Carbon Storage Potential of Temperate Mixed Coniferous Trees in Community Forests of Bumthang

Anirban Sengupta[1*]

Siptangzur Community Forest, Bumthang

Abstract

Forest ecosystems capture and store a large amount of carbon over long stretches of time. International financial incentive such as UN REDD+ to mitigate climate change needs adequate records on the net carbon stocks available in the forests. To estimate the potential carbon stocks in the temperate mixed coniferous forests of Bhutan, a study was conducted in Siptangzur and Shambayung Community Forests (CF), the oldest CFs in Bumthang Dzongkhag. The total aboveground biomass of trees was estimated using an allometric equation based on trunk diameter developed by the Department of Forest and Park Services (DoFPS). Biomass estimate was converted to forest carbon stock. The study was conducted in the forests dominated by blue pine and spruce. 60% of the trees had diameters of less than 20cm, suggesting a high potential of increasing biomass over time. The above ground biomass for Siptangzur and Shambayung CFs based on sample area was 67.74 t ha-1 and 205.28 t ha-1 respectively.

The total carbon stock at Siptangzur and Shambayung was 4619.49 ton and 6650.29 ton respectively. The results show high carbon stocks and future increase of biomass available for carbon sequestration.

1 SIES Indian Institute of Environment Management.
* Corresponding author's email: anirnans@sies.edu.in

Keywords: Climate Change; Mitigation; Carbon Stocks; Above-ground Biomass; Community Forests; REDD+

Introduction

Global climate change and global warming are the most pressing issues in the world today.

They are mostly attributed to the increasing level of carbon compounds in the atmosphere. The concentration of carbon in the atmosphere post-industrial revolution increased rapidly, reaching 380 parts per million (ppm) in 2005 (Banskota et al., 2007). The CO_2 level continues to grow at an upward trend, reaching 402.9 ppm in 2016 (Lindsey, 2017).

From 1750 to 2011, CO_2 emissions from fossil fuel combustion and cement production have released an estimated 365 (335 to 395) Gt C to the atmosphere, while deforestation and other land use change are estimated to have released 180 (100 to 260) Gt C. (IPCC, 2013). Globally, forest destruction causes 25% of the total human-induced carbon emission and 18% of all GHG emissions (Schoene & Netto, 2005). In contrast, forest conservation, sustainable forest management, and forest enhancement can reduce the CO_2 emission, and that should be rewarded under the UN REDD+ mechanism.

The quantification of forest biomass and carbon estimation is useful in assessing important physical and socio-economic parameters of forest ecosystems, such as the amount of food, fuel, fodder and fibre. It is equally important for estimation of forest productivity, carbon fluxes and to estimate the amount of carbon in different parts of the plants (Schroeder, 1992). It is also useful as an indicator of ecological and economic values (Henry & Sandeep, 2014). Forest ecosystem plays an important role in global nutrient cycling and storing, and the United Nations Framework Convention on Climate Change (UNFCC) and its Kyoto Protocol recognized the role of forests in carbon sequestration and storage (Chhetri et al., 2016). According to Mackey et al. (2013), the avoided forest degradation and deforestation can generate 1-4 billion tons of CO_2 globally.

Bhutan has constitutionally declared to maintain at least 60% of its territory under forest cover. Currently, Bhutanese forests cover more than 70.5% of the land surface and are net carbon (C) sinks (NSSC 2011). The rapid growth of community forestry in the past decade and the government reserve forests (GRF) are being mostly converted to Community Forests and managed by local people and having rights on the timber collection, sale, and income generation as its main motive besides sustainable forest management. Studies conducted by Lee et al. (2016) on carbon stocks estimation by forest biomass and dead organic matter carbon (FBDC) modelling for *Tsuga dumosa* and *Juniperus* spp. in Paro and Bumthang showed that the total C stocks (Mg C ha^{-1}) ranged from 118.35 to 200.04 with an average of 168.41, and the biomass and mineral soil were dominant components of total forest C stocks.

