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Editorial

It is our pleasure to introduce this edition of the Journal. This volume has a definite international flavour along with some excellent articles. Sixteen peer reviewed articles on different thematic areas and cross cutting issues have been included here. Environmental knowledge and data generated in environmental sectors by different researchers, GOs/NGOs/INGOs, academic institutions has been assembled in the form of Journal of Environment Sciences, Volume X, 2024 as our yearly publication.

Journal of Environment Sciences aims to share environmental information and also promote to establish link among professionals, researchers, academicians and policy makers by providing them a common platform for further coordination and cooperation. We believe that the findings, outcomes, and suggestions obtained from these researches could serve for betterment of society and help to achieve environmental governance. We also believe that this journal will further help to pile up the scattered knowledge, information, techniques and technologies that have been generated in different environmental paradigm.

We want to assure here that the views expressed in the articles are those of authors and do not represent the official views of the Department of Environment. We could not have brought this edition together without help of reviewers. We would like to acknowledge the valuable contribution from authors, researchers, reviewers and other human resources of the Department of Environment to continue this publication. With your cooperation, coordination and feedback, this Journal will remain uninterrupted.

Thank you !

Editorial Board

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Comparison of Vermicomposting Quality using Different Food beds

Ganga Shrestha[1,3*], Sushila Gwachha[2], Mohan Bikram Shrestha[3]
[1] Central Department of Environmental Science, Tribhuvan University, Kathmandu,
[2] Department of Environmental Science, Tribhuvan University, Kathmandu
[3] Wildlife Research and Education Network (WREN), Kathmandu, Nepal
*Correspondence: shresthaganga080@gmail.com

Abstract

Organic waste management has been one of the great problem in urban areas. Among various efforts carried for managing the organic waste, vermicomposting is one of the efficient efforts that have been effectively applied in household and community level. Studies on vermicomposting process have proved vermicompost is quality compost with higher percentage of nutrient contents. However, based on the solid waste types and organic materials available in the waste, comparative study on the vermicompost is limited. This study was carried out to compare vermicompost quality using different organic wastes as food beds. A research was carried out at Madhyapur Thimi, Bhaktapur using cow dung, tea leaf, vegetables and their combination as food substrates. 100 gm of Red worms (*Eisenia foetida*) was used. Different parameters such as pH, Moisture content, Electrical Conductivity (EC), Organic Matter (OM), C: N ratio, Nitrogen (N), Phosphorus (P) and Potassium (K) were analyzed. Positively strong correlation was found between electrical conductivity and potassium whereas negatively strong correlation found in nitrogen and C:N ratio. There is found to be have a significant difference in parameters between different treatments. However, all are effective compost producing quality nutrients among which vermicompost with tea leaf possess high nitrogen and phosphorus, while combination of vegetable and cow dung gave high potassium value.

Keywords: *Eisenia foetida*, nutrient value, organic waste

Introduction

Growing urbanization and population growth has not only increase solid waste generation, but also increase challenges for its management. Due to lack of appropriate technical team, people's participation and resources, it has been remained as an unsolved topic. In recent years, concept of reuse and recycle is approaching to deal with the solid waste of Kathmandu Valley. Among which, Vermicomposting is also one of them and it is gaining its momentum as can be initiated by household to enterprise level. Vermicomposting is an environmental friendly technology used in solid waste management which has two ways advantage: it helps in management of organic waste and the worm cast can be used as vermicompost, useable forms of compost without any adverse impacts to soil, plant and environment (Gheisari et al., 2009; Mehta & Karnwal, 2013). It involves joint action of earthworms and mesophilic microbes (Benitez et al., 1999). The main aim of vermicomposting is to increase number and weight of worms and convert substrate material into vermicompost in shortest duration and highest recovery as possible (Rupani et al., 2013).

Earthworm acts as a mechanical blender by grinding organic matter and increasing surface area exposing to microorganisms (Yadav & Garg, 2011). During composting processes, the micronutrients present in the feed materials are converted through microbial action into forms that are more soluble and available to plants than those in parent substrate (Kaushik & Garg, 2003). Therefore, vermicompost enriches soil with microorganisms which improves soil texture, structure, nutrient retention, water-holding capacity and aeration (Shrivastava & Singh, 2013). Therefore, increase in germination and plant growth from 50-100% over conventional compost and 30-40% over chemical fertilizers is the main success of this simple method degrading by over 75% faster than conventional systems (Sinha et a., 2010). The nutrient analysis (Aryal & Tamrakar, 2013; Bajal et al., 2019) and humic substances (Dominguez et al.,

1997) also found to be better in vermicompost than other types of composting. It also reduces proportion of water soluble chemical which causes less possible environmental contamination (Mitcheell, 1997). Some study showed phenolic substances produced in this method causes the plant's resistance against pathogens (Hanc & Vasak, 2015). Further, use of vermicompost is relatively free from odor and pathogens especially the coliforms therefore can be used in indoor plants too.

Different species of earthworm are used in this process such as *Eisenia foetida*, *Eisenia anderi*, *Lumbricus rebellus*, *Epiges, Endoges* etc of which *Eisenia foetida* is commonly used in our country (Devkota et al., 2014). This species of worms has high growth rate, early sexual maturity and extensive reproduction (Devi et al., 2012). Along with selection of worm's species, selection of substrate materials and their combination for bedding purpose and worm food sources plays important role to optimize vermicomposting efficiency, influence the activity of worms and alters the quality of manure formed (Jafarpour et al., 2017; Manaig, 2016). In the world, studies have used different food beds like cattle manure, chicken manure (Manaig, 2016), cow dung, kitchen waste, foliage waste (Das et al., 2014), water hyacinth, paddy straw and sawdust (Das et al., 2016), waste rose flower (Daman et al., 2016), tea leaves mixed with cow dung (Kaur et al., 2014), mixed vegetable waste with soil (Shah et al., 2013), sewerage sludge mixed with composted cow dung (Ludibeth et al., 2012) and rice bran with food waste (Pourzamani & Ghavi, 2016) whereas Elephant dung, Rhino dung, litter, garbage (Dhimal et al., 2013) , vegetables wastes (MGN/JICA, 2005), agricultural wastes like *Lantana camara, Ageratum conyzoides*, banana pseudo stem, garden waste, vegetable waste, mycostraw cow dung (Bajal et al., 2019) was used in our country. However, use of cow dung, tea leaf, vegetables and their combination for quality analysis are really scarce. Vegetables, tea leaf and cow dung are common organic waste released in our community. Therefore, this study aims to compare vermicompost quality using different food beds. Specific objectives include to know the time period of formation of vermicompost and to analyze physical and chemical parameters.

Material and Methods

The experimental set up was designed in author's home: Madhyapur Thimi, Bhaktapur from February-March, 2018. Vermicomposting process was carried out in following steps:

Methods

Vermi bin set up with food substrates: Seven rectangular container having similar dimensions of 14×18 inches was used. Bedding was prepared from newspaper (2 bundle) and wet straw (20 gm) in each bin. Bedding provides comfy living material for worms. Food sample of different ratios (150gm) was used in each set up container. The three major food substrates i.e. cow dung, vegetable waste (green leafy vegetable mostly mustard leaf) and dry used tea leaf were used. Pre-composting was not done for any food substrate but partially decomposed cow dung was used as fresh cow dung may be harmful to heating process. Below table shows the combination of food substrate (Table 1).

Table 1: Combination of food beds

Sample No.	Combination of food beds
1	Cow dung only (CD)
2	Vegetables only (V)
3	Tea leaf only (TL)
4	Tea leaf and cow dung (1:1) (CD:TL)
5	Tea leaf and Vegetables (1:1) (TL:V)
6	Vegetables and cow dung (1:1) (V:CD)
7	Tea leaf, Vegetables and cow dung (1:1:1) (CD:V:TL)

Introduction of worms: Red worms (*Eisenia foetida*) weighing 100 grams was introduced (Fig. 1). The pile was covered with jute soaked with water to maintain moisture and to avoid direct light and flies. The mixtures were turned manually every 2 days for 10 days to increase aeration.

Feeding worms: Feed (450gm) to worms was added after 2 days of set up followed with 600gm feed after a week. Additional 300gm foods was added in sample 2 (tea leaf) and sample 5 (tea leaf and cow dung) due to prompt composting process (Fig. 2).

Harvest the compost: After seven weeks of composting process, the foods substate turned into

deep, dark brown and earthy-looking material. It is loosely crumbly at the top of bed and consider it as vermicompost. Prior to harvest, compost was refrained from watering for one week to ease the separation of castings from worms and preventing the castings to become compact.

Figure 1: Weighing of Red worms (Eisenia foetida)

Figure 2: Vermicompost bin set-up

Data Analysis

Physio-chemical parameters of vermicompost such as Soil pH, electrical conductivity, moisture content, organic matter and C: N ratio were analyzed in lab of Khwopa College whereas for the available forms of NPK analysis, samples were sent to MIRON Laboratory and Research Center in Kathmandu. Among the total portion of nutrients NPK, only certain portion is readily available for the plants to use. For example, in case of phosphorus the amount of P available to plants is generally not exceeded 0.01% of the total phosphorus (Kayastha, 2014).

Below table 2 shows parameters along with methods for each parameter. One-way ANOVA was used to test for significant differences among treatments. The data were entered and analyzed in MS-excel.

Results and Discussion

Time period for the formation of the compost

Out of seven samples of vermicomposting, six of them were harvested while remain one do not formed compost (Fig. 3). The time period to harvest was about 7 weeks (Fig. 4) which is quiet similar with Shah et al. (2013) i.e. following 50 days when used mixture of sewerage sludge with cow dung. Average days for vermicompost to formed is from 42 to 70 days when prepared using elephant dung and rhino dung (Dhimal et al., 2013). Pourzamani and Ghavi (2016) formed pleasantly earthy, granular nutrient rich vermicompost after 30 days when used rice bran and food waste. Sample having vegetables only (Sample 3) caused mortality of worms, may be due to lack of pre-composting (Frederickson et al., 2007). Since it releases turbid water during decomposition process that may cause souring

Table 2: Parameters and methods adopted for the laboratory analysis of vermicompost samples

S.N.	Parameters	Unit	Methods
1	Soil pH		pH meter
2	Electrical conductivity	µS/cm	Conductometry
3	Moisture content	%	Oven-dry method (Jackson, 1967)
4	Organic matter	%	Walkley and Black method (Walkley & Black, 1934)
5	C:N ratio		
6	Nitrogen	%	Kjeldhal Method (Bremner& Mulvaney, 1982)
7	Phosphorus	%	Olsen's Method (Olsen et al., 1954)
8	Potassium	%	Flame Photometer (Okalebo et al., 2002)

environment to the composting environment that may stressed earthworms causing to death. Therefore, either doing pre composting first and or using cow dung supplementation 50% or more in the feed help to solve this problem (Asadollahfard & Mohebi, 2012; Garg & Gupta, 2011; Huang et al., 2013). Adopting the concept of High-rate Vermireactor operation which was quenched by use of soil with phytomass is very successful to achieve sustainable vermicomposting of vegetable waste without any pre composting or cow dung supplementation (Shah et al., 2013).

Figure 3: Freeze and death worms in Sample No.3

Figure 4: Researcher harvesting compost

Change in physical and chemical parameters of vermicompost

There showed the significant differences in parameters ($P<0.05$; $p=2E-14$) among the different food beds (Table 3). Other researchers also have similar findings (Bajal et al., 2019; Chaulagain et al., 2017; Kaur et al., 2014; Ludibeth et al., 2012). The below table (Table 3) shows statistical analysis using one-way ANOVA test in Ms-Excel.

Positively strong correlation was found between electrical conductivity and potassium whereas

Table 3: One-way ANOVA table between parameters in different food beds

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	45882083	7	6554583	31.40852	2.49E-14	2.249024
Within Groups	8347522	40	208688			
Total	54229605	47				

Table 4: Correlation between physical and chemical parameters

	pH	EC	Organic matter	Moisture	C:N ratio	Nitrogen	Phosphorus	Potassium
pH	1							
EC	.563	1						
Organic matter	-.367	.408	1					
Moisture	-.234	-.173	.098	1				
C: N ratio	-.247	.331	.244	.555	1			
Nitrogen	.249	-.342	-.282	-.580	-.998**			
Phosphorus	.181	-.593	-.615	-.100	-.560	.569	1	
Potassium	.333	.944**	.535	-.186	.379	-.389	-.810	1

**. Correlation is significant at the 0.01 level (2-tailed).

negatively strong correlation found in nitrogen and C: N ratio. Positively moderate correlation was found in pH and EC, C: N ratio and moisture content, nitrogen and phosphorus and organic matter and potassium. Negatively moderate correlation was found in nitrogen and moisture content, phosphorus and electrical conductivity, organic matter and phosphorus, C: N ratio and phosphorus and phosphorus and potassium. The correlation table is shown in Table 4.

During the examination of vermicompost's, the pH ranged from 7.49 to 8.12 indicating that the composts are alkaline in nature and is similar with Aryal and Tamrakar (2013) i.e 7.6. pH value is near neutral which might be due to secretion of NH_4^+ ions that reduce concentration of H^+ ions and catalytic fixation of CO_2 as $CaCO_3$ by carbonic anhydrase in the earthworm's gut (Haimi & Huhta, 1987; Pattnaik & Reddy, 2010). The research done by other researchers are within our range: Muthukumaravel et al. (2008) have 8.3 in vegetables vermicompost while 7.9 in cow dung. Chaulagain et al. (2017) gives 7.4 in cow dung whereas HMGN/JICA (2005) reported 8 in vegetables wastes. pH is increased in tea leaf than in tea leaf+cow dung i.e. from 7.76 to 7.49 which is similar with study of Kaur et al. (2014). The pH ranged from neutral to slightly alkaline is best for crop production (S et al., 2013).

The highest electrical conductivity (EC) of the vermicompost was 3999 µS/cm. The lowest was 1158.67 µS/cm in tea leaf which is similar with Kaur et al. (2014). EC generally estimates the soluble salt concentration in soil and commonly used as measure of salinity. Sample 2 have low EC because it releases less salt such as potassium (0.19 %) during vermicomposting process. The reason of low EC might be due to utilization of soluble salts by micro-organisms for the microbial biomass (Yadav & Garg, 2011) and also due to absorption of soluble salts by earthworms and enhanced microbial activities (Kumar & Singh, 2001). However, in case of sample 5, sample 6 and sample 7, there is high release of salt i.e. potassium than other samples due to mixing of two or more food substrate types and hence high in EC. The reason for equal EC in these samples is due to almost equal release of potassium %. (sample 5: 0.7 %, sample 6: 0.85 % and sample 7: 0.78 %). The range are similar with other findings (Chaulagain et al., 2017 gave 3780 µS/cm in cow dung; Mousavi et al., 2017 i.e. 8940 µS/cm the highest and the lowest 2310 µS/cm for vermicompost from food wastes, rotting foliage and cow dung).

Moisture content ranged from 64.8% to 69.3% which is higher than Dhimal et al. (2013): 24.93% and 30.66% in elephant and rhino dung respectively and nearly similar with HMGN/JICA (2005) i.e 58.70% in vegetable waste. Aryal and Tamrakar (2013) also have 62.5% in vermicompost. The moisture content having value 60-70% was proved to having maximal microbial activity (Liang et al., 2003).

Organic matter was found to be maximum in sample 7(10.16%) which may be due to mixture of three food substrate: tea leaf, cow dung and vegetables. While in sample 2 (only tea leaf), the organic matter was minimal i.e. 8.77. However, very low when comparing with other studies. In the experiment done by Dhimal et al. (2013), it is found to be 26.915 and 26.9425 in rhino dung vermicompost and elephant dung vermicompost respectively which is more than double with our findings. Also, research by Ludibeth et al. (2012) have range of 70.02% to 47.32% when used sewerage sludge as food beds which is not equivalent with our findings. Aryal and Tamrakar (2013) also have high value i.e. 31.49. This implies that among different criteria for producing efficient compost, various aspects play important role and selection of raw composting material is major one in determining nutritional composition such as organic matter (Chandna et al., 2013; Confesor et al., 2009).

The C: N ratio is mostly used indexes of organic waste maturity: higher the value, slow the rate of decomposition (Christopher, 1996). In this study, it ranged from 1.21 to 2.86. The finding is very lower than other researchers (Aryan & Tamrakar, 2013; Mahaly et al., 2018). This means the vermicompost formed from above used food substrates tend to have a fast rate of decomposition when applied to the soil and act as nitrogen fertilizers than others food substrates (Yadav et al., 2017).

The gut of earthworm plays important role in converting organic residue to plant available macronutrients such as nitrogen, phosphorus and potassium in vermicomposting process. Also, acid production during decomposition by microorganisms converts these nutrients into its respective soluble forms (Lee, 1992; Sharma, 2003). Significantly higher nitrogen content suggested the high composting ability of worms which range from 0.1% to 4% or even more (S et al., 2013). The high nitrogen content is found in sample 2 (4.22%) which may be due to high nitrification rate in which ammonium ions converted into nitrates (Dominguez, 2004). The lowest is in sample 1 (1.83 %). However, mixing any other plant materials along with cow dung was found better in terms of percentage of nitrogen after sample 2 (Bajal et al., 2019) which is similar with our findings too. In the research done by Muthukumaravel et al. (2008), the value of nitrogen in Vegetable waste- Cow dung was 1.76% and 1.62% in cow dung. The report of HMGN/JICA (2005) value 0.62% whereas 2.55 % to 1.86% ranges in different proportion of sewerage sludge and cow dung vermicompost (Ludibeth et al., 2012). Chaulagain et al. (2017) have percentage range of 0.19% to 0.23%. when used cow dung and other banana pseudo stem, leaf litter and saw dust.

The available phosphorus ranges from 0.92% to 1.66% and highest found in sample 2 (only tea leaf). Euras et al. (2009) found high phosphorus over the initial substrate from cow manure, followed by aquatic weeds, grasses and municipal waste. The obtained value of P is quite similar with Muthukumaravel et al. (2008) i.e. Vegetable waste+Cow dung – 1.60% and 1.20% in cow dung. However, found less in HMGN/JICA (2005) with the value of 0.84% and, Aryal and Tamrakar (2013) with value 0.70%. Also, low phosphorus was found in Unito (2023) (0.2% to 0.4%). In this study, potassium ranged from 0.19% to 0.85%. which is similar with Chaulagain et al., 2017 (ranged from 0.42% to 0.63%). The available potassium is highest in sample 6 (vegetables and cow dung) and low in sample 2 (tea leaf only). Higher potassium value was found in sewage sludge vermicompost of Delgado et al. (1995). In the article of Aryal and Tamrakar (2013), the potassium content of vermicompost was found to be 4.99% using the domestic waste which is higher than this study. HMGN/JICA (2005) gave the value 3.49% with vegetable waste and 4.98% and 2.65% in vegetable waste + cow dung and cow dung only in Muthukumaravel et al. (2008). Value of potassium in Unito (2023) have a range of 0.46% to 1.18%.

The summarized values are shown in below (Table 5).

Conclusion

According to the result of present experiment, the survival of compost worms in food bed having only vegetables was not possible. The final vermicompost was pleasantly earthy in odor, granular, nutrient-rich, much darker in color, and more homogeneous than initial materials after 7 weeks by *Eisenia foetida* earthworm activity. There were significant differences in the tested parameters when used different food beds. However, food bed with tealeaf give more nitrogen and phosphorus content whereas potassium is high in vegetables+cow dung. Also, the vermicompost quality results are quite similar with prior vermicomposting findings. The results from

Table 5: Summary of physical and chemical analysis of Vermicompost

Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
pH	7.93	7.76	-	7.49	8.12	7.84	7.7
Electrical Conductivity(µS/cm)	3057.67	1158.67	-	1598	3999	3999	3999
Organic Matter (%)	8.99	8.77	-	9.75	9.46	9.27	10.16
Moisture Content (%)	68.3	64.8	-	69.3	66.6	66.3	65.3
C:N ratio	2.86	1.21	-	2.51	1.49	2.85	2.33
Nitrogen (%)	1.83	4.22	-	2.26	3.7	1.89	2.54
Phosphorus (%)	1.52	1.66	-	1.2	1.32	0.92	1.15
Potassium (%)	0.44	0.19	-	0.37	0.7	0.85	0.78

the casting analysis (in all food beds) had revealed that the organic wastages can be converted into usable form with its nutrient release. And, hence it is considered to be a potent organic fertilizer for sustainable agricultural practices.

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Status of Regeneration in Burnt and Unburnt Sites of Chuliban Community Forest, Dhankuta

Prativa Khatri*, Prakash Chandra Wagle
Department of Environmental Science, GoldenGate International College, Kathmandu, Nepal
Correspondence: prativakhatri0@gmail.com

Abstract

Several forest fires occur in forests of Nepal causing loss of life and property, that is visible, but the loss of forest's health has always been in shade. It is essential to determine the ecological health of fire-affected forests to save them from degradation. This study has assessed the status of soil properties (soil pH and moisture), regeneration and phytosociological parameters of burnt and unburnt sites in Chuliban Community Forest, Dhankuta. Burnt and unburnt sites were identified by site survey, and simple random sampling was adopted for forest and soil sampling. There was a significant difference between soil pH and moisture values in burnt and unburnt sites ($p=0.029$ for soil pH and $p=0.002$ for soil moisture). Both sites dominated by *Pinus roxburghii* showed fair regeneration as a whole, however the burnt site recorded no seedlings of *Pinus roxburghii* while the unburnt site recorded 208 seedlings of it. Soil moisture was positively correlated with number of seedlings ($r=0.203$, $p=0.01$) whereas the correlation of soil pH and number of seedlings was moderately positive ($r=0.013$, $p=0.54$). Burnt and unburnt sites had Shannon Diversity Index 3.12 ± 0.18 and 0 ± 0, and Simpson's Diversity Index 0.34 ± 0.08 and 1 ± 0 respectively. Though burnt site recorded higher diversity, the tree density was low as a result of chopping of dried and injured trees affected by forest fire. Overall, the results showed that soil properties, regeneration and phytosociological parameters were altered due to frequent forest fires in burnt site, and the site is in need of special attention and restoration programs.

Keywords: *Diversity, forest fire, seedling, soil properties*

Introduction

Forest fires have become an important environmental concern in today's world. It has been accepted as an alarming global environmental process that has been altered due to the influence of the biosphere and atmosphere (Bowman et al., 2009). Forest fires pose serious environmental and ecological challenges, and cause significant damage to human lives and properties (Russell et al., 2007). Due to the impact of uncontrolled burning of forest's undergrowth on natural regeneration, forest fires are considered to be the main cause of forest degradation (Matin et al., 2017).

In Nepal, the pre-monsoon season (March to May) appears to be a time of high temperatures that causes drought and forest fires (Matin et al., 2017). Every year, forest fires threaten to destroy the tropical, subtropical, and temperate forests of the Terai, Siwalik, and mid-hills, especially in the areas where *Shorea robusta* and *Pinus roxburghii* are widely distributed (Matin et al., 2017). The dramatic increase in forest fires over recent years in Nepal has caused significant negative effects on the country's forest ecology and environment, leading to the destruction of natural vegetation and severe harm to human settlements (Parajuli et al., 2020).

Fueled by the drought in dry seasons, several forest fires occur in Nepal's forest causing loss of lives and property (Matin et al., 2017), which often make news headlines, but there are limited studies carried out on the ecological impacts of forest fire in spite of its great significance in Nepal. Therefore, this study focused on ecological impact assessment of forest fire will provide a clear picture about the impacts of forest fire on regeneration and biodiversity of Chuliban Community Forest, and pave a new way for similar research in future.

The degradation of forest and absence/ lack of its natural regeneration has become a serious issue in many forests of the world including Nepal's

forests (Shrestha, 2003; Vetaas, 2000). Considering this, the findings of this study assess the relation between number of seedlings and pH and moisture content of soil, and determined the regeneration pattern of burnt and unburnt areas of Chuliban Community Forest. Additionally, this study assesses phytosociological parameters of burnt and unburnt sites.

Materials and Methods

Study Area

The study was carried out in Chuliban Community Forest which lies in Dhankuta municipality, ward no. 7, Dhankuta district in the eastern mid hills of Nepal. Its altitude ranges from 1000 to 1250 m above mean sea level. The climate is warm and temperate. The average annual temperature and rainfall are 19.3ºC and 2603 mm respectively. The forest occupies an area of 14.69 hectares, and is divided into three blocks: Block 1, Block 2 and Block 3 as documented by Divison Forest Office, Dhankuta. 75% of the forest is dominated by *Pinus roxburghii*; Block 1 and Block 2 are composed of *Pinus roxburghii* forest with an area of 5 ha and 3.69 ha respectively whereas Block 3 comprises of mixed forest with an area of 6 ha. The major tree species found are *Pinus roxburghii*, *Schima wallichii, Castonopsis indica,* etc.

Site Identification Survey

In order to understand the circumstances and identify burnt and unburnt sites of the Chuliban Community Forest, a field visit was conducted in October, 2022. Signs of forest fire (burned, dead and dried trees and saplings) were observed. The field visit was accompanied by Mrs. Chandra Kumari Rai, President of Chuliban Community Forest Users Group and officials of Division Forest Office (DFO), Dhankuta. Thus, site identification was carried out by direct observation and expert consultation. GPS was used to record the coordinates of the sites. ArcGIS was used to generate the map of the study area (ArcGIS, 2011).

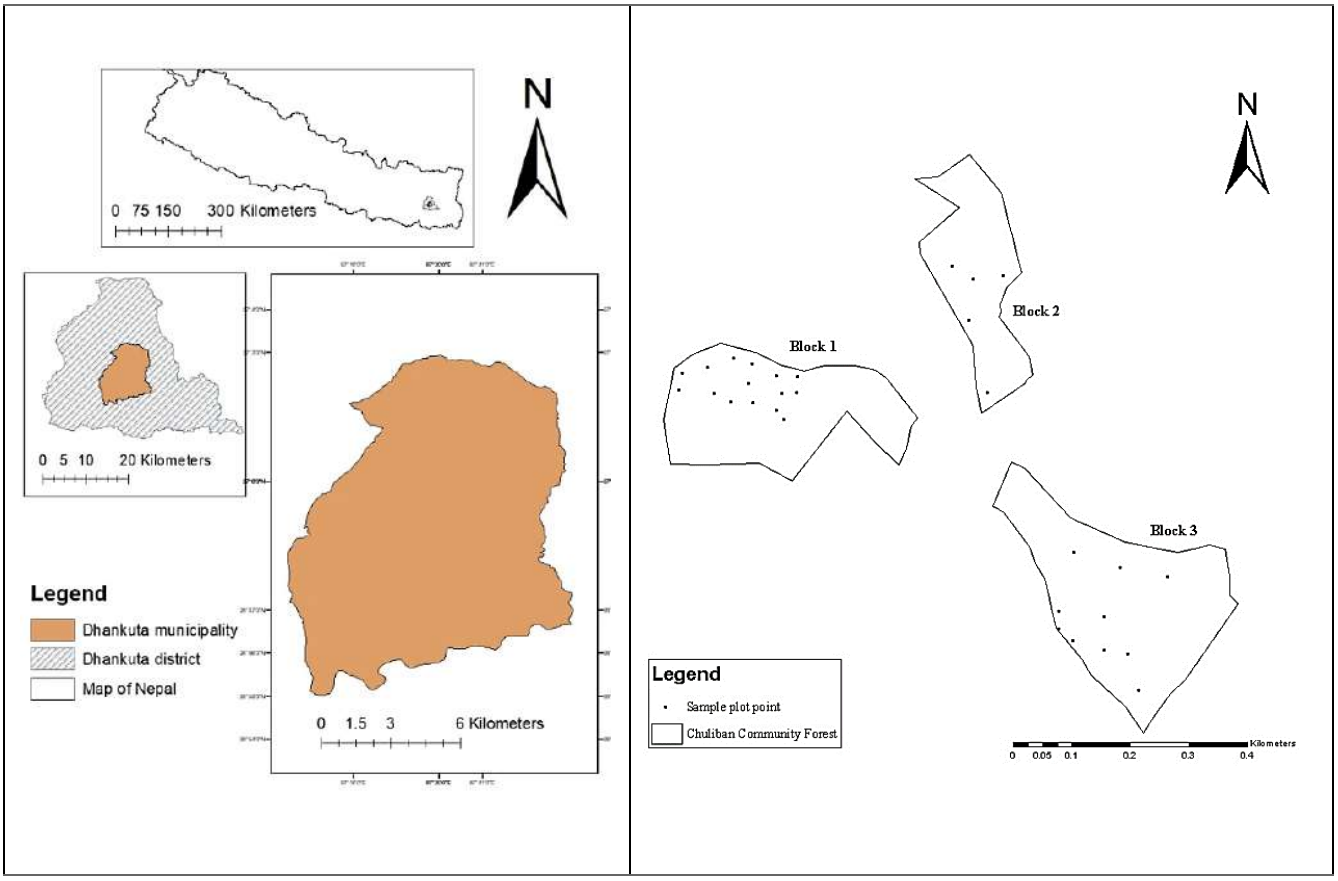

Figure 1: Map of study area (ArcGIS, 2011)

Sampling Techniques

Forest Sampling: Altogether 30 sampling plots each of 10*10 m in the burnt (15 plots) and unburnt sites (15 plots) of the Chuliban Community Forest were laid following simple random sampling technique in October, 2022. Seedlings, saplings and tree species within the sampling plots were counted and recorded. Tree species with DBH equal to or greater than 10 cm were considered as trees whereas DBH less than10 cm were considered as saplings and DBH less than 10 cm with height less than 30 cm were considered as seedlings (Rao et al., 1990).

Data was analyzed by using following formulas:

1. Important Value Index (IVI) = Relative Density + Relative Frequency+ Relative Basal Area (Curtice, 1959).
2. Diversity Indices:
   Shannon Diversity Index (H') = ∑ Pi ln (Pi) (Weaver and Shannon, 1963)
   Where,
   H' = Shannon Diversity Index, Pi = Proportion of the species (Pi = ni/N), N = Total importance value of plants, ni = Importance value of each species
   $Simpson's\ Diversity\ Index\ (D) = \sum \left(\frac{ni}{N}\right)^2$ (Simpson, 1949)
   Where,
   D= Simpson's Diversity Index, N= Total importance value of plants, ni= Importance value of each species
3. Regeneration Status (Shankar, 2001)
   - Good regeneration (GR): If number of seedlings > saplings > adults regeneration,
   - Fair regeneration (FR): If number of seedlings > or < saplings < adults,
   - Poor regeneration (PR): If the species occupy only at sapling life forms there are no seedlings (Number of saplings may be more, less or equal that of adults),
   - No regeneration (NR): If individuals of species are present only in adult form
   - New regeneration or not abundant (NA): If individuals of species have no adults only occupy in seedlings or saplings.

Soil sampling and laboratory analysis: Soil samples were collected from all the 30 sampling plots laid in burnt and unburnt sites. In each sampling plot, a composite soil sample was formed by mixing 4 soil samples collected each from 4 corners and one sample collected from the center of the sampling plot. The soil samples were collected from 15 cm depth. Altogether 30 soil samples were collected, air dried in shade, and stored in plastic bags until laboratory analysis (Kalu et al., 2015).

Soil pH was determined using 1:5 soil to distilled water ratio and then analyzed by using a digital pH meter in the Laboratory of GoldenGate International College, Kathmandu.

Soil moisture was determined by calculating the difference between the soil sample and the oven-dried soil sample, and calculation was done by using the following formula (Shukla et al., 2014):

$$Soil\ moisture\ (\%) = \frac{Weight\ of\ wet\ soil\ tare - Weight\ of\ dry\ soil\ tare}{Weight\ of\ soil\ tare - tare}$$

Data Analysis

Standard Deviation (SD) was calculated for phytosociological parameters. To analyze the variation between soil pH and soil moisture in burnt and unburnt sites, Analysis of Variance (ANOVA) was performed and Whisker box-plot was used. Scatter diagrams and Karl Pearson correlation were applied to analyze the relationship between the distribution of seedlings and parameters of the soil. Microsoft Excel (Microsoft Corporation, 2018) was used for all the statistical analyses.

Results and Discussion

Soil pH and soil moisture in burnt and unburnt site

The soil pH and moisture values were found to be significantly different in burnt and unburnt sites with ($F=5.28$, $p=0.029$) and ($F=10.83$, $p=0.002$) respectively.

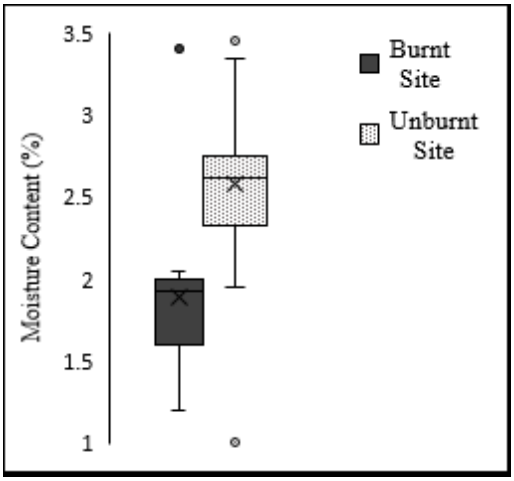

Figure 1: Box-plot showing soil pH in burnt and unburnt sites

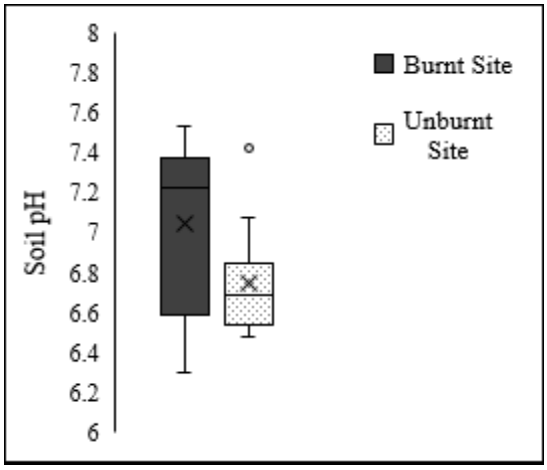

Figure 2: Box-plot showing soil moisture content in burnt and unburnt sites

Higher values of soil pH in the burnt site than unburnt site may be due to the presence of ash after burning (Molina et al., 2007). Study on soil pH conducted by Verma and Jayakumar (2012) had also found similar results in their study on impacts of forest fire on soil properties. The pH value of ash is higher, and the accumulation of ash in soil after forest fires resulted in the increase of soil pH (Schafer & Mack, 2010). According to Litton and Santelices (2003), burning destroys vegetation cover and causes more evaporation in the burnt site as a result of increase in temperature during hot seasons. This results in drier soil i.e. low moisture content in the burnt soil as compared to the unburnt soil. The lower value of soil moisture content in the burnt site in comparison to the unburnt site might be due to drying of soil as a result of forest fires in the burnt site. Destruction of vegetation cover and litter from the ground might have exposed the soil surface and increased the rate of evaporation resulting in comparatively lower moisture content in the plots of burnt site.

Status of regeneration in burnt and unburnt sites

In this study, in both burnt and unburnt sites, the number of seedlings was greater than the number of saplings, and the number of saplings was less than the number of trees. This distribution of population of trees, seedlings and saplings in burnt and unburnt sites indicated that the regeneration status of both sites was fair (Shankar, 2001).

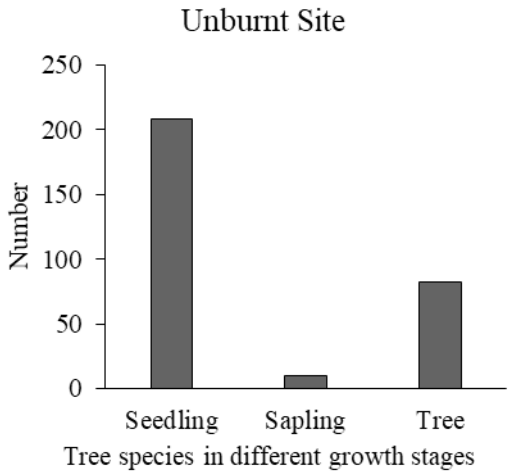

Figure 3: Bar diagram showing tree species in unburnt site

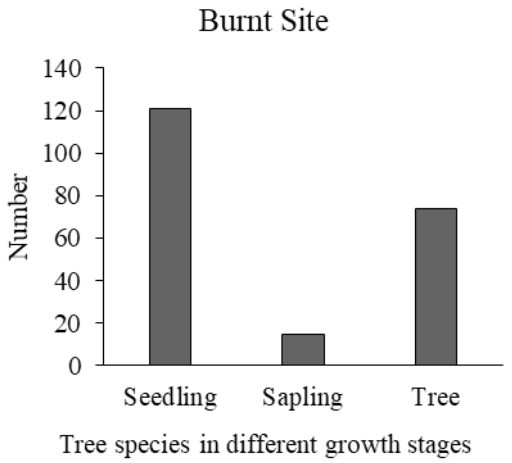

Figure 4: Bar diagram showing tree species in burnt site

The study conducted by Nauni (2008) in *Pinus roxburghii* forests in Himanchal Pradesh, India found the greater density of seedlings of trees in the occasional fire affected areas than the control

areas, and the density of sapling was found more for control areas. In contrast to the study, seedlings were less in the burnt site of this study area. As mentioned by DFO, burnt sites had a history of severe forest fires every year, and it was not occasional. The frequent fires might have contributed to the lesser number of seedlings in the burnt site. Although the latest fire in the site in 2021 had killed many seedlings, the CFUG of the forest had planted useful tree species like *Schima wallichii, Cinnamomum tamala*, *Zanthoxylum piperitum*, *Phyllanthus emblica*, etc. in burnt site at the time of the forest sampling. Thus, seedlings were planted more in burnt sites (less natural regenerated) than in unburnt sites (naturally regenerated seedlings).

Species wise regeneration in burnt and unburnt sites

The burnt site was composed of mixed tree species dominated by *Pinus roxburghii*. Out of 16 tree species found in the burnt site, only 5 tree species had all three stages: seedlings, saplings and tree. No seedlings of *Pinus roxburghii* were recorded in the burnt site in spite of its dominance.

The unburnt site was composed of *Pinus roxburghii* forest with no other species of trees present in any of the three stages: seedlings, saplings and trees. Total 208 seedlings of *Pinus roxburghii* were recorded at the site.

Pinus roxburghii being the dominant species in the burnt site recorded zero seedlings in the site. The regeneration status of *Pinus roxburghii* in the burnt site was poor whereas in the unburnt site, it showed fair regeneration with 208 seedlings of it alone. Studies have shown that frequent fire incidences affect regeneration of *Pinus roxburghii*. *Pinus roxburghii* in spite of having fire-resistance capacity can be negatively affected by different intensities of forest fire (Aryal et al., 2016). A study conducted by Sharma and Ahmed (2014) on regeneration of *Pinus roxburghii* in Ponda watershed of Rajouri Forest Range, Jammu and Kashmir, India found that the regeneration of *Pinus roxburghii* in the areas with negligible fire incidences was good whereas it was poor in the areas prone to fire and grazing. In the burnt site of this study area, frequent forest fire incidences with different intensities might be the reason behind the burning of seedlings and zero seedlings count. The burnt site experienced forest fires every year due to human negligence and misuse of fire. The latest fire that occurred in the site was in 2021, and the site had a history of frequent fires

Table 1: Regeneration status of tree species in burnt site

Local Name	Scientific Name	Seedlings number	Saplings number	Trees number	Regeneration Status
Dalle Katus	*Castanopsis indica*	13	4	10	Fair
Chilaune	*Schima wallichii*	37	1	2	Fair
Salla	*Pinus roxburghii*	0	1	41	Poor
Kag Bhalayo	*Rhussuccedanea*	0	1	1	Poor
Bach	*Anogeissus latifolia*	16	1	3	Fair
Sach	*Terminalia tomentosa*	8	2	5	Fair
Mauwa	*Engelhardia spicata*	18	2	7	Fair
Khaneu	*Ficus semicordata*	0	1	2	Poor
Pipri rukh	*Ficus amplissima*	0	1	1	Poor
Jamuna	*Syzygium jambos*	0	1	1	Poor
Angeri	*Lyonia ovalifolia*	0	1	1	Poor
Musure Kattus	*Castanopsis tribuloides*	11	0	0	New
Timur	*Zanthoxylum piperitum*	3	0	0	New
Tes patta	*Cinnamomum tamala*	2	0	0	New
Aamala	*Phyllanthus emblica*	8	0	0	New
Katmero	*Litsea polyantha*	5	0	0	New

Table 2: Regeneration status of tree species in unburnt site

Local Name	Scientific Name	Seedlings number	Saplings number	Trees number	Regeneration Status
Salla	*Pinus roxburghii*	208	10	82	Fair

in previous years. This might have affected the regeneration of *Pinus roxburghii*, and resulted in low number of saplings and zero seedlings of it in spite of having dominance in the burnt site.

Different species of trees like *Schima wallichii* were planted in the burnt site by CFUG of the community forest in order to regenerate the forest after frequent forest fires. Out of 121 seedlings recorded in the burnt site, 42 seedlings were found to be naturally regenerated while 79 seedlings were planted and not naturally regenerated. Majority of trees and saplings recorded in the burnt site were dry, injured and had signs of burning in their stems. This indicated that forest fires had negatively affected the trees in all stages: seedlings, saplings and trees, and the regeneration of many tree species in the burnt sites.

Relation between soil pH and soil moisture with number of seedlings

The number of seedlings was statistically insignificant (r=0.013, p=0.54) with pH values of soil samples but statistically significant (r=0.203, p=0.01) with soil moisture.

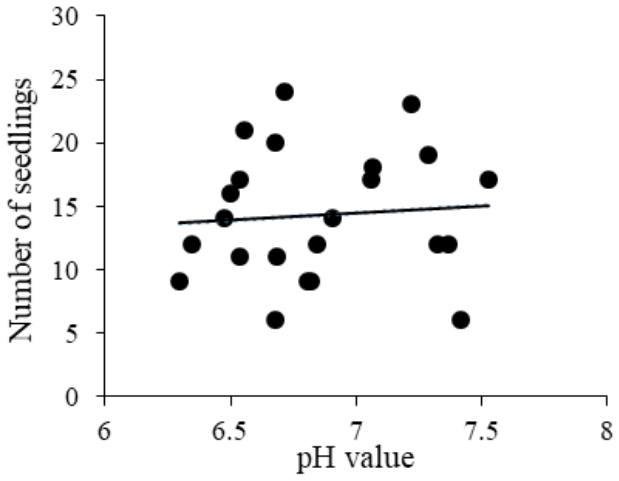

Figure 5: Scatter plot diagram showing relationship between soil pH and number of seedlings

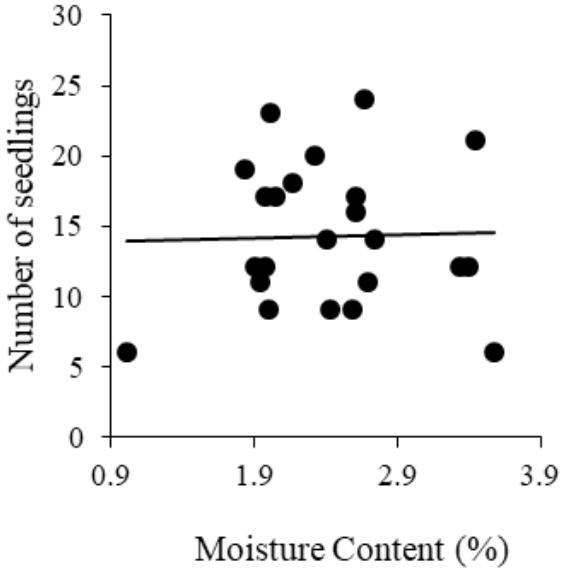

Figure 6: Scatter plot diagram showing relationship between soil moisture and number of seedlings

Soil moisture content is taken as an important factor in regeneration. As the promotion of photosynthesis by the presence of the high levels of moisture affects all the physiological processes of species (Bhattarai & Vetaas, 2003), it favours the growth of a large number of seedlings. In the study conducted by Ghimire and Lekhak (2007) on regeneration, the sampling plots with high moisture content had comparatively higher number of seedlings than other plots with low moisture content. Similar to the study, the sampling plots of the unburnt site of this study area recorded the highest number of seedlings as those plots had comparatively higher moisture content than the plots in the burnt site. Frequent forest fires in the burnt site might have burned the vegetation cover and dried the soil increasing the soil exposure to the sun i.e. evaporation rate, and as a result, the moisture content of many sampling plots of the burnt site was low. The low moisture content in the burnt sites might have affected the germination of seedlings and its development. This might have resulted in a lower number of seedlings in the burnt site as compared to the unburnt site.

Table 3: Phytosociological parameters in burnt and unburnt sites

Phytosociological Parameter	Burnt Site (±SD)	Unburnt Site (±SD)
Shannon Diversity Index	3.12±0.18	0
Species Richness	16	1
Simpson's Diversity Index	0.34±0.08	1±0
Tree Density (number/hectare)	493	547

Phytosociological parameters in the burnt and unburnt sites

Forest fire has a significant impact on how the ecosystem and plant variety are shaped (Joern & Laws, 2013). The composition of forest in burnt and unburnt sites of this study area was different. There was variation in the diversity and evenness index values in the sites. The unburnt site had only one tree species i.e. *Pinus roxburghii* whereas the burnt site recorded 16 tree species. In contrast to the study conducted by Bhatta et al. (2022) which reported the lower value of Shannon Diversity Index in burnt site than unburnt site, the study calculated the higher value of Shannon Diversity Index in burnt site than unburnt site. Although burnt site recorded the highest value Shannon Diversity Index, the tree density of the site was lower than the unburnt site. This indicated that the burnt site had less number of trees as compared to the unburnt site. Forest fire had injured, burned and dried many trees of Chuliban Community Forest. The severely fire-affected trees were fell down by the CFUG of the community forest. Thus, felling of those trees in the burnt site might have reduced the tree density of the site.

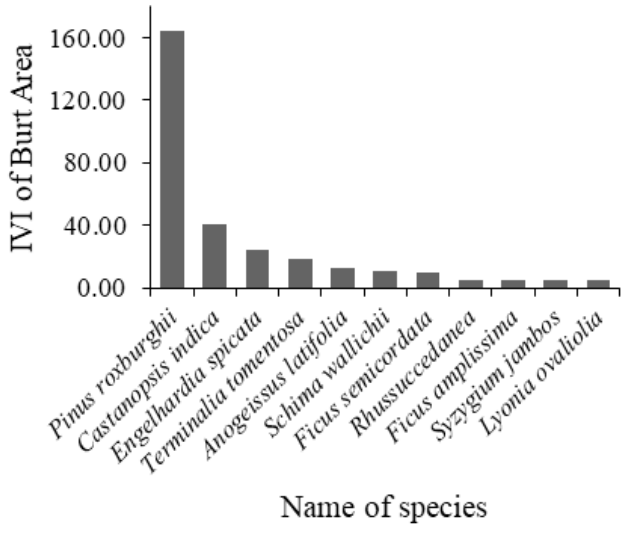

Figure 8: Bar diagram showing IVI of tree species in burnt site

Pinus roxburghii had the highest IVI values in both burnt and unburnt sites. Other species in the burnt site had significantly lower IVI values than *Pinus roxburghii*. Literature suggests that some plants are fire-adaptive (Narendran, 2001). In spite of frequent forest fires, fire adaptive plants dominated the forest community and slowly replaced other species as reported in the study conducted by Narendran (2001) in Madhumalai Sanctuary in India. *Pinus roxburghii* is a fire adaptive plant (Hoecker, 2021). The highest IVI value of *Pinus roxburghii* in the burnt site (Figure 8) might be due to its fire adaptive capacity than other species present in the site. Although the regeneration status of *Pinus roxburghii* in the burnt site was found poor during this study, its IVI value suggests that it had adapted in the history of forest fires more than other tree species. Low IVI values of some tree species recorded in the burnt site might be due to the lack of fire adaptive capacity and poor regeneration. The IVI value of *Pinus roxburghii* was 300 in the unburnt site due to the absence of other tree species in the site.

Conclusion

There was change in soil pH and moisture due to forest fire in the burnt site of Chuliban Community Forest, Dhankuta. The burning of forest increased soil pH and decreased soil moisture. There was a significant effect of moisture content on the number of seedlings in burnt and unburnt sites. The number of seedlings in the burnt site was found to be less as soil moisture content reduced due to burning and drying of soil. However, there was no relationship between soil pH and number of seedlings.

The overall regeneration status of the burnt and unburnt site was fair. However, more seedlings were planted by CFUG after fire in 2021 as a restoration strategy in burnt sites. In contrast, there was more natural regeneration in the unburnt site. In spite of the highest IVI value of *Pinus roxburghii* in both burnt and unburnt sites, there were no seedlings of it in the burnt site. This indicated poor regeneration of *Pinus roxburghii* as a result of frequent forest fires in the burnt site.

CFUG fell down severely burnt trees in the burnt site affecting other trees. This reduced tree density in the burnt site despite its higher diversity values than in the unburnt site. Likewise, the seedlings

recorded in the burnt site were planted and not naturally regenerated. This suggested that frequent forest fires in the burnt site had adversely affected the soil parameters, forest composition and regeneration while the unburnt site recorded no such significant variation. Hence, the burnt site of the study area was found to be adversely affected by frequent forest fires, and there was a need for active programs to combat this loss.

Acknowledgements

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Potential Sources and Seasonal Transport Pathways of Organic and Elemental Carbon in the Lesser Himalayan Zone of Central Nepal

Kundan Chaudhary[1*], Sanjay Nath Khanal[1, 2] and Kundan Lal Shrestha[1]
[1] Department of Environmental Science and Engineering, Kathmandu University, Dhulikhel, Nepal
[2] School of Environmental Science and Management, Pokhara University, Kathmandu, Nepal
[*]Correspondence: kundanchaudharynp@gmail.com

Abstract

Carbonaceous aerosols consist of a bulky but highly variable mass of atmospheric aerosols, mostly comprised of Organic Carbon (OC) and Elemental Carbon (EC). OC is emitted directly into the atmosphere or formed secondarily from the photo-oxidation process that condensed semi- or non-volatile compounds and polymerizes organic species in the atmosphere. EC mainly originate from incomplete combustion of biomass and fossil fuels, and have an instantaneous consequence on radiative forcing effect on regional climate. This study was carried out in Dhulikhel Municipality to determine the potential sources and seasonal pathways of carbonaceous aerosols (OC and EC) transporting to receptor site by measurement and modeling approaches. The 72 samples were collected (24-hrs) over a year (January-December 2018) using a medium volume air sampler. The minimum and maximum concentrations of Total Suspended Particulate ranged from 38.00 μg/m^3 to 442.45 μg/m^3. The annual average OC/EC ratio 2.73 ±0.84 indicates the presence of Secondary Organic Aerosols and other major sources of carbonaceous aerosols including biomass burning, vehicular emission, and coal combustion. Hybrid-Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) air-mass back trajectory analysis integrated with meteorological fields was used to identify the potential sources and their atmospheric transport pathway. The back trajectories of the 96-hrs period were plotted at 6-hrs intervals starting from a single observation location at Dhulikhel. The back trajectories were clustered into four distinct seasons to trace temporal variation in the atmospheric aerosols during the study period. The results from the HYSPLIT revealed that the sources of particulate pollutants reaching Dhulikhel are local as well as of regional origin and are mostly transported from the Middle East and South Asian countries like India, Pakistan, Bangladesh, Iran, Saudi Arabia, and Egypt.

Keywords: *Back trajectory, EC, OC, sources, TSP*

Introduction

The atmospheric aerosols consist of a bulky but highly variable mass of carbonaceous aerosols, mostly comprised of Organic Carbon (OC) and Elemental Carbon (EC), constituting nearly 30-70% of the fine particulate mass typically in the urban atmosphere (Cao et al., 2003; Fuzzi et al., 2006; Rengarajan et al., 2007). Generally, OC accounts for 10-50%, while EC accounts for minor portion (<10%) of the total mass concentration of atmospheric particulate matter (Pandit & Seinfeld, 2006).

EC is primary pollutant originates from incomplete combustion of biomass and fossils fuel (Seinfeld and Pandis 1998), while OC is either emitted directly into the atmosphere or formed secondarily from the photo-oxidation process that condensed semi- or non-volatile compounds and polymerizes organic species in the atmosphere (Shakya et al., 2010; Jimenez et al., 2009). During the thermal analysis, EC is differentiated from OC based on thermal or optical measurements, therefore OC can be regarded as the carbon fraction that evolves under a heating cycle in an inert atmosphere, and EC as the fraction that evolves during a subsequent heating process in presence of oxygen (Karanasiou et al., 2015).

Both OC and EC have significant roles in radiative forcing and cloud microphysics, and consequently, in regional climate change and precipitation (Wan

et al., 2017). Also, the relationship between OC and EC provides information on the source of origin of the carbonaceous aerosols and the positive correlation between them indicates a common source of origin (Shakya et al., 2010). The OC/EC ratio is developed as an essential diagnostic index that has been used to reflect the types and source strength of carbonaceous aerosols (Turpin & Lim, 2001). OC/EC ratios depends on emission sources and the secondary organic aerosol formation and the relative amount of OC and EC in the atmosphere, and OC/EC ratios are the important parameters for the assessment of direct/indirect impacts of aerosols on the regional scale radiative forcing (Novakov et al., 2005). However, these ratios depend on the fuel type, quantity, and, more importantly, their combustion efficiency (Bond et al., 2007; Streets et al., 2004).

The particulate matter including OC and EC can remain airborne from days to weeks; therefore, can undergo long-distance transport, producing global and regional in addition to local impacts on the air quality. The transport of air pollutants is mostly driven by weather phenomena like vertical air motions, along with prevailing winds both dilute and disperse particles and gases emitted from various sources (Sen et al., 2017), it is also influenced by seasonal climate and the atmospheric circulation systems (Tripathee et al., 2017). The air-mass back trajectories are valuable for the apportionment of potential source regions and their pathways, and to sightsee the influence of the long-range transport of aerosols (Tripathee et al., 2017).

This study aims to determine the concentrations, seasonality, possible sources, and transport pathways of carbonaceous particles (OC and EC) reaching the receptor site (Dhulikhel, Kavrepalanchok from the aerosol sample collected from January to December 2018. Four distinct seasons—winter (December–February), pre-monsoon (March-May), monsoon (June–September), and post-monsoon (October–November) – are characterized by South Asian Monsoon circulations that affect the weather in Nepal (Bonasoni et al., 2010). Based on this, seasonal variation has been observed in this study.

Materials and Methods

Study site description

Dhulikhel (27.601°North, 85.538°East) is a pleasant hilly city located in the lesser Himalayan zone of central Nepal. The city is situated about 30-kilometer south-east downwind of Kathmandu Valley and about 3 kilometer north-west of Banepa Municipality. The ambient air quality of the study area is influenced by large scale transport of pollutants from the Indo-Gangetic Plains and by local sources around the highly polluted Kathmandu Valley (Shrestha et al., 2010). The southwesterly and northwesterly are major surface winds in the Kathmandu Valley, which merge into the westerly wind channeled to Banepa Valley (Regmi et al., 2003). The particles concentration gets increased by 10-20 $\mu g/m^3$ at Banepa when the westerly winds are blown, carrying pollutants out of Kathmandu Valley towards Banepa through the south-east Sanga Hill (Aryal et al., 2009). During the night time and early morning, the Kathmandu Valley is filled by a thick cold air pool at low elevations favored by the bowl shaped topography of the high mountains (Regmi et al., 2003). Thus, any transport of pollutants from the Kathmandu Valley to the sampling site at Kathmandu University is expected only during day time (Shrestha et al., 2010).

Moreover, the study site is located south-east downwind of Bhaktapur Industrial Estate, as well as several brick kilns that use low-quality coal from January to April (Sarkar et al., 2016). The study site is closer to the junction of two national highways (Araniko and B.P.), which connect central-hilly districts and Terai region to Kathmandu Valley. Aside from these sources, notable polluters include the pharmaceutical, brewing, plastics, brick, and plywood industries.

The study area records a daily mean temperature of 16.85°C (max: 24.32°C and min: 5.94°C) and a mean relative humidity of 95.91% (max: 100% and min: 71.3%) in 2018 (study period). The annual rainfall of 1360 mm was recorded in 2018, substantial rainfall (1008 mm) was observed in monsoon while mild rainfall (329 mm) in pre-monsoon. The meteorology of Dhulikhel and its

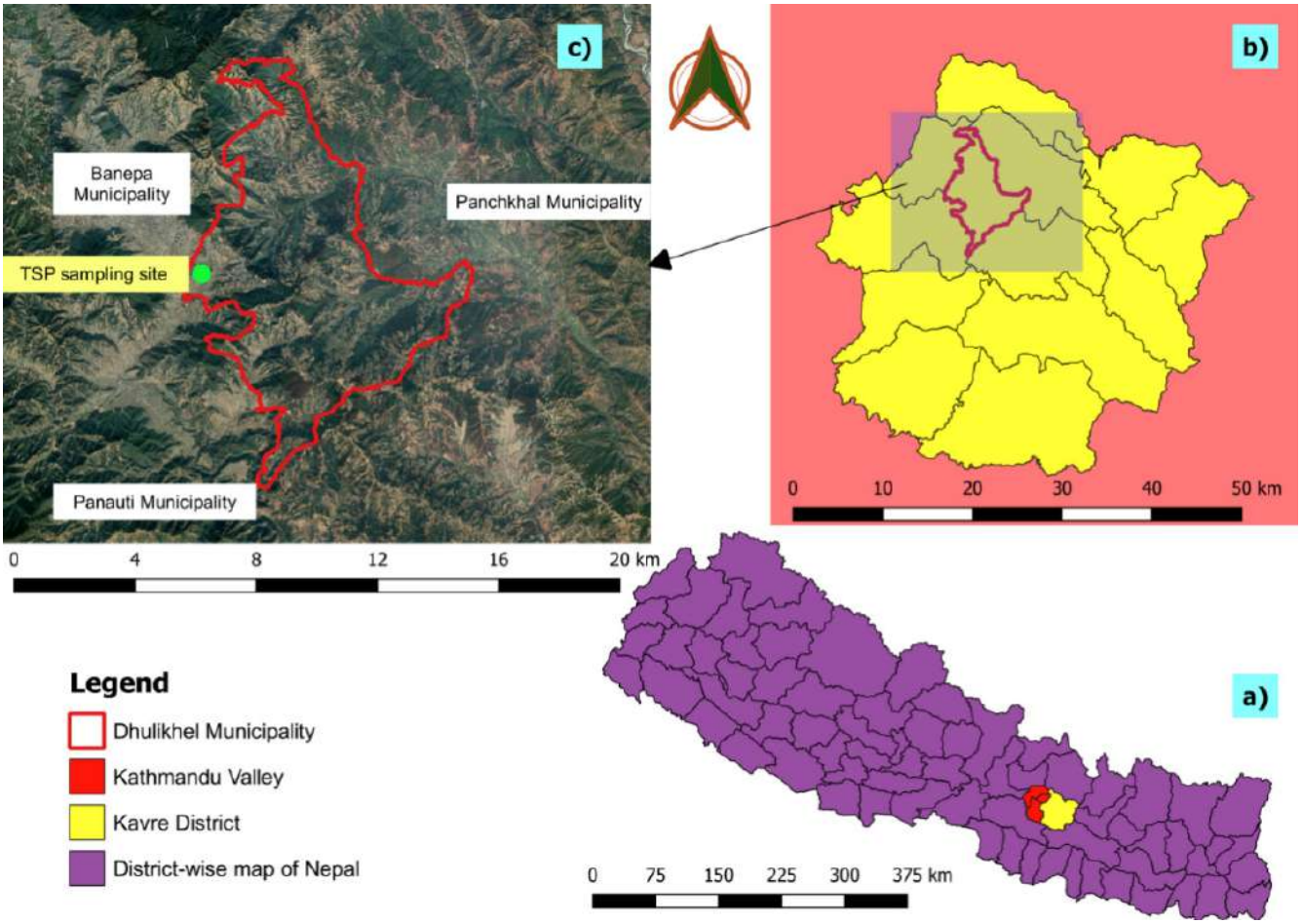

Figure 1: (a) Map of Nepal showing Kathmandu Valley and Kavrepalanchok District (b) Political boundary of Kavrepalanchok district and Dhulikhel Municipality (c) Location of sampling site in Dhulikhel

surrounding regions is controlled by the South Asian Monsoon circulations in the wet season (June-September), while Westerlies dominate the atmospheric circulation patterns in the dry seasons with limited precipitation (Pudasainee et al., 2006; Mues et al., 2017). Moreover, meteorology also gets influenced by local mountain valley circulation (Mues et al., 2018).

Sample collection and analysis

The sampling was carried out under the research framework called Atmospheric Pollution and Cryospheric Change (APCC), which was established in order to examine the transport and influence of atmospheric pollution to cryospheric environment (Kang et al., 2019). Total Suspended Particulate (TSP) samples were collected using medium volume air sampler (T2034, Qingdao Laoying, China) operated at a continuous flow rate of 100 L/min at standard condition based on the local meteorology. The flow rate was calibrated initially during the pre-test. The particles were collected on pre-combusted (550 °C for 5 h) quartz fiber filters (90 mm in diameter, Whatman plc, Maid-stone, UK).

The TSP sampler was set up on the rooftop of three storey building of Kathmandu University Central Library (25.61894° North and 85.53855° East, 1510 meters above sea level), situated approximately 2.5 kilometer north-west of nearest Banepa city in an open space, dominated by residential, agricultural and forest land use.

TSP sample (N=72) was collected on every six days with each sample lasting 24-hours. However, the frequency of sampling was increased for two to three samples per week in pre-monsoon (March-May), slightly modified from Ram et al. (2010b).

Ram et al. (2010a) collected 66 samples, Wan et al. (2017) collected 68 samples, Wan et al. (2019) collected 82 samples for a period of one-year to access carbonaceous aerosols.

