assigned to 2 x 2m plots in a completely randomized design (CRD) with four replications.

ii) Manure application

The dose rate for manure application in this experiment was adopted from the manure protocol developed by DEFRA, London (2009).According to the protocol, N requirement for wheat as fodder is 220kg/ha (88 kg/acre) which can be met from applying 14.96 tonnes cattle manure/acre or 5.72 tonnes poultry manure/acre. (Wheat is considered here because the report did not feature oat in its protocol and also because wheat is similar to oat in several aspects). Gaskin *et al* (2009) mentions that annual small grain forages in general requires 100 pounds (45 kg) of N per acre which can be met from applying 1-2 tonnes of poultry litter. Wangchuk*et al* (2008) recommends a fertilization dose rate of 20-40 kg nitrogen at sowing time followed by 30 kg after every cut. Gyaltsen (2000) applied urea to provide 20 kg N during sowing and after each harvest.

Accordingly in this study, the application rate was arrived at by taking 40 kg N as the base amount per acre. The dose rate for cow dung and poultry manure on a 2 x 2m plot was therefore calculated at 6.8 kg and 2.6 kg for treatment 1 (CD) and treatment 2 (PL) respectively. For treatment 3, which is a mixture of poultry litter and cow dung (PLCD), dose rate in the ratio of 40: 60 (1.04 kg: 4.08 kg) was used. Poultry litter, Ketkar (1993) claims, proved to be a better source among manures in combined organic sources. Treatment 4 (control) did not receive any manure. Post cut fertilization was carried out with half the initial dose after each harvest, which according to Wangchuk*et al* (2008) is necessary to replace the nutrients removed from the plants after cut.

iii) Seed sowing

Seeding was done during early November. The beds were directly broadcast with 50 g seed following the rate recommended by Wangchuk*et al* (2008) which is 50 kg/acre sown in late autumn (November and December) and harvested from January to March. Oats, according to Martini *et al* (2009) are more suited to late sowing than any other annual forage crops as they have better growth and good seedling vigour.

iv) Irrigation

Surface irrigation was provided daily until germination followed by once a week thereafter, the first of which was done immediately after sowing. Frequent irrigation was necessitated due to lower rate of precipitation which according to Fulton *et al* (2006) may be necessary if the residual soil moisture and rainfall are insufficient..

v) Weeding

Infestation of the oat plants by the weeds was not a very big problem, except for some broad leaved shoots that grew between plot spacing, therefore easy to manage.

vi) Harvest

The plant height and BM yield was measured at each harvest stage using a measuring tape and spring balance. For measuring plant height, five Sample plants were randomly selected in a zigzag proportion from each bed and the tillers measured from base to the tip. Before the oats were harvested another five plant samples were selected and the tillers collected for laboratory

analysis. The oat plants were then harvested and measures recorded using a simple spring balance. Plants were harvested using ordinary sickles ensuring that a minimum of 5 cm stubble height is maintained. According to Muyekho*et al* (2005), oats can be cut at 4-6 weeks when plants attain milk stage leaving a stubble height of 5 cm. Oats harvested at early stage, especially during late boot or milk stage, Wangchuk*et al*, (2008) confirms, can provide two to three harvests.

vii) Laboratory analysis

The fresh weights of the samples were taken and then oven dried for 24 hrs in the hot air oven maintained at temperature of 70 ℃ at the CNR laboratory. After drying, dry weights were taken and Dry Matter (DM) calculated following the formula: DM = ($\frac{Dryweight}{Freshweight}$ x 100).

The dried samples were then finely ground into powder to analyze for Ash and CP content. 1-2 g of samples was measured in a crucible (C), after taking the empty weight of the crucibles (A). The crucibles containing the samples are then transferred to a muffle furnace and heated at a temperature of 600 ℃ for 4 hours. The ashes were then brought to cooling for 8 hours and then the weights recorded (B) which gave the value of ASH using the formula ASH = ($\frac{B-A}{C}$ x 100).

To determine the CP content, Nirogen (N) value was first obtained (using Kjeldahal method) following the procedures of digestion, distillation and titration (Annexure 2). The equipment used for this test was of Pelican Company of India. Sample weights of 0.1 to 0.25 g were measured and then catalyst weighing between 3 g to 4 g added to the samples which were then placed in the test tubes. 10 ml of concentrated sulphuric acid was added to the test tubes and placed in the digestion chamber maintained at 420 ℃ for 1 hour and a half. This was followed by transferring the digestion tube to the distillation chamber after adding 10 ml of distilled water. The value of the solution was measured after titration of the solution with 0.1 N of concentrated HCL which gave the N percent of the solution: N % = ($\frac{14\,x(Normality of Acid)x(T.V-BLK)x\,100}{Sampleweightx\,1000}$) which gave the CP value, where CP = N % x 6.25.

2.2 Data analysis

The data was compiled in Microsoft Excel spreadsheet and analyzed using SPSS 16. Data was presented in descriptive statistics such as mean and standard deviation. The difference between mean of treatments was analyzed using ANOVA and Bonferroni test to see the significant differences among treatmentsat the significance level of $p < 0.05$. Correlation between the variables was tested using Pearson test at the significance level of $p < 0.01$.

3 Results and Discussion

3.1 Plant height

PL observed the tallest plant height followed by PLCD, CD and control in both the cuts (Table 1). The result is in consistent with the findings of Gyaltsen (2002), where the maximum height obtained was 46.35 cm from average of 3 cuts.Significant difference in height was observed between CD and PL, PL and PLCD and PL and control in both the cuts ($p < 0.05$) using

bonferonni test. Significant association was observed between height and biomass in the first cut (r = 0.854) and in second cut where r = 0.682.

Table 1 Mean plant height, two cuts

Treatment	Height			
	CUT1		CUT2	
	Mean	SD	Mean	SD
CD	23.75	2.86298	38.95	2.92176
PL	40.585	3.21054	48.345	1.87974
PLCD	30.65	5.15008	39.7	2.31948
CONT	22.4	3.6396	35.825	4.05494

While it took seven days for the seeds to germinate which is not very atypical for small grain forage, the early days was characterized by slow growth with the tillers lying close to the ground. This type of growth habit, Kim *et al*, (2006) explains is referred to as having a prostrate growth which requires more time and temperature to grow. The height obtained in the second cut was more vigorous with PL attaining the tallest plant of 48.34 cm.The highest re growth was observed in CD with an increase of 15.2 cm in the second cut followed by control with 13.42 cm and PLCD with 9.05 cm. Shoaib*et al* (2013) observed significant re growth in oat when first cut was done at stem elongation stage. Obviously, poultry litter containing higher amount of nitrogen must have contributed to maximum growth.

3.2 Biomass yield

The highest BM yield was also obtained from PL in both the cuts. PLCD ranked next to PL followed by CD and control (Table 2).This translate to 4.08 kg/bed on an average of two cuts in PL and 2.54 kg/bed for control which was similar to or higher than 3.71 kg/bed obtained by Gyaltsen (2002) from an average of three cuts.Significant difference in biomass was observed between PL and control and between PLCD and control ($p < 0.05$) in the first cut while no significant difference was observed in the second cut ($p > 0.05$). Significant association was observed between biomass yield and height in both the cuts ($p < 0.01$)

Table 2 Mean biomass yield, two cuts

Treatment	BM			
	CUT1		CUT2	
	Mean	SD	Mean	SD
CD	2.95	0.25166	3.4	0.84459
PL	3.675	0.22174	4.5	1.09848
PLCD	3.275	0.22174	3.95	1.36015
CONT	2.375	0.56789	2.675	0.59652

The difference in the second cut between PL and PLCD, PL and CD, PL and control was 0.55 kg, 1.1 kg and 1.28 kg respectively indicating an upward shift in difference between cuts.

3.3 Nutrient content

(a) Dry matter

The maximum DM in the first cut was obtained from control and the minimum from PL. In the second cut PLCD gave the maximum DM and control the minimum (Table 3).

Table 3 Mean Dry matter yield, two cuts

Treatment	DM			
	CUT1		CUT2	
	Mean	SD	Mean	SD
CD	18.1025	2.80023	23.0775	3.6805
PL	17.4875	1.15098	21.68	6.1215
PLCD	17.8825	3.97514	23.9625	2.65705
CONT	19.0325	1.17531	21.5575	1.83271

There was no significant difference in dry matter content between treatments in both cuts ($p > 0.05$). Association between DM and rest of the variables were also not significant.It was observed that the DM content increased with advancing maturity which was in conformity with the findings of Darby *et al* (2013) and Collar &Aksland (2001), where increased DM yield was reported from plants harvested at later dates. Delayed cutting increases DM yield which is attributed to lignifications and increased cell wall content as plants mature (Shoaib *et al*., 2013).

(b) Crude Protein

The highest CP content in both the cuts came from CD while PL gave the lowest. PLCD came next to CD followed by control (Table 4).

While there is variation in the CP content, there is no significant difference in CP between treatments in both cuts although CP content was higher during first cut than second cut ($p > 0.05$). The CP content decreased as plants matured which is in agreement with the findings of Chaturvedi*et al* (2000).Collar andAksland (2001) reported that the percent CP in wheat decreased from 25% during boot stage to just 12% at soft dough stage. Darby (2013) obtained lowest CP content during soft dough stage.

Table 4 Mean Crude protein content, two cuts

Treatment	CP			
	CUT1		CUT2	
	Mean	SD	Mean	SD
CD	20.6325	9.09168	10.98	2.11803
PL	11.97	5.61717	8.4725	0.87298
PLCD	16.145	10.10724	10.0125	1.96315
CONT	15.5225	4.44692	9.1775	1.05307

Even as the reasons could not be comprehended at this stage for the lower CP content in PL, similar results were also obtained by Khan *et al* (2013), where the CP content of oat obtained from organic manure (5.3%) was lower than control (9.63%). However, the organic manure used in their experiment was farmyard manure (FYM). Ahmad *et al* (2011) in an experiment on oat yield and quality assessment using inorganic and organic fertilizers, obtained CP content at higher proportion in controlled treatment than from treatment with mixture of organic and inorganic fertilizers which included poultry manure as well at 7.86% and 7.74% respectively, although no explanation has been made on this account. The fertilizers used in the fertilized treatment consisted of N: P2O5 at the dose rate of 37.5: 15 + poultry manure at the dose rate of 2250 kg/ha.

It may be assumed, that the plant height has a role in determining plant quality. Oat receiving PL being taller and herbaceous than the rest of the treatment could possibly have apportioned the nutrient content within the plant system as did stage of maturity. In an investigation carried out by Cupic*et al* (2001) on different cultivars of alfalfa plants to determine the dynamic of nutrient accumulation in leaves and plants, reported of decreased protein and increased fiber concentration in stems with increasing plant height. The records were taken at 30, 43, 55 and 65 cm for first growth and 30, 39, 45 and 58 cm for second growth respectively. Ball *et al* (2001) attributes the probable cause for this to the reduction in leaf-to-stem ratio as the plants mature which brings about decline in forage quality. Ball *et al* (2001) infers that leaves are higher in quality than the stem and as plants mature, the proportion of leaves decline and the stem increases resulting in lower CP and resultant increase in fiber. Assaeed (1994) in his study, claimed that taller plants yield less as they are susceptible to lodging. The findings of the current study is in agreement to their observations. The result of the highest CP content from the present experiment (20.63 %) was infact superior to the ones obtained by Ahmad *et al* (2013) at 10.67 percent and in consistent with Darby *et al* (2013) at 24.2 percent.

(c) Ash

The highest ash content was observed in PLCD and the lowest from PL in both cuts (Table 5).There was no significant difference in ash between treatments in both the cuts ($p > 0.05$). Ash content was higher during second cut and PLCD gave the maximum increase in ash with a difference of 3.5% between cuts followed by control with 2.65% and PL with 1.79% while the minimum increase was obtained from CD with 1.56%.

Table 5 Mean Ash content, two cuts

Treatment	ASH			
	CUT1		CUT2	
	Mean	SD	Mean	SD
CD	6.8175	2.10438	8.375	1.00749
PL	5.4375	0.99218	7.225	3.16726
PLCD	6.8575	1.8774	10.2475	0.99751
CONT	6.435	1.49997	9.085	1.88451

The highest ash yield is comparable to the findings of Ahmad *et al*, (2013) where 6.90 % was recorded as the highest yield in ash among the oat cultivars studied. Ash content in PL was

relatively lower than the rest of the treatment including control. A result where ash content being lower in organic treatment (6.83%) than the control (10. 83%) was also oberved by Khan *et al*., (2013) in a study conducted to evaluate the efficacy of organic and inorganic fertilizer on oat. Khan *et al* (2013) ascribes this to the reduction of mineral ratios occurring in organic sources.

4 Conclusion and Recommendation

The observations made from the field experiment as well as the results obtained from the laboratory undoubtedly explains that the changes take place in yield and nutritive value of oat at varying stages of harvest. Application of manures at different dose level either in single or in combination has corresponding effect on oat growth and production. While this experiment was constrained by time, resources and scope of the study, the experiences gained could serve as an input into future research to further investigate the optimal sowing time, harvest time and dose rate of manures for oat cultivation. The present study was limited to just two cuts and no tests have been conducted on the manures for determining the required nutrients for the plant. Therefore the study recommends for extending the harvest beyond two cuts. Furthermore, the energy content of the oat could not be determined in this study due to lack of equipment and should be included in any future studies

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Prevalence of Hypodermosis in Laya Yaks

Phuntsho Wangdi[1]

Abstract

A study using palpation methods was initiated at 12 summer grazing locations to find out the prevalence of hypodermosis in yaks. Study in 88 of 107 yak herds revealed that 85 herds were infected estimating to an overall high herd infection rate of 96.49%. Study results also showed that 3 herds of Goensa were not infected which indicated only Goensa grazing locations in Laya were free from hypoderma infection in 2011.

The study findings also showed that 4337 of 5486 yaks of all ages were infected leading to an estimated high hypodermosis prevalence of 79.05%. Hypodermosis prevalence were estimated as 25.59% and 53.46% for adults and young yaks 3 years and below, suggesting that the control strategies are to be implemented immediately to all age groups of yaks including strict imposition of movement control in particularly at summer grazing locations bordering China during hypoderma flight seasons.

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Keywords: Hypodermosis, Hypoderma and Prevalence

1 Introduction

Hypodermosis or warbles is a parasitic disease caused by larval stages of insects (Diptera)either by Hypoderma bovis or H.lineatum inducing myiasis in animals (Boulard 2002 and Guan et al 2005). It is most common and serious parasitic disease of yaks and cattle (Huang at al 1984). Frequently hypodermosis is also reported in sheep, goats, buffaloes, horses, and rain deer including humans (Soulsby 1992, Khan and Khan1997, Hongzhi and Aihua 2004). Life cycle of hypodermosis is complex and parasitic stage last about 1 year. Infection consist of deposition of eggs by adult females, hatching, penetration and migration of larvae to predication sites, usually on back of animals which later developed into warble swelling .Then third stage dropped to the ground, pupated and adults emerged for re-infection (Martinez-Moreno et al 1996, Liet al 2004 Simsek et al 2008 and Hassan et al 2010).

Hypodermosis or warbles is a notorious veterinary problem causing reduction in performances and mortalities in animals worldwide (Hassan, et al 2010). The most important pathological effects are caused by migration and growth of larval inside the body by depriving nourishment, decreased in appetite, reduced in milk yield meat and quality including oxide quality (Otranto et al 2004). As a result of infection the animals become thin, decreased in reproductive capacity, changed fur quality and reduced in resistant capacity to other diseases. Additionally adult flies caused great annoyance to animals such as restlessness and running crazily when warbles flies lay eggs resulting to injuries and abortions (Simrek et al 2008 and Martinz et al 1996). Similarly hypodermosis was recently identified in Laya yaks, which would have unknowingly caused considerable financial losses to yak herders. For this reason a preliminary study was initiated in 2011 in order to find out the prevalence of hypodermosis in yaks of Laya, so as to planned and developed as specific warbles control strategies in future.

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2 Materials and Methods

2.1 Study site

The study was carried out in June and July months in 2011 when the yak herds were stationed at summer grazing areas. For the present study 12 of 18 grazing locations were randomly selected vide Thangkhaphu, Tsharijathang, Lunay, Zomshina, Tashimakha, Omtsa, Chumdona, Yangzithaka, Tshachuphu, Dung-gonpa,Langothang and Goensa of Laya.

Animals
85 of total 107 yaks herds stationed at various grazing locations were randomly selected using random digets as described by Zar (1984) in Biostatistical Analysis,Prentice-Hall International ,Englewood Cliffs, New Jersey USA. For this a total of 5431 yaks of all age groups were randomly included for the present study.

2.2 Parasitological techniques

The clinical hypodermosis infections in randomly selected herds were assessed using palpation techniques described by Hendricks and his colleagues in 1993. The clinical examination consist of palpation of warbles swelling in the skin and subcutaneous tissues, observation of breathing holes with or without larvae and resorting or healed breathing holes. Warble swelling, breathing holes or healed holes consisting more than 3 counts were considered as warbled yaks or positive to hypodermosis infection as recommended by Boulard (2002).

2.3 Data analysis
The results were analyzed using the bio-statistical methods recommended by Cameron(1999), in survey toolbox for livestock disease, a practical manuals and software package for active surveillance in developing countries where prevalence =number of cases at one point of time ÷ population at risk at same point in time. The resulting data is multiplied by 100 to estimate and present the hypodermosis prevalence as percentage (%).

3 Results
Like in many yak rearing areas of the country, hypodermosis or warbles was prevalent in yak herds of Laya since time immemorial (Wangdi 2010). A study using palpation method (Hendricks et al 1993 and Mertinz et al 1996), in 85 of 107 yak herds at 12 grazing locations of Laya showed that 10, 14, 6, 6, 3, 7, 3, 11, 8, 6, 8 and 0) herds of Thangkaphu, Tasharigathang, Lunay, Zomshina, Tshimakha, Omtsa, Chumdona, Yangzithaka, Tshachhuphu, Dung-gonpa, Langothang and Goensa were infected with hypodermosis (Table I). The study findings obviously demonstrated that with the exception of 3 herds at Goensa, all 82 herds at 11 grazing locations were infected with Hypoderma arthropods estimating to an overall high herd prevalence of 96. 47%.

Study revealed that in a total of 5486 yaks examined, 4337 were infected by various stages and species of Hypoderma larvae. 465 of 686, 832 of 922, 415 of 508, 327 of 458, 145 of 216, 369 of 474, 250 of 271, 447 of 568, 389 of 412, 297 of 308, 401 of 508 and 0 of 155 yaks of Thangkaphu, Tsharijathang, Lunay, Zomshina, Tshimakha, Omtsa, Chumdona, Yangzithaka, Tshachuphu, Dung-gonpa, Langothang and Goensa were infected. Majority of 832 of 922 yaks

of Tsharijathang were infected compared to other grazing locations studied at Laya in 2011. But study also showed that 155 yaks at summer grazing location of Goensa were not infected with hypodermosis (Table I).

Table I: Total yak herds in 12 summer grazing locations, total yak herds selected and examined, total yaks infected and prevalence of hypodermosis at Laya in June to July 2011.

Grazing locations and total yak herds at Laya	Total yak herds studied	Total yaks examined	Total yaks infected	Prevalence in (%)
Thangkaphu-12 herds	10 herds	686 yaks	456 yaks	8.75 %
Tsharijathang – 16 herds	14 herds	922 yaks	832 yaks	15.17%
Lunay -8 herds	6 herds	508 yaks	415 yaks	7.56%
Zomshina -7 herds	6 herds	458 yaks	327 yaks	5.96%
Tshimakha-5 herds	3 herds	216 yaks	145 yaks	2.64%
Omtsa-9 herds	7 herds	474 yaks	369 yaks	6.73%
Chumdona -5 herds	3 herds	271 yaks	250 yaks	4.46%
Yangzithaka-12 herds	11 herds	568 yaks	447 yaks	8.15%
Tshachuphu -10 herds	8 herds	412 yaks	389 yaks	7.04%
Dung-gonpa-8 herds	6 herds	308 yaks	287 yaks	5.41%
Langothang -10 herds	8 herds	508 yaks	401 yaks	7.31%
Goensa -5 herds	3 herds	155 yaks	0 yaks	0.00%
12 locations – 107 herds	85 (96.47%)	5486 yaks	4337 yaks	79.85%

An overall of 4337 yaks of all age groups consisting 1476 males and 2861 females were infected by hypodermosis, in summer grazing locations studied at Laya. 1404 (407 males and 997 females), 1034 (386 males and 6648 females), 838 (280 males and 558 females), and 1041 yaks comprising of 393 males and 658 females in adult yaks, 3 years of age, 2 years of age and 1 year old young yaks respectively were infected (Table II). Studies also revealed 1404 adult yaks comprising of 407 males and 997 females and 2913 young yaks 3 years of age and below comprising of 1059 males and 1864 females were infected indicating that more young yaks were warbled compared to adult yaks. But interestingly in both age groups and when compared to a total of 1476 male yaks, more female yaks of 2861 were infected with warbles during June to July months of 2011 at summer grazing locations of Laya.

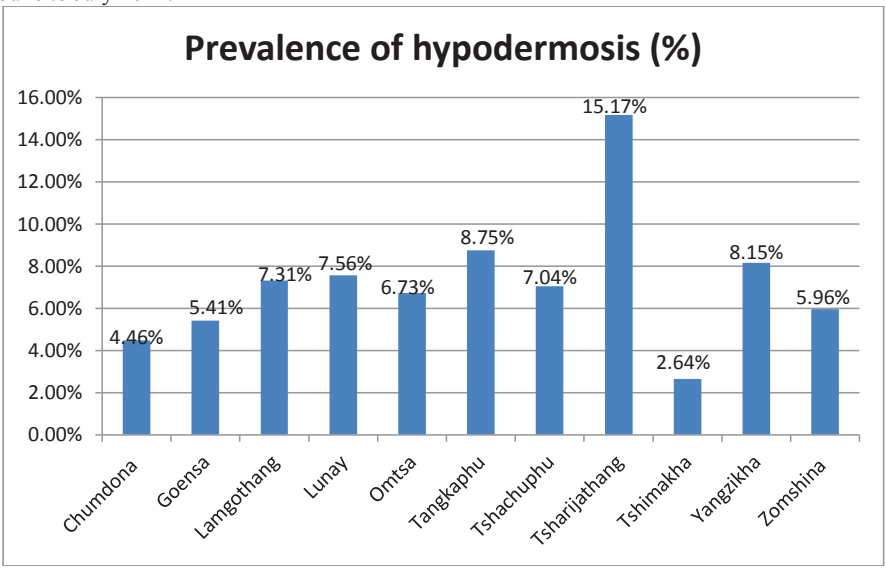
Table II: Total male and female yaks infected with and resulting hypodermosis prevalences in adults above 4 years, 3 years, 2 years and 1 year old yaks at 12 summer grazing locations of Laya in 2011.

Summer grazing locations	**Total yaks infected with clinical warbles**								**Total yaks infected**	
	Adl. Above 4yrs		**3 yrs old**		**2 yrs old**		**1 yr old**			
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
T/phu	66	134	42	91	12	30	38	52	158	307
T/jathang	101	295	60	90	44	86	68	98	273	569
Lunay	26	79	50	63	28	69	33	57	137	268
Zomshina	25	81	40	58	21	38	27	37	113	214
Tshimakha	8	19	13	20	15	23	16	31	52	93
Omtsa	22	69	25	33	38	73	40	69	125	244
Chumdona	21	32	18	35	25	39	30	50	94	156
Y/zithaka	31	75	41	57	30	77	40	96	142	305

T/chuphu D/gonpa L/thang Goensa	38 32 37 0	63 79 71 0	28 29 40 0	72 63 66 0	29 12 26 0	43 29 61 0	48 20 33 0	68 33 67 0	143 93 136 0	246 204 265 0
Total inft Prevalence (%)	407 7.42%	997 18.17%	386 7.11 %	648 11.81 %	280 5.1 0%	568 10. 45 %	393 7.16 %	658 11.4 9%	1466 26.42 %	2871 52.43 %
G. Total Prevalence	**1404 25.59%**		**1034 18.84%**		**848 15.45%**		**1051 19.15%**		**4337 79.05%**	

N.B Adl= adult yaks, F = female yaks, M= male yaks, G.total= grand total, %= percentage of infection and Y= years old and inft = total yaks infected.

Figure I: Prevalence of hypodermosis or warbles in Laya yak herds at summer grazing locations from June to July 2011.



Study also revealed that 4337 of 5488 yaks of all age groups were infected with warbles. The infection has resulted to an overall higher estimation of 69.12% hypodermosis prevalence for Laya yaks in 2011. Prevalence for summer grazing locations studied were estimated at 4.46%, 5.41%, 0.0%, 7.31%, 7.56%, 6.73%, 8.75%, 7.04%, 15.17%, 2.64%, 8.15% and 5.96% for Chomdona, Dunggonpa, Goensa, Langothang, Lunay, Omtsa, Tangkhaphu, Tsharchuphu, Tsharijathang, Tshemakha, Yangzikha and Zomshina yak yerds (Figure I). Study showed that highest prevalence was recorded for Tsharijithang (15.17%), followed by Tangkaphu (8.75%), Yangzithaka (8.15%) and Lunay with 7.56%, while lower prevalence were estimated for Dung-gonpa (5.41%), Chumdona (4.46%), Tshemakha (2.64%) and Goensa with 0.0%. Study thus demonstrated when compared to other summer grazing locations, highest hypodermosis prevalence totaling 15.17% was reported for Tsharijathang.

Excluding yaks of Goensa, all age groups of yaks studied at summer grazing locations of Laya were infected. Study revealed hypodermosis prevalence as 25.49%, 18.45%, 15.28% and 18.47% respectively in adult yaks 4 years old and above, 3 years, 2 years and 1 year old yaks. Compared to adult yaks with 25.49% prevalence, more young yaks 3 years and below were infected with hypodermosis at an estimated cumulative prevalence of 52.20%. Study findings obviously demonstrated that young yaks of Laya were more susceptible to hypodermosis than adults. But within young age groups, 3 years old (18.45%) and 1 year old (18.47%) were slightly more infected than 2 years old young yaks with 15.28 % prevalence during study period (Table I).

4 Discussion

In recent years hypodermosis or warbles have had emerged as an economically most important arthropod parasite disease at yak rearing locations of the country with prevalences ranging from 15.5% to 95% (Wangdi 2011). Based on this a study was initiated at 12 summer grazing locations of Laya in June and July months of 2011, using palpation methods described by Handricks and his colleagues (1993). In the study 4337 of 5486 yaks of all ages were infected, resulting to an overall high estimated prevalence of 79.12% (Table I). Compared to earlier study by Wangdi (2005) at same grazing locations and periods, recent study revealed that hypodermosis prevalence has increased by a large margin of 27.93% from 51. 19 % in 2005 to 79.12% by 2011. The huge increased in warble prevalence during past 6 years was mainly attributed for non-implementation of recommended control strategies due to lake of budgets (Wangdi 2005) and peculiar biological nature of Hypoderma parasites in which a single female fly can lay 400 to 800 eggs in a single host within radies ranging between 3 to 10 kms around their living sites. (Sol and Sampimon 1997, Boulard 2002 and Haine et al 2004). Similarly across yak rearing borders of Bhutan, in Tibetan province of China, the average warbles infestration rates in yaks at some endermic areas were reported as 81.86% (Ma et al 2003) and in some regions even up to 90% were reported (Huang 1984 and Huang et al 1986). Based on this, restriction of movement for free grazing across borders is to be strictly implemented during warble fly seasons.

In a total of 107 yaks herds stationed at 12 summer grazing locations of Laya, only 85 herds were studied. Study showed that excluding 3 herds of Goensa, all yak herds in other grazing locations were infected with warbles but at varying degree of intensity. Estimated herd prevalence during the period were recorded as 15.41%, 11.46%, 12.5%, 6.85%, 9.04%, 7.95%, 6.85%, 6.85%, 3.41%, 3.41% and 0.0% for Tsharijathang, Thangkaphu, Yangzithaka, Luney, Langothang, Tshachuphu, Zomshina, Dung-gonpa, Chumdona, Tshimakha and Goensa respectively (Figure I). Study results obviously revealed that higher prevalence was recorded at Tsharijathang with 15.17%, while no hypodermosis cases was observed at Goensa. Absence of hypodermosis at Goensa is due to non-migration of yaks to infected grazing areas throughout the year. While higher prevalence at Tsharijathang was attributed to seasonal migration of herds to already infected areas before peak of warble fly months of May to July (Wangdi 2005). Also as reported by Hassan and colleagues (2010) reinfection occurs due to untreated herds that remained as reservoir, thus resulting to increase in hypodermosis prevalence year after year as occured at Tsharijathang.

Study showed that 4337 yaks of all ages, comprising 1466 males and 2871 females were infected with clinical warbles indicating that both sexes were susceptible to hypodermosis at grazing locations of Laya in 2011 (Table II). Through present study findings comparatively more females

were reported to be infected than male yaks. This was mainly attributed to rearing of more female yaks by yak herders for milk purposes, thus proportionally more females were infected by hypodermosis than male yaks. Other study findings in yaks and cattle of China, also showed that both sexes were equally infected with total hypodermosis prevalence approaching to 100% accompanied by infection intensities exceeding 400 larvae per animal (Huang and Ma 1985, Yan et al 1993, Ma et al 2003 and Yin et al 2003). In a review study for cattle hypodermosis in whole of Europe by Boulard (2003) also showed that both sexes of cattle were equally infected with hypodermosis.

Yaks comprising 842, 467, 447, 415, 401, 389, 369, 325, 297, 250 and 145 totaling 4337 heads in summer grazing locations of Tsharijathang, Thangkaphu, Yangzithoka, Lunay, Langothang, Tshachuphu, Omsta, Zomshina, Dungongpa, Chumdona and Tshemakha were infected in descending order of infection. Surprisingly not a single yak of Goensa was infected obviously indicating that Goensa grazing areas were free from hypodermosis infection at the time of study (Table II). But study revealed that 1404 (25.49%) adult yaks 4 years and above, and 2933 young yaks consisting 1034 (18.45%), 838(15.28%), and 1041 (18.47%) in 3 years, 2 years and 1 year old year infected. Comparatively less adult yaks were infected indicating that young yaks were more susceptible to hypodermosis in Laya summer grazing locations. Similarly studies in cattle and yaks of China revealed that more young yaks of 1 to 2 years old were infected, its prevalence reaching 80 to 100% (Huang and Ma 1985, Yin et al 2003 and Otranto et al 2006).

In contrast with some infections disease, hypodermosis does not kill many animals but leads to great economical losses resulting from huge reduction in productivity (Yin et al 2003, Ma et al 2003, Otranto et al 2004 and Balkaya et al 2010). These occur as a result of increased abortion, reduced milk production, losses in weight and fertility, poor hide quality, impairment of hosts immune system as well as general health status (Hassan et al 2010). Such impacts in yaks were primarily reported from inner Mongolia, Tibet and Gansu province of China (Jiang et al 1994, Yin et al 2003 and Otranto et al 2006). Also a study on economic significance of hypodermosis in cattle (55.06)and buffaloes (9.51%) by Muhammad (2002) in Pakistan showed that economic losses due to warbles alone were estimated as Rs. 22.8 millions. Although economical losses in terms of production losses, mortalities in young animals and treatment costs were not studied, significance losses could have had occurred to Laya yak herders, since comparative study revealed a huge increased in prevalence from 51.19% in 2005 (Wangdi 2006) to 79.12% 2011. Because of this high prevalence and intensity, it may be very vital for immediate implementation of control strategies at summer grazing locations of Laya. As recommended by Boulard (2003) in Europe, successful control of hypodermosis could be achieved through strict implementation of control schemes vide creating awareness about the economical importance of warbles problems to yak herders, initiate studies for the epidemiology and biological factors of warbles; introduce both chemotherapeutic and chemoprophylactic control strategies using efficient anthelmentics; develop and introduce a monitoring system for the control programmes; developed a national warble fly legislation making the treatment compulsory and initiate strict control movement of animals during warble fly seasons.

5 Conclusion

A study was initiated at 12 randomly selected summer grazing locations of Laya in June and July 2011 in order to find out hypodermosis prevalences in all ages of yaks. Using palpation methods as described by Handricks and collegues in 1993, 88 of 107 yaks herds were studied during the

period. Study showed that 85 of 88 herds were infected estimating to an overall high infection rate of 96.49%. Herds infection rates were estimated at 15.41%, 11.46%, 12.5%, 6.85%, 9.04%, 7.95%, 6.85%, 3.41%, 3.41% and 0.00% for Tsharijathang, Thangkaphu, Yangzithaka, Lunay, Langothang, Tshachuphu, Omtsa, Zomshina, Dungongpa, Chumdona, Tshemakha and Goensa grazing locations. The results obviously demonstrated that with the exception of Goensa, hypodermosis infection is widely distributed in all summer grazing locations of Laya, indicating that control strategies should be in placed immediately.