Carbon sequestration gained attention in the South Asia region as it became clear that the subtropical and temperate forests there have a high potential for carbon sequestration and storage, which could attract financial resources under the Clean Development Mechanism of the Kyoto Protocol. However, the pre-requisites for the commercialization of carbon stock depend on accurate measurements and estimation of carbon sequestration rates (Sandeep et al., 2016). Since direct measurements for calculating carbon stocks are not economically feasible, the most widely used indirect method involves the use of allometric equations for the size of trees to calculate above-ground biomass. Most equations use biometrics such as trunk diameter (DBH), tree height. and specific gravity of wood (Tashi et al., 2016). Recent development in that process to estimate carbon sequestration was made by Chettri et al. (2016), using Randomized Branch sampling (RBS) to sample aboveground biomass of tree species in a way that is cost effective and statistically sound.

The reward policy under the REDD+ mechanism is one of the better options to motivate sustainable forest management (Carlson 2009), but it requires robust records of forest carbon stock change, which is very limited in developing countries. Hence, this research is carried out objectively to assess the current forest stand conditions and the net carbon stock in community managed forests. Our objective was to establish a baseline for estimating carbon sequestration potential. We calculated the current net carbon stock of two moderately harvested community forests of mixed coniferous tree species. This method would allow valuing community forest not only for timber but also for other alternative ecosystem services.

Methodology

Study area

Bumthang in central Bhutan is one of twenty districts of the country. The district headquarter, Jakar, is located in Chhokhor Gewog. It has 101 villages and 1,490 households covering an area of 2,708.46 sq. km. Bumthang is adjacent to Lhuntshi district in the east, Wangdi and Trongsa districts in the west, Zhemgang in the south, and China (Tibet) in the north. The altitude ranges from 2400 to 6000 meters above sea level (Dorji, 2011).

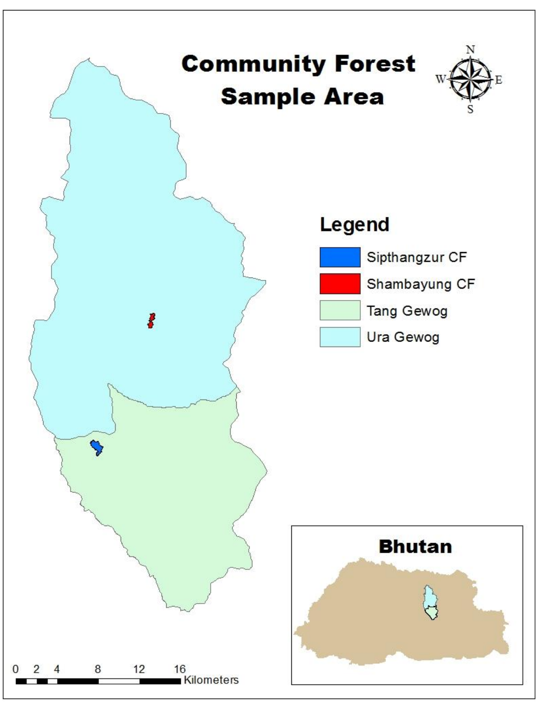

Figure 1. Map of Tang and Ura gewog and location of Siptangzur and Shambayung CF

Two community forests in the Bumthang Dzongkhag were selected for the study, namely Siptangzur Community Forest and Shambayung Community Forest at Tangsibi, under Ura Gewog and Tang Gewog respectively. These CFs are adjacent to government reserved forests (GRF). They are the oldest CFs in Bumthang Dzongkhag as shown in (Figure 1).

Shambayung Community Forest

Shambayung CF is located at 27°62´ N and 90°90´E, elevation ranges from 3000 to 4100 masl in Ugyencholing Village, Tang Gewog. The CF has an area of 67.46 hectares (ha). The area also falls within the buffer zone of Thrumshingla National Park (TNP). The forest is mixed conifer-dominated by blue pine (*Pinus Wallichiana*) followed by spruce (*Picea spinulosa*) and other scrubby woods. According to Phuntsho & Sangay (2006), the natural regeneration was good where the canopy density was less than 50%.

Siptangzur Community Forest

Siptangzur CF is situated north-east of Tangsibi Village under Ura Gewog. It is situated at 27°50´ N and 90°85´ E. The elevation ranges from 2700 to 4000 masl. The CF is adjacent to Thrumshingla National Park (TNP) and is near the national highway. It is a mixed conifer forest of 136.37 Ha, with >70% comprising of young stand of blue pine, spruce, and hemlock as the dominant species.