The field blank samples were collected approximately once after every five samples at the site. All filters were carefully transferred in a clean disc, wrapped with aluminum foil, and stored in a freezing temperature until further analysis (Tripathee et al., 2016). The aerosol mass loadings were obtained gravimetrically using microbalance by weighing the filters twice before (w_o) and after sampling (w_t). The net accumulation mass for each filter was calculated as the difference between the pre and post sampling weight.

Chemical analysis (OC and EC)

The collected quartz filters were punched in 1.5 cm^2 rectangular filter aliquots to analyze OC and EC using EC–OC analyzer (Sunset Laboratory, Forest Grove, USA) following the thermo-optical transmittance protocol (Ram et al., 2008; Rengarajan et al., 2007). The instrument allocates OC and EC by applying thermal, chemical and optical properties, the OC fraction, evolved during sample heating in the inert atmosphere readily gets converted to CO_2; whereas EC (of refractory nature) is converted to CO_2 under an oxidizing medium, these evolved CO_2 was reduced to methane (CH_4) and measured on Flame Ionization Detectors (FID) (Ram & Sarin, 2010b). For defining the split-point between OC and EC and to correct for the pyrolyzed carbon formed during the initial charring of organic carbon in an inert condition, a 678nm laser source was used and every post-analytical run, fix the volume of methane was injected as an internal standard to assess the performance of FID; whereas potassium hydrogen phthalate was used as an external standard (Ram & Sarin, 2010).

Furthermore, quality assurance was regularly maintained using Standard Reference Materials (GB W08606) designated by National Research Center for Certified Reference Materials, China. Field blank filters were also analyzed similar to test samples.

Cluster analysis of air mass back trajectory

Four-day (96-hrs) air-mass back trajectories arriving at the receptor site (Dhulikhel) were computed using the NOAA–Air Resource Laboratory's Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler & Rolph, 2003), at an altitude of 500 m above the ground level, which is within the planetary boundary layer over Himalayas and Tibetan Plateau (Ram et al., 2010a).

The HYSPLIT model was driven by the 3-dimensional meteorological fields adopted from the GADS- 1° dataset available at National Centers for Environmental Prediction Final Analyses-NCEP (3-hours temporal resolution, 1°, 111 kilometer horizontal resolution and 24 vertical levels). The dataset was downloaded from January to December 2018 (ftp://arlftp.arlhq.noaa.gov/pub/archives/gdas1), and these datasets are available in ARL format, readable format for the HYSPLIT model. Total of 1190 trajectories were given as an input to the HYSPLIT model. The four trajectory clusters (1, 2, 3, and 4) were computed for each seasons, as it gives the best representation of air-flow classification (Prabhu & Shridhar, 2019). The HYSPLIT model provides information on the long-range distribution of atmospheric pollutants including carbonaceous aerosols, thus can help to

assume the location of the source of originating air-borne pollutants (Wong, et al., 2012).

Results and Discussions

TSP mass and seasonal variation

The 24-hour average mass concentration of TSP observed to be 226.48 ±106.39 µg/m³ (±Standard deviation), that is quite close to the National Ambient Air Quality Standard (NAAQS), 2012 of Nepal (annual limit: 230 µg/m³). TSP mass ranged from 38.00 µg/m³ (in monsoon) to 442.45 µg/m³ (in pre-monsoon) in 2018. (Table 1).

The mean TSP mass in winter (298.66 ±71.42 µg/m³) and pre-monsoon (277.67 ±90.50 µg/m³) are more than twice that in monsoon (99.02 ±42.52 µg/m³) and post-monsoon (190.86 ±40.38 µg/m³) as presented in Table 1. Moreover, the average TSP mass in winter and pre-monsoon was 31.87% and 22.6% more than the annual average, whereas, in monsoon and post-monsoon, it was 56.28% and 15.73% less than the annual average.

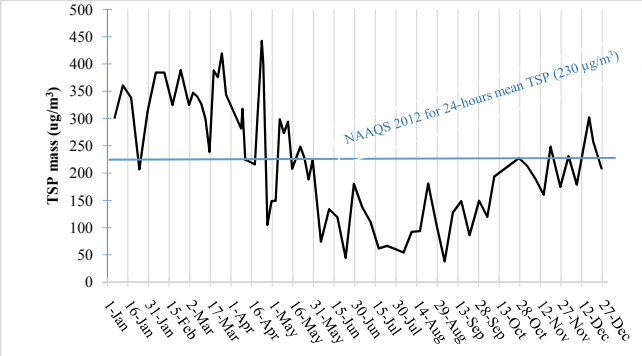

Figure 2: 24-hrs TSP mass collected at sampling site (Jan-Dec 2018)

The study done in Bode, Bhaktapur in April 2013-March 2014 shows that the annual average concentration of TSP was 238.24 ±162.24 µg/m³ and also indicated mass of TSP in ambient air was more in winter (370.21 ±105.12 µg/m³) > pre-monsoon (357.69 ±181.53 µg/m³) > post-monsoon (225.13 ±71.58 µg/m³) > monsoon (113.35 ±51.33 µg/m³) respectively (Tripathee et al., 2017). According to data recorded by the Dhulikhel Air Quality Monitoring Station, established by Department of Environment, the concentration of TSP in 2018 ranged from 511.47 µg/m³ (in winter) to 8.14 (in monsoon) (DOE, 2021).

Sometimes low wind speed and shallow planetary boundary layers in winter and post-monsoon could easily form stagnant weather conditions, which is favorable for the accumulating air pollutants. Meanwhile, excessive rainfall in monsoon lowers TSP levels because it prevents the resuspension of dust and wash-out suspended particulates in the ambient atmosphere. For most dry days, the TSP has exceeded the standard threshold concentration (Table 1).

Source Characterization

Inference from OC and EC concentration and correlation: The annual average OC and EC concentrations in TSP was found to be 18.78 ±12.6 µg/m³ and 6.42 ±2.89 µg/m³, respectively (Table

Table 1: Annual and Seasonal maximum, minimum and average TSP mass at Dhulikhel (2018)(Jan-Dec 2018)

Season	Minimum TSP (µg/m³)	Maximum TSP (µg/m³)	Average TSP (µg/m³)	Number of samples	Number of days TSP exceeded the standard
Pre-monsoon (Mar-May)	74.14	442.45	277.67 ±90.50	30	20
Monsoon (Jun-Sep)	38.00	180.69	99.02 ±42.52	20	0
Post-monsoon (Oct-Nov)	119.73	248.44	190.86 ±40.38	8	1
Winter (Dec-Feb)	178.62	388.76	298.66 ±71.42	14	11
Annual (Jan-Dec)	38.00	442.45	226.48 ±106.39	72	26

2), which accounts for 8.29% and 2.83% of the TSP mass at the study site. The seasonal average mass concentration of EC and OC are presented in Table 2, exhibits lower seasonal variability (except monsoon) suggesting the study site gets common sources and types of aerosols.

The low concentration during monsoon is attributed to relative decrease in the source strength of biomass burning emission and removal by wet deposition (Ram et al., 2010a). The study done by Islam et al., 2022 in January 2018 observed the concentration of OC in $PM_{2.5}$ ranged from 20.7 - 9.6 µg/m^3, and EC in $PM_{2.5}$ ranged from 6.6 - 3.3 µg/m^3 in Dhulikhel.

The OC% and EC% in total carbon (TC) were found to be 72.03 ±5.53% and 27.97 ±5.53%, respectively. The annual and seasonal, maximum, minimum and average OC%, EC% in TC and TC% in TSP mass are presented in Table 2.

The scattered plot (Fig. 3) showed a stronger linear relation (R^2=0.758) between OC and EC in 2018.

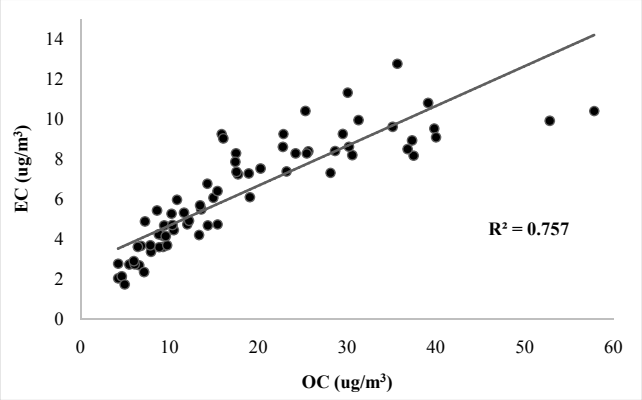

Figure 3: Annual correlation between OC and EC (2018)

The relationship between OC and EC in different seasons are shown in Fig-4. The correlation coefficient of the relationship between OC and EC in pre-monsoon was 0.836, likewise in monsoon, post-monsoon and winter was 0.764, 0.87, and 0.77, respectively (Fig. 4). The significant linear correlation between OC and EC suggests that the carbonaceous aerosols probably have a common source of origin (Ram et al., 2012).

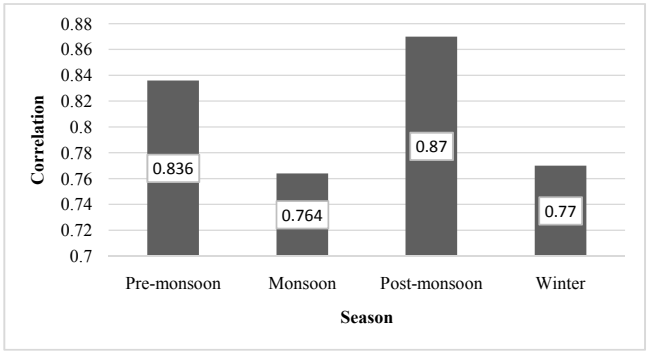

Figure 4: Seasonal correlation between OC and EC (2018)

Inference from OC/EC ratios: The annual average OC/EC ratio was observed to be 2.73 ±0.84 in 2018, the OC/EC ratio in TSP ranged from 1.48 (in monsoon) to 5.55 (in pre-monsoon) as presented in Table 3. The higher OC/EC ratio indicates prevalence of the OC species over EC, attributed to biomass burning, whereas the low ratio indicates the higher emissions from fossil fuel (coal and vehicular exhaust) combustion (Rai et al., 2021). The lower ratio also highlights that the samples contain almost entirely primary carbonaceous compounds which can be influenced by various factors such as meteorology, local sources, and long-range aerosol transport (Dinoi et al. 2017).

Table 2: Average OC%, EC% in total TC and TC% in total TSP mass

Season	Average OC (µg/m^3)	Average EC (µg/m^3)	OC % in TC	EC % in TC	TC % in total TSP mass
Pre-monsoon (Mar-May)	21.62 ±13.67	6.87 ±2.2	73.06 ±6.23	26.94 ±6.23	9.63 ±2.77
Monsoon (Jun-Sep)	7.25 ±2.44	3.22 ±0.91	68.87 ±4.27	31.13 ±4.27	10.84 ±5.97
Post-monsoon (Oct-Nov)	20.19 ±8.13	7.69 ±2.29	71.56 ±4.05	28.44 ±4.05	14.56 ±3.91
Winter (Dec-Feb)	28.39 ±9.07	9.32 ±2.14	74.61 ±4.43	25.39 ±4.43	13.36 ±5.65
Annual	18.78 ±12.6	6.42 ±2.89	72.03 ±5.53	27.97 ±5.53	11.20 ±4.84

The average OC/EC ratio in winter (~3.01) was higher compared to other seasons. Moreover, the average OC/EC ratios in the four seasons (~2.24–3.01) exceeds 2, which indicates the presence of secondary organic aerosol (Chow et al., 2005).

The prior study done in Dhulikhel (January 2018) measured OC/EC ratio in $PM_{2.5,}$ ranged from 2.9 to 3.4, with an average OC/EC ratios of 3.1 (Islam et al., 2022). OC/EC ratios of 2-4 have been previously observed at urban locations in South Asian region (Islam et al., 2020; Sharma et al., 2017; Stone et al., 2010) and are attributed to diesel emissions with OC to EC ratio of 0.6438 (Schauer et al., 1999) and low-efficiency biofuel combustion (Venkataraman et al., 2005).

The literature suggests that the OC/EC ratio can significantly vary while measuring when it is carried away from the source of origin (Lim et al., 2003). As well, it is claimed that the ratios are likely to be influenced by the primary sources of OC, emission sources, SOA formation, and deposition removal rate (Cachier et al., 1996; Ram et al., 2012).

Table 4 depicts the OC/EC ratio of the present study to that of prior studies.

Air-mass back trajectory analysis and satellite observations

To explore the possible source regions of aerosols, four-day air-mass back trajectories were computed using HYSPLIT model for different seasons as shown in Fig-7. However, due to complex topography of the Himalayan region and the influence of local/regional transport processes related to thermal valley winds, back-trajectory results should be described with caution (Tripathee et al., 2017). Moreover, the transport of air pollutants is mostly driven by weather phenomena like vertical air motions, along with prevailing winds both dilute and disperse particles and gases emitted from respective source (Sen et al., 2017).

Consequently, the results of HYSPLIT model have been discussed together with the satellite-derived information on Aerosol Optical Depth (AOD) and fire hotspots for the study period. AOD was obtained from Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) sensor at 550 nm wavelength (50 km resolution), while fire hotspots map was generated from Moderate Resolution Imaging Spectro-radiometer

Table 3: Annual and Seasonal OC/EC ratio of the study period (2018)

Season	Min. OC/EC	Max. OC/EC	Average OC/EC	Std. Deviation
Pre-monsoon	1.59	5.55	2.93	1.04
Monsoon	1.48	3.05	2.24	0.44
Post-monsoon	2.10	3.84	2.74	0.55
Winter	1.71	4.33	3.01	0.64
Annual	1.48	5.55	2.73	0.84

Table 4: Comparison of OC/EC ratios with prior studies

Study Area	Study Period	Mean OC/EC ratio	Source	Reference
Northwestern Colorado	1995	1.1	Motor vehicle	Watson et al., 2001
	1995	2.7	Coal combustion emission	
	1995	2.97	Coal-fired boilers	
Xi'an, China	Sept 2003 to Feb 2004	4.10	Vehicular exhaust	Cao et al., 2005
Kathmandu, Nepal	Dec 2007 to Jan 2008	4.47	Vehicular emission	Shakya et al., 2010
Central California	July-Aug 1990	6.6	Biomass burning	Chow et al., 1996
Helsinki, Finland	March 2006 to Feb 2007	3.3	Secondary Organic Carbon	Saarikoski et al., 2008
		6.6	Biomass combustion	
		0.71	Traffic	
Kanpur, India	Jan 2007 to Mar 2008	7.84 ± 2.4	Biomass burning	Ram and Sarin, 2010
Dhulikhel, Nepal	January-December 2018	2.73 ± 0.84		Present study

(MODIS) sensors onboard on Terra satellites of National Aeronautics and Space Administration (NASA).

The air-mass reaching receptor site has illustrated two distinct pathways, i.e., during the dry period air-mass arrives from Indo Gangetic Plain regions of north-west India and eastern Pakistan, while during monsoon air-mass arrives mostly from the Bay of Bengal (Fig-7), which could be the source regions of polluted air mass to our site. Furthermore, the results of active forest fire and non-forest fire hotspots for the study period showed the occurrence of concentrated fire hotspots during dry periods (winter and pre-monsoon) as presented in Fig-5, which causes an intense haze over this region (Tripathee et al., 2017). The prior studies have also reported intensive haze in Indo Gangetic Plain and Himalayan region during the dry periods (Bonasoni et al., 2008; Ram and Sarin, 2015; Tripathee et al., 2017).

Besides, the monthly-averaged AOD map at wavelength of 550 nm showed the higher aerosol loadings across the Indo Gangetic Plain and surrounding region, mostly during dry months (Fig-6). The high AOD during the dry period is mostly from biomass burning (Ram and Sarin, 2015; Wan et al., 2017) and anthropogenic emissions (Tripathee et al., 2017). In the previous discussions, biomass burning and anthropogenic activities were identified for sources of Carbonaceous Aerosols in TSP of the study area. Further, the seasonal pollution over the region is shown by satellite data during the study period, which could have influenced the carbonaceous species at different periods through long-range transport and deposition over the Himalayan region.

The air-mass back trajectories obtained from the HYSPLIT model for different seasons are described below:

a. **Winter season (December-February):** Most of the air-mass arriving at the receptor site originates from Middle East and West Asian countries. Specifically, cluster-1, accounting for about 23% of all trajectories ends up at the Arabian Sea and travels through the Uttarakhand and Madhyapradesh region of India. Cluster-2 and cluster-4 end up in Egypt contributing 23% and 26% of total trajectories, respectively, and cluster-3 originates from Pakistan (Balochistan) contributing 28% of total trajectories reaching Dhulikhel. The plotted trajectory clusters (1, 2 and 3) show more than 60% of trajectories of air mass enter the receptor site through northern India from the Indo-Gangetic Plain which is regarded as the most polluted region in Asia (Thamban et al., 2017; Prabhu & Shridhar, 2019) that can consequently affect the air quality of the study area. Cluster-1 and cluster-3 represent slow-moving air mass compared to cluster-2 and cluster-3. Figure 5 shows that fire incidents are spatially distributed mostly in western and central lesser Himalayan regions in winter season.

b. **Pre-monsoon season (March-May):** The air mass associated with cluster-1 and cluster-3, accounting for about 68% of all the trajectories could be considered major air masses that end up in Pakistan (Punjab) and central Iran, which may have significant implications for aerosol concentration at the study site. Additionally, air-masses cluster-2 ended up in India (Jharkhand), and cluster-4 ended up in Saudi Arabia, contributing 18% and 14% of all trajectories reaching the receptor site.

More than 80% of air mass appeared from strong westerly wind arriving at the study site and entering through the western region of Nepal, northwest India, and Pakistan, and the climate in the Himalayas is strongly influenced by western disturbances during this season (Bonasoni et al., 2010). Similar results were presented by Tripathee et al. (2017); in the dry season, a significant amount of pollutants appeared at sampling sites in the central Himalayas of Nepal (Jomsom and Dhunche) from the Middle East region entering through western Nepal, northwest polluted Indian cities and Pakistan. Furthermore, during the non-monsoon seasons, the transport pathways of air masses arriving at the central Himalayas of Nepal were similar, and northern India appeared to be the foremost

source region of particle pollutants (Tripathee et al., 2017). As shown in Figure 5, most of the fire hotspots were recorded in pre-monsoon when the annual average concentration of Carbonaceous Aerosols and TSP mass concentrations are also higher. The fire hotspots mostly occurred in Terai region.

c. **Monsoon season (June-September):** Most of the air mass reaching Dhulikhel is highly influenced by the South Asian Monsoon as shown in Fig. 6, where air-mass cluster-1 ends up at the Bay of Bengal contributing to the highest proportion of all the air mass (44%) that went through Bangladesh and entering receptor site from the eastern part of Nepal. The air mass of cluster-3 also seems to be prominent because it accounts for 29% of total trajectories reaching the receptor sites bypassing the northeast region of India. The air masses of cluster-2 and cluster-4 were considered to account for a small portion of all the trajectories that originate from India (Uttar Pradesh) and Myanmar, contributing 13% and 15% of total trajectories respectively.

d. **Post-monsoon season (October-November):** Most of the air mass was found to be originated from the Middle East (76%) as shown by air-masses cluster-1 (39%), cluster-3 (30%) and cluster-4 (7%) respectively that ended up in Saudi Arabia, Egypt (near the Red Sea) and Turkey. The air-mass cluster-2, solitarily end

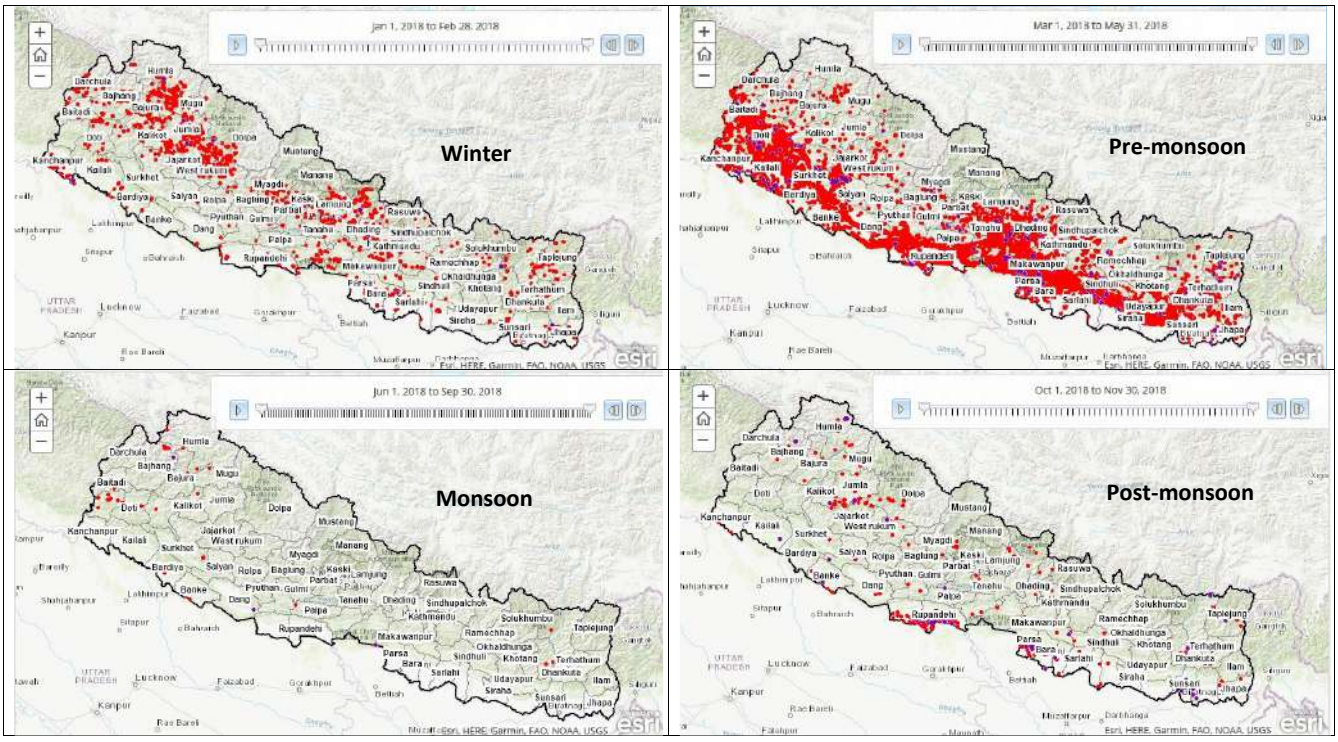

Figure 5: Fire hotspots in four distinct seasons during the study period in 2018 (red dots symbolize the fire hotspots)

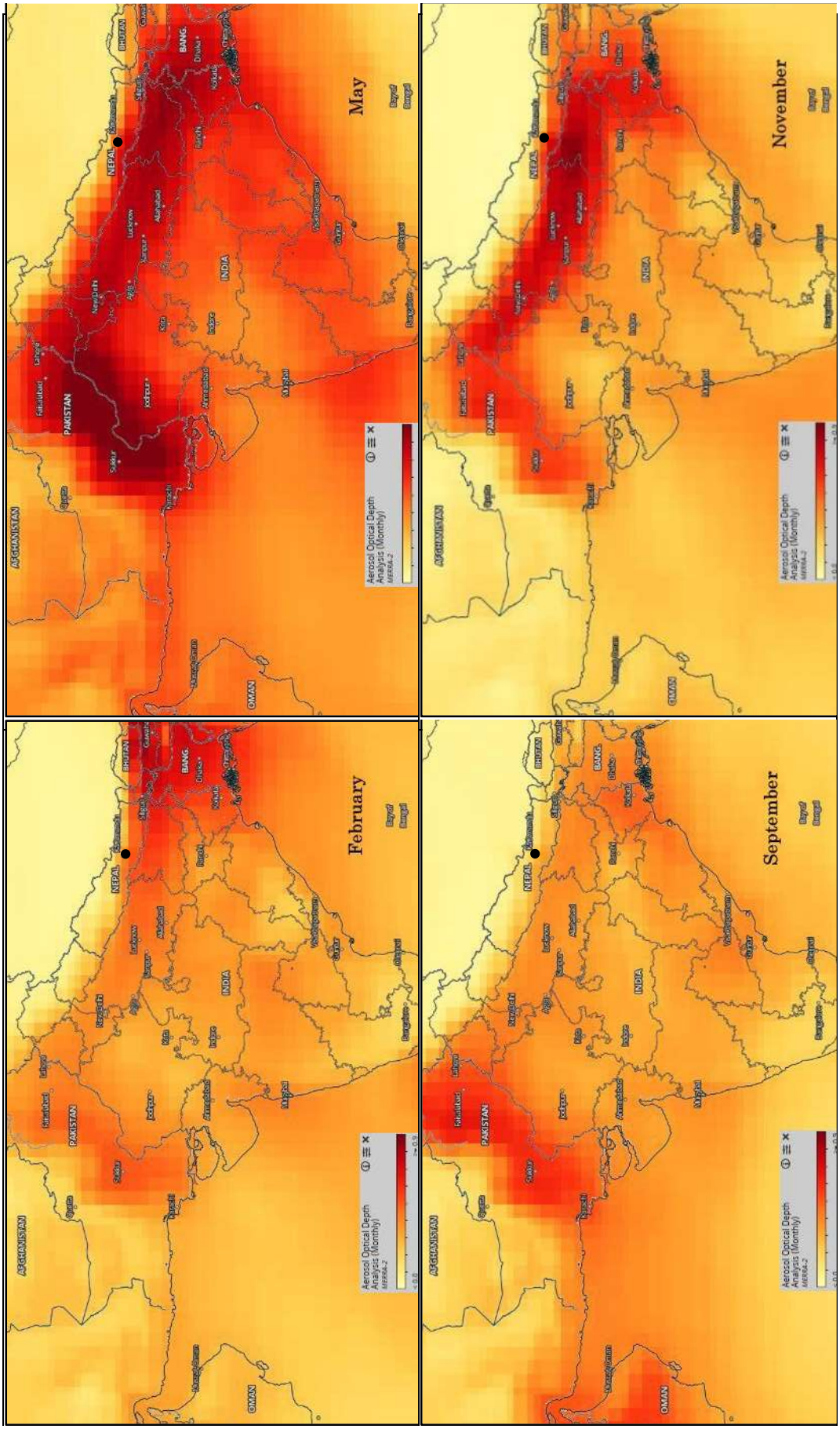

Figure 6: Monthly-averaged AOD map obtained from MERRA-2 sensor (550 nm wavelength; 50 km resolution) in February, May, September and November (2018) The black circle represents the location of the sampling station (Dhulikhel).

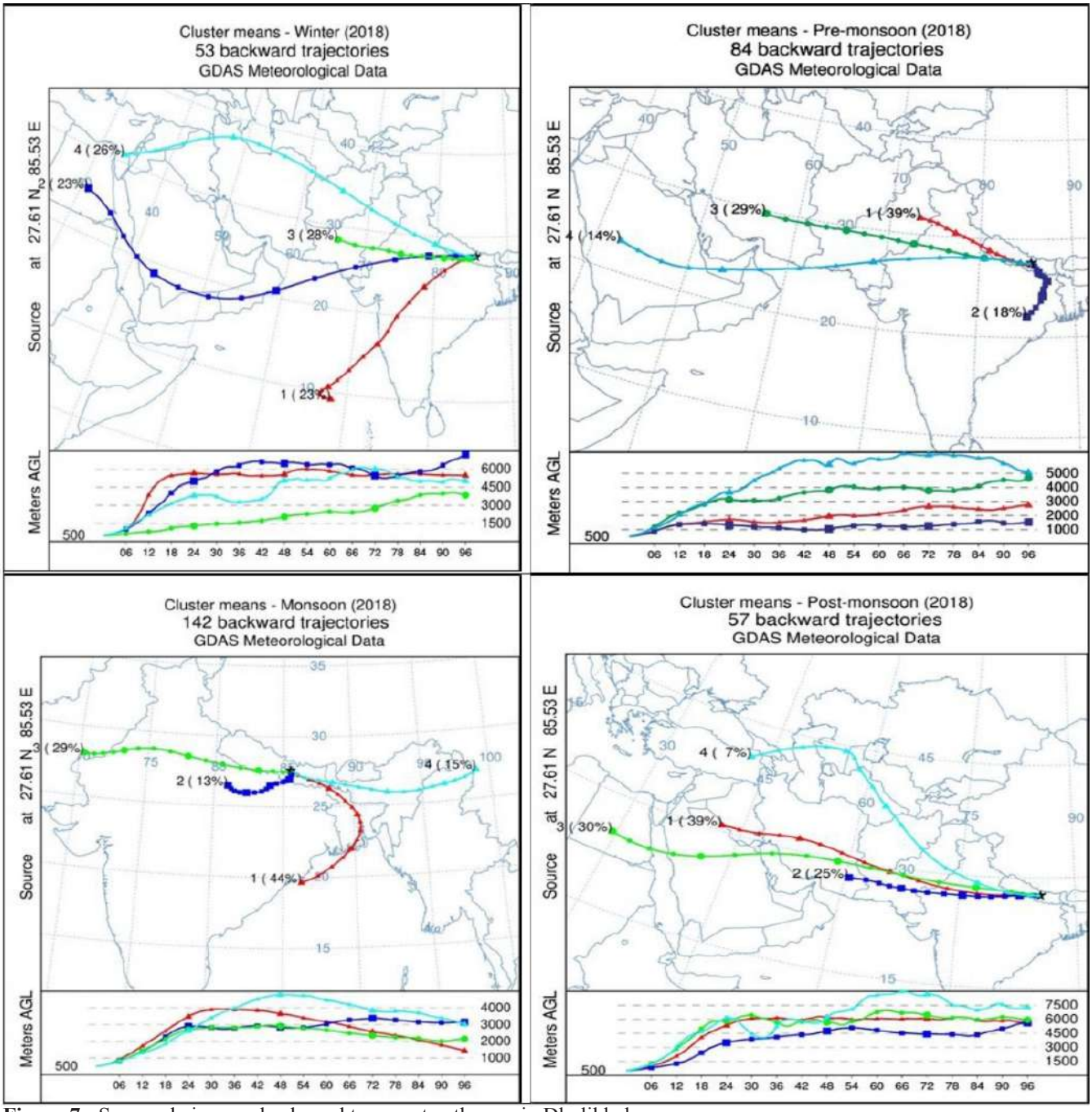

Figure 7: Seasonal air-mass backward transport pathways in Dhulikhel

Conclusion

The measurements of the Carbonaceous aerosols (OC, EC and TC) in the coarse aerosols were conducted during a year between January and December 2018 at the middle hill site of the central Himalayas, Dhulikhel, Nepal. The incidences of surpassing the National Ambient Air Quality Standards, 2012 prescribed limit for a 24-hour daily average mass of TSP were observed with an average mass of 229.35 μg/m^3. The seasonal TSP, OC, and EC levels remained high in pre-monsoon and winter, while during the monsoon, TSP mass is relatively lower due to the settling down of particles from precipitation.

The annual average OC and EC concentrations in TSP was found to be 18.78 ±12.6 μg/m^3 and 6.42 ±2.89 μg/m^3, which accounts for 8.29% and 2.83% of the TSP mass at the study site. Similarly, OC% and EC% in total carbon (TC) were found to be 72.03 ±5.53% and 27.97 ±5.53%, respectively. A

stronger linear relation (R^2=0.758) between OC and EC suggests that the carbonaceous aerosols probably have a common source of origin. The annual average OC/EC ratio was observed to be 2.73 ±0.84 in 2018, the OC/EC ratio in TSP ranged from 1.48 (in monsoon) to 5.55 (in pre-monsoon). The higher OC/EC ratio indicates prevalence of the OC species over EC, attributed to biomass burning, whereas the low ratio indicates the higher emissions from fossil fuel (coal and vehicular exhaust) combustion. Moreover, the average OC/EC ratios in the four seasons (~2.24–3.01) exceeds 2, which indicates the presence of secondary organic aerosol.

The results from air-parcel backward trajectory analysis indicates the atmospheric transportation that appeared to be reaching Dhulikhel is influenced by the two distinct pathways, i.e., from Indo Gangetic Plains (IGP) regions during the dry period (north-west India and eastern Pakistan) and the Bay of Bengal during the monsoon period which could be the source regions of polluted air mass to our site. The air mass appeared to be transported from the Middle East, Bay of Bengal, Arabian Sea, and neighboring South Asian countries, passing over the desert and Indo-Gangetic Plain before reaching Dhulikhel. Thus, the transboundary atmospheric aerosol transport and dispersion were observed to be significant across the western and central regions of Nepal, including the receptor site. Further, the seasonal pollution over the region is shown by satellite data during the study period, which could have influenced the carbonaceous species at different periods through long-range transport and deposition over the Himalayan region.

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Estimation of Greenhouse gas emission from municipal solid waste management techniques - A case of Rampur Municipality, Palpa District, Nepal

Bibek Khanal*, Kishor Kumar Maharjan
[1]Department of Environmental Science, Tri-Chandra Multiple Campus, Tribhuvan University, Nepal
*Correspondence: bibekkhanal5698@gmail.com

Abstract

This paper explores the rising global solid waste issue and its often-overlooked contribution to climate change. Most studies view waste as a significant parameter of public health and aesthetic value but neglect its role in climate change. Focusing on Rampur municipality, the study quantifies waste from households, commercial hubs, and institutions, using IPCC guidelines for greenhouse gas emission estimates. The waste generated by 84 households, 26 commercial hubs, and 14 institutions for seven consecutive days was studied and quantified. The IPCC's 2006 Guidelines for National GHG Inventories were applied to estimate GHG emissions from landfills and composting. In Rampur municipality, 2772 tons of waste was generated and only 40 % of the generated waste was landfilled. The generation rates of Households, Commercial, and Institutions were 141.5 ± 7.16 g/capita/day, 1933 ± 0.32g/day, and 826 ± 0.46 g/day respectively. Organic waste emerges as a key contributor in Households and Commercials while Paper dominates institutions. Rampur Municipality emits approximately 2,629.77 tons of CO2eq GHG annually from waste management, divided as 0.06 tons of CO2eq GHG annually per individual, with households contributing 55%, commercial sectors 41%, and institutions 4%. Furthermore, composting was identified as an effective mitigation strategy, potentially reducing emissions by 81%. Overall, this research sheds light on the significant contribution of municipal waste to GHG emissions. It underscores the need for enhanced waste management strategies, particularly emphasizing composting's role in global climate change mitigation. It can be useful for policymakers to address waste-related emissions.

Keywords: *Climate change, composition, emission, generation, mitigation*

Introduction

The global waste generation was 2.24 billion tons of solid waste in 2020 and is projected to increase by 73% to 3.88 billion tons by 2050 due to rapid urbanization (World Bank, 2022). Although it's widely known that proper waste management is important for people's health; many do not realize that waste management practices also affect the climate (US EPA , 2002). Municipal solid waste (MSW) encompasses waste from households, businesses, and discarded items that are no longer useful (Tchobanoglous and Krieth, 2002; Vergara and Tchobanoglous, 2012). In landfills, organic waste breaks down and releases GHG, primarily methane into the air. The methane's warming potential is 28 times stronger than carbon dioxide's (Clean Energy Regulator, 2022; IPCC, 2021). Improper waste disposal, like open dumping and inadequate landfilling, contributes to 3-19% of human-caused methane emissions globally. Addressing methane emissions from landfills can significantly reduce greenhouse gases in the atmosphere (Taylan et al., 2007).

In the context of Nepal, the rapid and uncontrolled growth of cities, along with limited public awareness and poor management by municipalities, has worsened environmental issues (Asnani and Zurbrugg, 2007). Household waste makes up 50% to 75% of all the waste with a generation rate of 170 grams(g) of waste per day (ADB, 2013). Based on this and the population in 2011, the 58 municipalities create about 1,435 tons of waste every day and 524,000 tons each year. Overall, Municipal Solid Waste (MSW) consists of 56% organic waste, 16% plastics, and 16% paper and paper products (ADB, 2013).

In recent decades, global warming has emerged as a significant and pressing concern, evidenced by an approximate temperature rise of 1°C above pre-industrial levels (Rogelj, 2021). The current trajectory suggests a projected temperature increase of approximately 1.5°C between 2030 and 2052, as reported by the Intergovernmental Panel on Climate Change (Beck and Mahony, 2018). During the 21st Conference of Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC), the Paris Agreement was ratified by 192 parties to limit global temperature rise to well below 2°C and striving to keep it below 1.5°C (UNFCCC, 2016).

According to MoPE (2017) for Third National Communication (TNC) to the UNFCCC (MoPE, 2021), Nepal's net GHG emissions were calculated to be 31,998.91 gigagrams of CO_2eq. Taking the waste section only, Nepal emits 923.58 Gg of CO_2eq annually. Solid waste disposal represents about 28% of the total emission from the waste, which is almost equal to 261.581 Gg of CO_2eq per annum (TNC, 2021). So, the contribution of the waste section is around 3 % of the GHG emissions in Nepal.

Existing research has predominantly focused on waste characterization and management, leaving a substantial gap in our understanding of emissions originating specifically from municipal waste sources. Despite growing concern about climate change and global warming, many municipalities lack accurate information on their emissions and contributions to global issues. Without accurate data on their greenhouse gas emissions, municipalities may be unable to effectively manage their carbon footprint and implement strategies to reduce their environmental impact. The local government can select from a variety of solutions for managing solid waste by being aware of the quantity and types of garbage produced within its borders and planning and implementing policies and planning in accordance (Kaza et al., 2018). Thus, in this study, we have attempted to assess the generation and composition of MSW to quantify the GHG emission from the Solid Waste Management (SWM) sector.

Materials and Methods

Study Area

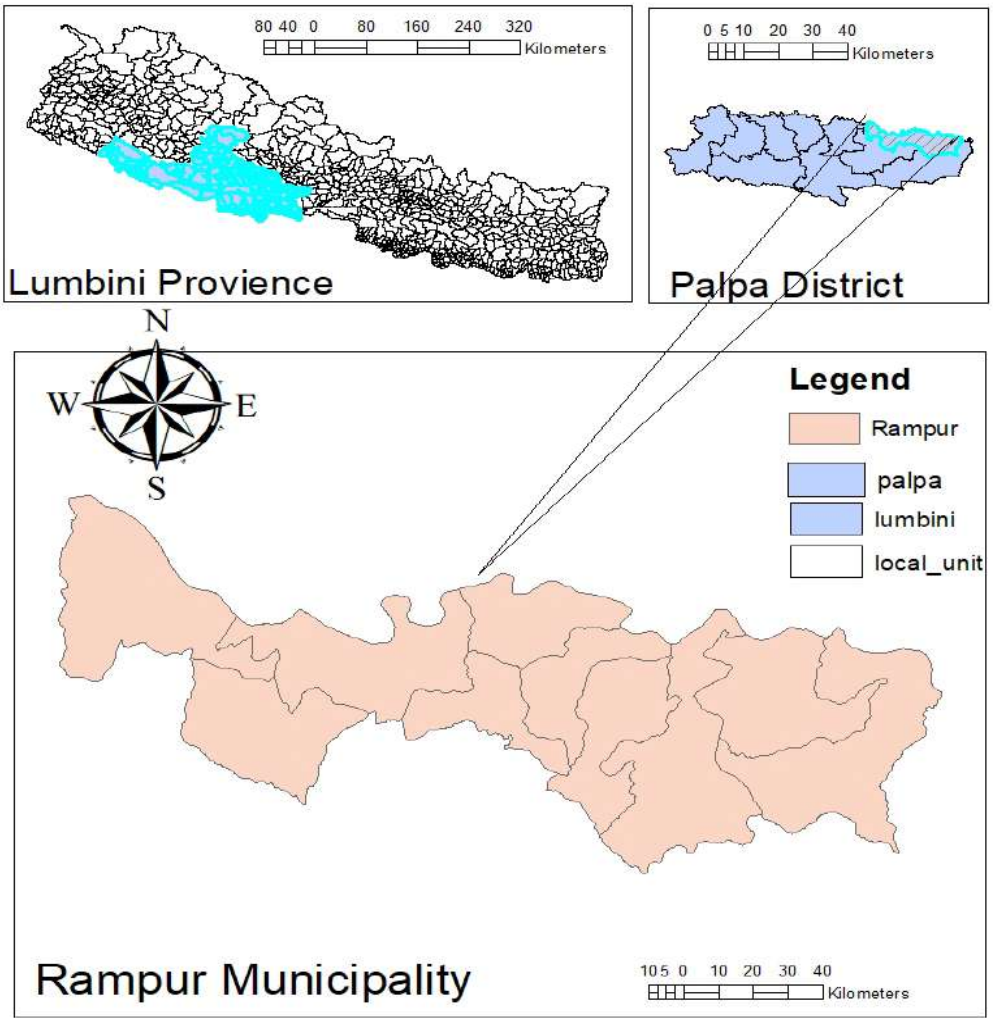

Figure 1: Map of Study Area

This study was conducted in Rampur Municipality as shown in Fig. 1, situated in the Palpa District of Lumbini Province, Nepal. The semi-urban municipality with an area of 123.34 km and a total population of 40883 (NSO, 2023) has a population density of 331 persons per km², which is higher compared to the national urban population density of 207.55 persons per km², and the average household size is 3.6, lower than the national average of 4.37 (NSO, 2023). Solid waste is a growing issue in the municipality but the study hasn't been done yet. So, the study area can represent all urban local bodies of Nepal in the context of waste management and emissions.

Rampur Municipality (27° 51' 41" N latitude and 83° 53' 16" E longitude), with elevation ranges from 350 meters to 1100 meters above the mean sea level lies in the midland range of the nation and Monsoon – Influenced Humid Subtropical Climate according to Köppen climate type (Mindat, 2021).

Methods

A reconnaissance survey was done to know the current status of the Solid Waste Management (SWM) practices, generation rate, and collection and disposal system. A checklist was prepared to record the generation rate and weight of the composition studied. Semi-structured Questionnaires were made to assess the SWM practices in the municipality.

The sample size was calculated using (Arkin and Colton, 1963) model as given in Equation I;

$$= \frac{z^2 * Np(1-p)}{N * d^2 + z^2 * p(1-p)} \quad \text{.....(i)}$$

Where,

z = Confidence level (95%, z = 1.96)
N = Total number of households (11363 for this survey)
p = estimated population proportion (0.05)
d = margin of error/Error limit 5% (0.05)
n = Sample size

The total household (HH) in the municipality was 11363 according to census 2021(NSO, 2023), the sample size was found to be 72 with a 5 % margin of error. Altogether 84 samples from HH were taken to mollify the risk of non-response and 26 and 14 were the sample for commercial (total 836) and institutions (total 237), respectively, on a proportionate basis. The sampling was done from 25th May to 19th June 2023.

Sampling for waste generation and composition: Two dustbins were used for sample collection over seven consecutive days in each chosen residence. Each family was encouraged to use a different dustbin for biodegradable and non-biodegradable waste. The biodegradable waste was weighed on the same day for 7 days while non-biodegradable trash was collected in bags, which were then further divided and weighed using a digital spring balance (100 kg). The generation rate of HH, institution, and commercial hub was computed separately.

The sampling was done on a purposive basis. The door-to-door interview was done in households, institutions, and commercial hubs at the time of the sample collection. Different compositions of MSW were separated and sorted out by quartering methods as in multiple papers (Kumar et al., 2004; Babel and Vilaysouk, 2016; Umar, 2022). The categories for the waste composition were classified based on the IPCC Sixth Assessment Report (IPCC, 2021) and the Waste Management model (Shapiro-Bengtsen et al., 2020) which includes yard waste in addition to predominant categories.

Estimation of GHG Emission

Estimation of Methane from Landfill: The estimation of the GHGs from the dumping site was done using the default or Tier 1 methodology outlined in the IPCC 2006 guidelines (IPCC, 2006), primarily due to the absence of country-specific data. Methane (CH_4) emissions were calculated based on the waste composition, quantity, and biodegradable organic carbon content. Tier 1 involves the gain-loss approach outlined in the IPCC GHG Inventory Guidelines and the default emission factors (IPCC, 2021) and other parameters provided by the IPCC (IPCC, 2015). The landfill of Rampur municipality is simple and doesn't fulfill the basic criteria of a sanitary landfill so this landfill is considered as the uncategorized landfill with MCF of 0.6. The CH_4 emitted from the dumping site was measured through Equation ii.

$ECH_4 = MSW_{(Land\ Fill)} \times MCF \times DOC \times DOC_f \times F \times (16/12)\text{-}R) \times (1\text{-}OX)$ ..... (ii)

Where, ECH_4 = Total Methane Emitted per year in Gigagram(1Gigagram = 10^9gram), $MSW_{(Land\ Fill)}$ = total amount of MSW in the landfill in wet weight basis (Giga gram/year), MCF = methane correction factor, DOC = the fraction of degradable organic carbon in MSW (Gigagram C/Gg MSW), DOC_f = the fraction of DOC that can decompose, F = the fraction of methane in generated landfill gases, R = the recovered methane(Giga gram/year), 16/12 is the molecular weight ratio CH_4/C, OX = the oxidation factor

The DOC values depend on the composition of the waste in the landfill (Berisha et al., 2018). DOC_f value ranges from 0.42 to 0.77 and depends on pH, temperature, moisture, and waste composition (Aguilar-Virgen et al., 2014). The main GHG emitted is methane which accounts for about 50% of the total GHG emission. So, the F values are taken as 0.5 (IPCC, 2006). Due to the lack of a proper energy recovery system in the landfill, R is taken to zero. The landfill is unmanaged with proper liner and cover so the OX, the amount of methane oxidized at the cover of the landfill is taken to zero.

The collection efficiency of the municipal waste collection was 75% for commercial and institutional sectors and roughly 30% for HH waste according to the municipality. The waste collection has been done only in four wards to date. The annual waste generation per annum going to the dumping site was calculated by multiplying the per day waste generation of three sectors, number of the establishments or individuals, no. of days in a year, and the collection efficiency of the respective sectors.

GHG Emission from the Transport of the Waste: The emissions of greenhouse gases (GHG) during waste transportation from the generation site to the disposal site are significant. Three months of data on fuel consumption by Truck and tractor for waste transport was generalized to calculate the annual fuel consumption. The GHG emitted by the combustion of fossil fuel used in the Trucks and tractors for the transport of Municipal waste was derived using the following equation iii (IPCC, 2006; Umar, 2022).

$Emissions_t$ = Fuel(l)/Waste (tons) × Energy (MJ/unit) × EF (kg CO_2/MJ)..... (iii)

Where,

$Emissions_t$ = the amount of GHG (CO_2 in kg) emitted per ton of the waste transported.
Fuel = amount of diesel consumed in a liter
Waste = amount of the waste transported.
Energy = Energy content of the fossil fuel used. (Diesel 36.42 MJ/L)
EF = Emission factor for the fossil fuel. (Diesel: 0.074 kg CO_2/MJ)

Composting and Anaerobic Digestion: GHG emissions from composting and anaerobic digestion processes were estimated considering the biogenic carbon content. Methane and Nitrous oxide production during composting depends on factors such as material quantity, moisture, temperature, and aeration (Kumar et al., 2014). Equation iv is used to estimate CH_4 and N_2O emissions in our research. (IPCC,2006; Babel and Vilaysouk, 2016; Umar, 2022).

$E_{GHG} = [W \times ef] \times 10^{-3} - R$ .....(iv)

Where;

E_{GHG} = GHG emissions from composting (Giga gram/year)
W = amount of MSW composted (Giga gram/year)
ef = emission factor (gram /kg of waste) ;(EF for CH_4 and N_2O is 4 and 0.3 respectively)
R = amount of methane recovery (Gg/year); (value used is 0)

Conversion of GHGs emitted in CO_2eq: The term "Carbon dioxide equivalent" denoted as "CO_2eq," is a standard unit used to measure different greenhouse gases consistently. It represents the quantity of CO_2 that would produce an equivalent global warming impact for a specific amount and type of greenhouse gas. To convert greenhouse gas quantities into CO_2eq, you multiply the gas amount by its Global Warming Potential (GWP). For example, emitting 1kg of methane is expressed as 29.8 kg of CO_2eq

(1kg CH4 * 29.8 = 29.8kg CO_2eq).CO_2eq is valuable as it facilitates representing bundles of greenhouse gases as a single values and enables easy comparison between different GHG bundles (IPCC , 2021). For the conversion of methane to CO_2eq, the derived methane is multiplied by the CO_2eq factor as mentioned in the IPCC Sixth Assessment Report (AR6) (IPCC, 2021). For this research, AR6 was followed in terms of all the parameters, guidelines, and values mentioned above and used in the above five equations.

The study acknowledges several limitations during waste sampling and measurement of solid waste composition. Purposive sampling may introduce biases, while inadequate sample sizes might hinder comprehensive understanding. Moreover, temporal variation in waste composition, influenced by factors like seasonality which can alter the value of DOC resulting in the impact on the calculation of GHG emissions from landfills, poses challenges in sampling. Extended study durations and multiple samplings are vital for accurate representation over time.

Results and Discussion

Generation and Composition of solid waste

The Household (HH) waste generation was found to be 141.5 ± 7.16 g/capita/day. The maximum and minimum waste was recorded as 385.71 g/capita/day and 11.43 g/capita/day, respectively. Each household had a waste generation rate of 730 g per household per day. This waste generation rate is slightly lower than the national waste generation rate of 170.2 g per capita per day (ADB, 2013) and the rate of 330.4 g per capita per day in Tulsipur of Dang district (Dangi et al., 2013),240 g/capita/day at Gorkha (Maskey and Singh, 2017)and slightly higher than the study done in 60 urban municipalities, 115 g/capita/day(Pathak et al., 2020), 110 g/capita/day at Bhaktapur (Kc and Karmacharya,2012), 120 g/capita/day at Simara (Dahal and Adhikari, 2018). The comparatively lower per capita waste generation may be due to differences in samples considered, collection time, and seasonal variation (Liguori et al, 2013). As the study area is a semi-urban area, the public uses the organic waste generated for animal feed. The generation rate can be affected by the lifestyle of the public, urban and rural proportions, and socio-economic factors (Kaza et al., 2018).

The average generation per commercial hub and institution was 1933 ± 0.32 g/day and 826 ± 0.46 g/day respectively. The average daily waste generation was 950g/office, 1100 g/shop, and 3100 g/hotel or restaurant in 60 urban municipalities(Pathak et al., 2020). A similar study in the Butwal sub-metropolitan city revealed commercial and institutional waste generation as 1960 g and 6970 g per day (Bhusal et al., 2020). As seen in other developing countries such as Uganda (Okot-Okumu and Nyenje, 2011), India (Pattnaik and Reddy, 2010), Tanzania (Kaseva and Mbuligwe, 2005), Kenya (Henry et al., 2006), and Indonesia (Supriyadi et al., 2000; Henry et al., 2006), households in Nepal (Pathak et al., 2020) are the primary sources of solid waste.

The waste generated by Rampur municipality is shown in Table 1. The total waste generated by the municipality was 2772.79 tons per annum. But only about 40% of the waste, 1129 tons of the waste was found collected. The yearly average cumulative waste collected per municipality of the nation was 2231.0 tons in FY 2073/74, 2164.40 tons in FY 2074/75, and 2232.7 tons in FY 2075/76 (CBS, 2020). The waste collected was comparatively lower than in other municipalities of Nepal because of the low collection efficiency.

Table 1: Waste generation and landfilled

Sector	Avg. Waste per sector per day (g)	Total Waste generated per Annum (tons)	Waste Landfilled per Annum (tons)
Per capita per HH	141.5	2111.50	633.45
Commercial hub	1933	589.83	442.38
Institutions	826	71.45	53.58
Total		**2772.79**	**1129.42**

Table 2: GHG Emission from various sectors and management technique

The Composition of the solid waste collected was divided into nine different categories (IPCC, 2018) viz; Organic, yard waste, plastic waste, rubber and leather, paper and cardboard, glasses, mixed metals, textile waste, wood waste, and other waste. The composition of Household waste, Institutional waste, and Commercial waste are presented in Figure 2 which shows that the amount of organic waste is higher in the HH and commercial sector while paper waste is predominant in institutions.

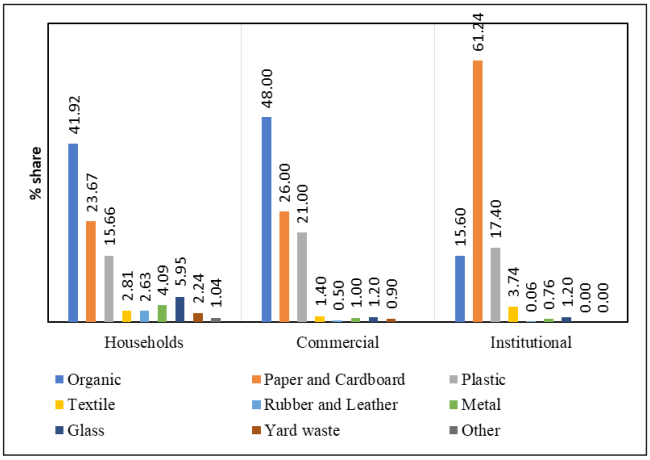

Figure 2: Composition of the waste in categories based on source

The volume and composition of municipal solid waste disposed of have a direct impact on the quantity of methane released (Hoeks, 1983; US EPA, 1994; Mor et al., 2006, Kumar et al., 2014). Organic and paper waste was found predominant in our study. The worldwide composition of waste demonstrates that 44% consists of food and green waste, while plastics and paper waste account for 12% and 17%, respectively, with the remaining categorized as "others" (Kaza et al., 2018). The organic waste fraction in Asian cities varies significantly by lifestyle; Jabalpur, India shows 39%, 47%, and 44% for high, middle, and low-income areas respectively (Thanomnim, Papong, & Onbhuddha, 2022), 46% in Tulsipur (Dangi et al., 2013), 67% in Butwal (Bhusal et al., 2020), and 71 % in Kathmandu (Dangi et al., 2011). Yard waste was found dominant in HH in Bukidnon city of Philippines (Medina and Forten, 2015) but in our study organic or food waste was dominant. It can be because the yard waste is treated as agricultural waste in the majority of the HH and also the garden waste was found to be used for cattle feeding.

The average composition of municipal solid waste (MSW) in the 60 newly declared municipalities was as follows: Organic waste constituted 62% of the waste stream, followed by plastics (12%), paper and paper products (11%), glass (6%), metals at 1%, textiles (1%), rubber and leather (1%) and other (6%) (Pathak et al., 2020). The study by ADB in 2012 in Tansen municipality of the Palpa district reveals the composition of the commercial establishments as 46% organic followed by 24% of paper and 10% of plastic (ADB, 2013). The organic content ranged significantly, from nearly zero to 57%, in Api Municipality in ward-wise data, while the plastics varied from the lowest of 3% in Kamalbazar Municipality to a maximum of 62% in Shani Arjun Municipality (Pathak et al., 2020). The result of the baseline study by ADB in 2012 in Siddharthanagar municipality reveals an organic content of 1% while the paper segment dominates almost 75% of the total waste composition (ADB, 2013). The lower fraction of organic was found as fresh foods are less handled by the institutions (Ramchandra et al., 2018).

Greenhouse gas emission

The findings regarding emissions resulting from municipal solid waste (MSW) management practices are displayed in Table 2. The total GHG emission was found to be 2696.39 t CO_2eq and the per capita emission of the municipality was 0.066 tCO_2eq/capita/annum.

The Valentine City in 2011 with waste generation of 0.69 kg/capita /day and collection efficiency of 31 % emitted 110182 tCO_2 eq/annum, which is 0.15tCO_2eq/capita/annum (Babel and Vilaysouk, 2016). The GHG emission from the waste sector in Nepal was 923590 tCO_2 eq/annum i.e. 0.035 tCO_2 eq/capita/annum(TNC, 2021). The higher per capita emission in this paper may be due to the higher population density of the study area compared to the urban population density of 58 municipalities in 2012. GHG emissions from MSW management vary significantly across regions. In the Lao People's Democratic Republic, the emissions are notably low at 0.02 tCO_2 eq/capita/annum (Ministry of Natural Resources and Environment of Lao PDR, 2013). Similarly, European nations release 0.19

Table 2: GHG Emission from various sectors and management technique

Category	Annual Waste Generated	Waste Landfilled	GHG emitted annually		CO_2eq
	Tons	Tons	Tons		Tons
Household	2112.41	633.45	48.53		1446.12
Institution	71.45	53.58	3.72		110.71
Commercial	589.84	442.39	36.01		1073.10
GHG from Landfill	2773.70	1129.42	88.25		**2629.93**
Composting	278.59		CH_4	1.11	33.21
			N_2O	0.08	22.82
Transport	1129.42				10.602
Total	**2696.56**				

tCO_2 eq/capita/annum (EEA, 2019). In contrast, the United States exhibits relatively high MSW-related emissions, equaling 0.4 tCO_2 eq/capita/annum, primarily due to the widespread practice of landfilling. Conversely, Japan and Germany have achieved relatively low per capita emissions by utilizing incineration processes for energy recovery, with current figures at 0.02 tCO_2 eq/capita/annum and 0.17 tCO_2 eq/capita/annum, respectively (UNFCCC, 2014). These variations underscore the significant impact of waste management practices on GHG emissions at the national level. In 2007, the methane (CH_4) emissions from the majority of landfills in China were relatively low, measuring less than 700 tons of CO_2 equivalent. However, emissions from 279 landfills exceeded 1,000 tons of CO_2 equivalent, and only 10 landfills had emissions surpassing 10,000 tons of CO_2 equivalent (Bo-Feng et al., 2014). The uncategorized dumping site of Rampur municipality lies similar to the majority of landfills in various states of China. A similar study in Germova landfill located in the Mitrovica Region found that the cumulative methane (CH_4) emissions produced in the landfill totaled 19.3 gigagrams (Gg), which is equivalent to 485 gigagrams (Gg) of carbon dioxide (CO2) emissions between 2006 and 2019. It further illustrated the GHG emission per year was 0.22-0.24 Gg of GHGs equivalent to 4620 CO_2 eq per year (Dimiskovska et al., 2021). The GHG per capita per annum of this study is similar to this research.

The greenhouse gas (GHG) emission intensity of the landfill based on the waste generated and waste landfilled was estimated to be 0.97 tCO2e/t MSW generated and 2.38 tCO_2e/tMSW landfilled for the Rampur Municipality. This finding is quite higher than 1.79 tCO_2e/t MSW in Beijing (Li et al., 2022), 0.27 tCO_2e/tMSW in Saudi Arabia (Yaman et al., 2020), 0.78 tCO_2e/tMSW in Vietnam (Verma & Borongan, 2022), 0.49 tCO_2e/tMSW in Malaysia (Devadoss et al., 2021) and 0.40 tCO_2e/tMSW in UK (Jeswani et al.,2013). This discrepancy is attributed to differences in waste generation and disposal methods. The emission in this paper is higher compared to other studies because the dumping site of Rampur municipality is unmanaged category compared to other sanitary landfills in other areas. It lacks the resource recovery mechanism, incineration system, Oxidation system, advanced composting practices, methane recovery or capture facilities, and lower collection efficiency as compared to other regions. Methane emissions were found to be strongly linked to economic progress and population increase, while greater population density led to increased municipal solid waste (MSW) generation (Singh et al., 2018). So, with the rise in economic activities and population, proper technologies for the SWM can not only reduce the waste landfilled but also mitigate the GHG emissions. The intensity of the emission is also related to the constituent of the waste landfilled.

Sectoral Contribution

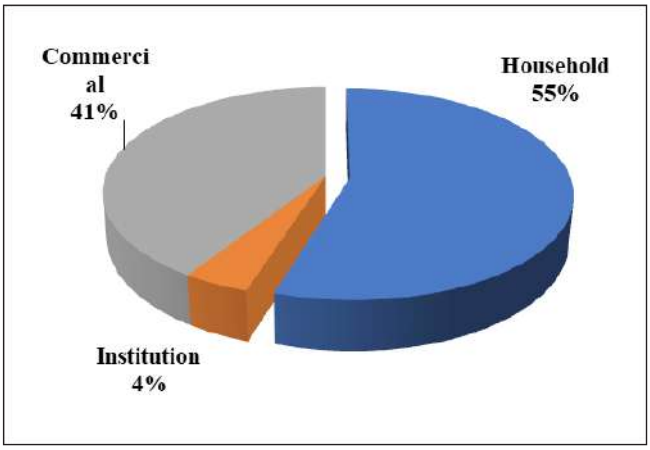

Figure 3: Sectoral contribution to emission

The contribution of Household (HH), Commercial, and Institutions in overall emissions are shown in Fig. 3. The HH is responsible for more than half of the total emissions from the waste sector while institutions have a minimal contribution of 4%. The biodegradable waste contributes about 76.9 % of the total MSW in the dumping site of the municipality. The GHG emission is directly proportional to the organic waste content (Kumar et al., 2014). In this study, organic waste dominates HH followed by Commercial and Institutional, as their contribution to GHG emissions.

In China, MSW typically exhibits a high organic fraction (60-70%) and moisture content exceeding 50%, particularly in smaller and medium-sized cities. These characteristics of MSW in China result in notably higher greenhouse gas (GHG) emissions from MSW treatment compared to developed countries. This is due to the rapid decomposition of organic matter and low efficiency in gas collection systems at initial storage sites (Liu et al., 2017). In a similar study in Hanoi city of Vietnam with approximately 71% of organic waste, the scenarios for organic waste recovery have been found to reduce GHG emissions by 15 % - 98 % (Thanh et al., 2015). Furthermore, a study in India underscores the higher composition of biodegradable waste (50-60%) in developing nations results in higher GHG emissions per ton of the MSW compared to developed nations (BP et al., 2023). This highlights the strong correlation between organic waste and the intensity of GHG emissions.

GHGs from Transportation of the Waste

The annual greenhouse gas (GHG) emissions resulting from waste transport between the generation site and disposal site amount to approximately 10.602 tons of CO_2 equivalent, representing a minimal fraction of the total emissions, specifically less than 0.4%. In Ho Chi Minh City, Vietnam, the emission from the transport of waste was 0.7 % of the total emission (Verma & Borongan, 2022). In contrast, the total carbon emissions from household waste in Shanghai reached 4.7 million in 2015, with the collection and transportation processes accounting for 2.2% of the overall emissions from solid waste management (Jiang et al., 2020). Factors such as collection efficiency, landfill location, and the presence of waste treatment facilities like transfer stations, resource recovery facilities, and so on contribute to this variation. The municipality's landfill, situated 4km from the commercial hub and within a 7km radius of major populated areas, likely minimizes transportation emissions. However, the absence of a transfer station and poor household waste collection efficiency may also play a role in limiting emissions from waste transport.