In the present study 4337 of 5486 yaks were infected resulting to an estimated overall high hypodermosis prevalence of 79.05%. Prevalence were estimated as 4.46%, 5.41%, 0.0%, 7.31%, 7.56%, 6.73%, 8.75%, 7.04%, 15.17, 2.64%, 8.15% and 5.96% for Chumdona, Dung Gonpa, Goensa, Langothang, Lunay, Tshemakha, Yangzithaka and Zomshina grazing locations. The results demonstrated that compared to other grazing locations, Tsharijathang and Thangkaphu showed higher prevalence while no infection was recorded at Goensa. The study clearly desmonstrated that Goensa was free from hypodermosis infection. Additionally all age groups of yaks studied were infected with an estimated prevalences of 25.59%, 18.84%, 15.45% and 19.15% for adult yaks 4 years above, 3 years, 2 years and 1 year old young yaks. Compared to adult yaks of 25.59% prevalence, more young yaks 3 years below were infected with 53.46%. Based on the study findings it is suggested to initiate the recommended control strategies at the earliest in particularly at grazing locations boarding China.

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FORESTRY

Coppice Management System for Disturbed Oak forests

(Quercus semecarpifolia) in Western Bhutan

Tshering[1] , Gratzer, G. , Wangda, P , Darabant, A. , Phuntsho

Abstract

Quercus semecarpifolia, forests have *multipurpose utilization potentials and they are being managed under traditional coppice system for fuel wood and fodder production. These forests, mainly adjoining settlements are under intense and constant anthropogenic pressure, exacerbated by low generative potential of this high altitude Himalayan oak species. The study showed that different intensities of anthropogenic and site disturbances, and coppicing regimes have detrimental effects on the growth and vigor of sprouts (coppices) and natural regeneration establishment. A need for a sustainable coppice management strategy, including a system to promote poor generative natural regeneration, in order to restore the degraded oak forests, is suggested*

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Key words: *Quercus semecarpifolia* , Coppice, anthropogenic pressure , natural regeneration,

1 Introduction

The main factors leading to degradation of *Q. semecarpifolia* forests in the Himalayas are intense human pressure (Subedi, 2006; Singh *et al.*, 2010) and seed predation (Shrestha, 2003; Aryal and Kreigenhofer, 2009). Troup (1921) also reported continuous degradation of *Q. semecarpifolia* forests by high grazing pressure and heavy lopping by cow herders combined with slow growth and low regeneration. Such continuous, unchecked utilization of the species may lead to its final disappearance from the Himalayas in the near future (Singh *et al.*, 2010), threatening the Himalayan ecosystem (Shrestha, 2003; Thakuri, 2010).

Anthropogenic disturbances like lopping, felling, grazing and fire, in most circumstances lead to development of mixed conifer-oak forests, which can be considered a serial stage of secondary succession (Shrestha, 2003). The present study investigates the coppicing ability of the species under intense anthropogenic disturbances and the contribution of coppicing towards the sustainability of highly degraded *Quercus semecarpifolia* dominated mixed forests.

2 Study site

The study sites were situated in the dry lower Paro valley of western Bhutan. The two sites were selected at different distances from the village, having experienced different anthropogenic disturbance levels. The highly disturbed site (27°20'49.69"N, 89°27'16.72"E) and the least disturbed site (27°22'10.09"N, 89°28'12.78"E) were situated in the same valley, at the same altitude (2400-2550m) and share a similar vegetation type and environmental conditions. The areas represent mixed forest dominated by *Quercus semecarpifolia* (oak) with the continuous presence of *Pinus wallichiana* (blue pine). *Q. semecarpifolia* forests in the study areas were a degraded and low productive forest.

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Over the past 15 years, the mean maximum temperature of 28.84^{o}C was recorded in August and the mean minimum temperature of 7.9^{o}C was recorded in January. Precipitation is approximately unimodal with its maximum during the monsoon period from May to end of October and an average annual rainfall of 662 mm, recorded during 1996-2011.

The boundary of the highly disturbed site lies at 50m from the village settlement and is under frequent influence by people. The least disturbed site lies at about a kilometer distance from the village and is separated by a deep narrow ravine, which serves as a natural boundary, controlling anthropogenic disturbance. The least disturbed site without coppiced trees was selected to see the impact of anthropogenic disturbance on the productivity of the oak forest.

The coppicing ability of *Quercus semecarpifolia*in highly disturbed area and non-coppiced trees in the least disturbed area were examined.

3 Methods

Systematic sampling was carried out in both study areas. Total of 35 permanent plots (20 plots in the highly disturbed and 15 plots in least disturbed site) with 5 x 5 m size were laid out at 50 m distance along a contour line. Plot centers were then located with the help of Trimble Juno SC (GPS) navigation with an accuracy of +/- 5m. Plot to plot distance was also measured to verify the exact plot center given by the GPS. Contour lines were considered as transects and a minimum of two plots were laid per contour line. The distance between the two adjacent contour lines was a vertical distance (contour height) of 40 m.

Coppiced *Quercus semecarpifolia* trees were enumerated based on following parameters: number of coppice stems per stump, DBH of the largest coppice stem, height of the coppice stems, height and vitality status of the stump. For tree data analysis, coppice stems originating from below 1 m stump height were counted as individual tree, while the ones originating above were considered branches of a pollarded individual tree.

3.1 Data analysis

SPSS version 19 software (Landau and Everitt, 2004) was used to analyze the data. A normality test (Kolmogorov-Smirnov and Shapiro-Wilk) was performed to check if the data was normally distributed, before subjecting the data to parametric tests (simple One way ANOVA, Pearson's correlation and Linear regression). Levene's Test of Equality of Error Variance was also performed to check the equality of variances of different dependent variables. Variables recorded in percentages, like soil Nitrogen percent and Carbon percent were Arcsin transformed and other non-percent dependent variables were normalized using the natural logarithm transformation.

One way ANOVA was used to test for differences in coppice percent, number of coppice stems per stump and average coppice height of *Q. semecarpifolia* at different distances from the village. Correlation between different distances from the village and average coppice height, number of coppice stems per stump, stump height and coppice percent was tested using Pearson's correlation.

ANOVA along with Pearson's correlation was used to investigate the influence of height and health (dead or alive) of the stumps on the coppicing ability of *Q. semecarpifolia.*

A general linear regression model was fit between the independent variable number of coppice stems per stump and the dependent variable average coppice height. For both parametric and

non-parametric statistical tests performed, differences were considered statistically significant for p-values less than or equal to 0.05 and highly significant for p-values less than 0.001.

4 Results

4.1 Population structure of Quercus semecarpifolia in relation to the proximity of village

The maximum height and DBH recorded in the least disturbed site was 10.3 m and 65 cm, respectively, while on the highly disturbed site the maximum height and DBH were recorded at 11.5 m (17.5 m outside the plot) and 35 cm, respectively. The highest stem density was observed in the height class of 1-5 m followed by the height class < 1 m in areas near the village. Trees of 10 m height or above were completely absent in areas near to the village. *(Figure 1)*

Q. semecarpifolia stem density per hectare differed highly significantly between the two sites ($p \leq 0.01$). *Q. semecarpifolia* stem density on the highly disturbed site was 9663.15 ± 5539.77 and on the least disturbed site was 1893.33 ± 1156.01.

The height class of 1-5 m had the highest mean rank of stem density at 101.74, followed by height classes 5-10 m and < 1 m. The lowest mean rank of stem density was observed in the height class of > 10 m. Both sites showed low height growth.

On the highly disturbed site *Q. semecarpifolia* density showed significant differencesbetween distance classes from the village for height class < 1 m and 1-5 m (Mann Whitney U test, $p \leq 0.05$). The test showed higher stem density (Mean Rank, 24.83) near to the village than those further away (Mean Rank, 16.18).Quercus semecarpifolia tree distribution in different height classes of two different study siteswas indicated in *Figure 2*

4.2 Coppicing in relation to distance from the village

Number of coppice stems per stump, height of the stump, average height of coppicestems and coppice percent showed significant differences between the two distance classes from the village (ANOVA, $p \leq 0.05$). The average height of coppice stems on each sprouting stump far from village **w**as 3.01 ± 1.84 meters (Mean ± Standard deviation) and close to the village was 1.95 ± 0.91 meters. Difference in height of the coppice stems at different distance classes was indicated. A positive correlation was observed between average coppice height and distance from the village *Figure 5*.Number of coppice stems sprouting from each stump was 4.21 ± 3.30stems at distance far from the village and 5.68 ± 3.15 stems at distance near to the village. Average number of coppice stems per stump was found negatively correlated with distance from the village *Figure 3*

The stump height observed was 50.47 ± 37.55 cm at distance far from the village and 25.75 ± 20.43 cm at distance near to the village *Figure 3*. Similarly, coppice percent (proportion of coppiced trees observed in the plot) was 61.68 ± 14.10 percent at far from the village and 77.58 ± 15.91 percent near to the village. Coppiced percent was also found negatively correlated with distance from the village *Figure 4*.

4.3 Influence of height and status of stump on coppicing ability

There was no significant difference in the number of coppice stems per stump and in average coppice height between different stump height classes and stump status classes (live and half dead/dead) (ANOVA, p>0.05). The average number of coppice stems per stump and the average coppice height on each stump on the highly disturbed site was 4.69 ± 2.34 stems and 1.82 ± 0.17 meters, respectively.

4.4 Relationship between number of coppice stems per stump and average coppice height

The average height of the coppice stems per stump was significantly but negatively correlated with the number of coppice stems per stump at ($p \leq 0.01$) but not with stump height.

General linear regression between the independent variable number of coppice stems per stump and the dependent variable average coppice height was highly significant ($p \leq 0.01$). Fifty percent of the variation in average coppice height was explained by the model (adjusted $r^2 = 0.495$) *Figure 6.*

5 Discussion

5.1 Population structure of Quercus semecarpifolia in relation to the proximity of villages

The higher stem density of *Q. semecarpifolia* in the highly disturbed site as compared to the least disturbed site is attributed to intense coppicing and shrub like tree architecture in the highly disturbed site. Low basal area per hectare in the highly disturbed site was due to absence of bigger diameter trees and presence of small shrub like young as well as old and suppressed re-sprouts. Many small coppiced re-sprouts were measured only for their height and number, therefore, basal area of trees in the highly disturbed site does not include many small re-sprouts. In the highly disturbed site, disturbance from people comes mainly in the form of fuel wood extraction, bush cutting for fencing and litter raking. Disturbance from fuel wood extraction had high influence on the stump height and trees with bigger diameters *Figure 9*. The cutting of small branches as fencing bush from the re-sprouting stump was very common in the nearby community.Cutting of young small coppices as fencing bush was observed having strong impacts on the young re-sprouts. However, if the cutting is done as selective thinning through proper management it will benefit the tree as well as the farmer. The re-sprouts of one or two years old were usually cut for fencing without maintaining a standard stem*Figure 10*. Continuous lopping of the newly coppiced stems further produce more re-sprouts thus increasing the stem density in the area. Some remains of the small diameter stems which are cut away from the mother stump were observed dying back into the stump but bigger diameter cut stems were observed producing re-sprouts. Therefore, bigger stems werefound better for re-sprouting when cut. The trend of continuous cutting of the already coppiced re-sprout stems produced many but low vigor and unstable re-sprouts. In this study, frequent anthropogenic disturbance was seen as the main reason for increasing stem density and reduced vigor of *Q. semecarpifolia*re-sprouts.
High stem density in lower height classes (< 1 m and 1-5 m) show that the forest in the highly disturbed site despite being under frequent constant anthropogenic pressure reproduces well through re-sprouts. The low stem density in higher height classes (5-10 m and < 10 m) is because of demand for bigger trees for fuel wood. Disturbances trigger regeneration and lead to high densities of young sprouts but found to reduce older individuals.

The plots further away from the village had the lowest stem density in the lower height classes (< 1 m and 1-5 m) and trees in the height class of more than 10 meters were also recorded Therefore, human influence had played an important role in shaping the dynamics, composition and structure of the forests in the area.

5.2 Coppicing ability of Q. semecarpifolia under different levels of anthropogenic disturbances

High number of coppice re-sprouts per stool, poorly cut stumps with splits and low average height of the re-sprouts near to the village is attributed by frequent and unmanaged cutting regime by the locals. Re-sprouts near to the village were so frequently cut that they never exceeded a shrub like stature. Poor health of stools and re-sprouts can also be attributed to the quality of stump cuts (Harmer, 1995) and repeated or heavy lopping of the re-sprouts (Moench and Bandyopadhyay, 1986; Singh and Singh, 1992).

High stump heights and low coppice percent i.e. the number of coppiced trees in relation to total trees in a plot at distance further away from the village reflects intense human utilization of the forest for fuel wood, in which oak stumps are most favored. People prefer to collect fuel wood as near as possible to their village which had led to repeated cutting of the old stumps. The young leaves of *Q. semecarpifolia* coppice shoots (Shrestha, 2003) and saplings in highly grazed sites (Dorji, 2012) develop spiky leaf margins. Coppice re-sprouts were therefore, the most preferred fencing bush in the locality as their spiky green leaves become sturdy when dry.

The pressure on the forest was shifting deeper and further away from the village as resources become scarce nearby. According to some villagers, they have to walk for hours to get a back load of oak firewood now days due to declining resources nearby. However, with signs of economic development reaching to the villages and rural urban migration the pressure seems reduced compared to past decades. Yearly collection of fuel wood had reduced drastically from 1998 when the locality was electrified according to some village elders. However, the collection of leaf litter remained somewhat constant.

Today, major pressures from people come in the form of fuel wood and leaf litter collection. These pressures on the forests will remain as long as no alternative heating energy and raw materials for farm yard manures are adopted.

The observed inverse relationship between the stump height and number of coppice stems present on the stump has to be interpreted with care because the high stumps observed at distance further away from the village are freshly cut stumps without re-sprouts. High stumps observed further away from the village seems to have less chance of producing enough re-sprouts as it too will be cut in the coming winter for fuel wood. Due to such trend of continuous cutting of the stumps the ability of the re-sprouts to grow into healthy coppice stems were reduced.

5.3 Influence of height and status of stump on coppicing ability

The height and status (healthy/half dead) of the stumps were found to have no relation with the number of coppice stems per stump and the average coppice height. These observations are in accordance with the recordings of Pyttel *et al.* (2013) who also found no relation between maximum sprout height (used as an indicator for re-sprouting intensity) to stump height or parent tree characteristics for *Quercus petraea*.

In this study, re-sprouting from many old hollow stumps were observed. According to Green (1993)and Rayner (1996) hollowing is considered to be a natural process of ageing. Therefore,

the oak stools and trees in the study area were assumed to be old as predicted from the presence of numerous hollow stumps and trees.

Q. semecarpifolia showed re-sprouting from half dead stumps which can be attributed to the living underground basal buds and its deep rooting system. This is in line with the findings of Pyttel *et al.* (2013) where it was reported that in the central European aged oak coppice forests, a considerable proportion of dead trees developed new sprouts after coppicing.Guidici and Zingg (2005) also reported similarly for *Castanea sativa* in Switzerland. Rackham (1980) and Buckley (1992) also assumed that coppicing is a repeatable trait and a key to a long lasting tree life. Käpler (1805) also reported that intensity of re-sprouting of Oak stumps does not decline even after coppicing for the fourth time. For Central European and North American oak species, however, a negative relationship between parent tree age and stump sprouting was observed instead of stool age as reported by Groos (1953) for *Quercus petraea*, Johnson (1977) and McGee (1978) for *Quercus alba L.* and Dey and Jensen (2002) for *Quercus velutina Lam.* and *Quercus coccinea Muenchh*. *Q. semecarpifolia* seems toshow similar characteristic in coppicing like many other Oak species. However, further study on its coppicing ability could corroborate or disprove these preliminary findings.

5.4 Relationship between number of coppice stems per stump and average coppice height

A negative correlation between average height of the re-sprouts per stump with number of re-sprouts on the stump can be attributed to density dependent competition among the re-sprouts themselves as there was no significant relation between average coppice height and species diversity. According to findings of Gracia and Retana (2004) re-sprouts in the early stages depend more on the parent tree internal resource reserves rather than on competition from neighboring plants or site quality. Therefore, the re-sprouts on the stool compete with each other for resources from the parent stool and it seems to influence the growth of re-sprouts. Competition and natural self-thinning among the coppice re-sprouts of many trees were reported by Tanaka (1989); Rydberg (2000); Lutz and Halpern (2006) and Zhu *et al*. (2012). The deep rooting system of *Q. semecarpifolia* may have an added advantage over shallow rooted herbs and shrubs for soil nutrient competition. Therefore, optimum number of re-sprouts on the stool will not only reduce competition for resources but will also reduce mortality and increase the growth vigor of individual re-sprout. However, optimum number of *Q. semecarpifolia* re-sprouts that can be maintained on a stool could be dependent on parent tree and site characteristics and needs further investigation.

6 Conclusion

Adverse environmental condition along with heavy anthropogenic disturbance had led to current shrub like tree stature. Main human disturbance was found in the form of fuel wood extraction and litter raking. The study also found out that continuous cutting of young re-sprouts produce numerous weak re-sprouts in the coming growing season. Increased stem density in the highly disturbed site was attributed only by anthropogenic disturbance.

Frequent and unmanaged cutting regime by the locals was found to be the main force behind poor health of the surrounding forest. Browsing impact on young coppice shoots was found non-significant in the study area.

The oak forest in the study area was found to be old forest, however, the vigor of regenerating through re-sprouts was found high. Density dependent competition among the re-sprouts was found more prominent in reducing their height growth.

The study concluded that, although natural regeneration through seed is important for tree regeneration in old growth oak forests and other least disturbed forests, however, coppicing is the major pathway of regeneration in the intensively utilized *Q. semecarpifolia* forests of western Bhutan.

The current study therefore recommends a sustainable coppice management of the forests for fuel wood extraction, soil and water conservation through a participatory approach involving the local communities.

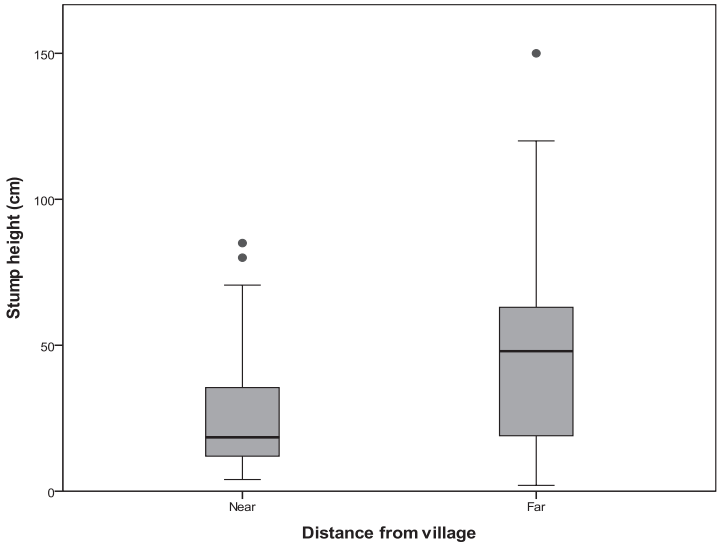


Figure.1. Stump height recorded at distance near and further away from the village

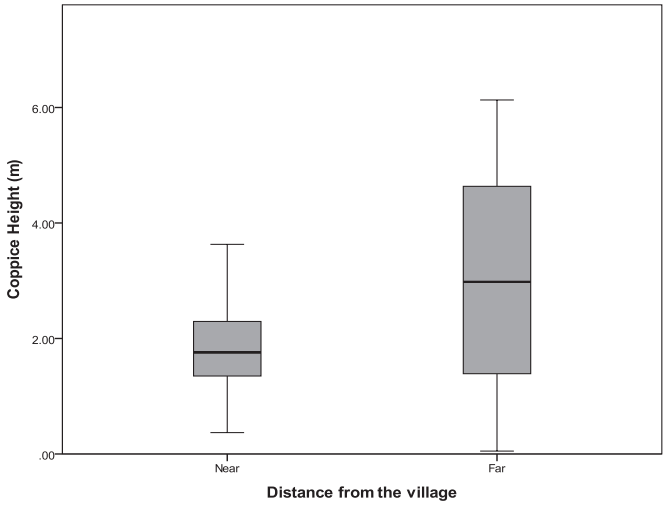
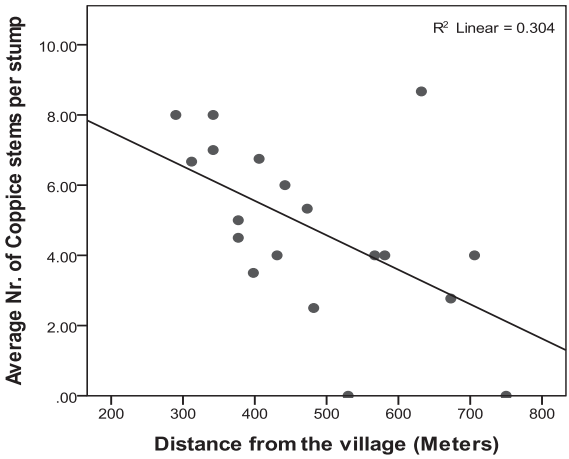


Figure.2. Coppice heights at distance classes near to and far from the village



3.

Figure.3. Regression between average number. of coppice stems per stump and distance from the village. (R^2=0.304)

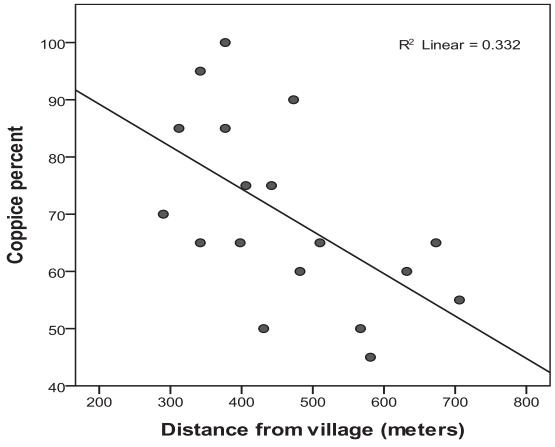


Figure.4. Regression between coppice percent (Percent of coppiced trees in the plot) and distance from the village. (R^2 = 0.332).

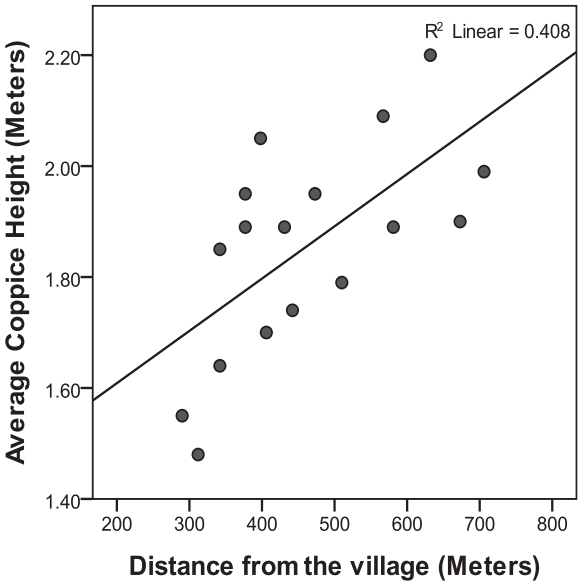


Figure 5. Correlation between the average heights of the coppice stems and distance from the village. (R^2=0.408)

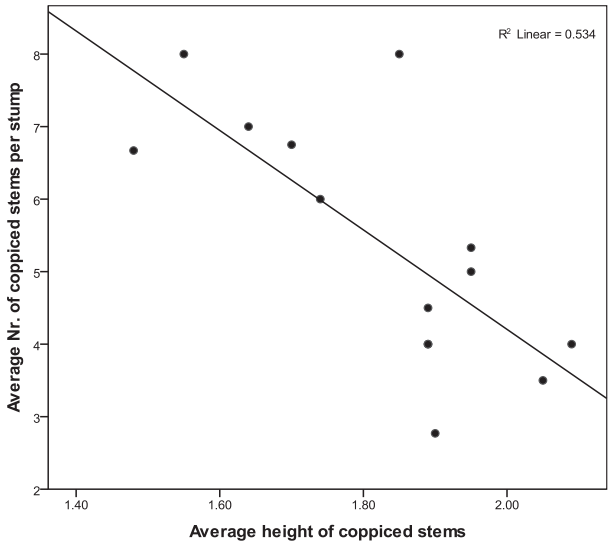


Figure.6.Indicating correlation between the average number. of coppiced stems per stump and average coppice height. (R^2=0.534)

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Feeding Behaviors of Brown-Headed Barbet *Megalaimazeylanica*: Opportunistic observations during winter, spring and summer season

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Abstract

Understanding the nature of consumer-food interactions is critical to study avian ecology. Though fruits of different tree species constitute the main diet of Barbets, almost all Indian Barbets feed on insects to a considerable extent (Yahya, 2001).Barbets are considered economically important since they help in seed dispersal and also feed on various harmful insects. Sipping nectar further helps in pollination. Many of the activities of an animal are oriented towards the procurement of food (Thorington, 1970). According to Simmons (1970) food supply plays an important role in determining a species breeding biology, dispersion pattern and social system through natural selection. I will describe apart from food items, fruiting seasons and abundance of fruiting trees, the food and feeding methods of coexisting Brown-Headed and other Barbets species to ascertain the extent of isolation in food habits of the two co generic species. An attempt was made to assess the impact of food habits of Barbets on the fruiting trees of the study area. An optimal forager is predicted to allocate more time on profitable patches than on less profitable ones, depending on the quality of environment as a whole. The foraging behavior of birds in a particular environment may therefore give an idea about environmental conditions of the area.

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Keywords: : *Barbets, Megalaima zeylanica, mixed hunting party, feeding cycle, food preference*

1 Introduction

Barbets form one of the vociferous components of the forests (Yahya, 2001). The majority of barbets are multicolored in striking plumage. Brown-headed Barbets are typical *Megalaima* barbet of the Himalayan foot hills i and the plains of Deccan peninsula. Fruits, berries, buds, flowers, nectar, insects, etc. form major diet components of the Barbets,; larger species like Lineated Barbets are known to consume tree frogs, lizards and even other smaller birds (Yahya, 2001).One of the important species of hole-nesting birds, Barbets and their role at different trophic level is equally significant. In order to elucidate the Barbet behavior, feeding pattern and their role in food chain is inevitable.

2 Materials and Method

Hartley's (1948) "Repeated standard field observation", adapted by Vijayan (1975) was carried out in an area of 203 ha (see map plate). The hours of the day were divided into three two-hour shifts: 0600 to 0800, 1000 to 1200 and 1500 to 1700 hours. The observations were based on opportunistic sightings and during weekends. Fruiting of trees was recorded during the season of the entire study area.

The data collected includes food items, feeding heights, the number of birds feeding at a time and antagonistic behaviour. Barbets are arboreal and most behaviours were observed using

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binocular. The zones studied were based on ocular estimation, primary level 1-4 m, secondary level 4-8 m and tertiary level above 8 m. At the outset it was tried to distinguish different canopies at which the birds fed, but discarded later as sometimes birds were found to feed amidst thick canopy cover.

One bird- one food item record was maintained while calculating the number of birds on the fruit trees. As the Barbets are primarily fruit eating birds and it was possible to make fairly accurate visual observations of their feeding but no specimen was collected for stomach analysis. Fruit sizes were measured using mini vernier calliper. ArcGIS 9.3 was used to prepare maps to analyse the extent of study area.

A total of 30 observations were made and 42 Brown-headed Barbets (*Megalaimazeylanica*) were counted. This study is a first attempt to study in detail the feeding behaviour of Brown-headed Barbets for a particular season.

3 Results and Discussion

3.1 Fruiting Seasons

Almost all the trees except few *Ficus* species, fruit annually. Though the fruiting period varies from species to species and from individual to individual, there are two peak periods of fruiting seasons- April-June and November-December. During April-June trees such as *Ficus benghalensis, F. benjamina, F. racemosa, F. retusa, F. religiosa, F. gibbosa, Syzigium cumini,* etc. were the main fruiting trees. During November-December different species of *Ficus* were in fruiting including *Adina cordifiolia and* Sal *(Shorea robusta)*. *Chorisa speciosa* and *Bombax ceiba* flower between November-February. *Bischofia javanica* fruits from November to January whereas *Bridelia retusa* from August to November.

Lantana camara and *Solanum indicum* constituted the two main shrub species of certain Barbets including Brown-headed Barbets and fruits throughout the year. *Ficus benjamina* and *F. retusa* are more versatile and one other tree of these species may be found fruiting throughout the year; however no fruits were recorded in the latter in July-August. *Ficus hispida* and *F. glomerata* found invariably throughout the study area were never found eaten by Brown-headed Barbets.

Fewer species of trees fruit during February and March in the study area like *Morus indica, Santalum album* and *Melia azedarach*. During this period almost all the trees shed their leaves and rainfall subsides. Being the drier months, perhaps in February-March, most of the trees prepare for the forthcoming fruiting season. According to Champion and Seth (1968) even the seasonal distribution of rainfall exerts an equally far-reaching influence in determining the nature of vegetation.

The fruit abundant from April to June appears to exhibit a reciprocal adaptation with the breeding season of local birds. Most of the resident birds of area breed during this period (Yahya, 1988) and thus chances of seed dispersal are high, for birds exploit maximum food during breeding seasons.

3.2 Food Preference

Brown-headed Barbets show preference for certain fruits in each season but restricts mostly on being above 7 m of the vertical tree height. Before analyzing the data for a possible explanation of how Brown-headed Barbets mix with other co generic species of Barbets, a broad outline of their month-wise food items and preference were observed.

The common trees on which other Barbets considerably fed during lean month of fruiting season were *Ficus benjamina*, and *F. benghalensis*. During March, *F. glomerata* and *F. gibbosa* were the main trees on which all Barbet species fed. Brown-headed Barbets shows greater affinity towards *F. religiosa* and *F. hispida* as the later one is available throughout the year at the study site. On two occasions during this month, it was observed that Brown-headed Barbets were feeding on *Lantana camara* shrubs at about 2 m height.

Grewia elastic and *F. retusa* were the main fruiting trees on which Brown-headed Barbets fed from May to August. During this period Brown-headed Barbets show a higher preference for *Grewia elastica* than other fruits, though as usual *Ficus* trees were also visited and fed on the fruits. In addition, Brown-headed Barbets also fed on the fruits of *Lantana*, *Solanum* and nectar of *Bombax ceiba* in the early days of its flowering and occasionally the nectar of *Chorisa speciosa*. *Eucalyptus globulus* fruits were rarely fed. During this period young fruits of *Eucalyptus* were often eaten by the Barbets, mainly in the morning hours of observations. Though Barbets were thought of not preferring *Euclayptus*, in due course of time they have developed taste for introduced species.

In the month of April-May, *Syzigium cumini*fruits were the main fruits preferred by the Brown-headed Barbets and continued till late June. During November-December they exhibited greater preference towards *F. bengalensis*, which usually fruits in the month of October- November. Also *Solanum indicum* fruits were found feeding by Brown-headed Barbets. Therefore, it has been observed that apart from feeding on the fruit trees of native origin, introduced species played an important role in food preference behaviour of the Brown-headed Barbets.

3.3 Possible Reasons for Food Preference

On analysing the data, the most obvious reason for food preference in Brown-headed Barbets appear to be the size of the fruit. However, selection of food may also depend on various other factors such as colour, taste, nutritive value and even aroma as stated in certain literatures. The availability of fruit during a particular season also adds to the preference.

Fruits of *F. retusa, F. bengalensis, F. gibbosa* and *F. hispida* were the most preferred fruit trees of Brown-headed Barbets. Fruits of *Grewia elastica* and *Syzigium cumini* were also preferred and least was shrub species. *M. zeylanica* in the study area appeared to show remarkable preference for food according to size preferring *F. bengalensis* and *F. benjamina* fruits.

Table-1 Percentage of Brown-headed Barbet (*Megalaima zaylanica*) feeding on fruits of different sizes, as recorded from December 2010 to June 2011

Species	Total birds observed	Average size of the fruit		
		<8mm	8-16mm	>16mm
Megalaima zaylanica	*42*	*18 (42.85%)*	*15 (35.71%)*	*9 (21.43%)*

3.4 Animal food of *M. zeylanica*

A month wise food intake of animal and plant matter has been tabulated (Appendix 2). However, during breeding season they searched for insects individually or in pairs. Quite often the species was found capturing winged termites by 'fly catching' sallies after a light rain during March-April. These hunts normally take place in groups.