Data collection

The data were collected with the objective to calculate the total carbon storage by the dominant species in the study area. In each CF, three transects were laid, 200m apart, and on each, three temporary circular elevational plots were established at 100 m apart (Figure 2). Nine circular plots were established in each CF and each plot had a 12.62m radius. Each plot thus covered an area of 500m^2. In each plot, the diameter at breast height (DBH) and a number of all trees with a DBH greater than 5 cm were measured and counted.

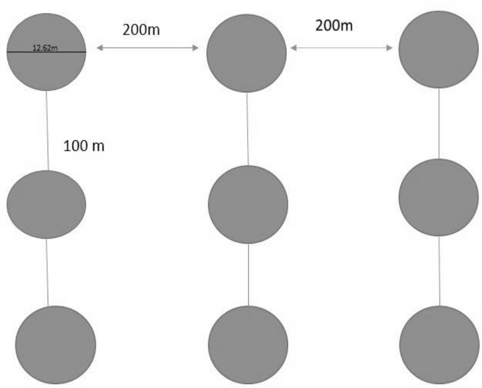

Figure 2. Schematic diagram of methodology for laying the transect in each study area

Data analysis

The above-ground biomass (AGB) was estimated using allometric, an equation based on DBH. The diameter was fitted to the existing allometric function for conifer species developed by DoFPS (2013), which is

Total aboveground biomass ($TAGB_{BP}$) ________________Equation 1,

where a= 0.0621 and b= 2.496 for blue pine, and a =0.0516 and b= 2.495 for spruce. The other species were not taken into account. This was used to calculate the carbon stock, which is estimated to be 50% of the total value of biomass (Field et al., 1998) as this value has been globally used to this purpose (Roy et al., 2001).

Total carbon stocks (t ha^{-1}) = Biomass (t ha^{-1}) × 0.5 _________Equation 2

Results

Standing trees characteristics:

A total of 611 trees from the two CF were recorded (mostly alive but some dead). Siptangzur CF had 553 trees ha^{-1} (S.E= 61), and Shambayung CF had 743 trees ha^{-1} (SE= 110). The plots when segregated elevation-wise depict close to an inverse J-graph with the most tress in the two lowest diameter classes (Figure 3.). The mean basal area of the CFs from the transect survey plots was found to be 18.04 m^2 and 35.11 m^2 in Siptangzur and Shambayung CFs respectively. Both estimates are higher than the estimated basal area of 10.6 m^2 and 17.67 m^2 in the Community Forest Management Plan (CFMP) of both Siptangzur and Shambayung CF respectively. The t-tests showed that the basal area of target species was significantly higher in Shambayung than in Siptangzur (p=0.00731).

Above-Ground Biomass (AGB) estimation and total carbon stock estimation

From the current inventory undertaken in the two CFs, based on the sample area, using equation 1, the estimated above-ground biomass (AGB) for trees with greater than 5cm DBH was 67.74 t ha^{-1} and 205.28 t ha^{-1} in Siptangzur and Shambayung CF respectively. Employing equation 2, estimated total carbon was found to be 33.87 t ha^{-1} in in Siptangzur FC and 102.64 t ha^{-1} in Shambayung FC. Scaling up to the entire forest areas, the net amount of carbon stored in the above-ground biomass was estimated to be 4619.49 ton and 6650.29 ton in Siptangzur and Shambayung CFs respectively.

Discussion

The CFs studied were young mixed coniferous forests with 59% of the trees less than 20cm in diameter. The inverse-J curve of the stand structure suggests a normal curve for forests with more trees in growing stage and lesser-matured trees. Being young growth stands, both CFs hold potential for future growth in the amount of biomass in the forest that can