Composting Practice as a Means of GHG Mitigation

20 % of the respondents were found using the composting practice as the means of waste management at the HH. This diversion of 278.59 tons of waste from going to landfills prevents approximately 81.6% of the greenhouse gas emissions from being released into the atmosphere. Composting results in the release of 56.01 tons of CO2 equivalent into the atmosphere, significantly lower than the 306.04 tons of CO2 equivalent that would have been emitted if the waste had been landfilled, as depicted in Fig. 4.

Composting organic waste, as opposed to depositing it in landfills, has the potential to mitigate over 50% of carbon dioxide-equivalent greenhouse gas emissions, totaling 2.1 giga tons from 2020 to 2050, assuming successful mitigation of climate change to limit global temperature rise to 2 degrees Celsius (TALT, 2020). An emission reduction of 1.8 t CO_2 eq/t of MSW was possible with composting as per

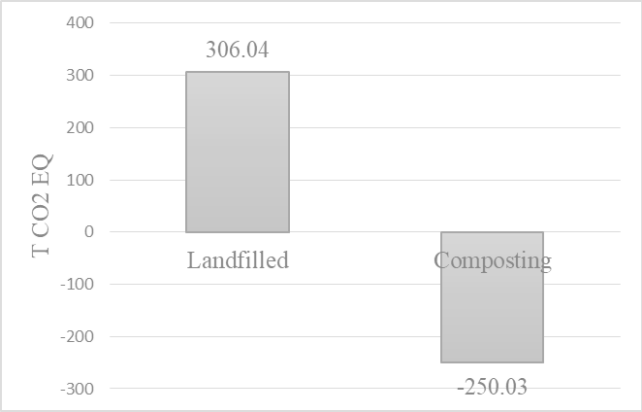

Figure 4: Composting vs. landfilled emission statistic

the study done in 2002 (Ngnikam et al., 2002). Waste recovery, encompassing recycling and composting, emerges as a pivotal force in curbing greenhouse gas emissions. A study in Switzerland underscores this significance, with an impressive 87% probability that altering the waste recovery variable could yield emission reductions (Magazzino et al., 2020).

The difference in GHG emissions between landfills and composting systems is notable, mainly because anaerobic decomposition in landfills produces methane with a global warming potential (GWP) 25 times greater than carbon dioxide. Although methods such as energy recovery and appropriate landfill capping can help reduce this impact, composting remains a straightforward and highly efficient approach to diminish GHG emissions(Lou & Nair, 2009).

Conclusion and Recommendations

The GHG emission from MSW management of the Rampur municipality was estimated considering the current SWM practices. About 2772.79 tons per annum of solid waste was generated while only 1129.42 tons of the waste was landfilled due to poor collection efficiency of the Household (HH) waste. Organic waste dominates the HH and Commercial sector while paper-based waste is a major chunk in Institutions. A total of 2696.39 tCO2eq with GHG emission intensity of 2.38 tCO2 e/t MSW landfilled was emitted from the waste handling and operation. The composting practice has diverted 20 % of HH waste from landfills and abated 81 % of the GHG emissions. So composting practices can be used as the mitigating option for global climate change. The transport sector contributed 0.4 % of the total GHG emissions of the waste sector. Thus, it can be recommended that the priority to Composting practice can significantly mitigate GHG emissions. These findings can be useful for policymakers to prioritize the means for proper SWM and GHG mitigation.

Recommendations

In this research, composting has been found to reduce GHG emissions by 81.6 % compared to waste landfilled. Composting, known for its lower greenhouse gas emissions compared to landfilling, is a recommended waste management practice at household and municipal levels. For commercial waste, community composting can be a good source of income and employment for youth groups, women's alliances, and marginalized groups in the municipality. The decentralized nature of composting aligns well with waste management practices in smaller settings, ensuring a more localized and efficient approach. The utilization of composting techniques not only reduces the carbon footprint associated with waste disposal but also transforms organic waste into valuable compost that enriches soil fertility when reintroduced into the environment.

At the household level, adopting compost bins proves to be an important strategy for proper organic waste management. These bins provide a convenient and manageable means for residents to segregate and decompose organic waste on-site. By using compost bins, households actively contribute to diminishing GHG emissions. Furthermore, vermicomposting emerges as an additional environmentally friendly option for organic waste management at both household and community levels. Vermicomposting utilizes the natural processes of earthworms to break down organic matter, resulting in nutrient-rich vermicompost.

Nevertheless, composting and vermicomposting face various challenges. To achieve effective waste management and quality compost, users must undergo training. Additionally, access

to compost bins is not readily available for all municipal residents. Although vermicomposting is an eco-friendly and straightforward technology, its successful implementation requires adequate knowledge, and acquiring the necessary worms may pose a challenge for those interested in adopting vermicomposting practices. A robust policy intervention regarding waste collection, segregation, composting, and resource recovery is essential to decrease the overall CH_4 emission from the waste.

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Zoo from Visitors' Perspective: Exploring the Role of Central Zoo, Nepal in Biodiversity Conservation with Emphasis on Conservation Education

Chandra Mani Aryal[1,2,*] Karuna Devkota[1], Poonam Dhakal[1], Pooja Paudel[1,2], Shrijana Karki[1], Neelam Dhakal[1], Aastika Bhujel[1]

[1]Department of Environmental Science, Padma Kanya Multiple Campus, Tribhuvan University, Kathmandu, Nepal
[2]Environment Protection and Study Center (ENPROSC), Kathmandu, Nepal
[*]Correspondence: aryal.mani@gmail.com

Abstract

Human induced wildlife loss is driving many species on the brink of extinction and conservation of those species in their native habitat is not sufficient in many cases, which provides the rationale for initiation and execution of ex-situ measures. Zoological gardens (in short zoo), are an important form of ex-situ conservation which can play a diverse role in complementing in-situ measures of conservation, research, conservation financing, captive breeding and conservation education. Among these roles, conservation education is one front where zoos can play a pivotal role which is poorly explored in Nepal. Thus, in this article we have attempted to assess the role of Central Zoo in conservation. For this purpose, the responses of the respondents were collected by using the standard questionnaire. Data were managed in Microsoft Excel and the percentage of the respondents for each response category was calculated. Association between the variables were explored by using Chi-square test. Respondents perceived that the information boards are sufficient but they need to be complemented by dedicated staff for visitors who read and write. Furthermore, respondents perceive that their conservation mindedness such as willingness to volunteer in nature based organisation and activities, willingness to make donations and support the wildlife friendly policies were significantly enhanced after their visit to the zoo. These behaviours were found to be significantly associated with the frequency of the visit as frequent visitors were found to have more positive attitudes towards wildlife and environment. Most of the visitors claimed that they were satisfied with the visit and are willing to visit again. However, they have suggested care on aspects of animal welfare and conservation education. The findings of this study is useful for the zoo management to improve the visitors' experience while visiting their facility.

Keywords: *Conservation, perception, satisfaction, visitors, willingness to pay, Zoological garden*

Introduction

Conservation of the species in their natural habitat is the most desirable option, as the species will evolve with the change in the environment to develop the traits that are suitable for them to survive in their natural habitat (Engels et al., 2008). However, when the population of the species plumps greatly, the in-situ conservation measures are insufficient alone. Ex-situ measures, where the individuals of the species are protected outside their native habitat, than become essential to complement the conservation in native habitat (Engels et al., 2008; Maxted, 2013) as highlighted by Article 9 of Convention on biological diversity (CBD, 1992). Various forms of ex-situ conservation are practised throughout the globe that includes gene bank, seed bank, botanical gardens and zoological gardens, to name some. Zoological gardens and aquariums (Zoo here after) are the place where animals are kept for public display temporarily or on permanent basis.

In the past, zoos used to serve merely as the exhibition centre with entertainment as the sole focus. Even today, the primary motive of the zoo is to serve as an entertainment centre. However, the changing context, where the biodiversity is experiencing the critical threats, demands the transition in the role of those institutions (Sampaio et al., 2020). Nowadays, zoos are considered as one of the leading organisations for the conservation of fauna and their habitat on the full fledge (Conde, 2013; Cuarón, 2005; Fraser & Wharton, 2007). Zoo usually performs three functions: firstly they support

the in-situ conservation initiatives, secondly; they provide support and facilities to generate knowledge for conservation and third they raise public and political awareness about conservation (Tribe & Booth, 2003). Zoo also receives the confiscated and donated animals which can be used to monitor the live trade of the species (Cuarón, 2005). Furthermore, deliberate captive breeding or unintentionally growing population of individuals of animals work as seed for many reintroduction programs throughout the world including Nepal (Aryal & Aryal, 2023; Conde et al., 2011). In brief, zoos are instrumental in providing conservation education, conduct the research on the behavioural and other aspects of species biology, contribute to the conservation of the species in the natural habitat by providing the finance and other support for research and conservation of the species and their habitat (Gross, 2015).

Despite these transitions from exhibition centre to conservation institution, we cannot expect a zoo to be the organisation with full focus on conservation. Studies show that, even today the size and attractiveness outweigh conservation needs and taxonomic uniqueness in selection of the species for their collection indicated by species selection criteria used by the zoos (Frynta et al., 2010). In the meantime, the primary motive of many zoos are cultural and educational meaning they have to select the species that can lure the visitors to the zoo and the impact can spill over to conservation (Frynta et al., 2010). Many zoos are reported to help to raise the awareness in the general public, for example zoo visitors, in comparison to the general public, were found to be more knowledgeable on the aspect of natural history and conservation of lion-tailed macaque (Mallapur et al., 2008). Furthermore, some selected zoos where animals are kept in the human modified landscape that resembles their wild habitat serves as a living natural history museum (Ash, 2018). This exemplifies that the principal role zoos can play in conservation is through their contribution in conservation education.

Nepal has a long history of ex-situ conservation and particularly of the zoo. Central Zoo was established in 1932 by the Late Rana Prime Minister Juddha Samsar Rana and is one of the popular recreation destinations to the visitors visiting the Kathmandu valley (Sharma et al., 2020). Numerous research has been carried out in the central zoo on various topics. For example, the behavioural response of the birds to the visitors (Sharma et al., 2020), physical and psychological wellbeing of animals (Gurung, 2022) animal behaviour (Sharma et al., 2020), animal welfare (Joshi, 2007) and wildlife conservation and management (Prajapati, 2019). However, the role of zoos in conservation particularly on fronts of conservation education and awareness are explored to a limited extent only (Gurung, 2022; Prajapati, 2019). Zoos are thought to play a role in the conservation of the species, however it is hard to select the indicators for the same. However, financial contribution and influence in policy making are two behaviours that can indicate to some extent (Swanagan, 2000).

Thus, we have attempted to explore the role played by the zoo in conservation. The study has dual objectives: exploring the perspectives of people on the aspects of conservation education in the zoo and studying the impacts of zoos on the pro-environmental behaviours of the visitors.

Materials and methods

Study Area

Study was conducted at the Central Zoo Jawalakhel, Lalitpur, Nepal. It has been under the ownership of Nepal Government since 1950 (2007 BS) and has been managed by National Trust for Nature Conservation (NTNC) since 1995. Central Zoo covers the area of nearly six hectares and holds a wide variety of mammals, birds, and reptiles.

Methodology

The study was designed on the exploratory framework and is solely based on the questionnaire survey. For this purpose, a standard questionnaire consisting of three primary sections was prepared. The first section constituted the questions related to the general characteristics of the respondents along with one question to explore the primary motive of the visitors to visit the zoo. Second segment primarily contained the questions related

to the different aspects of conservation education offered by the zoo and the third section consisted of the question related to the influence of the zoo on the perception and motivation of the visitors. Questions related to the suggestion to the zoo for improvement were kept as open ended questions giving the options for the visitors to give more than one suggestion. The questions thus prepared were discussed in the group for any confusion and finalised.

The visit to the zoo was done on September 18, 2022 (Sunday) with the permission from the zoo authority. After visiting the zoo, visitors were approached in the zoo and they were explained about the motive of the visit and we obtained verbal permission to continue the survey. The question was administered in Nepali language and was filled in a questionnaire.

The data thus obtained were entered and managed in the Microsoft Excel Software. Descriptive statistics were carried out and the number of the respondents in each category were calculated. Finally, the Chi-Square test of independence was used to assess the association between the variables. Cramer V was calculated to assess the degree of association between the variables and was performed by using 'rcompanion' package (Mangiafic, 2023) in R Software. All the analyses were conducted by using the R Software (R Core Team, 2021) in the R Studio platform (RStudio Team, 2022). Recommendations given by the respondents were analysed qualitatively and were categorised on the basis of the theme of the respondents and the frequency of each category were calculated and were plotted in bar-diagram using the ggplot2 packages (Wickham, 2016).

Results and Discussion

The age of the respondents ranged from 16 to 47 years (mean = 27.92, Standard deviation =7.14). The fraction of female respondents were slightly higher and more than half had completed secondary level education (Table 1). Most of the respondents were infrequent visitors visiting for recreational purposes (Table 1).

Table 1: General characteristics of the respondents. The values in the parenthesis represents the percentage of the respondents as of total (n=85)

SN	Particulates	Category
1	Gender	Male (45.88%) Female (54.12%)
2	Education	Illiterate (2.35%) Primary Level (5.88%) Secondary Level (50.59%) Higher Education (41.18%)
3	Frequency of Visit	Infrequent (62.35%) Frequent (37.65%)
4	Purpose of Visit	Recreational (85.88%) Educational (11.77%) Photography (1.18%) Volunteering (1.18%)

Perception about zoo

Purpose of establishment: The fraction of people who think the primary motive of establishment of central zoo is for display of animals was higher followed by those who believe the zoo is established for conservation and recreational purposes (Figure 1).

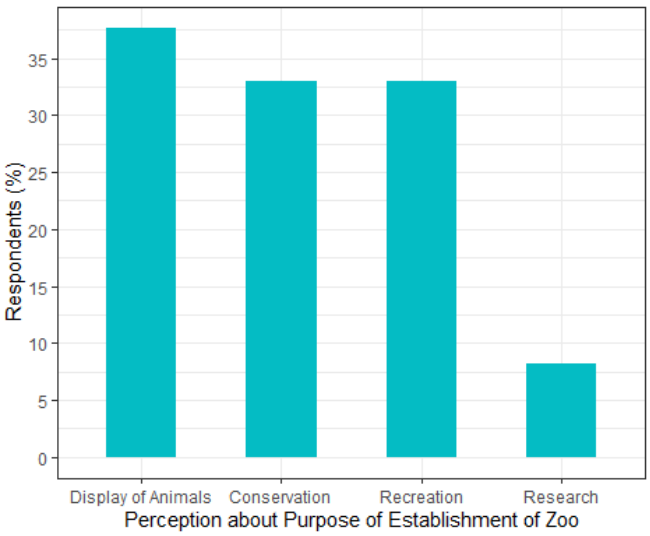

Figure 1: Perception of the respondents about the purpose of establishment of zoo (Multiple answers were given by the respondents in some cases)

Zoo and conservation education: Majority of the respondents agree that there are sufficient information boards for the visitors in the zoo and nearly half of the respondents agree that there are sufficient provisions for conservation education. However, the majority of the visitors perceive that neither the information materials

are sufficiently provided nor the staff in different sections provide required guidance and information. (Table 2). Education level of the respondents and their perception about provision of conservation education in the zoo were significantly associated (χ^2 = 15.566, d.f.= 6, p=0.016, N=85, Carmer's V= 0.303) with the people who have completed primary or secondary level education agreed about the provision more than the other groups. As people with different educational backgrounds, one type of conservation materials visit zoos are not sufficient. Information boards and other informational materials could be useful to those who can read and write. However, for other fractions of respondents, guidance of the staff are essential, which were found to be lacking in the Central zoo. Zoos play a pivotal role in increasing the curiosity in the people and motivate them to visit the natural habitat to gain additional insight in the people (Adetola & Akinboboye, 2020). Through properly designed and marketed campaigns, zoos can help to establish the connection of the zoo visitors with the species and can develop the flagship status of the many species (Skibins & Powell, 2013). Furthermore, raising awareness among the visitors about the threatened status of the species can help to generate the funds for conservation programs in the zoo (Colléony et al., 2017). The influence of zoos in the visitors is not universal with some developing positive attitudes and ultimately developing empathy towards animals that inspires them to work in the conservation sector while the other may develop negative attitudes as well (Bacon et al., 2021). The visitors who are exposed to the conservation education program were found to develop positive attitudes towards the conservation compared to others (Powell & Bullock, 2014). Saying this, many zoos in South Asia still do not have the dedicated conservation education program. Only four out of 300 zoos in India have education staff (Mallapur et al., 2008). Similar is the situation in the central zoo, Jawalakhel. Though the zoo has a dedicated information officer, their interaction with the zoo visitors were found to be limited.

Perception on the impact of Zoo visit on environmental perspectives: Majority of the respondents agree that their motivation to buy environment friendly products increased after visiting zoo (Table 3). Furthermore, the fraction of respondents willing to buy groceries and products that support wildlife conservation are slightly greater than those reporting increased willingness to buy environmentally friendly products even if they have slightly higher prices (Table 3). As this is the stated behaviour of the respondents meaning the fractions of respondents who would actually buy the product might be different. This still indicates the avenue for generating additional funds for zoos by selling the environmentally friendly products within their premises.

The percentage of the respondents willing to volunteer in nature based organisations and volunteer in conservation related activities are identical (Table 3). Volunteering in the nature based organisation represents the relatively long term commitment while volunteering in nature conservation activities represents the short term commitment. Both short term and long term commitment to nature conservation were found to be significantly

Table 2: Perception of the respondents on the different aspect of conservation education in the Central Zoo Jawalakhel

SN	Questions	Fractions of Respondents (%)		
		Yes	Neutral	No
1	Do you agree with the statement '**there are sufficient information boards for visitors within the Zoo**?	**71.77**	12.94	15.29
2	Do you agree with the statement '**visitors are provided with proper guidance and information in the zoo'**?	44.71	10.59	44.71
3	Do you agree with the statement '**staffs in different sections are providing required information for the visitors'**?	24.71	9.41	**65.88**
4	Do you agree with the statement '**there are sufficient provisions to provide conservation education for the visitors'**?	**50.59**	35.29	14.12
5	Do you agree with the statement '**Zoo is providing materials to the visitors to support conservation education'**?	37.65	21.18	**41.18**

Table 3: Perception of the respondent on change in attitude of respondents after visiting central zoo

SN	Questions	Fractions of Respondents (%)		
		Yes	Neutral	No
1	Do you agree with the statement '**your motivation to buy environmentally friendly products increased after visiting the Zoo**'?	61.18	12.84	24.71
2	Do you agree with the statement '**your willingness to volunteer for nature based organisations increased after visiting the Zoo**'?	74.12	11.76	14.12
3	Do you agree with the statement '**your willingness to volunteer in nature conservation activities increased after visiting the Zoo**'?	74.12	9.41	16.47
4	Do you agree with the statement '**Even if you never return, you are going to provide financial support to this zoo**'?	49.41	18.82	31.76
5	Do you agree with the statement '**you are going to provide a donation as much as NRs 5000 (or US $ 50) to protect species you have never heard of** '?	31.77	11.77	56.47
6	Do you agree with the statement '**you are going to endorse public policy that severely restricts future growth and development in order to protect wildlife**'?	60	21.78	18.82
7	Do you agree with the statement '**you are going to buy the groceries and products that support wildlife conservation even when they are more expensive or harder to find**'? (n=84)	69.41	-	20

associated with frequency of visit to zoos of the respondents. Visit frequency was found to be significantly associated with both increased willingness to volunteer in nature conservation organisation ($\chi^2 = 7.606$, d.f.= 2, p=0.022, N=85, Carmer's V= 0.299) and increased willingness to volunteer in environmental conservation activities ($\chi^2 = 22.280$, d.f.= 6, p=0.001, N=85, Carmer's V= 0.349). Frequent visitors were more willing to volunteer than infrequent visitors (Figure 2).

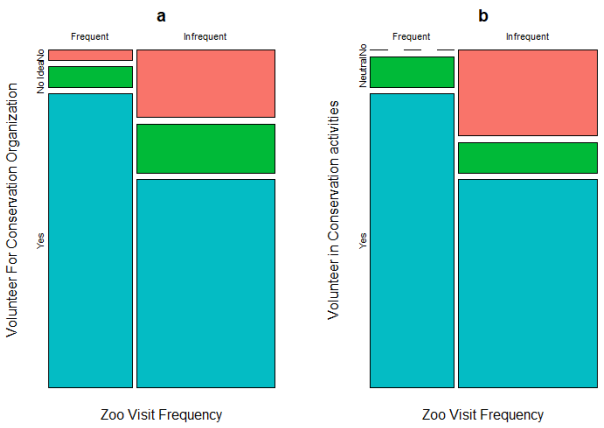

Figure 2: Association of Zoo visit frequency of respondents with their willingness to (a) Volunteer for organization working on front of nature conservation and (b) volunteer in conservation activities

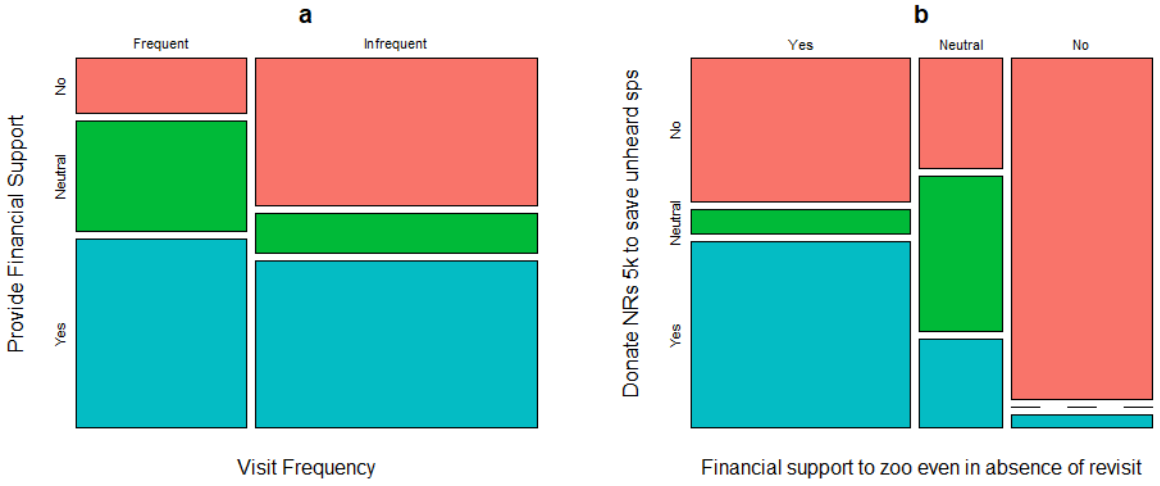

Figure 3: Association between (a) visit frequency and willingness to provide financial support to the zoo and (b) association between the willingness to provide financial support to zoo and provide financial support to the conservation of unheard species

Nearly half of the respondents were looking to provide the financial support even if they do not revisit the zoo again (Table 3). Furthermore, there was significant association (χ^2 = 8.562, d.f.= 2, p=0.014, N=85, Carmer's V= 0.317) between visit frequency and willingness of people to provide financial support to zoos (Figure 3).

The association between the zoo visit frequency and willingness to provide the financial support for the zoo even though they will not visit again were statistically significant (χ^2 = 41.684, df = 4, p-value = 1.939e-08, Cramer's V = 0.317). The fraction of the respondents who are willing to provide the support for the conservation of unheard species is slightly fewer than those willing to provide support to the zoo (Table 3, Figure 3b). Providing adequate knowledge through different forms of conservation education seems inevitable to generate support for the conservation of the species. In the meantime, the willingness of the people to support the zoo and willingness of the people to provide the financial support of Nepali Rupees five thousand (NRs 5000) were also significantly associated (χ^2 = 41.68, df = 4, p<0.05, Cramer's V = 0.495). This indicates that slightly less than 50% of the respondents who are willing to provide financial support to the zoo are willing to contribute to the conservation of unheard species.

The fraction of the respondents who are willing to support the endorsement of wildlife friendly policies that restrict the development of infrastructure in order to protect the wildlife habitat are encouraging (Table 3). Additionally, among the respondents, 92.94% were willing to visit the zoo again while only 5.88% of the respondents were not interested. One respondent remained neutral in this regard.

Altogether 106 suggestions were received from the 82 respondents with some giving more than one suggestion. Improvement of sanitation status for the animals was recommended by the highest number of visitors followed by addition of information, verbal guidance to the visitors, space management and care and treatment (Figure 4). This implies that visitors cared about the animal welfare and conservation education more than other aspects of the zoo.

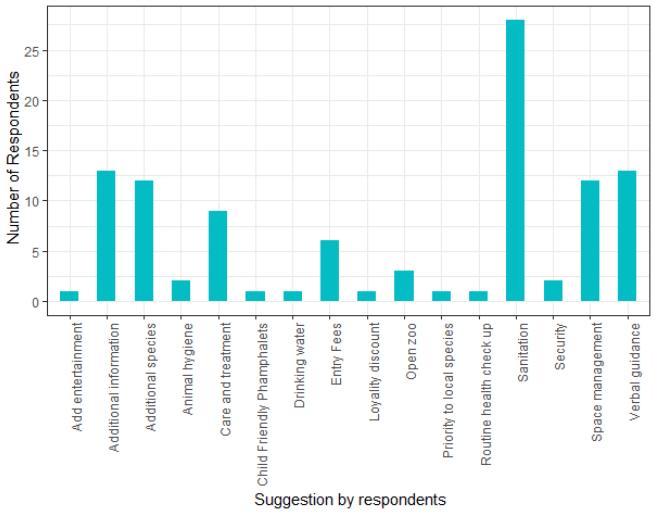

Figure 4: Suggestion for the zoo management given by the visitors, altogether 82 respondents gave 106 different suggestions

The finding of the study represents only the willingness of visitors, not the actual behaviour performances of the visitors. Furthermore, not all species receive equal response from the visitors, and in many cases, the characteristics of the species play an important role in shaping those responses (Powell & Bullock, 2014). Understanding what factor shapes the connection of the visitors to the particular species can be pivotal in designing the conservation education so that the species can be used as flagship species for conservation are vital for the zoo (Skibins et al., 2017) which needs further exploration in case of Nepal.

Conclusion

Globally, both the species and habitat are being threatened by anthropogenic influences and they are not showing signs of slowing down. Meaning, the significance of ex-situ approaches to conservation such as zoos to complement the in-situ measures are increasing. Zoos, though they are gradually making transition from exhibition centres to conservation organisations, are still perceived as entertainment destinations. Zoos have their own limitations, they have to focus on the attractive species so as to lure more visitors to their institution as the visitors are the primary source of finance for the operation of the zoos. Even in such a case, through properly designed and executed conservation campaigns, zoos can be

pivotal in delivering conservation education and generate support for in-situ measures in different forms. Contextual and policy of the individual zoos are pivotal in shaping their contribution to conservation which was not adequately addressed in the case of Nepal. In this article, we have focused on assessing the role of zoos in conservation education and behavioural aspects of visitors through the stated preferences of the respondents. Most of the visitors perceived that the information materials were adequate while the engagement of staff with the visitors and conservation education were not necessarily adequate. Furthermore, willingness to contribute to the conservation of species is higher than the willingness to provide financial support to unknown species – provides additional rationale for dedicated conservation education programs for visitors. Sanitation situation, animal welfare and engagement with the visitors needs improvement in case of central zoo Jawalakhel. Understanding what factor shapes the connection of the visitors to the particular species can be pivotal in designing the conservation education. The information can be used to shape a particular species as a flagship for conservation. This could be a new avenue for further exploration in case of Nepal.

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Waiting Time Countdown Displays Affect the Idle-Stopping Behavior of Motorcyclists at Signalized Traffic Intersections

Rikita Bhandari[1], Arina Lama[2], Narayan Babu Dhital[2]*
[1]Central Department of Environmental Science, Tribhuvan University, Kirtipur 44613, Nepal
[2]Department of Environmental Science, Patan Multiple Campus, Tribhuvan University, Lalitpur 44700, Nepal
*Correspondence: narayan.dhital@pmc.tu.edu.np

Abstract

Transportation is an important driving force behind the surging global energy demand and a key emission source of air pollutants and greenhouse gases. Turning off vehicle engines while waiting for extended periods at traffic intersections can help reduce transport sector fuel consumption and mitigate air pollution. However, idle-stopping is a personal choice and depends on behavior and awareness among drivers. In this study, we conducted a stated preference survey among motorcyclists in Kathmandu, Nepal, to examine the effect of installing traffic lights with waiting time countdown displays at signalized traffic intersections on idle-stopping behavior and investigated if the display of waiting time countdowns could encourage idle-stopping behavior among motorcyclists. Through logistic regression analysis, we found a significant effect of waiting times on idle-stopping choices ($p < 0.001$). The odds ratio for waiting time was 1.051 (95% CI: 1.046-1.057), suggesting that with a 1-second increase in waiting time, the odds of motorcyclists idle-stopping their motorcycle engines increase by 5.1%. Likewise, the most commonly perceived deterrent to idle-stopping choices was the uncertain waiting time. Therefore, our results suggest that installing waiting time countdown displays at signalized traffic intersections may offer an often overlooked benefit by reducing idling fuel consumption and tailpipe emissions from on-road vehicles. Our findings will provide valuable insights for policymakers in formulating evidence-based policies and city planners in improving transportation infrastructure, especially in cities in developing economies.

Keywords: *Air pollution; ecodriving; logistic regression; road infrastructure; traffic light*

Introduction

Transportation is one of the crucial factors causing a rapid increase in global energy demand and a key emission source of air pollutants and greenhouse gases (GHGs). Globally, it accounts for approximately 25% of energy consumption (Lindstad et al., 2023) and contributes to 20% of CO_2 emissions, with road transportation being a major contributor (Albuquerque et al., 2020). Therefore, the decarbonization of the transport sector is advocated as a requirement to mitigate GHG emissions and global climate change (Lindstad et al., 2023). Moreover, it contributes notably to air pollutant emissions in many countries around the world (Paschalidou et al., 2022; Wu et al., 2023).

Nepal, a developing country in South Asia, has been grappling with degrading air quality (Khokhar et al., 2023). Transportation is the third-largest sector in terms of energy consumption and CO_2 emissions in Nepal (Sadavarte et al., 2019). As such, reducing emissions from this sector can notably contribute to mitigating the country's GHG emissions and reducing air pollution. Over the last two decades, Kathmandu, the capital city of Nepal, has witnessed a significant rise in the number of vehicles, especially motorcycles, with over eightfold increase in its number from 2000 to 2017 (DoTM-GoN, 2017). The city has been facing significant air pollution challenges, with its severity increasing over the past couple of decades (Mahapatra et al., 2019). The city's motorcycle fleet contributes to over 50% of carbon monoxide emissions and 66% of volatile organic compounds (VOC) emissions from road transportation (Shrestha et al., 2013). Motorcycle ownership typically follows a hump-shaped pattern

with per capita income (Chu et al., 2020), implying that motorcycle numbers may continue to grow in developing economies. Consequently, controlling emissions from motorcycles may have a substantial impact on air quality in Nepal and its major cities, such as Kathmandu.

Vehicle idling refers to the state in which the engine is running without power transmission to the wheels. On urban roads, idling may constitute approximately 20% of the trip duration (Dhital et al., 2021). However, it can vary across cities and vehicle types. Gasoline vehicles, including motorcycles, emit significant amounts of air pollutants, especially hydrocarbons and VOCs, while idling (Shancita et al., 2014; Tsai et al., 2000). Consequently, idling at signalized traffic intersections incurs significant costs in terms of fuel consumption, emissions, and economic loss (Sharma et al., 2019). Idle-stopping means turning off engines while not running. Idling-Stop-and-Go, a system that automatically shuts off the engine when the vehicle stops, has been found to enhance fuel economy and reduce tailpipe emissions from motorcycles (Yu & Tseng, 2014), making idle-stopping an important aspect of eco-driving.

Traffic lights and the display of waiting time countdowns at signalized intersections inform vehicle drivers and motorcycle riders about anticipated waiting times, enabling them to judge whether or not to turn off their vehicle engines. However, in Kathmandu, very few traffic intersections have traffic lights and waiting time countdown displays. The majority of intersections in the city rely on manual traffic control, creating a chaotic situation, especially during peak traffic hours, where drivers and riders are unable to decide whether or not to idle-stop their vehicle engines. In this study, we conducted a stated preference survey to examine the effect of waiting time countdown displays at signalized traffic intersections on the idle-stopping behavior of motorcyclists in Kathmandu, Nepal. The main objective was to investigate if waiting time countdowns at signalized traffic intersections could encourage idle-stopping behavior among motorcycle riders in Kathmandu.

Materials and methods

Study area, sample size, and data collection tools

This study was conducted in Kathmandu, the capital city of Nepal. In this study, structured interviews were conducted during September–June 2023, among motorcyclists (n = 179), who use motorcycles as the primary mode of transportation for their daily commutes in Kathmandu. The motorcyclists were selected and interviewed from the parking lots located on and inside Ring Road, with surveyed locations including Koteshwor, Lagankhel, Patan Dhoka, Balkhu, and Balaju, distributed across Kathmandu and Lalitpur districts. The interview questions included information about the respondents' motorcycle characteristics, as well as their preferences and opinions regarding idle-stopping motorcycles on Kathmandu's urban roads. Respondents were presented with different waiting scenarios at traffic intersections in Kathmandu through color-printed photographs. These photographs were taken at two intersections in Kathmandu, one representing an intersection with traffic lights and waiting time countdowns and the other representing a manually controlled intersection without traffic lights and waiting time countdowns. The first photograph showed an intersection with waiting time display (time ranging from 10 to 180 seconds) and the second photograph showed an intersection without any display of waiting times. While waiting under each scenario, respondents were asked to express their preference to idle-stop or not to idle-stop their motorcycle engines, as shown in Fig. 1.

Data analysis

The survey data were coded and entered into spreadsheets. The spreadsheet data were checked against the field data for any errors introduced during the data entry. First, the data were analyzed using descriptive statistics. Additionally, in order to test the dependence of idle-stopping behavior on waiting time, a binary logistic regression analysis was employed using the statsmodel Python module (Seabold and Perktold, 2010).

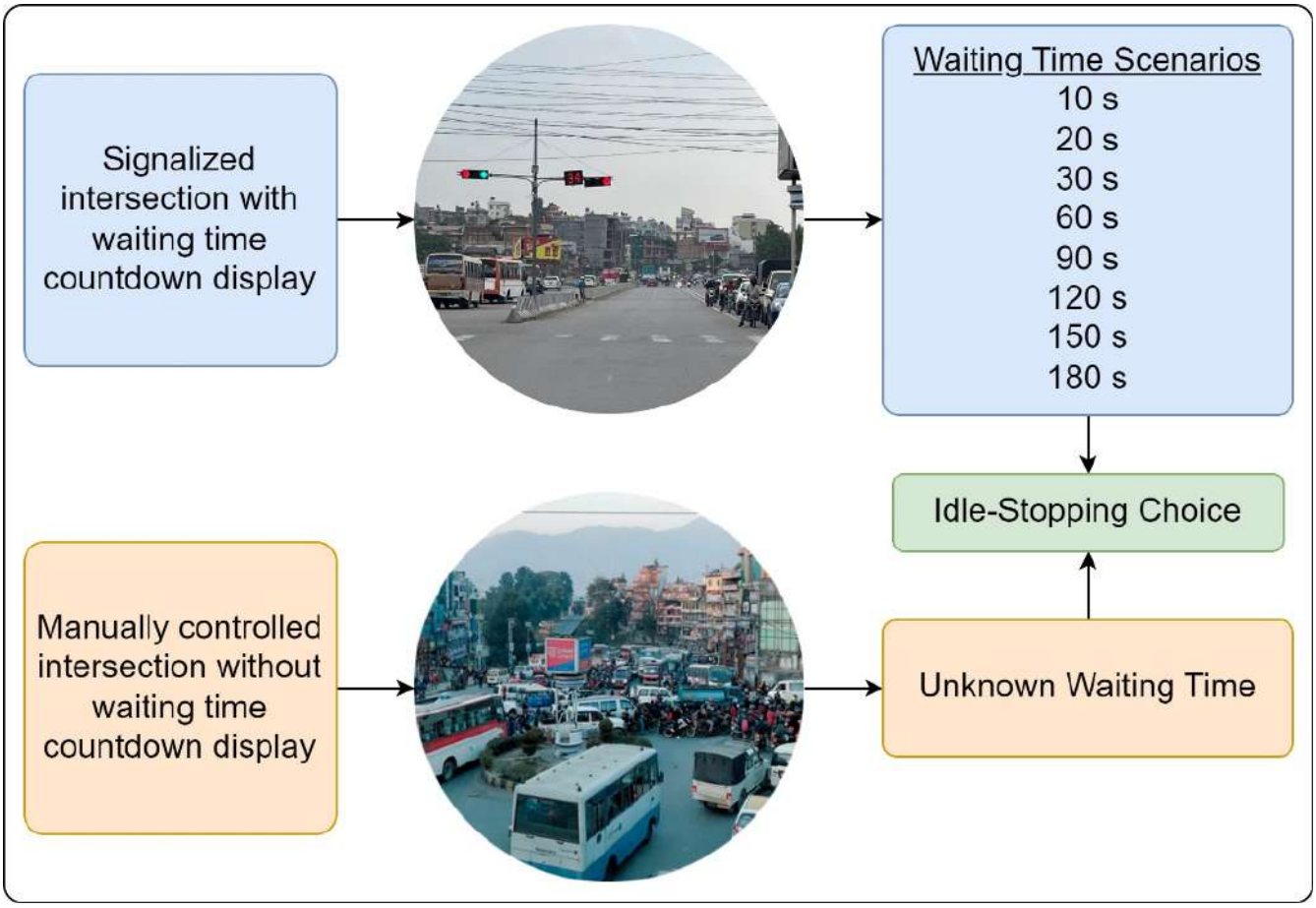

Figure 1: Traffic intersection scenarios presented to respondents

Ethical considerations

In order to protect the privacy of the respondents, no personal or identifying information was collected. Each respondent was provided with an explanation of the purpose of the survey, and their consent was obtained before interviewing them. The respondents were neither compelled to participate in the survey nor provided with any incentives or compensation.

Results and discussion

Motorcycle fleet characteristics

The characteristics of the surveyed motorcycle fleet are illustrated in Fig. 2. The fleet comprised motorcycles of 13 brands, with Honda representing the largest share (32.4%), followed by Bajaj (20.7%), and TVS (11.2%) (Fig. 2a). The remaining brands collectively represented approximately 19% of the surveyed motorcycles. Likewise, Fig. 2b shows the fleet characteristics based on engine displacement volume. It was found that the largest fraction of the motorcycles had engine displacement volume of 101–150 cm^3, representing 72%, while the remaining categories combined accounted for 28% of the fleet. Our results on engine size distribution were consistent with those reported by a prior study (Filippini et al., 2021). The motorcycle age distribution is presented in Fig. 2c. It showed a decreasing population of motorcycles with increasing age. The fleet-average motorcycle age was 4.8 years (range: < 1 to 25 years), slightly higher than that of the 2010 fleet (Shrestha et al., 2013). Approximately 50% of the surveyed motorcycles were ≤ 3 years old. Modern motorcycles often have electric start functions, while some are even equipped with automatic idle-stopping functions, which will help avoid idling motorcycle engines for extended periods. The relative dominance of newer motorcycles in this study suggests that they would have such functions, which will be discussed in more detail in the following sections. A study reported that the 2010 motorcycle fleet in

the Kathmandu Valley consisted of approximately 60% motorcycles with age ≤ 3 years (Shrestha et al., 2013). Our results showed a decrease in the fraction of new motorcycles (≤ 3 years) compared to the 2010 fleet, indicating a potential increase in older motorcycles over time due to the aging effect. Older motorcycles, due to engine wear and emission control system deactivation, often have reduced performance (Chen et al., 2009), which may increase the fleet-average emission and fuel consumption as idling emissions and fuel consumption are affected by engine age (Shancita et al., 2014).

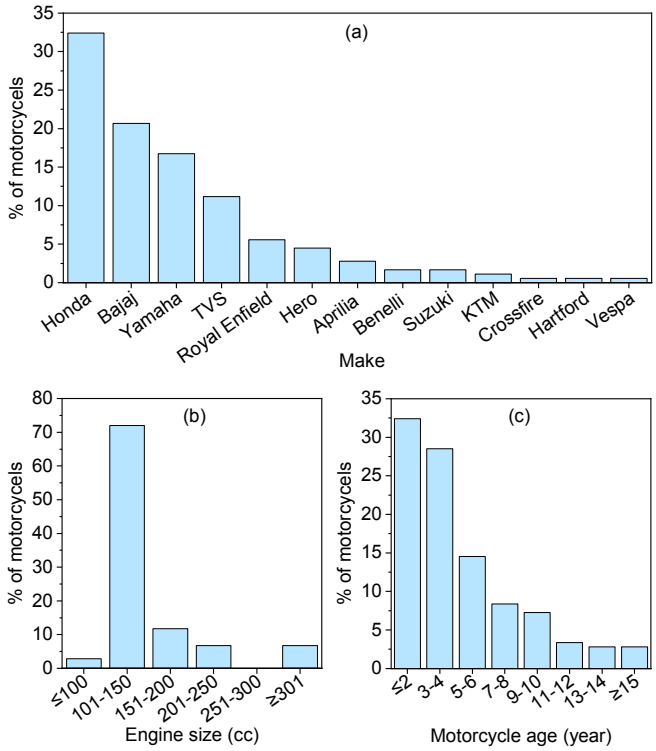

Figure 2: Fleet composition (%, total n = 179) of sampled motorcycles by (a) motorcycle make, (b) engine displacement volume, and (c) motorcycle age

Fig. 3 presents the distribution of accumulated mileage. The accumulated mileage ranged from 30 to 100000 km, with a mean of 29833 km and a standard deviation of 21839 km. Pearson's correlation between age and accumulated mileage was found to be 0.687, which was relatively weaker in the present study than previously reported for motorcycles (Shrestha et al., 2013), suggesting a wide variation in annual vehicle kilometers traveled in the recent motorcycle fleet of Kathmandu.

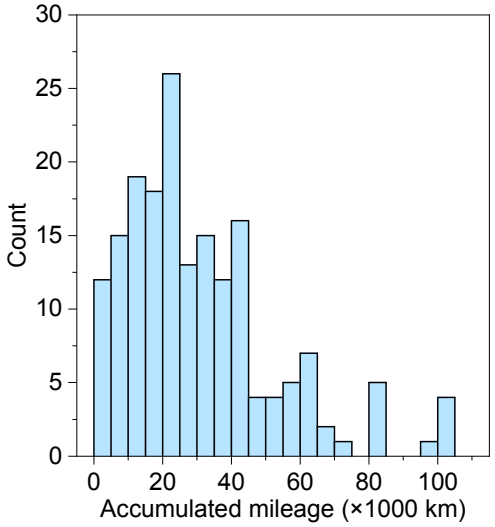

Figure 3: Distribution of accumulated mileage

We analyzed whether the surveyed motorcycles had an electric start function and an engine kill switch in hand (Fig. 4a). It was found that the majority of the motorcycles had the electric start function available (>90%), while for the remaining motorcycles, the electric start function was either absent by design or malfunctioning. Similarly, 56.4% of the surveyed motorcycles had the engine kill switch in hand (Fig. 4b). While driving on busy urban roads, the availability of an electric start function (in addition to kick start) and engine kill switch in hand (in addition to engine kill function with key) may affect riders' preference to idle-stop at traffic intersections. The electric start function and engine kill switch can ease the process of turning off/on motorcycle engines, and hence could positively affect the riders' preference to idle-stop the engine.

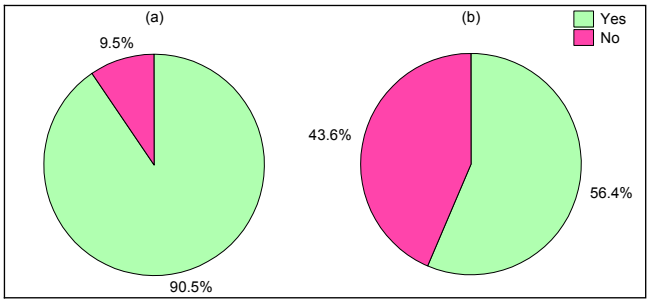

Figure 4: The availability of (a) the electric start function and (b) the engine kill switch in hand in the surveyed motorcycles

Waiting time and idle-stopping preference

We analyzed motorcyclists' stated preference for idle-stopping motorcycles at signalized traffic intersections. Respondents (motorcyclists) were

asked if they would prefer to turn off their motorcycle engine while waiting at traffic intersections under different waiting time scenarios in their day-to-day commutes in Kathmandu. The scenarios included waiting times ranging from 10 to 180 seconds, which were displayed to respondents by showing waiting time countdown photographs. The responses (preference) were mutually exclusive.

Fig. 5a shows the percentage of respondents who prefer to idle-stop their motorcycle engines at different waiting times at signalized traffic intersections with the display of traffic light countdown. Interestingly, with the increase in waiting time, more number of motorcyclists preferred to idle-stopping their motorcycles. As Fig. 5a depicts, the proportion of motorcyclists who prefer to turn off engines while waiting increased sharply and consistently from approximately 4% at 10 s waiting time to 82% at 60 s waiting time. Beyond 60 s, the proportion still showed an increasing trend, albeit at a lower rate. At 150 s and beyond, the proportion leveled off at approximately 97%. Likewise, a majority of motorcyclists (>50%) would prefer to turn off the engine when the waiting time is approximately > 42 s. Moreover, the Spearman correlation between waiting time and the percentage of respondents who prefer to turn off the engine was found to be 0.994, which was statistically significant ($p < 0.000$).

We tested the relationship between idle-stopping choices and waiting time using a logistic regression analysis. It was found that the regression coefficient for waiting time was 0.0498 (95% CI: 0.045-0.055), which was statistically significant ($p = 0.000$) (Table 1). The pseudo R^2-value of the regression was 0.4922. Likewise, the odds ratio for waiting time was 1.051 (95% CI: 1.046-1.057), suggesting that with a 1 s increase in waiting time, the odds of motorcyclists idle-stopping their motorcycle engines increase by 5.1%.

Using the logistic regression model, the probabilities of idle-stopping motorcycles at different waiting times at signalized intersections with the display of waiting time countdowns were predicted. The predicted probabilities (Fig. 5b) showed a pattern similar to the actual observed stated preferences (Fig. 5a), with the probability of idle-stopping increasing sharply first, especially between 10 and 100 seconds, and then slowing down. Beyond 140 s, the probabilities were more than 99%, suggesting that almost everyone would turn off the motorcycle engines if they knew that the waiting times were more than 140 s.

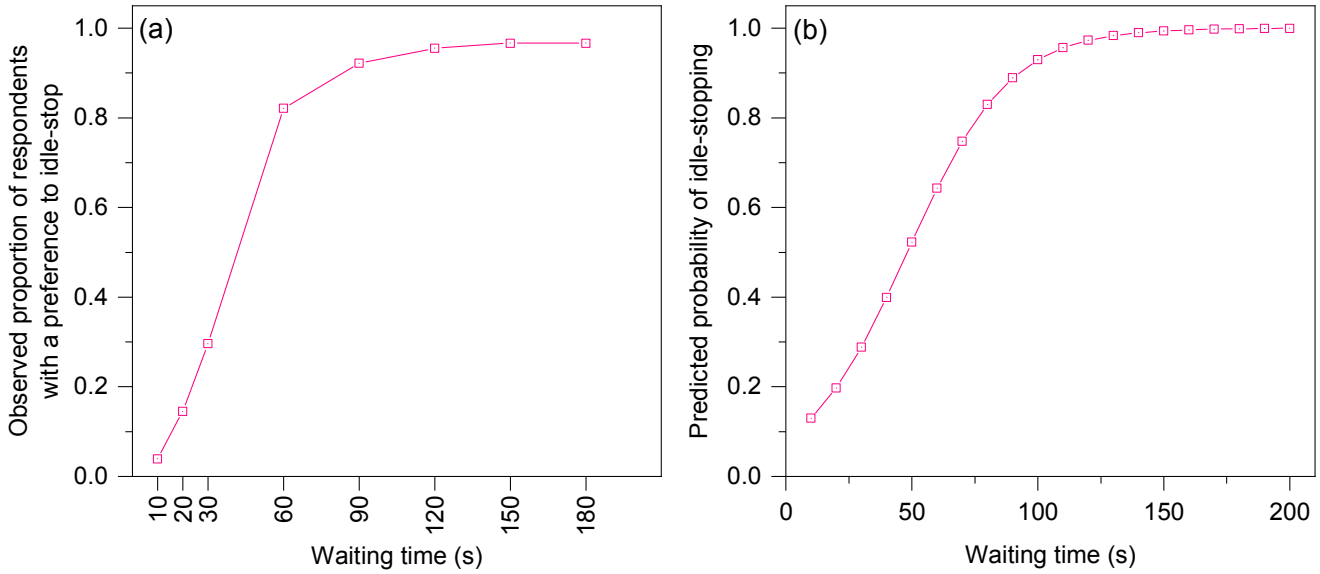

Figure 5: Observed and predicted idle-stopping behaviors of motorcyclists at signalized traffic intersections: (a) stated preference of idle-stopping motorcycles under different waiting time scenarios at traffic intersections with the display of waiting time countdowns, (b) predicted idle-stopping probabilities at different waiting times at traffic intersections with the display of waiting time countdowns

Table 1: Binary logistic regression between idle-stopping behavior and waiting time

Parameters	Constant	Waiting time (s)
Coefficient	-2.3996	0.0498
Standard error	0.145	0.003
z	-16.564	18.582
p-value	0.000	0.000
2.5th percentile	-2.684	0.045
97.5th percentile	-2.116	0.055
Odds ratio (95% CI)	0.091 (0.068– 0.121)	1.051 (1.046– 1.057)
Pseudo R^2	0.4922	

Signalized traffic intersections are generally hotspots of air pollution, mainly due to the acceleration of a large number of vehicles after idling, especially during rush hour traffic congestions (Goel and Kumar, 2015). Implementing idle-stopping policies may help reduce unwanted idling fuel losses and emissions at such intersections (Pai et al., 2016; Sharma et al., 2019), which will help mitigate air pollution, as well as protect commuters' health from the harmful effects of air pollution. Many countries around the world have policies recommending turning off engines beyond specified idling time thresholds at intersections (NRC, 2016; Pai et al., 2016). In the present study, a majority (> 50%) of the respondents expressed a preference to turning off the engine, instead of extended idling (beyond 42 s), if they knew the waiting times. Therefore, the installation of waiting time countdown displays will help people determine the waiting time, which will assist them in making decisions about idle-stopping engines.

Idle-stopping preference at intersections without waiting time countdown

In addition to the waiting time scenarios, respondents were also presented with a scenario (by showing an actual photograph) when they were waiting at a manually-controlled traffic intersection without the display of waiting time countdowns, and the results are presented in Fig. 6. It was found that only 16.2% of respondents preferred to turn off their motorcycle engine when they have to wait at such intersections. In contrast, 30.7% of the respondents preferred not to turn off the engines. Interestingly, a majority of the respondents (53.1%) could not decide whether or not they would turn off their motorcycle engines when they have to wait at intersections without waiting time countdown displays. These findings suggest that the display of the waiting time countdown is crucial for motorcycle riders to make decisions about whether or not to idle-stop their motorcycle engines.

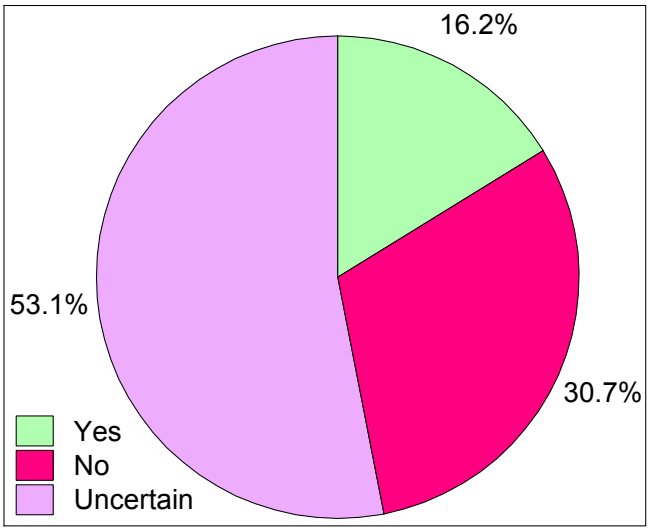

Figure 6: Motorcyclists' preference to idle-stopping engines while waiting at manually-controlled traffic intersections without traffic lights and waiting time countdowns

Perceived motivators and deterrents of idle-stopping

In order to understand the pulling and pushing factors of idle-stopping, we asked respondents about the benefits and deterrents of idle-stopping. The responses were categorized, and the results are presented in Fig. 7. Among the different perceived benefits, potential fuel saving by idle-stopping was the most important pulling factor with 88.2% of the respondents stating that it was a reason for idle-stopping (Fig. 7a). Additionally, 22.2% respondents stated that idle-stopping will help reduce air pollutant emissions, 36.8% stated that it will reduce noise, and 5.6% respondents stated other

benefits (e.g., engine durability, reduced maintenance cost).

Several factors were reported as deterrents to idle-stopping behaviors. Among such factors were inconvenient to frequently turn on/off the motorcycle engine (31.4%), malfunctioning electric start function (11.4%), and uncertain waiting times (57.1%), no significant perceived benefits (8.6%) and others (8.6%) (Fig. 7b). It is worth noting that uncertain waiting time was the major deterrent, as stated by a majority of respondents, suggesting that motorcyclists tend to turn off their motorcycle engines while waiting at traffic intersections if they know the waiting time. Therefore, traffic lights and waiting time count-down at traffic intersections can be crucial road infrastructure to reduce idling fuel consumption and tailpipe emissions.

Limitations

We focused on stated preference for idle-stopping motorcycle engines while waiting at signalized traffic intersections, while we did not measure actual fuel consumption and emissions during idling. Since tailpipe emissions can be significantly higher during the engine startup process than during idling, they can outweigh idling emissions if the idling periods are brief. Therefore, it is crucial to determine the breakeven time for idle-stopping emissions, which can be an important subject for future research.

Conclusion

In this study, we used a stated preference survey to investigate the effect of waiting time countdown displays on idle-stopping choices of motorcyclists at signalized traffic intersections in Kathmandu, Nepal. We performed a logistic regression analysis between idle-stopping choices and waiting time, and the result revealed that the idle-stopping choices of motorcyclists were significantly affected by waiting times ($p < 0.001$). The odds ratio for waiting time was 1.051 (95% CI: 1.046–1.057), suggesting that with increasing waiting time, motorcyclists tend to have more probability of idle-stopping the engine. Moreover, the most commonly perceived benefit of idle-stopping motorcycles was fuel saving, followed by reducing noise and emissions. Likewise, the most commonly perceived barrier of idle-stopping engines at traffic intersections was found to be the uncertain waiting time. Overall, our results suggested that installing traffic lights

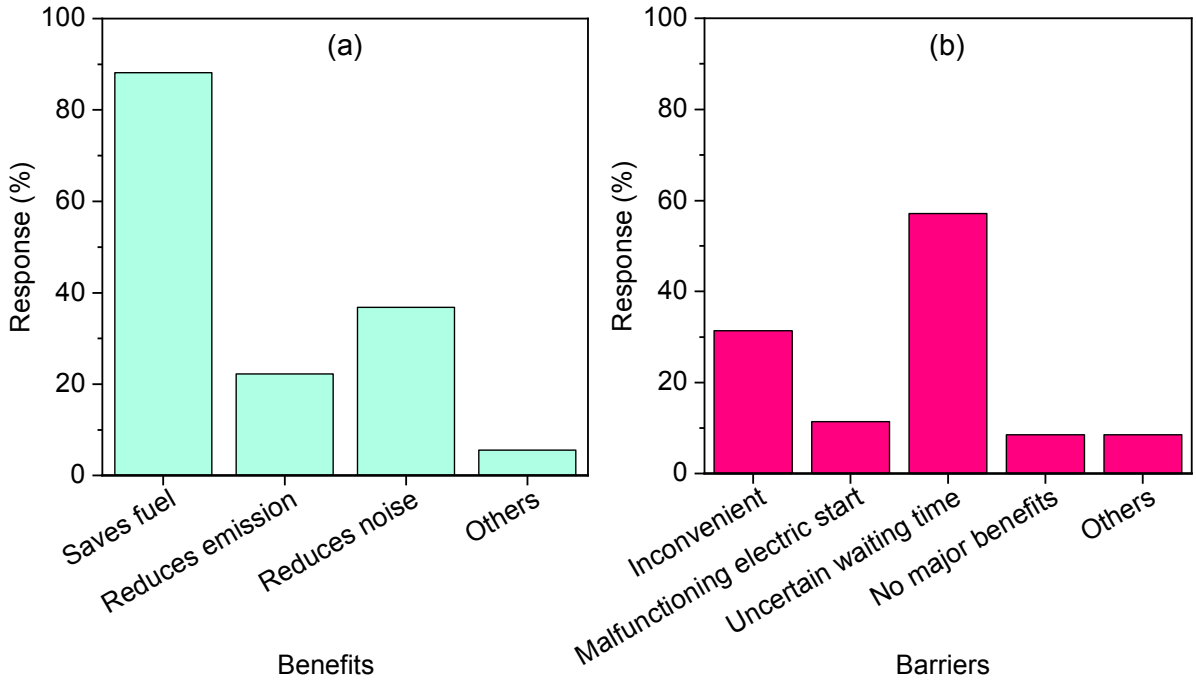

Figure 7: Perceived benefits and barriers of idle-stopping: (a) percentage of respondents stating different benefits of idle-stopping, (b) percentage of respondents stating different barriers of idle-stopping. The responses are not mutually exclusive

and waiting time countdown displays at signalized traffic intersections might offer an often overlooked benefit by reducing idling fuel consumption and tailpipe emissions from on-road vehicles, providing important insights for policymakers and city planners for building sustainable cities.

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Butterfly Diversity and Distribution in Lowland of Western Nepal: A Case Study of Thakurbaba Municipality, Bardiya, Nepal

Lila Paudel [1*], Ram Devi Tachamo Shah [2,3], Bijay Bashyal[1]
[1]Central Department of Environmental Science -Tribhuvan University, Kirtipur, Nepal
[2]Department of Life Sciences, School of Science, Kathmandu University, Dhulikhel, Nepal
[3]Aquatic Ecology Center, Kathmandu University, Dhulikhel, Nepal
*Correspondence: leeza.paudel@gmail.com

Abstract

Butterflies are insects known for their large, colorful wings and distinctive, fluttering flight. They serve as both pollinators and important environmental indicators. Previous researchers have predominantly centered on assessing the status and creating checklists of various butterfly species across the country. However, there has been a notable lack of comprehensive, habitat-focused investigations into butterflies. In the face of ongoing, rapid anthropogenic development and environmental changes, it is imperative to regularly monitor the status of butterflies in diverse habitats and consider the influence of environmental factors. This study was conducted during the winter season (January 2020) to assess the spatial distribution and diversity of butterflies in Thakurbaba Municipality, Bardiya. The study was conducted in three riverbank, forest, and farmland habitats. Sampling was carried out along a line transect of 10 meters length and butterflies encountered within 5 meters wide along each side were recorded. A total of 12 transects across the different habitats were studied: 5 in farmland, 3 in riverbank, and 4 in forest respectively. Altogether 130 individual butterflies belonging to 27 species, 18 genera, and 4 families were recorded from three different habitats. Nymphalidae was the most abundant family with 18 species. The forest seemed highly diverse and rich in butterflies during the study period followed by the riverbank. Additionally, evenness was higher in the riverbank than in the other two habitats. Intensive and regular monitoring is necessary to determine butterflies' seasonal variability and recognize their ecological significance in the study area.

Keywords: *Disturbance, ecological habitat, lepidoptera, transect, similarity coefficient*

Introduction

Butterflies are the most widely studied insects in the world. They are classified under the order Lepidoptera, together with moths (Marren et al, 2010). Butterflies are regarded as good indicators of anthropogenic disturbance in ecosystems' habitat quality (Khanal et al., 2012; Kocher & Williams, 2000). They hold a significant position within ecosystems, serving as both a pollinator and a source of food, while also serving as an indicator of the ecosystem's health (Stokl et al., 2011, Shi et al., 2009; Webb, 2008). They are the prey for several animals such as birds, reptiles, amphibians, etc. in every stage of their life cycle. Reduction in their abundance can result in the reduction of their predator species. Similarly, their caterpillar stage acts as biological pest control as they feed on harmful insects (Ehrlich, 1984). Butterflies play a crucial role in dispersing pollen throughout the ecosystem over a range of 3,000 miles (Stokl et al., 2011). Their sensitivity to abrupt environmental changes, such as those brought about by climate change (Subedi et al., 2021; Woods et al., 2014), affects pollination patterns and leads to habitat loss, underscoring their responsiveness. The presence of a substantial butterfly population indicates a significant amount of plant diversity and other pollinator groups within an ecosystem indicating a clear signal of its overall well-being (Ghazanfar et al., 2016).

Being a mountainous country located in the junction of Indo-Malayan and Palearctic biogeographic realms (Paudel et al., 2012), Nepal possesses a wide variety of climatic and topographic variability. This variability within a certain range and distance has provided the habitats

for unique biodiversity within the country (Paudel et al., 2012). Within the narrow geographic range, 693 species of butterflies with 29 subspecies, and 11 families are documented from Nepal (K.C. & Pariyar, 2019; Sapkota et al., 2020; Oli et al., 2023; Smith, 2011). Out of these about four species and 25 subspecies of butterflies are endemic to Nepal. Similarly, a total of 142 butterflies present in Nepal are categorized in the Red Data Book of Nepal as 12 endangered, 43 vulnerable, and 87 susceptible (BPP, 1995; ICIMOD & MOEST, 2007). Likewise, three species (Swallowtail butterfly *Teinopalpus imperialis*, Golden Birdwing *Troides aeacus*, and, Common Birdwing *Troides helena*) are placed under CITES Appendix II (UNEP-WCMC, 2014, CITES, 2023).