During April-May the teak defoliator, *Hyblaea puera*, swarm on young teak leaves and the barbets congregated in good numbers to feed on these caterpillars along with other birds in the Reserved Forest area of the study area. Except for this caterpillar no swarming of any particular species was noticed.

3.5 Formation of Mixed Hunting Parties (MHP)

In the study area, formation of large MHPs is a common avian activity and was observed at several occasions with variety of species. Generally bright hours of the day and comparatively open areas are selected for forming of MHP. In the non-breeding season these barbets hunt with MPHs. The MPH sometimes follow a longer route, but normally limits themselves to a circumference of 250m or less.

3.6 Position of Barbets in Mixed Hunting Parties

Normally 10-20 bird species comprise a single MHP in congregated bird exodus, but sometimes as many as 25 species were recorded, the commonest and perhaps the 'nucleus 'of the party being Drongos. The common species forming the MHP were usually the Racket tailed Drongo (*Dicrurus paradiseus),* Grey Drongo *(D.leucophaeus),* Bronzes Drongo *(D.aeneus),*Rufous Tree Pies *(Dendrocitta vagabunda),* Common Woodshrike *(Tephridornis virgatus),* Common and Jungle Mynas*, (Acridotheris sp.),* Minivets*(Pericrocotus flammeus, P. Cinnamomeus)* Tits *(Parus major, P. xanthogenys),* Velvet-Fronted Nuthatch *(Sitta frontalis)* and various species of flycatchers. Barbets are 'opportunist' members of the party, whenever an MHP passes through; they invariably join and become active hunters as the rest. *M. viridis* is far more active than *M. zeylanica* and *M. rubricapilla* exploits the maximum feeding zone. And moreover Barbets were never observed more than a pair but occasionally in triplets.

Intra-specific aggression between them is not as common in MHP as noted on fruiting trees. This could be due to the marked difference in their feeding zones and larger feeding areas. When the fruits are scarce, there is more rivalry and aggression while in MHP the food resource is always scattered. At one time it was observed that Brown-headed Barbets chasing other species of bird from the tree on which they were feeding.

3.7 Competition for Food and Coexistence

It appears that *M. zeylanica* do not compete severely for food and space. However, they do overlap on certain fruiting tress or when in a mixed hunting party of insectivores with other co generic species like Coppersmith barbets. The competition is further reduced owing to their different feeding zone and behavior.

3.8 Feeding Habitat

Utilization of different parts of vegetation by *zeylanica* differs from *viridis* and *rubricapilla.* The feeding zone is clearly distinguishable when they all feed in a single microhabitat. During feeding on fruit or hunting insects, individually or with MHP, it was observed that *zeylanica* and *rubricapilla* feed mostly on the tertiary level while *viridis* feed less on this level. It was observed that *zeylanica* prefered feeding or hunting on the top canopy. This is the reason why data regarding feeding behavior for Brown-headed Barbets in my study is inadequate.

Table-2 Percentage of *M. zeylanica* feeding at different vertical zones

Tree Height	***M. zeylanica***
Ground	***0***
Primary level, 1 to 4m	***0***
Secondary level, 4 to 8m	***(42.86%) 18***
Tertiary level, above 8m	***(57.14%) 24***
Total birds observed feeding for 7 months	***42***

3.9 Method of Feeding

The difference in feeding method is obviously due to differences in their beak size. While *zeylanic*a swallows larger fruits easily, *haemacephala* cannot do so and hence the latter has to spend more time and energy on the same fruit. The two species *zeylanica* and *haemacephala*were recorded feeding together on *Ficus benjamina* and *Ficus benghalensis* trees. The method of feeding between the two species was notably different; *zeylanica* with larger beaks normally swallowed the entire receptacles whereas *haemacephala* pecked bit by bit. Even while hunting insects individually or with MHP, *zeylanica* frequently catches cicadas, butterflies and larger insects, while *haemacephala* restricts itself to ants, small flies, termites and other relatively smaller species.

3.10 Feeding Cycle and Call

The feeding intensity reduced during the hot day. Their calls were restricted during cold winter. The calls of Brown-headed Barbets during cold winter season were seldom heard. However, the feeding activity varied during different hours of the day. Table 3 shows feeding activity of *M. zeylanica* during different hours of the day. The maximum feeding activity of the bird was during the morning hours and less activity in afternoon hours.

Table-3 Percentage of *M. zeylanica* feeding on different hours of the day on different plant matters. (Dec 2010- June 2011)

Species	0600 to 0800 hrs	1000 to 1200 hrs	1500 to 1700 hrs	Total No. Birds observed
M .zeylancia	*28 (66.67%)*	*2 (4.76%)*	*12 (28.57%)*	*42*

3.11 Aggression at the Feeding Sites

M. *zeylanica*is tolerant of other species at the feeding site. Rare incident of Brown-headed Barbet chasing Jungle Babbler was observed. It was observed *zeylanica* feeding together with the mixed flocks of Plum-headed Parakeet, Rose-ringed Parakeet, Chesnut-tailed Starling, Coppersmith Barbet, Indian Grey Hornbill, Warblers and other species in the study area.

3.12 Morphological Adaptations for Feeding

In physical dimensions, *zeylanica* is different from *haemacephala*. *M. zeylanica* has larger beak enabling them to swallow larger fruits and insects. This reduced food competition and promoted successful coexistence. Another point which supports the view that overall size differences in barbets may play important role in their coexistence is common occurrence side by side of two species of different sizes. The same mild coexistence between *zeylanica* and *haemacephala* was observed at several occasions during the field visit. Thus food being a primary requirement of an animal, for the successful coexistence of two closely related species in a single habitat, divergent morphological adaptations could be a process of natural selection.

4 Conclusion

It is clear from that food competition between the coexisting Indian Barbet species is not severe, for normally they procure food from different feeding zones. *M. zeylanica* being a versatile vegetarian exploits a wider zone of feeding habitat. Owing to is large beak, it prefers swallowing the whole fruit. Intra-specific aggression among *M. zeylanica* is less observed though some don't let others species perch for food, either on a fruit tree or with a mixed hunting party of insectivores. The study also supports Huxley's (1942) postulate that "big size difference between co generic species are means of ecological isolation". Relative food preferences also plays role in their differences apart from isolation. Their rare calls during cold season relatively made my observation difficult as I had to search for one for a longer duration. Based on observations of present study it could be further added that since food is the primary requirement of an animal, for successful coexistence of two closely related species and with other unrelated species in a single habitat, divergent morphological adaptations are an outcome of the processes of natural selection. Barbets are ecologically important since they help in dispersal of seeds and feed on various harmful species of insects including Teak Defoliator caterpillars. In the process of sipping nectar, Barbets may also help in the pollination of flowers. Therefore, Barbets deserve due consideration and importance in the biodiversity conservation status.

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Climate Change and River Flow in the Chamkhar Chhu Basin

Chhimi Dorji[1]

Abstract

Climate Change is a real phenomenon of the current generation that is caused by anthropogenic emissions of Green House Gases. The study tried to understand the physical realities of climate change, experiences and perceptions of the villagers in the Chamkhar valley. A semi-structured interview of 100 households, analysis of hydro-met data and physical inspection of the river was done to ascertain the risks and issues in 2012. The widespread perceptions of changing climate such as temperature increase, warmer winters and lesser snowfall were supported by hyro-meteorological data that showed similar trend of rise in temperature and decrease in total annual rainfall. This suggests that climate change is already occurring in the valley, and people are also experiencing the changes. The average monsoon flow shows an increasing trend for the Chamkhar Chhu while the lean flow in the Chamkhar Chhu tributaries shows a decreasing trend. Many infrastructure and agriculture fields in the vicinity of Chamkhar Chhu face a high threat of flood due to their location on the floodplain and eroded banks, which are aggravated due to the threat from climate change.

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Keywords : Climate Change, Bhutan, Chamkharchhu, Perceptions, Flood

1 Introduction

Climate Change is referred to any significant change in mean values of meteorological parameters over a decade or longer (NSIDC, 2011). Changes in the climate occur due to both natural and anthropogenic causes. The key anthropogenic factor is increasing concentrations of greenhouse gases which affect the atmospheric absorption properties of longwave radiation, which leads to increased radiative forcing warming the lower atmosphere and the earth's surface (Solomon et al, 2007). Temperatures and precipitation are the most common parameters changed over the years. The impacts of climate change are many and increasing, but some of the most common impacts are; temperature rise, increasing in magnitude and frequency of floods, cyclones and storms, sea level rise, melting of arctic and other snow and glaciers reserves, increase in climate sensitive diseases, worsening air quality, and etc(IPCC, 2007).

Bhutan is a net carbon sequester, Bhutan's carbon emissions in 2000 was 1,560Gg CO_2-equivalent, against forest sequestration capacity of 6,309 Gg CO_2-equivalent which means that only a third of Bhutan's carbon budget is used up(NEC, 2011).However, melting glaciers at higher elevations, erratic rainfall and increasing temperatures due to

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climate change compounded with population increase and lifestyle changes, are anticipated to cause water issues and flooding in Bhutan(Bhutan Climate Summit Secretariat, 2011) and (NEC, 2011). Problems are also anticipated in the Chamkhar Chhu basin including disasters due to Glacier Lake Outburst Flood (GLOF) from the three potentially dangerous lakes upstream(ICIMOD, 2001). A previous hazard Zonation in the Chamkhar Chhu basin identified that some 3,499 people and 326 households will be impacted in the event of a GLOF(DGM, 2007). A study was also conducted in the northern parts of Chamkhar Chhu within the Wangchuk Centennial Park to assess vulnerability of the park and document people's experience with regard to Climate Change(Lhendup et al, 2011). The study confirmed that local people have observed Climate Change and experienced by the flora and fauna. Invading weeds, pest and disease outbreaks, landslides, and soil moisture deficiency are indicators found that support the above claims (ibid).

Bumthang is the cultural capital of Bhutan and one of the few valleys in Bhutan. There are some 2,870 households in the district with projected population of 17,837 in 2011 covering an area of 2,708Sq.km of which about 14,000 Acres are cultivated(NSB, 2011). The Chamkhar Chhu flows through Bumthang district right next to the Chamkhar town and the major part of Chokhor Gewog/block is on the either sides of the Chamkharchhu. The Royal Government of Bhutan and the United States Geological Survey (USGS) identified the Chamkhar Valley as a place of high risk for future water-based disasters (Shuji, 2004) and (UNDP ALM, 2011). The threat of flooding induced by cyclones and Glacial Lake Outburst Floods (GLOFs) and the potential for loss of fresh water security are some of the identified risks for the valley. It was also found that maximum numbers of high altitude wetlands[3] (52% of the total wetlands in Bhutan) are found in the Drangme Chhu ribasin, primarily contributed by Mangdechu and Chamkharchhu river systems(Sherub et al, 2010).

ICIMOD study through Glacier Inventory of Bhutan indicated that the total glacier for Bhutan has decreased by 189.38 Sq.km from 1980 to 2010 with the actual increase in number of glaciers by 70, increase in elevation of the glaciers and decrease in mean size by 0.31 Sq.km (Gurung et al, 2011). Similarly, in the Chamkhar Chhu basin during the last 30 years the glacier area has reduced by -26.37 Sq.km the mean glacier elevation (MASL) has increased by 39m (Table 1)

Table 1. Glacier Area of Bhutan 1980-2010

Year	Basin	Nos	Elevations (MASL)			Glacier Area (Sq.km)			
			Min	Mean	Max	Total	Mean	Max	Min
1980	All	796	3945	5300	7246	860.15	1.08	42.26	0.02
2010	All	866	4085	5371	7246	670.77	0.77	34.93	0.01
Change in 30 years		70	140	71	0	-189.38	-0.31	-7.34	-0.01
1980	Chamkhar	124	4698	5331	6625	103.71	0.84	20.07	0.02
2010	Chamkhar	124	4700	5370	6625	77.33	0.62	17.70	0.02
Change in 30 years		0	2	39	0	-26.37	-0.21	-2.36	0.00

[3] *High altitude wetlands are open water lakes and marshes above 3000 meters of elevation.*

From another study, 103 glaciers lakes have been identified in the Chamkharchhu basin with glacier lake coverage of 9.8 Sq.Km and lowest glacier lake elevation being at 4568, while maximum altitude is 4989masl (JAXA_JST, 2012).
In 2001, there were 2,674 glacial lakes in Bhutan from which 562 lakes were considered to be associated with glaciers. Among the identified potentially dangerous lakes, three lakes are located in the Chamkhar Chhu basin(ICIMOD, 2001).An expedition to the ChubdaTsho/lake in the headwaters of the Chamkhar Chhu to revealed that the ChubdaTsho was attached to a glacier which conformed that Chubda glacial lake poses a major hazard to the lower valleys of Bumthang and deemed to be monitored constantly. Subsequently, a hazard zonation in the Chamkhar Chhu basin was conducted by the Department of Geology and Mines. It has identified that some 3,499 people and 326 households will be impacted in the event of a GLOF (DGM, 2007). A hazard zonation mapping was also done for the Chamkhar valley, which is marked with red markers by the riverside.

However, no study was done to ascertain the climate parameters and their trend in the lower Chamkhar valley nor people's perception and experiences collected. A complete vulnerability assessment of the Chamkhar valley to a flood was also not carried out before. Thus, this study was conducted to understand the physical realities of climate change in the valley, experience and perceptions of the villagers of the Chamkhar valley with regard to climate and flood.

2 Materials and Methods

The study was conducted through analysis of 21 years (1992-2012) of flow data collected at the Kurjey Principal Hydrological Station of Department of Hydro-Met Servicesand spot lean flow record of 3 other stations (Ura, Chumey and Tang) in the Bumthang district, which join the main Chamkharchhu river downstream. Almost16 years (1996 - 2010) of temperature and19 years (1992 - 2010) of rainfall record collected at the Chamkhar Class A Meteorological station by the Department of Hydro-Met Services of Bhutan were also used for comparison. For the purpose of hydro meteorological data analysis, monsoon was considered from May- October, while November through April was considered as winter/dry period.

The primary analyses of the data were done on Microsoft Excel, while detailed analysis and statistical inferences were made through R software package Rx64 2.15.1.The Confidence Interval for all statistical inferences was kept at 95%. The analysis of trend is done using both parametric and non-parametric statistical tests based on the distribution of the sample data. Shapiro test of normality, probability plot and Normal Q-Q plot were done to ascertain normality of the samples. The parametric test includes regression tests, whereas non-parametric tests include Kendall and Pearson Ranked tests. The trend in this study is done using regression test under the assumption that the sample data satisfies all conditions of normality. Auto-correlation test was also used to test the independence of sample data.For all trend analysis, the Null Hypothesis (Ho) is that slope of the line is =0. So when P-Values >0.05 the Ho is accepted and the trend is considered as not significant.

Pearson's chi-squared tests were also done to determine association ofclimate literacy to education level, age and gender.The Ho here is that there is no Association, i.e., when

P>0.05 there is no association. Similarly Pearson's Correlation was used to determine correlation between different parameters and observations. The Ho in this case was correlation = 0. So when P-Value<0.05 the Alternative Hypothesis (H_A) is accepted to show that there is correlation.

The above was complemented by semi-structured questionnaire of 58 questions with key household information of 100community households in the Chamkhar valley that consisted of the villages of Wangdichholing, Dekiling, Chamkhar village, Chamkhar town, Bathpalathang, Jalikhar and Gongkhar. The interviews were done through translators mostly in Dzongkha, while some were done in Bumthapkha, Nepali and Tshangla. The assistance from local gewog/block and thromde/town officials were sought for informing about the interviews. No sampling procedure was used for selection of the households interviewed and verbal consensus was sought from households available for the interviews. Households that were available and willing were chosen and interviewed by a group of researchers for a period of five days.

A bio-physical inspection and characterization of both banks on a 10km section of the Chamkharchhu river through 500m stretch on flood plain, slope, bank heightand land use were also carried out.

3 Results

Based on the analysis of the observed data, household interviews, physical inspections and literature reviews following results were obtained for the Chamkhar valley;

3.1 Physical Inspection Results

Although 46% of the banks surveyed are manmade barriers, many levees and gabion walls are leaking or inadequate for withstanding major flood events(Neill, 2012).The residential, commercial, agricultural, public, school, and airport structures located in the floodplains have minimal protection and are at a high risk of flooding. Simultaneously, 59% of the banks surveyed are severely eroded and lacking vegetation (**Error! Reference source not found.**).

Many major infrastructure and roads in the valley are located on the banks of the river on the flood plain as indicated in Figure 1(Neill, 2012). Gabion walls or rock barriers protect some, but many stretches are atop erosional banks or cliffs at the river's edge.

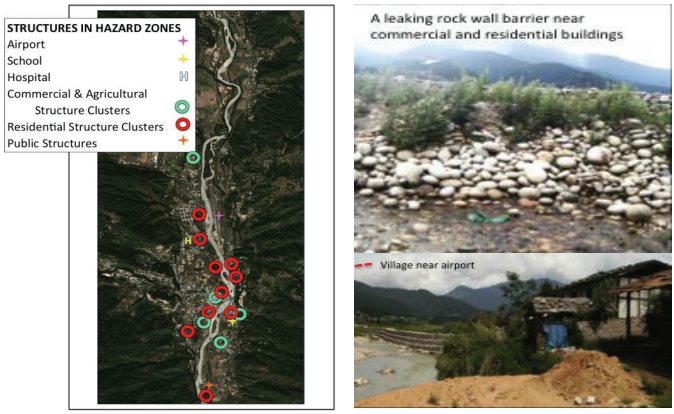


Fig1. Bumthang valle with infracture

3.2 Hydro-Meteorological Data Analysis Results

Following are the results from the analysis of Hydrological and Meteorological Data collected at Kurjey Principal Hydrological Station and Chamkhar Class A Meteorological Station, Department of Hydro-Met Services.

i. MaximumTemperature

At the Chamkhar Class A Meteorological station, the Annual Average Maximum temperatureis increasing with a slope of 0.05 and R^2 of 0.14, while the summer average maximum temperature is increasing with a slope of 0.05, R^2 of 0.12and the winter maximum average temperatureis increasing with a slope of 0.05 and R^2 of 0.013. All the data passed the normality test, but P-Value of the trends are all above 0.05 and thus no statistically significant (Fig 2).

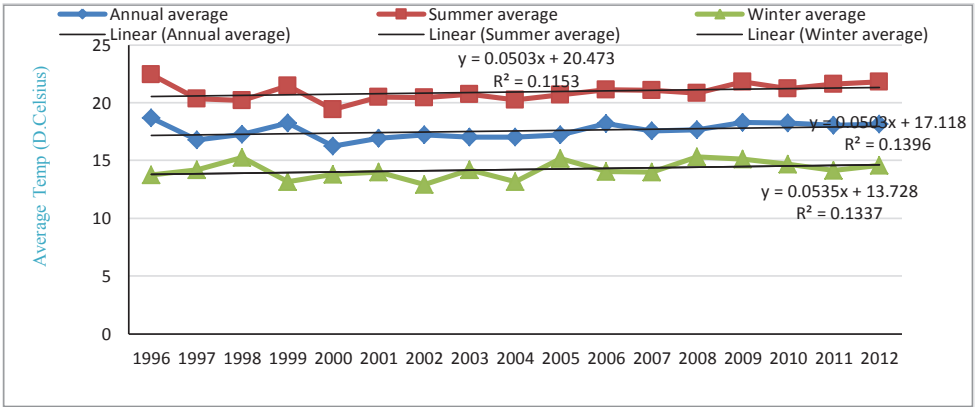


Fig 2.Average Maximum Temperature (Annual, Summer & Winter 1996-2012)

ii. MinimumTemperature

The Summer Average Minimum temperatureis increasing with a slope of 0.008 and R^2 of 0.006, while the Annual Average minimum temperature is increasing with a slope of 0.02, R^2 of 0.05and the Winter Average minimum temperature is increasing with a slope of 0.03 and R^2 of 0.06. All the data passed the normality test, but P-Value of the trends are all above 0.05 and thus no statistically significant (Fig3).

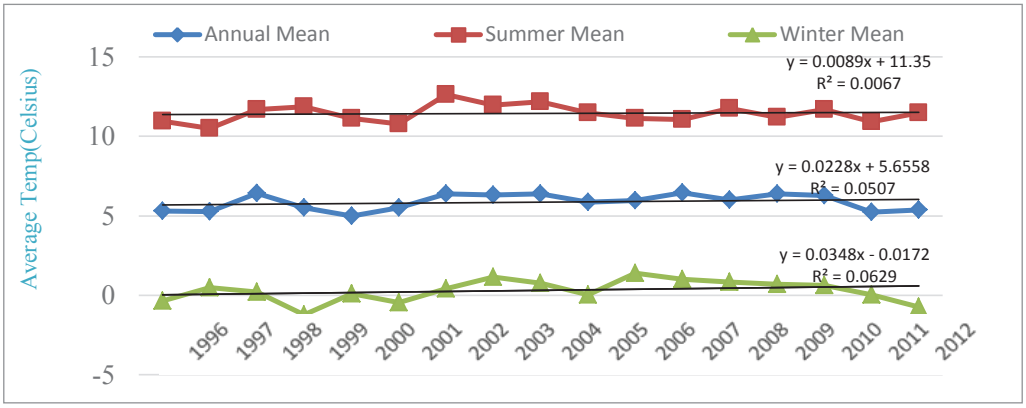


Fig 3. Mean Minimum Temperature (Annual, Summer& winter 1996 to 2012)

iii. Precipitation

The total observed precipitation at Chamkhar has been decreasing at slope of -8.778 with R^2 of 0.199 and P-Value of0.07, the monsoon/summer total precipitation is also reducing at the rate of -7.538, R^2 of 0.202 and P-Value of 0.07. Similarly the winter precipitation has been decreasing at the rate of -2.02, R^2 of 0.032 and P-Value of 0.619 (Fig 4).

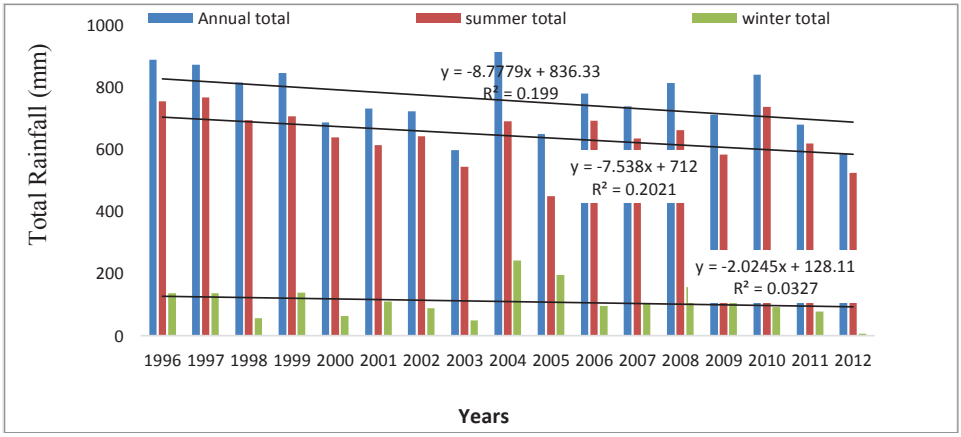


Fig 4. Rainfall trend at Chamkhar from 1996-2010

iv. Chamkharchhu River Flow

Based on the mean daily-observed discharge measurements the flow in the Chamkharchhu is decreasing in the summer with slope of-0.17, R^2 of 0.012, and P-Value of0.66. In winter the flow trend is increasing with slope of 0.161, R^2 of 0.125 and P-Value of 0.9, but the mean annual discharge is almost constant with slope of -0.002, $R^2$of 0.00 and P-value of 0.99 (Fig 5).

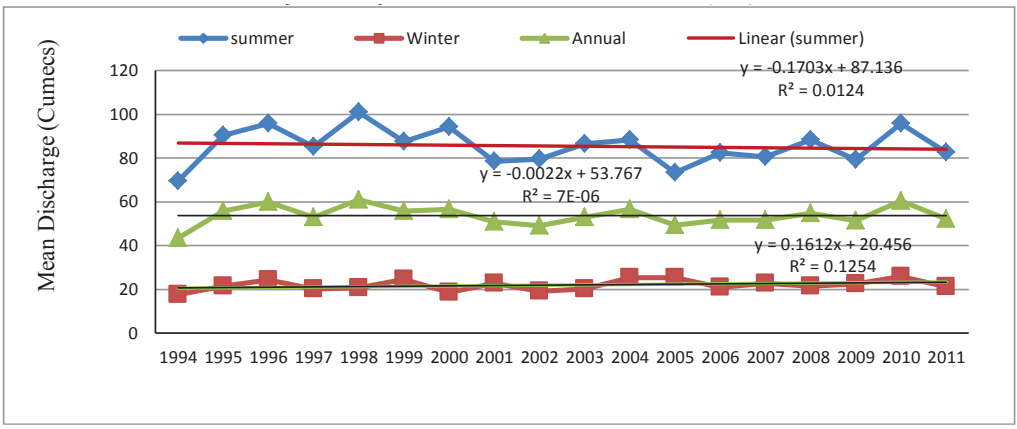


Fig 5.Flow trend of the Chamkharchhu from 1994-2011

v. Rainfall and Discharge Correlation

The correlation between mean annual Discharge at Kurjey on Chamkharchhu and the total annual rainfall observed at Chamkhar has been compared. It was found that the correlation is positive with a Pearson correlation coefficient of 0.60 and P-value of 0.0135, which is significant as shown below in Fig 1.

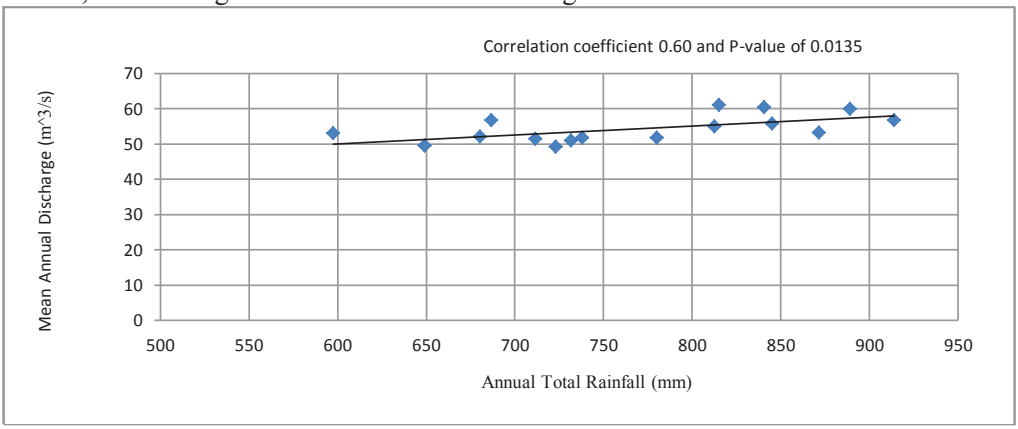


Fig 1.Correlation plot of Total Annual Rainfall and Mean Annual Discharge (1996-2011)

vi. Lean Flow in other tributaries

The spot lean flow measurements done annually during the winter from the adjacent smaller streams which are tributaries of the Chamkharchhu were analyzed and it was found that the flow in all the three stations of Chumey, Tang and Ura are more or less constant with very slight decrease in winter at the rate of 0.04 for Tang with R^2 of 0.12, 0.003 for Chumey with R^2 of 0.002 and 0.001 for Ura with R^2 of 0.013 (Fig).

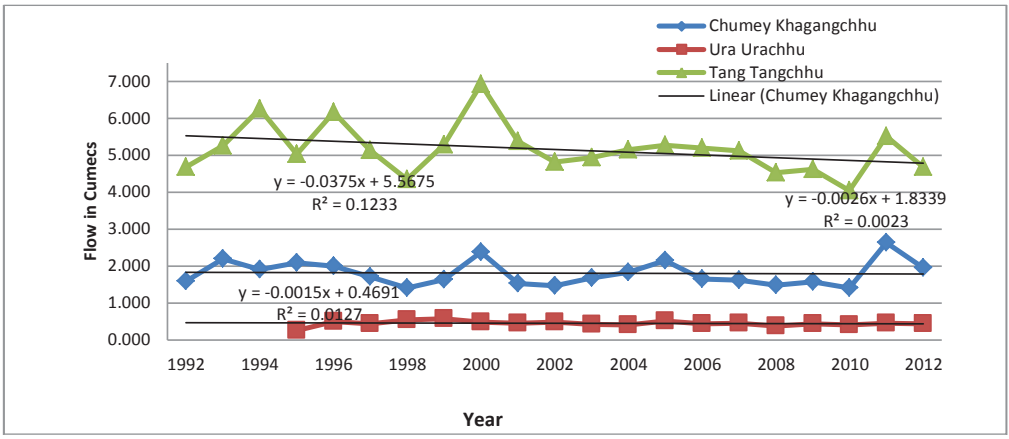


Fig7. Lean Flow Trend on tributaries from 1992-2012

The lean flows from the tributaries have been correlated to the main Chamkhar Chhu river flow and it has been found that the correlation is negative for Tang and Chumey, but positive for Ura, but the p-values are above 0.05 and not statistically significant as shown below in Table 2.

Table 2 Correlation of river flows (1996-2011)

Rivers	**Correlation Coefficient**	**P-Value**
Chamkhar Chhu and Tang Chhu	-0.032	0.903
Chamkhar Chhu and Ura Chhu	0.071	0.787
Chamkhar Chhu **and Chumey** Chhu	-0.083	0.752

3.3 Household Survey Results

A total of 100 households were interviewed through the key informants in the Chamkhar valley, which consisted of 65% male and 35% female respondents. The key results from the interviews are as below

i. Climate Change Awareness

About 26% of the respondents believe that they understand Climate Change, 28% sort of understand it, 21% just heard about it and rest are not sure or never heard of Climate Change. However, overall more than 85% of the respondents believe that Climate Change is happening (Fig. 8).

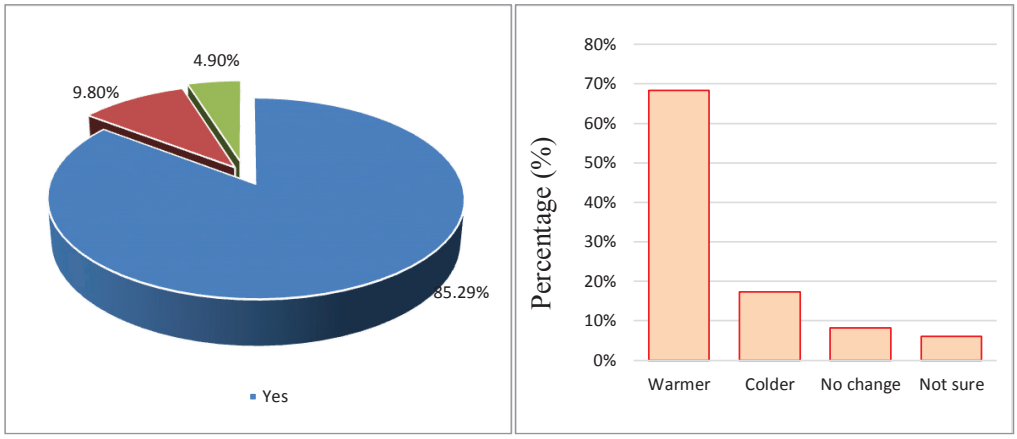
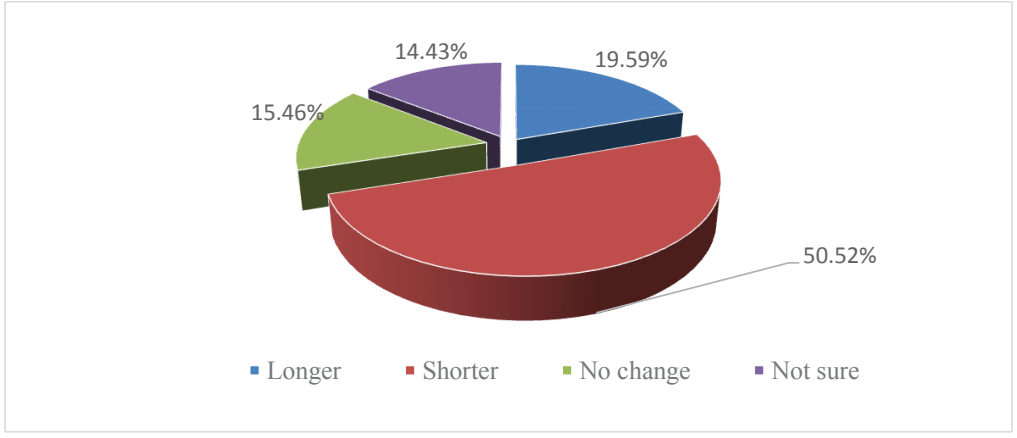


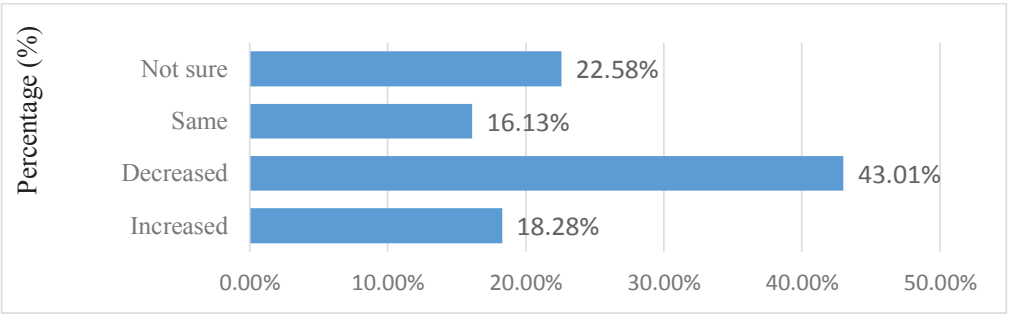
Fig 8 and FiG 9 Perception of winter temperature over last 20 years

ii. Temperature and winter change

It was found that 91% of people surveyed experienced that overall temperature is increasing while the rest felt it was same (4%), decreased (2%) and no idea (1%). It was also confirmed that the winters are becoming warmer with more than 68% of respondents saying that, while 17% also mentioned it is getting colder and others are not sure or not experiencing any change (Figure 8)

More than half (51%) of the respondents also stated that winters are becoming shorter, while 20% said they are becoming longer and the rest (29%) are not sure or see any change.