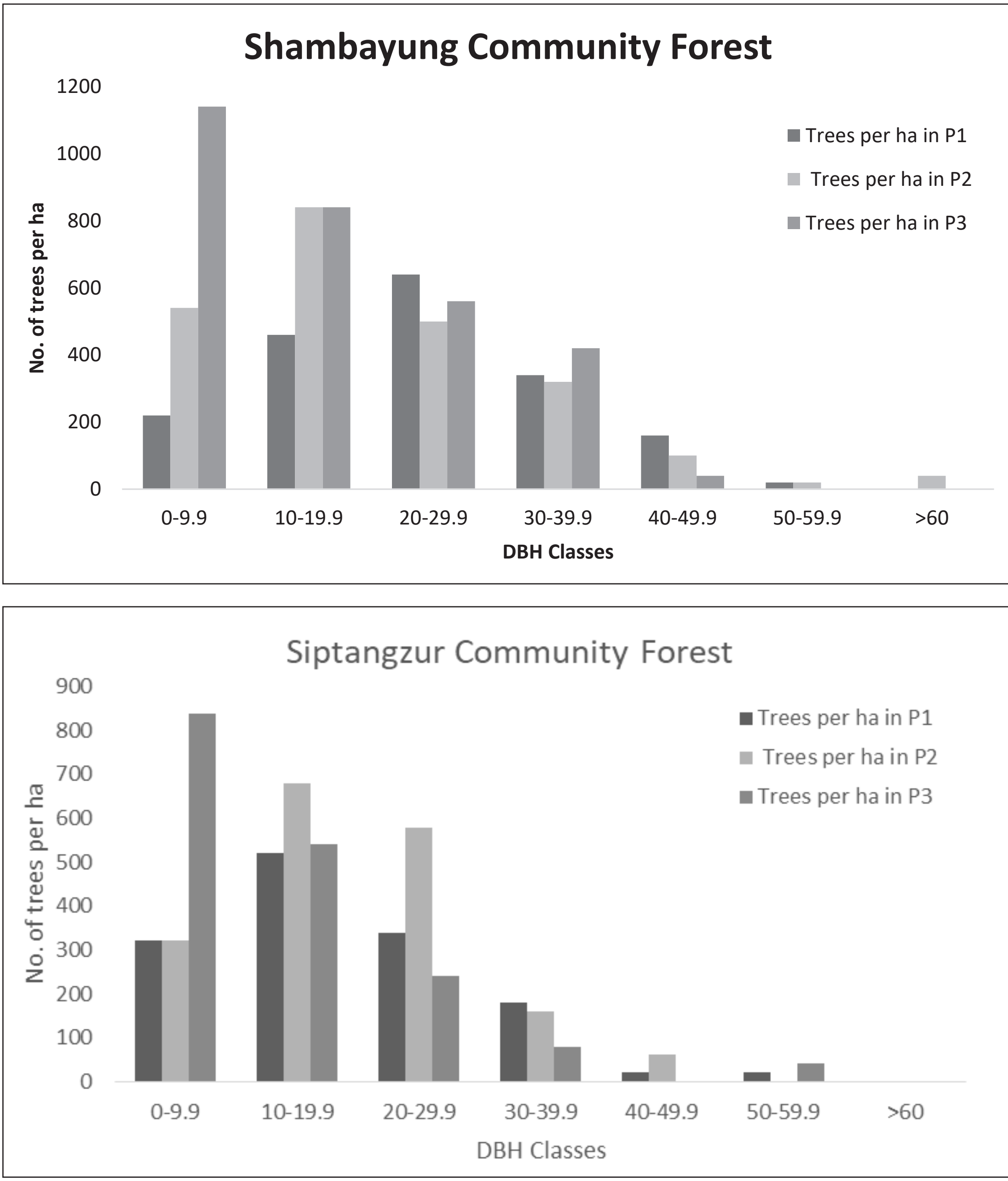

Figure 3: Estimated tree density by diameter class in Siptangzur and Shambayung CF. (P1=lowest elevational plot, P2=middle elevation, P3= highest elevation)

further increase the total amount of carbon stocks in the forest.

According to Torres and Lovett (2012), trees with higher basal area will have more carbon storage as compared to trees with lower basal area as there is a linear relationship between carbon storage and basal area. But the equation is limited to a specific set of data where the proportionality constant for the equation holds true (Chiba, 1998).