The presence of butterfly species is associated with the components and quality of particular habitats such as vegetation types, the presence of floral plants, canopy cover, wind speed, etc (KC, 2023). Because of their phytophagous nature, they feed on nectar and pollen (Bauder et al., 2011 and 2013). Butterfly diversity is highest in areas where large amounts of host plants are available (Ghorai & Sengupta, 2014) and lowest in shrubs, grassland, and open areas (DeVries, 1988). Food preferences and floral preferences determine their presence, which can be influenced by flower color, nectar concentration, nectar quantity and quality, flower structure, flower shape, and size (Tiedge & Lohaus, 2017; Subedi et al., 2021). Thus, understanding the butterfly composition within the different habitats will help develop species-focused conservation action plans. Based on their habitat preferences we can focus on the microhabitat conservation for their survival. Understanding Organic and inorganic components in focusing on different habitats is fundamental for their sustainable conservation (KC, 2023; Kumar et al., 2017).

Despite their ecological importance for healthy habitats and ecosystems (Molina & Palma, 1996), they are facing a huge population decline (Pullin, 1996) due to increasing anthropogenic disturbances. Nepal is progressing towards rapid development, resulting in habitat degradation, modification, and fragmentation, which has increased threats for sensitive species like butterflies. Excessive use of forest resources and habitat alteration in the country are threatening the current population and status of the butterflies (Khanal, 2008; Joshi, 2023). The use of different agricultural fertilizers (Braak et al., 2018), increasing invasive species and Climate change (Choudhary & Chishty, 2020), monocultural farming practices, and pollution (Gaudel et al., 2020; Shrestha et al., 2018) are slowly damaging the valuable and pristine macro-habitats of rare butterflies. However, none of the species under the Lepidoptera order are considered for regional (Asia region) assessment by the IUCN Red List (IUCN, 2023). Conservation of butterflies is crucial as they offer vital ecological services to native wild plant species, crops, and livestock in many habitats across the world. It is necessary to preserve them to sustain the agricultural and natural ecosystem's productivity (Davies et al., 2018). Protecting butterflies and their habitat can also help to control the agricultural pest. They have an important position in the Trophic structure as they serve as a primary consumer and act as food for birds and other predators (Summerville and Crist, 2001). Regardless of being of huge ecological importance, their study is shadowed over the other charismatic species.

The number of research on butterflies and their associated habitat is limited in Nepal and the case for the western region (Suwal et al., 2019a; Suwal et al., 2019b; Joshi, 2023; Khanal, 2008) including Bardiya is nothing different. Post Smith's (1994) variation of the butterfly diversity and richness over the country with increasing anthropogenic disturbances and habitat type change is unexplored and unidentified. Due to the major focus on charismatic species in the field of ecology; research and identification of insect species are lacking (Prajapati et al., 2000). Bardiya National Park has categorized Butterfly species as one of the least studied species and needs to prioritize research works on these species under the current management plan (BNP, 2022). Also, butterflies are sensitive to anthropogenic disturbances like pollution, they are facing a risk of survival. Thus, understanding the species composition and regular

monitoring in different habitats in terms of both area coverage and taxonomic investigation are crucial.

This study aims to document the diversity of the butterflies within the three different habitats of Bardiya in the winter season. This research will act as a foundation for further detailed and systematic research on butterfly species present in the Thakurbaba Municipality of Bardiya District.

Materials and Methods

Study Area

The study was conducted in Thakurbaba Municipality of Bardiya District located in Lumbini Province, Nepal, which covers an area of 104.57-kilometer square (km²) (CBS, 2013) (Fig. 1). Most of its area is fertile Terai plains covered with agricultural land and forest. Bardiya districts have a minimum average annual temperature in the range is 18°C to 20°C and the maximum average temperature has varied from 28°C to 30.5°C. The average annual rainfall for the Bardiya is 1900 millimeters (mm) (AEPC, 2014). The studied farmland habitat was filled with wheat *Triticum aestivum* and mustard *Brassica nigra* plants. Additionally, it also inhabited invasive species like *Ageratum houstonianum*. The municipality is surrounded by the Bardiya National Park from the east, west, and north, and Madhuwan and Barbardiya Municipality from the south. Bardiya National Park (BNP).

BNP covers an area of 968km². It is one of the largest undisturbed wildernesses in Nepal's Terai. Bardiya National Park is rich in biodiversity which inhabits several rare and endangered species of flora and Fauna. Being a sandwich between the tropical and sub-tropical zone it has alluvial grassland and sub-tropical deciduous and riverine forest, which supports a suitable habitat for Large wild lives. For the butterfly study, we selected the riverbank and forest habitats of BNP (Fig. 1). Among the mentioned two habitats river bank was a little bit disturbed compared to the forest habitat and has an open canopy as well. BNP is one of the major habitats for wildlife of high conservation significance (Dhakal et al., 2023; Thapa et al., 2021).

The Park is home to 60 mammalian species, 513 bird species, 52 herpetofauna species, and 121 fish

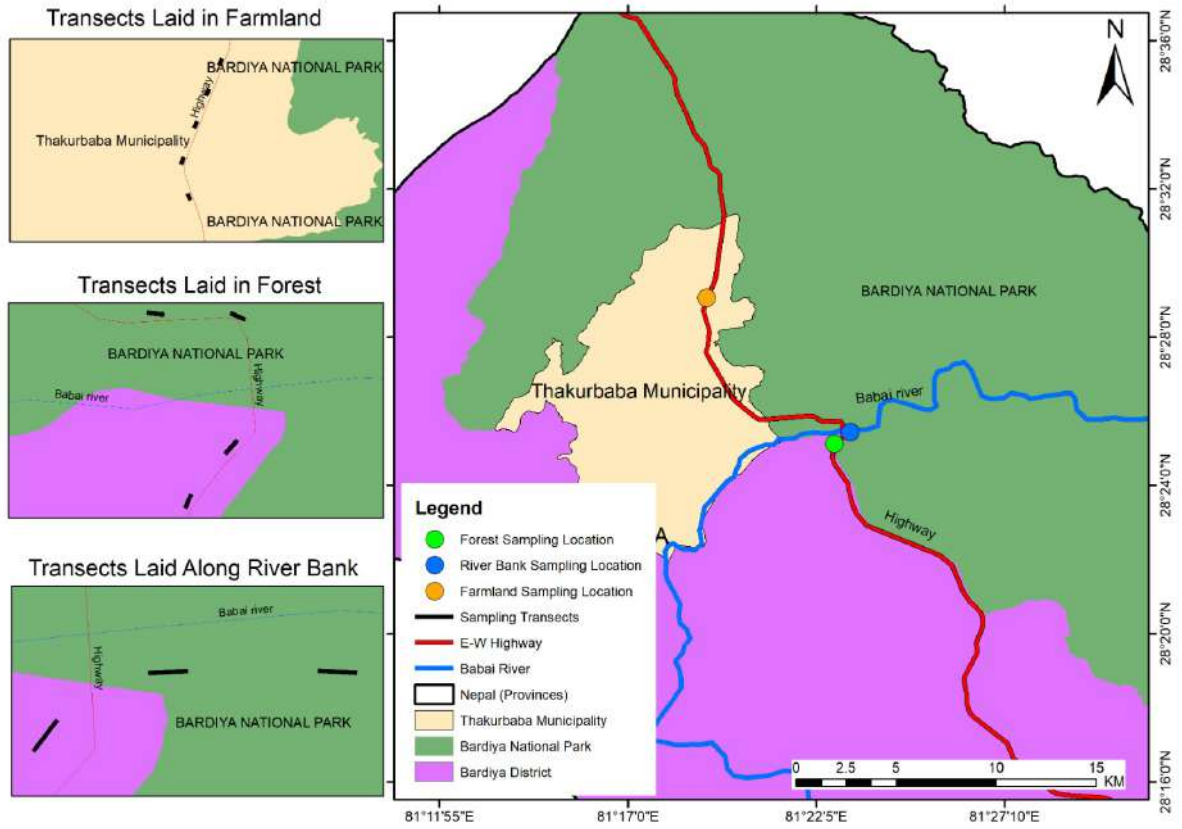

Figure 1: Study area including three different habitats denoted by different dot colors (Yellow dot= farmland, blue dot= Riverbank, and green dot= Forest habitat)

species (BNP, 2022). Some of the charismatic species found in BNP are the Royal Bengal Tiger (*Panthera tigris tigris*), Asian Wild Elephant (*Elephus maximus*), One-Horned Rhinoceros (*Rhinoceros unicornis*), Dolphin (*Platanista gangetica*), among many mammals; Gharial Crocodile (*Gavialis gangeticus*), and Burmese Python (*Python molurus*) among many other reptiles; Bengal Floricans (*Houbaripsis bengalensis*), White-Rumped Vulture (*Gyps bengalensis*) and Giant Hornbill (*Buceros bicornis*) among many of the bird species (BNP, 2022).

Sampling Methodology

The study was conducted during the winter season (January 2020). Each habitat was observed for two consecutive days from 10 a.m. to 4 p.m. The temperature ranged from 13 to 16 ºC on the sampling days, and there was cloud cover and haze. Notably, during the sampling days we experienced light rain. Sampling was avoided during rainy days. The east-west highway was considered as a sampling transect for the forest and farmland. Similarly, the Babai River is considered the transect for the Riverbank sampling. Within each habitat, we set up a 100-meter horizontal line transect referencing the east-west highway and Babai River, and sampled butterflies within a 5-meter on both sides of the transect (Pollard, 1977). For the river bank sampling, only the eastern section of the Babai River was considered for sampling due to inaccessibility considering 10m in the accessible section. We used 12 transects for this study: 5 in farmland, 3 in riverbank, and 4 in forest respectively (table 1). To minimize duplication of species, a 500-meter distance between each transect was maintained. Butterflies were captured using a circular sweeping net with a mesh size of 1.2 millimeters (0.047 inches) and a diameter of 28 cm (11.0236 inches). After capture, we photographed each butterfly from multiple angles to aid in accurate identification before releasing them unharmed back into their natural habitat. The recorded species were identified using the field guidebook "Butterflies of Western Ghats" (Kasambe, 2018) and "Butterflies of Nepal (Central Himalaya)" (Smith, 1994), and released unharmed. For those unidentified species in the field, the photographs taken were used as

Table 1: Number of transects and spatial location of each habitat under study of Bardiya District, Nepal

S.N.	Habitats	Coordinates	Altitude	Transects Used	Sampling Date &Time
1	Farmland	28º 23' 3.72" N 81º 19' 6.58" E	212m	Transect 1	21 January (10:15 am to 11:15 pm), 22 January (3:00 pm to 4:00 pm)
				Transect 2	21 January (11:15 am to 12:15 pm), 22 January (2:00 pm to 3:00 pm)
				Transect 3	21 January (12:15 pm to 1:15 pm), 22 January (12:30 pm to 1:30 pm)
				Transect 4	21 January (2:15 pm to 3:15 pm), 22 January (11:30 am to 12: 30 pm)
				Transect 5	21 January (3:15pm to 4:15 pm), 22 January (10:30 am to 11:30 am)
2	Riverbank	28º 25' 26.24" N 81º 22' 59.80" E	118m	Transect 1	17 January (10:05 am to 12 pm), 18 January (2:30 pm to 4:15 pm)
				Transect 2	17 January (12 pm to 2:30 pm), 18 January (1:30 pm to 2 pm)
				Transect 3	17 January (3 pm to 4 pm), 18 January (11 am to 1:15 pm)
3	Forest	28º 25' 13.18" N 81º 22' 50.44" E	200m	Transect 1	19 January (10 am to 11:30 am), 20 January (10 am to 11:30 am)
				Transect 2	19 January (11:30 am to 1:15 pm), 20 January (11:30 am to 1 pm)
				Transect 3	19 January (1:30 pm to 3 pm), 20 January (1:30 pm to 2:45 pm)
				Transect 4	19 January (3 pm to 4:15 pm), 20 January (2:45 pm to 4 pm)

reference seeking expert judgment for species identification. .

Data Management and Analysis

Quantile classification was initially employed to classify butterflies documented in the study region. The categorization was predicated on the recorded abundance of butterflies across all three habitats. Afterward, butterflies were delineated into three categories, namely frequent, co-dominant, and dominant, owing to their homogeneous distribution and comparable abundance.

Similarly, Various diversity indices such as Margalef's richness index, Pielou evenness index (e), and Simpson's diversity index were calculated to assess species richness, evenness, and diversity. To evaluate habitat similarity, the Jaccard coefficient index was employed (table 2).

Results and Discussion

Butterfly Diversity and Distribution

Altogether 130 individuals of 27 species of butterflies belonging to 18 genera under four families namely: Nymphalidae, Pieridae, Lycaenidae, and Hesperiidae were recorded from three different habitats (Annex I & II) which contributed around 4% of the total butterfly species in the country (Smith, 2011). We found a majority of the species recorded from the study area have oriental elements characteristics of tropical to subtropical climatic types (Khanal, 2006; Khanal et al., 2013). In comparison to previous studies (Khanal, 2008), we recorded a lower diversity of butterflies. Sampling during the winter season might be the reason for the lower detection of these cold-blooded species. Similarly, butterflies go into hibernation as they have a low ability to survive in cold climatic and weather conditions (Khanal et al., 2012). Raining and cloudy weather addition to the winter climate during the study period could be another reason for lesser flighting events of the butterflies.

The quantile classification method has grouped butterflies into three categories: frequent, co-dominant, and dominant. Among the total 27 species recorded, 16 were identified as frequent, while the remaining 11 were categorized as co-dominant (6) and dominant (5) (Annex I). It's important to highlight that the limited detection of certain

Table 2: Methodologies to calculate the status of butterflies in different habitats of Bardiya District, Nepal

S.N.	Method	Formula	Description
1	Margalef's index (DMg)	$DM = (S-1)/\log N$ Where, S= the number of species recorded, N = the total number of individuals summed over all S species (Odum & Barrett, 2005)	To measure the richness of butterfly species
2	Pielou index (e)	$e = H'/\log S$ H'= Shannon index, S= Number of species recorded (Pielou, 1969)	To calculate the evenness of butterflies
3	Simpson's index:	$D= \sum[ni\ (ni-1)/N(N-1)]$ Where, D= Dominance, ni= Importance value for each species, N= Total number of importance value Simpson's diversity = 1-D or 1/D (Magurran, 2004)	To measure the diversity of butterfly species within a community or habitat
4	Jaccard Coefficient index	$S_J = a/(a+b+c)*100\%$ Where, = Jaccard similarity coefficient, a = number of species common to (shared by) habitats, b = number of species unique to the first habitat, c = number of species unique to the second habitat (Jaccard, 1912)	To estimate the community similarity among butterfly species in different habitats

butterfly species during the winter season is likely a result of seasonal characteristics and the constraints of our sampling efforts, rather than an indication of the rarity of these species.

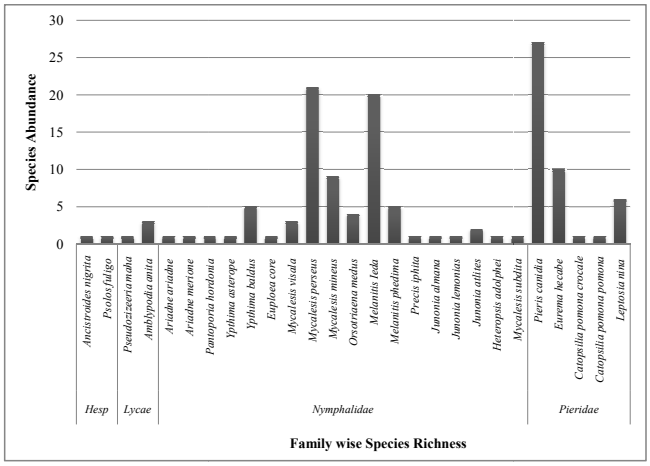

Figure 2: Species richness and abundance of butterflies in Bardiya District, Nepal across three different habitats recorded during January 2020

Family Nymphalidae contributed to 18 species (66.66%); the highest number of individuals from the study area, followed by 5 species (18%) from the family Pieridae, and two species each (7.4%) from Lycaenidae and Hesperiidae family (Fig. 2). In our study, Nymphalidae is the most dominant family in all the habitats. Khanal (2008), and Khanal and Bhusal (2008) also observed a higher abundance of the Nymphalidae family in the Western lowland and Eastern Siwalik of Nepal respectively. A similar observation was also highlighted in Kathmandu Valley by Thapa and Bhusal (2009). Family Nymphalidae represents the largest and most common family signifying nearly one-third of known butterflies in the world (Kasangaki et al., 2012; Al Haidar et al., 2017). Because of their higher ecological adaptation (Jiggins et al., 1996), speciation, high dispersal ability (Dudley & Adler, 1996), distance migration, and powerful flight (Kasambe, 2018; Al Haidar et al., 2017), they can adjust to any type of habitat condition. Several species under the Nymphalidae family are considered model organisms in evolutionary biology due to their adaption capability (Brakefield et al., 2009; Khyade et al., 2018).

Altogether, Indian Cabbage White (*Pieris canidia*) (n=27) was the most dominant among the recorded species which was followed by Common Bush Brown (*Mycalesis perseus*) (n=21) and Common Evening Brown (*Melanitis Ieda*) (n=20).

Similarly, the Indian Cabbage White, Common Evening Brown, and Common Bush Brown were found to be dominant in farmland, forest, and Riverbank respectively (Fig. 2). The common nature and distribution of Common Bush Brown and Common Evening Brown make them resist in any kind of season and habitat (Khyade et al., 2018; Dwari et al., 2017). They are the tropical species that occur in shady parts of the jungle, are dominant in the forest habitat, and are commonly found under leaf litter (Cowan & Cowan, 2019; Kasambe, 2018). Whereas, Indian Cabbage White is found to be the major pest for crucifer plants which are cultivated in the winter season (Evans et al., 1932; Braak et al., 2018). Due to the availability of crucifer plants in farmland during the study period such as mustard, cauliflower, and cabbage attracted the Indian Cabbage White making it dominant on farms (Evans et al., 1932; Wang et al., 2020). According to Khanal et al. (2012) and Kasambe (2018) Indian Cabbage White and Common Grass Yellow (*Eurema hecabe*) from the family Pieridae, are confined to cultivated land of lower and midland regions up to 3000m. Moreover, the presence of butterfly species in any habitat is determined by different abiotic and biotic factors in that particular habitat.

Butterfly Diversity in Different Habitats

Different components of biotic and abiotic factors such as host plants, plant parts, food availability and latitude and altitude, temperature, humidity, rainfall, wind pressure, light, etc. affect the distribution and diversity of butterflies in any habitat (Khan et al., 2004; Khanal et al., 2012; Lien & Yuan, 2003). Among the three habitats, species diversity and species richness of butterflies in the forest habitat were found higher at 0.87, and 9.85 followed by the riverbank at 0.86, and 6.1 and farmland at 0.67, and 4.73 respectively (table 3). Kitahara and Fujii (1994) in central Japan also observed the matching kind of result in their study. However, Lien and Yuan (2003) and Bhusal et al. (2018) recorded higher butterfly diversity in agricultural land than in grassland and forest. In our case, the higher diversity of the forest

habitat may be because of the higher preferences of forest area by the dominant Nymphalidae family (Bobo et al., 2006; Miya et al., 2021). Open canopy and homogeneity of plants like *Eulaliopsis binate* might have affected the diversity of butterflies on the riverbank. Saikia et al. (2009), in their research, stated forest gaps, heterogeneous vegetation, close canopy cover and moisture in the ground can affect the density and distribution of butterflies in any habitat. Additionally, changes in the canopy cover and light penetration relating to moisture content can affect the survival of a butterfly's adult and larva. Forest gaps due to the east-west highway in the forest area and the light penetration through it might result in the higher density of the butterflies in the forest area.

Table 3: Measures of diversity indices of butterflies for the three different habitats in Bardiya district, Nepal during January 2020. Bold values with an asterisk sign (*) indicate higher values for each index

S.N.	Indices	Riverbank	Forest	Farmland
1	Margalef richness measures	6.1	**9.85***	4.73
2	Pielou evenness index	**0.89***	0.8	0.67
3	Simpson diversity index	0.86	**0.87***	0.67
4	Species richness	8	**19***	9
5	Species abundance	14	**67***	49

Moreover, different environmental factors within different habitats mentioned above are more responsible for supporting the population of butterflies rather than the habitat itself. Likewise, Rija (2022) stated that butterfly diversity is correlated with the canopy cover and lower ground cover of any habitat. Equally, species richness of butterflies tended to increase at high canopy cover and in sites closer to the water source. Shade availability is known to favor egg ovipositioning and larval development during butterfly breeding (Warren, 1985; Grundel et al., 1998). Because of higher canopy cover, plant diversity, and near water sources, studied habitats forests and river bank holds a higher density and diversity of butterflies compared to farmland.

Different habitats were covered by different plant types and floral plants. For example, the forest was covered by Sal *Shorea robusta*, Saaj *Terminalia tomentosa,* Balki *Anogeissus latifolia,* and Bhellar *Trewia nudiflora, etc.; the* riverbank with khair sissoo forest with domination of Kans Grass *Saccharum spontaneum*, Congongrass *Imperata cylindrical*, Baruwa grass *Saccharum bengalensis*, Khus *Vetiveria zizanoides*, *Nepeta* species, *Elsholtzia* species, and Dhursul *Colebrookea oppositifolia;* and farmland with mustard and wheat, and an invasive *Ageratum houstonianum*. The presence of each butterfly species in different habitats reflects their preferences for specific plant types.

The unfavorable conditions for butterfly survival are evident in the continuous changes in land use, habitat quality, and evolving crop types in farmland. Butterfly populations in the area face increased risks due to habitat conversion and fragmentation resulting from human activities. Research has indicated a decline in insect abundance and diversity over the past several decades, attributed to the use of pesticides (Gilburn et al., 2015; Olaya-Arenas et al., 2020). Effects of pesticides on agricultural-oriented butterflies are majorly observed rather than butterflies associated with other habitats (Olaya-Arenas et al., 2020). In our case too, the presence of pesticides could be the reason behind the lower diversity and abundance of butterflies in farmland. In general, butterfly prefers a habitat with lower disturbance (Tamang et al., 2019). Construction of road and vehicle mobility from the protected areas has massively increased wildlife mortality due to road accidents in Nepal. The presence of the east-west highway along the Bardiya NP is also risking the survivability of butterflies in Bardiya. Gaudel et al. (2020) have reported 364 individual butterflies were recorded from road kill along an east-west highway in Nepal within three months in 2017. Their findings revealed that butterflies made a more substantial contribution to both road-killed and living specimens compared to those found in human settlement landscapes. The majority of the roads and highways of the country go through the forest area affecting the biodiversity and habitat quality of the region. Similarly, increasing pollution along human settlements and highways is also risking the lives of insect species. Habitat disturbances hampers the habitat quality required for butterfly breeding affecting their overall abundance and richness (Hellmann, 2002).

Local habitat characteristics variously influenced species diversity, abundance, and species richness in the study area. The increasing rate of human encroachment has led to habitat loss and fragmentation and a direct impact on the habitats of butterflies (Blair & Launer, 1997) and the situation is similar to the study area. Increasing pollution near the riverbank has disturbed and altered their habitat. The expansion of human settlements and the use of pesticides, and insecticides are the reasons for reducing the abundance of species in farmland (Khanal et al., 2015). Blair and Launer (1997) mentioned that disturbance can result in the increasing diversity of species but decreasing abundance but this research contradicts their prediction. This study found that diversity and richness decreased with human disturbances (Bhusal et al., 2018).

Community Similarity Index and Habitat Preferences by Butterflies

In terms of community similarity, Riverbank, and forest had a higher similarity of 22.72% in comparison to another group of habitats (table 4). Forest and riverbanks show similar kinds of habitat structure, components, and resource availability for plants and species development concerning microclimatic habitats. The interconnectedness between the forest and riverbank habitats in our butterfly research study may be a key factor contributing to the higher level of similarity observed between these two environments. Two species Purple Leaf Blue (*Amblypodia anita*, Hewitson, 1862) and Common Bush Brown (*Mycalesis perseus*, Fabricius, 1775) were common in all three habitats (Fig. 3) which resemblances their wide distributional range and survivability. Similarly, among the recorded species about 51% recorded butterflies individual preferred forest habitat whereas only 11% as riverbank (Fig. 3).

Table 4: Community similarity of different habitats

S.N.	Habitat Communities	Jaccard coefficient
1	Riverbank and forest	22.72%
2	Forest and farmland	16.66%
3	Farmland and riverbank	13.33%

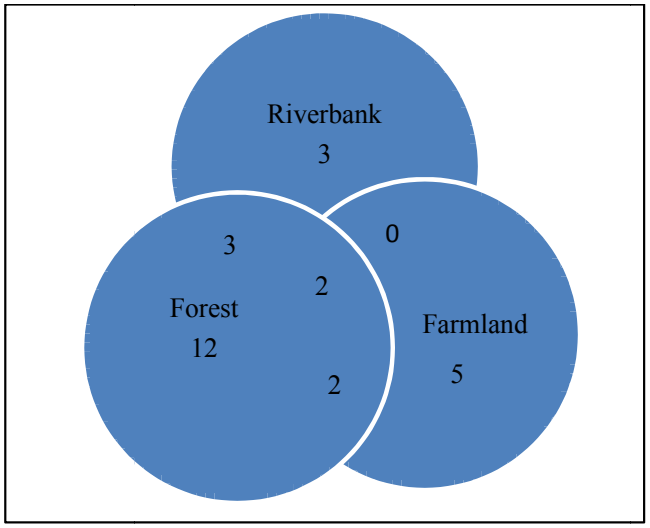

Figure 3: Species richness of butterfly species across different habitats in Bardiya District, Nepal during January 2020

Consistent and systematic monitoring across various habitats and seasons, along with comprehensive environmental assessments, is essential for the successful implementation of butterfly species conservation measures. It is vital to comprehend how population changes are influenced by human-driven alterations and development to ensure the sustainable survival of these important pollinators.

Conclusion

This study provides a checklist of butterfly diversity in Thakurbaba Municipality of Bardiya district across three habitats for the winter season. Family Nymphalidae was the most dominant family and Lycaenidae was the least dominant family in the study area. In comparison to the three habitat groups riverbank and forest were more similar in terms of resource availability and characteristics. Forest habitat is observed to be the most preferred habitat for butterflies.

This baseline study serves as a reference for future butterfly species monitoring, but its short sampling period lacks conclusive evidence regarding the relationship between butterflies and associated environmental factors. The seasonal constraints in this study have hindered the recording and assessment of a more wide-ranging butterfly population in the study area. Therefore, a prolonged and consistent assessment is essential to establish a robust connection between butterflies and their associated

environmental factors. Additionally, to ensure the sustainable survival of these indicator species, it is imperative to document and monitor threats associated with both natural and anthropogenic disturbances. There necessary to examine the unknown existing threats in the study ecosystem which will help track changes in the butterfly communities inhabiting a particular habitat. Thus, for long-term species conservation habitat habitat-focused and species-focused, seasonal monitoring of butterflies is crucial.

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Annex I: Overview of butterflies recorded in Bardiya District, Nepal during January 2020

Family	Scientific name	Common name	Quintile Classification	Habitat	Abundance recorded
Hesperiidae	*Ancistroides nigrita* (Latreille, 1824)	Chocolate Demon	Frequent	F	1
	Psolos fuligo (Mabille, 1876)	Coon/Dusky Partwing	Frequent	F	1
Lycaenidae	*Pseudozizeeria maha* (Kollar, 1844)	Pale Grass Blue	Frequent	F	1
	Amblypodia anita (Hewitson, 1862)	Purple Leaf Blue	Co-dominant	F,Fa, RB	3
Nymphalidae	*Ariadne ariadne* (Linnaeus, 1763)	Angled Castor	Frequent	Fa	1
	Ariadne merione (Cramer, 1777)	Common Castor	Frequent	Fa	1
	Pantoporia hordonia (Stoll, 1790)	Common Lascar	Frequent	F	1
	Ypthima asterope (Klug, 1832)	Common Three Ring	Frequent	F	1
	Ypthima baldus (Fabricius, 1775)	Common Five Ring	Co-dominant	F,RB	5
	Euploea core (Cramer, 1780)	Common Crow	Frequent	Fa	1
	Mycalesis visala (Moore, 1858)	Long Brand Bush Brown	Co-dominant	F	3
	Mycalesis perseus (Fabricius, 1775)	Common Bush Brown	Dominant	F,Fa, RB	21
	Mycalesis mineus (Linnaeus, 1758)	Dark-Brand Bush Brown	Dominant	F,RB	9
	Orsotriaenamedusmedus (Fabricius, 1775)	Nigger/Jungle Brown	Co-dominant	F	4
	Melanitis leda (Linnaeus, 1758)	Common Evening Brown	Dominant	F,RB	20
	Melanitis phedima (Cramer, 1780)	Dark Evening Brown	Co-dominant	F	5
	Precis iphita (Cramer, 1782)	Chocolate Pansy	Frequent	F	1
	Junonia almana (Linnaeus, 1758)	Peacock Pansy	Frequent	Fa	1
	Junonia lemonias (Linnaeus, 1758)	Lemon Pansy	Frequent	RB	1
	*Junonia atlites (*Linnaeus, 1763)	Grey Pansy	Frequent	F	2
	Heteropsis adolphei (Guérin-Méneville, 1843)	Red Eye Bush Brown	Frequent	RB	1
	Mycalesis subdita (Moore, 1890)	Tamil Bush Brown	Frequent	RB	1
Pieridae	*Pieris canidia* (Linnaeus, 1768)	Indian Cabbage White	Dominant	F, Fa	27
	Eurema hecabe (Linnaeus, 1758)	Common Grass Yellow	Dominant	F, Fa	10
	Catopsilia Pomona crocale (Fabricius, 1775)	Common Emigrant	Frequent	F	1
	*Catopsilia pomona pomona (*Fabricius, 1775)	Lemon Emigrant	Frequent	F	1
	Leptosia nina (Fabricius, 1793)	Psyche	Co-dominant	Fa	6
Total butterfly abundace recorded					**130**

Note: F=Forest, Fa=Farmland, RB= Riverbank

Annex II: Photographs of Butterflies recorded in Bardiya District, Nepal during January 2020

Photograph 1: Common Caster *(Ariadne merione)*

Photograph 2: Common Lascar (*Pantoporiahordonia*)

Photograph 3: Common Evening Brown (*Melanitisleda*)

Photograph 4: Lemon Emigrant (*Catopsiliapomonapomona*)

Photograph 5: Lemon Pansy (*Junonialemonias*)

Photograph 6: Long Brand Bush Brown (*Mycalesisvisala*)

Photograph 7: Common Emigrant (*Catopsiliapomona*)

Photograph 8: Peacock Pansy (*Junoniaalmana*)

Photograph 9: Jungle Brown *(Orsotriaenamedusmedus)*

Photograph 10: Common Grass Yellow (*Euremahecabe*)

Photograph 11: Indian Cabbage White (*Pieriscanidia*)

Photograph 12: Pale grass blue (*Amblypodiaanita)*

Photograph 13: Common Bush Brown *(Mycalesis perseus*)

Photograph 14: Dark Brand Bush Brown (*Melanitisphedima*)

Photograph 15: Butterfly Sampling in Riverbank

Photograph 16: Butterfly Sampling in Farmland

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Effects of Grazing in Natural Regeneration at Tree Line region in Lamtang National Park, Nepal

Manisha Basnet[1*], Tika Regmi[2], Man Kumar Dhamala[1], Shankar Adhikari[3]
[1]Central Department of Environmental Science, Tribhuvan University, Nepal
[2]Department of Environment, Ministry of Forests and Environment, Government of Nepal
[3]REDD Implementation Centre, Ministry of Forest and Environment, Government of Nepal
*Correspondence: mansabasnyat@gmail.com

Abstract

Livestock grazing in the form of transhumance activities is common practices in the mountainous region of Nepal. Such grazing activities can impact on natural regeneration of tree species. Being grazing practices as major occupation, not enough research has been carried out on impacts of grazing and management of grazing area in Nepal. This study was conducted with an aim to assess the effects of grazing in natural regeneration in tree line region of Lamtang National Park (LNP). Transect method was carried out for study after identifying different grazing intensities in field. Data were analyzed to study phyto-sociological characteristic (species richness, Shannon-Wiener Diversity Index and density) of vegetation, health of seeding, soil characteristic and disturbance index in grazing region. ANOVA, Kruskal-Wallis test and linear regression were performed to elucidate the relationship between vegetation attributes and grazing intensities. The relationship was further analyzed using post-hoc test i.e., Tukey post hoc test for normal data and Dunn test for skewed data. The result shows that *Abies spectabilis* has set the upper altitudinal limit in all sampling areas i.e., ungrazed, least grazed and moderately grazed area at 3803 m, 3827 m and 3860 m respectively. Moderately grazed area had the higher tree richness, diversity, density and natural regeneration. The density of seedlings was also higher in moderately grazed area. Only 18.3% of seedlings were found to be healthy in moderately grazed area which is comparatively lower than in ungrazed area (69.8%). Soil parameters such as Bulk density, Moisture content, pH and Nitrogen showed the variation with grazing intensities. The linear regression analysis showed the insignificant decrease ($p=0.18$) and insignificant increase ($p=0.08$) in seedling density with increase in disturbance score in ungrazed and least grazed area respectively. However, for the moderately grazed area, there is significant increase ($p=0.02$) in seedling density with increase in disturbance score. As moderate forest grazing helps to maintain the natural regeneration, grazing management is recommended in the higher Himalayan region.

Keywords: *Regression analysis, seedling sapling ratio, seedling density, seedling health, soil parameters,*

Introduction

Livestock grazing in mountainous rangeland is one of the common practices around the world. In Nepal, animal husbandry is one of the major occupations in mountain areas where, livestock are being grazed for forage and fodder in forest and rangeland (Gurung et al., 2009). Livestock in high hills and mountains are mostly managed under a migratory system in Nepal known as transhumance. Transhumance is a form of livestock production in which the livestock are moved between fixed points to utilize seasonal availability of grazing resources over a year (Nyssen et al. 2009). There is definite spatio-temporal movement of herds throughout the year. During the movement, around four months between June to September, grazing takes place in periphery of treeline region during summer season (Aryal et al., 2014). In high mountainous regions, the alpine treeline ecotone is an important altitudinal boundary of vegetation where grazing practices are regular. There is abrupt decline in vegetation where the forest meets grassland/rangeland creating unique ecosystem. The grazing practices along with climate stress have major effect in such area.

The chronological disturbance has exhibited the reducing diversity level due to grazing for long period of time (Hofgaard, 1997). Higher grazing intensity can have significant effects on herbaceous species biomass, grass composition, number of seedlings, age category, basal cover, and woody plant diversity. It can bring out undesirable change on the condition of rangeland (Mathewos et al., 2023). For the maintenance and preservation of biodiversity, natural regeneration is important. It's a process of reproducing new plants in the community that determines the composition of the species and its stability in the near future (Napit, 2015). Natural regeneration of tree depends upon exclusive interaction of biotic and abiotic factors in specific environment. The major biotic factors are: accessibility of seeds, interactions between different plant species, the frequency of herbivore seed predators, pathogenic microbes, intra- and interspecific competition, structure of vegetation etc. (Gordon & Rice, 2000).

Grazing is an important biotic factor that poses a serious impact to biodiversity and regeneration via different ways i.e. defoliation through eating, physical damage such as animal trampling, soil compaction and mineralization by deposition of urine and faeces (Lempesi et al., 2017). Seed survival is greatly impacted by the trampling of seedlings and soil compaction by animal activity and seed predation is considered as the limitation to regeneration and migration (Cairns & Moen, 2004). But, if grazing is controlled, it can be sustainable. It enhances the tree growth by reducing the biomass of grasses and sedges (Gratzer et al., 1999). Natural regeneration can be promoted at moderate level of grazing intensity (Darabant et al., 2007). Despite of having large grazing area in mountain region and grazing practices as major occupation, a limited research has been carried out on impacts of grazing and management of grazing area in Nepal. LNP is one of the areas where transhumance is practiced for long period of time as has more than 300 sq. km of rangeland area for grazing. Thus, this study aims to explore the impacts of grazing in regeneration in Lamtang region.

Materials and Methods

Study area

Lamtang National Park lies in Central Himalayan region comprising core area of 1,710 sq. km and 420 sq. km of buffer zone in Nuwakot, Rasuwa, and Sindhupalchowk district. It is distinguished as having high climatic and altitudinal variations (alt. 792 m –7,245 m asl). Seasonal climate is dominated by the southerly monsoon, which occurs between June and September. Plant communities extend from upper tropical forest of *Shorea robusta* to hill forest of *Pinus roxburghii*, Rhododendrons and *Alnus nepalensis,* temperate oak forests and northern alpine scrub. The Park consists of more than 1,000 plant species of which 21 species are endemic. The faunal species found in the park includes 46 species of mammalia, 345 species of birds, 11 species of herpetofauna, 30 species of fishes, 10 species of spiders, 58 species of butterflies (DNPWC, 2023). The local population of the park is culturally and ethnically heterogeneous. The three main ethnic groups are the Tamang, Yolmo, and Bhotia. Animal husbandry is the major source of livelihood followed by agriculture and tourism. Herders in Lamtang have a trans-human mode of lifestyle.

The study was carried out in Vrana, tree line ecotone situated between Lauribinayak and Cholangpati near to Chandanbari Cheese Factory at (28.094609°, 85.376936°) in LNP (Figure 1). The numbers of livestock have increased in recent years due to establishment of the Chandanbari Cheese Factory. It exists between the altitudes of 3771 m to 3860 m and consists undulated rocky terrain mostly covered with algae and mosses. The site is dominated by *A. spectabilis* with rhododendron under the canopy and few herbs and mosses. The particular place was chosen considering the seasonal pattern of grazing history.

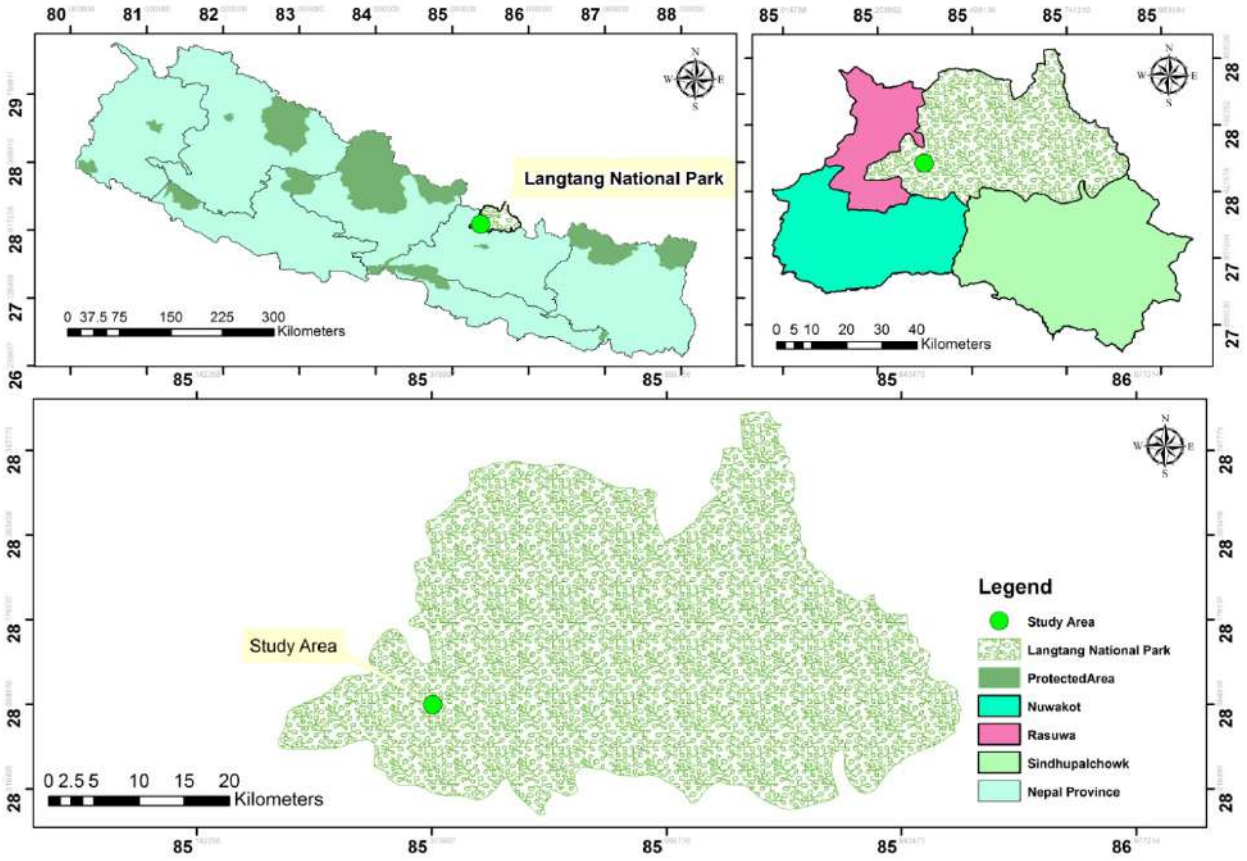

Figure 1: Map of Study Area

Field Methods

The study area (Vrana), was selected considering the seasonal pattern of grazing history where every year grazing takes place for 5-6 months. Based on grazing intensity as defined by Kikoti et al., 2015 (Table 1), moderately grazed area, least grazed area and ungrazed area were selected where detailed investigation on the natural regeneration of trees was conducted.

Table 1: Grazing intensity classes and their interpretation

S.N.	Grazing Intensity Class	Interpretation
1.	0	No grazing
2.	1	1%- 20% (least grazed)
3.	2	21%- 60% (moderately grazed)
4.	3	61%- 100% (heavily grazed)

The study was designed following Potthoff, 2009. In north to south direction, two transects of 170 m in length and 10 m in width were set to record the characteristics of tree and sapling layers on the three grazing intensities. Transects were spaced to encompass the upper altitudinal limits of the tree species. The upper altitudinal limits of the tree were the 1st point in the study. The transects were then divided into 17 segments of 10 m in length, each thus creating, 10 m x 10 m plots. All trees, irrespective of size, were identified, counted, and their heights (height of tallest stem per individual) were estimated in 10 m x 10 m plots. Each 10 m x 10 m plot was divided into four equal plots, and in each plot, a 1 m x 1 m quadrat was placed where regenerants were studied.

The regeneration status was determined following Shankar (2001) that classifies regeneration as: i) 'good', if seedling > sapling > adult; ii) 'fair', if seedling or sapling > adult; iii) 'poor', if species survives in only sapling stage but not as seedling; iv) 'none', if a species is an absence in both in sapling and seedling stage; v) 'new', if a species has no adult but only sapling or seedling or both.

The soil sample was collected from the depth of 0-10 cm, 10-20 cm and 20-30 cm and made a

composite sample for lab analysis. As described in Marques et al., 2001, by measuring percentage of trampling area and dung number in each 10mx10m quadrat, the degree of trampling and dung count were assessed.

Lab analysis

Soil samples analysis was carried out following the standard method described in Trivedi & Goel (2015). (Table 2).

Table 2: Soil Sample Analysis Method

S.N.	Parameters	Unit	Standard Method
1.	pH	-	pH meter YSI 1200
2.	Bulk Density	g/cm^3	Oven dry
3.	Organic matter	%	Walkley- Black titration
4.	Nitrogen	%	Kjeldahl digestion method
5.	Phosphorus	Kg/ha	Bray II (SS1 UV 2101 Spectrophotometer)
6.	Potassium	Kg/ha	Normal ammonium acetate method

Data analysis

At growth stage with <2 cm diameter were classified as tree seedling, plants with diameter 2-4 cm were classified as saplings and at growth stage with 4-9 cm diameter were classified as poles (Miligo et al., 2011).

Health of the seedlings was categorized to one of the three categories i.e. perfect health (buds exists and are healthy), semi-healthy (no terminal bud, lateral buds), browsed (missing most lateral buds and terminal buds) as described by Pour et al., 2012.

By measuring the percentage of trampling (in area) and dung (in area) in each 10 m x 10 m quadrat, the degree of trampling and dung count were assessed (Marques et al., 2001). The disturbance index value was calculated according to the class of trampling percentage (%) (Table 3). Similarly, disturbance index for dung was calculated according to the count of dung percentage (%) (Table 4). Finally, the disturbance score considered here as the total score for the grazing intensity class, disturbance index of dung count and disturbance index of trampling.

Different phyto-sociological parameters such as richness, diversity and density were calculated for

Table 3: Disturbance index for trampling

S.N.	Trampling (%)	Disturbance index value	Disturbance intensity
1.	0	0	Low
2.	0-30	1	Medium
3.	>30	2	High

Table 4: Disturbance index for dung count

S.N.	Dung count (%)	Disturbance index value	Disturbance intensity
1.	0	0	Low
2.	0-5	1	Medium
3.	>5	2	High

tree species. The parameter i.e. density (Zobel et al. (1987) was also calculated for seedlings, saplings and poles. Species diversity was calculated by using Shannon Weiner Index (H) (Shannon & Weiner, 1963) and species richness by counting the total number of species per sampling unit under a given grazing intensity (Pielou, 1966).

Before analysis of data, normality of data was studied through Shapiro-Wilk test. One- way ANOVA was carried out for normal data and Kruskal test for non- normal data to elucidate the relationship between vegetation attributes and grazing intensities. The relationship was further analyzed using post- hoc test i.e. Tukey post hoc test for normal data and Dunn test for skewed data. Linear regression was carried out to establish the relationship between disturbance score and seedling density across different grazing intensities.

Results and Discussion

Grazing plays an important role in the establishment of seedlings. Livestock returns to the tree line area during the mid-summer monsoon season. This cycle repeats every year and regulates the forest regeneration since the browsed area lacks healthy seedlings. Wildlife species like Musk deer had little impact on the study area as no major signs of other wildlife were witnessed. All together two tree species (*Abies spectabilis* and *Betula utilis*) were observed in ungrazed area and least grazed area. In moderately grazed area, additional one species, *Sorbus microphylla* was spotted. *A. spectabilis* was most commonly occurring plant species in

entire studied area. Considering the tree line, in ungrazed area, the upper altitudinal limit of *A. spectabilis* was 3803 m whereas in least grazed and moderately grazed areas, it was 3827 m and 3860 m respectively.

Vegetation characteristics

The calculated diversity index of 2.43 shows the highest diversity for moderately grazed area followed by ungrazed area with 1.87, which is slightly higher to that of least grazed area with diversity index of 1.83. There was a significant difference (H = 6.3764, df = 2, p-value = 0.04125) found across different grazing intensities. The post- hoc Dunn test indicated that the difference was observed between the least and moderately grazed area (p=0.025). No significant difference was observed between least grazed and ungrazed (p=0.961) area as well as between the moderately grazed and ungrazed area (p=0.083).

A. spectabilis, B. utilis and *S. microphylla* were the tree species found in the study area and the upper altitudinal limit was created by *A. spectabilis* in all the study areas. The observed variation in altitudinal limit resembles the conceptual model proposed by Cairns & Moen (2004) which mentioned the low upslope migration potential of tree line in low animal activity and highest migration potential of the tree line at intermediate levels of animal activity. According to local herders, moderately grazed area was found to be grazed from longer period of time with various intensities and intervals compared to that of least grazed and ungrazed area. Higher species richness in moderately grazed area here, accepted the theory of intermediate-disturbance hypothesis.

Similarly, in many cases grazing alters the competitive hierarchy and supports the species abundance of those that might otherwise be rare or excluded (Callaway, 1997). Comparable result was observed in Manaslu Conservation Area by Thapa et al. (2016) in which result agrees with intermediate-disturbance hypothesis. In case of diversity index, ungrazed and least grazed area were recognized for lower diversity. A similar finding reported by De Gabriel et al. (2011) who found lower diversity at the site where sheep grazing was absent. There is little impact on the most unproductive communities but the larger impact on the productive grassland of Scotland after the cessation of deer grazing (Virtanen et al., 2002). The transport of seeds induced by grazing might influence diversity (Olff & Ritchie, 1998). The slightly higher diversity in the ungrazed area was due to the higher evenness despite being the same species richness.

The tree density was found to be higher in moderately grazed area followed by least grazed area and ungrazed area (Figure 2). Kruskal test showed significant difference (H = 7.9021, df = 2, p-value = 0.01923) across different grazing intensities. The post-hoc Dunn test indicated the difference between least and moderately grazed area (p=0.0363) as well as between moderately grazed and ungrazed area (p=0.148). No difference was observed between least grazed and ungrazed area (p=1).

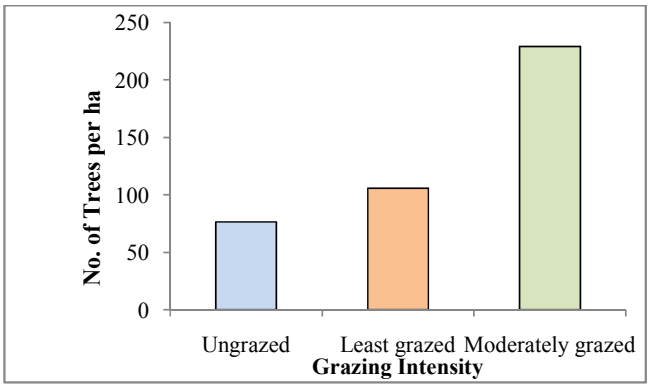

Figure 2: Tree density per hectare area

The density of trees has changes with respect to grazing intensity. Grazing and trampling support to create micro-habitat for the tree species reducing the density of herbs, ultimately reducing the competition for water and nutrients (Castro et al., 1999). As well as, grazing intensity seems to depend on herbivore density, i.e., only medium grazing pressure allowed massive regeneration (Chauchard et al., 2007). Though the species richness of ungrazed and least grazed area were similar, but the abundance of *B. utilis* were higher in the ungrazed area; which was the north-facing tree line (windward side in Nepal). The similar observation was made by Shrestha et al. (2007) where the dominance of *B. utilis* was observed in trans-Himalayan north-facing tree line.

Soil Parameters

Among the seven soil parameters, only four parameters (Bulk density, Moisture content, pH and Nitrogen) showed the variation in different grazing intensities (Table 5). Intensity of grazing significantly alters the soil attributes. Forest area, compared to other lands, has loose soil due to the decomposition of fallen litter. However, presence of animals brings about the changes in soil compactness. The increasing bulk density from ungrazed to moderately grazed area may have attributed by grazing. Brady & Weil (2008) and Warren et al. (1986) also reported that grazing significantly altered the bulk density. Similarly, moisture content also increases with grazing. Increased livestock deposition enhances organic matter which, in turn increases the decomposition rate of soil microbes making soil more porous and hence increases the water holding capacity (De Gryze et al., 2006). In addition, litter content also acts as mulch by both adding organic matter through decomposition and shading soil from direct exposure of solar radiation. The shades reduce the loss of moisture through evaporation (Jeddi & Chaieb, 2010).

The soil was acidic across different grazing intensities which might be due to the active rain that leached out basic cations making the soil acidic (Brady & Weil, 2008). On the other hand, the acidic soil in the least grazed area may be due to the acids released by the decomposition of organic residues i.e. litter from forest vegetation (KC et al., 2013). Similar finding was reported by Yates et al. (2000) who found the alteration of pH due to grazing. In contrast to the finding, the study carried out by Milchunas et al. (1988) and Akhzari et al. (2015) reported no relation exist between grazing and pH.

Grazing either increase or decrease organic matter or have no effect on it (Zarekia et al., 2012). High amount of organic matter in ungrazed area might be due to the decomposition of plant residues which in turn favors high microbial activity (Jeddi & Chaieb, 2010). The increase in organic matter in moderately grazed area was attributed to the deposition of dung and urine by livestock. Organic matter returns back to the soil in the form of manure after been grazed. Also, the movement of livestock results in the better mixing of the plant remains. Al-Seekh et al. (2009) reported no any significant difference in the amount of organic matter with different 30 grazing intensities. However, Pappas & Koukoura (2013) reported medium grazing intensity to enhance organic matter at higher altitude. Nitrogen shows similar trend with organic matter since large amount of nitrogen is bound to organic matter (Kalu et al., 2015). In case of the phosphorus, excreta enhance its content and there is more mobility of phosphorus due to trampling (Zarekia et al., 2012). Baron et al. (2001) also observed the positive change in phosphorus due to grazing. Although, availability of nutrients in moderately grazed and ungrazed areas has increased, the decrease in potassium may be due to increased nutrient consumption by plants (Xu et al., 2016).

Table 5: Impacts of grazing on various soil parameters with mean ± SD

Grazing Intensity	BD (g/cm3)	MC (%)	pH	OM (%)	N (%)	P (Kg/ha)	K (Kg/ha)
Ungrazed	0.52 ± 0.05	29.38 ± 2.64	5.29 ± 0.49	8.74 ± 0.69	0.40 ± 0.09	30.68 ± 7.11	170.06 ± 70.77
Least grazed	0.67 ± 0.07	38.44 ± 5.57	4.73 ± 0.13	8.29 ± 1.41	0.32 ± 0.09	24.04 ± 2.94	256.08 ± 159.12
Moderately grazed	0.82 ± 0.08	40.77 ± 2.63	4.38 ± 0.58	8.82 ± 0.97	0.47 ± 0.08	34.00 ± 13.56	149.52 ± 3 1.43
p- value	6*10-5***	0.001**	0.02*	0.4	0.03**	0.03	0.01
Test	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	Kruskal	Kruskal

Health of the seedlings

The number of perfect health seedlings was greater in the ungrazed area where no seedlings were found browsed. Whereas, a large number of browsed seedlings observed in moderately grazed area followed by least grazed area. 69.8% of the seedlings observed to be perfect health, 30.2% to be semi-healthy and absence of browsed seedlings in ungrazed area. Whereas, 51.4% of seedlings were found to be perfect health, 28.8% of the seedlings were found to be semi-healthy and 19.8% were found to be deformed in least grazed area. Similarly, 18.3% of seedlings were found to be healthy in moderately grazed area which is comparatively low, 34.8% were found to be semi-healthy and 46.9% were found to be deformed.

The browsed seedlings were the clear indication of the effect in their health. Seedlings were usually grazed and deformed in the moderately grazed area, which does not guarantee for the future of forest if this continues for the long term (Pour et al., 2012). If the process of being eaten repeats every time, this might affect forest regeneration. The browsing observed was expected to affect the growth forms of tree species through the browsing of both terminal and lateral twigs and buds which reduces the growth rate of seedling. The reduction in the growth rate of seedling will have more influence from browsing since it takes a longer time to escape the effect (Mcevoy et al., 2006). In general, complete exclusion of forest from grazing would only facilitate the quick recovery of degraded forests (Teich et al., 2005). In the study carried out by Wilson (1990) and Harrington (1976) in which the effect of goat browsing was considered. Wilson (1990) reported random browsing by goats eventually killed it whereas Harrington (1976) reported though the random browsing was repeated it mostly influenced the twigs not the leaves, only a few plants were killed. If the browsing continues, it not only endangers the sustainability of forest ecosystems, but also increases the challenges for sustainable forest management.

Effects of grazing on regeneration

A. spectabilis was dominant plant species in entire studied area representing good regeneration status in all three grazing zones. There was no regeneration of *S. microphylla,* where *B. utilis* were present only in ungrazed and moderately grazed area (Table 6).

With different grazing intensities, the natural tree species regeneration changes. The density of regeneration showed the maximum density of seedlings in moderately grazed area followed by least grazed area and ungrazed area (Figure 3). The dominance of seedlings is obvious where there were large groups of trees along with dense branches and foliage that reaches the ground. The majority of seedlings were established under this condition since foliage protects the seeds from being grazed. Similar findings were observed by Milchunas et al. (1988). Newton et al. (2013) result supported this fact that the fallen branches or trunks protect the young ones from disturbance such as grazing within the protective microsites.

Table 6: Regeneration Status of Vegetation

Grazing Area	Seedling	Sapling	Poles	Result
For *A. spectabilis*				
ungrazed area	66	10	8	Seedling>sapling>pole (good)
Least-grazed area	169	25	2	Seedling>sapling>pole (good)
Moderately-grazed area	156	10	9	Seedling>sapling>pole (good)
For *B. utilis*				
ungrazed area	15	1	2	Seedling>sapling<pole
Least-grazed area	0	0	0	Absent (none)
Moderately-grazed area	21	1	1	Seedling>sapling=pole
Total				
ungrazed area	81	11	10	Seedling>sapling>pole (good)
Least-grazed area	169	25	2	Seedling>sapling>pole (good)
Moderately-grazed area	177	11	10	Seedling>sapling>pole (good)
Note: The number of seedling, sapling and poles in the table represent the total number in transect. i.e. number per 34 sq. m.				

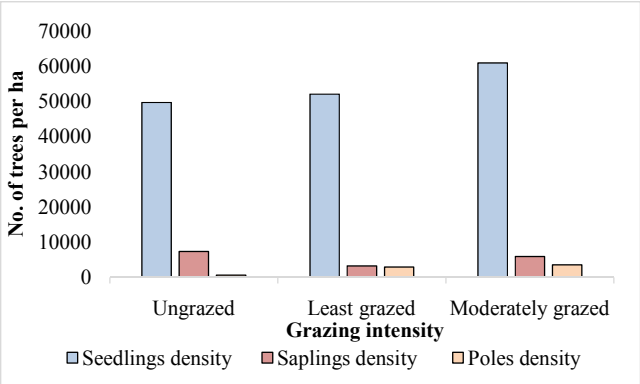

Figure 3: Density of regeneration

The finding shows that moderate level of grazing had been facilitating to sustain the species of *A. spectabilis.* The result supported Buffum et al. (2009) who found that moderate intensities of forest grazing can be sustainable as long as the grazing intensities are controlled since a moderate level of grazing facilitates the area without a negative impact on natural regeneration. Similarly, a mechanism like grazing, trampling, and dung promotes the area. The fleece supports the area through nitrogen fixation whereas grazing and trampling facilitate to create micro-habitat for the vegetation. Also, livestock grazing helps in the canopy opening, facilitating the gap opportunistic plant species (Pekin et al., 2014).

Apart from *A. spectabilis*, remaining two species *S. microphylla* and *B. utilis* grazing may not have supports its growth. Although grazing supports the dispersal of seeds, it prevents seedlings from developing into saplings (Wassie et al., 2009). A similar observation was made by Mcevoy et al. (2006) where greater numbers of saplings were found in ungrazed forest than in grazed forest of NW Spain. Smit et al. (2006) reported the destructions of newly grown seedlings, which in turn influences the lower density of saplings in the Swiss Jura Mountains. This result is similar in case of *B. utilis*. Although, a good number of seeding was observed, very few have reached the sapling phase. Kikoti et al. (2015) found the lower density of seedlings in a moderately grazed area compared to that of ungrazed and least grazed area. This shows restricted seedlings recruitment probably due to the effect of grazing, leading to the negative impacts on natural regeneration pattern in the montane forests of northern slopes of Mount Kilimanjaro. The long period of grazing and change in microclimate by grazing limits the existence of some common as well as rare species (Song et al., 2020). This may have resulted in absence of regeneration in *S. microphylla.*

The high proportion of poles in moderately grazed area was an indication that after the new recruitment reached to the certain height, it escapes the effect of grazing thus would not affect their growth (Mcevoy et al., 2006). The smaller number of poles individuals compared to the seedlings and saplings were may be due to the extraction of fuelwood and fodder by local people. In a similar study, a lower proportion of seedlings conversion to poles was reported by Baboo et al. (2017) since the fuelwood and fodder extraction by local people was a major problem. Similarly, in the study carried out by Sagar & Singh (2004), lower proportion of seedlings conversion to poles was accounted for anthropogenic pressures. They also reported the lower recruitment of poles and accounted for the influence to be illegal harvest of poles, density-dependent mortality of seedlings and grazing.

Relationship between seedling density with disturbance score

The linear regression analysis showed the insignificant decrease in seedling density with increase in disturbance score in ungrazed area (Figure 3a). However, the result was opposite (Figure 3c) in case of moderately grazed area. There is a significant increase in seedling density with increase in disturbance score. Least grazed area also showed insignificant increase in seedling density with increased disturbance (Figure 3b). Dung count, trampling and grazing had resulted in an increase in seedling density following the grazing intensity (Pollock et al., 2013). Grazing supports the establishment of the seedlings providing the microsites which otherwise might not be able to compete with established vegetation (Shaw et al., 2010). It mentions structural heterogeneity to be the lowest at heavily or ungrazed area and to be the highest structural heterogeneity at moderate levels of grazing (Augustine et al., 2012). Also, the variation in the spatial distribution of the quantity

of dung influences in the community composition (Valdés-Correcher et al., 2019). However, the variation must be large enough. The apparent decrease in disturbance might be the reason for the ungrazed area and least grazed area not to be significant (Valdés-Correcher et al., 2019).