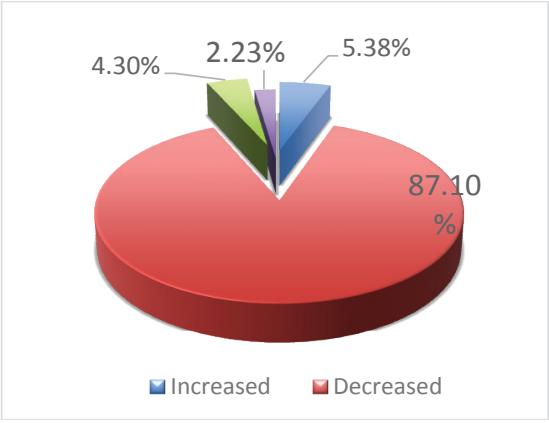


iii. Rainfall and Snowfall change

More people (43%) perceive that overall rainfall has decreased, while 18% felt it is increasing and 38% are not sure or did not see any change (Fig 9.

Fig 9.Perception of overall Rainfall

A huge majority of people (87%) consider that snowfall is decreasing in Bumthang, while 5% remark it is increasing, 4% said it is same and 2% are not



3.4 Association on Climate Change awareness

An association tests was conducted to determine the correlation/association between Education and Age to knowledge on Climate Change using Pearson's Chi-squared test. The P-value is greater than 0.05 in both the cases and the null hypothesis that there is no association is accepted and confirmed that there is no association between both Age and Education to Knowledge on Climate change i.e., the literacy on climate change is less known to both old or young and Education or uneducated. (Confidence level=95%).

	Climatechange	
Education	Yes	No
Yes	15	43
No	9	33

```
Pearson's Chi-squared test with Yates' continuity correction

data: M
X-squared = 0.0757, df = 1, p-value = 0.782
```

```
       Climatechange
Age    Yes    No
<40    16     51
>40    6      20
```

```
> chisq.test(M)
Pearson's Chi-squared test with Yates' continuity correction

data: M
X-squared = 0.0361, df = 1, p-value = 0.8493
```

4 Discussion

Chamkhar Chhu basin is an important basin in Bhutan that is susceptible to Climate Change impacts including flooding as one of the few river valleys in Bhutan along with substantial socio-economic infrastructures like airport, national highways, hospitals, schools and settlements close to the river. It is also important due to the presence of risky glaciers and glacier lakes in the upstream, planned hydro-power projects downstream(DGPC, 2013) and due to the vulnerability of the Chamkhar area which is not very well protected on certain parts as determined by the study in 2012 with 59% of the banks surveyed on 10km stretch being eroded.

It has been established that the glaciers on the northern parts of Bhutan in general and in the Chamkharchhu river basin in particular, have decreased by -26.37 Sq.km over 30 years (1980-2010) and the mean elevation of glaciers have increased by 39 masl and the snow covers are decreasing (-3.27%) from satellite imagery studies(Gurung et al, 2011). The survey respondents of the Chamkhar valley who responded with a resounding 87% stated that snowfall in the area has decreased. This is a very good indication that decreasing snowfall and melting of glaciers are the impacts of climate change in the Chamkharchhu river basin felt by people living in the valley.

Both the maximum and minimum temperature in the area are also increasing for all seasons and on annual average. This also conformed to the perceptions of local people as many as 91% of the respondents citing that it is becoming warmer now. Similarly, 68% of the respondents also mentioned that the winter temperatures over the last 20 years have been increasing. More than half, 51%, also expressed that the cold winters are becoming shorter. Both the physical observations at the site in Chamkhar and people's experience are very much in agreement and confirming that climate change in the form on rise in temperature in the valley is already being experienced.

The total annual and seasonal precipitation in the Chamkharchhu river basin is decreasing at the rate of -2.0 to -8.77 for all the seasons that are also in conformity to 43% of the respondents saying that the total rainfall in the valley has decreased. Although the total precipitations are decreasing at the above rates, the river flow in the Chamkharchhu is decreasing only at the rate of -0.002 and -0.170 for mean annual discharge and summer

flow respectively, while it is increasing for the winter at the rate of 0.161. The correlation between annual average flow of Chamkharchhu and total annual rainfall at Chamkhar is 0.60 with P-Value of 0.0135, which is lower than 0.05 and statistically significant. This indicates that there is a significant relationship between the rainfall and flow, which is obvious as flow is only due to rainfall, but the correlation is not very strong indicating that the increased flow is perhaps due to melting of the glaciers in the northern regions of the basin and other sources, not just due to rainfall.

Similarly the analysis of the lean season flows on the major tributaries of the Chamkharchhu from Tang, Ura and Chumey shows that the lean flows in all these tributaries are decreasing over the period of 17-20 years while the winter flow in main Chamkharchhu is very slightly increasing. The correlation between the main Chamkharchhu flow and the tributaries are not strong (-0.083to 0.07) which could be due to the difference in their catchment size and characteristics. It should be noted that the lean flow measurements are made in Jan/Feb during the most lean season of the year, whereas the winter flow of the main Chamkhar Chhu consists of average flow in the months of Jan-April and Nov-Dec, so the main Chamkhar Chhu winter flow could be increasing due to higher melt contribution from glacier/snow that could be increasing for the warmer spring and autumn months. This is in concurrent to a study done in the neighboring basin of Mangdechhu by a team from USA and Hydro-met whereby they found that the Bhutanese Himalayas are melting due to energy imbalance (Rupper et al, 2012).

5 Conclusion

The study has confirmed that the Chamkharchhu river valley which is an important cultural, economical link and agricultural district with many infrastructures in the river valleyis both at risk and has the potential for contribution to the socio-economic development of Bhutan. Although only a handful of people (26%) clearly understood Climate Change and only 21% heard about it, the changes are expressed by more than 85% of respondents. Any connection of understanding of Climate Change to gender, age or education level was not visible. People are also experiencing warmer (68%) and shorter winters (51%) with decreased snowfall (87%) and decreased rainfall (43%).

All these perceptions and experiences of the local people are in concurrent with previous studies in other parts of the country and very much similar to the analysis of hydro-meteorological parameters that has been observed in the area which proved increase in temperature, increase in the main Chamkhar Chhu river flow, decrease in glacier areas and snow cover and decrease in total rainfall over the period of 15-20 years of observation period. A correlation of 0.60 was also found between the total annual rainfall at Chamkhar and annual average discharge for Chamkhar Chhu, which indicates that the rest 64% of the river flow is due to other sources than rainfall in the area. The correlation between the average annual flow of main Chamkhar Chhu river and the spot lean season flow of its major tributaries of Tang Chhu, Ura Chhu and Chumey shows that the correlation is negative for Tang and Chumey, but positive for Ura.

It is very clear that people in the Chamkhar Chhu river basin are already experiencing Climate Change and proven with physical observations. While the recent floods in the valleys were minor, there is potential for future hydro-meteorological hazards and other

impacts of Climate Change that could affect the local people. It is therefore, important to ensure that necessary mitigation and adaptation measures are planned and implemented accordingly in the basin. Appropriate planning and incorporation of the current and similar results should also be made by relevant planning agencies such as the airport authority, municipality, district and hydropower planners. Planning and implementation of Integrated Waster Resources Management principles is also necessary as indicated in the Bhutan Water Act of 2011.

While it is evident that Climate Change is happening in the valley and experienced by the local people which is a very reliable cross-verification, it should be noted that most of the field survey were done within a span of 5 days in 2012 without a proper sampling procedure and untrained student researchers. The limitations in understanding of the snowpack and glaciers in the region is also serious one as some of the inference drawn from the study is based on satellite imagery. It will also be worthwhile to analyze the rainfall data from the sub-basins of Chamkhar Chhu and compare the overall data with some adjacent basins of Bhutan.

Acknowledgement

All of the field data collection for this study has been carried out by wonderful students of the SFS Bhutan 2012, Water Group, through the School for Field Studies (SFS), USA and Ugyen Wangchuk Institute for Conservation and Environment (UWICE), Bhutan Summer Program, my sincere thanks goes to all of them. I would also like extend my sincere acknowledgement and appreciation to all the students of SFS-UWICE 2012 program, the SFS faculty and staff, and faculty and staff of UWICE. The financial support provided by SFS for conducting the Directed Research at Bumthang is highly appreciated as well. I would also like to extend my gratitude to the Department of Hydro-Met Services and my colleagues at DHMS for all the flexibility and cooperation provided to us for working on the SFS 2012 program and writing of this paper. I would also like to acknowledge the support and help received from my colleague Ugyen Chophel for helping me with the statistical analysis and inferences.

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Impact of Integrated Conservation Development Programme (ICDP) on the Livelihoods and Biodiversity Conservation in the Wangchuck Centennial Park, Bumthang

Tshering Dendup[1]

Abstract

Integrated Conservation and Development Programme (ICDP) has been found as an effective mean to harmonize the socio-economic and conservation needs of the local people through promotion of eco-tourism avenues, fostering infrastructure and human capacity development amenities. The study undertaken in Wangchuck Centennial Park (WCP), showed that the ICDP had positive contribution towards improving local livelihoods and biodiversity conservation. Majority of the communities in WCP, held favourable attitudes towards the ICDP on biodiversity conservation and this could be attributed to effective dissemination of awareness on biodiversity conservation during project intervention. Additional care should be to taken to include participation from more poorer households and younger generation in the future implementation of the ICDP.

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Keywords: : ICDP, biodiversity conservation, farmer attitudes, WCP, Intervention livelihood

1. Introduction

The conservation and socio-economic development in the protected areas pose the greatest challenges to conservationists. They have been generally figured as antithetical alternatives (Alpert, 1996) and that it is difficult to strike critically balanced win-win situations as conservation project brings development benefits with protection costs to local communities and that sometimes the costs outweigh the accrued benefits. Over the recent decades, a paradigm shift of conservation strategy from the protectionists to people-oriented approaches (Garnett *et al.,* 2007) has given birth to an integrated and holistic mechanism that equates and reconciles development and biodiversity conservation (Abbot & Thomas, 2001) in the name of Integrated Conservation and Development Programme (ICDP).

ICDPs are designed on the premise that poverty is the main threat to biodiversity and by providing development opportunities to local communities will reduce pressure on park resources (MacKinnon, 2002) and that diversified options (e.g. alternatives to natural resources dependency) will lead to improved biodiversity conservations. The term ICDP was first used in the Luangwa Valley Integrated Conservation and Development Project jointly undertaken by FAO and the Government of Zambia in the mid-1960s (Garnett *et*

[1]*Corresponding author: Wangchuck Centennial Park, Bumthang*

al., 2007). However, the concept of ICDP approach first came into vogue in early 1980s (Richard, 2001; Boker & Gurung, 2006) introduced by the World Wide Fund (WWF) for Nature (Hughes & Flintan, 2001) in Ngorongoro Conservation Area in Tanzania Africa (Newmark & Jhon, 2000). There are over 300 ICDPs world-wide (Hughes & Flintan, 2001).

In Bhutan, the concept of ICDP was first conceived in 1998 (Wangchuk, 2008) and was implemented in Thrumshingla National Park through support of WWF. Since then, many parks in the country have started to implement the programme to harmonize the socio-economic development and the conservation goals in the protected areas (primarily protected areas with people). In 2008, WCP started to implement the ICDP interventions. The intervention covered five geogs out of nine that fall within the jurisdiction of the park. However, it has not conducted evaluation to document the contribution of ICDP to people's livelihoods and biodiversity conservation. Therefore, the objective of this study was to assess the contribution of ICDP to the livelihoods of local residents and biodiversity conservation in WCP by documenting the local people's attitudes towards ICDP and biodiversity conservation during the five-year ICDP implementation.

2 Materials and Method

2.1 Study Area

The study was conducted in four Dzongkhags (administrative jurisdiction) of Bumthang, Wangduephodrang, Trongsa and Lhuentse spreading over total of nine Geogs (Chokhor, Tang, Sephu, Dangchu, Kazhi, Nubi, Khoma, Gangzur and Kurtoe) under three ranges in WCP.

It is located at 27.45°N and 90.45°E. Major vegetation in the study area comprises of cool broadleaved, mixed conifer (hemlock and spruce), fir and juniper forest, alpine meadows, scrubs and screes with elevation ranges from 2700 m to beyond 5000m (Wangchuk, 2008). The records show about 244 species of vascular plants, 23 species of large mammals and 134 species of birds (DoFPS, 2012). The species not reported elsewhere in Bhutan, the Tibetan wolf (**Canis lupus chanco),** that has a high conservation importance is found confirmed in the park.

There are a total of 1601 households with 10,388 people (Office of the WCP, 2012) residing inside the park. The most of the occupants within the park, except in the Lhuntse and Trongsa Districts are primarily agro-pastoralist nomadic herders and mostly depend their livelihood on the livestock products and collection of high value Non-Timber Forest Products (NTFP) like *Cordyceps sinensis*.

2.2 Data collection

The research was conducted during January–February 2013. The primary qualitative data was collected through household questionnaire survey. The secondary data were obtained by informal interviews with key local informants and park staff. The review of project records and other published literatures like By-laws of Women Weavers' Association and Business plan of Alpine Organic Farmhouse Co-operative helped to provide additional insights into understanding the management issues of different ICDP interventions to local communities.

The survey was conducted in 498 randomly-selected households. The households were selected using the random number generator in MS Excel to avoid subjective bias. Stratified quota sampling was employed to ensure a representative proportion of respondents. The updated list of household names obtained from the Gup's office of the respective geogs formed the sampling frame. The three field rangers of WCP assisted the data collection works. They were briefed on the questionnaires before the actual conduct of the survey to avoid misinterpretations.

The survey team faced difficulties due to unavailability of participants during day time. In most cases, the participants were made to gather in the evenings at Tshogpa's house and the RNR office with the help of the geog leaders and the extension agents. In some cases, the survey was conducted by visiting individual households. Most of the questions were close-ended where respondents selected from a predetermined list of response categories.

2.3 Data Analysis

The field data were decoded and entered into MS Excel sheets and exported to analyze in the Statistical Package for the Social Sciences (SPSS) Version 16.0. The variables of three-, four-, or five-point scales were collapsed to form dichotomous responses based on the negative and positive point scales. Demographic variables were dichotomized into a dummy (indicator) variable by using the median score of the scale. *For example, the gender of the respondent was coded 1 if male and 0 if female; 1 if the age is ≤ 44 years and 0 if the age is > 44; 1 if the response is positive and 0 if negative; and 1 if literate and 0 if not*. Logistic (also logit model) regression was performed to determine whether predictor variables such as gender, age, education, household size, income, cattle and land holding influenced respondents' perceptions towards the ICDP interventions

3 Results and Discussion

3.1 Socio-demographic characteristics

The gender breakdown of the sample was 172 men (34.5%) and 326 women (65.5%). Table 1 shows the breakdown of demographic characteristics of respondents with ICDP intervention and without intervention. The median age of the respondents was 44. The average family size was 7 with mean income of Nu.6,000 (six thousand). The mean land holding was 2 acres with livestock of 6 heads.

Around 87.0% of respondents were illiterate, defined as those who had never attended any formal or adult literacy education against 13.0% literate; those who could at least read and write in Dzongkha. The respondents who had basic non-formal education (NFE) in Dzongkha were included as literate. Ninety two percent (n=458) of the respondents were farmers by occupation while 4.2% (n=21) were students. Others comprised of employees (2.8%, n=14) and businessmen (1.0%, n=5)

Table 1. Demographic characteristics in the study area (percentages in parentheses) *N*= 498

Characteristics	Intervention count (Percent)	No intervention count (Percent)	Total count (Percent)
Gender			
Male	93 (30.0)	79 (42.0)	172 (34.5)
Female	217 (70.0)	109 (58.0)	326 (65.5)
Age			
≤ 44 years	177 (57.1)	118 (62.8)	295 (59.2)
> 44 years	133 (42.9)	70 (37.2)	203 (40.8)
Education			
Literate	41 (13.2)	24 (12.8)	65 (13.1)
Illiterate	269 (86.8)	164 (87.2)	433 (86.9)
Livestock holding			
≤ 6	195 (62.9)	90 (47.9)	285 (57.2)
> 6	115 (37.1)	98 (52.1)	213 (42.8)
Family size			
≤ 7	227 (73.2)	94 (50.0)	321 (64.5)
> 7	83 (26.8)	94 (50.0)	177 (35.5)
Land holding (acre)			
≤ 2	148 (47.7)	89 (47.3)	237 (47.6)
> 2	162 (52.3)	99 (52.7)	261 (52.4)

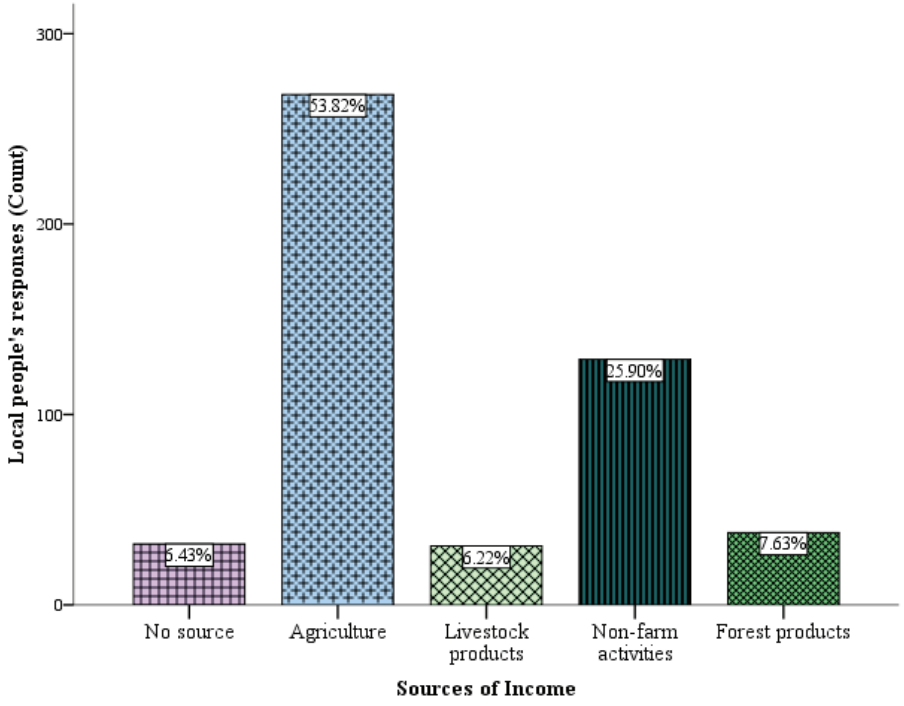

Figure 2. Different income sources of the respondents

The income was derived mainly from sale of agriculture products like rice, vegetables, chili and potatoes. Non-farm activities (contract and portering, business and shops, weaving, salary, carpentry, farm house and sale of bamboo products) and sale of livestock products formed other sources of income (Figure 2). The respondents owned 66.9% of local cattle with 14.9% of cross bred cattle (Jersey and Brown Swiss cross) and 5.4% yaks. Thirteen percent did not own any cattle.

3.2 Local people's knowledge about ICD Programme

Since the intervention coverage of ICDP was limited to the selected geogs of Bumthang, Lhuntse and Wangdiphodrang Dzongkhags (five geogs out of nine), many people did not know about the project interventions. Posters and signage, and meetings with park staff served as the best media for the dissemination of knowledge on the project interventions (Table 2).

Table 2. Local people's knowledge about ICDP intervention

Know		Known from (%)	
	Percent	Park staff	Relatives/ Neighbours
Know	41.0% (*n*=204)	28.1% (*n*=140)	13.1% (*n*=65)
Didn't know	59.0% (*n*=294)		
Total	100% (*N*=498)		

Logistic regression statistics (Table 3) revealed that local people's knowledge regarding ICDP was more likely to be associated with females ($p < 0.01$) and older people ($p \leq 0.05$) attributing to the fact that females attended more public meetings than males since the latter more often had to attend to off-farm activities like contract and portering works (personal conversation, 2013).

Table 3. Logistic regression of relationship between demographic variables and knowledge of community on ICDP intervention (*N* =498). *B* = Logistic regression coefficient, SE = Standard error, Wald = Wald statistic (which has a χ^2 distribution), p = significance (*= $p < 0.05$, **= $p < 0.01$, *** = $p < 0.001$).

						95.0% C.I. for EXP(B)	
Variables	B	S.E.	Wald	p	Odds ratio	Lower	Upper
Age (≤ 44)	-.385	.199	3.744	.053*	.681	.461	1.005
Gender (male)	-.591	.206	8.190	.004**	.554	.370	.830
Education (literate)	.052	.292	.031	.859	1.053	.594	1.866
Family (≤ 7)	.344	.199	2.975	.085	1.411	.954	2.086
Land (≤ 2acre)	-.162	.187	.747	.387	.850	.589	1.228
Cattle (≤ 6)	-.204	.194	1.105	.293	.816	.558	1.193

The direction of each independent variable is indicated in parenthesis (variables column) and the sign of the coefficients (B) shows whether associations with that value in parenthesis are positive or negative.

3.3 Attitude towards forest conservation

The forest resources that local people mainly rely on were timber, fuel wood and high value Non-Timber Forest Produces (NTFPs) particularly *Cordyceps sinensis* primarily for those living in the higher altitudes above 3000 m. The majority of respondents held positive perceptions towards importance of forest conservation (97.8%, n=487). The attitudes towards conservation were attributed to importance of timber and firewood (44.0%), source of revenue (11.8%), collection of NTFPs (11.4%) and environmental importance like soil protection, water recharge, clean air and watershed protection (18.1%). Other respondents acknowledged the importance to wildlife conservation (2.4%) and preservation of nature (8.8%) as a legacy to the future generations and, cattle grazing (1.0%).

3.4 Attitude towards Integrated Development activities

The general spatial coverage of the intervention is 55.6% by the number of geogs (five out of nine geogs) with 310 households (more than 62.0%) out of 498. Roughly 26.0% of the respondents in the areas with ICDP intervention had positive opinions because only a few received an equitable share of the economic benefits arising from the intervention. Less vocal and poor people appeared to be excluded from the benefits as resubmitted by respondents elsewhere in Bumthang dzongkhag.

The logistic regression revealed that the older respondents above 44 years ($p < 0.05$) and family size less than or equal to 7 ($p < 0.05$) had positive attitudes towards ICDP. Often elderly members (especially female) from the households attend most of the meetings and understand the benefits better; and are those who availed project sponsored training opportunities ($p < 0.001$). Mehta & Heinen (2001) also made a similar observation in Anapurna Conservation Area (ACA) in Nepal which states that people who got trainings through financial assistance from project possessed positive attitudes towards conservation. The family size ≤ 7 was two times more likely than larger family size (> 7) to have favouring opinions towards the integrated programmes because better understanding within the smaller family facilitates consensual decisions to avail project supports easily like CGI sheets which are also consistent to the findings by Katel & Schmidt (2011) that mentioned smaller families had got project aids in form of CGI sheets in Jigme Singye Wangchuck National Park .

3.5 Attitude towards wildlife conservation

People in and around the park invariably confront perennial problem of human-wildlife conflicts such as livestock depredation by wild animals (tiger, leopards and bear) and crop damages due to wild pests (wild boars, barking deer, sambar and porcupines). Similar findings were also reported by (Spierenburg & Namgyal, 2002) in Jigme Singye Wangchuck National Park where livestock depredation and crop damage by wild pests

was noted high. Further, the hardship of guarding (50.4%) their crop fields and keeping their cattle inside the shed in the nights were faced by the farmers as concurrent to the findings of Choden & Namgay 1996 as cited in Wang *et al.,* (2006) that guarding, which is mostly done at night, costs farmers untold hardships, additional expenses and possible personal injury.

7.6% of the respondents desire for extermination of the problematic wildlife in order to curb the human-wildlife conflict. (Figure 3). This conforms to the findings of Wang *et al.,* (2006) who mentioned that the majority of respondents from both the literate and illiterate groups supported extermination, indicating the seriousness of wildlife conflicts.

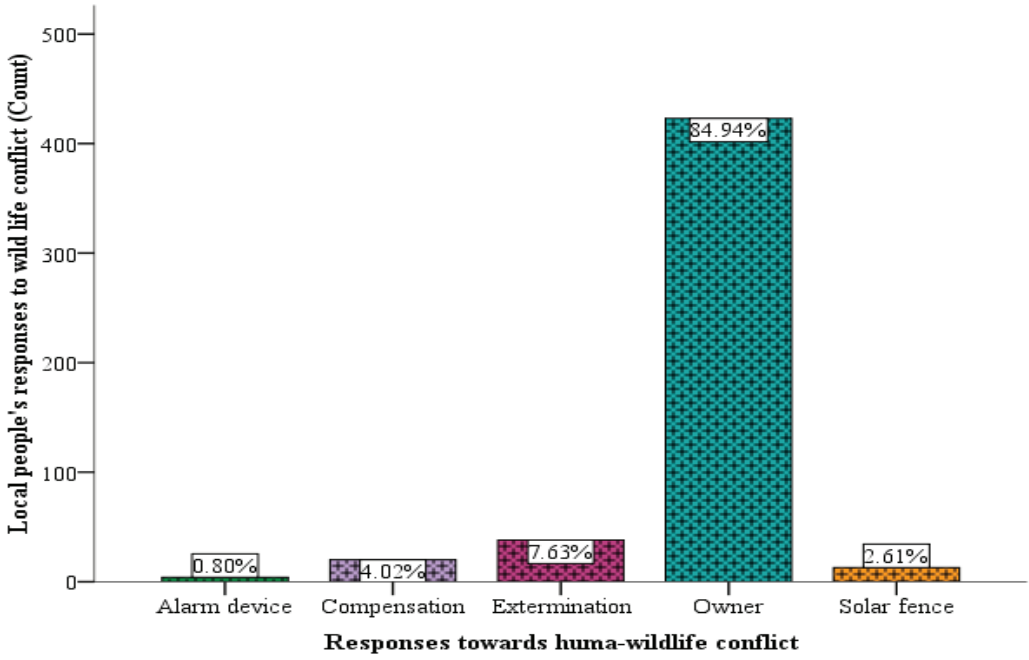

Figure 3. Responses towards human-wildlife conflict

The results of logistic regression (Table 4) established that the family size with less than or equal to 7 ($p < 0.001$) expressed the desire to exterminate problem animal attributing to the location of their agriculture fields either at the edge or inside forest, making more prone to the wildlife depredation and increased pressure on less family members. This concurs to the hypothesis by Mehta & Heinen (2001) that when people could not afford economic loss from wildlife damage, they wanted to kill wild pests and tend to hold less favourable attitudes towards wildlife conservation.

Table 4. Logistic regression of relationship between demographic variables and attitudes of local people towards extermination of problematic wild pests (N =498). B = Logistic regression coefficient, SE = Standard error, Wald = Wald statistic (which has a χ^2 distribution), p = significance (*=p<0.05,**= p<0.01, *** =p<0.001)

Variables	B	S.E.	Wald	P	Odds ratio	95.0% C.I. for EXP(B)	
						Lower	Upper
Age (≤ 44)	.022	.393	.003	.956	1.022	.473	2.205
Gender (male)	-.607	.409	2.209	.137	.545	.245	1.214
Education (literate)	.915	.453	4.076	.043*	2.498	1.027	6.074
Family (≤ 7)	1.334	.466	8.205	.004***	3.798	1.524	9.463
Land (≤ 2acre)	-.494	.359	1.889	.169	.610	.302	1.234
Cattle (≤ 6)	-.910	.359	6.414	.011**	.403	.199	.814

3.6 Attitude towards livestock compensation scheme

Roughly 45.0% of the respondents knew about the scheme with only 6.5% considering it as efficient (defined as timely and cash worth equal to livestock killed) in delivery of compensation to the farmers effectively. Most of the respondents (93.3%) possessed negative perception towards the scheme. The findings by Wang et al., (2006) also exerted that the current ICDPs compensation schemes were unable to offset the sacrifices local people made, and that the scope of programmes needed to be expanded.

Besides its limited spatial coverage in five years, the scheme compensates only the charismatic faunas like tiger and leopards while the loss incurred due to predation by bear on heifers and calves were more apparent especially in Bumthang Dzongkhag. Lack of expeditious mode of paying off the compensations; which is also concordant to the findings of Dorji (2009) was other reason for less appreciation of the scheme.

3.7 Attitude towards Ecotourism

One component of eco-tourism is promoting farmhouses (rural home-stay guest houses) that offer the communities with opportunities to enhance their livelihoods through income generation amenities. Local people (64.3%) had benefitted through rents (lodging and catering) and sale of local hand-woven products such as *yathras* and livestock products (cheese and butter) and exchange of cultures with visitors.

The logistic regression revealed that there was a strong association between the benefits derived from the farmhouse and the monthly income (p < 0.001) and the family size (p < 0.01). The respondents with smaller family (≤ 7) and those earn monthly income of Nu. 6,000 and more were more likely to have positive perception towards ecotourism (farm houses). It is true to the fact that the houses that are leased out as farmhouses are large and spacious. Field observation chanced upon that these houses remain empty due to less number of family members thus rendering fit to be converted as home-stay guest houses.

Ninety five percent (n=44) of those who held high supports for eco-tourism (restoration of historic sites and cultural trails) derived their direct cash benefits from portering which is consistent with the findings of Mehta & Killert (1998) who states that nature-based tourism, however little, provide much needed economic support.

Another element of ecotourism, nomadic festival provides opportunities to highlanders to gather together and showcase their locally produced products and handicrafts. Renting farmhouses (8.3%) and catering local cuisines to the visitors (53.6%), showcasing the country's rich culinary arts and traditions (2.4%), and exchange of cultures with the visitors also came as part of eco-tourism avenues. Community elites revealed in the interview that an average of Nu. 50,000 (fifty thousand) could be earned by the people who installed hotels and farmhouse owners.

The logistic regression results depicted that there was a significant association between the attitudes towards nomadic festival and family size ($p \leq 0.001$) attributing to the fact that the larger family size (> 7) had enough labour force to contribute to income generating activities through stalls and temporary employments like local guides.

3.8 Attitude towards Capacity Building

The project has provided trainings and educational opportunities to local people to build up human capacity like training nature guides, supply of improved churning machines and formation of weavers' association. Close to 60.0% (n=50) of people had benefitted from the training on nature guides. Roughly 50.0% (n=43) derived benefits from supply of churning machines. The improved churning machine had reduced the churning time duration by 1 hour per churn compared to the traditional way. They churn once in 2-3 days.

As a part of capacity development, formation of Women's Weaving Association had provided self employment opportunity. The focused interview with the chairperson of the association established that minimum net profit of Nu. 100,000 (One hundred thousand) could be realized per annum. Similar success stories from Nepal also show that formation of Mothers' Group had helped in generation of self-employment to poor women in the remote areas of Anapurna Conservation Area (ACA) (Boker & Gurung, 2006).

3.9 Attitude towards Community Services Development

The community services like supply of drinking water and CGI were the main activities taken to the local people to reduce pressure on local resources and to improved livelihoods.