The carbon storage did not take into account the biomass of lesser species like hemlock (*Tsuga dumosa),* willow (*Salix* spp.), *Populus* sp*.,* and other woody shrubs in the plots, which would increase the total carbon storage. This study field tests the allometric equation based on the power function of diameter at breast height (DBH) developed by the Department of Forest and Park Services (DoFPS), but it fails to compare the results with other allometric equations available for above-ground biomass calculations in which case could show different values of carbon. The forest stand inventory and carbon stock estimation can be used by the community forest management groups for better management. Estimating the amount of forest biomass is important for monitoring and estimating the amount of carbon that is lost or emitted during deforestation. According to Hunt (2009), 1 tonne of carbon stored in trees is the result of the removal of 3.67 tonnes of carbon dioxide from the atmosphere. The management of forests and calculation of annual carbon increment and subsequent carbon sequestration potential can be rewarded under REDD+ activities.

Acknowledgements

I would like to thank Dr. Purna B. Chhetri for his guidance and support for the entire course of the project. The SFS staff, Casey Kohn, Matt Wojcik and Matt Kohn for helping with the data collection. Tsethup Sir for his constant support during the data collection process. My friends, Jasmine Powell, Nick Dawkins, Amar Dayal, Adair Andre, and Kanchan Kattel for their help at different stages of completion of the entire process. I am also thankful to SFS and UWICER and SAF- UMCSAFS for giving me the opportunity to undertake my research and providing the resources and infrastructure for the successful completion of this project.

Literature Cited

Banskota, K., Karky, B.S, and Skutsch, M. 2007. Reducing Carbon Emission Linking Community Managed Forests in the Himalayas. Kathmandu: International Centre for Integrated Mountain Development.

Carlson, M. K. 2009. REDD pilot project scenarios: are costs and benefits altered by spatial scale? Environment Resource Letter 4: 31-34

Chave, J., C. Andalo., S. Brown, M., Cairns, J., Chambers and D. Eamus. 2005. Tree Allometry and Improved Estimation of Carbon Stocks. Oecologia 145: 87-99. http://chave.ups-tlse.fr/chave/chave-oecologia05.pdf

Chhetri, P.B., Katwal, S., Dukpa, T., Drugyel, S, and Gregorie, T.S. 2016. THE RANDOMIZED BRANCH SAMPLING - A COST EFFECTIVE ESTIMATION METHOD OF ABOVE GROUND BIOMASS. Indian Forester: Vol.142(1): 47-61

Chiba,Y. 1998. Architectural analysis of relationship between biomass and basal area on pipe model theory. Ecol.Model. Vol.108 (pg. 219-225). DOI: https://doi.org/10.1016/S0304-3800(98)0030-1

Department of Forests and Park Services (DoFPS) 2013. Status of Community Forests in Bhutan (unpublished). Data management section: Thimphu.

Dorji, W. 2011. Opportunities and Constraints To Community Forests For Local Income Generation And Livelihood: A Case Study

Of Four Community Forests In Bumthang District, Bhutan. Graduate Student Theses, Dissertations, & Professional Papers. 720. https://scholarworks.umt.edu/etd/720

Field, C.B., Behrenfeld, M.J., Randerson,J.T, and Falkwoski,P.(1998). Primary production of the Biosphere: Integrating terrestrial and Oceanic Components. Science. 281(5374):237-240

HunC.A.G .2009. Carbon sinks and climate change: forests in the fight against global warming: e-book. Cheltenham, UK: Edward Elgar.

IPCC .2013. Fifth Assessment Report Climate Change :The Physical Science Basis Summary for Policymakers. Intergovernmental Panel on Climate Change. Geneva, Switzerland.

IPCC .2014. Climate Change 2014: Synthesis Report. IPCC:Geneva, Switzerland

Karky, B. S., Skutsch, M. 2010. The cost of carbon abatement through community forest management in Nepal Himalaya. Ecological Economics, 69: 666-672

Lee, J., Dorji, N., Kim, S., Wang, S.W., Son, Y. 2016. Piloting the FBDC Model to Estimate Forest Carbon Dynamics in Bhutan. Korean Journal of Environmental Biology. Volume 34, Issue-2 http://dx.doi.org/10.11626/KJEB.2016.34.2.073

Mackey, B., C. Prentice., W. Steffen., I. J. House., D. Lindenmayer., H. Keith, and S. Berry. 2013. Untangling the confusion around land carbon science and climate change mitigation policy. Nature Climate Change Vol.3: 552-557

McKinley, D.C., Ryan, M.G., Birdsey,R.A., Giardiana, P.C., Harmon, M.E., Heath, L.S., Houghton, R.A., Jackson, R.B., Morrison, J.F., Murray, B.C., Pataki, D.E., and Skog K.E. 2011. A synthesis of current knowledge on forests and carbon storage in the United States. Ecological Applications. Vol.21, Issue:6: page 1902-1924.