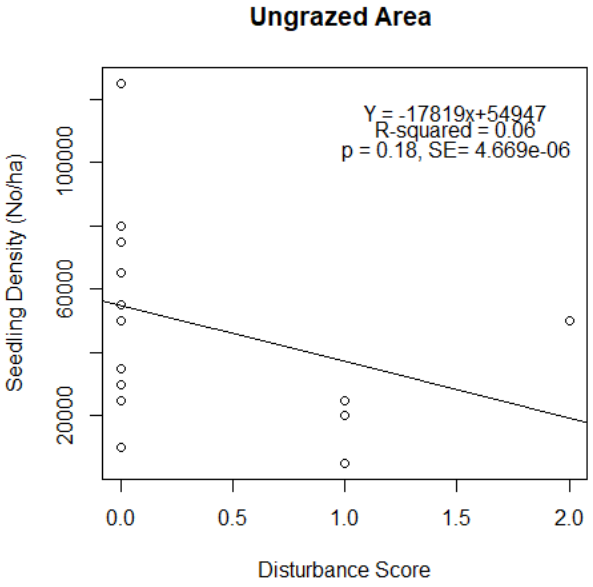

Figure 4a: Linear regression between seedling density and disturbance score (ungrazed area)

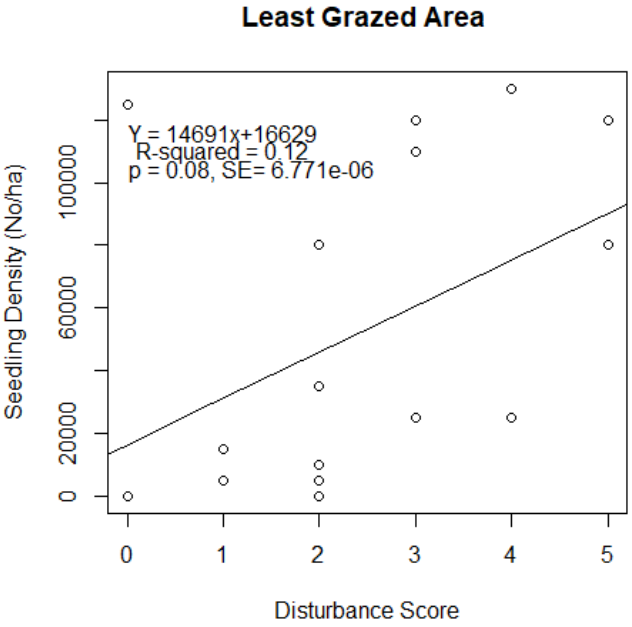

Figure 4b: Linear regression between seedling density and disturbance score (least grazed area)

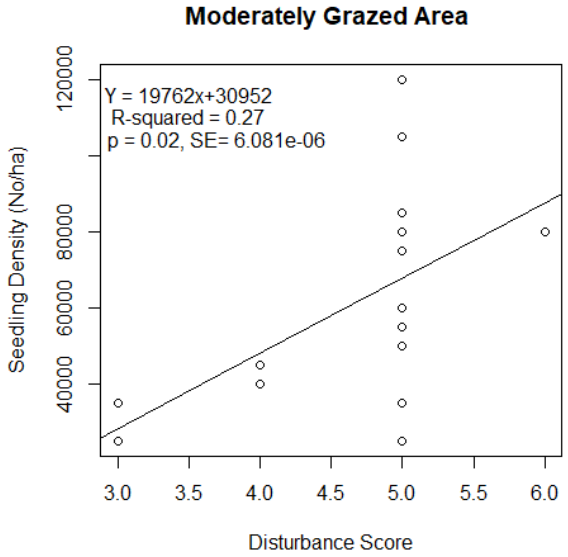

Figure 4c: Linear regression between seedling density and disturbance score (moderately grazed area)

Although these results suggest that grazing has importance in shaping the community composition of plants species, there are also other unexplored factors such as fire effect, below ground competition of seeds, canopy cover, micro climate, climate change etc. that need to be researched along with grazing. This study provides a general idea of effect of grazing in limited area of high-altitude region. However, for more generalization of the result, this type of study needs to be conducted in a large scale.

Conclusion

Grazing was found as an important factor for natural regeneration. Effects of grazing in natural regeneration were studied through relationship between seedling density and disturbance score of grazing. The natural regeneration was higher in moderately grazed area. The species richness, diversity, and density of trees were also found to be higher in moderately disturbed forest. Further, soil characteristics also got altered by grazing. Forest grazing can be sustainable as long as grazing intensity does not impact its natural community composition. Moderate level of grazing facilitates the regeneration of *A. spectabilis* but not all the species respond similarly to the disturbance. Hence, different level of grazing intensities needs to be plan for areas with different species composition.

Since livestock herding is the major occupation in high altitude areas of Lamtang National Park, the findings of the present study carried are expected to influence the decisions regarding grazing management and serve as a baseline for long term monitoring of treeline ecology.

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Data availability statement

Our research is primary research. Most of the data collected and used in analysis are available with us in excel file. We have not put them in any internet platform yet. But we are able to provide dataset on request.

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Assessment of Sound Pollution and Control Initiatives in Growing Suburb of Jhapa, Koshi Province of Nepal

Nisha Neupane[1], Raju Chauhan[1,2*]
[1]Department of Environmental Science, Amrit Campus, Tribhuvan University, Kathmandu, Nepal
[2]Department of Environmental Science, Patan Multiple Campus, Lalitpur, Nepal
*Correspondence: chnraju@outlook.com

Abstract

This study presents an assessment of noise pollution in Gauradaha Municipality, Nepal, focusing on sound level measurements and evaluation of noise control initiatives across five categorical areas: commercial, industrial, quiet, rural, and urban residential zones. Using a systematic sampling approach, three sites per category were selected across nine wards, with sound level measurements conducted using a Sound Level Meter at 10-second intervals for 10 minutes, five times between 6 am and 9 pm. Questionnaire surveys were also administered to assess community perceptions and existing noise control measures. Results indicate widespread noise pollution exceeding both national and WHO standards, with an overall equivalent sound level of 65.19 dBA. Industrial areas exhibited the highest levels (90.78 dBA), while rural areas showed the lowest (47.34 dBA). Control measures predominantly included no horn zone declarations and physical barriers such as cemented structures and bamboo barriers. However, effectiveness varied across areas, suggesting a need for enhanced enforcement and community awareness. This study underscores the urgent need for targeted interventions to mitigate noise pollution, recommending strengthened enforcement of regulations, increased community awareness, and innovative solutions tailored to specific sources of noise pollution in each area.

Keywords: *Gauradaha, guideline and standard, noise pollution, noise status*

Introduction

Noise is defined as a harmful, disturbing, undesirable loud sound that causes discomfort and hearing loss and at the same time disturbs physiology and psychology (Kam et al., 1994; Miller, 1998). Urban noise is increasing daily at a high rate and significantly affecting human health and the environment. The main sources of urban noise are population growth, urbanization, and technological development (WHO, 1999). People in urban environments experience a high level of sound in different sectors such as shopping malls, schools, the workplace, recreational centers, and at home in many cases (Chauhan et al., 2021). The effects of these noises may be direct and indirect, mainly on health, and can cause disturbances in social, working places, and environment as a whole (Goines & Hagler, 2007). Continuous exposure to noise over a long period within a range of 85 to 95 dBA leads to hearing loss and psychological disorders. Noise has also been seen as a minor factor in cardiovascular diseases and blood pressure (Stansfeld & Matheson, 2003). The reduction of noise pollution requires a coherent strategy of long-term and medium to short term, which tend to be focused on mitigation of more specific and localized noise conflicts (Loucks, 2012). There are several methods by which noise problems can be controlled. Commonly adopted methods include design and specification change, command and control, and economic instruments (Peters et al., 2018). In a country like Nepal, which is technically behind in developing new technologies, command and control methods have been used widely. For instance, after enforcing the no-horn regulation in Kathmandu Valley, the noise level was reduced significantly by 2.1 dB(A) in high-traffic, low-traffic, and residential zones (Chauhan et al., 2021). The use of barriers is another option for noise reduction through path interventions. According to Önder & Akay (2015), if suitable areas and proper maintenance facilities exist, vegetation could be preferred to mitigate traffic noise. The diversity of plant species and green space establishment techniques should be according to scientific methods and appropriate to

local ecology. These must be increased in terms of both quality and quantity due to their positive effects on the environment, which in turn will be very effective in reducing noise pollution. In the context of Nepal, many of the studies regarding noise pollution are focused on Kathmandu Valley and urban areas. Kadell et al. (2003) investigated noise levels in Kathmandu Valley and found that the maximum temporal distribution of average noise level was 83.5 dBA at ring road in the morning time and the maximum traffic noise level was 83.5 dBA at Putalisadak (Kadell et al., 2003; Sapkota et al., 1997). A recent study conducted by Chauhan et al. (2021) in 23 locations of four different zones (high traffic, low traffic, commercial, and residential) shows that 65.2% of the sampled sites had noise levels beyond the permissible limit of WHO and the National Sound Quality Standard of Nepal. Similar studies are lacking in rural and sub-urban areas even though the problem is not confined only to urban areas. Therefore, this study aims at measuring noise pollution in the sub-urban area, comparing the level of noise with established guidelines and standards, and assessing the control measures in the suburban setup.

Materials and Methods

Study site

The present study was carried out in Gauradaha Municipality in the Jhapa District. It is one of the growing urban centers in eastern Nepal. The incorporation of former VDCs Maharani Jhoda, Baigundhura, Juropani, Kohabara, and Gauradaha formed Gauradaha Municipality on 19th September 2015. Geographically it is located from 26.675 to 26.708 N latitude and 87.291 to 87.341 E longitude. According to the 2021 Nepal census, it has a total population of 60,459. There are nine wards within this Municipality. The Municipality is surrounded by Kamal Rural Municipality in the east and north, Ratuwamai Municipality in the west, and Gaurigunj Rural Municipality in the south. It is the plain Terai of Nepal. The residents of Gauradaha Municipality are mostly Brahmins, Chhetri, Rajbansi, Tajpuriya & Sataar (Santhaal). Most of the local people depend on agriculture. Rice is the main crop grown in this Municipality. Gauradaha, Gwaldubba, Schoolchaun, and Kohabara (Damuna) are the places for trade in this Municipality.

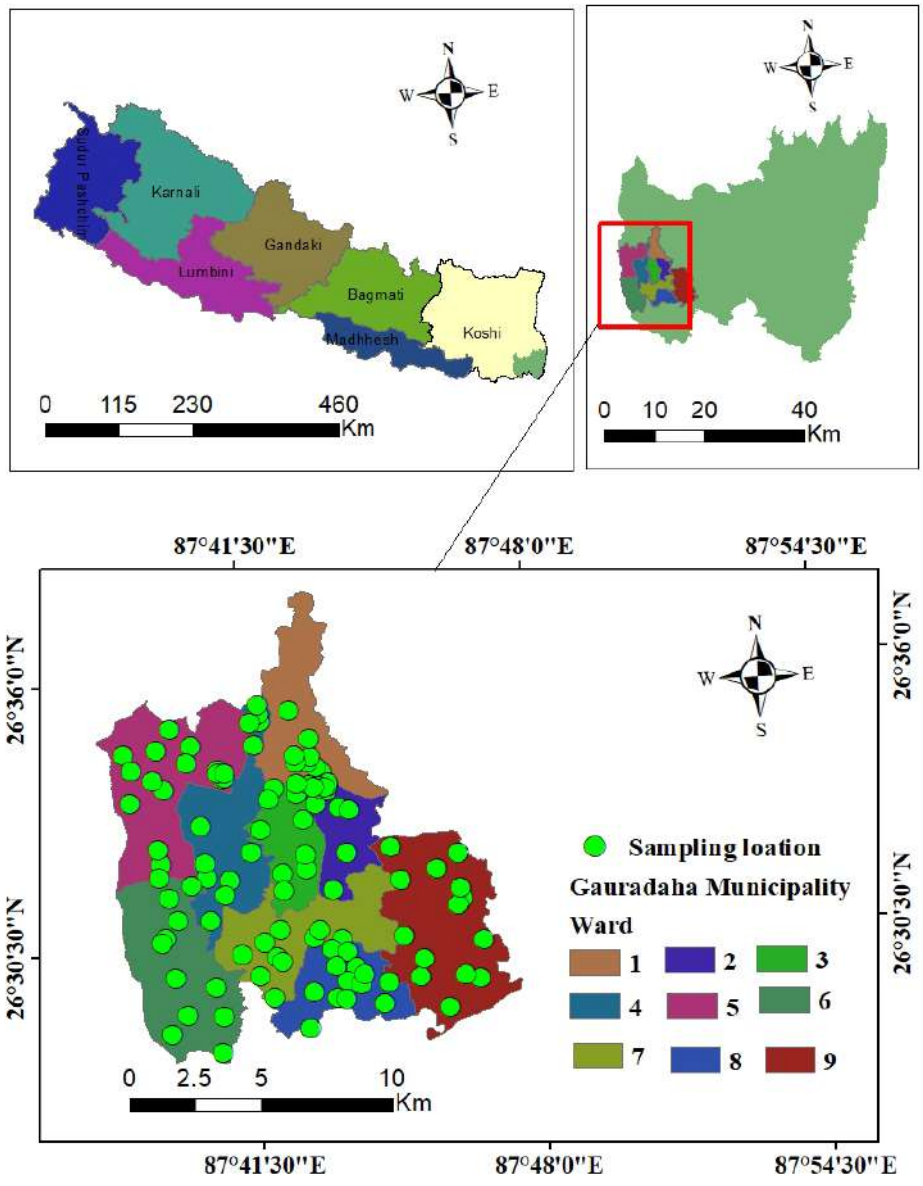

Figure 1: Location map of study Site

Sample Size

The sample size was selected by using a stratified sampling method. Five categorical areas in nine different wards were selected as commercial, industrial, quiet, rural, and urban areas. Data was collected from all 135 locations under the five different categories in nine wards (Table 1). To represent at least three to four respondents from each ward, 35 respondents were selected for the questionnaire. The respondents were local government representatives and officials like the Mayor, ward chairperson, planning officer, IT officer.

Figure 2: Auto ranged sound level meter with data logger

Table 1: Sample for data collection

Category	Number of measurement sites	Site Types
Quiet areas	3x9=27	Health post, social area (School, Clinic)
Commercial	3x9=27	Cloth store, food shop, market area
Industrial	3x9=27	Rice mills, Furniture
Rural	3x9=27	Rural residential areas
Urban	3x9=27	Urban residential areas
Total	135	

Data collection

The noise level was measured in decibels (dB) using the sound level meter (SLM) (Lutron, SL-4012) (Figure 2). It is used in the acoustic measurement. For the collection of primary data, the measurement instrument was carried out for the weighting scale. For the measurement of noise level, an SLM was taken in hand at a height of 0.5-1.7 meters at a distance of 1.5 meters from the window in an industrial area, and 5 meters from the roadside and hat bajar (local markets). The measurements were taken during sunny days having normal wind speed, atmospheric conditions, and devoid of rainfall. The measurement was done for 10 minutes with readings taken at 10 seconds interval. The process was carried out five times a day, which as shown in Table 2.

Table 2: Time allocation for data collection

Time	Duration
Morning	6am-9am
Morning- Afternoon	9am-12pm
Afternoon-Evening	12pm-3pm
Evening	3pm-6pm
Late evening	6pm-9pm

Data analysis

Collected data were analyzed by using Microsoft Excel for the quantitative and qualitative data analysis. The sound level was analyzed for different wards and categories and presented in bar charts, pie charts, and histograms. The temporal pattern of noise was also analyzed. All the results were compared with NSQS (Nepal Gazette,2012) & WHO (1999) guidelines. The given formula was used to calculate the equivalent sound level.

$$L_{eq} = 10log\left(\frac{1}{N}\right)\sum\frac{10^{SPL}}{10} \quad \text{.....Equation (1)}$$

Where,

L_{eq} = Average sound level
N = Total number of observations
SPL = Sound Pressure Level

Results and Discussion

Various nations have different standards for noise levels. Nepal has established standards for noise levels in various categories. There have been a lot of studies conducted in municipal areas in other countries, but not many in Nepal.

Comparison of sound level by category

The bar chart below (Figures 3a, 3b, 3c, 3d, and 3e) shows the findings of each selected area. In Figures (3a, 3b, 3c, 3d, and 3e), The World Health Organization (WHO) and the National Sound Quality Standard, 2012 both have noise levels that are higher than the Leq sound levels at each of the locations shown. Ward 9 in the industrial area had a maximum Leq of 93.16 dBA while Ward 6 in the rural area had a minimum Leq of 44.15 dBA. In the other remaining areas category; falling between those figures is the Leq ranging from 45.61 to 92.12 dBA.

The present charts (Figures 3a, 3b, 3c, 3d, and 3e) show the sound levels from different categories commercial, quiet, industrial, urban, and rural. The maximum and minimum sound levels for commercial areas are given by ward-1 with a value of 69.47 dBA and ward-9 with a value of 58.90 dBA as shown in Figure 3(d). About this matter in the industry section, the highest peak and lowest troughs of sound have been recorded at ward-9 being equal to 93.15 while it stood at 87.02 in ward-1 for instance.

There were rural areas, which had sound levels ranging from a maximum of 50.13 dBA in Ward 7 to a minimum of 44.15 dBA in Ward 6. On the other hand, urban areas covered by these wards had their highest and lowest recorded sound levels at 60.96 dBA in Ward 1 and 53.78 dBA in Ward 9 respectively.

The graphic of the sound pattern in Figure 3(b) reveals that the quiet zone's highest and lowest sound levels were 56.15 dBA at Ward 2 and 46.07 dBA at Ward 4, respectively. Out of the three wards analyzed, Ward number nine in industries had the highest level of sound due to the absence of engineering control measures and machinery sounds.

The charts presented in Figures 3(a) to 3(b) depict the sound levels across various categorical areas such as commercial, quiet, industrial, urban, and rural. Figure 3(d) highlights that in the commercial area, the highest sound level recorded was 69.47 dBA in Ward 1, while the lowest was 58.90 dBA in Ward 9. In contrast, for the industrial zone, the maximum and minimum sound levels were 93.15 dBA in Ward 9 and 87.02 dBA in Ward 1, respectively.

Figure 3 displays the varying sound levels, in settings such as industries, health facilities, schools,

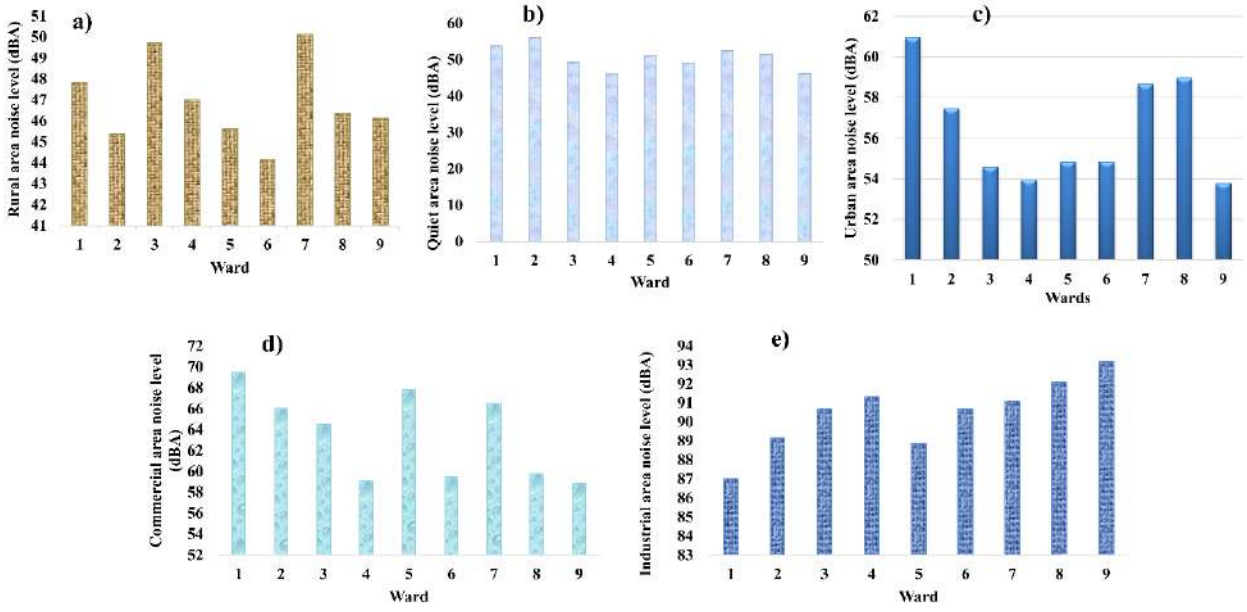

Figure 3: Noise level at rural areas (a), quiet area (b), urban area (c), commercial area (d) and industrial areas (e)

stores, rural regions, and urban areas. The initial column presents the levels while the second column indicates the National Sound Quality Standards. Upon reviewing Figures 3(a) to 3(e) it is evident that industrial sites generally exhibit noise levels compared to stores in tranquil environments, urban locales, and rural areas. Despite this observation all locations – be it establishments, industrial zones, serene spots, or urban and rural areas – surpass the recommended National Sound Quality Standards. This implies that noise pollution is prevalent, across settings even though industrial regions tend to be the loudest.

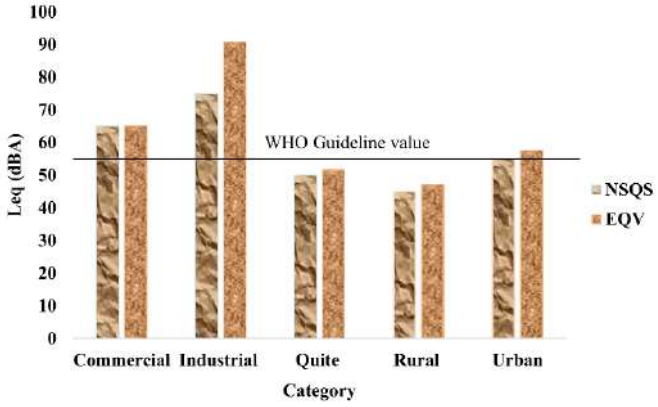

Figure 4: Comparison of L_{eq} of the different categorical areas with NSQS

In Gauradaha none of the types of areas have met the National Sound Quality Standard except, for the area, which has stayed within the recommended limit of 65 dBA during the day. Notably, the industrial area exhibits sound levels exceeding the standards set by the sound quality standard of 2012.

Additionally, sound levels, in the silence zone fail to meet the standard of 50 dBA as illustrated in Figure 4 where recorded sound values surpass this threshold.

Comparison of Sound Level within Nine Ward

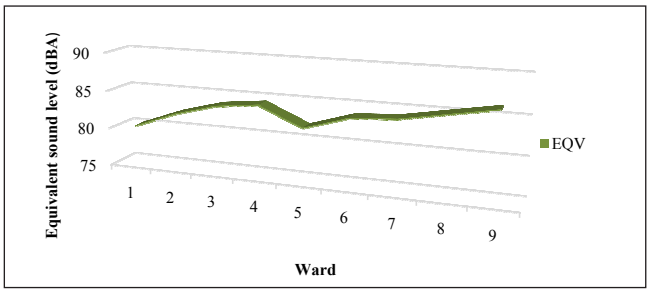

Figure 5: Overall ward wise noise level comparison

The chart illustrates that sound levels recorded across different wards consistently exceed prescribed standards, with ward 9 notably exhibiting exceptionally high levels, particularly in the industrial area. Across various wards, noise levels surpass standards in commercial, industrial, quiet, and urban areas, while rural areas generally meet standards, except in a few instances such as ward 3 where industrial and rural areas exceed standards but others meet them. Notably, Ward 8 stands out as meeting National Sound Quality Standards in the Quiet zone.

Figure 6 demonstrates that the sound levels across all wards exceed the WHO community guideline of 55 dBA. By referencing Figure 8, we identify Ward 1 as having the lowest recorded sound value, while Ward 8 registers the highest sound value among all wards, surpassing levels observed in other areas.

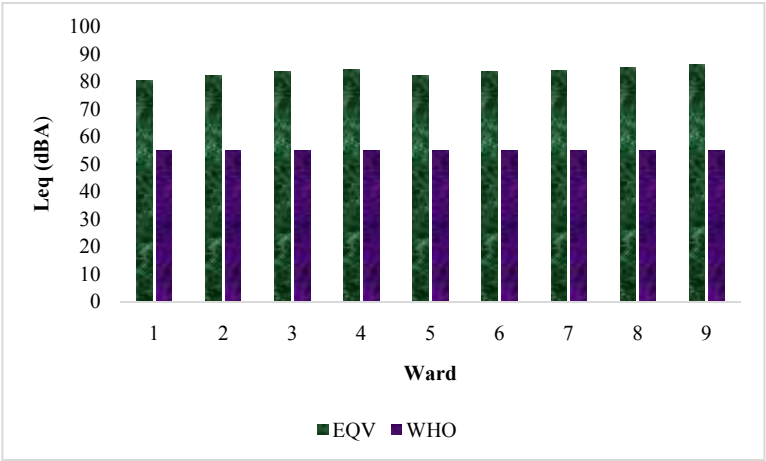

Figure 6: Comparison of noise level with its WHO Guidelines

Temporal pattern of noise pollution

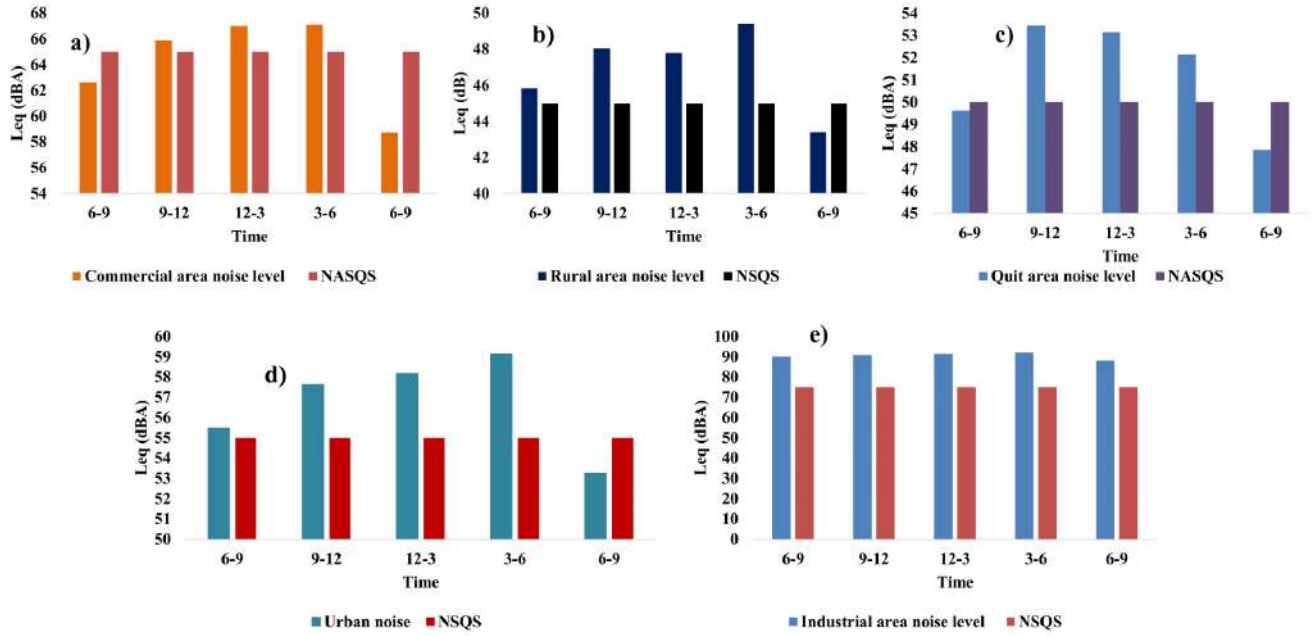

Figure 7: Comparison of temporal noise level for different category with NSQS (a. commercial, b. rural, c. quiet, d. urban and e. industrial)

Figures 7(a) to 7(e) depict various trends in sound levels across different periods and areas. The highest observed Leq during the observation period was 92.10 dBA in the industrial area from 3-6 pm, while the lowest was 43.39 dBA in the rural area from 6-9 pm. Notably, Figure 7 shows the highest noise level trend in the commercial area between 3-6 pm, exceeding the National Sound Quality Standard, whereas noise levels between 6-9 am and 6-9 pm meet the standard. Similarly, in rural areas, both maximum and minimum sound levels were observed between 3-6 pm and 6-9 pm, meeting the standard during other times. In the urban area, the maximum sound level was recorded from 3-6 pm and the minimum from 6-9 pm, meeting the standard during the latter period. Likewise, in the Quiet zone, maximum and minimum sound levels were observed from 9-12 pm and 6-9 pm, while meeting the standard between 6-9 am and 6-9 pm.

Assessment of Control Measures

In the assessment of control measures within the municipality, various stakeholders including local government officers, IT officers, the chairman, ward officers, the mayor, and health post officers participated in the survey. Findings revealed that 46% of respondents utilized barriers, while 41% did not employ barriers in residential areas, supermarkets, and the local market (hatbajar). Interviews with the mayor disclosed that only 13% of locations were designated as no-horn zones. Questionnaire surveys with local government officers from different sectors indicated the use of various barrier types, with most wards utilizing cemented and bamboo walls, while a minority opted for Tin (Galvanised tin sheet) barriers to mitigate noise pollution. The types of barriers employed in the municipality are illustrated in Figure 8 in a pie chart format.

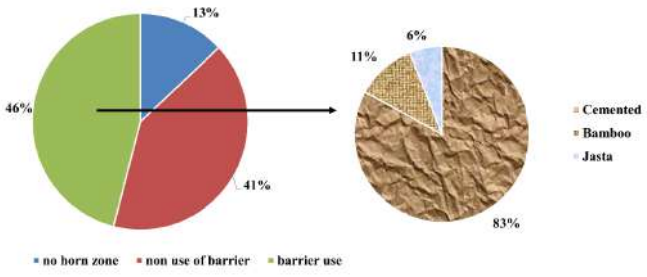

Figure 8: Noise pollution control methods

The maximum and minimum sound levels of the commercial area were 69.47 dBA at Ward 1 and 58.90 dBA at Ward 9 respectively due to maximum vehicle pressure, the crowd of people, construction work, trading market. The noise level of the industrial area recorded in 9 different wards is compared with past studies done in "Friendship Textile Mill Limited, Ubongo- Da (Yhdego, 1991) shows a similar result to this study, the noise level of industrial area is comparatively higher than the prescribed standard.

From the survey, it was found that within the nine wards, the maximum sound level of the rural area recorded at ward 7 was 50.13 dBA. It may be caused by farmers using the tractor for plowing land, harvesting products, over the volume of TV and speaker, birds and other animals added the sound level in a rural area, the minimum sound level was recorded at ward 6 that was 44.15 dBA. Similarly, for urban areas maximum and minimum sound levels were found at Ward 1 and Ward 9 it may be due to urban areas being very close to commercial areas, use of old and noisy vehicles, and urban areas roads being very wide which is the main reason for the overflow of vehicles in the urban area at ward 1. The maximum and minimum sound levels in the urban residential area were 104.2 dBA and 60.0 dBA (Murthy et al., 2010). In the present study, it was found that the urban area noise level was beyond the prescribed standard. From the survey, it was found that the maximum and minimum sound levels of the peace area were 56.15 dBA in ward 2 and 46.07 dBA in ward 4. It may be due to the noise from students and people crowding in the hospital area. A similar reason was found by (Ibrahim et al., 2000) and (Chauhan & Bhatta, 2019) which showed that there are many sources to introduce noise pollution in the school environment, such as where the school is built, near the city Centre, traffic congestion, construction, people pass by and shop can affect on school and hospital activity. The sound value recorded in different wards crossed the national ambient sound quality standard. In ward 9, the industrial area has the highest sound level as compared to other commercial areas due to the big machines (mainly rice mill and furniture) working at very high speed with high noise intensity. (Vattanaprateep, 2020) suggested that heavy mechanical gears and machinery installed in industries contributed to the reduction of hearing abilities of people living in such industrial regions. Ward 2 in the rural area meets the noise level standard. It may be due to low vehicle pressure because of the narrow road, and most of the households of this area are made near the agricultural land, but other areas of these wards (commercial, industrial, urban) don't meet the standard. At Ward 3 sound levels were high in the commercial area as compared to other areas (peace, urban, and rural) area. In the industrial area sound level of this ward is too high as compared to all the selected areas (commercial, industrial, rural, urban, and peace). Similarly, in different wards, 4,5,6,7 and 8 wards sound levels are too high as compared to other areas (commercial, industrial, peace, urban, and rural). It may be caused due to the use of high-noise intensity machines, and lack of engineering control. (Goswami & Swain, 2011) suggested that gathering people with their vehicles around any commercial or administrative regions was also a source of acute noise pollution. Indiscriminate noise that was created by the horns of vehicles and loudspeakers played near temples or in different rituals are also major contributors to noise pollution. Hypertension, heart disease, and mental breakdown were some of the immediate impacts of noise pollution on people (Singh & Davar, 2004). Poor road conditions and the increment of Tuk-Tuk vehicles in both cities and rural regions contributed to noise pollution (Datta et al., 2006, Vattanaprateep, 2020).

Comparison of sound level with guideline and standard

The noise level in all wards had exceeded the noise level standard prescribed by WHO due to the high noise level produced by the industrial area movement of vehicles, wider roads, trading market, in the urban and commercial areas, the sound produced by speakers and TV in a rural area, noise from students and people in a peace zone. Europen countries had developed community noise guidelines to control noise pollution, in comparison with these guidelines noise levels exceeded the guideline. Sound level in the commercial area

between the period of 6-9, 9-12 noon, and 6-9 pm meet the standard but the period of 3-6 pm exceeded the sound level. It may be caused by the commercial area being near the industrial area and in the evening time (3-6 pm), the trading market gets too busy for selling and buying the product. In Australia, the noise level standard of the commercial was set at 55 dBA (Chauhan & Pande, 2010) which is ten times greater than Nepal's sound quality standard and it was revealed that the noise level of the commercial area didn't meet the Australian standard. Similarly, the level of sound in the peace zone in which the maximum level of sound is recorded between the morning and afternoon time (6-9 am & 9-'12 noon), and it is minimum in the evening time (6-9 pm). Around noon the noise level was statistically very low as compared to other times because at lunchtime people have their lunch in the canteen at work or they go to a hotel or food shop and home on foot if near so that noise level is decreased. In the U.S. (E.P.A) the noise level standard in silence areas during day time is 45 dBA (Chauhan & Pande, 2010). The temporal pattern of the urban sound level is just opposite to the peace zone. The high sound level in the urban area is recorded at 6-9 pm; the reason for obtaining this result may be due to the school and hospital area of that Municipality getting more engaged with children and people. The period between 6-9 am and 9-12 noon is regarded as the school and hospital starting time that's the reason that that time sound level in peace area is too high But in the urban area, only in the afternoon and evening time sound level is very high as the maximum vehicles are used by people to reach hatbazzar and other commercial areas in the afternoon time, and the crowd of people increases during duty off time in the evening time (3-6 pm). In Japan, the noise level standard of residential areas has been set at 50 dBA (Chauhan & Pande, 2010). Thus, the present sound level in Gauradaha Municipality is above than permissible level. According to a study done in Kathmandu Valley by Sapkota et al., (1997), recorded a harmful sound level was found above 80 dBA. Most of the different countries have different noise level standards for the different categorical areas while in Nepal there is no such variation in the standard for the different categorical areas.

Assessment of control measure

Control measures assessment carried out by a questionnaire method. For the assessment of control measures in that Municipality, the interview is taken with a total of 34 respondents and the mayor of that municipality. From the survey, it was found that the use of barriers is very high in peaceful areas as the area is regarded as a silent zone, and in these areas, noise should be controlled otherwise it will hamper on education and health of patients. Similarly, in industrial areas cemented walls, bamboo, and tin (Galvanized tin sheet) walls were used to control the noise produced by the machines such as saws, generators, and grinders. For the reduction of noise pollution, the local government hasn't made any policy and hasn't estimated the budget to control noise pollution except for the declaration of no horn zones in 5 places(Sen et al., 2015) surveyed noise pollution assessment in Greater Agartala city and found that different development activities like industrial development, growth of commercial complexes, huge crowed, construction and demolition of building activities produced the considerable noise problem in the city and highlights that the noise pollution can be controlled through the use of barriers, implementation of environmental protection law, pollution and discharge fees and awareness. (Singh & Davar, 2004) also suggested that local governing bodies should be made responsible for managing the emission of noise in the locality. The civil administration and police should be equipped with proper instruments so that they can measure and control unwanted noise emitted by public vehicles. (Vattanaprateep, 2020) also mentioned the implication of fines and taxes for people using old and noisy vehicles or creating loud noise in public places. Administrations were also encouraged to employ architects and engineers to prepare concrete plans to minimize the interference of noise from busy areas to local people. It also suggested keeping schools, residential areas, and hospitals as far from noise-inducing zones as possible. Schools and other residential areas should be declared as noise-free zones. Heavy and old vehicles should also be controlled during rush hours to minimize heavy noises from such vehicles. Along with this,

workers who were working in noisy places should be recommended to wear appropriate gear to prevent damage to the ear from excessive noise. Along with the government, the non-governmental organization should also understand their responsibility to spread awareness among locals to make people aware of the impacts of noise pollution (Darshana et.al., 2013, Oluwasegun et.al., 2015).

Conclusion

The purpose of this study was to evaluate the noise pollution status in Gauradaha Municipality and to assess the control initiatives to control noise pollution. From this study, it was found that the noise level of this Municipality was above the level which is prescribed by WHO. Only the commercial area of the Municipality meets the NASQS. The result of this study indicates that a maximum noise level Leq of 93.16 dBA in the industrial area and a minimum of 44.15 dBA was recorded in the rural area. Among the entire ward, Ward 9 is a noisier area than all wards due to industrial activities. Comparatively 4, 5 & 6 wards are considered as less noisy areas. From the assessment, it was concluded that maximum noise level was observed at 3-6 pm in industrial areas and minimum between the periods of 6-9 pm

Authors Contribution

N.N. and R.C. conceptualized and designed the research; N.N. collected and processed the data; N.N. and R.C. analyzed the data, contributed to data interpretation, wrote and revised the manuscript. All authors have read, revised and approved the manuscript.

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Efficiency of Ceramic Candle Filters towards Purification of Drinking Water

Santosh Thapa[1,2], Narayan Niraula[3,4*], Padmaja Shrestha[5,6], Rejina Maskey Byanju[1]
[1]Central Department of Environmental Science, Tribhuvan University, Kirtipur, Kathmandu, Nepal
[2]Chilime Engineering and Services Company Ltd., Kathmandu, Nepal
[3]Rural Self-reliance Development Centre, Kathmandu, Nepal
[4]Environment Protection and Study Center, Kathmandu, Nepal
[5]Environment and Public Health Organization, Kathmandu, Nepal
[6]Environmental Solution and Research Centre, Kathmandu, Nepal
Correspondence: niroulanavin@gmail.com

Abstract

This study addresses a critical research gap in Nepal, focusing on the effectiveness of ceramic candle filters for purifying drinking water. The research assesses their performance in removing physico-chemical and microbiological parameters, along with flow rates. A market survey in Kathmandu and Surkhet informed the selection of five brands. A cross-sectional, block design experiment over two cycles measured water quality and flow rates. Physico-chemical parameters met NDWQS standards. Microbial tests revealed a significant reduction in *E. coli* and total coliform bacteria, albeit not within NDWQS limits. Flow rates showed no significant variations. Comparative analysis favored silver-coated (CS) filters, with Apollo among non-CS filters exhibiting the highest microbiological efficiency, followed by Hotsun, Surya Vinayak, Surya Nepal, and Milton. This research aims to contribute valuable insights for promoting efficient point-of-use water treatment practices in Nepal.

Key words: *Colloidal silver (CS), NDWQS, point-of-use water treatment, water borne diseases*

Introduction

Safe drinking water and basic sanitation are fundamental human needs. Despite this, approximately two billion people worldwide lack access to clean and safe drinking water, and about 3.6 billion people lack adequate sanitation services (UN, 2023). Drinking contaminated water is the leading cause of various diseases, including infectious hepatitis, cholera, bacillary dysentery, typhoid, paratyphoid, salmonellosis, colibacillosis, giardiasis, cryptosporidiosis, and amoebiasis (Pal et al., 2018).

The absence of safe drinking water and sanitation, particularly in developing countries, results in approximately half the population suffering from one or more of the six main water-related diseases (Diarrhoea, Ascariasis, Dracunculiasis, Hookworm, Schistosomiasis, and Trachoma). Tragically, about 400 children under the age of five die per hour in the developing world from waterborne diarrheal diseases (WHO, 1996; 2017). Annually, around 4 billion cases of diarrhea occur, causing 1.8 million deaths, with 90% of these deaths occurring in children under the age of five in developing countries (UNICEF, 2008).

Despite having abundant fresh water resources in the Indian subcontinent, issues arise from spatial and temporal discrepancies in distribution (Subramanian, 2004). Industrial growth, unplanned urbanization, and population growth contribute to water pollution in developing countries (Cohen, 2006). Poor sanitation and contaminated drinking water, resulting from both human activity and natural phenomena, pose serious health problems (Pandey, 2006).

Nepal has made significant strides in child health, yet child mortality remains high, with diarrhea as the leading cause (WHO, 2018). The Nepalese population primarily relies on three water sources: surface water, ground water, and municipal supplied piped water. In rural areas, especially in the central and northern parts of the country, people predominantly use surface water such as springs and streams, where water quality varies with seasons

(Sagara, 2000). Bacteriological contamination is the primary concern for drinking water in mountainous regions like Kathmandu valley (Rai et al., 2009; Warner et al., 2008).

Intermittent water supply systems increase the risk of microbial contamination (Kumpel & Nelson, 2013). Water-related disease outbreaks are common in the western part of Nepal (Bhandari & Bhusal, 2013; Bhandari et al., 2009). Limited resources hinder Nepal from investing in large centralized projects, leading to pollution of surface and ground water through sewage, domestic waste, and industrial and agricultural effluents, impacting the health of all life forms (Hunter et al., 2009).

Household water treatment and safe storage technologies (HWTS) play a crucial role in providing safe drinking water, serving as an additional barrier against waterborne diseases (Dore, 2015). Various HWTS, including chlorination, combined coagulant-chlorine disinfection, SODIS, ceramic filters, and bio-sand filters, are commonly used in developing countries (Sobsey et al., 2008). The selection of HWTS depends on factors such as cost-effectiveness, people's willingness, availability, and ease of use. Ceramic water filters stand out as an easy, convenient, and effective means of treating water at the household level, particularly in developing countries like Nepal (Clasen et al., 2004; Clasen et al., 2006; Johnson et al., 2015; Lamichhane and Kansakar 2013; Sobsey et al., 2008). Despite the high affordability, willingness to pay, and usage of ceramic candle filters in different districts of Nepal (ENPHO, 2013), there is a lack of comparative studies assessing the efficiency and effectiveness of filter candles available in the Nepalese market under different brand names. This study aims to fill that gap by assessing the performance of different ceramic filter candles available in the Nepalese market.

Materials and Methods

Study Area

The survey sites for this study were purposefully selected to include Kathmandu Valley and Surkhet district in Nepal. Kathmandu Valley, situated in the mountain region, encompasses three major districts:

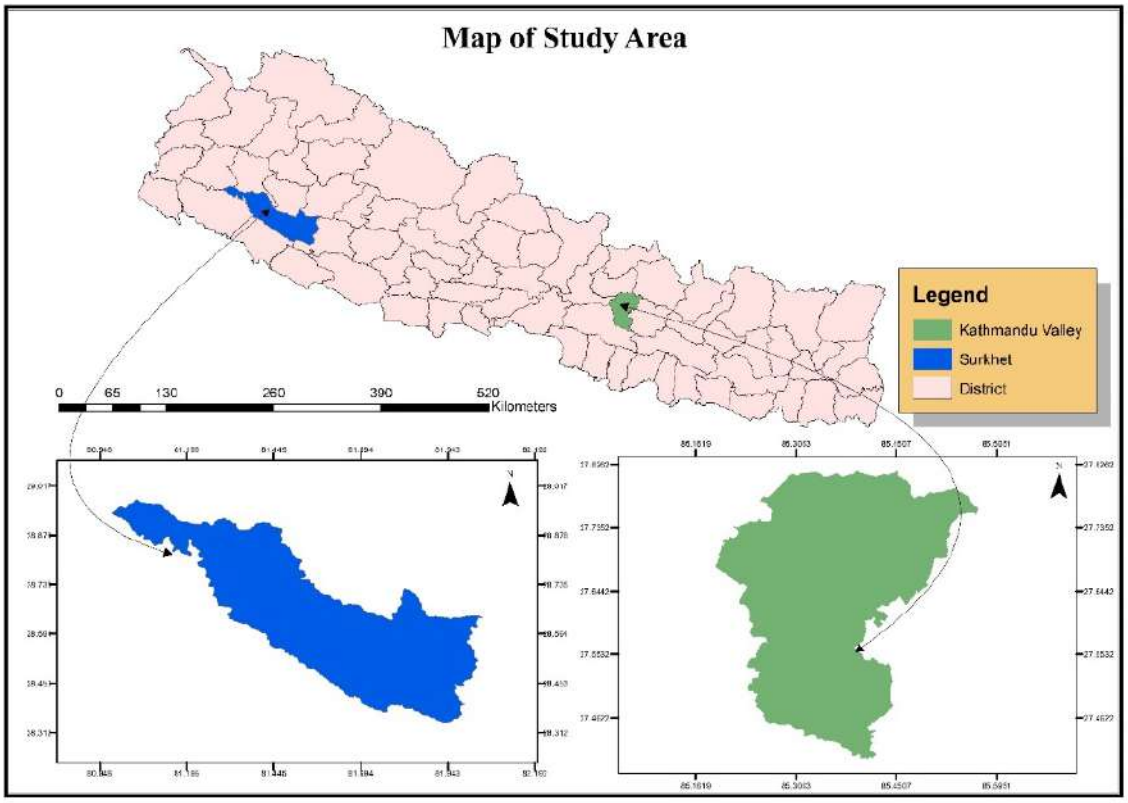

Figure 1: Study area map featuring Kathmandu and Surkhet districts, showcasing the sampling sites for commonly used filter models

Kathmandu, Lalitpur, and Bhaktapur. Serving as the capital city, it functions as a central hub for politics and the economy, located in the central development region of Nepal. On the other hand, Surkhet is one of the 77 districts of Nepal, situated in the mid-western development region. It is surrounded by Dailekh, Jajarkot, Salyan, and Bardia in the mid-western development region, as well as Kailali, Doti, and Achham in the far-western development region, areas known for a high occurrence of waterborne epidemics.

Design of Experiment

To initiate the study, a survey of ceramic candle filters available in the market was conducted, leading to the selection of the top five brands based on interviewee preferences and cost-effectiveness. The experimental design adopted a cross-sectional, block structure to fulfill the study's objectives. The entire experiment unfolded over two cycles, each spanning 14 days, encompassing three replicates for each selected filter brand.

Before installation, all ceramic candles underwent a 24-hour soaking in plain water. Subsequently, they were meticulously cleaned under running water, eliminating any attached ceramic materials. The cleaned candles were then fitted into serialized stainless-steel housing. In the first cycle, the experiment utilized high-turbidity well water (> 5 NTU) as the raw water (acting as a challenge). Following the completion of the first cycle, all ceramic candles were removed and delicately cleaned using a soft nylon brush under running water.

Moving to the second cycle, low-turbidity reserve tank water (< 5 NTU) was employed, mirroring the predominantly clear and low-turbidity water commonly used as raw water in households. In this phase, two additional silver-coated filter brands, namely Madhyapur Clay Crafts (MCC) – a locally produced filter brand – and Tripti (promoted by SMART PANI in the private sector), were introduced, each with three replicates. This expansion aimed to broaden the scope of the study and assess the performance of these additional filter brands.

Figure 2: A photograph showcasing the filter setup for experimentation. Initially, 15 filters from five brands were utilized. In the second phase, two additional brands were incorporated, bringing the total to 21 filters from seven brands.

Analytical Procedures

Table 1: Details of the methodology used to assess each parameter

SN	Parameters	Unit	Description
1	Flow Rate	Water Yielded (in L)/Candle	Measurements were conducted for two types of water, i.e., > 5 NTU turbidity and < 5 NTU, respectively. The water collected after a five-hour period was measured to calculate the flow rate, which was then converted into flow rate per candle. We adjusted the usual 12-hour sampling period, commonly used (Annan et al., 2014), to ensure that the quantity corresponds to the amount generated in a single sitting.
2	pH		Potentiometric Method (APHA, 2012) – using the calibrated pH meter whose electrode was calibrated using standard buffer solution ((pH 4, pH 7 and pH 9.2)
3	Turbidity	NTU	Measured using Nephelometric method (APHA, 2012) by a Hach 2100P portable turbidimeter.
4	Iron Content	mg/L	Measured using Atomic Absorption Spectrometric method (APHA, 2012) by Atomic Absorption Spectrometer, ICE 3000 SERIES, Thermo-Scientific.
5	Total coliform and *E. coli*	Numbers of "colony forming units" (CFU) per 100 ml of original sample	Membrane Filtration Technique (MF) was used for assessment of microbial density in the water sample (APHA, 2012).

Data Analysis

The mean of different parameters (from three replicates of each filter brands) were calculated to compare with the National Drinking Water Quality Standards (NDWQS, 2005) for each day.

Microbiological quality of raw and treated water was compared to qualitative multi risk level (Reygadas et al., 2015) as presented in Table 2.

Table 2: Bacteriological Risk Level based on Reygadas et al. (2015)

CFU/100mL	Risk Level
0	No risk (NR)
1-10	Low risk (LR)
10-100	Intermediate risk (IR)
100-1000	High risk (HR)
>1000	Very high risk (VHR)

Quality Control

The experiment and lab analysis were conducted under sterile conditions to minimize microbial contamination, utilizing analytical-grade chemicals and apparatus. Prior to each cycle, the filters underwent sterilization with 95% ethanol. Autoclaved sampling bottles were employed for microbial parameter analysis, while clean bottles with preservatives were used for iron content sampling. Additionally, clean sampling bottles were utilized for other parameters. To ensure accuracy and precision, a sample blank was included on each sampling day. Water quality analysis for each parameter included intermittent introduction of a blank and a standard after every 8 samples.

Results and discussion

Parameters

Flow Rate: Flow rates for all Ceramic candle filter brands were tested across two cycles, consistently showing higher rates in the second cycle (Figure 3). This difference is attributed to the higher turbidity in the water samples used during the first cycle, leading to clogged pores in the ceramic candles and subsequently lower flow rates. Notably, the MCC brand exhibited the highest initial flow rate, followed by Tripti, while the Apollo brand demonstrated an overall lower flow rate. Porosity plays a key role in filtration capacity, influencing flow rates positively (Mellor et al., 2013).

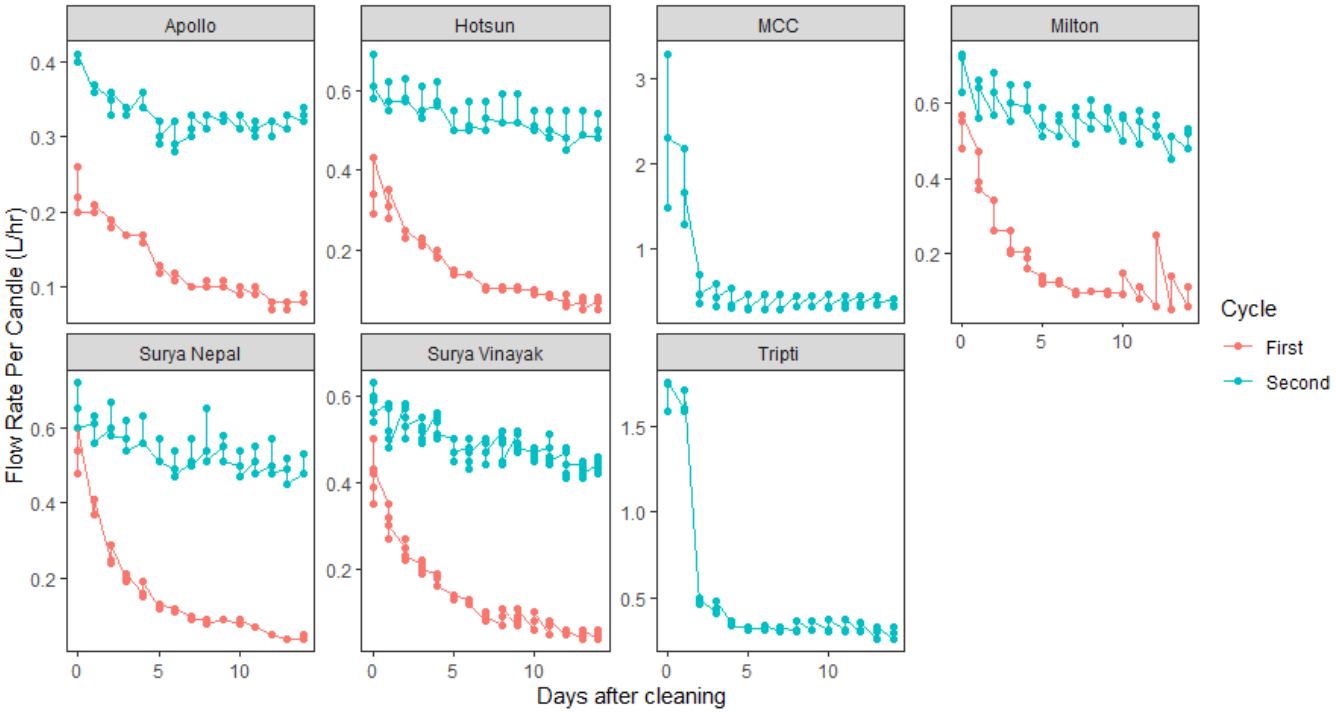

Figure 3: Comparison of flow rates among various candle brands in the first and second cycles. MCC and Tripti brand filters were introduced exclusively in the second cycle. Additionally, the y-axis has been plotted on a free scale for better visualization

pH: Comparison of pH values revealed that the filtered water exhibited a consistently higher pH than the raw water. The treated water's pH ranged from 7.3 to 8.5, while the raw water's pH ranged from 6.73 to 7.97. Although the pH of the treated water in the second cycle complied with NDWQS limits, the first cycle's pH exceeded the permissible range. This discrepancy may be attributed to the ceramic material's alkaline components, such as calcium carbonate (Mellor et al., 2013). Additionally, the leaching of minerals like alumina or zeolites in some ceramic filters can impact water pH (Sobsey et al., 2008). The buffering action of the ceramic filter may have contributed to the slight pH increase in the filtered water (Mellor et al., 2013). However, we did not assess the chemical composition of the ceramic filter to state with confidence.

Turbidity: In the first cycle, raw water with turbidity ranging from 5 to 25 NTU was used, while in the second cycle, water with turbidity below 5 NTU was employed. All filter brands efficiently removed turbidity in both cycles, consistently meeting the NDWQS limit (>5 NTU), except on the seventh day of the first cycle when an anomaly occurred. Although all filter brands showed higher turbidity than the NDWQS limit on that day, the levels remained lower compared to the raw water (Figure 5). This aligns with findings by Sagara (2000), who observed similar turbidity removal in a study on point-of-use drinking water treatment in Nepal. Laboratory experiments suggest that candle filters are highly effective in removing

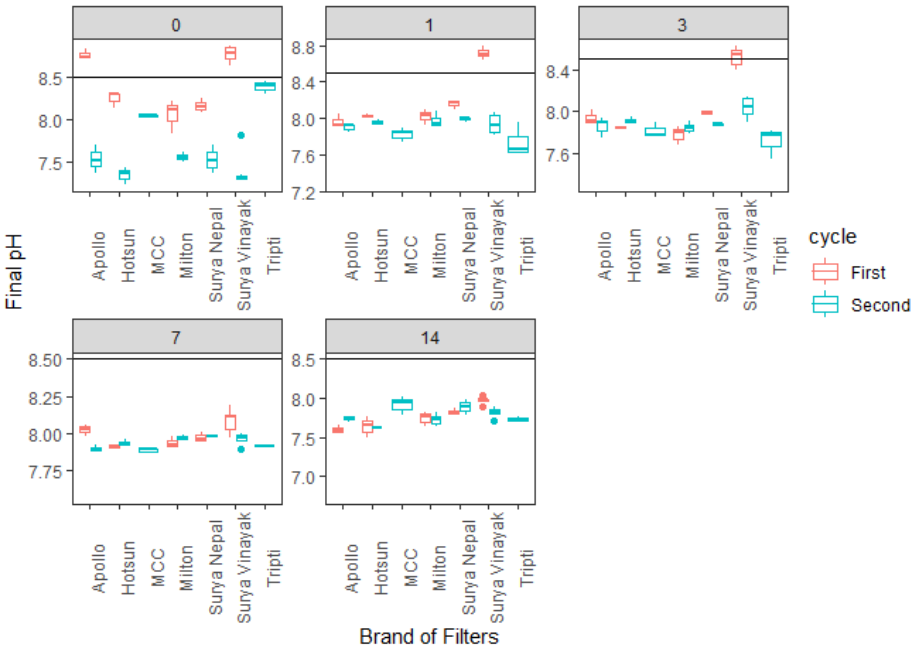

Figure 4: Final pH of Water Sample after filtering. The number on the heading (top of each box) represents the days after cleaning the filter, and the colors represent the cycles.

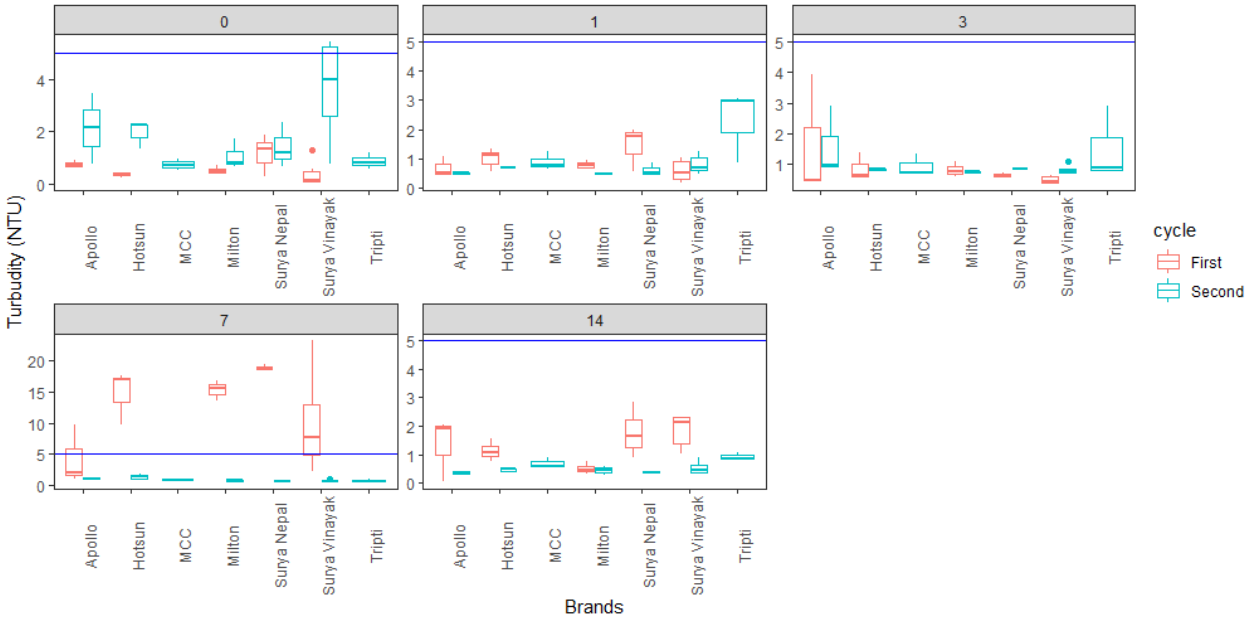

Figure 5: Turbidity of water sample (the scale along y axis is in free scales).

turbidity, achieving 100% removal, and are also capable of removing pathogens due to their pore size being less than 40 nm (Suribabu et al., 2020). The results indicate significant turbidity removal by filter systems, achieving levels less than 1 NTU. The efficiency of candles increases as the days pass by since the pores get clogged and filtration becomes even slower (Sagara, 2000).

Iron content: All studied filter brands demonstrated effective removal of iron content from raw water in both cycles when water with iron content ranging from greater than 0.3 mg/l up to 3.5 mg/l was used. However, an exception occurred on the seventh day of the first cycle when the treated water exceeded the NDWQS limit of the maximum concentration of 0.3 mg/l, as illustrated in Figure 6 below. This anomaly might be due to the fact that the raw water samples used on that day for the first phase contained unusually higher level of pollutions along with its dissolved iron, which we can also observe in the figure. In addition, candle filters don't have 100% iron removal efficiency (Zereffa & Bekalo, 2017; Bulta & Micheal, 2019), as iron in dissolved (ferrous) form may pass through the filter unless it is precipitated. The primary mechanism for iron removal is aeration, wherein the aeration of water leads to the oxidation of ferrous iron by oxygen, resulting in the formation of precipitation (Mazzei, 2011).

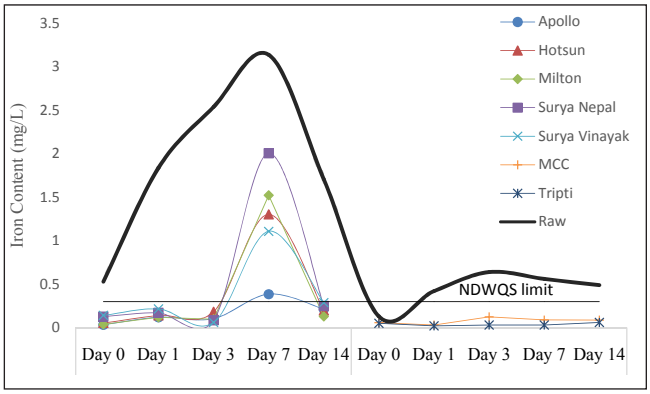

Figure 6: Iron content in raw and filtered water.

Total Coliforms and *E. coli*: All studied ceramic filter brands significantly reduced total coliforms and *E. coli* in filtered water compared to raw water. However, in most cases, the filtered samples exceeded the NDWQS limit for microbial parameters (Figure 7 and Figure 8). In the first cycle, where raw water had very high levels of total coliforms and *E. coli*, reductions in total coliforms were within the Very High Risk (VHR) level. For Apollo, most samples exhibited an intermediate risk level for *E. coli*, while all samples from Milton fell into the high-risk level zone. In the second cycle, with low turbid water as raw water, bacteriological load was lower than in the first cycle. As raw water microbial concentration decreased, total coliform and *E. coli* concentrations ranged from High Risk (HR) level to Low Risk (LR) level.