Eighty eight percent (n=38) of the respondents interviewed reported that the facilities of safe drinking tap water had benefitted them very much and eased their lives from the drudgery of daily fetching drinking water from the stream. Close to 97.0% (n=57) of the interviewees mentioned that supply of CGI as a very good way to reduce dependency on the local resources. Every family needs at least five to ten large trees for shingles in three

to four years (Wangchuk, 2008). Approximately 70.0% of the respondents were in agreement that this initiative would assist conservation of the forest trees through reduction of demands for shingles.

The result of the logistic regression showed a significant relationship between community services taken to the people and the demographic variables such as gender ($p < 0.01$). It depicted likelihood of female respondents to have better perceptions towards the community development activities than the male respondents. It could be attributed to the reality that most often female members attend meetings called in by the park officials and know more about the interventions.

Literate respondents and fewer family members (≤ 7) were more likely to hold positive attitudes towards the community development efforts. Similar results were also discovered by Katel & Schmidt, (2011) in JSWNP that smaller families could easily get the community development services (e.g. CGI sheets) since it is easier within the smaller families to reach an agreement on any issues of discussion. It is also likely that literate respondents comprehend better about the relationships bewteen the social development and the biodiversity conservation.

4 Conclusion

In general, the local people's attitudes towards integrated development programme (ICDP) including human capacity development, local community services and promotion of eco-tourism activities were positive (26%). This indicates that trainings and other incentives related to conservation, when provided fairly, works well in development of favourable attitudes towards biodiversity conservation. Further analysis showed that demographic variables like family size, income level, gender, literacy rate and age determines peoples 'perceptions towards the ICDP interventions. It appeared that rich, literate, elderly, female dominated and small family- sized households had positive attitude towards ICDP, indicating that project benefits (e.g. Community capacity building and services) were skewed towards such households during the past project intervention. In future, planning, ICDP program could be inclusive of pro-poor, illiteracy, elderly and gender disparity, so that all categories of individuals, households and communities could participate and reap the benefits of the programme. Majority of respondents (97.8%) were aware of the importance of forest conservation despite high illiteracy level (84.0%), substantiating that ICDP had provided enough awareness campaigns on conservation aspects to the general public. Hence, the awareness campaign should continue to be one of important activities in the ICDP.

Wild animals cause crop and livestock depredation incurring heavy economic losses to farmers and impose unfavourable attitudes towards wildlife protection. Literate respondents seemed to exhibit more favourable attitudes towards wildlife conservation indicating the importance of education and awareness. Although , more than 50.0% opted guarding their fields as main curbing mechanism for the economic loss due to wildlife damage, 7.6% desires to opt for extermination of problematic wild pests. Many respondents (93.0%) of showed negative attitudes towards the economic compensation

scheme, indicating that the present compensation scheme within ICDP need to be reviewed and revised.

The study revealed that eco-tourism benefitted the larger and richer family size, as they have more opportunities to attend to other off-farm activities like portering and employ as guides with tourists. Small and poor families should be made to benefit by local ecotourism initiatives through promotion of farmhouses (renting and catering, sale of local goods to tourists) and restoring and showing cultural trails and sites..

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Assessing Local Factors to Vitalize the Lemon Grass Oil Industry in Eastern Bhutan

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Abstract

A *structured questionnaire survey was administered in 20 villages of four geogs under two Dzongkhags of Monggar and Trashigang in 2011 to study the challenges of the lemongrass oil industry and how the industry could be improved to boost farmers' income. The study focussed on farmers' problems in oil production, forest fires, knowledge about management practices, decline of oil production and the support provided by the government to the industry. The study showed that the lack of labour supply appeared to be the greatest problem besides fire-wood shortages in the distillation units. A good coordination was required among the various government agencies providing services to the oil industry. Alternative source of fuel wood for distillation processes was required. It is envisaged that farmers would eventually face shortage of lemon grass due to frequent forest fires and large unproductive cattle grazing in the area. There are persistent problems of oil market and marketing. Every year there is excess product not sold due to absence of market. The lack of interest of the farmers themselves and low prices fetched by the oil product are attributed as the main causes for the decline of the industry. The lack of timely rainfall and shortage of water and fuel wood were stated as some other problems leading to the industry's decline. The farmers have yet to build the overall management capability and remained dissatisfied with the support received from the government in capacity building. Therefore, the government is expected to continue to play the key role in the lemon grass oil industry in Bhutan.*

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Keywords: : lemongrass, oil industry, environment, market, sustainable production, forest fire

1 Introduction

In the last 50 years of planned socio-economic development, Bhutan has progressed from a traditional farming economy to the precondition for fresh economic take off. Today, the government recognises that the promotion of the private sector is the most viable source of income and employment for the people. Towards this, the Ministry of Economic Affairs has put enormous efforts in facilitating and promoting Micro, Small and Medium Enterprises (MSME) in the country. The establishment of the cottage industries in eastern Bhutan, particularly that of the distillation of lemongrass oil (*Cymbopogon flexuosus*) industry has become a major source of income for rural communities in the eastern

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*Dzongkhag*s. During the 10th FYP, Creative Industries (CIs) and Micro, Small and Medium Enterprises MSME development was promoted as potential sources of income generation that benefit rural development and youth and women employment. MSME is labour intensive but it contributes to the economic growth through reduction of poverty in rural and sub-urban areas.

The establishment of the essential oils project under Monggar *Dzongkhag* became the major source of income for rural communities in the eastern *Dzongkhag*s contributing up to 30% to the annual income of about 2,000 people in the four eastern *Dzongkhag*s of Monggar, Trashigang, Luentse and Trashiyantse, where lemongrass grow abundantly in the Chir Pine forest (Budur *et al*., 2005; Lama, B., 2003; Mukhia, P., 2006; Namgyel, P., 2005 in Yangzom *et al* 2008). The lemongrass is the primary raw material for extracting essential oils. In the late 1980s, His Majesty the Fourth King commanded to expand the scope of distillation plants in eastern Bhutan. In 1990 the FAO-supported project, "Production of Essential Oils by Small Holders in Remote Areas," was operationalized and two essential oil distilleries were established with the capacity to process 2.5 tons of lemongrass per eight-hour working day. The project also helped in establishing germplasm and multiplication nurseries at Gyelpoizhing and Chhali, both under Monggar *Dzongkhag*, using plant materials from India and Europe (FAO, 1996).

A complexity of environmental and economic factors, including the decrease of grass and firewood resources brought about by unsustainable resource management and price competition from cheaper Indian oil, has led to a decline of lemongrass oil (LGO) production in Bhutan. Budur *et al*. (2005) in Yangzom *et al* (2008) pointed out that if clear management guidelines are not put into place, the industry will suffer within a couple of years and thus take away income opportunities of the distillers, firewood collectors and the mostly female grass collectors.

There are frequent disputes over land resources among private distillers (Dhungyel *et al*., 2009), and also forest fires are a frequent occurrence. While the local people believe that forest fires stimulate the growth of lemongrass, research findings indicate that they favour the growth of weeds such as *Lantana* spp. and *Stipa* spp. leading to declining yields of lemongrass (Dungyel, D. 2002; Budur *et al*., 2005 in Yangzom et al 2008). At the same time, forest fires lead to decline of firewood resources required for the distillation process. The other big challenge faced by the distillers of lemongrass oil is marketing. For producing quality oil, it is essential to create a favourable environment for the production. The world market for lemongrass oil is dwindling while Bhutan has to compete stiffly with Indian oil in the markets. One of the potential buyers from the United Kingdom (UK) has recently stopped importing oils, leaving the fate of our distillers in the hands of the small domestic markets.

The marketing of lemongrass oil was initially done by Tashi Commercial Cooperation, which exported to various places in India. The expansion to European markets began from 1990. The Primavera Company based in Germany, specialising in the import and distribution of aromatherapy products, was the first and only customer of the EODP for several years. Europe-based importers often complained that Bhutanese exporters do not correspond to the technical specifications, are not of a consistent quality and are often

wholly unsuitable for their purpose (CTA, 1999). Consequently, the MTI established a quality processing unit at Monggar and started exploring new markets, primarily in Western Europe. Bio-Bhutan, a local enterprise in Bhutan which specializes in product development and marketing of natural and organic certified products from Bhutan for local and international markets was involved in buying directly from the local distillers and exporting the organic certified LG oil.

1.2 Research questions

The study attempted to answer the following main question:
What are the reasons for the decline of the lemongrass oil industry and how can the performance of this industry be improved?

The following sub-questions were set to address the above question:

1. What are the key problems faced by the lemongrass industry?
2. How can the management practices of the farmers be improved to re-develop the industry in Monggar *Dzongkhag*?
3. What role should the government take to improve the competitiveness of the industry?

2 Materials and Method

The focus of the study was Monggar *Dzongkhag* but given the proximity of some of the LG growing villages of Trashigang, some of the samples chosen for the interview also included farmers from Trashigang *Dzongkhag*. A simple random sampling was administered and chose 35 sample farmers who were interviewed using a structured questionnaire. Out of these, only 31 farmers could be met for interviews. One response format was not useable and rejected. The survey was preceded by clearly instructing the interviewers how to conduct the interview. The data set was designed using the Statistical Package for the Social Sciences (SPSS) software for analysis. The Likert-type rating scales were used in the questionnaire administered for interviews.

The results of various response formats used were interpreted mostly in percentages (%). The variables measured through Likert-type rating scales formats were mostly interpreted in varying methods besides percentages. To draw the overall inferences of variables, interval mean mid-scores were calculated, based on the number of interval levels each rating scales were composed of, by using the following equation:

$$\text{Interval level} = \frac{\text{Highest level score} - \text{lowest level score}}{\text{Number of levels}}$$

The number of levels for the Likert-type rating scales was 5 in all the variables. The calculation of the interval levels and the mean interval scores were demonstrated individually for the respective variables being discussed subsequently under the result.

3 Results and Discussion

3.1 Personal characteristics of respondents

The number of samples for the study was 30 LG oil distillers from four *geogs* of Trashigang and Monggar *Dzongkhag*s. There were four farmers from Uzorong *geog* under Trashigang *Dzongkhag* and the rest were from Monggar *Dzongkhag*. A total of 20 villages were covered for the purpose of the study. From the total of 30 samples surveyed, only two of them were female respondents. The representation of male respondents is thus more than 93%. The age of the respondents ranged from 27 to 58 years. The maximum number of respondents was from Dremitse *geog* with 60% representation followed by Chaskar and Uzorong *geogs* with 23.3% and 13.3% respectively. Narang *geog* was represented by only one sample.

3.2 Problems faced in LG production

Table 1 shows the key problems measured including, shortage of LG resources, methods of harvesting, grazing, forest fire and its risks, fuel wood shortage, firewood collection, firewood affordability, water scarcity, labour supply, allocation of LG areas, coordination among stakeholders and, external / government agencies and their roles.

The result of the study showed that the lack of continuous labour supply at the time of LG oil distillation could be the greatest problem farmers are facing in the sampled areas. The statement, lack of continuous labour supply affect LG oil distillation, showed the highest mean (M=3.40) and an overall slightly agreement level as compared to the other statements. The percentage agreement also scored the highest 56.7% for this particular statement.

In order of importance through mean differences, the following statements were the other key problems encountered in the LG oil industry: farmers cannot afford to buy fire-wood from the contractors (M=3.14); there is uneven allocation of LG areas to different distillers (M=3.21); improper methods of harvesting LG have adverse effects on the quantity of LG production (M=3.10); there is the need for the various government agencies to synchronise their agenda concerning farmers involved in LG industry (M=2.80); there is always shortage of fuel wood during distillation process (M=2.70); and, shortage of lemongrass raw materials is the greatest problems faced by farmers (2.67).

All of these statements identified as problems to the LG oil industry received an overall 'slightly agree' rating and with standard deviation less than 0 for all statements indicated there were no significant deviation of opinions from the mean.

Table 1: Problems faced in LG oil production (n=30)

Sl. No.	Variable level	SA (%)	A (%)	Sl.A (%)	D (%)	S.D (%)	M	SD	OA-level
1	Shortage of lemongrass raw materials is the greatest problems faced by farmers	-	3.30	60.0	36.7	-	2.67	0.547	Sl.A
2	Improper methods of harvesting LG have adverse effects on the quantity of LG production	-	33.3	43.3	23.3	-	3.10	0.759	Sl.A
3	Open grazing by livestock reduces LG	-	-	48.3	51.7	-	2.48	0.509	D
4	Fire is the greatest risk to sustainable LG production	-	3.3	53.3	43.3	-	2.60	0.563	D
5	Forest fire is necessary for re-growth of LG	-	6.7	36.7	56.7	-	2.50	0.630	D
6	There is always shortage of fuel wood during distillation process	-	16.7	36.7	46.7	-	2.70	0.750	Sl.A
7	Collection of firewood from the open forests are not allowed by forestry officials	-	-	56.7	43.3	-	2.57	0.504	D
8	Farmers cannot afford to buy fire-wood from the contractors	-	41.4	31.0	27.6	-	3.14	0.833	Sl.A
9	Scarcity of water supply to cool distillation plants is a major constraint	-	-	55.2	44.8	-	2.55	0.506	D
10	Lack of continuous labour supply affect LG oil distillation	-	56.7	26.7	16.7	-	3.40	0.770	Sl.A
11	There is uneven allocation of LG areas to different distillers	-	42.9	35.7	21.4	-	3.21	0.787	Sl.A
12	Un-even allocation of land resources often lead to frequent disputes among oil distillers	-	-	56.7	43.3	-	2.57	0.504	D
13	There is lack of coordination among stakeholders engaged in LG oil production	-	3.3	43.3	53.3	-	2.50	0.572	D
14	There is the need for the various government agencies to synchronise their agenda concerning farmers involved in LG industry	-	10.0	60.0	30.0	-	2.80	0.610	Sl.A

Note: SA = strongly agree; A = agree; Sl.A = slightly agree; D = disagree; S.D = strong disagree; M = mean; SD = standard deviation; OA-level – overall agreement level

3.3 Forest fires in the LG growing Chir Pine forests

Table 2 shows the result of the study on forest fires in Chir Pine forests. According to the farmers, forest fires are perceived to be significant in their day-to-day lives. The result of the statement, forest fires are important to scare wild animals in order to protect the crops (M=3.17), showed that forest fires could be very useful to them. About 43% of the farmers plagued by the destruction of their crops by wild animals, agreed that forest fires are important to scare away wild animals. If the forest fires are useful to the farmers, then there could also be implications in the causes of the fires.

The statement, forest fires are set deliberately by farmers to establish grazing resources for cattle with the mean of M=2.90, showed 10% 'agree' and 70% 'slightly agree' rating, very clearly indicating that farmers are responsible for causing much of the destructive forest fires in the wild Chir Pine forests of Bhutan. This statement also received an overall agreement rating of the farmers that forest fires are deliberate.

The farmers also responded that forest fires are caused accidentally by human movements with 13.3% and 56.7% agree and slightly agree ratings respectively. An overall agreement rating was also received on the statement.

Table 2: Reasons for forest fire occurrence in Chir Pine forests (n=30)

Sl. No.	Variable level	SA (%)	A (%)	Sl.A (%)	D (%)	S.D (%)	M	SD	OA-level
1	Forest fires are set deliberately by farmers to establish grazing resources for cattle	-	10.0	70.0	20.0	-	2.90	0.584	Sl.A
2	Forest fires are important to scare wild animals in order to protect the crops	-	43.0	30.0	26.7	-	3.17	0.834	Sl.A
3	Forest fires are important to induce LG growth	-	-	53.3	46.7	-	2.53	0.507	D
4	Forest fires are caused accidentally by human movements	-	13.3	56.7	30.0	-	2.83	0.648	Sl.A
5	Forest fires happen naturally during dry season	-	3.3	30.0	66.7	-	2.37	0.556	D

Note: SA = strongly agree; A = agree; Sl.A = slightly agree; D = disagree; S.D = strong disagree; M = mean; SD = standard deviation; OA-level – overall agreement level

The result of the study showed that farmers, however, do not seem to believe that forest fires are important to induce LG growth in the Chir Pine forests with 53.3% and 46.7% 'slightly agree' and 'disagree' respectively with an overall disagreement rating. This result, though, contradicted with the statement that farmers deliberately set fires to the forest to enhance the grazing resources of the cattle.

The farmers are also of the opinion that forest fires do not happen naturally during the dry season (unless they are set by somebody) with 30.0% and 66.7% slightly agree and disagree rating respectively. There was overall disagreement rating observed on the statement, forest fires happen naturally during dry season.

3.4 Management practices of LG resources and oil production

The result of the study on management practices in Table 3 showed that farmers do not seem to believe that burning of the LG growing areas will stimulate new growth of grass. The statement, it is not true that burning of LG growing areas will stimulate new growth of grass (with the mean of 3.13) received 3.3% and 20% strongly agree and agree rating respectively. The statement also received an overall slightly agree rating.

A total of 76.7% and 13.3% of the respondents perceived it important to maintain the Chir Pine forests cover for water and soil conservation reasons. The statement with the mean of 3.67 also received an overall agree rating.

The statement, farmers maintain maximum of two cuts of LG per year (M=3.57) received 63.3% and 30.0% agree and slightly agree rating along with an overall agree rating. The statement, all farmers know the proper / scientific harvesting practices (M=3.50) also received a high 53.3% and 43.3% agree and slightly agree rating respectively along with an overall agree rating.

Regarding the quantity of LG oil and marketing of the product, the result of the study showed that there could be problems of marketing. There was 73.3% disagree rating over the statement, the quantity of oil produced is not sufficient to meet market demands (M=2.30) and with an overall disagree rating. On the other hand, the result of the study showed that, there was 10% and 43.3% agree and slightly agree rating respectively over the statement, every year there is excess product not being able to sell due to lack of market (M=2.63). The statement also received an overall slightly agree rating.

Table 3: Farmers' knowledge about management practices and reasons for the decline of LG oil production (n=30)

Sl. No.	Variable level	SA (%)	A (%)	Sl.A (%)	D (%)	S.D (%)	M	SD	OA-level
1	It is not true that burning of LG growing areas will stimulate new growth of grass	3.3	20.0	63.3	13.3	-	3.13	0.681	Sl.A
2	It is important to maintain the chirpine forests cover for water and soil conservation reasons	-	76.7	13.3	10.0	-	3.67	0.661	A
3	Farmers maintain maximum of two cuts of LG per year	-	63.3	30.0	6.7	-	3.57	0.626	A
4	All farmers know the proper / scientific harvesting practices	-	53.3	43.3	3.3	-	3.50	0.572	A
5	LG oil production decline in recent years is due to lack of rainfall	-	26.7	30.0	43.3	-	2.83	0.834	Sl.A
6	LG oil production decline in recent years is due to frequent forest fires	-	7.1	53.6	39.3	-	2.68	0.612	Sl.A
7	LG oil production decline in recent years is due to domination of weeds in the LG growing areas	-	23.3	60.0	16.7	-	3.07	0.640	Sl.A
8	LG oil production decline in recent years is due to lack of water and fuel wood needed for distillation	-	23.3	50.0	26.7	-	2.97	0.718	Sl.A
9	LG oil production decline in recent years is due to lack of interest of local people in LG oil production	-	30.0	63.3	6.7	-	3.23	0.568	Sl.A
10	LG oil production decline in recent years is due to low prices in the markets	-	31.0	48.3	20.7	-	3.10	0.724	Sl.A
11	LG oil production decline in recent years is due to problems of markets and marketing of oil	-	16.7	50.0	33.3	-	2.83	0.699	Sl.A
12	The quantity of oil produced is not sufficient to meet market demands	-	3.3	23.3	73.3	-	2.30	0.535	D
13	Every year there is excess product not being able to sell due to lack of market	-	10.0	43.3	46.7	-	2.63	0.669	Sl.A

Note: SA = strongly agree; A = agree; Sl.A = slightly agree; D = disagree; S.D = strong disagree; M = mean; SD = standard deviation; OA-level – overall agreement level

3.5 Reasons for the decline in LG oil production

There were seven statements / variables measured to identify the reasons for the LG oil production decline in Monggar *Dzongkhag*. Based on the mean differences the result showed that lack of interest of the farmers themselves is one of the biggest causes of the decline of the LG industry in eastern Bhutan. The statement also received, 30% and 63.3% agree and slightly agree rating with an overall slightly agree rating. The second most important reason for the decline is stated to be the low prices of LG oil fetched at the market. There was 31% and 48.3% agree and slightly agree rating with an overall slightly agree rating. The next important reason was the domination of the weeds in the LG growing areas which meant there is a decline in the raw materials from the Chir Pine forests. The statement received an overall agree rating with a 23.3% and 60% agree and slightly agree rating.

The lack of water and fuel wood needed for the distillation purpose was also stated as one of the main reasons for the decline of the LG oil production besides the lack of rainfall. The study showed that the decline of the LG oil production is also caused due to the problems of markets and marketing of oil. More than 16% and 50% agree and slightly agree rating were received on the market and marketing of oil as the reason for the decline of the LG industry and with an overall slightly agree rating.

There was also overall slightly agree rating on forest fires as one of the causes of the decline of the LG oil production with 7.1% and 53.6% agree and slightly agree rating.

3.6 Capacity of farmers and support from government agencies

Table 4 shows the result of the study on capacity building and support received from the government. There were two variables measured to find out the capability of the farmers to manage their LG oil business and external assistance received to enhance this capability. The result of the study indicated that farmers have yet to build the capability to collect oil, undertake the packaging, transporting and marketing of the LG product on their own. About 70% of the respondents said they do not have those capabilities. The statement also received an overall disagree rating against it.

The result also showed that farmers are not satisfied with the support received from the government regarding the training on book keeping, organisational management and marketing techniques to build their capacity. With the mean of M=2.50, there was 50% disagree rating observed. There was also an overall rating of 'disagree' observed against it.

Two variables were measured to find out the capacity of the farmers to manage their LG oil business on their own. The result of the study showed that farmers were not confident to take over the management of the business independently without the facilitation of the government. Although the statement, institutionalisation of farmers' group or co-operative approach to manage LG industry would ensure better success (M=2.63), received an overall slightly agree rating, there was still 50% disagree rating observed and only 36.7% slight agree independent rating.

Moreover, it was observed that farmers were still not prepared to take over the management ownership. The statement, the government can now transfer the industry management ownership and resource allocation to the farmers (M=2.30), received 76.7% disagree rating with only slightly 16.7% slightly agree independent rating. Overall, the statement received disagree rating.

Table 4: Support from government agencies (n=30)

Sl. No.	Variable level	SA (%)	A (%)	Sl.A (%)	D (%)	S.D (%)	M	SD	OA-level
1	Farmers now have the capability to collect oil, package, transportation and marketing on their own	-	-	30.0	70.0	-	2.30	0.466	D
2	The government can now transfer the industry management ownership and resource allocation to the farmers	-	6.7	16.7	76.7	-	2.30	0.596	D
3	Farmers receive training on book-keeping, organisational management, marketing techniques, etc. to build capacity	-	-	50.0	50.0	-	2.50	0.509	D
4	Institutionalisation of farmers' group or co-operative approach to manage LG industry would ensure better success	-	13.3	36.7	50.0	-	2.63	0.718	Sl.A
5	The LG industry receive the required support from government agencies	-	33.3	43.3	23.3	-	3.10	0.759	Sl.A
6	The government facilitate securing markets and marketing LG oil for farmers	10.0	30.0	23.3	36.7	-	3.13	1.042	Sl.A

Note: SA = strongly agree; A = agree; Sl.A = slightly agree; D = disagree; S.D = strong disagree; M = mean; SD = standard deviation; OA-level – overall agreement level

3.7 Support from the government

Regarding the support provided by the government to the LG oil distillers, the result showed that the government is playing a key role in the LG industry. More than 33% and 43.3% agree and slightly agree rating respectively were observed from the statement, the LG industry received the required support from government agencies, with the mean of M=3.10. The statement also observed an overall slightly agree rating.

Regarding another statement, the government facilitate securing markets and marketing LG oil for farmers (M=3.13), 10% and 30% strongly agree and agree rating respectively were observed from the respondents. More than 23% and an overall slight agree rating were observed on the same statement.

4 Conclusion and Recommendation

The result of the study showed there is lack of continuous labour supply at the time of LG oil distillation. This appeared to be the greatest problem confronted by the LG industry. This may be because farmers give priority to their farms and attending to the crops. The fire-wood for the distillation units has also become a problem. As farmers are required to buy firewood from contractors, it becomes expensive since the running costs of the oil distillation are rising. The industry is also facing improper methods of harvesting LG, lack of coordination among government agencies to provide services to the industry and the need to provide alternative source of providing fuel wood for distillation process. It is likely that the farmers would also ultimately face shortage of lemongrass raw materials given the fact that there is environmental damage through forest fires and huge number of unproductive cattle grazing the entire forest.

Farmers seemed to have favourable perceptions on some issues viewed as problems. They are of the opinion that open grazing in the forests by their cattle does not reduce the LG resource. They also do not agree that forest fires are the greatest risk to sustainable LG oil production while they considered forest fires are useful to scare away wild animals and help protect the crops. Therefore, farmers could be involved in deliberately setting fires to the forest and responsible for causing much of the destruction in the wild Chir Pine forests of Bhutan.

The study showed that farmers perceived it important to maintain the Chir Pine forests cover for water and soil conservation reasons. It also showed that the farmers are engaged in maintaining maximum of two cuts of LG per year and most farmers are educated to be engaged in proper / scientific harvesting practices. At the same time, farmers expressed problems of LG oil market and marketing. The farmers disagree that the quantity of oil produced is not sufficient to meet market demands. The study found that every year there is excess product where farmers are not able to sell due to lack of market.

The study showed that the lack of interest of the farmers themselves is one of the biggest causes of the decline of the LG industry in eastern Bhutan. The low prices of LG oil fetched at the market are the second most important reason for the decline of the industry.

Farmers stated that the problems of weeds in the LG growing areas have also caused the decline of the raw materials in the Chir Pine forests. The natural causes like the lack of timely rainfall for LG growth, lack of water and fuel wood needed for the distillation purpose were some other problems stated that contributed to the decline of the LG oil production.

The farmers have yet to build the capability to collect oil, undertake the packaging, transporting and marketing of the LG product on their own. The result also showed that farmers are not satisfied with the support received from the government regarding the training given to them on book keeping, organisational management, marketing techniques to build their capacity.

The study also revealed that farmers were not confident to take over the management of the business independently without facilitation of the government. The farmers are still not confident on the institutionalisation of farmers' group or co-operative approaches to manage LG industry for faster development and success. Moreover, it was observed that farmers were still not prepared and confident enough to undertake the industry management ownership and resource allocation on their own. Therefore, the government is still required to directly facilitate the marketing of LG oil product and exploring and securing LG oil markets for the industry.

Recommendations

Based on the findings of the study, the following recommendations are made:

- To resolve the shortage of labour supply, the industry should take urgent measures to increase the wage rates of grass collectors, fire wood collectors and all other types of labour required in the industry.
- To relieve fuel wood shortage problems, the government agencies, particularly the forestry officials could facilitate in issuing fire wood permits on time during the peak LG oil distillation.
- The uneven allocation of LG resource areas to different distillers has to be taken with caution to ensure there is no discontentment among farmers.
- To provide regular training to refresh farmers on the scientific practices of harvesting to ensure sustainability of the resource.
- Farmers should be educated on the negative consequences of forest fires. Forest fire fighting campaigns should be run in the villages during the dry season and awareness created on environmental conservation and sustainable utilisation of resources.
- The government should continue to explore markets in the region, make them accessible, facilitate marketing of products and ensure consistent income generation.
- The only way to enhance the interest of the farmers in the industry is to make it lucrative and business-viable, profitable and beneficial. Finding access to markets at the regional and international levels could be the only way to making the industry lucrative.

- The government should continue to build the capacity of the LG oil distillers and farmers, empower them and ultimately handover the industry management ownership and resource allocation. The capacity building should include providing training on book keeping, organisational management, marketing techniques, collection of oil, packaging of product, transporting and marketing of the LG product on their own.
- Further study should be conducted to explore the possibilities of introducing a co-operative approach of running the LG oil industry. The study could identify the potentials of co-operative concepts and practices and recommend how such cooperatives could be formed through the various phases that could further boost the LG oil industry in eastern Bhutan.

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Effects of Silvicultural Openings, Livestock Grazing, Understory Competition and Microsites on Mixed Conifer Regeneration in Western Bhutan

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Abstract

Commercially harvested group openings were studied for a period of five years to assess the effects of different opening sizes, livestock grazing, vegetation competition and micro-sites on regeneration success. Three opening sizes were defined for the study: small (≤ 0.25 ha), medium (0.25-0.35 ha) and (> 0.35 ha) large. The effect of grazing was quantified by creating exclosures in all three opening sizes. The effect of ground vegetation competition was assessed by clipping, while that of microsites was determined by scarification of soils. Micro-site preference was evaluated by comparing proportions of tree seedlings growing on different micro-site conditions.

Large openings showed significantly lower tree seedling recruitment densities, as compared to intermediate and small openings and unfenced control plots showed significantly higher seedling densities as compared to fenced plots. The latter effect, however, was opposite in large openings, where fencing exerted a positive effect on seedling densities. Control of competing vegetation and soil scarification had highly significant positive effects on tree seedling densities, with the effect of the second being stronger. Survival of hemlock (Tsuga dumosa) seedlings was higher on moss compared to other micro-site types. Inappropriate opening sizes in connection with livestock grazing, as well as a lack of livestock grazing leads to insufficient regeneration in mixed conifer forests of Bhutan. Modifications to the uniform silvicultural prescription for mixed conifer forests based on the silvics of dominant species is recommended.

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Keywords: Opening size; Vegetation competition; Microsites; Grazing; *Tsuga dumosa*; Mixed conifer forest

Introduction

An essential element of sustainable forest management is the natural regeneration of forests that have been harvested or disturbed in other ways (Blackhall et al., 2012). The establishment and early growth of seedlings are the most critical determinants of this process, as they determine future stand structure and composition (Oliver and Larson, 1990). Tree regeneration in logged over areas depends on abundant and viable seed supply, suitable seedbeds, low enough seed and seedling predation for establishment and suitable environmental conditions for germination and establishment (Kozlowski, 2002).

Of these factors, forest management interventions most easily influence environmental conditions through the creation of canopy openings (Raymond et al., 2006; Zhu et al., 2003) as well as seedbeds through topsoil scarification (Calogeropoulos et al., 2004). When the buffering effect of the forest canopy is removed, temperature, relative

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humidity, wind speed and solar radiation become significantly more variable in the openings than beneath the forest canopy (Lankia et al., 2012). Specifically in large gaps, regeneration success is strongly influenced by microclimatic factors, resulting in poor seedling recruitment, even if seedbeds are favorable and distance to seed sources is small (LePage et al., 2000). Smaller gaps can buffer the negative effects of environmental extremes as found in clear cuts or large gaps, usually leading to higher seedling densities of highly and intermediately shade tolerant trees (Coates, 2002; Dorji, 2004). The dispersal abilities of the species and the proximity of mother trees to the intended area of regeneration play major roles in restocking the forest after harvest (Holladay et al., 2006). Irrespective of dispersal agents, the density of dispersed seeds decreases with increasing distance from seed sources (Nathan and Muller-Landau, 2000), effectively restricting seed dispersion into clear cut areas (LePage et al., 2000).

Besides the availability of seed sources, natural regeneration from seeds depends on the physical characteristics of the microsite surface, on which the seeds land, such as moisture content and the amount of light that reaches to the forest floor (Kozlowski, 2002). The forest floor consists of a small-scale mosaic of microsites with different germination and survival success for tree seedlings, adding a strong stochastic component to their recruitment success (Kuuluvainen and Juntunen, 1998).

After the release of plant growth resources subsequent to canopy disturbances, grasses, herbaceous plants, and non-vascular plants compete with tree seedlings for growth space (Ehrenfeld, 1980). These plants can exclude trees permanently or over a long period of time from the area (Oliver and Larson, 1990; Royo and Carson, 2006), especially by effectively competing for light and soil nutrient and - water resources (Kumar, 2008; Page and Cameron, 2006). Under certain circumstances, however, non-tree species can also facilitate the establishment of tree seedlings and promote the development of a forest stand (Laskurain et al., 2012; Oliver and Larson, 1990). Under open conditions, adjacent vegetation greatly reduces the mortality of tree seedlings by protecting them from solar radiation (Isagi et al., 1997). Understory vegetation reduces soil temperature and creates moister microsites relative to exposed bare soil patches (Uchimura, 1980).Understory vegetation exerts facilitative effects also by protecting tree seedlings and saplings from herbivory (Callaway et al., 2000; Smit et al., 2006), which affects growth (Rossell Jr. et al., 2005) and survival (Rossell Jr. et al., 2005). Unpalatable plants provide refuge to tree seedlings growing on the same site from browsing by herbivores through mechanical defense, for example through thorns and spines (Castañeda-Mendoza et al., 2005; Wimbush, 1945) or chemical composition of leaves (Oshima, 1961c). Facilitators may also reduce the probability of finding the facilitated plants by grazers via reducing the conspicuousness or attractiveness (Brooker et al., 2006; Oshima, 1961d).