MoPE.2004. Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change. Ministry of Population and Environment: Kathmandu.

Muradian, R., M. Arsel., L. Pellegrini., F. Adaman., B. Aguila., B. Agarwal., E. Corbera., B. Ezzinede., D. Farley., J. G. Froger., E. Garcia-Frapolli., E. G. Komez-Baggethun., J. Gowdy., N. Kosoy., J. F. LeCoq., P. Leroy., P. May., P. M. Peral., P. Mibielli., R. Norgaard., B. Ozkaynak., U. Pascual., W. Pengue., M. Perez., D. Pesche., R. Pirard., J. Ramos-Martin., L. Rival., F. Saenz., G. VanHecken., A. Vatn., B. Vira, and K. Urama. 2012. Payments for ecosystem services and the fatal attraction of win-win solutions. Conservation Letters, Vol. 6: 274–279.

National Soil Services Centre (NSSC).2011. Bhutan Land Cover Assessment 2010. Ministry of Agriculture and Forests Royal Government of Bhutan, Bhutan

Roy, J., H.A. Mooney, and B. Saugier. 2001. Terrestrial Global Productivity: 1st edition. Academic Press, USA

Saatchi, SS., Harris, NL., Brown S., Lefsky M., Mitchard TAE., Salas W., Zutta BR., Buermann W., Lewis SL., Hagen S., Petrova S., White L., Silman, M, and Morel A. (2011) Benchmark map of forest carbon stocks in tropical regions across three continents. PNAS, 108(24): 98999904

Sandeep, S., Henry, M. 2014. Proceedings of the regional technical workshop on Tree Volume and Biomass Allometric Equations in South Asia, 26 -29 May, 2014. KFRI: Peechi, India

Sandeep, S., Henry, M.,Sivaram, M. Birigazzi, L. 2016. Tree allometric equations in South Asia. Retreieved from https://www.researchgate.net/publication/296026007

Schoene, D & Netto, M. 2005. The Kyoto Protocol: What Does it Mean for Forest and Forestry. Unasylva, 222(56).

Schroeder, P. 1992. Carbon storage potential of short rotation tropical tree plantations. Forest Ecology and Management. Vol: 50, Page 31–41.

Skutsch, M., Van Laake, P. 2009. REDD as Multi-level governance in Making. Energy & Environment Vol. 19: 831-844.

Torres, A.B., Enríquez R,O., Skutsch,M., Lovett, C.J. 2013. Potential for climate change mitigation in degraded Forests: A study from La Primavera, Mexico. Forests:vol: 4-1032-1054

Torres, A.B., Lovett,J.C. 2012. Using basal area to estimate above ground stocks in forests: La Primavera Biosphere's Reserve, Mexico. Forestry (Lond), 86(2): pg267-281.DOI: https://doi.org/10.1093/forestry/cps084

UNFCCC (2011). Fact Sheet: Reducing Emissions from the Developing countries. Available at http://unfccc.int/files/press/backgrounders/application/pdf/fact_sheet_reducing_emissi ons_from_deforestation.pdf

Walkley, A. E., Black, J, A.1958. An Examination of the Method for Determining Soil Organic Method, and Proposed Modification of the Chromic Acid Titration Method. Soil Science 37: 29-38

About Author

Anirban Sengupta Anirban Sengupta is presently pursuing a M.Sc. in Sustainable Development and Environment Management (2017-2019) at SIES Indian Institute of Environment Management, under University of Mumbai. He received his Diploma in Himalayan Studies from SFS Bhutan (2017) and was an intern at UWICE, under UNESCO Madanjeet Centre for South Asia Forestry Studies (August, 2016- January,2017). He completed his B.Sc. in Sustainable development from the College of Natural Resources (2013-2016).