By the end of the second cycle, when bacteriological concentration in raw water was in the high-risk level range, most filter brands reduced total coliform and *E. coli* to Low Risk to No Risk levels. Calculating the average microbial log reduction for different brands revealed that MCC achieved the maximum log removal for both bacteriological parameters, while Surya Nepal showed the minimum reduction. Among non-silver-coated filters, Apollo exhibited the highest reduction for both bacteriological parameters (Table 3).

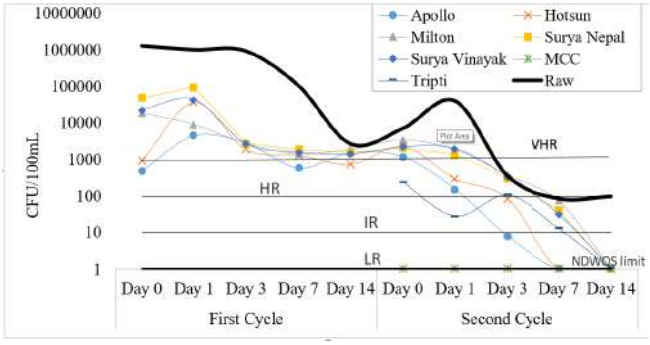

Figure 7: Total coliform in raw and filtered water. (VHR – very high risk, HR- High Risk, IR – Intermediate Risk, and LR- Low Risk)

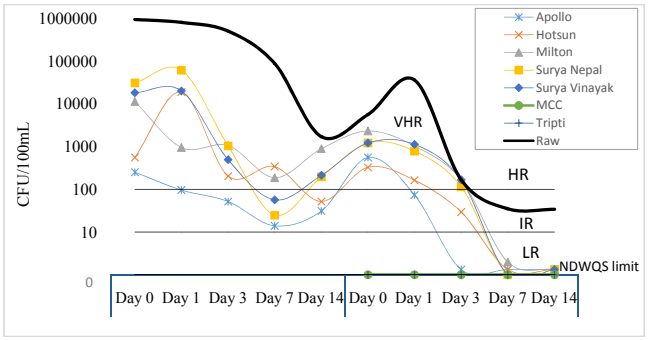

Figure 8: *E. coli* in raw and filtered water (VHR – very high risk, HR- High Risk, IR – Intermediate Risk, and LR- Low Risk)

Table 3: Average log reduction of total coliform and E. coli

Brands	Log reduction in Total coliform removal	Log reduction in *E. coli* removal
Apollo	2.01	2.64
Hotsun	1.79	2.22
Milton	1.33	1.66
Surya Nepal	1.26	1.65
Surya Vinayak	1.34	1.80
Madhyapur Clay Craft	2.99	2.72
Tripti	2.33	2.72

Conclusion

The markets in Kathmandu and Surkhet feature various non-silver-coated (non-CS) filters, with some organizations independently producing and promoting silver-coated (CS) filters. Regarding the enhancement of physio-chemical parameters in treated water compared to raw water, ceramic candle filters prove effective in efficiently reducing turbidity and iron content below the maximum NDWQS limit. However, challenges arise in rare conditions, particularly when raw water exhibits high turbidity and iron content.

In terms of microbial removal, both CS and non-CS filter brands exhibit significant reductions in microbial concentration but often fall short of meeting the NDWQS requirement of 0 CFU/100mL for E. coli and total coliform. Yet, when microbial concentration is relatively low, below 100 CFU per 100mL, silver-coated ceramic candle filters demonstrate complete removal of microbial contaminants. The anti-bacterial properties of silver in CS filters, in addition to potential blockage prevention, contribute to the thorough elimination of total coliforms and E. coli in treated water.

Flow rates for all filter brands were consistently less than one liter per hour per candle in most cases. Flow rates are dependent on the turbidity of raw water, as higher turbidity leads to pore blockage in candles, causing reduced flow rates. The use of low turbidity water is crucial to achieving maximum and consistent water volume, reducing cleaning intervals, and enhancing the durability of candles.

Data Availability Statement

The data presented in this study are available upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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ANNEXES

ANNEX-I: Available filter brands, frequency and price

Thirteen brands of ceramic candle filters were identified through a purposive questionnaire survey in major markets in Surkhet and Kathmandu Valley. Five of the most commonly available and cost-effective brands—Apollo, Hotsun, Milton, Surya Nepal, and Surya Vinayak—were selected for the efficiency study (Table 4).

Table 4: Frequency and price of available ceramic candle filters in Kathmandu and Surkhet

	No of Shops			Price (NRs)		
Filter Brands	Kathmandu	Surkhet	Total	Min	Max	Mean
Surya Vinayak	4	15	19	1050	1450	1129
Milton	10	7	17	1050	1660	1321
Surya Nepal	5	6	11	1050	1350	1164
Apollo	4	1	5	1050	1400	1263
Hotsun	0	1	1	1100	1100	1100
Famous Nepal	5	0	5	1100	1350	1230
Puro	2	0	2	1900	2100	2000
Natural	1	0	1	1300	1300	1300
Perfect	2	0	2	2450	2800	2625
Youwe	2	0	2	2600	2800	2700
Maharaja	0	3	3	6000	6000	6000
Saga	0	1	1	6080	6080	6080
Tulip	0	1	1	1050	1050	1050

ANNEX-II: Efficiency of microbes, turbidity and iron removal

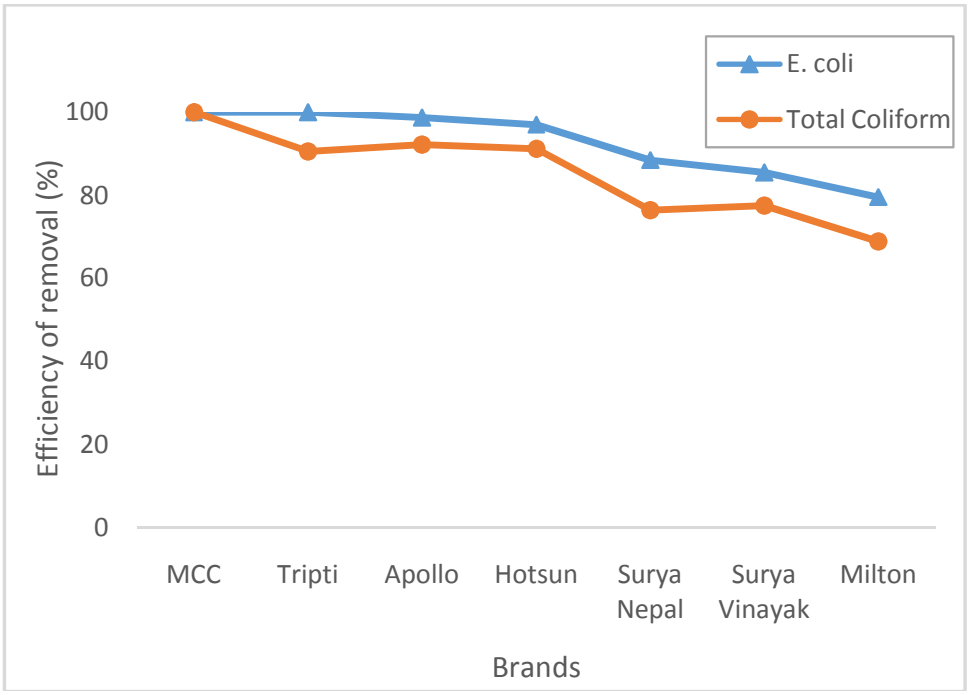

Figure 9: Efficiency of microbial removal

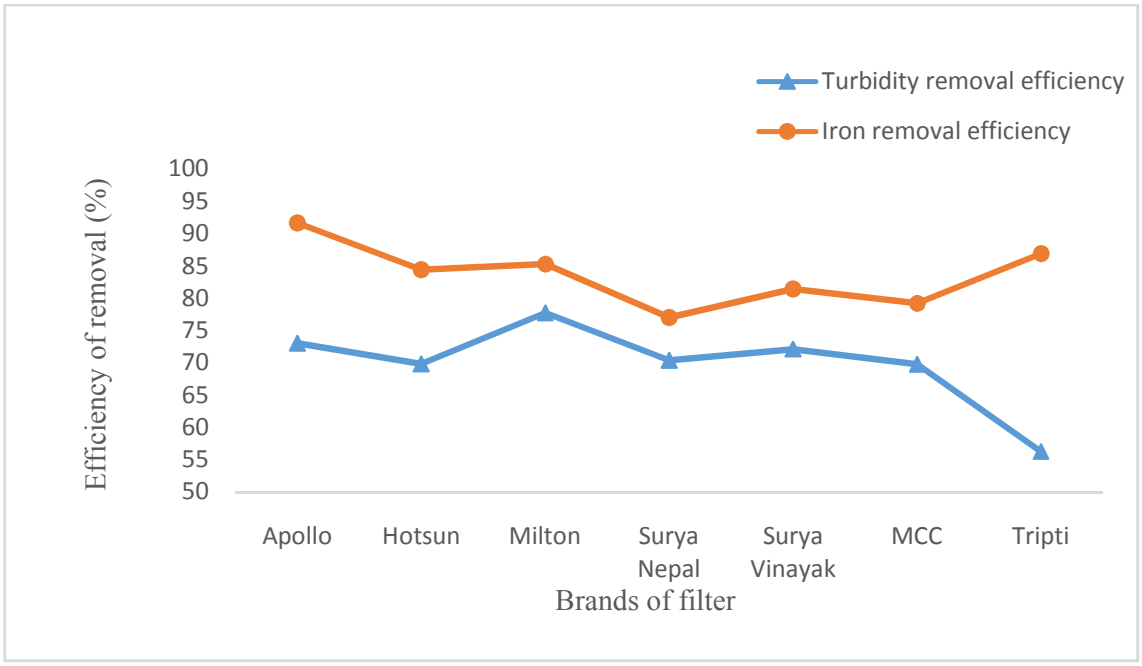

Figure 10: Efficiency of iron and turbidity removal

ANNEX-III: Relationship between iron content and turbidity in the filtered water

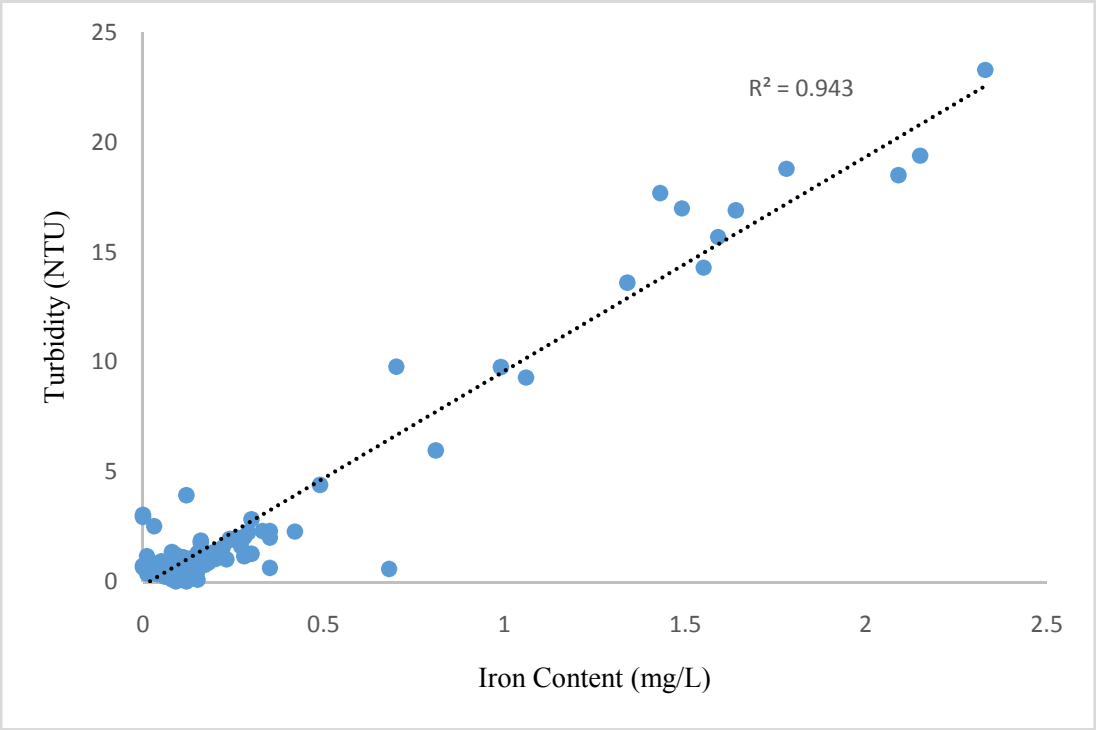

Figure 11: Relation between turbidity and iron content in filtered water

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Tree Regeneration Status in Community Forests of Mid Hills, Nepal

Dipak Khadka[1,2,3], Dinesh Raj Bhuju[4,5], Prakash Chandra Aryal[2,3] and Narendra Raj Khanal[7]
[1] Guangdong Key Laboratory for Innovative Development and Utilization of Forest Plant Germplasm, College of Forestry and Landscape Architecture, South China Agricultural University, Guangzhou, China
[2]GoldenGate International College, Tribhuvan University, Kathmandu, Nepal
[3]Environment Protection and Study Center (ENPROSC), Kathmandu, Nepal
[4]Nepal Academy of Science and Technology, Kathmandu, Nepal
[5]Resources Himalaya Foundation, Kathmandu, Nepal
[6]Central Department of Geography, Tribhuvan University, Kathmandu Nepal
*Correspondence: d.khadka@goldengate.edu.np

Abstract

Tree regeneration is one of the determinant factors for forest sustainability. We assessed the regeneration status of tree species in the four selected community forests of subtropical hills in Lamjung District, central Nepal. We laid 30 square plots (400 m^2, 50 m^2, and 4 m^2) to collect vegetation data and recorded 23 tree species, with seedlings 53,583 individuals/ha, saplings 3,273 individuals/ha and trees 892 individuals/ha. Among the studied community forests, Kirtipur Community Forest had the fairest regeneration with seedlings, i.e., 58,438 individuals/ha. Tree DBH showed the value of the shape parameter of Weibull (c) > 1, supporting 'mound-shaped' distribution, indicating a newly regenerated forests with a possibility of attaining sustainable regeneration. The proportion of seedlings showed a good response to medium grazing, trampling, and litter collection. Protecting adult trees with higher DBH is essential to maintain continuous regeneration.

Key words: *Community forest, himalaya, nepal, regeneration, seedling*

Introduction

The regeneration of trees has been a topic of discussion among researchers (Ceccon et al., 2004; García et al., 2020; Khurana & Singh, 2001). Regeneration in plants is a natural phenomenon of forming new generations in their communities (Wang et al., 2008) and forest regeneration pattern helps to understand the management and conservation status of the forests (Eilu & Obua, 2005; Vieira & Scariot, 2006; Wale et al., 2012). The assessment of phytosociological characters, plants' floristic composition, structure, development, and distribution (Poore, 1995), helps to understand the regeneration status of trees (Foster, 1980; Harper, 1977; Lykke, 1993; Saxena et al., 1984).

Plant regeneration depends on the survival and growth of seedlings and saplings (Good & Good, 1972; Mishra et al., 2013). Density, relative density, frequency, and important value index can provide insights of the phytosociological character of the forests (Sheikh, 2017). Similarly, number of seedlings, saplings, and adult trees also provide the idea on the status of the regeneration of trees (Ballabha, 2014; Pokhriyal et al., 2010). A diameter size class distribution diagram based on the survivorship curve is often used to assess the regeneration of mature trees (Leak, 1964; West et al., 1981), as Buchholz and Pickering (1978) reveal that population growth in plants is more dependent on DBH size than on age. Researchers have suggested a reverse J-shaped DBH size-class distribution for undisturbed forests with sustainable regeneration and a bell-shaped DBH size-class distribution for disturbed forests with poor regeneration (Bernadzki et al., 1998; Saxena et al., 1984). Environmental factors affect tree regeneration at local and regional scales (Sheil, 1999; Ramirez-Marcial et al., 2001). People near the community forests use forest areas for grazing their cattle and collect litter from the forests, creating disturbances like grazing, trampling, and litter, which in turn affect vegetation regeneration (Malik et al., 2016). Grazing pressure might cause failure of natural regeneration (Stern et al., 2002; Teich et al., 2005) and trampling affects the

regeneration of plants directly through physical damage and soil erosion and indirectly through low seed production (Tonnesen & Ebersole, 1997).

There are several studies conducted in community forests of Nepal to present their status, including regeneration of trees, for instance, Oli & Subedi (2015), Paudyal (2012), and Sapkota et al. (2009). However, those studies were either species-focused (viz. *Shorea robusta*) or carried out in the Terai region of Nepal. We did this study in the community forests of sub-tropical mid-hills in Madhya, Nepal. We prepared the database on the regeneration of tree species in the four community forests at various levels of disturbances, and this work is expected to benefit forest user groups of studied CFs.

Materials and Methods

Study area

The study was conducted in four community forests of two villages, namely, Jita and Tandrang-Taksar, in Madhya Nepal Municipality of Lamjung District of central Nepal (Figure 1). Altogether, we sampled 30 plots (Table 1) dominated by *Shorea robusta*, except for one (Pisti CF). The average maximum temperature of this area is 26.67°C, and the average

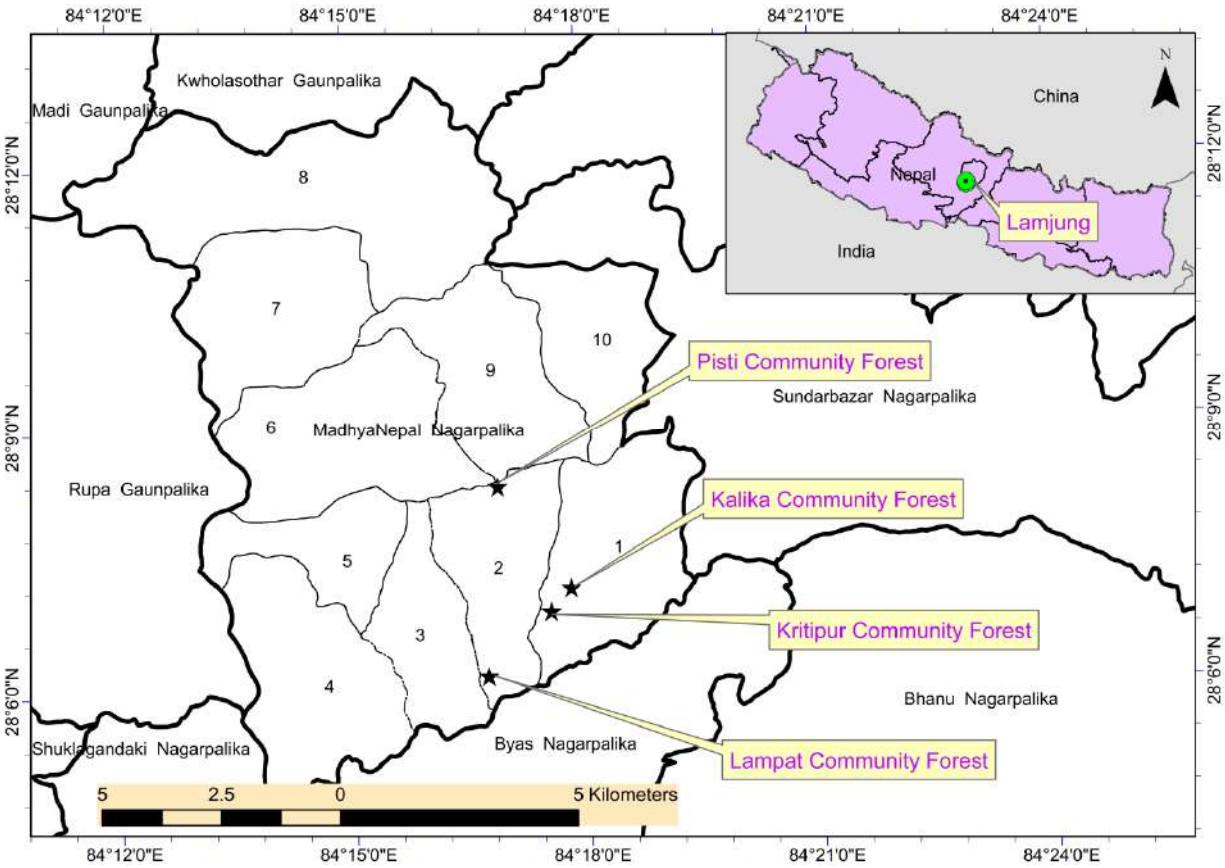

Figure1. Study sites, Lamjung, Nepal

Table 1: General characteristics of the studied community forests in Lamjung

Village	Community Forest	Area (ha)	Survey Plots	Altitude (masl)	Dominant Tree	Users (Hh)
Jita	Kalika	37.26	6	700 - 900	*Shorea robusta*	54
	Kirtipur	66.45	8	600 - 800	*Shorea robusta*	154
Tandrang-Taksar	Pisti	30.00	6	1050 - 1300	*Castanopsisindica*	38
	Lampat	84.27	10	500 - 650	*Shorea robusta*	260

minimum temperature is 14.08°C. The average annual rainfall is 2944.23mm (DFO, 2016).

A total of 30 stratified (based on community forest) random plots, each of size 400 m^2 that accounts for 0.56% of the total forest area (217.98 ha), were placed to sample the vegetation. Individuals of tree species, encountered in the sample plots, were divided into three growth stages: trees (DBH>5cm), saplings (DBH<5cm, height > 1.37 cm), and seedlings (height < 1.37cm), similar to Timilsina et al. (2007). In each plot all the individual trees were counted, the DBH (measured at 137 cm above the ground) and height were measured. Saplings were counted in two opposite corners (5m x 5m) of each plot (400m^2). Seedlings were counted in 1 m^2 quadrats at all four corners (1m x 1m plots= 4m^2). Tree DBH and height were measured using DBH tape (Keson, D18646) and clinometer (Suunto PM-5/360 PC Clinometer, accuracy 1/4°) respectively. The state of grazing, trampling, and litter cover were estimated visually and were categorized into high, medium, and low based on the sign presence percentages in the sample plots viz. (1-33.33% low, 33.33-66.66% medium, and 66.66-100% high).

Data analysis

The frequency, density, basal area, Importance Value Index (IVI) of adult trees was determined by adopting the methods described by Kent (2016). The Shannon index developed by Shannon and Weiner (1949) is employed for the estimation of species diversity.

Shannon diversity Index (H') = -Σ Pi. ln (Pi)

Where,
H' = Species Diversity Index
Pi = proportion of the species Pi = ni / N
N = total importance value of plants
ni = importance value of each species

The summary of the DBH of trees of each community forest was calculated by using R (R Core Team, 2018) . Skewness was calculated by using Bowley coefficient of skewness (Zar, 1999):

$$\text{Skewness} = \frac{(Q3 + Q1 - 2Q2)}{(Q3 - Q1)}$$

Where,
Q3: Third quartile
Q1: First quartile
Q2: Second quartile (median)

The DBH of adult trees was grouped into different size class starting from lower DBH size 5 cm with the interval 10 cm in successive classes. Two parameter Weibull distribution was fitted to the DBH of trees (Weibull, 1951).

$$f(D) = \frac{c}{b}\left(\frac{D}{b}\right)^{1/c} e^{-e\left(\frac{D}{b}\right)^{c}}$$

Where,
f (D) = probability density function
D = Weibull's variate (DBH with D1, D2, ……., Dn of sample size n)
b = Scale parameter of Weibull distribution
c = Shape parameter of Weibull distribution

Changing the shape parameter (c) Weibull distribution can model wide varieties of data (Bailey & Dell 1973; Nord & Cao, 2006) such as;

If,
c = 1, Exponential distribution
c < 1, Inverse J shaped distributions
c > 1, mound shaped distributions, in which if c = 2, Rayleigh distribution, c= 3.6, Equal to normal distributions and c = 1 to 3.6, Positively skewed (right skewed) and c > 3.6, Negatively skewed (left skewed)

We followed Shankar (2001) to assess the regeneration status of trees (Table 2)

Table 2: The criteria used for assigning the regeneration status of trees.

Description	Regeneration Status
Number of seedlings > saplings > adults regeneration	Good regeneration (GR)
If number of seedlings > or < saplings < adults	Fair regeneration (FR)
If the species occupied only as sapling life forms, there are no seedlings (Number of saplings may be more, less or equal that of adults)	Poor regeneration (PR)
If individuals of species were present only in adult form,	No regeneratio (NR)
New regeneration or not abundant (NA)	If individuals of species had no adults only occupy in seedlings or saplings.

The Shapiro test was performed to test the normality of the variables of interest. Kruskal-Wallis test was performed to test the differences of seedling presence in relation to the extent of disturbance.

Results and Discussions

Results

We recorded 23 species of trees (18 species at the adult stage, 14 species at the sapling stage, and 11 species at the seedling stage). *Shorea robusta, Schima wallichii,* and *Castonopsis indica* had higher densities than other species. The trees of *S. robusta* had higher population density, i.e., 413 ha^{-1}, basal area 6,009.52m^2, and relative basal area 73.8%, although *S. wallichii* had the higher frequency (30%). The other species, except *S. robusta, C. indica, and S. wallichii,* had lower population density, i.e., 61.67ha^{-1}, basal area of 44.99 m^2, and relative basal area of 0.56%. The IVI value of *S. robusta* was the highest (144.06) compared to other species (Table 2). The adult tree's Shanon diversity index (H') was 0.03.

Forest Wise Regeneration Status of Trees

The average number of seedlings, saplings, and adults in all four studied forests (in 30 plots) were 53,583 individuals/ha, 3,273 individuals/ha, and 892 individuals/ha with the coefficient of variation (C.V) 39.07%, 49.07%, and 45.5%, respectively. Among the four community forests, Kirtipur CF had the most number of adults (969 individuals/ha)), saplings (3,500 individuals/ha)) and seedlings (58,438 individuals/ha). The Pisti CF had the least number of adults (771 individuals/ha), saplings (2200 individuals/ha) and seedlings (41667 individuals/ha) (Figure 2).

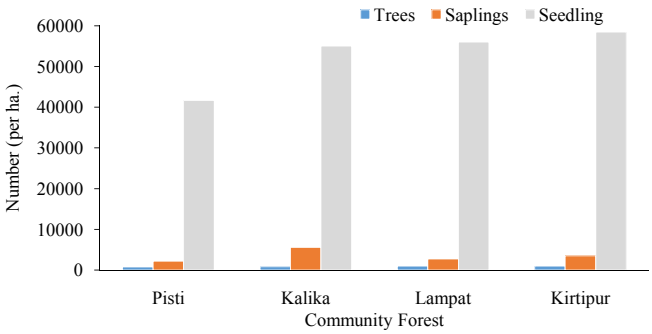

Figure 2. Comparison of tree regeneration in the studied community forests

The mean DBH of adults was higher in Kalika Forest compared to Kirtipur, Lampat, and Pisti, respectively (Table 3). The Bowely coefficient of skewness was observed more in adults of Lampat CF than in Kirtipur, Kalika, and Pisti. The DBH size class diagram showed a higher number of adults in size class 5-15 cm. The Weibull shape parameter for DBH was obtained between 1 and 2, showing a right-skewed diagram (Figure 3). The value of the Weibull shape parameter was higher in Kirtipur CF and lower in Lampat CF, whereas the value of the scale of Weibull was observed highest for Kalika CF and the lowest for Pisti CF (Table 5). The probabilities of densities in different sites were found to be different from each other (Figure 4).

Table 4: Summary Statistics of DBH (cm) of adults in different community forest

Parameters	Kalika	Kirtipur	Lampat	Pisti
Mean	17.76	16.84	15.53	13.53
Max.	68	65	113	74
Min	5	5	5	5
Q_1	6	8	6	6
Q_2	13	13	9	10.6
Q_3	25	21.75	22	15
Bowely coefficient of skewness	0.26	0.27	0.63	-0.02

Table 3: Phytosociological character of major adult tree species found in the studied community forests in Lamjung

Parameter/ Species	*Shorearobusta*	*Castanopsisindica*	*Schimawallichii*	Other species
Tree Density (ind.ha^{-1})	413	238	181	62
Relative Tree Density (%)	46	27	20	7
Tree Frequency	24	22	30	24
Basal Area of Tree (m^2) ha^{-1}	5008	667	1074	37
Relative Basal Area of Tree (%)	74	10	16	1
Importance Value Index IVI	144	58	66	31

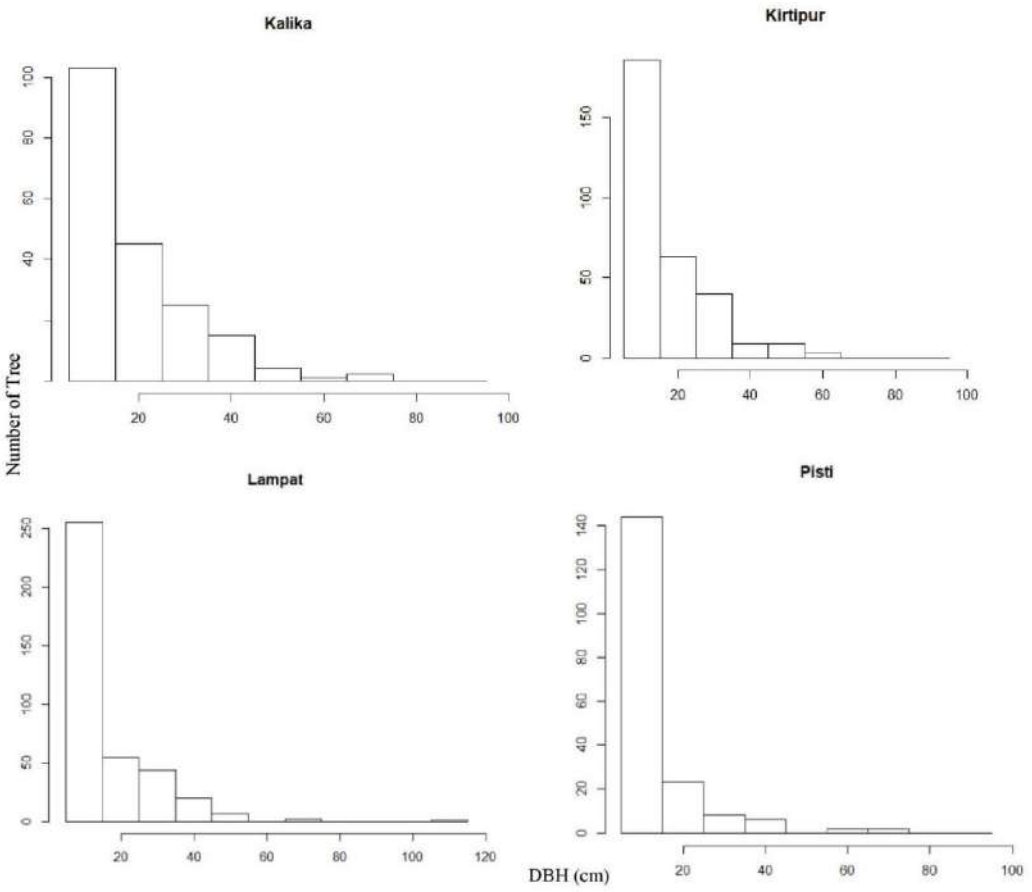

Figure3: Diameter at breast height (cm) size class of adults in the community forests of Lamjung.

Table 5: Shape and scale parameters (with standard errors) of Weibull distribution for different CFs.

Community Forest	Shape (c)	Scale
Kalika	1.38 (0.08)	19.59 (1.07)
Kirtipur	1.57 (0.07)	18.93 (0.73)
Lampat	1.31 (0.05)	16.81 (0.7)
Pisti	1.41 (0.07)	15.06 (0.84)

Species wise Regeneration

Out of the total species recorded (Table 3), only six species of the trees have all three stages, i.e., seedling, sapling, and adult; five species had no adult stage, nine species had no sapling stage, and 12 species had no seedling stage plants. Among the 23 tree species recorded, *S. robusta*, *S. wallichii*, and *C. indica* have fair regeneration status, whereas *Pinus roxburghii, Mucuna macrocarpa, Ajuga bracteosa,* and *Lagerstroemia parviflora* had no saplings and seedlings, i.e., no regeneration at all.

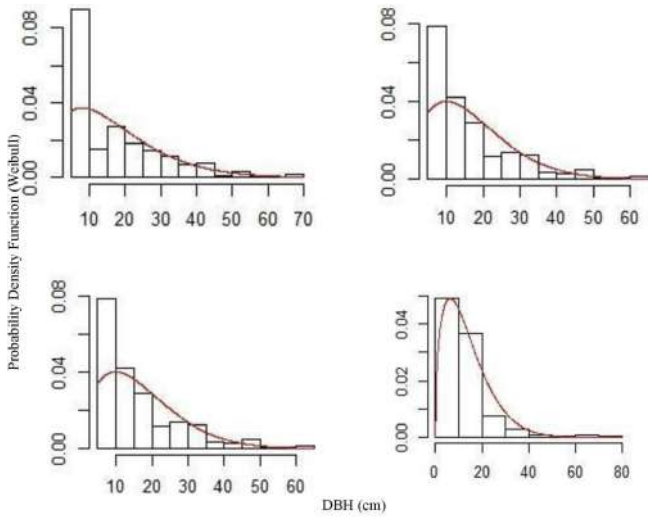

Figure 4: Probability Density Function for Weibull Distribution plotted with DBH classes (Kalika, Kirtipur , Lampat and Pisti respectively from top left side to down right)

Table 6: Regeneration status of the tree species found in the studied community forests in Lamjung.

Scientific Name	Local Name	Family	Adult ha^{-1}	Sapling ha^{-1}	Seedling ha^{-1}	Regeneration Status
Shorea robusta C.F. Gaertn	Sal	Dipterocarpaceae	413	1367	28833	Good
Schima wallichii (DC.) Choisy	Chilaune	Theaceae	181	320	5667	Good
Castanopsis indica A.DC.	Kattus	Fagaceae	238	1253	15833	Good
Engelhardia spicata Lechen ex Blume	Mauwa	Juglandaceae	4	73	417	Good
Myrica esculenta Buch.-Ham. ex D.Don	Kafal	Myricaceae	1	27	333	Good
Mesua ferrea L.	Phalame	Clusiaceae	9	27	416	Good
Adina cordifolia (Roxb.) Brandis	Pakhale	Rubiaceae	16	7	None	Poor
Pinus roxburghii Sarg.	Salla	Pinaceae	12	None	None	No
Mucuna macrocarpa Wall.	Buldhangro	Fabaceae	1	None	None	No
Mallotus philippensis (Lam.) Müll.Arg.	Sindhure	Euphorbiaceae	2	None	None	No
Fraxinus floribunda Bunge ex A. DC.	Lakuri	Oleaceae	1	13	None	Poor
Morus indica L.	Simal	Moraceae	1	None	None	No
Neolamarckia cadamba (Roxb.)	Kadam	Rubiaceae	3	None	None	No
Falconeria insignis Royle	Khirro	Euphorbiaceae	8	7	None	Poor
Lagerstroemia parviflora Roxb.	Botdhangero	Lythraceae	2	None	None	No
Toona ciliata M.Roem.	Tuni	Meliaceae	1	None	83	Fair
Trichilia connaroides (Wight & Arn.) Bentv.	Aakhatare	Meliaceae	1	67	None	Poor
Ficus glaberrima Blume	Pakhuri	Moraceae	3	None	83	Fair
Rhus chinensis Mill.	Bhakimlo	Anacardiaceae	None	20	None	New
Diospyrosex sculpta Buch.-Ham.	Tendu	Ebenaceae	None	60	1583	New
Casearia graveolens Dalzell	Barkamle	Flacourtiaceae	None	None	250	New
Syzygium cumini (L.) Skeels	Jamun	Myrtaceae	None	27	83	New
Quercus lanata Sm.	Phalat	Fabaceae	None	7	None	New

Seedling and Disturbances

The plot level seedling numbers significantly differed for different disturbance intensities, grazing, and trampling (Table 5). Medium trampling, grazing, and litter presence have responded well to the number of seedlings. High grazing and trampling intensities have not shown a good response to the number of seedlings, whereas high litter has shown a good response to seedlings, but the response is less compared to medium grazing intensity. Low grazing, trampling, and litter have not shown a good response to a number of seedlings in comparison to medium grazing, trampling, and litter (Figure 5)

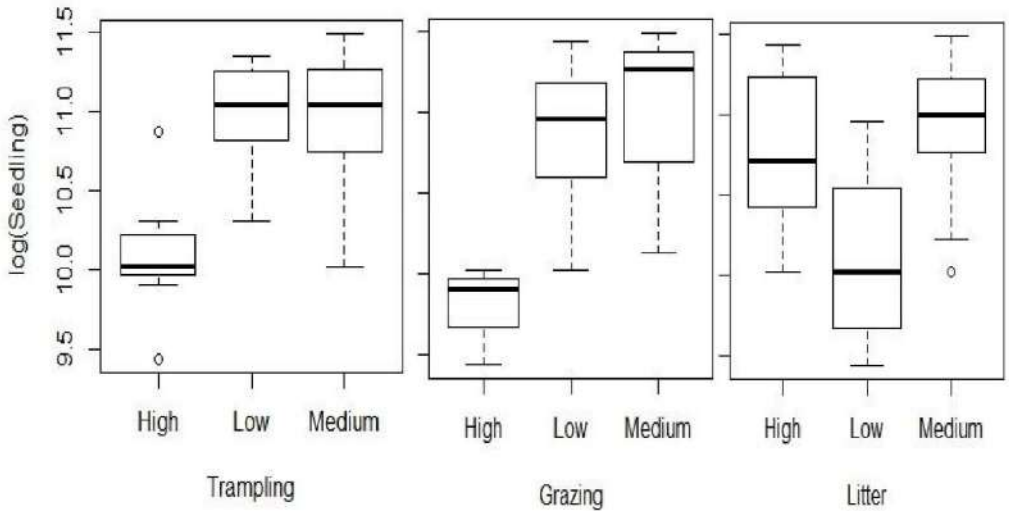

Figure5. Difference between seedling density and disturbance levels

Table 7: Seedling presence with respect to intensity of trampling, grazing and litter cover

Variable	x^2	d.f	P-value
Grazing	7.921	2	0.019
Litter	5.071	2	0.079
Trampling	11.812	2	0.003

Discussions

We found low tree richness and diversity similar to the other studies in *Shorea robusta*-dominated subtropical forests of Nepal (Chapagai et al. 2021;DFRS, 2015; Stainton, 1972). The *S. robusta*-dominated forests have acidic to neutral soils with a carbon content of 0.11 to 1.8%, which might limit the diverse tree species (Gangopadhyay, 1990). The management strategy plays a fundamental role in the composition of trees in Forests (Dhamala et al. 2023; Oli & Subedi, 2015). The *S. wallichii* and *Castonopsis indica* do not have good wood either, and the domestic animals do not prefer to eat their leaves, but their wood can be used for fuelwood; therefore, their densities are higher after *S. robusta*. Domestic animals prefer to eat the leaves of species like *Fraxinus floribunda* and *Ficus glaberrima,* leading to the low density of these species. In community forests, people also introduced some new species as a management strategy, such as *Toona ciliata, Neolamarckia cadamba,* and *Pinus roxburghii,* through different plantation programs. Besides the significant species *S. robusta*, *C. indica*, *S. wallichii,* and other species, *Fraxinus floribunda,* and *Ficus glaberrima,* have an essential role in improving the livelihood by providing fodder to the cattle and maintaining diversity. Therefore, CF management should focus on conserving these species and improving their densities to gain long-term benefits.

The seedling, sapling, and adult density indicated the overall regeneration is fair. This could be attributed to the spatial condition and *S. robusta* dominated forest properties (Mishra & Garkoti, 2016; Sapkota & Oden, 2009). The C.V. of the vegetation stages- adult, sapling, and seedling indicated that adult numbers are more consistently distributed than seedlings and saplings in the studied plots. This indicated that some sites need more care for growing seedlings and saplings to maintain stability in regeneration.

The community forests support livelihood by providing timber, fuelwood, fodder, and grasses in rural areas of Nepal. The livelihood and spatial arrangement of both forests and settlements, and local socio-economic conditions influence the forest resource utilization reflected by state of seedlings, saplings, and trees in community forests. Higher slope and altitude of the Pisti CF might have caused fewer adults, saplings, and seedlings than in the other forests (Bhandari et al., 2000; Sapkota & Oden, 2009). Moreover, Pisti CF is near the Gurung ethnic community, which uses diverse forest products compared to other local groups, resulting in a low number of adult status of trees in this forest. The concentration of people affects forest dependency (Illukpitiya, 2006), and disparities in socioeconomic conditions, values, beliefs, goals, and preferences have influence on the forest (Adhikari et al., 2004). This will change resource use conditions (Cavendish, 2000) and forest structure.

The Pisti CF does not have a population of *S. robusta* trees, whereas all the remaining 3 CFs have *S. robusta.* As a result, all forests have more seedlings and saplings than this forest. The Kalika CF is near the village with more disturbed sites, resulting in lower tree density. The Lampat CF is near the village, but some interventions like tree enrichment and forest management activities such as thinning and cleaning might have helped to support the number of trees. The Kirtipur CF is far from settlement compared to others; it has medium disturbances, which might have resulted in more standing trees (Cierjacks et al., 2008). Besides these, forest management practices might also have influenced the number of adult trees in the forest (Ujhazy et al., 2017).

This study found more tree in 5-15 cm DBH size class in all four CFs studied, indicating that forest user group activities have supported the regeneration of trees, similar to the other community forests of subtropical Nepal (Maharjan et al., 2006). There was a low number of large DBH-size classes, which might be due to the disturbances in the past before the formation of the community forestry program (Acharya, 2002). The value of the shape parameter of Weibull is (c) above one supported mound shape

diameter distribution, and the Weibull's shape parameter estimate lower than 3.6 confirmed right skewness of diameter distribution curves (Husch et al., 2003; Nord-Larsen & Cao, 2006) for all the studied community forests. The shape of Weibull (c) distribution for DBH indicates that Lampat CF has a good regeneration status compared to Kalika CF, Pisti CF, and Kirtipur CF respectively. None of the studied forests have attained a reverse J-type curve, so the management should focus on managing population strata. This result indicates that the community forestry program in the studied area is on the path to success in improving the forest's population structure. Locals can use the information on the diameter distribution of adult trees to strengthen the forest management through different interventions (Sapkota et al., 2018) to ensure more trees reach larger size class.

The presence of seedlings and saplings compared to adults is fundamental to knowing the regeneration status of trees. Among the recorded species, 6 had good regeneration, 2 had fair, 4 had poor, 5 had new regeneration and 6 had no regeneration status. *S. robusta*, *S. wallichii*, and *C. indica* were naturally growing species; their seedling and saplings did not reflect high disturbance in the community forests. *S. robusta* is a tree protected in Nepal and might have experienced low disturbances, especially from cutting and felling, in the community forests (Paudyal, 2012). Some disturbance activities, such as selective logging introducing new species, were also evident in the study area and might have supported more seedlings of natural species like *S. robusta*. As no seedling or saplings of *P. roxburghii*, *M. macrocarpa*, *N. cadamba*, and *L. parviflora* were recorded, the regeneration of these species is bleak, at least for the next few years (Brendler & Carey, 1998).

The anthropogenic and ecological factors determine the forest structure and composition (Dolezol & struck 2008). Regeneration is one of the significant factors that is important to show forest structure and composition. Different natural and anthropogenic disturbances like fire, landslide, trampling, grazing, and litter collection occur in nature. Medium disturbances support the regeneration of trees, whereas low disturbances and high disturbances lower the regeneration, which is evident in a study in Bardia National Park of Nepal at elevation 153 m to 1,247 m (Napit & Paudel, 2015). We found a good response from seedlings with medium trampling, grazing, and litter, similar to other studies (Bhuju, 1998). It is also evident that intermediate disturbances support the regeneration of trees in tropical forests (Bongers et al., 2009; Mayor et al., 2012). The community forest groups and forest managers can maintain the intermediate disturbances in the forest through thinning, cutting of branches, and other interventions that will promote the regeneration status of the trees in the forest.

Conclusion

We recorded a total of 23 tree speices, with only 18 species at the adult stage, 14 at the sapling stage, and 11 at the seedling stage. *Shorea robusta*, *Castonopsis indica,* and *Schima wallichii* were the dominant species. The number of seedlings indicated a fair regeneration status of the trees. Kirtipur CF had the highest, and Pisti CF had the lowest tree regeneration. Tree species such as *Pinus roxburghii, Mucuna macrocarpa, Fraxinus floribunda, Morus indica, Neolamarckia cadamba, Lagerstroemia parviflora, Toona ciliata, Trichilia connaroides* and *Ficus glaberima* had neither saplings nor the seedlings. The poor regeneration of these species indicate either higher disturbances or simply a lack of care and inappropriateness of the forest conditions for healthy regeneration. Some species, such as *Casearia graveolens,* had only the seedlings, indicating that they were newly introduced species in the area. The diameter size class diagrams indicated that tree regeneration in all the forests is on the path to maintaining a good population structure of trees in the future, if present situation persists. New regeneration, namely, seedlings are seen to fare better in medium-level grazing, trampling, and litter cover. Therefore, a balanced intervention for growing the forest to ensure more adult-staged trees for a balanced population structure, and at the same time promoting the survival and growth of minor species to promote the tree diversity in the forest is recommended.

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Energy Recovery from Municipal Solid Waste by Production of Refuse Derived Fuel

Luna Thapa[1], Krishna Raj Shrestha[1,2], Tejendra Regmi[1] Haikam Ghising[3]
[1]Central Department of Environmental Science, Tribhuvan University, Kathmandu, Nepal
[2]Center for Energy and Environment Nepal, Kathmandu, Nepal
[3]Goldengate International College, Tribhuvan University, Nepal
[*]Correspondence: thapaluna1@gmail.com

Abstract

Waste to energy options can present an opportunity for effective waste management and addressing the energy crisis. This study aimed to produce Refuse Derived Fuel (RDF) from combustible Municipal Solid Waste (MSW), primarily plastics and paper. Cylindrical briquettes were manufactured from shredded raw materials using a screw extruder. The study examined the energy content, physical properties, and proximate analysis of the produced RDF. The briquettes exhibited a high calorific value of 6,736 Kcal/kg. Experimentation on briquette combustion was conducted in a pottery kiln in Thimi, Bhaktapur, revealing that RDF outperformed fuelwood both in terms of quality and quantity. The RDF shows promising potential due to its high calorific value and favorable combustion properties when supplied with air. However, the study recommends further analysis of the combustible characteristics of MSW.

Keywords: *Energy content, municipal solid waste,* refuse *derived fuel*

Introduction

Municipal Solid Waste (MSW) consists of combustible and decomposable component with energy potential (Sodari & Nakarmi, 2017). Waste to energy option can be viewed as an opportunity for waste management and resolving the energy crisis. Various methods of energy recovery exist, including anaerobic digestion, gasification, combustion, pyrolysis, refuse-derived fuel (RDF), and landfill gas recovery (Suthapanich, 2014). Research suggests an increasing interest in utilizing fuel derived from municipal solid waste, with the aim of improving environmental pollution management while simultaneously providing sustainable energy resources (Churkunti, 2015). The conversion of waste not only prolongs the lifespan of landfills but also provides alternative energy resources by utilizing the waste (Shrestha & Singh, 2011). In Nepal, plastic waste accounts for 16% of urban waste generation, amounting to 2.7 tons of plastic garbage produced daily (ADB, 2013). Within Municipal Solid Waste (MSW), the heating value of plastic bags can be equivalent to that of kerosene in terms of energy content (Heejoon et al., 2006). In this regard, the production of RDF stands out as one of the waste-to-energy options that can be leveraged to manage waste effectively and address the energy crisis. Utilizing alternative fuels in industries such as cement and brick manufacturing holds significance in conserving fossil fuels and reducing CO_2 emissions (Kara et al., 2009).

The RDF refers to the high calorific fraction derived from processed MSW, which includes materials such as plastics, paper, and other combustible matter (Gallardo et al., 2014). The calorific value of RDF is approximately 4000 Kcal/kg (Thirugnanam & Pragasam, 2014). The RDF is commonly produced through a process involving the sorting, shredding, and pelletizing of MSW to create a dense fuel (Krizan et al., 2011). The RDF is considered a renewable energy source and is utilized as a Clean Development Mechanism (CDM) enhancer to promote sustainable development (Nithikul, 2007). Energy can be extracted directly from solid waste as heat, or the waste can be processed into stable RDF for further utilization. Most of the MSW generated globally consists of paper and plastic materials. These components are particularly efficient in managing high energy content, ignitable elements, and flammability compared to other

waste constituents. By combining these two materials in appropriate proportions and utilizing briquette technology to create compact forms, a fuel alternative to coal can be produced (Psomopoulos, 2014).

Nepal, as a developing nation, faces challenges in effectively managing its municipal solid waste. Environmental concerns are increasingly prominent, particularly in urban areas, where improper utilization of resources and technology exacerbates the issue (Shrestha & Singh, 2011). On the other hand, the widespread use of fossil fuels has led to escalating energy-related issues on a daily basis. Therefore, waste-to-energy could emerge as a significant alternative for recovering and repurposing MSW, often converted into RDF, a form of solid waste fuel. This approach could represent one of the most viable solutions for managing MSW while also partially addressing energy demands. The objectives of this study were to produce RDF and assess its fuel properties and energy potential. It investigates how employing such fuel in a furnace influences combustion and pollution emissions.

Materials and Methods

This study was grounded in experimental research aimed at evaluating energy recovery from Municipal Solid Wase (MSW). A cylindrical shaped sample (Figure 1) from the prepared materials was produced using a screw extruder briquetting machine (Figure 2) at a temperature of 300°C. Plastic proportion was kept optimum up to 50% as per the literature. The prepared briquette (Figure 1) was undergone proximate analysis, energy content and fuel combustion assessments in the laboratory.

The raw materials, including wrappers and papers, were gathered from households and waste transfer stations and transported to the laboratory. Combustible fractions such as packaging plastics, cardboard, newspapers, and noodle wrappers were sorted for use in the briquetting process. Plastic and paper waste were shredded using a shredding machine to reduce them to smaller pieces, ideally less than 5 mm in size. These materials were then mixed in the appropriate ratio using a hammer mill. The RDF was produced from a mixture of plastics (50%) and paper (50%) using a screw extruder briquetting machine at a temperature of 300°C.

Laboratory Analysis

The proximate analysis, which included assessing moisture content, ash content, volatile matter content, and fixed carbon content, was conducted.

Determination of Moisture Content (MC) Test: A porcelain crucible was preheated in an oven at 110°C for 1 hour. And the dish was taken out from the oven and cooled in the Desiccator. 1gm of the sample was weighted into the crucible. The sample was oven-dried at about 110°C for an hour. The weighing was done in mass balance. Then the calculation for Moisture content (MC)

$$\text{MC (\%) of sample} = \frac{\text{Initial wt (g)} - \text{Final wt(g)}}{\text{Initial wt(g)}} * 100$$

Determination of Ash Content (AC) Test: The ash content is the insoluble residual inorganic matter remaining in the sample after combustion. A sample of one gram was weighed into the crucible and heated in the muffle furnace (without lid) for 1 hour at 815°C, after which it was removed and allowed to cool in a desiccator and re-weighted. The incombustible residue constitutes the ash content was calculated as follows.

$$\text{Ash content (\%) of sample} = \frac{\text{Wt of sample after heating (g)}}{\text{Wt of sample taken (g)}} * 100$$

Determination of Volatile Matter Content (VMC): The amount of volatile matter was determined in a muffle furnace by heating closed crucibles (with lid) at the temperature of 900°C for seven minutes. A sample of one gram was weighed into the crucible then contents were heated in the furnace at 900°C for 7 minutes with the lid on. The loss in weight for the volatile matter present in the coal and briquettes were equal to the loss in the weight were calculated as:

Volatile Matter Content =*100

Determination of Fixed Carbon Content: Fixed carbon is the solid combustible residue that remains after a coal particle is heated and the volatile matter is expelled. The fixed-carbon content of coal is

determined by subtracting the percentages of moisture, volatile matter, and ash from a sample.

Fixed Carbon Content (%) = 100- MC (%)- Mean AC (%)-VMC (%)

Determination of Calorific Value: It indicates the amount of heat that is released when the sample is burned. The calorific Value of samples was determined using the Toshniwal Bomb Calorimeter. A Bomb Calorimeter measures the amount of heat generated when materials of a certain mass are burnt in a sealed chamber known as a Bomb provided with an atmosphere of pure Oxygen gas. The heat energy measured in a bomb calorimeter may be expressed either as calories (cal), British thermal units (Btu) or Joules.

Figure 1: Production of Briquette

Figure 2: Screw Extruder

Combustion Test Methods: A test was arranged to examine the combustion characteristics in a double cross-draft kiln. Initially, 2 kg of briquettes were placed in the tray of the combustion chamber. Subsequently, 1 kg of briquettes was consistently added as the temperature inside the insulator chamber increased, reaching up to 700°C. A blower was employed continuously to supply air. Emission readings were recorded after one hour of combustion.

Suspended Particulate Matter (SPM), Carbon monoxide (CO), Carbon dioxide (CO_2), NOx, and SOx were monitored during the experiment. The SPM levels were measured using gravimetric determination, while a Flue Gas Analyzer was employed to measure the other parameters at stack emissions. Stack emission variables were assessed by SMS Environment & Engineering Pvt. Ltd. The average concentration of emissions was measured, with readings taken approximately every 45 minutes.

Results and Discussion

Physical characteristics of fuel

The physical characteristics of the sample briquettes from each production batch were randomly measured to determine density. Table 1 presents the characteristics of RDF.

Table 1: Physical description of RDF

Parameter	Description
Color	Blackish
Shape of Briquette	Hollow Cylindrical
Outer Diameter	40.7 mm
Inner Diameter	19.08 mm
Length	79.5 mm
Weight	0.0479 kg
Density	531.7649 kg/m^3

Fuel Characteristics

The average results of the proximate analysis, obtained from triplicate analyses, are depicted in Figure 3. According to the proximate analysis, the mean moisture content of raw materials (plastics) is low, with plastics at 2.38%, paper at 8.05%, and the briquette samples ranging from 3.04% to 5.16%. The lower moisture content is conducive to enhancing the heating value of the fuel (Krizan et al., 2011).

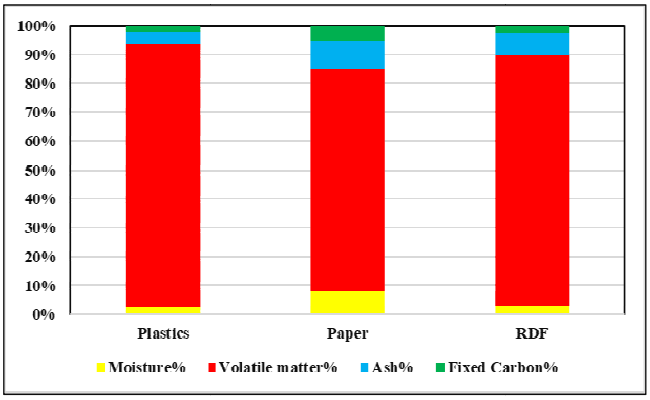

Figure 3: Proximate analysis of Produced RDF

The volatile content of plastics was estimated to be 91.35%, while that of paper was 76.77%. The RDF samples in this study predominantly consisted of volatile matter (VM), ranging up to 84.81%. This finding is consistent with the volatile matter content observed in the RDF sample, which was 81.8% (Akdağ et al., 2016). This indicates that a significant portion of the solid product is converted into gaseous products. It's observed that an increase in volatile matter leads to a decrease in fixed carbon content.

With respect to the ash content of RDF, it represents the residue left behind after combustion. Plastics exhibit a low ash content of 4.24%, while paper has a higher ash content of 9.89%. The produced RDF displayed ash content ranging from 4.24% to 9.92%, consistent with findings of ash content ranging from 2.8% to 9.2% by weight (Kimambo & Subramanian, 2014). The sample containing 70% paper and 30% plastics recorded the highest value of 9.94% by weight. Plastics have a fixed carbon content of 2.03%, while paper has 5.29%. Ash content represents the mass of incombustible materials remaining after burning a given waste sample. It's observed that the ash content of briquettes decreases as the percentage of polyethylene in the briquette composition increases (Akowuah et al., 2012). The material remaining after the volatile components have been driven off is known as fixed carbon. The higher the fixed carbon content of a fuel, the longer the combustion process tends to be. For instance, Ajimara coal contains a fixed carbon content of 63.78%. The high percentage of fixed carbon in waste materials necessitates longer detention times on the furnace surface to achieve complete combustion (Bajracharya et al., 2016).

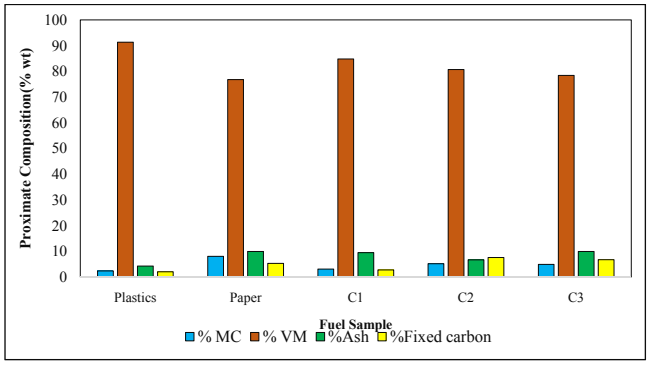

Figure 4: Proximate analysis of Produced RDF

The results depicted in the graph (Figure. 4) illustrate the overall proximate differences among the fuel samples. Parameters such as moisture content, ash content, volatile matter, and fixed carbon can offer valuable insights into the combustibility of the MSW (Zhao et al., 2016).

Calorific Value

The calorific values of polyethylene and paper samples were determined in the laboratory using a Digital Bomb Calorimeter (Figure. 5). The calorific value of the sample briquettes in the RDF varied from 6,789.15 Kcal/kg to 5,694.96 Kcal/kg, which is comparable to the calorific value range of 6,474 kcal/kg to 5,085 Kcal/kg (Kimambo & Subramanian, 2014). Moreover, the energy content of waste depends on its composition. RDF is comparable to coal with a minimum value used in electricity production in India, which is typically around 4,000 Kcal/kg (Thirugnanam & Pragasam, 2014). Similarly, the results obtained for all briquettes closely align with literature data for the coal used in Vertical Shaft Brick Kilns (VSBK), which typically has a calorific value of 7,168 Kcal/kg in its boulder form (Bajracharya et al., 2016). Studies conducted in Japan, India, and Germany have shown that pellets produced from waste materials have calorific values ranging between 12-20 MJ/kg. It's noteworthy that many of these countries are utilizing such pellets for electricity and heat production (Hlaba et al., 2017). According to Hlaba et al. (2017), solid waste typically possesses a calorific value ranging from 11-17 MJ/kg or even higher. Hence, it is highly recommended for use as RDF.

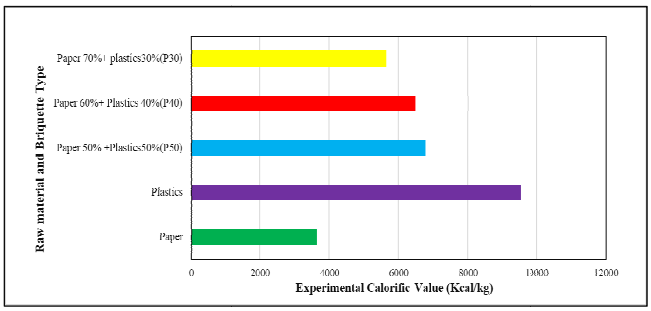

Figure 5: Calorific Value of the Sample

Combustion test

Emissions from the fuel briquettes were evaluated in a pottery kiln equipped with a cross-draft gasifier stove during testing, and stack emissions were recorded. The results include measurements of CO, CO_2, NOx, SOx, and SPM concentrations during various combustion phases, as detailed in Table 2. These results were compared to the national standard for stack emissions in Nepal applicable to brick kilns. The SPM concentration was assessed with an average value of 78.59 mg/Nm^3. It was found that the SPM concentration in pottery kilns was well below the existing standard for brick kilns promulgated by the Ministry of Government, which sets a maximum limit of 250 mg/Nm^3 for SPM emissions (MoFE, 2018).

Table 2: Test Result of Stack Emission

Parameters	Measured Value
Suspended Particulate Matters (SPM)	78.57 mg/Nm^3
CO_2	5.3%
CO	0.22%
NOx	14.4 mg/Nm^3
SOx	<0.02 mg/Nm^3

Conclusion

The quality of RDF hinges on key fuel parameters such as calorific value, proximate analysis, and combustion characteristics. RDF exhibited a high calorific value, low moisture content, high volatile matter, and low fixed carbon. Emission levels indicated an increase in CO emissions, while average permissible levels of SPM, NOx, and SOx were observed. The produced RDF could potentially be utilized for industrial applications with appropriate air pollution control technology. The study results suggest that combustible municipal solid waste could serve as an energy recovery option to address waste management challenges. Further investigations could focus on detailed combustion characteristics, efficiency, and fuel-to-air ratio optimization.