Harvested stands in Bhutan often experience prolonged delays in regeneration (Dhital, 1999), leading to adverse environmental effects and extended rotation periods, decreasing Annual Allowable Cuts. In the mixed conifer belt of Bhutan (27°N, 2700-3200 m.a.s.l.) solar radiation loads are high. Seedlings of the dominant tree species hemlock (*Tsuga dumosa*), spruce (*Picea spinulosa*) and fir (*Abies densa*) are small-seeded and highly prone to desiccation and therefore regenerate on sun-exposed slopes mainly in small openings (Darabant et al., 2007). Traditionally, grazing by domestic ungulates was held responsible for the lack of tree regeneration in the forests of Bhutan (Buffum et al., 2009; Norbu, 2002; Rosset, 1999; Van IJssel, 1990). However, there is contrary evidence,

demonstrating beneficial or neutral effects of moderate grazing on conifer regeneration under certain stand conditions, when control of competing vegetation facilitates establishment, growth and survival of tree seedlings (Darabant et al., 2007; Gratzer et al.1999).

Competition by understory vegetation was shown to be an important factor influencing tree regeneration in the conifer forests of Bhutan (Darabant et al., 2007; Gratzer et al., 1999; Tenzin, 2008). Negative correlation of conifer seedlings densities were detected with that of understory vegetation cover in several studies conducted in Central and Western Bhutan (Gratzer et al., 2001; Tenzin et al., 2008; Tshering, 2005; Wangchuk, 2007). The availability of suitable microsites is a crucial factor in recruitment success of small-seeded conifer species dominating the mixed conifer belt of Bhutan (Darabant et al., 2008; Dorji, 2004; Gratzer et al., 1997; Tenzin et al., 2008; Wangchuk, 2007). In accordance with the complexity of tree regeneration processes and the multitude of factors influencing it, we investigated the effects of canopy opening sizes, livestock grazing, competing vegetation and microsites on conifer tree regeneration. Gaining information on the above factors in the local environmental context was essential to provide recommendations for improved silvicultural methods in addressing tree regeneration problems in Forest Management Units of western Bhutan, where commercial harvesting has started more than two management plan periods (20 years) ago, and where the issue of poor tree regeneration is most pressing.

2 Materials and Method

2.1 Site description

The study areas were located in the Forest Management Units (FMUs) of Chamgang and Gidakom in western Bhutan at an altitude range between 3030 and 3370 m.a.s.l. The parent materials for soil formation were gneiss and mica schist in both locations, on which two major soil types, Haplic Cambisol and Stagnosol occur (Simon, 2012). Climatic conditions recorded at the closest weather station for Gidakom valley at 2210 m state a mean annual maximum temperature of +21.2 °C, a mean annual minimum temperature of +7.7 °C and a mean annual precipitation of 622 mm. For Chamgang, the weather station located at the end of the valley in Simtokha at 2310 m recorded a mean annual maximum temperature of 21.1 °C, a mean annual minimum temperature of 9.3 °C, and a mean annual precipitation of 707 mm. The forests in the research areas are dominated by *Tsuga dumosa* (D. Don) Eichler (Himalayan Hemlock) on rather moist and mesic sites, and by *Picea spinulosa* (Griff.) Henry (East Himalayan Spruce) and *Quercus semecarpifolia* Sm. on drier sites. *Pinus wallichiana* A.B. Jacks. (Blue Pine) is intermixed in the canopy on disturbed sites and *Abies densa* Griff. (East Himalayan Fir) frequently occurs above 2900 m, in its lower ranges especially in the understory. Subcanopy tree and shrub layers are well developed and consist of *Acer* sp., *Enkianthus deflexus* C.K. Schneid., *Rubus ellipticus* Sm., *Piptanthus nepalensis* Sweet, *Rosa sericea* Lindl., *Berberis* sp., *Cotoneaster bacillaris* Wall. ex Lindl., *Daphne bholua* Buch.-Ham. ex D.Don., *Litsea* sp., *Lonicera* sp., *Rhododendron arboreum* Sm. and *Spiraea* sp. Frequent understory species are the bamboos *Thamnocalamus spathiflorus* Munro and *Yushania microphylla* (Munro) R.B.Majumdar, the ferns *Osmunda* sp. and *Dryopteris* sp.

and other species including *Synotis alata* (Wall. ex DC.) C.Jeffrey & Y.L.Chen, *Sambucus adnata* Wall., *Salvia* sp., *Rubus nepalensis* Hort., *Lindera* sp., *Artemisia* sp. and *Senecio diversifolius* Wall.. Both sedentary and migratory cattle, as well as yaks graze in both FMUs. Grazing pressure in Gidakom FMU is considerably higher as compared to Chamgang FMU.

2.2 Experimental design

In both FMUs, silvicultural group openings created 2-6 years earlier along cable corridors were sampled to assess natural regeneration, competing vegetation & microsites. In the selected sample openings, every second group opening of every fourth cable corridor was assessed. It was hypothesized that opening size, livestock grazing and competing vegetation were the main factors influencing tree regeneration. Accordingly, we used a split-plot experimental design in each location with two replications to test the effects of location, opening size class (small openings ≤ 0.25 ha, medium size openings of 0.25-0.35 ha and large size openings >0.35 ha), livestock grazing (fenced versus non-fenced) and microsite treatment on conifer seedling regeneration. In total, 24 openings were selected and their boundaries were mapped. In spring 2005, we set up pairs of adjacent permanent sample plots in the centre of these openings, consisting of a fenced and an unfenced plot of 9m * 9m size each. Sample plots were divided into 9 subplots of 3m * 3m size each for microsite treatments. Thus, our design included random effects for the nesting of fencing within opening size, and microsite treatment within fencing.

Micro-site treatments applied to subplots included control with no interference, vegetation cutting at a height of 5 cm above ground once per vegetative period and soil scarification with subsequent removal of upcoming vegetation once per vegetative period. In each sub plot, vegetation was assessed using a modified Braun-Blanquent scale and the cover percentage of microsites was estimated. Recordings for individual tree seedlings included species, diameter, height, microsite, vitality class (Carter and Klinka, 1992) and the number of whorls of conifers. During the subsequent five years, plots were monitored in summer. During monitoring, new tree seedling recruits were enumerated species-wise by microsite. Old existing seedlings were enumerated according to different height classes. The vegetation was clipped in the treated plots.

2.3 Data Analysis

SAS 9.2 for Windows was used for data analysis (SAS Institute Inc., 2002-2008). In order to correctly characterize the distribution of the response variables for regeneration, a generalized linear mixed models utilizing a log link function and assuming a negative binomial distribution for the response variables was used. The initial number of seedlings assessed in 2005 was included as a covariate in all analyses. Non-significant 3-way interactions were dropped from analyses with the goal of model parsimony. The total numbers of seedlings, as well as the total number of seedlings of major species at the end of the 2009 were the dependent variables in the analyses. Differential survival of hemlock and spruce seedlings was tested in both fenced and unfenced plots separately. Observed values were tested against expected values using χ^2 tests of goodness of fit, assuming an even distribution of seedlings among microsites, considering the particular

cover of each microsite. In the associated a posteriori analyses, standardized residuals with critical values of the normal distribution to obtain significance levels (Lowry, 1998-2006) , were compared.

3 Results

3.1 Distribution of seedlings.

The vast majority of seedlings regenerated in small openings. *T. dumosa* was the most frequent tree species (Table 1). In small and medium sized openings, all species with the exception of pine and yew had more recruits in control plots than inside fenced enclosures. Hemlock, pine, oak and yew regenerated best in small openings, while spruce and fir achieved highest seedling numbers in medium sized openings (Table 1).

Table 1: Seedling densities [individuals/plot] by species across opening sizes in fenced and unfenced plots

Opening size	small		Medium		large		Total
Fence	unfenced	fenced	Unfenced	fenced	unfenced	fenced	
Species							Total
Tsuga dumosa	3546	303	358	137	91	146	4581
Picea spinulosa	98	26	139	60	40	66	429
Pinus wallichiana	153	172	17	64	8	9	423
Abies densa	0	0	16	13	3	8	40
Quercus semecarpifolia	62	39	7	6	2	1	117
Taxus baccata	1	7	1		1	2	12
Juniperus recurva	0	1	0	3	1	4	9
Acer sp.	4	2	1	23		10	40
Grand Total	3864	550	539	306	146	246	5652

3.2 Effects on seedling recruitment

Opening size ($p \leq 0.01$), fencing ($p \leq 0.05$) and micro-site treatment ($p \leq 0.001$) along with initial seedling numbers in 2005 ($p \leq 0.01$) showed significant effects on seedling densities at the end of 2009. There was no difference in final seedling densities between FMUs and no interactions were significant ($p<0.05$; Table 2).

Table 2: Estimated fixed effects from GLMM on final seedling densities at the end of 2009

Effect	Num df	Den df	F	Pr > F
Seedlings present in 2005	1	287	7.67	0.006
FMU	1	18	1.23	0.2826
Opening size	2	18	6.83	0.0061
FMU*opening	2	18	1.24	0.3117

size				
Fence	1	23	4.34	0.0485
Microsite Treatment	2	92	22.83	<0.0001
Fence*Treatment	2	92	1.01	0.3680

Seedlings densities in large openings were significantly lower as compared to small openings ($p \leq 0.01$, Table 3, Figure 1). No other significant difference between size classes was found in terms of seedling abundance (Table 3).

Table 3: Scheffè post-hoc test on differences between three different opening sizes on final seedling densities at the end of 2009

Opening size	Opening size	Estimate	SE	DF	T value	Pr>T	Adj p
1	2	.9501	0.7234	18	1.31	0.2055	0.4388
1	3	2.7423	0.7478	18	3.67	0.0018	0.0066
2	3	1.7923	0.7487	18	2.39	0.0278	0.0831

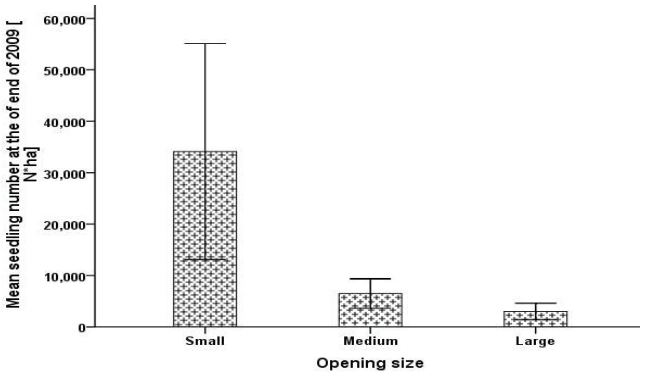

Figure 1: Mean seedling densities at the end of 2009 including 95% confidence intervals in three different opening size classes.

Unfenced control plots had significantly higher ($p \leq 0.05$, Table 2) density of seedlings at the end of 2009 as compared to fenced plots (Figure 2).

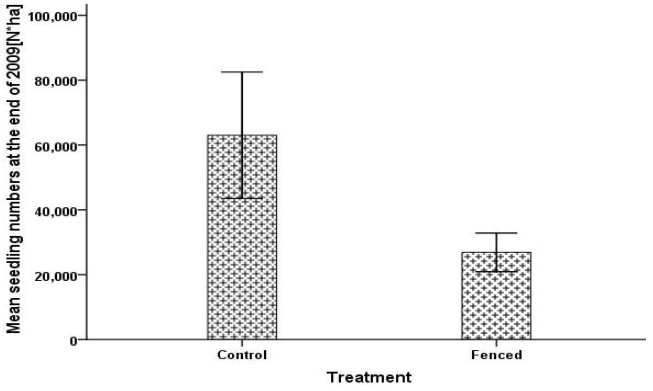

Figure 2: Mean seedling density at the end of 2009 including 95% confidence intervals in fenced and control plots.

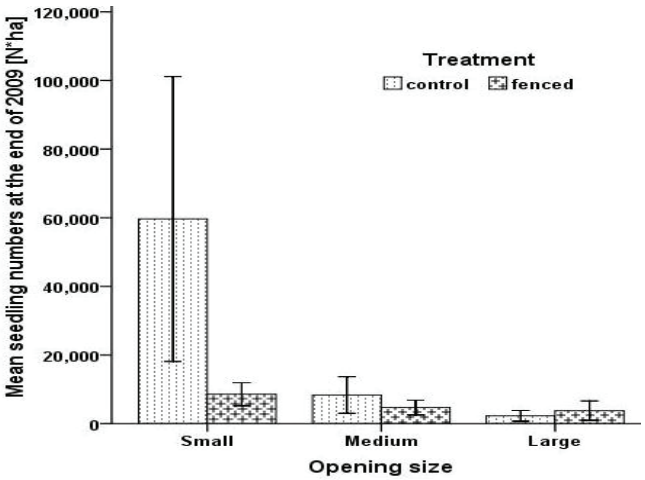

Figure 3 : Mean seedling densities at the end of 2009 including 95% confidence intervals in different opening sizes under grazed and ungrazed conditions.

While medium and large openings showed similar seedling densities irrespective of grazing, grazed subplots in small openings showed considerably higher seedling densities as compared to ungrazed ones (Figure 3).

Micro-site treatment had a highly significant effect on seedling densities ($p \leq 0.001$, Table 2). Subplots with removed topsoil had significantly more seedlings at the end of 2009, compared to subplots where vegetation was mowed once a year ($p \leq 0.001$) or was left untouched ($p \leq 0.001$, Figure 4), with no differences between the latter two.

Table 4: Scheffè post-hoc on differences between three levels of microsite treatments on final seedling densities at the end of 2009 (1 control, 2 clipped vegetation and 3 topsoil removed).

Treat				Treat	Estimate	SE	DF	T value	Pr>T	Adj p
1				2	−0.3675	0.2600	92	−1.41	0.1609	0.3722
1				3	−1.5987	0.2531	92	−6.32	<0.0001	<0.0001
2	3	−1.2313	0.2454	92	−5.02	<0.0001		<0.0001		

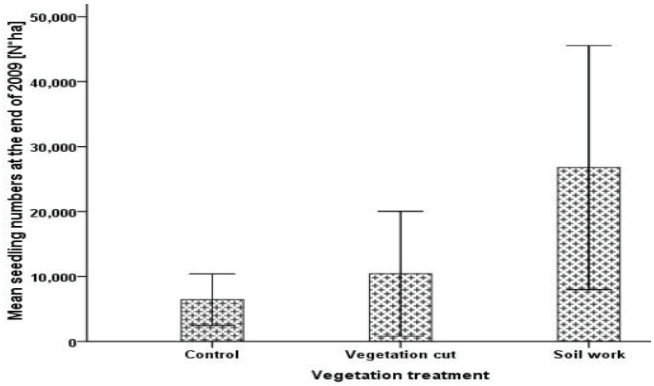

Figure 4: Mean seedling densities at the end of 2009 including 95% confidence intervals under three different microsite treatments.

3.4 Micro-site types

Observed seedling densities differed significantly from expected seedling densities for all microsites and species in both fenced and unfenced plots (P<0.001). Both hemlock and spruce seedling densities were disproportionately high on moss and disproportionately low on other litter, nurse log and bamboo litter microsites. On mineral soil under unfenced conditions, hemlock showed disproportionately low while spruce disproportionately high densities (Table 5).

Table 5: Densities on various microsites under grazed and ungrazed conditions. Observed vs. expected values of *Tsuga dumosa* and *Picea spinulosa* seedling

	***Tsuga dumosa* fenced**			***Tsuga dumosa* unfenced**			***Picea spinulosa* fenced**			***Picea spinulosa* unfenced.**		
	Obs	Exp	Res	Obs	Exp	Res	Obs	Exp	Res	Obs	Exp	Res
Moss	391	69,9	321,1**	3587	470,7	3116,3**	77	17,0	60,0**	196	32,0	164,0**
Other litter	62	303,1	-241,1**	92	2118,3	-2026,3**	18	76,7	-58,7**	21	138,7	-117,7**
Mineral soil	4	23,3	-19,3**	78	156,9	-78,9**	3	5,7	-2,7*	27	10,7	16,3**
Nurse log	18	87,4	-69,4**	38	588,4	-550,4**	1	22,7	-21,7**	8	40,0	-32,0**
Bamboo litter	102	93,3	8,7*	79	627,6	-548,6**	43	19,9	23,1**	12	42,7	-30,7**
Total	577			3874			142			264		

4 Discussion

In the study, four factors opening size, grazing, competing vegetation and microsites played important roles in determining the abundance of conifer tree seedlings.

4.1 Opening size

Gap size and shape, as well as understory vegetation determine light penetration to the ground where seedlings establish (Gray and Spies, 1997). Careful matching of tree species to group size can minimize early mortality and increase growth rates (Coates, 2000). In our study, opening size and seedling density were inversely related: small openings supported higher seedling densities than medium and large openings. Findings of our work agree well with some of the pioneer works done in western Bhutan (Dorji, 2004; Rai, 1997; Wangchuk, 2007). Elsewhere similar results were also reported (Coates, 2002; LePage et al., 2000). Comparison of gap size has revealed that solar radiation along with soil and air temperature increases with gap size (Phillips and Shure, 1990). High

radiation loads (Bader et al., 2006; Canham et al., 1990) have been confirmed for more northerly latitudes than Bhutan, overheating microsites in large gaps, thus impeding seed germination and negatively influencing seedling physiology, leading ultimately to plant death (Oliver and Larson, 1990). Smaller gaps show buffered environmental conditions as compared to clear cuts or large gaps. This leads to higher seedling densities of highly and intermediately shade tolerant species (Coates, 2002). *Tsuga dumosa* and *Picea spinulosa* seeds are highly prone to desiccation and successfully regenerate in small openings (Darabant et al., 2008), which is valid for other hemlock species as well (Coates, 2002). Poor survival of small seeded Sitka spruce was reported in the areas where the excessive drying of seedbed occurred (Harmon, 1987).

4.2 Grazing effect

The impact of grazing has been reported both in terms of positive (Darabant et al., 2007; Gratzer et al., 1999; Holladay et al., 2006) and negative or no effects on tree regeneration (Russell et al., 2001). In our experiment, a positive effect of grazing on conifer regeneration was detected, however, only in small sized openings.

Grazing of competing vegetation by herbivores reduces competition for resources and makes them available to tree seedlings. Grazing of thick bamboo understories effectively reduced bamboo height and thereby increased the amount of light reaching the forest floor, facilitating establishment and growth of hemlock, fir and other conifer seedlings (Darabant et al., 2007; Gratzer et al., 1999). Similarly, van Uytvanck et al. (2009), reported that emergence of *Quercus robur* was significantly higher in vegetation types with high light penetration in grazed areas, than in un-grazed areas, where light penetration was low. In comparison to tall and dense vegetation, short grazed vegetation and gaps within may also reduce seed predation by rodents (Calviño-Cancela, 2007; Shibata et al., 2008).

The study detected a correlation between grazing and the opening size. In large openings, there was indication of negative effects of grazing on tree densities which was contrary to the small openings. This could perhaps be due to higher amounts of biomass available in larger gaps which attracts foraging ungulates which results in enhanced herbivory (Naaf and Wulf, 2007). Grazing pressure and regeneration success may be not linearly related: seedling densities were found to be highest with intermediate animal densities, while lowest seedlings densities were reported at highest animal densities (Zimmermann et al., 2009).

According to Wangchuk et al. (2012), the available forage can support 1 Livestock Unit (LU) per hectare in the in the Gidakom FMU. Management of palatable competitive ground vegetation through moderate grazing might be beneficial to tree seedlings at the initial stage of the regeneration. Phasing out the grazing after the tree seedling reaches the height when it becomes apparent for grazing and escapes the competition from other vegetation might be an option in the study area.

4.3 Microsite treatment

Heineman et al. (2005) reported that control of vegetation through brushing and grazing did not improve the growth performance of spruce seedlings. However, in the study, there was a significantly positive effect on the tree regeneration when the competing vegetation was removed. Soil scarification and vegetation clipping induce higher densities of tree seedlings when compared to the control. In North American fir and spruce species, seedbed scarification significantly increased germination and recruitment within patch cuts, which was especially important in the case of spruce, where germination without seedbed scarification was close to nil (Eastham and Jull, 2003). Conifer seedling densities negatively correlated with the cover of undergrowth vegetation according to studies carried out in western Bhutan (Tshering, 2005; Wangchuk, 2007). Competitive influence of ground vegetation on tree seedlings was detected in this study. Although soil scarification may not be feasible for vegetation control in Bhutan as practice elsewhere (Yoshida et al., 2005), it may be managed through grazing in small openings to enhance the germination and establishment of tree regeneration.

4.4 Microsites

Two most important factors that determine the recruitment of plant populations are availability of suitable micro-sites and seeds (Eriksson and Ehrlen, 1992). In this study, the discovery of the survival of *Tsuga dumosa* and *Picea spinulosa* seedlings on different seedbeds indicated disproportionally high survival on micro-sites with high moisture retention capacity, such as moss and nurse logs (Place, 1955). Continuous moisture supply is vital for germination and establishment especially of small-seeded seedlings and moss has been described as an important micro-site with other hemlock species in the absence of elevated microsites, such as nurse logs (Sugita and Nagaike, 2005). Thick moss carpets may also inhibit the establishment of seedlings as reported by Ohlson and Zackrisson (1992). However, some authors argue that seed limitation is a more predominant factor than the availability of suitable micro-sites (Eriksson and Ehrlén, 1992). Though the abundance of seeds might be the leading cause for successful regeneration, we argue that without suitable micro-sites, the possibilities of mortality from extreme environmental stress such as drought will be high.

5 Conclusion

Tsuga dumosa and *Picea spinulosa*, which are shade tolerant and intermediately shade tolerant respectively, would restock best in the small to medium size openings. Large openings are unfavorable due to extremes in microclimatic conditions. Control of competitive vegetation through regulated grazing seems to be an option during the initial seedling recruitment stage. In our study, we confirm that the critical factor leading to lack of conifer regeneration is due to the combination of large opening size and grazing. Creation of large openings does not support successful conifer regeneration due to increased grazing pressure, increased understory competition and unfavorable microclimatic conditions.

Acknowledgement

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SHORT COMMUNICATION

Factors Influencing Dropping out of Poultry Farming - A case study from Punakha Dzongkhag

Aita Kumar Bhujel[1]

Abstract

Recent past saw an upsurge in poultry farming business in Bhutan, contributing to livelihoods improvement of farmers. However, there are instances of farmers dropping out poultry farming business particularly in Punakha Dzongkhag. A semi-structured questionnaire surveys were conducted with 15 selected respondents in three Geogs to assess the factors contributing to dropping out of poultry farming. Amongst other contributing factors, in declining in poultry farming were the social and economic factors such as religious sentiment and rising feed cost are found to be contributing more to dropping out the poultry farming. Provision of inputs to famers such as capacity building, technical support, subsidy packages, feed price control and its access and means to dispose the spent birds, were recommended.

1 Introduction

In Bhutan, poultry production using improved genetics, proper feeding and management has grown rapidly since 2009 in response to increased market demand for livestock products including poultry. Since then, poultry farming has become one of the profitable farm lucrative business, helping farmers to generate income and create employment in the country. Bhutan is almost self-sufficient in egg production with the annual egg production of 57 million in 2012 (DoL, 2012). The Department of Livestock has plan to increase the production level to 92 million eggs during the 11th Five Year plan(FYP) Period (NPDC, 2012).Based on the target to be achieved, the production targets are further divided among the regions and dzongkhags.The West-central region is mandated to produce 15 million eggs while Punakha dzongkhag in this region has set the target to produce two million eggs in the 11th FYP (DoL, 2013).

The field observations suggest that the trend of poultry farming over the year has declined in Punakha dzongkhag and the implementing farmers are dropping out of poultry farming. This has been a concern to the dzongkhag livestock sector to meet egg production target set. There can be e various factors (technical, social, economical, environmental etc.) constraining farmers to continue with poultry farming. However, no study was conducted to understand the farmers' view on the factors that are compelling them that drop out poultry farming.

The Regional Livestock Development Centre, Wangdue in collaboration with Dzongkhag Livestock sector, Punakha conducted this survey to gather farmer's point of view on the factors that compelled farmers to drop out poultry farming and suggest appropriate recommendation to sustain poultry farming

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2 Materials and Method

The study was conducted in four geogs of Guma, Talo, Kabji and Toep where poultry farming has been reported dwindling over the recent years. Of the total 16 farmers in the dzongkhag that had dropped out, 15 farmers were interviewed individually using the pre-tested semi-structured questionnaires.. The data collected was validated and entered into Microsoft Excel spread sheet, further appropriate statistical test was done using SPSS version 16 to draw inferences.

3 Results and Discussion

3.1 Factors for dropping out poultry farming

There were various factors that influenced farmers in Punakha *dzongkhag* to drop out poultry farming. These factors include technical, social, economical and environmental factors which are detailed below:

i) Technical factors

farmers reported to received all the technical support on time and are technically competent to manage the poultry farms.Hence technical factors has very minimal affect on dropping out poultry farming. However, some farmers mentioned that due to recent disease outbreak in the farm that resulted in high mortality and economic loss which could have discouraged them to continue poultry farming. Besides many birds in the farm are killed by pecking one another (cannibalism). The de-beaking equipment was unavailable at the Dzongkhag and respondents were not aware on de-beaking technology.

ii) Social factors

Majority of the respondents (75%) mentioned that due to religious sentiment and stigma in rearing poultry birds, particularly when the farmers had difficulty in culling the spent birds at the end of its production phase had de-motivated them to continue. Rearing of spent birds with low production potential was not economic as the birds need to continuously feed with commercial feeds. In addition, farmers mentioned that in a religious society they are down looked by the neighbours when they dispose off or cull the spent birds.

About 27% respondents mentioned labour shortage in the household to take care of birds, which needs at least one attendant daily for routine management. In situation of inadequate people in a household, the respondents choose to discontinue with poultry farming. The other social factors include having no adequate land to establish poultry farm. Some farmers leased in land to established poultry farm, particularly in the case of a farmer in Petari village at Kabji geog who leased in land to start with poultry farming, but after a year the land owner took back the land, thus forcing him to drop out poultry farming. Similarly, a farmer in Gyensa village under Toep geog had his poultry farm away from his house due to inadequate land holding near his residence, in absence of his vigilance, there was theft of his poultry birds, which caused him huge economical loss in poultry farming.

iii) Economic factors

The respondents informed about the economic factors which created inconvenience for poultry farming. The economic factors includes the inflation in price of poultry feed, which was mentioned by 80% of the respondents and the lack of price control in the market. This supports the condition in Bangladesh, that there is declining trend of production in poultry industry mainly due to rise in poultry feed by 30% in six months (Ali & Hossain, 2012). In addition, the increasing price of transportation further added on the cost of poultry production. As a result, 47% of the respondent stated that poultry farming is not economic in terms of input-output price ratio.

The other economic factor according to 13% respondents was market competition with farmers from other *dzongkhags* bringing in eggs to the local market at a comparative lower price than their price tag. Therefore, it was not profitable to sell the eggs at the price sold by other farmers and it discourages farmers to continue with the poultry enterprise.

iv) Environmental factors

The environmental factor such as predation on poultry birds by wild animal, attributed to the location of villages near the forest areas. Further low cost locally available housing materials used was not effective in preventing the wild predation. Farmers reported that wild animal predation as one of the reasons to drop out poultry farming. According to Sonaiya (1990) in Ahuja and Sen (2007) suggests that approximate 825 million chicks in Africa die each year as a result of predators. The other environmental factor according to a respondent was unpleasant smell from the poultry farm that pollutes the surrounding areas. The misunderstanding with the neighbours over the issue of poultry unpleasant smell, that resulted the farmers dropped out poultry farming was also reported from elsewhere (Goan n.d.).

The respondents gave multiple reasons and it was understood that there was always combination of these factors that determined the farmers to drop out of poultry farming and these factors according to the respondents' point of views are presented in Table 3.

Table 1. Stated reasons by respondents for drop out

	Reason for Dropping Out								**Total**
Geog	**Social**	**Economic**	**Environment**	**Tech-Eco**	**Soc-Eco**	**Tech-Soc-Eco**	**Soc-Eco-Env**	**Tec- Soc-Eco-Env**	
Talo/ Guma	0	0	0	1	0	2	1	1	5
	.0%	.0%	.0%	20.0%	.0%	40.0%	20.0%	20.0%	100.0%
Kabji	0	1	1	1	1	0	1	0	5
	.0%	20.0%	20.0%	20.0%	20.0%	.0%	20.0%	.0%	100.0%
Toep	2	0	0	0	3	0	0	0	5
	40.0%	.0%	.0%	.0%	60.0%	.0%	.0%	.0%	100.0%
Total	**2**	**1**	**1**	**2**	**4**	**2**	**2**	**1**	**15**
	13.3%	**6.7%**	**6.7%**	**13.3%**	**26.7%**	**13.3%**	**13.3%**	**6.7%**	**100.0%**

The Statistical test showed that there was no significant association [$\chi^2(14, N = 15) = 19.50, p > .05$] between the views of the respondents. Different reasons mentioned by the farmers for their inability to continue with poultry farming and also it varied between the geogs as presented in Figure 5.

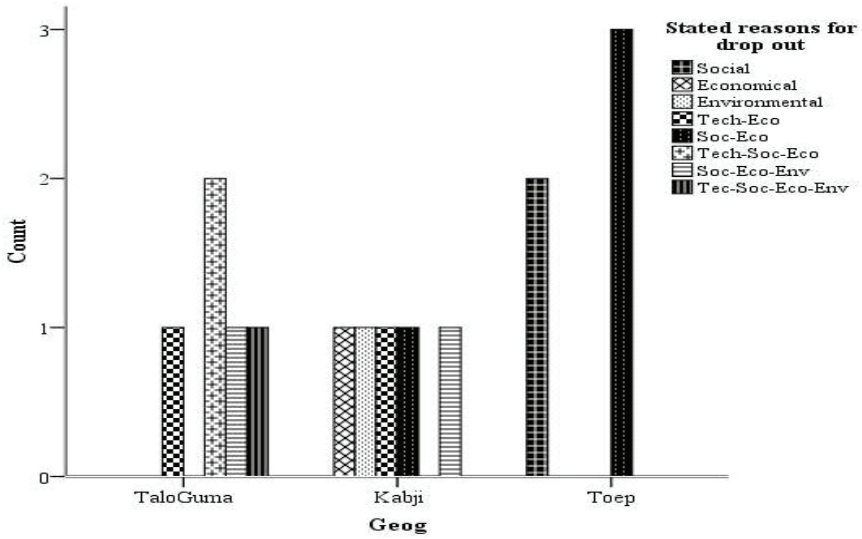

Figure 1. Stated reasons by geog for drop out in poultry farming

3.2 Future support

When respondents were asked on their interest to continue with the poultry farming in future, only 13.3% from Kabji geog stated that they would like to continue at the micro scale of 100 to 200 birds. The remaining 86.7% are not interested to continue due to the various reasons as mentioned above.

Among the various areas for future support, the most common that 40% of the respondents stated was on capacity building, technical support and controlling the increasing poultry feed price as shown in Figure 6. Besides, providing subsidy package was also mentioned as an alternative to encourage farmers in poultry farming which the dzongkhag had already initiated and further needs to continue. However, there was multiple responds on this and it varied between the individual respondents.

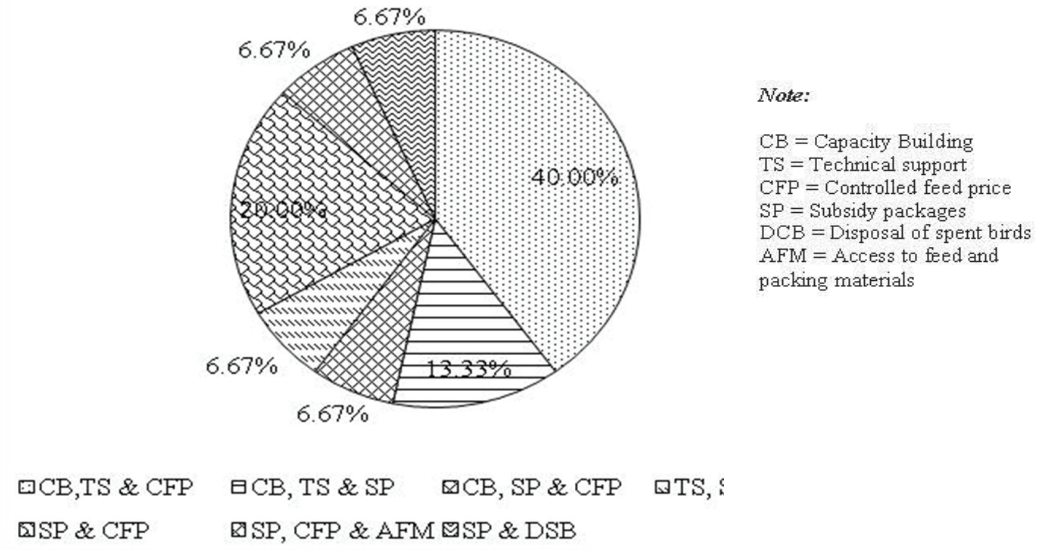

Figure 2. Stated response on the areas of future support required by respondents

4 Conclusion and Recommendation

Majority of the farmers have operated poultry farming on the trail basis for one to two years at the micro scale of 50 to 100 poultry birds. But recent year noted a decline in poultry farming with many farmers dropping out in Punakha Dzongkhag with 47% of the total poultry farmers have discontinued due to arious factors. The scale of operation was found not very economic in terms of input-output price ratio leading to failure to compete with cheaper eggs from other areas in the market. Besides, farmers had difficulty in disposing spent birds due to social and religious sentiments which further added cost for rearing unproductive birds.

In order to sustain the poultry farming in Punakha Dzongkhag and to meet the egg production target set for the 11th FYP, key recommendations are as follows:.

- Prior to supporting the poultry farmers in the remaining year, conducting a detail feasibility study should be mandatory, taking into consideration the availability of land, labour and capital, Continue building capacity of farmers prior to initiation of poultry farming, provide with subsidy packages support to stabilize the feed price

- Support scaling up the existing micro-poultry farming venture into larger scale of operation level that will have higher economic returns for farmers to continue profitable venture.
- Explore opportunity and network using various media to attract this youth to take up the poultry farming as an economic enterprise.
- There is need to support and strengthen the extension and monitoring system of the poultry farmers. In the process, the farmers' points of views on the overall production system are collected and areas requiring support are identified to continue with poultry farming.

Acknowledgement

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Facilitation Procedures to Managing Conflicts in Community Grasslands

Kesang Wangchuk[1], Karma Dorji and Ugyen Lhendup

Abstract

This paper reports the processes developed by the Dhur community on managing community grazing lands and steps undertaken to manage grazing conflicts. The discussions include the challenges of external facilitation in mobilizing Dhur community in the entire process of developing community bye-laws and grazing management plan. The use of Participatory Rural Appraisal (PRA) tools and conflict analysis of the community are discussed. The paper covers the importance of the involvement of stakeholders in the conflict management. The outcome of the facilitation support of RNRRC, Jakar to the Dhur community shows that a proper management plan, strong community bye-laws, learning processes and involvement of stakeholders are the important components of managing grazing conflicts in community grasslands.

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Keywords: Community; Conflict; Management; Tsamdro.

1 Introduction

Dhur is situated at an elevation of 3,000 masl, north of the Bumthang valley in east central Bhutan. The village comprises of 80 households and the village is one of the oldest in Bumthang. Horticulture and field crops activities were carried out on a small scale due to frequent damage by wild boar and inherent poor soil fertility. Large portion of barren land are the visible consequence of the traditional fallow land cultivation. Temperate *Tsamdros* are a major source of fodder for high altitude livestock at Dhur in Bumthang *dzongkhag*.

The RGOB through the tenth five year plan emphasized on development of the livestock industry to alleviate rural poverty and promote economic reliance amongst rural communities. It is also now commonly recognized that natural resources can be better managed if communities have clear rights, responsibilities and returns to those natural resources. However, over grazing is common in community *Tsamdro* and it is the main cause of a decline in grassland production (Miller 1986) and conflicts amongst communities. Conflicts often arise from unequal sharing of community grazing resources and dependence between community members for management. Conflicts are inherent in joint management of any system (Arya and Samra 2001). Their resolution requires a well established process to promote regulated grazing. At present, conflicts between community members are often solved by the *dzongkhag* court rather than resolving them at community level (Authors' personal conversation 2006). This is mainly because there are no systematic procedures at community level to resolve conflicts. The development of

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community based management is expected to minimize conflicts and promote sustainable use of temperate community *Tsamdro*.

This paper reports on the community based grazing management process developed by Dhur community. The objectives are to understand grazing conflicts and document processes developed by the Dhur community to minimize conflicts.

2 Materials and methods

2.1 Conflict Analysis

Through external facilitation and the use of Participatory Rural Appraisal (PRA) exercises, the community described the existing resources and related challenges. Additional external facilitation was provided to help community develop their management plan. The participatory rural appraisal tools used were:

- Social analysis;
- Participatory resource mapping; and
- Trend analysis.

1) Social Analysis
Social analysis was conducted to explore opportunities and interests of community members to form a group for the management of common grazing land and to classify its members in terms of agricultural practices, size of land holdings, herd size and sources of livelihood.

2) Participatory Resource Mapping
Although participatory mapping is not a recommended tool for establishing the scale and boundaries of community areas (Carter 1996), it provides a sound knowledge on community resources on which decisions are made. Therefore, each sub group was asked to carry out a resource mapping exercise. Their migratory routes and location of grazing resources were drawn on the floor and chart papers. Upon finalizing the resource map for each sub group, a final map of the common grazing area was drawn on chart papers and presented to the community.

3) Trend Analysis
Participants were asked to draw a time line on past and present areas of high altitude grassland used for grazing. In this analysis, the different social groups were asked to note the important farming characteristics ten years ago; present farming conditions and expected farming conditions in ten years. Based on the results of trend analysis, the community expressed the need to have regulated grazing systems in place to promote sustainable and harmonious use of the common grazing area. The first step in forming the grazing group focused on identifying and discussing the main problems and sources of

conflicts. Consequently, community members were asked to agree on possible solutions and prepare an action plan for the management of their resources.

2.2 Community Based Conflict Resolution

The community proposed to frame bye-laws to resolve the grazing conflicts. Facilitation was provided in terms of (a) Participatory mapping of conflict areas and resources (b) Developing a community management plan and (c) Framing community bye-laws.

i) Participatory Mapping of Conflict Areas

This mapping exercise is different from resource mapping. The purpose of this mapping was to identify conflict areas of the community. The problem areas were ranked.

ii) Community Management Plan

Discussions were initiated amongst committee members to highlight benefits, constraints and solutions related to the each of the conflict areas. Management prescriptions were then defined to address each issue raised. Steps leading to the management prescription were discussed by the committee of the grazing group and later presented and agreed by the community.

iii) Community Bye-laws on Utilization of Community Tsamdro

Through external facilitation, the committee members framed bye-laws for the grazing group of the community. These were then presented and discussed. The bye-laws provided clear prescription and rules and responsibilities of community members.

2.3 Involvement of Stakeholders

Given the integrated approach of the community to resolve conflicts, it was found necessary to include different stakeholders in the process of developing community grazing management plan. Dzongkhag Livestock Sector, Dzongkhag Forestry Sector, National Feed and Fodder Development Programme (NFFDP) and Renewable Natural Resources Research Center (RNRRC) were the main stakeholders identified by the committee. The stakeholders participated in the yearly general meeting of the community. The involvement of stakeholders was to assess the needs of the community and decide on providing technical and input support to the community. To implement the management plan, the community also identified support from the stakeholders.

3 Results and Discussion

3.1 Livelihood and Conflicts

The main sources of income for the Dhur community included off farm labor and livestock farming. Village also earned considerable income through the sale of cordyceps (*Cordyceps sinensis*) and tourism. Natural grasslands providing fodder for the livestock and blue pine forest providing firewood and timber were the major natural resources of the community. Limited land holding was a major constraint to producing sufficient fodder for livestock at Dhur. It is an issue of concern because limited land holding often leads to increasing pressure on grazing resources owned by others

individuals, thus resulting in conflicts. The issue was partly addressed by the Dhur community through sharing of community grazing areas.

However, conflicts are common in community areas where community members rely on each other for management of community resources. This leads to improper management and deterioration of grazing lands. Conflicts were often caused due to:

- Unequal herd size resulting in unequal utilization of grazing resources;
- Difference in the duration spent by herds on community grazing areas;
- The encroachment of community grazing areas by herders from other communities; and
- The overlap of grazing rights and illegal encroachment by herds in the absence of rightful owners.

3.2 Social Groups

The social groups defined by the community in Dhur were:

- Yak herders (*Bjop*);
- Farmers owning grazing land and cattle (*Threb* I);
- Farmers owning cattle and without grazing land (*Threb* II);
- Farmers owning horses; and
- Farmers without livestock and grazing land (*Zurpa*).

The grazing community of Dhur consisted of *Bjop, Threb I, Threb II* and Group owning horses.

3.3 Trend Analysis

The subgroups except farmers without grazing land and livestock saw increase in income from livestock over the last ten years. They expected increase in income from livestock after ten years. Similarly, the sub groups involved in tourism expected income from tourism to increase after ten years. The farmers owning both the livestock and grazing areas expected major income from potato after ten years. Cordyceps provided considerable income but the sub groups involved in cordycep collection agreed that the income from cordyceps would decline ten year later due to increasing number of collectors annually.

The sub groups owning livestock experienced decline in the conditions of winter grazing areas over the last ten year and the condition is expected to decline further after ten years because of increasing grazing pressure from different categories of livestock. However, the sub groups expected no major change in the conditions of summer grazing areas. Over all, the sub groups predicted *Tsamdro* holding to decrease after ten years. Following identification of problems and solutions, an action plan was prepared (Table 1).

Table 1: Problems and solutions proposed by the Dhur grazing community.

Problem	Solutions proposed
Over grazing of community *Tsamdro* at Gangkar by yaks, cattle and horses in winter and cattle and horse in summer.	Develop a grazing management plan to ensure adequate rest periods for the re-growth of *tsamdro*. Improve livestock breeds and reduce the number of less productive animals per household.
Invasion of *tsamdro* by unpalatable plants due to a ban on fire.	Burning of unpalatable plant species. Reseeding of *tsamdro* with native species.
Deterioration of community *tsamdro* above the village due to heavy grazing by community horses and cattle.	Study production potential of *tsamdro*. Plant improved pasture in individual fields to reduce pressure on community *tsamdro*.
Over grazing of *tsamdro* in transit camps by horses of Sephu herders and horses used for tourism.	Develop a grazing management plan with Sephu herders and people dependent on tourism. Introduce a minimal fee system for grazing *tsamdro* in transit camps.
Competition for fodder resources by wild animals especially the blue sheep.	Assess the amount of fodder utilized by the wild animals.

3.4 Mapping of Conflict Areas

The degraded community grazing area above the village received the highest rank. This area is actually owned by few individuals who have allowed the community to utilize it. This grazing area was further divided into four sub areas and the sub areas were ranked based on their grazing conditions. Sub area one was the priority area where overgrazing is frequent by yaks in winter and cattle in summer. Sub area four is the least utilized area because of some forest and bamboo cover.

3.5 Community Management Plan and Framing Bye Laws

There was a strong disagreement from yak herders on the number of days they should spend on winter grazing areas particularly on sub area one. This was mainly because of the existing traditional grazing practices being followed for generations and the lack of community bye-laws that governed the use of community grazing areas by yak herders in winter. The grazing management plan was specifically developed for the sub area one, two, three, and four. The highest priority was given to the sub area one as this area is frequently under grazing pressure from different categories of livestock. The grazing management plan took into consideration the grazing pressure from horses. According to the community, grazing by a horse for one day is equivalent to grazing by ten cattle in the same area. Further, the community is less supportive of the idea of sharing the community grazing areas with the herders from other community such as herders from Chumey *geog*.

The action plan (to execute management activities) developed by the community included the tentative dates for starting the planned activities (Table 2) and the support required by the community in executing planned activities.

Table 2: Community action plan for 2006-2007

Activities	**Responsible**	**Time for implementation**
Final discussion on formation of association, preparation of by laws and management plan.	Committee	25th March 2006
Registration of members	Committee	25th March 2006
Preparation of by laws, work plan and production of booklet on by laws	RNRRC Jakar	March-August 2006
Study visit to advance Action Research sites by selected members	Committee and RNRRC Jakar	September 2006
Final presentation and discussion on the booklet with community	RNRRC Jakar and Committee	November 2006
Translation of booklet into dzongkha	RNRRC Jakar	November 2006

Framing bye-laws was a new exercise for the community and the community made little progress in the initial stages of framing bye-laws. The facilitation was made easier through interpretation and elaborate explanation by the *Gup*, *Mang Ap and Tsokpa*.

The annual general meeting was found important by the community during which the community will revise the annual work plan, discuss achievements of the past year, report the financial details and solve constraints and issues between community members. The community agreed to conduct general meeting in January after the yak herders have settled on their winter grazing areas near to the village. This was decided because yak herders share the conflict grazing area during winter with the other social groups of the community. The late winter is also referred to as the most suitable time for the conduct of general meeting since at this time the community is not actively involved in their agricultural activities.

4 Conclusion

The community is committed to developing a community based management plan and utilize community grassland in a sustainable way. However, external facilitation plays an important role in helping the community develop a community based management plan and their bye-laws. Our exercise with the community revealed that it is not as difficult to manage the community grassland as it is to manage and mobilize the community in the management process. Soontornwong (2006) reported similar finding of her work on

community mangrove management in Thailand. Although conflicts related to the use of common grazing resources can be minimized, they can't be completely solved without proper community mobilization. Lack of clear pasture policy is also a factor contributing to the cause of grazing conflicts. Thus, community based management and the community bye-laws need to be emphasized as a part of conflict management process. Conflict minimization is better achieved with clear accountability and a strong sense of ownership of community grazing resources. Our exercise with the community suggests that accountability and ownership are ensured through strong community bye-laws, outlining the roles and responsibilities of community members and stake holders, as well as through a commonly agreed management plan for the resources.

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Organic Agriculture as a Sustainable Alternative: A brief synthesis of research findings in a vegetable system from abroad

Yadunath Bajgai[1]

Abstract

Due to sustainable qualities, organic agriculture is promoted in Bhutan. Generally, organic cropping systems utilize crop residues and other organic materials as key management inputs with soil cultivation also being employed as a means to manage weeds. In spite of scant crop residue input, tillage to control weeds in vegetable systems reduces soil organic carbon levels. This led to investigate the hypothesis that vegetable systems could be made more resistant to the effects of tillage by including a high-residue grain crop of sweet corn in the rotation with cabbage. Crop yields, weed biomasses, soil nutrients and soil organic matter fractions were examined in the organic and conventional farming systems with or without crop residues incorporation.

In the field experiment, total organic carbon increased significantly in the 0-0.1 m depth. Stable and labile forms of carbon and total organic carbon were also positively impacted by residue incorporation in both field and laboratory experiments. Residue incorporated and simulated tillage treatments emitted 2.3 and 1.5 times more carbon dioxide in comparison to unamended and undisturbed treatments, respectively. Due to equivalent macro-nutrient supplied, the agronomic outcome showed that yields of corn and cabbage and the nutrient uptake by corn stover and cabbage head were not influenced by residue incorporation or farming system.

Residue incorporation and the organic system increased the average total nitrogen compared to the treatments without residue and the conventional system, respectively, indicating the fertility benefits of these treatments. It can be deduced that nutrient lost in the conventional practice could be equivalent to nutrient retained in organic system since equivalent quantities were applied and yields obtained were similar. Soil incorporation of corn residue decreased the average in-crop weed biomass in cabbage crop. The corn residue-induced inhibitions on weed biomass may be used as a supplementary treatment to mechanical weed control for the organic system potentially reducing the negative effects of tillage.

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Keywords: **:**

1 Introduction

Organic farming is environment-friendly production system that produces healthy food, and it generally generates better income to the producer than the conventional farmers. As the principles of organic farming would help realize the development philosophy of Gross National Happiness, the Royal Government of Bhutan plans and prepares to go 100% organic in future. To enhance the policy initiative and to increase interactions and exposure to international experts, two international conferences on organic agriculture were held in Bhutan recently. In December 2013, a consultation workshop was held in Bajo to explore potential of bio-pesticide use and was organized by SAARC Agriculture, ICS and Department of Agriculture (RDC Bajo).

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In March 2014; experts, scientists, governments officials and farmers from about 30 countries deliberated in Thimphu on ways to further develop organic agriculture, particularly in the mountain ecosystems and was organized in collaboration with IFOAM, NOP (Department of Agriculture), Navdanya and Mellinium Institute under the leadership of the Ministry of Agriculture and Forests. Therefore, it is appropriate that scientific literature be collated and disseminated especially on the potentials, challenges and the findings from studies to broaden our understanding and prospectives. Globally, adoption of agriculture by farmers has grown but has not picked up as expected due to many constraints and challenges. There is growing public interest; policy support and readership on organic agriculture in Bhutan, which have led to generation of this synthesis. There is also strong enthusiasm and high expectations from organic farming and there is a need to present a balance view on potentials and challenges of organic agriculture based on the scientific evidences. Thus, this paper will make an attempt to synthesize some research findings from a higher degree research with a particular reference to a vegetable system.

Generally, organic cropping systems utilize crop residues and other organic materials from within the farm as key management inputs (Stockdale *et al.* 2002, Bajgai *et al.* 2013b), with soil cultivation or tillage also being employed as a means to manage in-crop weeds. In contrast, conventional agriculture relies on the application of mineral fertilisers rather than the regular application of crop residues and other organic materials for fertilization and weed management is normally achieved with the use of herbicides, not tillage (Chirinda *et al.* 2010, Bajgai *et al.* 2014c).

Soil organic carbon is the percentage of carbon in soil organic matter (SOM) (Bajgai *et al.* 2013a, Stockmann *et al.* 2013). The farming practices such as intensive cultivation and bare fallows decreases SOC (Johnson *et al.* 2007), and thus the adoption of conservation agricultural practices such as no-tillage, crop rotations and crop residue retention can increase SOC. Although, no-tillage cropping is suited for field crops like corn, it is generally unsuitable for most vegetable crops due to their subtleness and requirement of intensive care. Moreover, organic vegetable systems routinely use tillage to prepare beds and manage weeds. These cultivations damage soil structure and break soil aggregates, whereby exposing physically protected soil organic matter that leads to loss of SOC in the form of carbon dioxide (Six *et al.* 2002, Blanco-Canqui and Lal 2004). In spite of using tillage operations, the vegetable systems also have little or no crop residue input and so organic materials input is negligible for formation of SOM (Jackson *et al.* 2004, Bajgai 2013), the breakdown of which releases nutrients for crop growth (O'Donnell *et al.* 2001) in organic systems. Hence, if crop residue input is scant, the SOM likely to decrease (Bajgai *et al.* in press). Therefore, organic matter input through enhanced crop residue input in soil could balance out SOM reduction in both organic and conventional vegetable systems. This led to investigate the hypothesis that vegetable systems could be made more resistant to the effects of tillage by including a high-residue grain crop of sweet corn (*Zea mays* L. var. *rugosa*) in the rotation with cabbage (*Brassica oleracea* L.) (Bajgai *et al.* 2013b, Bajgai *et al.* 2014b). Crop yields, weed biomasses, soil nutrients and SOM fractions were examined in the organic and conventional farming systems with or without crop residues incorporation (Bajgai 2013).

2 Materials & Method

A research trial commenced from December 2009 and ended in December 2011 near Armidale, New South Wales, Australia. The experimental design adopted had a completely randomised layout with a factorial design with 2 residue managements × 2 farming systems × 2 soil types with 4 replications. A sweet corn (summer) and cabbage (winter) rotation with two systems (organic or conventional), and two residue management practices (+RES = with residue, or –RES = without residue) were carried out (Plate 1) and is as presented in Bajgai (2013). The new feature of this experiment was that the macro-nutrients of nitrogen, phosphorus and potassium supplied were matched for organic agriculture and conventional agriculture for the two crops at recommended rates since nutrients are normally not matched in farming systems research (Bajgai 2013, Bajgai *et al.* 2013b).To supplement and answer questions from the field trials, two laboratory experiments were also conducted in the University of New England, Armidale. All field and laboratory experiments of this research were conducted on Vertosol and Chromosol, two common agricultural soils in Australia. Yield components of corn and cabbage crops and weed biomasses and nutrient uptake by corn stover and cabbage heads; and total organic carbon and nitrogen and their fractions, and soil macro-nutrients were also analysed for the field experiment. In the laboratory experiments, total organic carbon and its fractions and carbon dioxide emissions were the main chemical analyses (Bajgai *et al.* 2011a, Bajgai *et al.* 2014a). The details of different experimental methods and laboratory analyses are presented in the related works (Bajgai 2013, Bajgai *et al.* 2013b, Bajgai *et al.* 2014a, Bajgai *et al.* 2014b). The paper is based on number published materials in major international scientific journals or forums as evident by the reference list; most of which can be accessed online.

A. Corn crop before maturity

B. Corn residue shredded mechanically

C. Cabbage seedlings transplanted

D. Residue reduces weeds in cabbage crop

Plate 1: Agronomic processes of the field experiment (order: A to D).

3 Results and Discussion

In the field experiment, total organic carbon concentration increased significantly in the 0-0.1 m depth by incorporating shredded corn residue; however the effect of organic and conventional management had inconsistent effect (Bajgai *et al.* 2011b, Bajgai *et al.* 2014b). The laboratory experiment that teased out confounding factors in the field trial showed that the use of atrazine herbicide and mineral fertiliser in the conventional system in the field experiment had no significant effect on total organic carbon, whereas the organic fertiliser significantly increased total organic carbon (Bajgai 2013). Therefore, organic fertiliser application in the field could balance out the SOC lost through tillage. Soil basal respiration and microbial biomass carbon data showed that the soil's biological fertility could be improved by incorporating residues and by combining residue incorporation with organic fertiliser. Evaluation of the SOC stock determined that residue incorporation at about 15 Mg/ha per year (oven-dry equivalent) in soil accumulated an average of 0.96 and 1.22 Mg C/ha for Chromosol and Vertosol, respectively, in the field trial after 2 years. That is based on the Intergovernmental Panel on Climate Change standards of 0.3 m soil depth (Bajgai 2013).

Corn residue incorporation in soil increased particulate organic carbon (labile form) in the field and the laboratory experiments. Mineral-associated organic carbon (stable form) and total organic carbon were also positively impacted by residue incorporation in both field and laboratory experiments. This result indicates that residue was the key determinants of particulate organic carbon and mineral-associated organic carbon fractions. Mineral-associated organic carbon was the major pool of total organic carbon in both experiments. The increase in the stable form of carbon, not just in the labile forms, indicates the potential for longer term carbon sequestration in soil through physicochemical stabilisation in vegetables systems, if not through aggregation (Bajgai *et al.* 2012, Bajgai *et al.* 2014b).

On average, residue incorporated and simulated tillage (sieving) treatments emitted 2.3 and 1.5 times more carbon dioxide in comparison to unamended and undisturbed treatments, respectively, in the laboratory emission experiment (Bajgai *et al.* 2014a). This suggests that carbon availability and form could be more important for carbon dioxide emission than physical disturbance in cropping soils (Bajgai *et al.* 2011a, Bajgai *et al.* 2014a). Both residues incorporated and sieved treatment (organic scenario) not only emitted more carbon dioxide but also had higher level of SOC in both Chromosol and Vertosol, compared with the treatment that was neither incorporated with residue nor sieved (conventional scenario) (Bajgai *et al.* 2014a). This observation from laboratory indicates that an organic system might retain more soil carbon than a conventional system.

The agronomic outcome showed that yields of corn and cabbage and the nutrient uptake by corn stover (except phosphorus) and cabbage head were not influenced by residue incorporation or farming system (Bajgai *et al.* 2013b). Unlike commonly reported in literature (Seufert *et al.* 2012), yields of both crops under the organic systems were not lower than the conventional system. This new finding could possibly be ascribed to the equivalent nitrogen, phosphorus and potassium nutrients applied and also soil nutrient status might not have reached the limiting level after imposition of the treatment. A global scale review and synthesis by Badgley et al.(2007) concluded that organic agriculture could provide sufficient food to the world population on current agricultural land. However, other authors (Trewavas 2001, Connor 2008) have argued

that agriculture may have lower yields and would thus need more land to produce the same quantity of food as conventional farms.

Uptake of nitrogen, phosphorus and potassium by cabbage heads showed no statistical difference between the two farming systems and two residue treatments. Evidences from 223 studies comparing of nutrient levels of organically and conventionally produced foods reported no nutritional benefits except for higher P levels in organic food (Smith-Spangler *et al.* 2012) and other authors have unclear differences (Biao *et al.* 2003, Hoefkens *et al.* 2009). However, a meta-analysis of 39 papers (Hoefkens *et al.* 2009) reported that only nitrate was significantly lower in organic vegetables and similar finding was also reported in a more recent study (Herencia *et al.* 2011). Therefore, scientific literature lacks a clear and consistent difference between the nutrient contents of organic and conventional produce.

Residue incorporation and the organic system increased the average total nitrogen compared to the treatments without residue and the conventional system, respectively, indicating the fertility benefits of these treatments. It can be deduced that nutrient lost in the conventional practice could be equivalent to nutrient retained in organic system since equivalent quantities were applied and yields obtained were similar (Bajgai *et al.* 2013b). Moreover, soil total nitrogen and its labile and stable fractions were found to be significantly higher in the organic system compared with the conventional system (Bajgai *et al.* 2014b), which the evidence that organic system can retain more nutrients. This could be due to slow nutrient releasing characteristic of organic fertiliser (Berry *et al.* 2002, Marinari *et al.* 2010) as compared to soluble mineral fertilisers that can easily leach down the soil profile. Further, N mineralisation rates in conventional farming can be as high as 100% compared with the organic farming (Poudel *et al.* 2002).

Soil total nitrogen status after cabbage harvest was impacted positively by the incorporated residue and the SMS due to the nitrogen input through residue and organic fertilisers. The slower mineralisation rate of nitrogen in organic fertilisers than in the mineral nitrogen-fertiliser may have increased the average total nitrogen and exchangeable sodium in the organic SMS. While sources of nitrogen in organically grown crops affect crop productivity by limiting the amount of available nitrogen to meet the crop demand (Berry *et al.* 2002, Stockdale *et al.* 2002), organic systems have the potential to meet the nitrogen requirement if sources of nitrogen, timing of application and selection of crops are matched (Berry *et al.* 2002). From the standpoint of mineral fertiliser, the faster mineralisation rate of fertiliser in conventional SMS may have emitted higher amounts of nitrous oxide (Bouwman *et al.* 2002) leading to lower levels of total nitrogen. Organic management also is reported to have significantly lower levels of nitrate and soluble nitrogen in soil compared with conventional management (van Diepeningen *et al.* 2006).

Soil incorporation of corn residue decreased the average in-crop weed biomass in cabbage crop (Plate 1 D) (Bajgai *et al.* 2013b, Bajgai *et al.* 2014c). The corn residue-induced inhibitions on weed biomass may be used as a supplementary treatment to mechanical weed control for the organic system potentially reducing the negative effects of tillage.

Plant protection in organic cropping is generally achieved by 'prevention' measures unlike 'curative' techniques used in the conventional farming. Preventive measures include cultural practices like crop rotation, crop diversification, mulching and by use of resistance cultivars. Curative measures in organic cropping mainly constitute of using botanicals or sometimes called

bio-pesticides. The efficacy of the bio-pesticides is not as effective as by the chemical pesticides. In summary, major challenges that organic cropping system are to gather sufficient organic materials (e.g. manure, leaf mould and compost) for crop nutrition and to get effective means of plant protection.

4 Conclusion

The observed short-term gains have the potential to translate into longer-term carbon sequestration and soil fertility gains, if sweet corn is rotated with vegetable crops. However, the effect of organic or conventional system was inconsistent. Although mulching of residue may not be practical for farmers, the results highlight the potential for increasing soil carbon using crop residues to lock more carbon in soil to mitigate climate change and improve soil health. Hence, if more atmospheric carbon dioxide-carbon can be converted in biomass carbon and then applied on soils over large spatial area, the increasing issue of global warming may be mitigated. Moreover, these practices may be an option to counteract the loss of carbon caused by tillage in organic vegetable systems. The increase in the stable form of carbon, not just in the labile (unstable) forms, indicates the potential for longer term carbon sequestration in soil through physicochemical stabilisation mechanism. However, the experimental period (two years) was short to ascertain results, however results provide useful indications. Yields of corn and cabbage under the organic cropping system were not lower than the conventional farming. Residue incorporation may supplement mechanical weed control in organic system. The organic fertiliser releases nutrient slowly helping to reduce nutrient losses to the environment for environmental protection and to supply nutrients for succeeding crops.

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Soil Nutrient Management for Rice in Bhutan: Current Practices and Future Strategies

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Abstract

Rice is one of the main food crops of Bhutan. Nationally, its self-sufficiency stands at just over 50%, which is approximately 60,000 MT in a year. Despite its national significance, enhancement in productivity by way of crop husbandry in farmers' field is still developing. The three major factors that hinder rice production are declining soil fertility, shortage of irrigation water and decrease farm labour. Of these, soil fertility management practices and strategies for future are synthesized in this paper. Most farmers used to depend on farmyard manure to maintain soil fertility, and the use of mineral fertilizers in rice is also becoming common in recent years due to improved accessibility and affordability. Even though some farmers commonly use mineral fertilizers, the imbalanced usage and poor matching application time with crop requirement, hinder gainful return on farmers' investment. To maintain or improve soil fertility an integrated soil fertility management system that includes organic materials like farmyard manure, leaf mould, crop residues along with the balanced application of mineral fertilizers is require. Organic materials would improve biological fertility of soil whereas minerals fertilizers supplement macro-nutrients. Broad long-term action plans and specific nutrient management strategies for four Bhutanese rice agro-ecological zones are identified as technical suggestion. The future strategies of soil nutrient management are to optimize rice productivity per unit area of land without depleting soil health

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Key words: Rice, nutrients, production, strategy, fertilizers, inputs

1. Introduction

Rice is the most important food crop in Bhutan. It is embedded in our traditional and religious values. During the 10th Five Year Plan (FYP) rice self-sufficiency target was at 65%, however the self-sufficiency stands only at 51.3%. The domestic production meets only about half of the national annual requirement of about 130,000 MT (Ghimiray, 2012). To make up for the rice deficit, imports from India range from 50,000 to 60,000 MT annually. At present, rice is cultivated in 59,609 acres of land with a national productivity of 1,312 kg/acre. To keep pace with the increasing population, rice production should further be increased. However, declining soil fertility coupled with shortages of irrigation water and household labour are the three most constraining factors.

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Often 'poor soil fertility' is reported as the main reason for rice yield decline (Yeshey, 2012).

Generally the wetland soil nutrient status is low across the entire rice growing region, for example in Guma geog under Punakha Dzongkhag (Bajgai, 2006). The major concerns are low pH, nitrogen (N), phosphate (P) status and imbalanced base nutrition (Norbu and Floyd, 2001 and Ghimiray *et al.*, 2008). In 1999/2000, a nationwide soil fertility (SFM) survey was conducted to evaluate the basic assumption of 'low productivity of land and unsustainable soil fertility management practices'. In this survey a total of 376 samples were collected and analyzed and these soil analytical results provided the most representative picture of the agricultural soil fertility status in Bhutan. According to the survey findings, the soils generally have low or very low pH (< 5.5). The total organic carbon levels are adequate but total N levels are low or very low. Available P and potassium (K) are both in low or very low range. Percent base saturation (BS%) and total exchangeable bases are low or very low in most soils across the country. The low to very low exchangeable calcium (Ca) and magnesium (Mg) levels as compared to predominately moderate to high levels of exchangeable K are reflected by unfavourable Mg:K and Ca:K ratios.

2. Changes in soil nutrient management for rice production

In Bhutan, the systematic collection, transportation and application of farmyard manure (FYM) and other organic materials such crop residues, forest litters, fodder residues, green legumes and mineral fertilizers are the major sources of plant nutrients for rice production. Farmers either use them individually or combine them to replenish the nutrients removed through rice harvests. The quantity and quality of FYM vary from one location to another or among the households. The sustainability of the traditional soil fertility management (SFM) system is dependent on the household labour availability and livestock number and management system. Similarly, types and amount of mineral fertilizer application is determined by the household resource status and availability of fertilizers.

While fertilizers have made their way in Bhutan only since the early 1960s, their use has been an important part of government agricultural development strategy to increase crop yields and production. In 1989 with the assistance from Food and Agriculture Organization (FAO), improvements in fertilizer usage were made and the first fertilizer recommendation for rice was developed. The recommendations were based on trials conducted at various places as part of the FAO fertilizer project (DoA, 1989). These recommendation rates have been the basis for fertilizer usage until 2009 and in 2009 National Soil Service Center (NSSC) has validated the FAO recommendation and published the Fertilizer Recommendation Guide for important crops (Table 1).