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Enhancing Water Quality in Biu, Borno State, Nigeria: Impact of Storage Duration on Sachet Water

K. M. Sabo, A. C. Salihu*, I. J. Dibal and N. N. Ubachukwu
Department of Environmental Management, Faculty of Environmental Sciences, Nigerian Army University, Biu, Nigeria
*Correspondence: salihu.chado@naub.edu.ng

Abstract

Concerns about expiry date and the purity of sachet water sometimes become evident after it has been stored for a long period. This study aimed at assessing the effects of storage duration on physicochemical and microbial parameters of some selected sachet water sold in Biu Local Government Area of Borno State, Nigeria. Four different sachet waters were sampled (A B C and D), for their physicochemical and microbial parameters using laboratory analysis by standard analytical procedures to ascertain the storage duration variation and the level of compliance with the National Agency for Food and Drug Administration and Control (NAFDAC) and World Health Organization (WHO) standards specification for drinking water. The results reveal that most of the parameters such as pH, turbidity, total dissolved solids, nitrate, dissolved oxygen, manganese, iron, salinity, total hardness and alkalinity, within 24 hours, 1 month, and 2 months of production vary and, has meet levels of standards that is set by the WHO and NAFDAC, except few parameters. Only phosphate exceeded the standards within 24 hours, 1 month, and 2 months of production, but for microbial, all the parameters for each sample A, B, C, and D and storage duration within 24 hours, 1 month, and 2 months of production has a wider increase respectively, and they exceeded the levels of standards set by WHO and NAFDAC. The increase in microbial counts over time suggests deterioration in water quality during storage, highlighting the need for improved sanitation practices, stricter quality control measures, and regular monitoring to ensure safety of sachet water throughout its shelf life.

Keywords: *Effect, quality, sachet water, storage duration, world health organisation*

Introduction

Access to clean and safe drinking water is a fundamental human right crucial for sustaining life and promoting public health. However, in many parts of the world, including Biu, Borno State, Nigeria, challenges persist in ensuring the availability of potable water, leading to the proliferation of alternative sources such as sachet water. Sachet water, also known as "pure water," has become a popular choice for quenching thirst and meeting daily hydration needs due to its affordability and convenience, particularly in regions with limited access to clean water infrastructure. While sachet water provides a readily available source of drinking water, concerns have been raised regarding its quality, especially after prolonged storage. The storage conditions and duration of sachet water before consumption can significantly impact its microbiological and chemical quality, potentially compromising its safety and suitability for human consumption.

Sachet water, a brand of packaged water has become the most widely consumed liquid for both the rich and the poor in Nigeria, it is the brand of choice to everyone because it is a cheaper alternative to the bottled brand, considered to be the refreshment of the affluent Hygiene, purity, tastes, and, most importantly, safety is probably amongst various reasons for sachet water consumption. Unfortunately, the problems of its purity and health concerns have begun to manifest (Oladipo, Onyenike, and Adebiyi, 2019). The commodity known as sachet water was introduced to the Nigerian market around year 1990 and started attracting nationwide attention from 2000 when the NAFDAC registered 134 different packaged water producers, this led to the emergence and proliferation of private water enterprises that operated side by side with

the government-owned public water utilities (Ezemonye and Akintokun, 2017). Sachet water is regulated as a food product in Nigeria by National Agency for Food and Drug Administration and Control (NAFDAC), the agency relies on World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) standards for the product regulation, registration and certification, there has been a tremendous improvement in sachet water regulations by NAFDAC as the number of illegal producers has drastically reduced and most brands on sale now have NAFDAC registration (NAFDAC, 2018).

Sachet water is not completely sterile, since it may not be entirely free of all infectious microorganisms, the potential danger associated with sachet water is contamination, which is a factor of the source of the water itself, treatment, packaging materials, dispensing into packaging materials and sealing (Omalu et al., 2010). Under prolonged storage of packaged water at favorable environmental conditions, total aerobic heterotrophic bacteria, indicators of fecal contamination and fecal coliforms can grow to levels that may be harmful to humans (Warburton et al., 2022). Total aerobic heterotrophic bacterial counts are sensitive and practical indicators of water treatment efficiency as well as after-growth and biofilm formation, some of the total aerobic heterotrophic bacteria have been identified as opportunistic pathogens (Warburton et al., 2022). These microorganisms can be found in source waters and in treated drinking water (Mustafa et al., 2012). Thus, consumption of water containing large numbers of total aerobic heterotrophic bacteria can lead to diseases such as gastroenteritis and mucous membrane infections particularly in persons whose immune systems are compromised by AIDS, organ transplantation or chemotherapy (WHO, 2019). The physical and chemical contaminants can easily be prevented at the pre-production stages, but the microbial contaminants need a disciplined effort sustained by a high level of hygienic sanitation (Aroh et al., 2013; Sapkota et al., 2021). Generally, the application of good manufacturing and automated process (GMAP) guidelines will reduce to the barest minimum the level of defects found in such products, most impurities in packaging water originate from the raw water, but may persist in the purified water due to poor or inadequate purification techniques extrinsic contaminants however emanate from the environments in which the water is produced or the container (Omalu et al., 2010). The provision of an adequate supply of safe drinking water was one of the eight components of primary health care, identified by the International Conference on Primary Health care (Edema, Atayese, and Bankole, 2014).

Several studies have investigated the microbiological quality of sachet water in various Nigerian cities, highlighting significant microbial contamination issues. Adamu et al. (2018) conducted a study in the Gusau Metropolis, Zamfara State, revealing concerning levels of microbial contaminants in sachet water brands. Similarly, Olawoyin et al. (2020) assessed sachet water quality in the Ilorin Metropolis, observing microbial contamination as a prevalent issue. These findings underscore the urgent need for interventions to address microbial risks associated with sachet water consumption in Nigeria. In addition to microbiological concerns, studies have also examined the physicochemical characteristics of sachet water, including changes during storage. Adelodun et al. (2019) investigated the effects of storage conditions on the microbiological and physicochemical qualities of packaged water, revealing a deterioration in water quality with prolonged storage. Ajanaku et al. (2017) reported similar findings, noting declines in pH levels and dissolved oxygen content in sachet water over time. These studies highlight the importance of considering storage duration as a critical factor influencing sachet water quality. Moreover, research has explored specific geographic areas within Nigeria to assess sachet water quality and identify local challenges. Eze et al. (2018) evaluated sachet water sold within the Federal University of Technology, Owerri campus, revealing microbial contamination issues. Similarly, Olaoye and Onilude (2018) conducted a quality assessment of sachet-packaged drinking water brands in Ilorin Metropolis, emphasizing the need for stringent quality control measures.

However, despite these studies' insights, widespread availability and consumption of sachet water in Biu, Borno State, Nigeria, with concerns persisted

regarding its microbiological and chemical quality, particularly after prolonged storage. Thus, this research aims to investigate the impact of storage duration on the microbiological and chemical quality of sachet water in Biu, Borno State, Nigeria. By assessing various parameters such as microbial load, pH levels, dissolved oxygen content, and chemical contaminants. The findings of this study hold significant implications for water quality management strategies in Biu, Borno State, Nigeria and other similar settings facing challenges in ensuring access to safe drinking water.

Materials and Methods

Study area

Biu is a town and a Local Government Area (LGA) in southern Borno State of Nigeria (Figure 1). The town is the administrative center of the LGA which is located at latitude N10°36'18" and longitude E12°9'2.76804" with altitude 685meters above sea level (Dibal et al., 2021). The town was once the capital of the Biu kingdom, and is now capital of the Biu Emirate. Biu lies on the Biu Plateau at an average elevation of 626 meters the region is semi-arid (Bukar 2019). The name of Biu was initially called Viu which in Babur and Bura Language means high, the Biu kingdom became established around 1670 in the reign of Mari Watila Tampta, King Mari Watirwa (1793–1838), whose capital was near Biu at Kogu, defeated Fulani invaders from the Gombe Emirate to the west (Bukar 2019).

Sample and Sampling Procedure

The sampling frame for this study consist of total number of sachet water factories which were ten (10) in numbers were identified by the researcher in the study area. Those factories that were having NAFDAC certification, constitute the sample size, and is consistent with the work of Duru et. al. (2017). One bag of sachet water was collected from each of the (4) selected sachet water firms that has a valid NAFDAC registration number. The water samples were collected immediately after production from their geographical location as shown in (Fig.1). In order to ensure that the samples

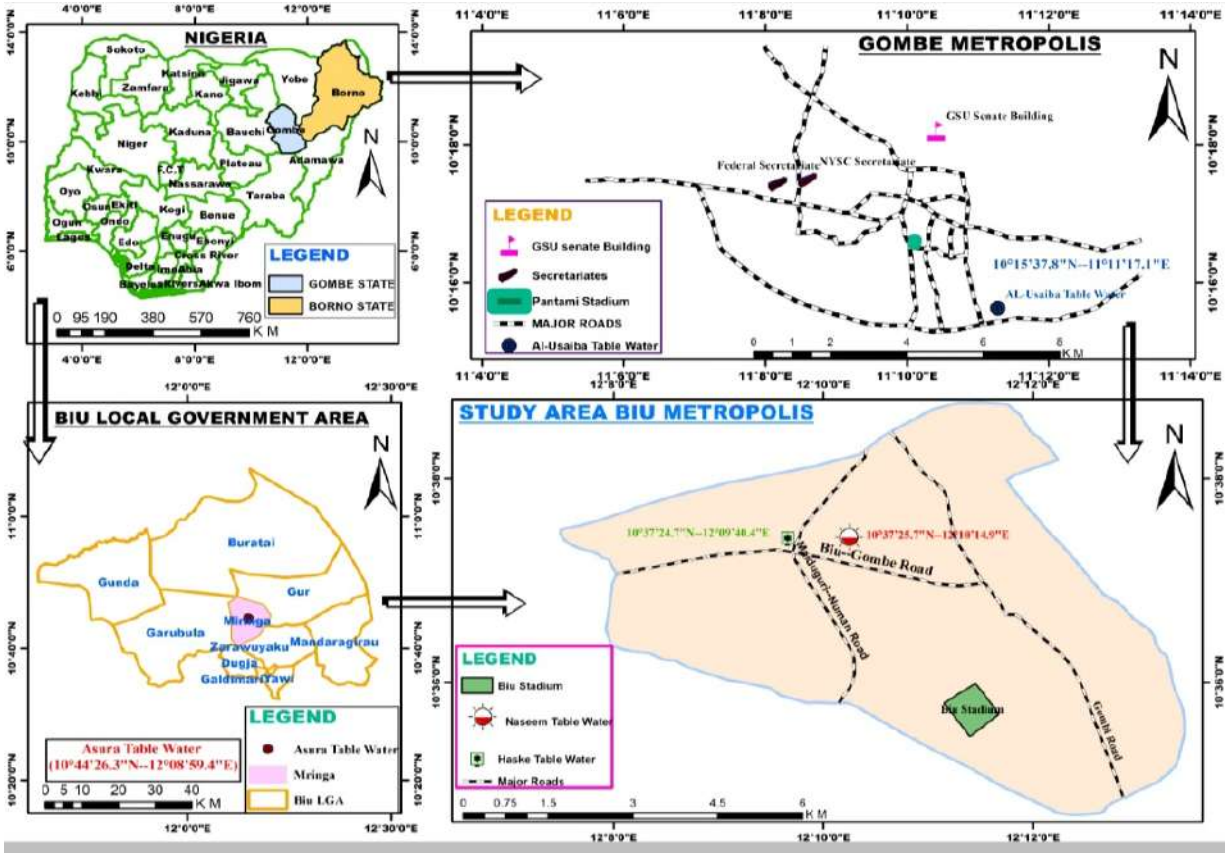

Figure 1: The Study area

were representative of the sachet water produced by each firm, a random sampling method was used, nine sachets water sample were selected from each bag and are divided into 3 different samples for each brand and each 1 sample from the 3 samples were then analyzed respectively in the laboratory within 24 hours of production, after 1month of storage, and after two months of storage.

Laboratory Analysis Procedure

The study collected sachet water samples from brands with NAFDAC certification. The samples were collected within 24 hours of production and stored in a room at ambient temperature for 2 months. Three laboratory tests were performed on the samples, including a test of the samples physico-chemical parameters and microbiological parameters. The first laboratory test within 24 hours of production was conducted on July 17, 2023. The second laboratory test was conducted after 1 month of storage, on August 17, 2023. The third and final laboratory test was conducted after 2 months of storage, on September 18, 2023. The physicochemical and microbial parameters include; pH, turbidity, total dissolved solids (TDS), *E. coli*, electrical conductivity (EC), nitrate (NO_3^-), total phosphate (PO_4), sulfate (SO_4^{2-}), and dissolved oxygen (DO) (Pant et al., 2018; 2021). Additionally, the research measured total coliform count, sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), manganese (Mn), iron (Fe), salinity, total hardness (TH), biological oxygen demand (BOD), and alkalinity (Adhikari et al., 2020). All laboratory tests were conducted at the Gombe State University Biochemistry Laboratory, Gombe State, Nigeria.

For ethical reasons, the study concealed names of the sachet water brands selected (Ojekunle, et.al, 2015). Samples were labeled as A, B, C, and sample D, in which sample A represent ASURA, sample B represent AL-Usaiba, sample C represent NASEEM and sample D represent HASKE. The equipment used are Flame Photometer (Jenway), A.A.S (BUCK205), UV/VIS (CE7000), Colony Counter. The Physico-chemical, microbial parameters were all analyzed using the above-mentioned equipment, with procedures as explained in AOAC official methods of analysis (1990).

Results and Discussion

Physicochemical and Microbial Parameters of Sampled Sachet Water

Results of the laboratory analysis of sachet water quality of various sampled brands are presented in Table 1.

Table 1: Laboratory test of physicochemical and microbial analysis of samples

Parameters	Sample A			Sample B			Sample C			Sample D		
	24Hrs	1Mth	2Mths	24Hrs	1Mth	2Mths	24Hrs	1Mth	2Mths	24Hrs	1Mth	2Mths
pH	7.25	7.85	7.19	7.12	7.82	7.57	7.29	7.25	7.23	7.84	7.45	7.02
EC	34.00	35.00	37.00	55.33	47.33	48.43	81.33	80.33	70.58	312.33	312.37	113.84
TDS	16.00	17.00	18.66	26.67	24.67	24.10	39.67	36.67	35.24	153.00	101.00	56.70
Salinity	0.08	0.18	0.10	0.13	0.27	0.10	0.18	0.16	0.10	0.72	0.42	0.20
Turbidity	0.41	0.61	0.45	0.35	0.85	0.34	0.47	0.44	0.51	0.95	0.45	1.03
TH	37.00	47.00	88.00	45.00	28.00	44.00	62.00	67.00	68.00	81.00	98.00	116.00
DO	5.17	2.17	4.02	6.26	7.06	4.84	5.93	5.00	4.24	5.45	4.45	3.92
BOD	4.25	4.85	2.17	3.31	2.91	2.65	3.66	2.64	2.04	2.89	2.86	2.80
Alkalinity	5.65	5.85	5.20	2.50	2.44	5.40	6.30	7.30	5.25	8.50	7.50	6.50
NO_3^-	1.27	1.77	1.85	4.64	7.64	4.44	6.29	6.79	2.59	15.49	17.47	13.33
PO_4	0.63	0.63	1.49	0.42	0.92	2.09	0.75	0.55	3.61	3.25	4.25	5.02
SO_4^{2-}	0.86	1.86	0.39	3.56	6.56	0.39	2.84	3.84	0.82	1.41	2.41	3.22
Na^+	2.86	2.46	1.56	5.33	5.53	4.19	9.65	9.45	8.73	21.43	22.43	19.39
K^+	0.92	0.90	0.62	1.06	2.06	1.16	1.56	1.87	1.84	6.59	7.52	7.21
Ca^{2+}	0.34	0.54	0.25	0.65	0.60	0.46	3.26	3.86	2.47	8.68	6.68	6.57
Mg^{2+}	0.51	1.51	0.59	0.87	0.77	0.63	7.33	7.83	5.26	11.34	14.34	9.59
Mn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.15	0.06
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.43	0.04
T. coliform	91	127	164	77	101	178	123	197	232	160	202	301
E. coli	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present

The variations in each sample across the storage durations do not follow a consistent pattern of either increasing or decreasing from 2 hours to 2 months of storage. Different parameters show different trends across the storage durations, and these trends vary from sample to sample. In sample A, pH fluctuates but generally remains within a narrow range. EC, TDS, salinity and turbidity show slight increases over time. TH increases significantly over time. DO decreases over time. BOD fluctuates but generally decreases over time. Alkalinity fluctuates but remains relatively stable. NO_{3-}, PO_4, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+} show varying trends over time, some increasing, some decreasing. As for sample B, pH, EC, TDS, salinity and turbidity exhibit similar trends to sample A. TH shows a decreasing trend over time. DO initially high and remains relatively stable. BOD varies but shows a decreasing trend overall. Alkalinity shows fluctuations similar to sample A. NO_{3-}, PO_4, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+} show varying trends over time (Table 1). Sample C on the other hand established pH, EC, TDS, salinity, turbidity and alkalinity fluctuate but remain relatively stable. TH shows variations but remains relatively stable over time. DO, BOD fluctuate but show no clear trend over time. NO_{3-}, PO_4, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+} show varying trends over time (Table 1). While in sample D, pH: shows significant variations over time. EC, TDS, salinity, turbidity show substantial increases over time. TH: Shows a significant increase over time. DO: Decreases over time. BOD fluctuates but generally decreases over time. Alkalinity varies but remains relatively stable. NO_{3-}, PO_4, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+} show varying trends over time (Table 1). In general, parameters like pH, EC, TDS, salinity, and turbidity largely increase over time in sample D and to some extent in samples A and B. TH tends to increase over time in samples A and D. DO tends to decrease over time in samples A and D. BOD shows a decreasing trend in most samples. Alkalinity fluctuates but generally remains stable across all samples. The presence of ions varies across samples and storage durations. Overall, the trends in parameters from 24 hours to 2 months of storage vary across samples and parameters, with some showing increasing trends, some decreasing, and others remaining relatively stable.

Furthermore, analysis of samples A to D reveals dynamic trends in physicochemical parameters and microbial presence over varying storage durations. Consistent with similar studies like Asante et al. (2020) and Saha et al. (2020), fluctuations in pH were observed, likely influenced by factors such as biological activity and mineral dissolution. Increases in electrical conductivity (EC) and total dissolved solids (TDS) align with findings indicating potential mineral leaching or anthropogenic inputs (Rahman et al., 2019). The decrease in dissolved oxygen (DO) over time reflects microbial respiration and organic matter decomposition, corroborating literature on water quality dynamics (Hoque et al., 2017). Presence of coliform bacteria and *E. coli* in all samples underscores concerns regarding microbial contamination, consistent with previous research on waterborne pathogens (Shamsudduha et al., 2021). It also, corroborate with Duru et al., (2017) study on storage and its effect on chemical quality indicators in sachet water brands. According to their results, pH values increased significantly in all brands after week 8. Moreover, nitrate and dissolved oxygen values decreased throughout the investigation period, while phosphate values increased in all brands tested. However, discrepancies exist with studies like Bain et al. (2018) reporting differing trends in total hardness (TH) and ion concentrations, potentially due to variations in sampling locations, environmental conditions, and anthropogenic influences.

Comparison of Sampled Sachet Water under Different Storage Duration

Comparison of sampled sachet water under different storage duration is presented in Table 2. Analyzing the variations of parameters of samples, A to D under 24 hours of storage reveals insights into the initial quality and characteristics of the sachet water. The pH in sample A, B, and C generally exhibit similar pH levels within the first 24 hours, ranging from 7.12 to 7.29, indicating a relatively neutral to slightly alkaline nature.

Table 2: Comparison of laboratory results of sachet water samples under different storage duration

Parameters	Within 24 hours				After 1 month				After 2 months			
	Sample A	Sample B	Sample C	Sample D	Sample A	Sample B	Sample C	Sample D	Sample A	Sample B	Sample C	Sample D
pH	7.25	7.12	7.29	7.84	7.85	7.82	7.57	7.45	7.19	7.57	7.23	7.02
EC	34.00	55.33	81.33	312.33	35.00	47.33	48.43	312.37	37.00	48.43	70.58	113.84
TDS	16.00	26.67	39.67	153.00	17.00	24.67	24.10	101.00	18.66	24.10	35.24	56.70
Salinity	0.08	0.13	0.18	0.72	0.18	0.27	0.10	0.42	0.10	0.10	0.16	0.02
Turbidity	0.41	0.35	0.47	0.95	0.61	0.85	0.34	0.45	0.45	0.34	0.51	1.03
TH	37.00	45.00	62.00	81.00	47.00	28.00	44.00	98.00	88.00	44.00	68.00	116.00
DO	5.17	6.26	5.93	5.45	2.17	7.06	4.84	4.45	4.02	4.84	4.24	3.92
BOD	4.25	3.31	3.66	2.89	4.85	2.91	2.65	2.86	2.17	2.65	2.04	2.80
Alkalinity	5.65	2.50	6.30	8.50	5.85	2.44	5.40	7.50	5.20	5.40	5.25	6.50
NO_3^-	1.27	4.64	6.29	15.49	1.77	7.64	4.44	17.47	1.85	4.44	2.59	13.33
PO_4	0.63	0.42	0.75	3.25	0.63	0.92	2.09	4.25	1.49	2.09	3.61	5.02
SO_4^{2-}	0.86	3.56	2.84	1.41	1.86	6.56	0.39	2.41	0.39	0.39	0.82	3.22
Na^+	2.86	5.33	9.65	21.43	2.46	5.53	4.19	22.43	1.56	4.19	8.73	19.39
K^+	0.92	1.06	1.56	6.59	0.90	2.06	1.16	7.52	0.62	1.16	1.84	7.21
Ca^{2+}	0.34	0.65	3.26	8.68	0.54	0.60	0.46	6.68	0.25	0.46	2.47	6.57
Mg^{2+}	0.51	0.87	7.33	11.34	1.51	0.77	0.63	14.34	0.59	0.63	5.26	9.59
Mn	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.06
Fe	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.43	0.01	0.00	0.00	0.04
T. coliform	91	77	123	160	127	101	197	202	164	178	232	301
E. coli	Preset	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present

However, sample D stands out with a higher pH of 7.84, potentially suggesting differences in the water source or processing methods. EC and TDS in samples A, B, and C demonstrate comparable levels of EC and TDS within the first 24 hours, suggesting similar levels of dissolved substances. Sample D, however, shows significantly higher EC and TDS values, indicating a potentially higher concentration of dissolved solids or contaminants. Salinity levels across samples A to D are relatively low within the first 24 hours, with values ranging from 0.08 to 0.72 (Table 2). Sample D again stands out with the highest salinity, potentially indicating differences in the mineral composition or source water quality. Turbidity levels vary slightly across samples A to D within the initial 24 hours of storage, with values ranging from 0.35 to 0.95. Sample D shows the highest turbidity, suggesting differences in the level of suspended particles or sedimentation. Total coliform counts and *E. coli* presence vary across samples, with Sample D showing the highest counts, indicating potential differences in microbial contamination levels. Overall, while samples A, B, and C generally exhibit similar characteristics within the first 24 hours of storage, Sample D consistently stands out with higher values across multiple parameters. These variations suggest potential differences in water quality, source, processing, or storage conditions, highlighting the importance of individual sample analysis and quality control measures in ensuring the safety and suitability of sachet water for consumption.

Furthermore, the variations in parameters under one month of storage indicate changes in water quality, with Sample D consistently exhibiting the most significant deviations (Table 2). These changes could result from various factors such as microbial growth, chemical reactions, or environmental influences, highlighting the importance of regular monitoring and quality control measures to ensure the safety of sachet water for consumption. Also, disparities in parameters under two months of storage highlight significant changes in water quality, with Sample D consistently showing the most pronounced deviations. The differences observed in the results of samples A to D under varied storage duration reflect dissimilarities in the quality and characteristics of sachet water, potentially influenced by factors such as source water quality, processing methods, and storage conditions. Comparisons with similar studies provide valuable

insights into these differences and contribute to a better understanding of packaged water quality dynamics. pH variations among samples A to D indicate potential differences in acidity or alkalinity levels, which can affect water taste and safety. Studies by Amoah et al. (2015) and Rahman et al. (2019) have also reported pH variations in packaged water, suggesting the influence of factors such as source water composition and storage conditions on pH levels. Electrical Conductivity (EC) and Total Dissolved Solids (TDS) differences across samples suggest variations in water purity and contamination levels. This finding aligns with studies by Hoque et al. (2017) and Asante et al. (2020), which have reported differences in EC and TDS values among different brands or sources of packaged water, indicating potential disparities in water quality standards. Salinity differences indicate variations in mineral composition or contamination levels among samples A to D. Similar studies by Ahmed et al. (2018) and Shamsudduha et al. (2021) have reported differences in salinity levels of packaged water, highlighting the influence of source water characteristics and processing methods on salinity levels. Turbidity differences suggest disparities in suspended particle content or sedimentation among samples. This finding is consistent with studies by Osei et al. (2016) and Saha et al. (2020), which have reported variations in turbidity levels among different brands or types of packaged water, indicating potential differences in water treatment and filtration processes. Microbiological parameter differences, such as Total coliform counts and *E. coli* presence, suggest variations in microbial contamination levels among samples A to D. Studies by Bain et al. (2018) and Shafiquzzaman et al. (2021) have similarly reported differences in microbial contamination levels among different brands or sources of packaged water, emphasizing the importance of stringent quality control measures to ensure microbiological safety.

Comparison of Physicochemical and Microbial Parameters of Sampled Sachet Water under Different Storage Duration with NAFDAC and WHO Standards

Table 3-5 respectively depict the comparison of laboratory results of physicochemical and microbial parameters within 24 hours, 1 month and 2 months of storage with WHO and NAFDAC standards for drinking water.

Initially, within 24 hours of storage, all samples exhibited relatively favorable characteristics

Table 3: Laboratory analysis of sachet water within 24 hours of storage in comparison with WHO and NAFDAC standards

Physicochemical and microbial parameters	Sample A	Sample B	Sample C	Sample D	WHO Standard	NAFDAC Standard
pH	7.25	7.12	7.29	7.84	6.5-8.5	6.5-8.5
EC	34.00	55.33	81.33	312.33	1200	1000
TDS	16.00	26.67	39.67	153.00	250-500	500
Salinity	0.08	0.13	0.18	0.72	5.0	5.0
Turbidity	0.41	0.35	0.47	0.95	5-25	5
TH	37.00	45.00	62.00	81.00	100-500	100
DO	5.17	6.26	5.93	5.45	4-6	4-6
BOD	4.25	3.31	3.66	2.89	4	4
Alkalinity	5.65	2.50	6.30	8.50	200	200
NO_3^-	1.27	4.64	6.29	15.49	10-50	10
PO_4	0.63	0.42	0.75	3.25	0.5	0.5
SO_4^{2-}	0.86	3.56	2.84	1.41	200-250	100
Na^+	2.86	5.33	9.65	21.43	200	200
K^+	0.92	1.06	1.56	6.59	20	20
Ca^{2+}	0.34	0.65	3.26	8.68	100	20
Mg^{2+}	0.51	0.87	7.33	11.34	50	20
Mn	0.00	0.00	0.00	0.05	0.5	0.2
Fe	0.00	0.00	0.00	0.03	1-3	1.0
T. coliform	91	77	123	160	(no/100mL)	(10/mL)
E. coli	Present	Present	Present	Present	Absent	Absent

according to WHO and NAFDAC standards for most parameters. pH, EC, TDS, salinity, turbidity, TH, DO, alkalinity, NO_3^-, PO_4, SO_4^{2-}, and cation concentrations fell within acceptable ranges. However, T. coliform counts were notably high in all samples, and *E. coli* was present, indicating a potential risk of microbial contamination despite meeting other standards.

As it is observable in table 4, upon assessing the samples after 1 month of storage, several parameters remained consistent with the initial analysis.

However, there were some notable changes. For instance, turbidity increased slightly in some samples, albeit still within acceptable limits. While most physicochemical parameters remained within standards, there were slight variations in TDS, DO, BOD, NO_3^-, and PO_4 levels. Importantly, T. coliform counts persisted, indicating a continued risk of microbial contamination. The presence of *E. coli* remained a concern, suggesting that microbial growth or contamination may persist over time.

Table 5 shows comparison of laboratory test result of samples after two months from production of selected water brands. After 2 months of storage, further changes were observed in some parameters. Turbidity showed variations, although still within acceptable limits. Notably, TDS levels decreased in some samples, potentially indicating some form of degradation or dilution over time. However, T. coliform counts increased across all samples, exceeding the initial counts, suggesting a potential deterioration in water quality over extended storage periods. While most physicochemical parameters remained within standards, there were minor deviations in NO_3^-, PO_4, and cation concentrations.

Moreover, comparing the results across the different storage durations reveals important insights. While the sachet water generally meets WHO and NAFDAC standards for physicochemical parameters initially, there are persistent concerns regarding microbial contamination, as evidenced by the presence of T. coliform and *E. coli*. Additionally, slight variations in some physicochemical parameters over time suggest potential degradation or changes in water quality during storage. Consequently, the forgoing findings are in tune with previous similar studies. One such study by Oyeyiola, Adeyemo, & Olutiola (2010) evaluated the microbiological quality of sachet water and found widespread contamination by fecal coliforms, indicating potential health risks associated with consumption. This finding

Table 4: Laboratory analysis of sachet water after 1 month storage in comparison with WHO and NAFDAC standards

Physicochemical and microbial	Sample A	Sample B	Sample C	Sample D	WHO Standard	NAFDAC Standard
pH	7.85	7.82	7.25	7.45	6.5-8.5	6.5-8.5
EC	35.00	47.33	80.33	312.37	1200	1000
TDS	17.00	24.67	36.67	101.00	250-500	500
Salinity	0.18	0.27	0.16	0.42	5.0	5.0
Turbidity	0.61	0.85	0.44	0.45	5-25	5
TH	47.00	28.00	67.00	98.00	100-500	100
DO	2.17	7.06	5.00	4.45	4-6	4-6
BOD	4.85	2.91	2.64	2.86	4	4
Alkalinity	5.85	2.44	7.30	7.50	200	200
NO_3^-	1.77	7.64	6.79	17.47	10-50	10
PO_4	0.63	0.92	0.55	4.25	0.5	0.5
SO_4^{2-}	1.86	6.56	3.84	2.41	200-250	100
Na^+	2.46	5.53	9.45	22.43	200	200
K^+	0.90	2.06	1.87	7.52	20	20
Ca^{2+}	0.54	0.60	3.86	6.68	100	100
Mg^{2+}	1.51	0.77	7.83	14.34	50	20
Mn	0.00	0.00	0.00	0.15	0.5	0.2
Fe	0.00	0.00	0.00	0.43	1-3	1.0
T. coliform	127	101	197	202	(no/100 mL)	(10/mL)
E. coli	Present	Present	Present	Present	Absent	Absent

Table 5: Laboratory analysis of sachet water after 2 months of storage in comparison with WHO and NAFDAC standards

Physicochemical and microbial	Sample A	Sample B	Sample C	Sample D	WHO Standard	NAFDAC Standard
pH	7.19	7.57	7.23	7.02	6.5-8.5	6.5-8.5
EC	37.00	48.43	70.58	113.84	1200	1000
TDS	18.66	24.10	35.24	56.70	250-500	500
Salinity	0.10	0.10	0.10	0.02	5.0	5.0
Turbidity	0.45	0.34	0.51	1.03	5-25	5
TH	88.00	44.00	68.00	116.00	100-500	100
DO	4.02	4.84	4.24	3.92	4-6	4-6
BOD	2.17	2.65	2.04	2.80	4	4
Alkalinity	5.20	5.40	5.25	6.50	200	200
NO_3^-	1.85	4.44	2.59	13.33	10-50	10
PO_4	1.49	2.09	3.61	5.02	0.5	0.5
SO_4^{2-}	0.39	0.39	0.82	3.22	200-250	100
Na^+	1.56	4.19	8.73	19.39	200	200
K^+	0.62	1.16	1.84	7.21	20	20
Ca^{2+}	0.25	0.46	2.47	6.57	100	100
Mg^{2+}	0.59	0.63	5.26	9.59	50	20
Mn	0.00	0.00	0.00	0.06	0.5	0.2
Fe	0.00	0.00	0.00	0.04	1-3	1.0
T. coliform	164	178	232	301	(no/100 mL)	(10/mL)
E. coli	Present	Present	Present	Present	Absent	Absent

resonates with the presence of *E. coli* in Sample D of the current analysis, suggesting ongoing challenges with microbial safety in packaged water products (Oyeyiola, Adeyemo, & Olutiola, 2010). Another study by Oluwale, Falegan, & Adeniyi (2019) examined the physicochemical properties of sachet water in Nigeria, highlighting variations in pH, turbidity, and total dissolved solids among different brands. The compliance of Samples A, B, and C with WHO and NAFDAC standards aligns with findings from this study, indicating that certain sachet water products meet regulatory requirements (Oluwale, Falegan, & Adeniyi, 2019). However, the deviations observed in Sample D, particularly in turbidity and nitrate levels, are consistent with the findings of a study by Babatunde, Efeovbokhan, & Isibor (2018), which reported instances of poor water quality and non-compliance with standards among certain sachet water brands in Nigeria. This underscores the persistent challenges in maintaining consistent water quality across the industry (Babatunde, Efeovbokhan, & Isibor, 2018). Moreover, studies by Okoko et al. (2017) and Adewunmi et al. (2021) have emphasized the importance of regulatory enforcement and monitoring mechanisms to ensure the safety and quality of packaged water products in Nigeria. The compliance of Samples A, B, and C with regulatory standards underscores the effectiveness of such frameworks when implemented adequately (Adewunmi et al., 2021; Okoko et al., 2017).

Conclusion

This study investigates the impact of storage duration on the microbiological and physicochemical quality of sachet water in Biu, Borno State, Nigeria. It is evident from the results that storage duration does have an effect on the sampled sachet water, potentially rendering it unfit for consumption over extended periods. While the physicochemical parameters of the sachet water generally remain within acceptable ranges according to WHO and NAFDAC standards across the different storage durations, there are notable concerns regarding microbial contamination, particularly the presence of T. coliform and *E. coli*. The persistence of T. coliform and *E. coli* in the sachet water samples throughout the storage durations indicates a significant risk of microbial contamination. While the initial levels of these contaminants were concerning, the fact that their counts increased over time, especially after 1 and 2 months of storage, raises serious concerns about the safety of the

water for consumption. High levels of T. coliform and the presence of *E. coli* suggest potential fecal contamination, which poses serious health risks to consumers if ingested. Microbial contamination in drinking water can lead to various waterborne diseases, including gastrointestinal infections, diarrheal diseases, and even more severe illnesses in vulnerable populations such as children, the elderly, and individuals with weakened immune systems. Therefore, the presence of T. coliform and *E. coli* in the sachet water samples, regardless of the storage duration, indicates a significant risk to public health and suggests that the water may be unfit for consumption. While the physicochemical parameters of the sachet water may initially meet regulatory standards, microbial contamination poses a direct threat to the safety of the water. The increase in microbial counts over time suggests potential degradation or deterioration in water quality during storage, highlighting the need for improved sanitation practices, stricter quality control measures, and regular monitoring to ensure the safety of sachet water throughout its shelf life.

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Urban Agriculture in the Kathmandu Valley: Assessing Practices, Impacts, and Challenges for Sustainable Food Production and Well-being

Kalpana Waiba[1]*, Alina Maharjan[1], Rashmita Shakya[2]
[1]Department of Environmental Science, Amrit Campus, Kathmandu
[2]Precise Geospatial Solutions Pvt. Ltd.
*Correspondence: waibakalpana57@gmail.com

Abstract

Agriculture, a pillar of human society, is undergoing dramatic changes as a result of global urbanization trends. Urban and peri-urban agriculture emerges as a critical method, providing numerous benefits such as increased food availability, poverty alleviation, and environmental mitigation. The Kathmandu Valley is the center of this study, which investigates the status and impact of urban agriculture on its population. It digs into topics including land availability, agricultural practices, food production, and health consequences. The study surveyed 230 families using a structured questionnaire method, indicating a male predominance (56%) and a diverse ethnic representation. The key findings show that 51% of respondents have access to growing areas, while 76% choose kitchen gardening. The biggest motivations are economic considerations (50%) and personal satisfaction (20%). Participants report cultivating 55% of their diet, which contributes to good health. Despite obstacles such as plant diseases (40%), 95% of respondents are satisfied with urban agriculture. This study sheds light on the potential of urban agriculture in solving Kathmandu's difficulties and offers actionable recommendations for the sustainable implementation of urban agriculture in urban settings.

Keywords: *Challenges, food security, Kathmandu Valley, livelihoods, sustainability*

Introduction

Agriculture has been an important aspect of human society since its inception and continues to play an important role in our lives now. Approximately 80% of the world's population lives in rural areas, where agriculture is the primary source of income (Castañeda et al., 2018). Agriculture employs about 3 billion people globally and involves the cultivation of plants, animals, and fungi to create food, fiber, and energy products. (FAO, 2022). Food and agriculture are key components of the global economy and its driving force, and they are part of a larger social, economic, cultural, and environmental system (Achterbosch et al., 2014; Siemen Van et al., 2018). Population urbanization causes considerable lifestyle changes, altering diets, intensifying land use patterns, and increasing agricultural output. This transformation has transformed agriculture into a worldwide interconnected economy, producing and exporting commodities on a vast scale to feed the world's rising urban and peri-urban populations, which now account for more than half of the total (Tomiyama et al., 2020). Urban areas are locations with high population density and a built environment, whereas peri-urban areas are transitional zones between rural and urban land uses located between the outer and regional centers and the rural environment.

It is estimated that 800 million people worldwide practice urban (and/or peri-urban) agriculture (Monroy et al., 2023). According to an FAO publication produced in collaboration with the NGO Rikolto, "urban and peri-urban agriculture is a critical strategy for building resilience in urban food provision, reducing poverty and increasing employment, improving nutritional outcomes, and mitigating environmental degradation of urban spaces" (Erwin, 2022). According to the publication, urban and peri-urban agriculture provides 26% and 23% of food in Quito (Ecuador) and Arusha (Tanzania, respectively). According to the statistics, urban and peri-urban farmers claim that practicing this sort of agriculture has benefited their income, community, and family harmony.

Growing food in and around urban and peri-urban terrain utilizing commercial, non-commercial, and hybrid technology, is a new strategy in the recent growth of agriculture and food security, and the practice of raising livestock is referred to as urban agriculture (Kafle, et al., 2022). According to the Urban Agriculture Committee of the CFSC (2003), urban agriculture is the growing, processing, and distributing of food and other products through intensive plant cultivation and animal husbandry in and around cities. It offers the opportunity to provide fresh, local food to urban communities contributing to local economic development, poverty alleviation, and social inclusion of the urban poor and women, as well as to the greening of the city and productive reuse of wastes (Orsini et al., 2013).

Urban agriculture includes guerrilla gardening, allotments, balcony, and windowsill vegetable growing, small-intensive urban farms, food production on housing estates, land sharing, rooftops gardens and beehives, school-yards greenhouses, restaurant-supported salad gardens, public space food production (Tornaghi, 2014). Considering the sustained trend of poverty and population concentration in urban areas of developing nations, urban agriculture could potentially serve as a solution to address the challenges associated with urban food security (Zezza & Tasciotti, 2010). Despite increasing recognition of urban agriculture's significance in addressing food security and alleviating poverty among urban populations, it predominantly operates within the informal sector (Rana et al., 2017).

Inadequate resource management in urban areas results in diminished quality of life within cities. Urban agriculture, as a broad strategy, is increasingly being embraced organically in developing countries to combat urban poverty and enhance the overall well-being of urban residents (Orsini et al., 2013).

Existing scenario of Kathmandu Valley

The Kathmandu Valley River basin, situated in Central Nepal, encompasses the foothills of the Himalayas and has a rich history of extensive agricultural activity. Roughly 30,000 years in the past, the Kathmandu Basin was submerged underwater (Saijo & Kimura, 2008). With the retreat of the lake, nutrient-rich mudflats surfaced. The topography and fertile soil of the Kathmandu Valley have played a pivotal role in influencing the expansion and progress of the communities within it (Mitchell & Tang, 2017). Farmlands, which were the source of the city's prosperity, are currently being lost to urbanization (Zurick & Rose, 2010). The encroachment of the city on fertile farmland has diminished the capacity of the farming community to adequately feed the current population of the valley (Haack & Rafter, 2006).

Since food is a fundamental requirement for our survival, it is crucial to establish sustainable methods of food production. Urban areas, with their heightened resource needs and environmental impacts, especially food production, present significant challenges. Hence, they warrant significant attention (FAO, 2022).

According to the study by Shakya et al. (2019), urban agriculture has the potential to provide multiple benefits in Kathmandu, including increased food production, income generation, and improved nutrition. The research conducted by Adhikari et al. (2018) found that urban agriculture in Kathmandu has created employment opportunities, especially for women and marginalized communities. A study by Shakya et al. (2017) unveiled that urban agriculture in Kathmandu enhances the accessibility of fresh, nutritious products, ultimately enhancing dietary variety and combating malnutrition. Beyond economic and nutritional advantages, urban farming also fosters sustainable methods and environmental responsibility. Shrestha and Dhungana (2016) conducted a study, which underscored that urban agriculture in Kathmandu alleviates the burden on rural agricultural lands and lessens the adverse effects of food transportation on carbon emissions.

Hence, this study aims to play a key role in bridging the prevailing gaps. The main objective of this study was to overlook the status of urban agriculture and its impact on people in Kathmandu Valley followed by specific objectives such as a) Access to the land for urban agriculture b) Involvement in urban agriculture c) Assessing the type of urban agriculture being practiced and the types of vegetation grown

d) Major reasons for practicing urban agriculture e) Assess the overall health condition of people practicing urban agriculture and f) Study types of fertilizers used, water management, and problems faced.

Materials and Methods

Study Area

The Kathmandu Valley, which includes Kathmandu, Lalitpur, and Bhaktapur and has a total area of 665 km^2 in central Nepal's Bagmati zone, was chosen as a study area. Kathmandu Valley is geographically located at a latitude of 27°42'14" North and a longitude of 85°18'31" East, with an average elevation of roughly 1300 meters above sea level. The valley's three urban hubs are Kathmandu Metropolitan City, Lalitpur Sub-Metropolitan City, and Bhaktapur Municipality, with a combined population of 2,996,341 in 2021 according to the Central Bureau of Statistics (CBS, 2021)

Methods

Pre-Field Visit: As part of the urban agriculture study, a carefully planned tour was conducted in chosen metropolitan areas.

Pre-Data Collection: The research utilized a closed-ended questionnaire survey to collect primary data. The questionnaire was designed based on the research objective. The survey covered Kathmandu (50%), Bhaktapur (32.60%), and Lalitpur (17.39%), with a total of 230 participants involved. Respondents were interviewed face-to-face during data collection. Among them, 115 were actively practicing urban agriculture, while the other 115 had no involvement in this activity. The sample size was determined using a specific formula by Wood et al. (2016).

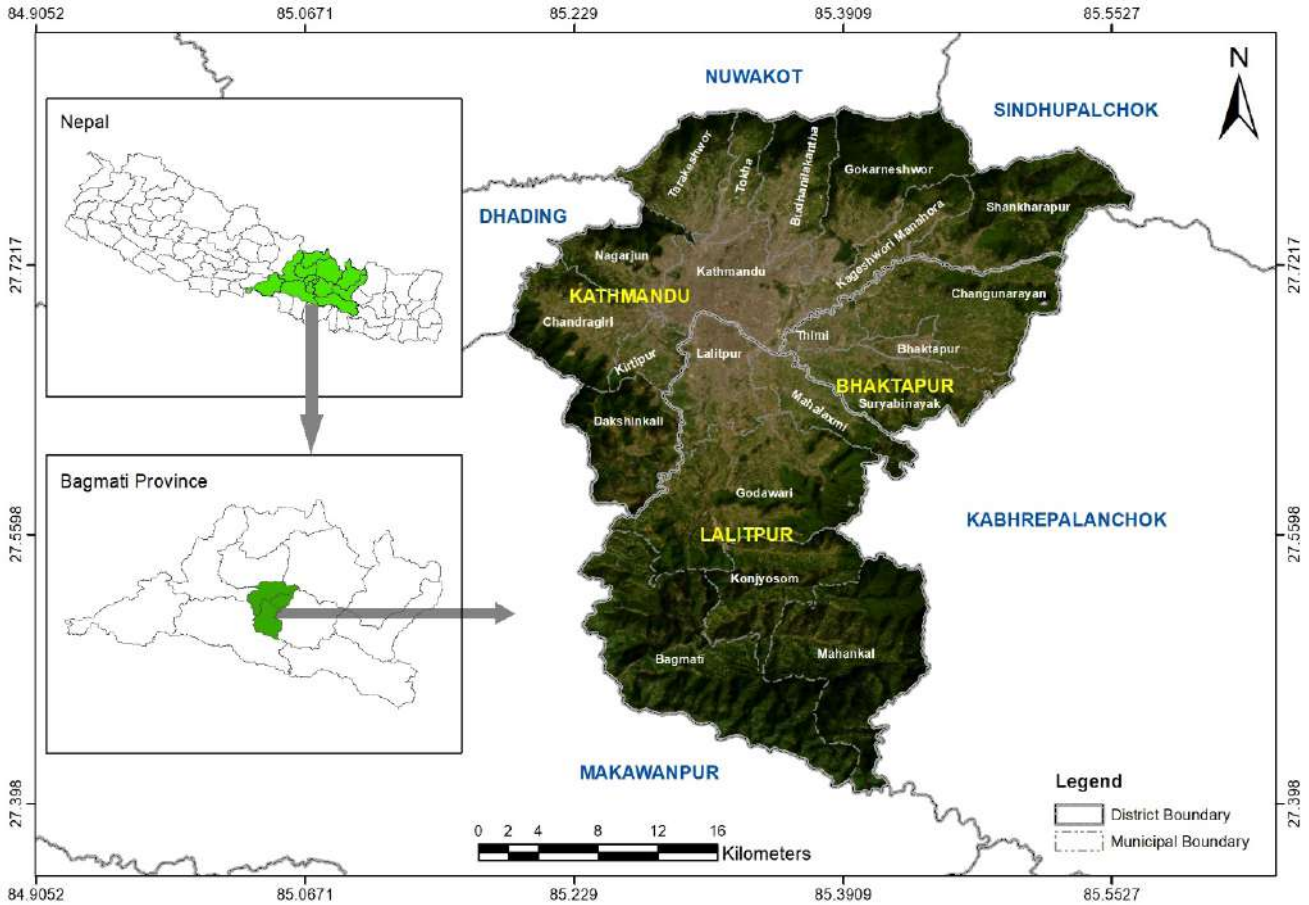

Figure 1: Map of the study area

$$Sample\ size = \frac{r+1}{r.SD^2}(ZB + Z\alpha/2)^2 \frac{1}{d^2}$$

r = ratio of control to cases, 1 for an equal number of cases, and control

SD = standard deviation from the previous study

d = expected mean difference between case and control, taken from the previous study

Z_B = 1.28

$Z_{\alpha/2}$ = 1.96

Key Informant Interview (KII): To gather comprehensive insights, the study employed Key Informant Interviews (KIIs) with legislators, accomplished farmers, and school instructors totaling 15 individuals.

Secondary Data Collection: Secondary data was obtained from a range of relevant literature sources including published/unpublished articles, abstracts, periodicals, free data sites, and various other online resources.

Data Analysis: The collected data was subsequently collected and analyzed using Kobo toolbox and MS Excel.

Results and Discussion

The study surveyed a total of 230 households and filled up a structured questionnaire form, resulting in 56% being male and 44% female participants. The study revealed a predominance of male participation in urban agriculture, possibly influenced by the higher number of male respondents in the survey. In terms of ethnicity, Janajati individuals accounted for 33% of participants, followed by Brahmins at 31%, and Chettri at 21%. Other ethnicities like Newar, Madeshi, and various others were also represented.

The collected data illustrated that the majority of respondents, i.e. 60%, lived in their own houses, while the remaining 40% were renters. This suggests that a significant number of respondents who were actively involved in urban agriculture owned their residences, providing them with a convenient setup for engaging in this practice.

Access to growing space/kitchen garden at home

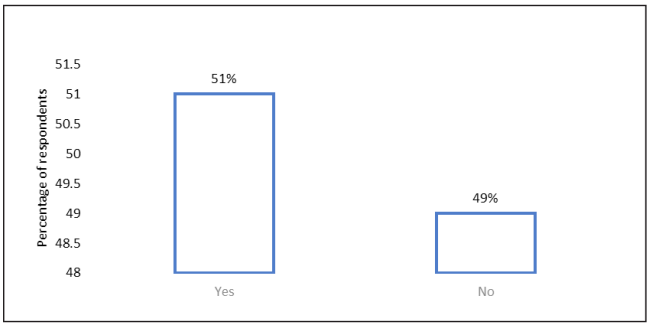

Figure 2: Access to growing space at home

According to the study, a majority of respondents had access to growing space or kitchen gardens at home. Specifically, 51% of respondents had land available for urban agriculture, whereas 49% did not. Some individuals without access to growing space still express interest in urban agriculture. They engaged in practices like rooftop farming using flower pots, grow bags, and various other equipment.

Involvement in urban agriculture

According to the collected data, the primary obstacle preventing participants from engaging in urban agriculture was their residency in rented homes, which resulted in a lack of access to suitable growing space despite their interest. Conversely, homeowners, while having both the space and interest to participate in urban agriculture, often faced a constraint in the form of limited free time for engagement.

Types of urban agriculture

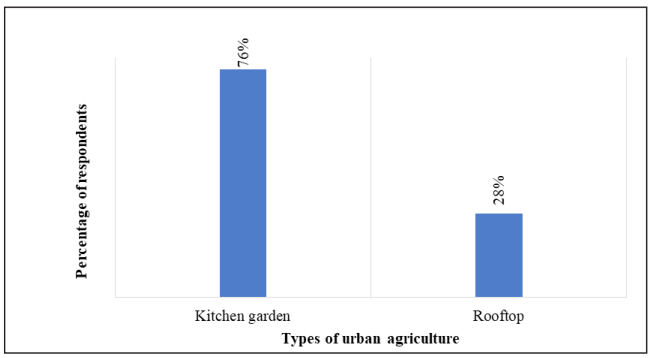

Figure 3: Types of urban agriculture being practiced

According to the collected data, it was evident that approximately 76% of the overall respondents engaged in urban agriculture preferred kitchen

gardening, while the remaining 24% opted for rooftop gardening. Respondents with ample space typically opted for kitchen gardening in their urban agricultural pursuits, whereas those with limited space gravitated towards rooftop gardening. The result is supported by the study conducted by Bhattarai and Adhikari (2023) which stated that in dense urban centers, such as the cities like Kathmandu Valley and Pokhara, thousands of residents have resorted to urban agriculture on rooftops, on balconies, and in backyards.

Reason for Practicing Urban Agriculture

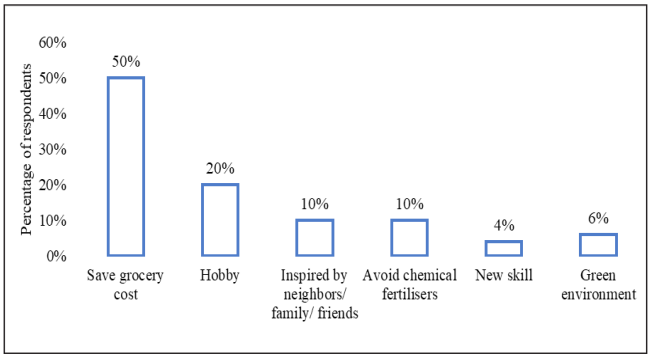

Figure 4: Graphical representation of reasons for practicing urban agriculture

Approximately 50% of participants began urban agriculture to reduce their grocery expenses. Another significant factor was the satisfaction derived from urban farming, with 20% stating it as their primary reason. Additionally, 10% were influenced by family, friends, or neighbors, appreciating the chemical-free nature of the practice. This meant they could consume products without added chemicals or preservatives, promoting safer and healthier eating habits. Furthermore, 6% undertook urban agriculture to contribute to a greener environment and cleaner air. Lastly, 4% embraced urban agriculture as an opportunity to acquire new skills and gain valuable techniques and knowledge in the process. Similar findings were noted by Ngahdiman (2017), who showed that beneficial perceptions, confidence in engaging in urban agriculture, the influence of the social environment, and the influence of role models greatly direct how urban people perceive these practices. Furthermore, a study by Shamsudin (2014) demonstrated that urban residents' attitudes about urban agriculture can be influenced by financial advantages.

Percentage of vegetables/fruits covered by agricultural production to the meal

Most participants engaged in urban agriculture reported that approximately 55% of their diet consisted of vegetables and fruits grown in their kitchen gardens and rooftops. They were successful in cultivating half of the needed vegetables at home, while the other half i.e., 45% had to be purchased from markets, indicating a shortfall in self-produced products. This shortfall was attributed to challenges such as limited space, subpar soil quality, a shortage of fertilizer, and a lack of expertise in vegetable cultivation. Research shows that gardeners incre

Overall, health condition

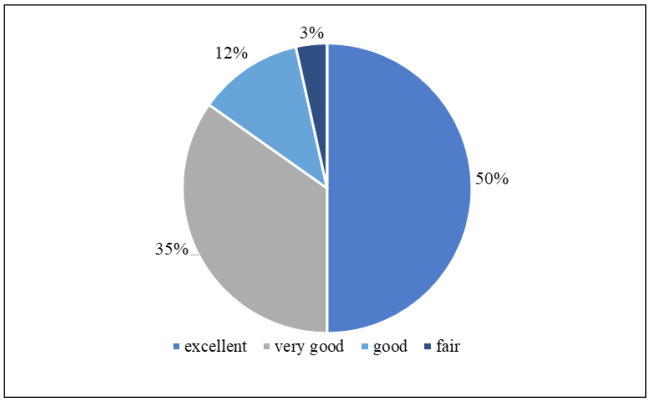

Figure 5: Overall health condition of respondents

Participants engaging in urban agriculture were asked about their health over the past four weeks. According to the study, none of the respondents indicated poor health, with 50% reporting excellent health condition, 35% feeling very good, 12% having good health and the remaining 3% reporting fair health. This positive health trend is likely a result of the prevailing healthier lifestyle in urban areas. A study by Hawkins et al. (2011) conducted previously, reported positive impacts of urban agriculture on physical health in general and improved muscle mass by Park et al. (2016). Other studies reported outcomes that were related to the health of people with mental disabilities (Dewi, et al., 2017) or mental health (Soga, et al., 2017). Park et al. (2016) found that urban agricultural activities improved the psychological health of women by demonstrating that women participants of urban agriculture exhibit lower depression scores compared to non-participants.

Impact on physical activity

The study highlighted that most participants in urban agriculture faced few physical limitations, allowing them to consistently perform at their best. Only 9% of respondents encountered hindrances due to their physical health, while an impressive 91% operated at peak levels. Those actively engaged in urban agriculture experienced minimal constraints due to their physical well-being, indicating that they tend to have superior work capabilities compared to non-participants. Their involvement in urban agriculture translates to the potential for larger and more significant accomplishments, as they maintain healthy diets and engage in regular physical activities. The correlation between regular exercise and involvement in urban agriculture may explain these positive outcomes.

In regards to this, gardening and food production is a beneficial exercise. The term "exercise" refers to a variety of tasks that require both fine and gross motor skills, such as moving compost piles or cutting flowers (Brown & Jameton, 2000). According to gardeners, "activity" in the garden boosts efficacy, pride, confidence, and self-esteem (Hanna & Oh 2000; Waliczek et al., 1996).

Use of fertilizer

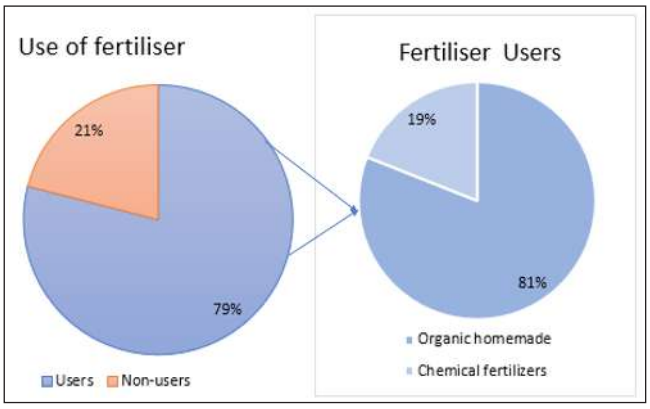

Figure 6: Graphical representation of the use of fertilizers

According to Fig. 6, 79% of urban agriculture participants use fertilizers. Among fertilizer users, 81% prefer organic homemade options like OWDC (Original Waste Decomposer), vermicomposting, leaf mold, composting, and animal waste to nurture their crops. The remaining 19% opt for chemical fertilizers such as urea, diammonium phosphate (DAP), and single super phosphate (SSP). Interestingly, 21% of respondents don't use any type of fertilizer; instead, they create compost manure at home through various methods to enhance crop yield. For pest control, they first use a homemade soapy water solution. If this proves ineffective, they resort to store-bought chemicals. This careful approach aims to ensure that the produced goods are as free from harmful chemicals as possible. A study by Wielemaker et al. (2019) also presented the types of fertilizer inputs used, showcasing a mix of on-site and off-site sources. Out of 25 urban farms, around 80% of the farms utilized compost, 60% used manure from their animals, all farms incorporated external inputs despite none of the farmers preferring synthetic fertilizers but rather preferred certified organic fertilizers derived from plant and animal residues and sourced as locally as possible.

Water used for urban agriculture

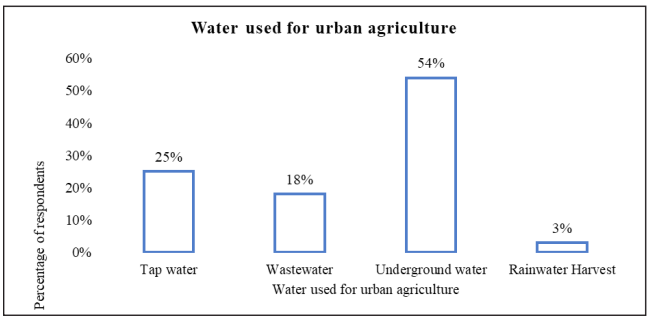

Figure 7: Water used for urban agriculture

More than half of the respondents (54%) primarily depend on underground water sources like wells and borewells for their irrigation needs. Tap water is the second most common source, utilized by 25% of participants, followed by wastewater at 18%, and collected rainwater at 3%. Regarding irrigation methods, a substantial majority (97%) employ manual techniques such as buckets, hoses, and watering cans, while only 3% opt for piped water supply.

In terms of water availability, 73% of respondents have not faced a shortage of water for their urban agriculture activities, 15% encounter occasional shortages, and 12% face regular scarcity. Interestingly, 78% of participants use wastewater for watering purposes at a level of 25% or less, while

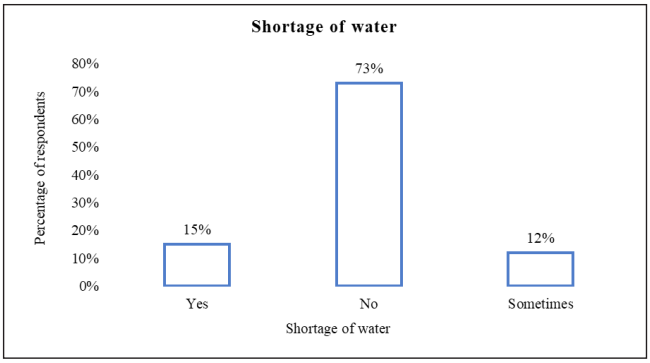

Figure 8: Graphical representation of shortage of water

12% rely on it for 75-100% of their irrigation needs. This suggests a need for more effective utilization of wastewater resources in urban agriculture.

Land area covered by the kitchen garden and rooftop farming

According to the study, most urban agriculture activities occur on plots of land under 100 sq. ft. (9.29 sq. meters). The next most common land size, at 19%, ranges from 500-1000 sq. ft. (46.45-92.90 sq. meter), while only 7% work on areas between 200-500 sq. ft. (18.58-46.45 sq. meter) Growers make creative use of space, employing techniques like utilizing old items and employing growing bags to fit urban agriculture into smaller areas of their homes. According to a survey conducted by Dhital et al. (2016), urban agriculture occupies between 0 and 300 m2 of land in municipalities like Dhulikhel and Pokhara. To cultivate the plants of their choice, practitioners employed a variety of containers, including paint buckets, tin bins, fish boxes, cement bags, rooftops, side walls, and pieces of land surrounding the house.

Participants in urban agriculture, whether they have limited or ample space, tend to focus on a small portion of their available area. Despite other professional commitments, they allocate time during the day or evening for urban agriculture. This practice not only granted them access to organic products but also led to savings on grocery costs. Many individuals preferred to engage in urban agriculture within compact spaces due to easier management and cost-effectiveness.

Types of Vegetation Grown

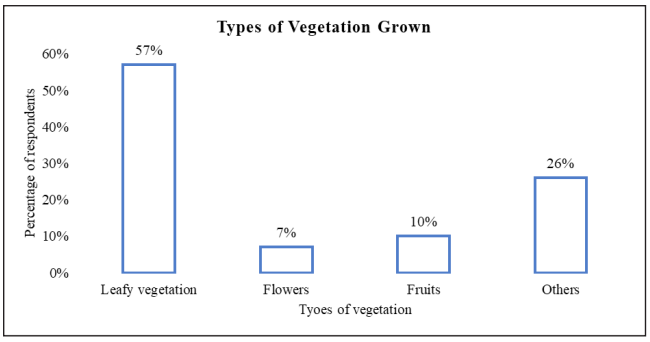

Figure 9: Types of vegetation grown in urban agriculture

Leafy vegetables were the most prevalent, accounting for 57% of all respondents. The second most commonly grown category, at 26%, consisted of various crops like grains, corn, and wheat. Fruits were grown by 10% of participants, while 7% focused on cultivating decorative flowers. The majority of products included staples like mustard greens, onions, garlic, and spinach, chosen for their high consumption rates. Some participants with ample land space also engaged in the cultivation of crops like wheat and barley. Additionally, several respondents planted a diverse array of plants and flowers to enhance the aesthetic appeal of their homes and surroundings.

A study conducted by Dhital et al. (2016) in Dhulikhel and Pokhara also represented that urban agriculture practitioners preferred growing vegetables such as cauliflower, beans, leafy vegetables, radish, cucurbits, onion/garlic, cabbage, and others.