Table 1: Fertilizer recommendation rates developed by NSSC for rice varieties

Dzongkhag	Fertilizer recommendations (kg/ac)					
	High-Resource Farmers			Low-Resource Farmers		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Local Rice Variety						
Gelephu	32	20	8	20	16	8
Paro	28	16	16	24	12	8
Punakha	28	16	14	16	8	8
Thimphu	30	16	12	20	16	8
Trongsa	24	14	8	20	12	8
Tsirang	36	16	8	20	16	8
Wangdue	24	14	14	16	12	8
Improved Rice Variety						
Geylephu	32	20	12	30	12	8
Paro	32	20	8	32	16	8
Punakha	32	16	8	28	16	16
Samtse	32	20	16	24	16	12
Thimphu	32	20	8	30	20	8
Trashigang	28	24	12	20	16	8
Tsirang	36	24	12	28	16	8
Wangdue	32	20	8	28	16	16

Source: A Guide to Fertilizer Recommendation for major crops (NSSC, 2009)

Fertilizer usage in rice production has changed (both types and amount) over the time. This change must have been stimulated by the introduction of improved rice varieties which are responsive to fertilizer application and also to increase the yields of local rice varieties to meet the demand of rice and substitute some import of rice. Consequently the amount of fertilizers imported and distributed in the country has increased over the years. The import of inorganic fertilizers increased from about 250 MT in 1960s to over 2,998 MT in 2006. This clearly indicates changing SFM system in Bhutan. However, the use of inorganic fertilizer in Bhutan is still very low as compared to many other countries (Dorji, 2008). While soil fertility plays an important role in increasing rice production, rice is not a priority crop for nutrient management as reported by Dorji (2008). The current soil fertility management of our rice farmers is inadequate. The traditional soil fertility management systems based on the use of animal manures are being undermined by socio-economic factors (Norbu and Floyd, 2001) and the use of inorganic fertilizers is limited by accessibility and affordability by resource poor farmers.

3. Rice agro-ecological zones and current soil nutrient management practices

Rice agro-ecological zone of the country are grouped by altitude, temperature and rainfall. The broadly grouped four zones are: the Warm Temperate, the Dry and Humid Subtropical zones and the Wet Subtropical zones. Although rice is cultivated in all the zones, the largest rice growing Dzongkhags from amongest the zones are Punakha, Sarpang, Samtse, Wangdue, Dagana, Chukha, Paro and Tsirang. The major paddy cultivation areas are found in the southern low altitude foothills but have the lowest productivity due to poor soils. According to RNR Statistics 2010, Samtse Dzongkhag

records the lowest rice productivity with 843 kg/ac with a total production of 7,126 MT from the largest area of 7,454 acres. This means that there is tremendous scope for enhancing productivity in the low altitude areas by increasing the rates of fertilizer inputs.

4. Current farmers' nutrient management practices and associated issues

The existing soil nutrient management does not meet the requirement of rice crop to attain the optimum rice yields. While most farmers in southern Dzongkhags do not apply any form of fertilizers (organic and inorganic), in some Dzongkhags, the commonly applied soil nutrient input is FYM supplemented with urea (Yeshey, 2012, Katwal *et al*., 2009 and Dorji, 2008).

4.1 Warm Temperate Zone

4.1.1 Farmyard manure (FYM)

In the warm temperate zone (Thimphu, Paro, Haa, Lhuentse, Trashigang), collection and application of farmyard manure is the main source of soil nutrient for rice production. Unlike in the southern Dzongkhags, farmers in these places accumulate manure in animal sheds, and then make into heap outside the shed and finally transport to the fields. This process of FYM production and application is not nutrient efficient as nutrients are lost through leaching and volatilization. According to Katwal *et al*.(2009), in the eastern region most farmers do not apply both organic and inorganic fertilizers in rice. The priority of application of fertilizers and FYM is given to upland fields where maize and potato are cultivated. In those Dzongkhags where FYM is applied, while NSSC recommends an application of 2-3 ton/acre of FYM, the amount applied by most farmers is usually lower than the recommended rate (Yeshey, 2012). The availability and application of FYM is determined by the availability of household labour, number of cattle and availability of bedding materials (Ghimiray *et al*., 2008). Over the years with household labour shortage emerged as nationwide problem (Yeshey, 2001), the numbers of livestock animals reared and amount of FYM supplied have been greatly affected.

4.1.2 Mineral fertilizer (Urea)

Fertilizer use has increased over the years mainly due to their effectiveness in providing substantial and cost effective yield increases. However, the total levels of chemical fertilizer use are still low compared to the global level, (Norbu and Floyd, 2001) and application of mineral fertilizers on rice is common to only farmers of Thimphu and Paro and the commonly used fertilizer is urea (single nutrient).

4.1.3 Other practices

Other soil nutrient management practices include direct application of forest leaf litter (Pine leaves), short fallow periods in between, bund slicing, weed management through use of butachlor and crop rotation (within rice variety) and with different crops such as pea, oat, potato and wheat. However, these practices are seemingly on decline (SSF and PNM, 2000).

4.2 Dry Sub-tropical

4.2.1 Farmyard manure (FYM)

In the dry sub-tropical zone (Wangdue, Punakha, Trongsa, Trashigang, Mongar, Lhuentse), rice nutrients are mostly derived from both locally available organic sources and chemical fertilizers. The systemic collection, transportation and application of FYM is common only to the rice farmers of Wangdue, Punakha and Trongsa Dzongkhags with amount applied lower than the recommended rate of 2-3 ton/acre. Household labour availability, number of cattle and availability of bedding materials determined the application of FYM (Ghimiray *et al.,* 2008). In Trashigang, Mongar and Lhuentse, application of FYM in rice is not a priority (Katwal *et al.,* 2009).

4.2.2 Mineral fertilizer (Urea)

Application of fertilizers on rice is common to the farmers of Wangdue and Punakha Dzongkhags. In these Dzongkhags, while the use of mineral fertilizers on rice is widespread, the imbalanced usage (only nitrogen fertilizer) and poor timing of applications (insufficient in critical crop growth stages) remain as the main issues (Ghimiray *et al.*, 2008). Though the mineral fertilizer recommendation rates existed both for local and improved varieties, adoption of the same is limited. Most farmers use lower than the recommended rates. Lack of awareness on the recommended rate among the rice farmers is the main issue (Yeshey, 2012). With constant imbalanced and inadequate nutrient application, the nutrient mining for other nutrients in the rice fields is an area of concern.

Other nutrient management practices include burning of crop residue (rice straw) after harvest, short fallow periods in between, bund slicing, weed control and management with the use of butachlor and crop rotation (with mustard and wheat).

4.3 Humid Sub-tropical

4.3.1 In-situ manuring through tethering

Humid Sub-tropical zone encompasses Tsirang, Dagana, Chukha, Zhemgang, Pemagatshel and Trashiyangtse Dzongkhags. In Tsirang and Dagana, application of manure through tethering is the only source of soil nutrient for rice production. In these places, tethering is usually done in the fields closer to the homestead only. Animals are tethered for few nights in each terrace and thus the amount of manure added through tethering is not much. Further, those fields which are located far away never get manure application in any form. In other Dzongkhags (Zhemgang, Pemagatshel, Chukha and Trashiyangtse), FYM is mostly applied on crops such as maize and potato and thus rice gets hardly any fertilization in any form (Katwal *et al.,* 2009 & Turkelboom and Wangchuk, 2009).

4.3.2 Green manure

Dhaincha (*Sesbania aculeata*) has been promoted as pre-rice green manure crop in dry and humid sub-tropical areas and countless trials and demonstrations have been conducted by different agencies to disseminate the technology. However, its adoption has been nil to limited among the rice growing farmers owing to the factors such as unavailability of seeds, lack of irrigation water during dhaincha germination and growth stage and free grazing (stray livestock) practice in rice fields before rice transplantation (NSSC, 2011).

4.3.3 Chicken manure

With the recent development of poultry farms in the southern Dzongkhags, some farmers have started to apply chicken manure on rice. According to some rice farmers in Tsirang, use of chicken manure has boosted rice yields appreciably. However, there are concerns regarding the correct rate of application on rice as this practice is fairly new.

4.3.4 Other practices

Other soil fertility management practices include short fallow periods in between, bund slicing, weed management using butacholar and crop rotation. While bund slicing and incorporation of the sliced materials adds nutrients, this practice is at the verge of disappearing in some geogs of Tsirang Dzongkhag as the herbicide glyphosate is substituting the farm labour to control grasses and weeds on terrace bunds (Yeshey and Bajgai, 2014)

4.4 Wet Sub-tropical

In this zone (Sarpang, Samtse, S/Jogkhar), the only soil nutrient source for rice production is manure added through free grazing of cattle during the day and limited tethering of animals during the night (in-situ manuring). As in other places where tethering is practiced, the amount of manure added through this practice is inadequate. Other soil fertility management practices include short fallow periods in between, bund slicing, weeding and crop rotation.

5 Rice yield gaps

Considering the results of the balanced fertilizer trials and demonstrations conducted at various places in the past both by NSSC and RDCs, there are large yield gaps that could be bridged. In Samtse and Sarpang, the rates used for the trials were 160 kg suphala in combination with 52.17 kg urea per acre on improved rice varieties released by the RDC Bhur. For Punakha, improved rice variety of IR-64 was experimented with 28:16:16 NPK kg/ac. However in Wangdue, local variety (Kashimer*)* was experimented with 16:12:8 NPK kg/ac (Yeshey *et al*, 2014 and NSSC, 2009).

In addition, trials conducted using dhaincha (*Sesbina aculiata*) as pre-rice green manure in Langchenphu geog under Samdrup Jongkhar yielded 2192 kg/ac as compared to the

fields without pre-rice dhaincha (1673 kg/ac) (NSSC back to office reports). These results further indicate the opportunities to increase rice yield.

As with other crops, the potential of rice crop can only be fully realized by careful application of inputs together with proper plant protection measures and sufficient irrigation at critical stages. However, based on farmers' feedback and field survey findings, there are other issues which constrain the farmers in improving soil fertility and rice production.

6 Other constrains in nutrient management for rice production

6.1 Policy

There is a lack of clear policy direction and strategy for nutrient management. However, MoAF has recently promoted organic farming and is seen as the main way forward for the country in the future. A clear delineation of geographical areas for organic rice production is desirable.

There is a policy of reducing less productive local cattle breeds to give way for less number of improved breeds. This policy has yielded in significantly decreasing total livestock numbers, and in increasing the number of cross breed livestock at the expense of a decreasing in the number of local breed (Norbu and Floyd, 2001). This has led to farmers moving from extensive (grazing) through semi-extensive (tethering) to intensive (stall feeding) systems. Through this practice, while the recovery of dung is greater, the overall production and supply of FYM has reduced (Norbu and Floyd, 2001). Furthermore, because of religious considerations, many farming households have given up rearing pigs and this has also impacted the FYM supply (NSSC, 2011).

6.2 Operational level issues

According to a survey report (Yeshey, 2012), use of fertilizers is still affected by unavailability and inefficient distribution system. The genetic yield potentials of improved varieties (responsive to fertilizer) cannot be realized without proper fertilization. There is a lack of effective promotion of fertilizer use through agriculture extension programs which has affected the effective dissemination of the technology. For increasing rice production in the country, the emphasis in crop yield improvement has always been on variety (genetic improvement) and not on inputs. Even when the fertilisers are available, majority of rice farmers are resource poor and simply cannot afford fertilizers (Yeshey, 2012). Negative implications of the use of urea (imbalanced) only, already have resulted in formation of large soil aggregates that affects the soil workability (NSSC, 2011).

The traditional soil fertility management systems based on the integrated use of the forest as a source of fodder and leaf litter, livestock for dung, and crops as supply of crop residues (Ghimiray *et al,* 2008) is on the decline. With rural urban drift, farm labour shortage has emerged as a nationwide issue and declining household labour is an established trend in Bhutan (Yeshey, 2001). Declining household labour availability means that the effectiveness of labour use is an overriding factor determining household

soil nutrient management strategies (Norbu and Floyd, 2001). With less labour, farming communities' priorities are towards meeting the immediate needs rather than focusing on long term investments such as soil fertility management and improving land productivity (Turlekboom and Wangchuk, 2009).

7 Suggestion of issues- and constraints-based interventions

7.1 Strategy

A clear well formulated strategies and programs for the types of soil fertility management technologies to be adopted in the country for sustainable production. Improving the availability and accessibility of fertilizer supply system at farm level through enhancing the efficiency of "Commission Agents" and other alternatives such as "One Stop Shop" will help in providing widespread and improved access to this important soil fertility management input. Encouragement of pasture development on the periphery government land to address the issues related to lack of fodder and animal bedding material, household labour shortage and to encourage stall feeding with adequate fodder and bedding materials to increase FYM supply.

7.2 Research and Extension

It would be counterproductive to develop capacity and skills of the farmers on the importance of balanced fertilization in rice through farmer trainings, demonstrations and field days. Awareness on the availability of different types of fertilizers would enable farmers understand fertilizers beyond the commonly known Urea and Suphala. There is a need to promoting labour-saving technologies such as crop rotation with leguminous crops. Shortage of irrigation water needs to be addressed. Farmers may go for green manuring if unavailability of seeds is solved. Trials to determine the suitable application rate chicken manure on rice is recommended as poultry farms are mushrooming in the country.

8. Specific nutrient management suggestions for each rice agro-ecological zone

Considering all the constraints and potentials of all the rice agro-ecological zones, suggested nutrient management technologies are provided in Table 2.

Table 2: Rice agro-ecological zone wise nutrient management recommendations

AEZs	Dzongkhags	Suggested technologies	Recommended rates/species/time
Warm Temperate	Thimphu, Paro, Haa, Lhuentse, Trashigang	• Use of balanced fertilizers. • Use of FYM. • Split application of farmers' practice of urea application. • Pre-rice green manure crop cultivation.	• Refer (Table 1) above • 2-3 ton/ac at land preparation • Farmer's practice split into two, one split apply at transplanting and the other half apply at tillering.

		• Crop rotation with legume crops (Pea, beans)	• Astragalus (Chinese milk vetch) with seed rate of 18-20 kg/ac and sow in November (Bajo, 1994)
Dry subtropical	Wangdue, Punakha, Trongsa, Trashigang, Mongar, Lhuentse	• Use of balanced fertilizers. • Use of FYM. • Split application of farmers' practice of urea application. • Pre-rice green manure crop cultivation. • Effective Shochum weed (*Potamogeton distinctus*) control/management • Crop rotation with legume crops (Pea, beans)	• Refer (Table 1) above. (Lhuentse and Mongar can adopt fertilizer rate recommended for Trashigang) • 2-3 ton/ac at land preparation • Farmer's practice split into two, one split apply at transplanting and the other half apply at tillering. • Dhaincha (*Sesbania aculeata*) with seed rate of 20-25 kg/ac, sow in April and incorporate 6-8 weeks after sowing (Bajo, 1994) • Herbicide (Sunrise) at the rate of 40 gm/ac, apply 10 days after rice transplantation (Yeshey *et al.,* 2013)
Humid subtropical	Tsirang, Dagana, Chukha, Zhemgang, Pemagatshel, Trashiyangsti	• Use of balanced fertilizers. • Use of FYM instead of tethering practice. • Pre-rice green manure crop cultivation. • Effective rice weed control/management both manually as well as through use of herbicides • Improve and promote the use of chicken manure • Crop rotation with legume crops (beans, soybean and other legume crops)	• Refer (Table 1) above. (Dagana and Chukha can adopt Tsirang's rate and Zhemgang, Pemagatshel and Tashiyangtsi can adopt Trashigang's rate). • 2-3 ton/ac of FYM at land preparation • Dhaincha (*Sesbania aculeata*) with seed rate of 20-25 kg/ac, sow in April and incorporate 6-8 weeks after sowing (Bajo, 1994) • Butacholar at the rate of 10-12 kg/ac, apply 3-4 days after rice transplantation • Research needed on use of chicken manure on

			rice to determine the suitable rate of application
Wet subtropical	Sarpang, Samtsi, S/Jogkhar	• Use of balanced fertilizers. • Use of FYM instead of tethering practice. • Pre-rice green manure crop cultivation. • Effective rice weed control/management both manually as well as through use of herbicides • Improve and promote the use of chicken manure • Crop rotation with legume crops (beans, soybean and other legume crops)	• Refer (Table 1) above. (Sarpang can adopt Samtsi's rate until a suitable rate for Sarpang is developed). • 2-3 ton/ac of FYM at land preparation • Dhaincha (*Sesbania aculeata*) with seed rate of 20-25 kg/ac, sow in April and incorporate 6-8 weeks after sowing (Bajo, 1994) • Butacholar at the rate of 10-12 kg/ac, apply 3-4 days after rice transplantation • Research needed on use of chicken manure on rice to determine the suitable rate of application

9. Action Plans

Long term strategies include mineral and organic fertilizers and green manure usages and management. Awareness creation of mineral fertilizers by audio-visual media is essential. Mass soil nutrient analyses would help adopt correct fertilizer rates. Annual fertilizer requirement needs of farmers and distribution systems should be worked out as a regular extension program. Subsidy in the form of transportation from the commission agents to the geog RNR centers needs to be considered.

For organic fertilizers, poultry manure along with the traditional farmyard manure is to be promoted. There is a need to develop and promote large scale composting (including vermi composting) of available green biomass in the sub-tropical areas and use for rice production. Perhaps, some subsidy for compost making will further encourage farmers. There is a need to change cropping pattern: instead of wheat/mustard) going for legume crops (e.g. lentil in Samtse) in winter. To improve the seed availability, NSC should (as agreed) initiate regional registered seed growers to produce dhanicha seeds annually like any other crops. Dhaincha is grown as a shade crop for ginger, encourage those farmers to collect the seed and sell.

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Distribution and Management Practices of Fodder trees and shrubs in West-Central Bhutan

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Abstract

Survey on local fodder trees and shrubs was carried out to know the extent of the distribution and to document local propagation and management practices. A semi-structured house-hold questionnaire also gathered information on annual fodder production potential, farmer preferences, plant parts fed, feeding methods, and ruminant production system. Nutrient content analysis was also carried out for fodder tree and shrub species.

Below 1700 m asl, about 50 palatable fodder tree and shrub species were generally used and domesticated by farmers. However, a few palatable fodder trees/shrubs species were domesticated above 1700 masl. It is seen that farmers have developed local methods of propagating and managing fodder trees and shrubs. Raising and managing leguminous fodder shrubs and trees such as ***Ficus semicordata, Buddleja asiatica*** *and* ***Leucaena*** *sp, are recommended, as these species are easy to establish and manage.*

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Keywords: Fodder trees, shrubs, Nutrient content

1 Introduction

Tree fodders are an important fodder resource in the traditional farming system across the foothills of the Himalayas (Roder *et al.* 2003). In subsistence livestock farming largely prevalent in Bhutan, the use of tree fodder is strongly favored by small land holdings, low input production system, and extreme topography (Roder *et al.* 2001). The advantages of growing fodder trees are described by Roder *et al.* (2003). In Bhutan, land for pasture is generally scarce and crop residues (straws and stovers) remain one of the major resources used for feeding ruminants in developing countries including Bhutan. Pastures through cut and carry system from roadsides, boundaries between crops and any other wastelands are also the major feed resources. Agro-industrial by-products such as molasses, sugar cane tops, oilseed cakes or meals and other by-products also help to supplement feed shortages. However, trees and shrubs and their introduction into cropping and grazing systems have significantly contributed in providing green fodder and considerable amounts of high protein biomass in enhancing ruminant production in Bhutan. Especially, during lean and dry season fodder trees are the major source of green fodder.

In view of increasing human population, decreasing land availability for forage crop production, increasing dependence of ruminants, tree fodders are increasingly seen as potential protein and energy supplements to increase productivity of ruminants. Although local fodder trees/shrubs have been a traditional supplement to straw based feed for ruminants in Bhutan, very little effort has been made to document and develop sound policy strategy and program for promotion and utilization of available indigenous tree/

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shrub species. Hence, it is important to document some of the promising and potential local fodder trees/shrubs species commonly grown and utilized by the farmers in the region. Further, it is also important to explore areas where research can intervene to improve tree fodder resources. Therefore, a survey on fodder tree resources was conducted with the objectives were to document and describe local fodder trees and shrubs, their distribution across different agro-ecological zones, document propagation and planting methods, attributes, management practices, and to build information base for future research/development interventions and approaches on selected potential fodder trees and shrub species.

2 Materials and Method

In consultation with the *Dzongkhag* development workers in the west-central region, we selected three *geogs*; Rangthangling, Goshi and Rubesa from Tsirang, Dagana and Wangdue Dzongkhags representing high, mid and low agro-ecological zones. The study areas were below 1700 m asl. In order to collect adequate information, in consultation with the knowledgeable informant, the survey was focussed in the areas within a geog. where maximum diversity of fodder trees and shrubs are known to exist.

The field interview was administered using semi-structured questionnaire. The questionnaire was divided into two main parts. The first part of the questionnaire was on fodder trees and shrubs, which covered identification, description and fodder production. The annual dry matter production per tree was calculated based on the information collected through survey from annual fresh matter yield per tree and its corresponding dry matter percentage. Extra emphasis was given to fodder trees having multipurpose uses. This part of the questionnaire also gathered some important information on annual fodder production potential and farmers' rating of different fodder trees in the order of preference as high, medium and low in the region. The second part emphasized on propagation and management. It also delved into feeding practices and fodder availability in a year besides interviewing farmers on collection rights.

The survey also gathered important information required for describing fodder trees. Plant samples of both identified and unidentified species were also collected for preparing plant herbarium along with the photographs for species identification. Various references such as Flora of Bhutan and other forestry books were referred to best describe a tree fodder**.** For nutrient content analysis, we collected over 700 gm fresh representative sample from each fodder tree and shrub species. The samples were later oven dried at 60 ^{o}C for 48 hours and analysed for nutrient and mineral contents at the Renewable Natural Resources Research and Development Center, Jakar. Additional information on dry matter, crude protein, crude fibre, total ash, nitrogen free extract, ether extract, modified acid detergent fibre, lignin and tannin percentages and mineral contents like Ca, Mg, in mmol/kg, Na, P, K, in percentages, Cu, Fe, Mn and Zn in Mg/Kg of the fodder species were gathered from available literatures(Panday, 1982; Subba,1998).

3 Results and Discussion

The survey team documented around 50 numbers of palatable fodder tree and shrub species from low (<1100m asl) and mid altitudes (between 1100-1700m asl) which were generally accepted and domesticated by farmers as good fodder species. However, only

few palatable fodder trees/shrubs species were domesticated above 1700 masl, which were generally accepted by farmers as good fodder species. Both tender and mature leaves and soft stems were commonly fed to the ruminants. Most tree fodders were fed through cut and carry system except in a few cases where direct lopping and browsing method were practiced. During severe shortages of fodder in winter, the edible plant parts were timely cut and carried to the stall instead of lopping and direct feeding in the field. Beside fodder, trees were also the sources of timber, fuel wood, fruits, and flowers. Barks of some fodder trees were used as pickle and to prepare homeopathic drugs to cure various diseases. Information on their attributes (positive and negative) and altitude ranges were collected

2.1 Annual fodder production potential and farmer preferences

Farmers have various reasons for rating fodder trees as good and average quality fodder. The most preferred fodder trees and shrubs were those possessing characteristics such as high palatability with high nutritive value, evergreen and high biomass yielding, and non-toxic. The fodder trees and shrubs that were rated medium were those having low palatability with lower nutritive value, and deciduous. The least preferred fodder trees and shrubs were those that were very fibrous with low nutritive value, thorny, not palatable, and toxic at certain stage when fed to ruminant. Farmers associated the high nutritive value of fodder trees to high milk yield of dairy cattle. These findings show that, farmers, through years of experience, have developed their own methods to judge and select trees that are like to give better milk production. The details of annual fresh and dry matter production per tree and farmers' ratings of fodder trees are presented in Table 1.

Table 1: Annual fodder production potential of tree fodder/shrub species

Tree fodder/ shrubs species by local name	Scientific name	Annual production of Fresh Matter / tree (Kg)	Annual production of Dry Matter / tree (Kg)	Farmers rating of fodder trees
Baar	Ficus benghalensis	625	137	high
Badahar	Artocarpus lacucha	1200	374	high
Bhatmase	Flemingia macrophylla	25	8	high
Badkaule	Casaeria glomerata	30	10	high
Chamlayo	Ulmus lanceifolia	75	-	high
Debre lahara	Butea parviflora	50	-	high
Dudhilo	Ficus neriifolia	50	17	high
Kabro	Ficus benjamina	50	16	high
Katahar	Artocarpus heterophyllus	1200	-	high
Khari	Celtis tetranda	225	63	high
Khasray Khanew	Ficus spp (small tree)	25	8	high

Labar	Ficus elastic	50	18	high
Lute khanew	Ficus subincia	50	17	high
Nebara	Ficus roxbughii	100	30	high
Somi	Ficus spp (climber)	50	-	high
Willow	Salix spp (Bais)	50	-	high
Pipal	Ficus religiosa	50	18	high
Chiuri	Diploknema butyraceae ?	50	22	medium
Chuletro	Brassaiopis hispidata	75	17	medium
Badkaule	Casaeria glomerata	25		medium
Gogun	Saurauja nepalensis	75	17	medium
Jamuna	Syzygium cumini	75	30	medium
Kaulo	Persia Spp.	50	15.3	medium
Khamari	Gmelina arborea	50	12	medium
Khanyu	Ficus spp (tree)	125	47	medium
Khirro	Holarrhena pubescens	50	12	medium
Kimboo	Morus macroura	50	13	medium
Koirala	Bauhinia variegata	75	27	medium
Kubinde	Kydia calycina	75	20.5	medium
Parari	Stereospermum chelo-noides	75	17	medium
Taki	Bauhinia purpurea	50	14	medium
Aule Pipli	Ulmus lanceifolia	25	7	low
Bohori	Cordia oblique	50	8	low
Dabdabe	Garuga pinnata	100	34	low
Dumri	Ficus virens	175	54	low
Faledo	Erythrina spp	50	19	low
Gayo	Bridelia stipularis	50	12.5	low
Ginderi	Premna bengalensis	75	18	low
Gueylo	Callicarpa arborea	100	35	low
Kaijal	Bischofia javanica	125	31	low
Khasre	Ficus spp	25	6	low
Kutmiro	Litsea monopetala	50	20.7	low
Malata	Macaranga denticulata	50	15	low
Phusro Khosray	Ficus spp (small tree)	25	-	low

Sindure	Mallotus phillipinsis	50	19.9	low
Sisi/Khasru	Quercus griffithi	50	20.4	low
Siyalfusre	Grewia asiatica	175	63	low
Sokey/Musre Katus	Castanopsis tribuloides	50	22	low
Thomb/Phalant	Quercus glauca	50	21	low
Totola	Oroxylum indicum	50	-	low

✧ *We would acknowledge the expertise of Mr. CB Rai, Research officer, RDC Sub-centre Darla in providing equivalent Scientific names for local fodder trees and shrubs (Editor-in-Chief)*

2.2 Tree fodder availability and ruminant production system

The crucial period of fodder shortage mostly fell between November and March when there is no green forage in and around farmland as well for foraging in the forest. The practice of feeding crop by-products and cultivating winter fodder like exotic oat was not adequate to address fodder shortages. The only option left to overcome the feed shortage was to feed these fodder trees particularly during extreme dry months. This demonstrates the importance of fodder trees as an important source of fodder during the lean season. Tree fodders are especially valuable during the dry winter season, when fodder from other sources becomes limited in quantity and quality (Roder *et al.* 2003). Farmers did not feed fodder trees indiscriminately to any livestock breed. Preference was given to milking cows, young calves followed by draft bull and the excess fodder was fed to other livestock categories. Similar finding was reported by Wangchuk et al. (2007) on the usage of fodder trees in the east central region. Farmers strictly followed proper schedule of lopping branches that gave sufficient time for the trees to regenerate. Most of the farmers in the region followed day grazing in their fallow land as well as grazing in the forest. Tethering and stall feeding practices were applied only to the crossbreed dairy cattle, cows in lactating stage and young calves. A very few farmers migrated to other registered *tsamdrogs* and meadows.

2.3 Propagation and planting method

Farmers had good knowledge and provided authentic information on propagation and planting of most of the domesticated fodder tree species. They commented that they had been collecting seeds and seedlings, stems and slips of fodder trees within and nearby villages as well as from the forest and propagated them for decades. It was also clear from our survey that some of the fodder trees were easily propagated as they were self-germinating. Farmers were found to collect these seedlings and transplant the naturally regenerated seedlings in their farm boundaries, as hedges, in marginal/ fallow/ unproductive land for diversifying their fodder resource base. However, farmers do not have sound technical knowledge on nursery raising and other management aspects. The tree fodder species raised through stem cuttings and slips, seed and seedlings and self germination are indicated in Table 2.

Table 2: Tree fodder and shrub species propagated through different methods

Stem cutting/ slips/rhizome	Seed and seedlings	Self germination
Aumliso, Baar, Badahar, Bainse, Barkuale, chuletroo, Dabdabee, dudila, Dumbree, Faledo, Guyeloo, Kabroo, Kaidal, Katar, Khosray, Khanue, Labar, Nibaroo, Pipal, Somi	*Aumliso, All Ficus species, Chiewri, Dabray lahra, Khirro, Phalido, Gayo, Ginderi, Kaijal , Katar, Jamuna, Kaula, Khamari, Khari, Khasru, Kinbu, Koirala, Kubinde, Kutmiroo, Bhatmase, Parari, Katus, Phalant, Sindure, Salphusray, Taki, Totola*	*Gogun, Bohori, Malata, Somi, All Ficus species,*

2.4 Tree Management practices

Farmers collect fodder trees most frequently from the wild especially during free time. When they were busy with farm activities they mostly lopped domesticated fodder trees from their farmland. Fodder trees on their farms received sound management practices such as timely lopping and feeding on a regular interval to important livestock. A few farmers were observed taking great care of tree fodder of wild origin with good lopping methods and allowing sufficient time interval for trees to rejuvenate for the successive lopping. In general, the management practices of domesticated fodder trees were found very sound although fodder collected from wild were mostly neglected.

Collection sites differed from one village to another. The distance and time for collection also varied from 20 minutes to 2 hours depending on the distance to forest and availability of fodder tree. The frequency of collection is governed by the number of factors such as category of livestock (milking and draft bull), total livestock number, availability of fodder within their farm land and manpower availability for collection from the wild. There is no right and bylaws within the villages or community of collecting fodder from the forest. It was noted that individual farmers had equal access and opportunity to lop and collect quantity of fodder trees any number of times from the wild. Most of the farmers did not give attention and importance to the implication on fodder quality and quantity due to excessive/indiscriminate and irregular lopping.

2.5 Criteria selecting fodder species for mass propagation

Through survey and interaction with people, the team identified some important points for consideration while selecting tree fodders and shrub species for mass propagation in nurseries.

1) heavy to medium foliage fodder production capacity
2) long longevity evergreen and early flushing
3) tall tree, profuse branching, manageable to lop
4) higher intake and feeding behaviour of animals when confronted with tree fodder
5) high voluntary intake of tree foliage under different environmental conditions
6) better adaptation of trees fodder to varied agro- ecological zones
7) the ease of seedling establishment, better rate of growth and regeneration capacity

8) the growth pattern in relation to crops or pasture and their compatibility
9) nutritive, mineral and chemical values of fodder and its change with harvesting, grazing or cultivation
10) fast to medium growth habit
11) farmer's opinion to be considered for selection and propagation in village nurseries
12) Optimum time of seed collection, their storage and sowing season
13) Easy nursery raising and management including seed treatment

4 Conclusion

The most important issues for small farmers are food, feed, fuel wood and timber. The order of their importance differs from region to region and village to village. Many of the other important uses of trees as medicine and their products will also influence the adoption of practical strategies for utilising tree foliage as an important component of ruminant diet. Fodder trees and shrubs shall continue to be the major supplements of ruminants' diet during lean seasons. Collecting native grass and fodder from distant forest areas, planting multipurpose tree/shrubs in farm boundaries, gullies, marginal lands, road sides and terraces as hedges will continue in order to provide fodder to animals of small farmers. Most farmers do not possess adequate technical knowledge on raising fodder nursery and fodder tree management practices. Many farmers in the region do not have knowledge on collection rights, collection sites, frequency of collection from a forest and their implications on fodder quality and quantity. Therefore, a complete package of good practices should be developed including hands-on training activities for farmers on domesticating and mass propagation of fodder trees. Farmers should also be encouraged to raise and manage leguminous fodder shrubs and trees such as *Ficus semicordata, Buddleja asiatica and Leucaena* sp. These species are easy to manage and establish on the bunds of cultivated terraces.

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