Problems Faced During Urban Agriculture

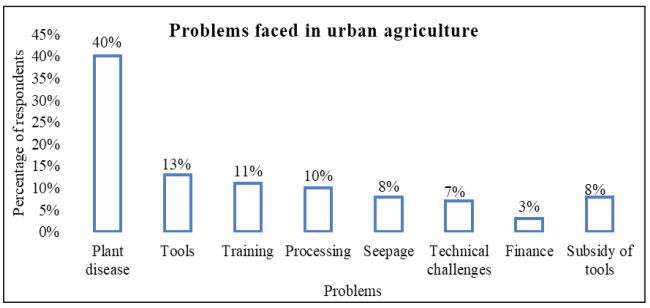

Figure 10: Problems faced in urban agriculture

According to Figure 10, the most common challenge faced by respondents, accounting for 40%, was related to plant diseases. The second-highest issue,

at 13%, pertained to problems with tools. Training-related difficulties were experienced by 11% of respondents, while process-related issues affected 10%. Additionally, 8% encountered problems with seepage and tool subsidies each, 7% faced technical challenges, and the remaining 3% dealt with financing problems.

Participants reported various problems and diseases affecting their plants, posing challenges for effective resolution. Among these, foreign invaders like insects and pests were a significant issue for those engaged in urban agriculture. To address this, participants typically used a combination of organic and store-bought pesticides to manage damage and improve their production outcomes.

Satisfaction from urban agriculture

According to the study, an overwhelming 95% of participants expressed satisfaction with the results and benefits they derived from their urban agricultural activities. The remaining 5% reported dissatisfaction and were less content with their urban agriculture efforts. This contentment is attributed to the consumption of organic, healthy products and the fresh air generated by the plants, contributing to overall well-being and satisfaction. The obtained result resembled that of a study by Park et al. (2016) which also showed that 95.8% of the interviewed elderly participants expressed their satisfaction with gardening intervention.

Conclusion

Finally, this study focuses attention on the critical role of urban agriculture in solving food security, poverty reduction, and general well-being concerns, particularly in the context of the Kathmandu Valley. With a sizable amount of the world's population living in cities and peri-urban areas, urban agriculture emerges as a strategic and linked strategy for enhancing urban food security.

The study emphasizes the various aspects of urban agriculture, such as kitchen gardens, rooftop farming, guerrilla gardening, and more. Urban agriculture not only helps with local economic development and poverty alleviation, but it also promotes social inclusion, especially among marginalized communities and women. According to the findings, urban agriculture in the Kathmandu Valley has the potential to improve food production, revenue generation, and nutritional outcomes.

The difficulties that urban agriculture practitioners encounter, such as restricted space, plant diseases, and tool-related issues, emphasize the importance of supportive policies and actions. Furthermore, the study underlines the favorable relationship between participation in urban agriculture and improved health outcomes, as evidenced by participants' overall health and physical activity levels.

The study reveals significant variables affecting urban agricultural adoption, such as a willingness to save money on groceries, satisfaction from the activity, and the development of a greener environment. Importantly, urban agriculture provides an alternative and sustainable way to food production by addressing the encroachment of urbanization on fertile farmland in the Kathmandu Valley.

Finally, the findings highlight the importance of urban agriculture as a comprehensive strategy that can change urban landscapes into more sustainable, resilient, and healthy ecosystems. As urbanization shapes the future of human habitation, integrating and encouraging urban agriculture can play an important role in guaranteeing food security, improving livelihoods, and supporting environmental sustainability in urban areas.

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Impact of Improper Shelters on Women on the Aftermath of Jajarkot Earthquake in West Rukum, Nepal

Reena Chaudhary[1*], Bal Deep Sharma[1], Sushil Shrestha[1], Sahadev Gautam[2], Ravi Dhital[1]
[1]National Disaster Risk Reduction and Management Authority, Kathmandu, Nepal
[2]Public Administration and Anthropology, Tribhuvan University, Kathmandu, Nepal
*Correspondence: reenu_chad@yahoo.com

Abstract

Disasters and emergencies affect each individual in different way based on age, sex, disability, community, geographic regions, etc. Women and children are disproportionately affected during and after disaster. The situation becomes pathetic when they loss their houses and live in tarpaulin tents. Lack of proper shelters influence daily life directly or indirectly viz. food and nutrition, mental and reproductive health, WASH, protection, education, etc. They often lag behind during preparedness, search and rescue, evacuation, response and recovery. The Government of Nepal has taken an initiation to make the temporary shelter of the Jajarkot earthquake, 6.4 ML, Nov 2023, affected families affected districts. For this, Government of Nepal (GoN) is providing housing grant to such affected families in two tranche amount of 25,000 NPR. This paper assesses the impact of improper shelters on earthquake affected women and their limitations to make their temporary shelters independently in West Rukum district, Karnali province of Nepal. This study is based on descriptive as well as explanatory research design. Primary sources for information collection based on questionnaire were Key Informant Interview (KII), Focus Group Discussions (FGD), household survey, field observation and interview whereas secondary sources for data collection were literatures review, articles and government offices. Both the qualitative and quantitative approaches were applied. The assessment shows that the improper shelters after earthquake disproportionately affects women. The disaster hits harder if comes to intersectionality of being marginalized, single and having disability. Need identification of such women is essential during the construction of their temporary shelters.

Keywords: *Beneficiaries, grant, migration, volunteers, vulnerability*

Introduction

An earthquake is an unpredictable disaster event occurring around the globe, and Nepal lies in a highly earthquake-prone area because it lies above the Indian and Eurasian tectonic plates, where the Indian plate and the overriding Eurasia plate to the north (USGS, 2024). The Gorkha Earthquake 2015 was the last major earthquake, greater than 7 magnitudes, in the central part of Nepal, and the Jajarkot Earthquake 2023 was the recently occurred earthquake. It affected people and infrastructure, including private properties, injured people, destroyed numbers of houses and public infrastructure, displaced hundreds of people, and impacted their livelihood. Nepal ranks 11th in terms of global risk for earthquake occurrence and impact (Maplecroft 2011, MoPE, 2016). The country is in the top 20 of all the multi-hazard countries in the world (UNDRR, 2019) as it is located in a high seismic hazard zone. More than 80% of the population is exposed to the risk of natural hazards (MoHA, 2015), which include earthquakes, droughts, floods, landslides, extreme temperature, and glacier lake outburst floods. Disasters and emergencies affect each individual in different way based on age, sex, disability, community, geographic regions, etc. Women, children, senior citizens, persons with disability are disproportionately affected from disasters like earthquakes and other types of disaster (NDRRMA, 2022). Among the population, women are especially hard-hit by the social impacts of environmental disasters (Gokhale, 2008) if linked to lactating mothers, pregnant women, single mothers, women headed family in marginalized and indigenous communities, women with disability. Resources to meet basic needs, including water, food, cash and

fuel, are scarce in disasters, and culture dictates that husbands, children, and in-laws are prioritized, so it is women who do without (OXFAM, 2016). Women and girls face particular challenges in term of access to essential services and vital relief items, to remain safe and to cover their basic needs for appropriate shelter, hygiene and sanitation, healthcare and protection; particularly acute for women with specific needs such as those who are pregnant and breastfeeding, who are single and single mothers, with disabilities or from rural areas (UNWOMEN, 2023). Notably, women are often considered the most vulnerable during disaster because they are exposed to more dangers due to their various roles, such as taking care of children, older family members, and people with disabilities before, during, and after a disaster event (Fan., 2023). The situation becomes pathetic when they loss their houses and live in tarpaulined tents. Lack of proper shelters influence daily life directly or indirectly viz. food and nutrition, mental and reproductive health, WASH, protection, education, etc. Due to these factors, they often lag behind during preparedness, search and rescue, evacuation, response and recovery.

After 2015, western part of Nepal experienced a 6.4 magnitude earthquake event on 3 November 2023 at 11:47 PM local time with its epicentre at Ramidada of Jajarkot district of Karnali province. Majorly, it impacted to Jajarkot and West Rukum district. Additionally, it affected 11 districts causing severe damage to adjoining districts Salyan. The Government of Nepal (GoN) has taken an initiation to make the temporary shelter of the affected family in the earthquake affected districts viz. Jajarkot, West Rukum, Salyan, Bajura, Bajhang and Doti. For this, GoN is providing housing grant to such affected families in two tranche amount of NPR 25,000. This paper assesses the factors that the impact of improper shelters on them on the aftermath of earthquake and also their limitation in making their temporary shelters on time.

Materials and Methods

Study area

West Rukum district of Karnali province was selected as the study area. It consists of three municipalities viz. Aathbiskot, Chaurjakari, Musikot and three rural municipalities *(palikas)* namely Sanibheri, Banfikot, Triveni. The district is connected to Jajarkot in the west, Salyan and Rolpa in the south, Dolpa in the north and East Rukum in the east. The district is located at 28.6° N, 82.4319° E covering 1,217 sq. km total area with population density 137/km^2 (Fig. 1). The total population residing in the district is 166,740 (NSO, 2021). Musikot, Khalanga is the headquarter of the district connecting to all the six palikas by road. The district has a good road

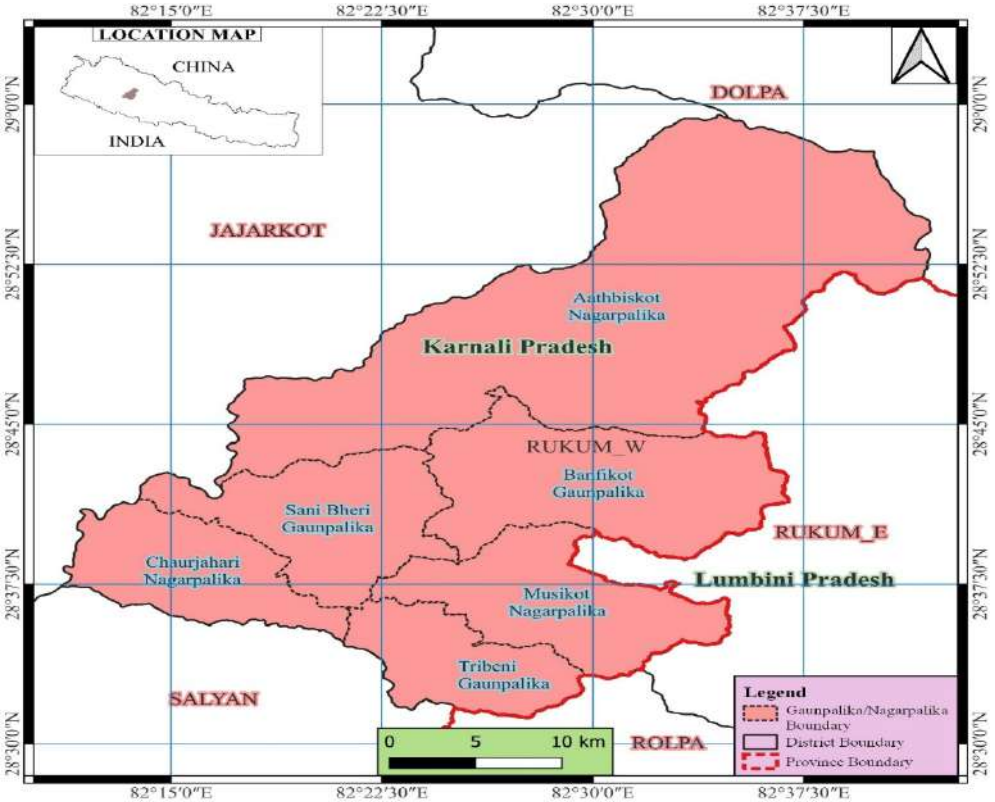


Figure 1: Municipalities of West Rukum (Study Area)

connectivity connecting the six palikas through motorable road, Rapti highway and mid-hill highway connecting East Rukum. The district hospital is located in Musikot, the headquarter of West Rukum district, which is located at the distance of 280 km west of country's capital Kathmandu. The hospital and is near to the small airport at Salle with the connection of blacktop road. The district has more than 40 health facilities including health posts. Aathbiskot municipality was severely affected in terms of the loss of physical infrastructure as the epicenter of the earthquake was adjoining area in Ramidada of Jajarkot district. But Sanibheri rural municipality has the highest number of human lives loss. Most of the houses in these areas were made up of rubble stone masonry.

Methodology

This study is based on descriptive as well as explanatory research design. The survey was carried out for 22 days with representing population from these 6 municipalities (colored marked Fig. 1). Primary sources for information collection based on questionnaire were Key Informant Interview (KII), Focus Group Discussions (FGD), field observation and interview with women of six local levels of West Rukum district (Musikot Municipality, Chaujahari Municipality, Aathbiskot Municipality, Sanibheri Rural Municipality, Banfikot Rural Municipality and Triveni Rural Municipality) whereas secondary sources for data collection were literatures review, articles and government offices. Both the qualitative and quantitative approaches were applied. A purposive sampling method was used for the interview of women those who were living in tarpaulin tent. Questionnaire was prepared for the interview of affected women. KII of households in the six local levels of the district was taken. FGDs was conducted with women, mayors and president of all the six local levels and bureaucrats working in the field offices. Semi structured interview with relevant persons was carried out to acquire answers to the research questions. Representatives of the wards, Chief District Officer (CDO), employees of District Administrative Office, International Federation of Red Cross (IFRC) were the key informants. Data are expressed in chart. Quantitative data were analyzed through descriptive statistics and described in result and discussion. Geographic Information System (GIS) mapping was used to locate the study area (all the 6 municipalities).

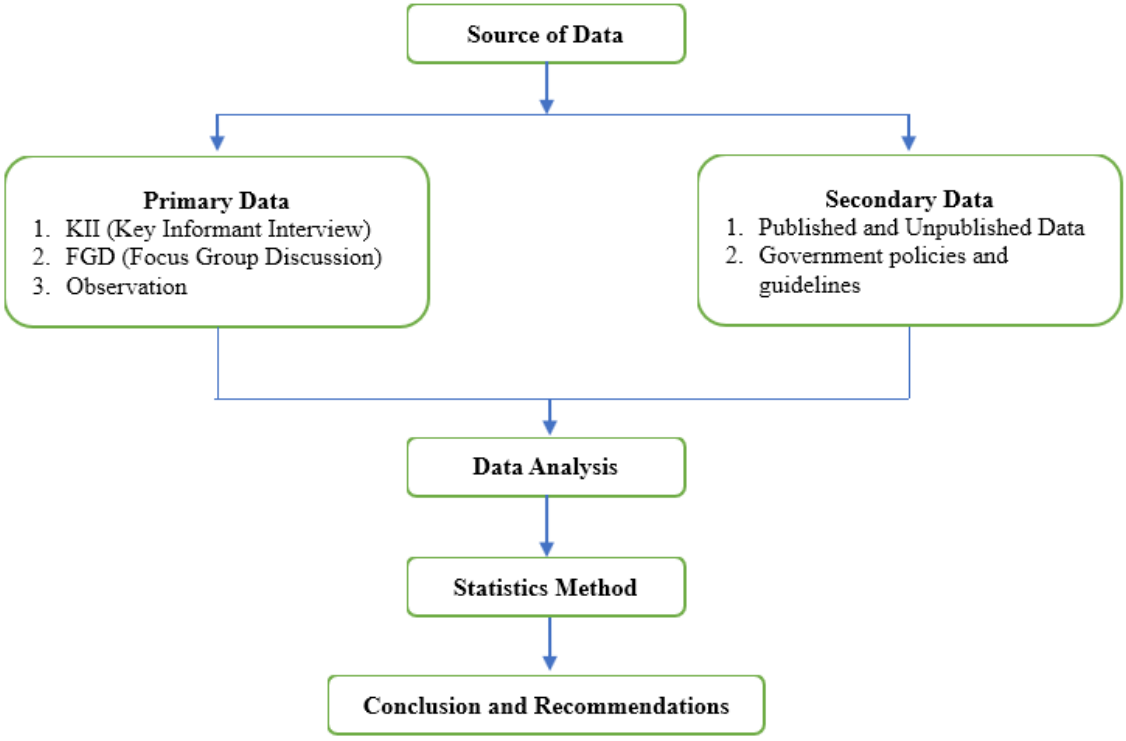
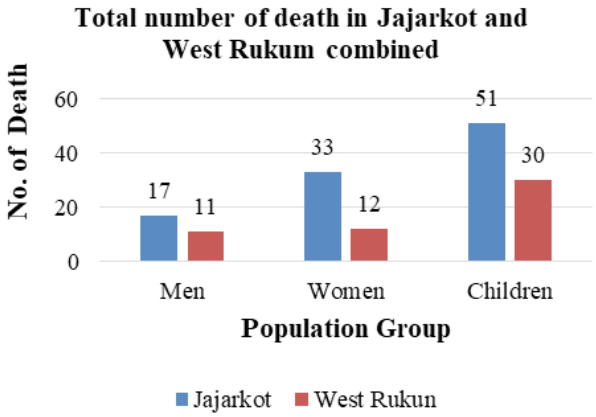


Figure 2: Methodology Chart

Results and discussion

Loss and Damage due to the Jajarkot Earthquake

The Jajarkot Earthquake resulted in the tragic loss of total 154 lives, 101 in Jajarkot and 53 in west Rukum (Fig. 3), and injured 366 individuals of varying degrees. Among them, the death of children and women was higher in number. Out of the total death in West Rukum, 11 men, 12 women and 30 children lost their live. Out of total 30 children, 15 were boys and 15 were girls. The number of death of children according to age group are shown in Fig. 4. According to the data, the children of age group 11 to 15 years old is higher i.e. 10.



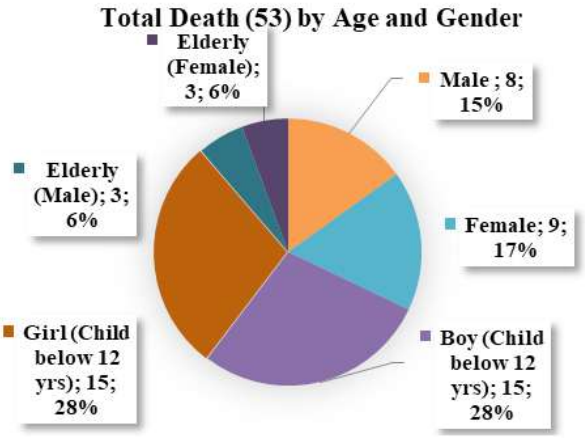


Figure 3: No. of death in Jajarkot Earthquake *(Source: District Administration Office (DAO) of Jajarkot and West Rukum)*

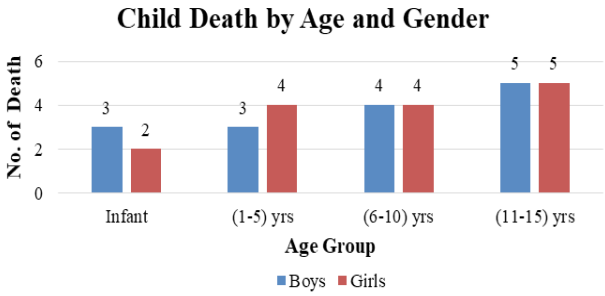


Figure 4: No. of death by age and gender *(Source: DAO, West Rukum)*

According to the Preliminary Damage and Needs Assessment (PDNA) of Jajarkot earthquake conducted by National Disaster Risk Reduction and Management Authority (NDRRMA), the earthquake affected across sectors and has significant impacts on Social Sectors (91.63%), Infrastructure Sectors (3.43%), Productive Sectors (1.76%), and Cross-cutting Sectors (3.18%). The assessment reveals that the overall need for reconstruction and recovery is estimated at USD 471,801,034 (471 million), cross-cutting Sectors, focusing on Gender Equality, Disability, and Social Inclusion (GEDSI), along with Employment and Livelihood, require a total of USD 15,000,000 (15 million) (NDRRMA). A total of 196 schools out of 308 were damaged only in West Rukum district.

The NDRRMA had preliminarily identified a total of 73,746 households eligible for receiving housing grant in the three districts i.e. Jajarkot, West Rukum and Salyan. Among them, 29,406 beneficiaries were identified in West Rukum district. But the number of affected households is in increasing trend (Fig. 5). Till date, 31,620 beneficiaries have been identified in West Rukum. The first tranche grant of NPR 25,000 had been started to provide from 64 identified beneficiaries in their personal account by Government of Nepal from 28 November 2023. Till date, 29,133 beneficiaries have received the first tranche grant of total amount NPR 72,83,25,000 (DAO, West Rukum). Out of the total grant recipients, only 24,726 temporary shelters have been completed and 5,493 temporary shelters are in the process of building (DAO, West Rukum). Rest of the 1,401 temporary shelters still remain to initiate (DAO, West Rukum).

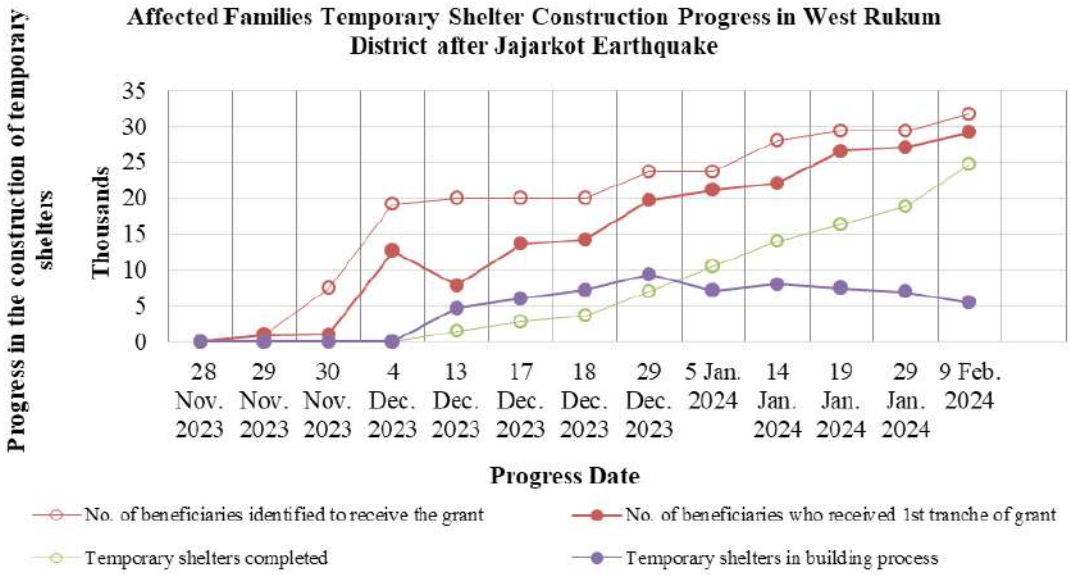


Figure 5: Progress of construction of temporary shelter. *(Source: DAO, West Rukum)*

The Jajarkot earthquake occurred at mid-night when people were in deep sleep and most of the houses were made up of rubble stone masonry. This led to massive loss of lives.

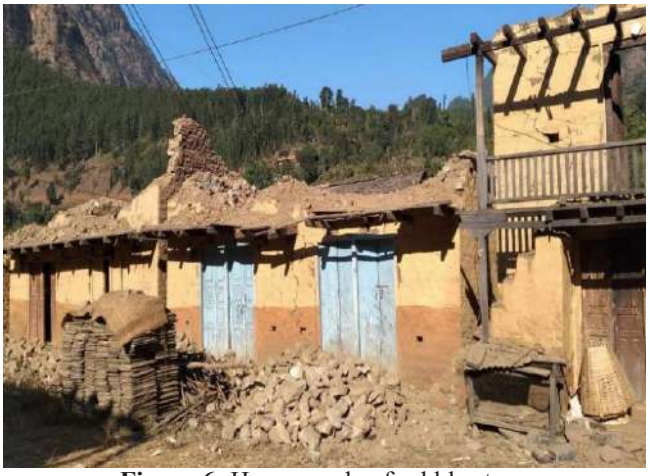


Figure 6: House made of rubble stone

Figure 7: Polyethylene Tarpaulin tent

Women facing challenges and problems on the aftermath of earthquake

The earthquake affected more than 3,147 women and 8,854 children unsheltered after Nov. 3, 2023 (DAO, West Rukum). They are compelled to live under tarpaulin tents in the winter night with their children and elderly. They face several problems and threat while living in the tarpaulin which is made of polyethylene tarpaulin and bamboo frame. A proper shelter links to security, privacy, food and nutrition, WASH and sanitation, reproductive rights and health, etc. Shelter is a basic human need crucial for survival in case of natural hazards and human-induced disasters, including conflict. Khosravi et al. (2021) explored similar challenges and problems faced by the 2017 Kermanshah earthquake survivors broadly categorized as physical, mental and psychological health issues, exacerbated economy, mismanagement of local, human and non-human resources, along with social and cultural disturbance. The study highlighted that the vulnerable groups suffered more; being neglected and dejected at the time of crisis. Shelter provides security, personal safety and protection from the weather, and prevents health problems and diseases (EU, 2021). A shelter is not just bricks and mortar, or a tent, but a means to protect those uprooted (Zhang et al., 2011). In emergencies, it is fundamental to provide shelter as part of the life-

saving responsibilities and mandate of humanitarian actors, so that forcibly displaced people can enjoy a secure and healthy living environment that protects them from weather conditions, and offer them privacy, dignity, comfort, and emotional security (UNHCR, 2024).

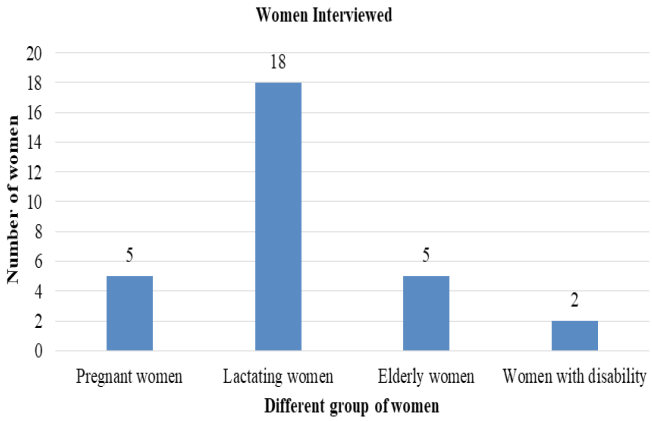


Figure 8: Group of women respondents

The representative Fig. 6 shows that almost the entire earthquake affected women had rubble stone masonry houses. Such infrastructures are fragile and weak and are highly susceptible to earthquake. Most of the women living under the tarpaulin had infants on their lap or breast-feeding babies or they were elderly. The lactating mothers face decrease in capacity of lactation since the night they started living under tarpaulin. It may be due to lack of nutrition and untimely sleep. Disturbed family functioning, and psychological impact of earthquake on the mental health of pregnant and postpartum women leads to mental disorders, some even long term (Ren et al., 2013). Poor diet and care to the lactating mother directly affects the breastfeeding practice and the infant. Breast milk insufficiency, disrupted social networks, and the availability of breast milk substitute add worries to the mothers; the quality of breast feeding is proportional to the health and growth of the infants (Dörnemann et. al., 2013). Additionally, Lack of latrines have made the survivors compromise hygiene, adding vulnerability to faecal contamination and subsequent communicable diseases. A temporary toilet was made for a group of affected family due to which they face problem during bathing, washing or mensuration period.

Figure 9: A lactating mother living under tarpaulin tent

Figure 10: Interaction with lactating mothers

Temporary shelter construction and constraints

The population of women in West Rukum district is 85,649 out of the total population 166,740 (NSO, 2021) constituting 51.36% of the total population of the district. The average age for first marriage of women between 14 to 24 years is peak in the district (NSO, 2021) and so as the reproductive rate. Labour migration for men is comparatively very much higher than women in the district. Migration for education is also prevailing in the district. International migration has become an integral part of Nepali society and has touched almost every Nepali family due to the large number of Nepalis being engaged in transnational migration, primarily for work and education (IOM, 2019; Sharma et al., 2014).

According to the preliminary findings of the 2021 Census, there are more than 2.1 million Nepali citizens living outside the country, a figure that

represents 7.4 per cent of the national population (NSO, 2022). Men make up 81.3 per cent (or 1.8 million) of this migrant group. In the context of West Rukum district, the sex ratio for labour migration is 30:1 (Nepal Labour Migration Report, 2022). The data indicates that out of 30 migrating labour population, only one is female. This leads a significant imbalance among residing population in the district. Also, here is also a significant number of students going abroad for study. The population in rural municipality of Nepal has remained 33.83 percent (NSO, 2021) while the rest of the total population has reached urban areas. most of young male population are migrated for foreign employment, leaving women and elderly at home. Some of the villages have a minimal number of young men. Consequently, all kinds of responsibilities are imposed upon women and the elderly people. They have to take responsibility for their family members. In post-disaster, constructing their temporary shelters become a challenging task for them.

The Government of Nepal is providing grant of NPR 50,000 to make temporary shelters so that the affected families could get a safe roof to protect themselves from the dropping temperature of winter. The grant has been sent to the beneficiaries' account in two trench of NPR 25,000. Despite the grant provided, most of the vulnerable people especially women are lagging behind to make their temporary shelters. Regarding this, a survey was conducted among women in all the six local levels (three municipalities and three rural municipalities) of West Rukum district who were affected by Jajarkot earthquake. Interview was taken based on questionnaires among the women who were living under tarpaulin on the open space. Besides this, different clusters data was collected with the support of District Administration Office of West Rukum including the WASH and shelters. A total of thirty women (five in each local level) were selected for the interview from the wider age group between 18 to 75 years to know their situation while they live under the tarpaulin and to check the barrier factors that limit making their temporary shelters. Eighteen young lactating mothers between the age group 18-23 years and five elderly women between the age group of 70-75 years were chosen. Early marriage under the age of 20 years old is still prevailing in the district.

In emergency situations such as those following natural disasters, women encounter significant hurdles in reconstruction efforts compared to men. This is largely due to gender disparities in resource access, decision-making authority, and societal expectations, which restrict their involvement in recovery initiatives. Consequently, women often face difficulties accessing financial aid, property rights, and job opportunities, hindering their ability to recover and reconstruct post-disaster (Fothergill, 1998). Almost all of the respondents responded that they need an additional human resource to support them making their temporary shelters besides receiving the grants from the Government of Nepal. Therefore, additional support beyond government grants is deemed essential for women to rebuild their lives, including assistance in constructing temporary shelters.

The data below, Fig. 11 shows that there are majorly four reasons behind the women are unable to make their shelters. Nearly, 76 per cent of the respondent's husband or the family member is out of the district or out of country. Labour migration factor is common for almost all the respondents and this factor drag behind to make their temporary shelters. According to the CDO of the district, mayors of municipalities and local level representatives, a few of temporary shelters are made with the support of local volunteers and volunteers of political parties. Vulnerable people e.g. single mothers, pregnant women, elderly, women with disability and marginalized women need support of trained human resources besides financial resources to make their shelters and they were kept in priority by DAO, West Rukum district. According to them, the affected district needed the support of Nepal Army and volunteers from Red Cross to build the shelters soon as possible.

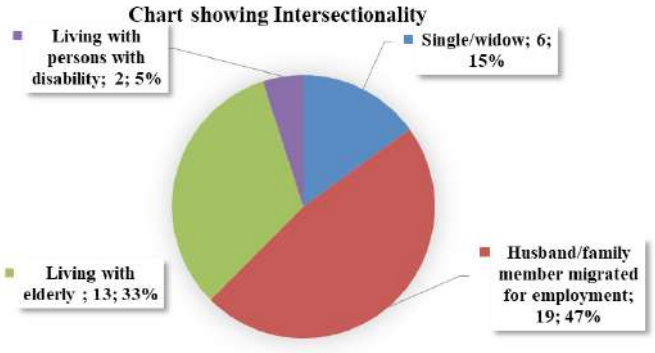


Figure 11: Intersectionality Chart

On the aftermath of the 2015 Gorkha earthquake, women, girls and the vulnerable groups endured multiple health and security risks; including domestic, sexual violence and trafficking (Tearne et al., 2021). Constraints in temporary shelter and latrine construction, including limited availability of resources; the concern regarding their physical well being and sanitation risks (unique to girls and women) still persists. The incorporation inclusive framework for gender mainstreaming is still lacking in risk reduction.

Conclusion and recommendations

Conclusion

KII and FGD were conducted with local representatives, local people and earthquake-affected women, mainly focused on women and old age groups. The disaster relief aid and subsidies were provided by GoN and different cluster lead and co-lead agencies to bring their livelihood on a normal track soon as possible. However, after receiving financial aid mostly women and old age people have faced barriers to constructing temporary shelter for themselves and their family members. Lack of human resources in the villages (especially male members) were not present with their family members. Because of foreign and domestic employment, they were migrated and could not contribute to reconstruction work as well as shelter making. Another reason is the early age mother faced difficulties in building temporary shelters for their family. The number of volunteers has been involved in the shelter from different organizations including governmental agencies like the Nepal Army, but the limited number of volunteers was not sufficient to construct temporary shelter within a limited period.

The absence of male family members has been observed and its impact on women, children, and old age people is significant. Additionally, these groups of people have been facing risk in daily life and vulnerability is growing up.

Recommendations

- Pregnant and lactating women, single women, elderly and women with disability should be prioritized in the phase of earthquake recovery and reconstruction.
- Needs of such vulnerable group should be identified before reconstructing their homes.
- Trained human resources should be managed from government agency to support women, children, and old age group people to make their temporary shelters immediately aftermath of earthquake.
- During the reconstruction of earthquake affected houses, 'accessibility to all' concept must be considered.
- Awareness program for the reason behind prioritization of vulnerable groups in all phases of disaster should be conducted in local levels.

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Role of International Relations to Solve Environmental Issues: An Emerging Discourse

Lila Prasad Sharma
Joint Secretary, Government of Nepal
Correspondence: s.lilapd71@gmail.com

Abstract

Environmental issues and international relations are increasingly interconnected as global ecological challenges—such as climate change, deforestation, and pollution— transcend national borders, demanding collaborative efforts among nations. These environmental problems can influence diplomatic agendas, trade policies, and international treaties, often leading to new alliances or irritating tensions. Multilateral agreements like the Paris Agreement signify how countries work together to address environmental concerns, reflecting the critical role of diplomacy in fostering global sustainability and managing shared resources. Consequently, environmental issues have become a central aspect of international relations, shaping both policy and geopolitical dynamics. International relations are crucial for addressing environmental issues because these problems transcend national borders and require coordinated global responses. Effective international cooperation enables the sharing of resources, knowledge, and technologies necessary to tackle challenges like climate change, biodiversity loss, and pollution. Through treaties, agreements, and collaborative frameworks, countries can establish common goals, enforce environmental standards, and mobilize collective action, ensuring that efforts to protect the environment are consistent and impactful on a global scale.

Keywords: Collective collaboration, environmental problem, global emerging issues, global impacts, international relations

Introduction

International Relations (IR) refers to the study of interactions between/among states, and other actors on the global stage. It encompasses a broad range of topics, including diplomacy, foreign policy, conflict resolution, globalization, and international law. International relations attempt to explain the interactions of states in the global interstate system, and it also attempts to explain the interactions of others whose behaviour originates within one country and is targeted toward members of other countries (Nye, 2011). The study of international relations is an attempt to explain behaviour that occurs across the boundaries of states, the broader relationships of which such behaviour is a part, and the institutions (private, state, nongovernmental, and intergovernmental) that oversee those interactions. International relations is the examination of the connections and engagements among nations, encompassing the actions and strategies of governmental bodies, global institutions, NGOs, and multinational corporations (Waltz, 2010). It serves as both a theoretical and practical field, with academic perspectives ranging from empirical observation to normative analysis, or a combination of both (Jackson & Sorensen, 2016).

International Relations uses ideas from various subjects like economics, political science, sociology, anthropology, and history, making it a multidisciplinary field (John et. al, 2017). However, the conventional view has been broadened over the years to include relationships between all sorts of political entities including old and new forms of security, dialogue and conflict between visions, beliefs and ideologies, the environment, space, the global economy, poverty and climate change (Glinchey, 2023).

It looks at how these interactions happen between governments, international organizations, companies, and other important groups. This field focuses on understanding how power, cooperation, and conflicts between these actors influence global rules, norms, and laws. In international relations,

in addition to the above, a state can take any of the three approaches: cooperation, unilateralism or inactivity. Within the realm of climate diplomacy, we witness states playing all these roles (Khan, 2016).

This work aims to elaborate the various dimensions of international relations, emerging global issues including environment that are being faced by international community, and various impacts of environmental degradation along with major endeavours taken by the global community collectively on the ground of international relations. In addition, author wants to insist on the necessity of paying same level of global attention towards environmental alarms along with other contemporary issues.

Methods

The bilateral and multilateral relations and interdependence among states has dimensional opportunity to analyse and solve the issues of mutual concerns including environmental aspects. The article is based on a mixed-methods approach, combining qualitative and quantitative data. Impacts from global challenges including environmental hazards are mainly presented in quantitative data. Collective policy efforts made in terms of global agreements through international relations along with major aspects are mentioned in quantitative and qualitative form, both from secondary sources.

Review and Discussions

Theories and coverage of International Relations

There are several theories that explain International Relations, each offering a different view on how it works. Specially, the covering areas including environment issues, the following theories have been studied for a long time (Khan, 2016).

1. **Realism:** This theory sees international relations as a competition for power and security among states. Realists believe that power balance is the key factor in international relations. Realism is perhaps the most influential strand in International Relations, particularly during the Cold War, to have guided nations in their foreign policy pursuits (Donnelly, 2005).
2. **Liberalism:** Liberals believe that international relations can be based on cooperation and mutual benefit instead of competition and conflict. They stress the importance of economic connections, global institutions, and norms (Burchill, 2005).
3. **Constructivism:** Constructivists focus on how ideas, norms, and identity shape international relations. They argue that how actors see and understand reality affects their behaviour and interactions (Reus-smit, 2005).
4. **Marxism:** Marxist theory views international relations as shaped by the capitalist system. Marxists argue that the drive for profit and resources leads states to exploit and dominate each other (Linklater, 2005).

In addition to above major theories, international relations cover various areas such as diplomacy, foreign policy, conflict resolution, globalization and international law.

Moving forward to the significance of international relations, it lies in its insightful impact on shaping global dynamics and fostering cooperation among nations in an increasingly interconnected world. Moreover, it equips us to tackle new challenges such as cyber threats, nuclear proliferation, and the emergence of powerful new global players (Waltz, 2010).

Over time, global interactions between countries have evolved to reflect changing world dynamics and the growing influence of individual nations. Each country pursues goals such as ensuring national security, economic growth, protecting human rights, and bolstering its international standing. These objectives drive countries to engage in diplomacy, provide foreign aid, participate in trade agreements, and collaborate on defence initiatives (Walt, 1997). International relations cover many different topics and areas around the world (Keohane & Nye, 2012).

International Relations are a lively and complex area of study that looks at how countries, states, and other groups interact worldwide. With its long

history, different ideas, and mix of subjects, it helps us understand the complicated world of global politics and how different players affect it (Jackson & Sorensen, 2016).

Major dimensions of international relations

Strength, peace, power and security are key factors shaping international relations. Each one is crucial for keeping things balanced and encouraging cooperation between countries. Together, these elements create a framework for international relations, making it easier for countries to interact confidently, solve problems through diplomacy, and tackle global issues together. The connection between strength, peace, power and security is what helps shape a world where diverse nations can work together towards stability and prosperity (Smith & Brown, 2022).

In today's transformed era, our perspective and approach towards global interactions have been radically altered. The emergence of globalization and cyberspace has effectively dismantled the barriers of distance, significantly influencing the dynamics of international relations. These relations between nations are governed by several factors aimed at fostering a mutually advantageous environment. Among these factors, strength, peace, and security often stand out as fundamental pillars of international relations, embodying key dimensions in this realm (Jones & Patel, 2021).

Strength: The strength of relationships between nations relies on mutual trust, crucial for addressing cross-border issues or crises effectively. Building strength regionally and globally is essential for a country to employ influence in global affairs, attracting allies and creating pressure on the international stage. Conversely, a lack of such strength can weaken trust, fostering uncertainty and potentially aggressive behaviour. For instance, the stressed relations between Israel and its neighbouring nations illustrate the impact of weakened international ties (Smith et al., 2017).

Peace: Peace is an essential right for every nation striving for respectful coexistence, facilitating smooth relations across economic, social, and other domains. It encourages creativity, collaboration, and synergies among nations, as seen during the industrial revolution in Europe coinciding with relative peace among European countries. Even when a country achieves strength and power, its commitment to promoting international peace enhances its influence significantly. Embracing peace as a cornerstone of foreign policy not only earns appreciation for peace-building efforts but also strengthens alliances for the future (Glinchey, 2023).

Security: Security stands as a primary objective for every nation-state, driving them to employ diplomatic, military, and economic measures to safeguard their people, resources, and territories. Both external and internal threats must be addressed for a country to apply influence in global politics; a weak and insecure nation finds itself marginalized on the international stage. However, the pursuit of security can sometimes lead to the misuse of power, with nations resorting to self-serving tactics that serve vested interests (Buzan, 2007).

Power: Power in international relations is multifaceted, encompassing both internal and external dimensions. Internal power pertains to a state's autonomy within its domestic affairs, while external power involves its ability to influence the behaviour of other international actors. This influence is shaped by economic, technological, and military factors, which contribute to the dynamics of global interactions (Morgenthau, 1978). Moreover, power takes on different forms, including compulsory, institutional, structural, and productive power. Financial capabilities also play a significant role, with states' positions as international creditors or debtors, the strength of their financial markets, currency stability, and their influence in global financial governance all contributing to their overall power in the international arena. In essence, power in international relations is a complex concept that manifests in various dimensions and forms (Nye, 2011).

Issues Faced by Global Community as Major Concern of International Relations

In an increasingly interconnected world, the global community faces several pressing issues that require

collective action and understanding. This article explores some of the major challenges identified by recent stakeholders, including climate change, global health crises, economic inequality, and social justice. By analysing the current academic discourse, we can better comprehend these complex issues in the following ways.

1. **Digital Privacy and Security:** With the rapid advancement of technology, digital privacy and security have become significant concerns. Cyber-attacks and data breaches threaten personal information and national security. According to Smith (2023), enhancing cyber security measures is crucial to protect against these evolving threats.
2. **Artificial Intelligence and Automation:** The rise of artificial intelligence (AI) and automation is transforming industries but also raising ethical and employment concerns. Brynjolfsson and McAfee (2021) discuss how AI can displace jobs while also offering opportunities for economic growth.
3. **Pandemic Preparedness:** The COVID-19 pandemic highlighted the need for better preparedness for future health crises. Studies suggest that global cooperation and investment in healthcare infrastructure are essential to mitigate the impacts of future pandemics (Johns Hopkins University, 2022).
4. **Mental Health Crisis:** Mental health issues are becoming more prevalent globally, exacerbated by social and economic stresses. The World Health Organization (WHO, 2022) emphasizes the importance of mental health services and policies to address this growing problem.
5. **Climate Migration:** Climate change is forcing populations to migrate, creating new challenges for countries in terms of resources and infrastructure. Research by McLeman (2021) indicates that climate-induced migration is likely to increase, necessitating comprehensive policy responses.
6. **Antimicrobial Resistance:** The overuse of antibiotics has led to the emergence of antimicrobial resistance, posing a significant threat to global health. The World Health Organization (WHO, 2021) warns that without effective measures, common infections could become untreatable.
7. **Sustainable Development:** Achieving sustainable development goals (SDGs) remains a challenge as environmental, social, and economic issues intersect. Sachs et al. (2022) highlight the need for integrated approaches to meet these goals by 2030.
8. **Block chain Technology:** Block chain technology is revolutionizing industries from finance to supply chain management but also poses regulatory challenges. Tapscott and Tapscott (2021) explore the potential risks associated with widespread block chain adoption.
9. **Food Security:** Food security remains a pressing issue due to population growth, climate change, and geopolitical conflicts. According to the Food and Agriculture Organization (FAO, 2022), innovative agricultural practices and policies are needed to ensure food availability and access.
10. **Water Quality:** Ensuring clean water is an on-going global challenge, exacerbated by pollution and climate change. The United Nations (2022) reports that billions of people still lack access to safe drinking water, necessitating improved management and conservation efforts.
11. **Education Inequality:** Disparities in educational access and quality continue to hinder global development. The UNESCO (2021) stresses the importance of inclusive and equitable education systems to bridge these gaps.
12. **Space Exploration:** As private companies and countries ramp up space exploration, issues such as space debris and space law are emerging. Lewis (2021) discusses the need for international cooperation to address the challenges of increased space activity.

13. **Aging Population:** The global population is aging, leading to economic and healthcare challenges. Harper (2022) highlights the need for policies that address the implications of an aging society, including pension systems and elder care.

14. **Climate Change:** One of the most critical issues facing the global community is climate change. Recent studies emphasize the urgent need for comprehensive strategies to mitigate its effects. According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures have risen significantly due to anthropogenic activities, leading to severe weather events, rising sea levels, and biodiversity loss (IPCC, 2023). Academics argue that immediate and sustained efforts are essential to curb greenhouse gas emissions and transition to renewable energy sources (Smith et al., 2022).

15. **Global Health Crises:** The COVID-19 pandemic has highlighted vulnerabilities in global health systems. Academic research underscores the need for robust public health infrastructure and international cooperation to manage and prevent such crises. A study by Johns Hopkins University (2022) suggests that pandemic preparedness must include investments in healthcare systems, research, and equitable vaccine distribution. Furthermore, scholars advocate for a One Health approach, recognizing the interconnectedness of human, animal, and environmental health (Lee et al., 2021).

16. **Economic Inequality:** Economic inequality remains a significant challenge, worsened by the pandemic. Literatures highlighted the widening gap between the rich and the poor, both within and between countries. According to Piketty (2021), economic policies favouring the wealthy have led to disproportionate wealth accumulation, while lower-income groups struggle with job insecurity and inadequate social safety nets. Academics suggest that progressive taxation, universal basic income, and investment in education and healthcare can help address these disparities (Stiglitz, 2022).

17. **Social Justice:** Social justice issues, including racial, gender, and income inequalities, continue

Table 1: Impact of Some major issues to global community

Major Issues	Global Impacts	Source
Climate Change	Average global temperature increases of 1.1°C since the late 19th century.	IPCC, 2021; NASA, 2022
Terrorism	Acts of violence and intimidation, especially against civilians, in the pursuit of political aims, 15,952 deaths from terrorism in 2021.	Global Terrorism Index, 2022
Pandemics	Over 6.8 million deaths from COVID-19 globally as of 2023.	WHO, 2020; CDC, 2021
Economic Inequality	Top 10% of the global population holds 52% of global income.	World Bank, 2021; OECD, 2020
Migration and Refugees	89.3 million forcibly displaced people worldwide by the end of 2021.	UNHCR, 2021; IOM, 2021
Cybersecurity Threats	$6 trillion in damages from cybercrime globally in 2021due to malicious activities conducted via the internet, targeting individuals, organizations, and states.	CSIS, 2021; NATO, 2021
Nuclear Proliferation	The spread of nuclear weapons and related technology to states not recognized as Nuclear Weapon States and estimated 13,080 nuclear warheads globally as of 2021.	SIPRI, 2021; IAEA, 2021
Human Rights Violations	Abuses and violations of basic rights and freedoms universally granted to all humans and 82 million people experienced torture or cruel treatment in 2020.	Amnesty International, 2021; Human Rights Watch, 2021
Resource Scarcity	2 billion people face moderate or severe food insecurity due to limited availability of natural resources like water, food, and energy.	UNEP, 2021; FAO, 2020

to spark global movements and academic inquiry. Scholars emphasized the importance of systemic change to achieve equity. For instance, Crenshaw (2021) highlights the concept of intersectionality, which examines how various forms of discrimination intersect and impact marginalized groups. Scholars argue for comprehensive policies that address the root causes of inequality and promote inclusivity in all spheres of society (Anderson, 2022).

Biggest Environmental Problems that we are facing

This article further aims to present and elaborate the various environmental issues and how they are being addressed by common efforts. The environment encompasses all living and non-living factors and their impacts on human life. Biotic components include animals, plants, forests, fisheries, and birds, while abiotic elements comprise water, land, sunlight, rocks, and air. Its primary roles include providing resources, supporting life, managing waste, improving quality of life, and serving as a basis for production. Environmental issues are the harmful effects of human activities on the environment (Miller & Spoolman, 2020). These include pollution, overpopulation, waste disposal, climate change, global warming, the greenhouse effect, etc (Cunningham & Mary, 2017).

In this article, the major and biggest environmental problems in addition to the climate change have been presented in the following ways.

1. **Deforestation**: Deforestation contributes to loss of biodiversity, disruption of water cycles, and increased carbon dioxide levels. According to the Food and Agriculture Organization (FAO, 2022), the world loses around 10 million hectares of forest each year, primarily due to agriculture and logging.
2. **Loss of Biodiversity:** The decline in biodiversity is attributed to habitat destruction, climate change, pollution, and overexploitation of species. A report by the World Wildlife Fund (WWF, 2022) indicates that wildlife populations have decreased by an average of 68% since 1970.
3. **Pollution:** Pollution in its various forms—air, water, soil, and plastic pollution—poses severe risks to human health and ecosystems. The World Health Organization (WHO, 2021) reports that air pollution alone causes approximately 7 million premature deaths annually.
4. **Ocean Acidification:** Increasing levels of carbon dioxide in the atmosphere are absorbed by the oceans, causing acidification. This disrupts marine ecosystems and harms shellfish and coral reefs (National Oceanic and Atmospheric Administration (NOAA, 2021).
5. **Water Scarcity:** Water scarcity affects billions of people worldwide, leading to conflicts and exacerbating poverty. The United Nations (UN, 2022) estimates that by 2025, half of the world's population will live in water-stressed areas.
6. **Overpopulation:** Overpopulation intensifies environmental problems such as deforestation, pollution, and water scarcity. The UN (2022) projects that the global population will reach 9.7 billion by 2050, intensifying these challenges.
7. **Soil Degradation:** Soil degradation, caused by deforestation, overgrazing, and industrial activities, reduces agricultural productivity and contributes to food insecurity. The According to the report of FAO (2021), the one-third of the world's soil is moderately to highly degraded.
8. **Waste Management:** The accumulation of waste, particularly plastic, is a growing environmental concern. According to a study by Geyer, Jambeck, and Law (2017), 8.3 billion metric tons of plastic have been produced since the 1950s, with most ending up in landfills or the environment.
9. **Ozone Layer Depletion:** The depletion of the ozone layer, primarily caused by chlorofluorocarbons (CFCs), increases the risk of skin cancer and cataracts in humans and harms ecosystems. The Montreal Protocol (1987) has been successful in reducing CFC emissions, but recovery is slow (UN Environment Programme, 2021).

10. **Overfishing:** Overfishing leads to the depletion of fish stocks, disrupting marine ecosystems and threatening food security. The FAO (2022) states that about 34% of global fish stocks are overfished.
11. **Coral Reef Destruction:** Coral reefs are being destroyed by climate change, ocean acidification, pollution, and overfishing. The NOAA (2021) estimates that about 75% of the world's coral reefs are threatened.
12. **Urban Extension:** Urban extension leads to habitat destruction, increased pollution, and higher energy consumption. A study by Seto et al. (2012) predicts that urban land cover will triple by 2030, intensifying these issues.
13. **Intensive Agriculture:** Intensive agriculture practices contribute to soil degradation, water pollution, and loss of biodiversity. The FAO (2022) emphasizes the need for sustainable agricultural practices to mitigate these impacts.
14. **Invasive Species:** Invasive species disrupt local ecosystems, outcompeting native species and causing economic harm. The International Union for Conservation of Nature (IUCN, 2021) lists invasive species as one of the top threats to global biodiversity.

Efforts for Solving the Issues through International Relations and Cooperation

International Agreements and Cooperation: Human activities have profoundly altered the Earth's ecology, leading to significant environmental changes. Particularly in developing countries, human intervention in natural ecosystems has worsened issues such as soil degradation, the greenhouse effect, global warming, and ecological imbalance. Without intervention, these challenges are likely to worsen in the near future (Sachs, 2022).

Addressing environmental issues requires a comprehensive and coordinated global effort that encompasses policy reforms, technological advancements, public engagement, and international cooperation (UN, 2022). Here's an in-depth look at what the world community has provisioned to tackle these challenges through mutual cooperation and international relations:

Table 2: Global impact of environmental issues being faced by world community

Major Issues	Global Impacts	Source
Deforestation	10 million hectares of forest lost annually from 2015 to 2020.	FAO, 2020
Loss of Biodiversity	1 million species are at risk of extinction.	IPBES, 2019
Pollution	9 million premature deaths in 2019 due to pollution.	Landrigan et al., 2018
Ocean Acidification	Ocean acidity has increased by 30% since the Industrial Revolution.	NOAA, 2020
Water Scarcity	2 billion people live in countries experiencing high water stress.	UN-Water, 2021
Overpopulation	World population projected to reach 9.7 billion by 2050.	United Nations, 2019
Soil Degradation	33% of global soils are degraded.	FAO, 2017
Waste Management	2.01 billion tonnes of municipal solid waste generated annually.	World Bank, 2018
Ozone Layer Depletion	The ozone hole over Antarctica was approximately 24.8 million square kilometres in 2020.	NASA, 2021
Overfishing	34% of global fish stocks were overfished in 2017.	FAO, 2020
Coral Reef Destruction	50% of the world's coral reefs have been destroyed in the last 30 years.	NOAA, 2021
Urban Extension	Urban areas are expected to triple in size by 2030.	Seto et al., 2012
Intensive Agriculture	Responsible for 80% of global deforestation and significant biodiversity loss.	WWF, 2020
Invasive Species	Invasive species cost the global economy an estimated $1.4 trillion annually.	Pimentel et al., 2005

Table 3: Descriptions of International Initiatives to Address Specific Environmental Issues

Initiative (Year)	Major Environmental Issue Focused	Objectives	Key Provisions/ Achievements	Challenges
Kyoto Protocol (1997)	Climate Change	Reduce greenhouse gas emissions	Legally binding emission reduction targets for developed countries (UNFCCC, 1998)	Limited participation by some major emitters, enforcement issues (Harris, 2007)
Paris Agreement (2015)	Climate Change	Limit global warming to well below 2°C above pre-industrial levels	Nationally Determined Contributions (NDCs), financial aid to developing countries (UNFCCC, 2016)	Insufficient commitments, lack of binding enforcement (Rogelj et al., 2016)
Montreal Protocol (1987)	Ozone Depletion	Phase out production of ozone-depleting substances	Global phase-out of CFCs, HCFCs, and other harmful chemicals (UNEP, 2000)	Illegal production and trade of phased-out substances (Andersen & Sarma, 2002)
Convention on Biological Diversity (CBD) (1992)	Biodiversity Loss	Conservation of biological diversity, sustainable use of its components	Aichi Biodiversity Targets, Nagoya Protocol on Access and Benefit-sharing (CBD, 2010)	Slow progress on targets, lack of funding (Pereira et al., 2013)
Basel Convention (1989)	Hazardous Waste	Control of transboundary movements of hazardous wastes	Regulates export and disposal of hazardous waste, reduces waste generation (Secretariat of the Basel Convention, 2011)	Illegal trafficking of hazardous waste, enforcement difficulties (Krueger, 1999)
Stockholm Convention (2001)	Persistent Organic Pollutants	Eliminate or restrict production and use of POPs	Lists POPs for elimination or restriction, promotes safe disposal (UNEP, 2009)	Slow implementation, lack of alternatives for some POPs (Breivik et al., 2010)
UN Convention to Combat Desertification (UNCCD) (1994)	Desertification, Land Degradation	Mitigate desertification, restore degraded land	National action plans, sustainable land management practices (UNCCD, 2015)	Insufficient funding, limited data on land degradation (Reynolds et al., 2007)
Ramsar Convention (1971)	Wetlands Conservation	Conservation and wise use of wetlands	Designation of Wetlands of International Importance, wise use principles (Ramsar Convention Secretariat, 2013)	Habitat loss, pollution, and climate change pressures (Davidson, 2014)
CITES (1973)	Endangered Species	Ensure that international trade does not threaten species survival	Regulates trade in over 35,000 species, includes Appendices I, II, and III (CITES Secretariat, 2020)	Illegal wildlife trade, insufficient enforcement (Reeve, 2002)
MARPOL (1973/78)	Marine Pollution	Prevent pollution from ships	Regulations on ship discharge, ballast water management (IMO, 2011)	Compliance monitoring, enforcement in international waters (Mikulski, 2008)

Despite ambitious goals, the relevancy and effectiveness of international environmental initiatives such as the Kyoto Protocol, Paris Agreement, and Montreal Protocol have been mixed. The Paris Agreement, with near-universal participation, aims to limit global warming but faces criticism for non-binding targets and insufficient national commitments (UNFCCC, 2023). The Kyoto Protocol set a model with legally binding targets but suffered from limited participation and enforcement

issues (Harris, 2022). The Montreal Protocol has been successful in significantly reducing ozone-depleting substances, yet illegal trade in these substances continues to pose challenges (UNEP, 2023). Overall, while these agreements have raised global awareness and prompted action, their long-term effectiveness is hindered by enforcement difficulties and inadequate commitments.

A. Climate Agreements:

- Paris Agreement: Countries need to commit to reducing greenhouse gas emissions and periodically review and enhance their climate action plans (Nationally Determined Contributions, or NDCs). This agreement is pivotal in uniting nations under a common goal to mitigate climate change.
- Montreal Protocol: Continues to be a successful example of international cooperation, targeting the reduction of substances that reduce the ozone layer. Its success highlights the potential of coordinated global action.

B. Shared Resources Management:

- Transboundary Water Management: Agreements on shared water resources, like the Nile Basin Initiative, help prevent conflicts and promote sustainable usage (Nicol & Cascao, 2011).
- Marine Conservation: International treaties like the United Nations Convention on the Law of the Sea (UNCLOS) are essential for protecting oceans and managing marine resources sustainably.

Policy and Legislation:

A. National Policies: Environmental Protection Laws: Implementing and enforcing strict laws on pollution, deforestation, and wildlife protection are crucial steps toward environmental conservation.

Incentives for Green Practices: Providing subsidies and tax incentives for renewable energy, sustainable agriculture, and eco-friendly industries can drive positive environmental outcomes.

B. Economic Instruments: Carbon Pricing: Implementing carbon taxes or cap-and-trade systems incentivizes the reduction of greenhouse gas emissions by making polluters pay for their emissions.

Green Bonds: Governments and corporations can issue green bonds to finance environmentally friendly projects, promoting sustainable development.

Technological Innovation:

A. Renewable Energy: Investment in Renewables: Increasing funding for solar, wind, hydro, and geothermal energy projects is vital for transitioning to a sustainable energy future.

Grid Modernization: Developing smart grids to efficiently integrate renewable energy sources can enhance energy efficiency and reliability.

B. Clean Technology: Waste Management Technologies: Innovations in recycling, waste-to-energy, and biodegradable materials are essential for managing waste sustainably.

Water Purification: Investing in technologies for desalination, water recycling, and purification ensures access to clean water, addressing water scarcity issues.

Sustainable Practices:

A. Agriculture: Sustainable Farming: Promoting organic farming, agroforestry, and conservation agriculture reduces the environmental impact of agriculture while maintaining productivity.

Precision Agriculture: Utilizing technology to optimize resource use and reduce waste in farming practices contributes to sustainability.

B. Urban Planning: Green Buildings: Encouraging the construction of energy-efficient buildings and retrofitting existing structures reduces energy consumption and carbon footprint.

Public Transportation: Developing efficient public transport systems helps reduce carbon emissions from private vehicles and improves urban air quality.

Public Engagement and Education:

A. Awareness Campaigns: Environmental

Education: Integrating environmental studies into school syllabuses raises awareness from a young age, fostering a generation of environmentally conscious citizens.

Media Campaigns: Utilizing media to inform the public about environmental issues and promote sustainable practices can drive behavioural change.

B. Community Involvement: Grassroots Movements: Supporting local environmental groups and community-based conservation projects empowers communities to take action on environmental issues.

Citizen Science: Engaging the public in scientific research through citizen science initiatives helps gather valuable data and raises awareness.

Biodiversity Conservation:

A. Protected Areas: - Establishment of Reserves: Designating and effectively managing national parks, marine protected areas, and wildlife reserves protect biodiversity and ecosystems.

Habitat Restoration: Investing in reforestation and habitat restoration projects aids in the recovery of degraded ecosystems.

B. Species Protection: Anti-Poaching Laws: Strengthening laws against poaching and the trade of endangered species is crucial for protecting wildlife.

Conservation Programs: Supporting breeding and reintroduction programs for threatened species helps in their recovery and preservation.

Addressing Pollution:

A. Air Quality: Emissions Control: Enforcing stricter emission standards for industries and vehicles can significantly improve air quality.

Clean Energy: Transitioning to cleaner energy sources reduces air pollution and mitigates climate change.

B. Water and Soil: Wastewater Treatment: Improving wastewater treatment infrastructure prevents water pollution and protects public health.

Soil Remediation: Investing in technologies to clean contaminated soils prevents further degradation and promotes agricultural sustainability.

Monitoring and Research:

A. Data Collection: Environmental Monitoring: Using satellites and other technologies to monitor environmental changes and gather data is essential for informed decision-making.

Research Funding: Increasing funding for environmental research helps develop new solutions and understand emerging issues.

B. Reporting and Accountability: Transparency: Countries should report on their environmental policies and progress transparently to ensure accountability and trust.

Independent Audits: Conducting independent audits of environmental projects and policies ensures their effectiveness and adherence to goals.

Conclusion and Way Forward

The success of efforts taken towards a sustainable future depends on collaboration and commitment at all levels, from local communities to global institutions. The relationship between international relations and environmental perspectives often establishes when environmental concerns are side-lined in favour of geopolitical interests or economic agendas. This phenomenon occurs when nations prioritize short-term gains over long-term sustainability, leading to policies that neglect environmental protection or exacerbate ecological degradation. However, there's a correlation between international relations and environmental perspectives, as evidenced by the growing recognition of environmental issues as global challenges that require collaborative solutions. Furthermore, environmental issues increasingly influence diplomatic relations, shaping alliances, trade agreements, and conflict resolution strategies. The honest status of implementation of environmental commitments by the world community reveals inconsistent progress, with some nation's leading while others lag behind in fulfilling their pledges.

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