ECOSYSTEM SERVICES FROM *SIWALIK* FORESTS AND THEIR CONTRIBUTION TO LOCAL LIVELIHOODS IN NEPAL

A Thesis Submitted by

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ABSTRACT

Forest Ecosystem Services (FES) play critical roles in people's livelihoods, their environments, and national economies. These services contribute to livelihoods in both high-income and low-income countries, although the contributions from forests vary widely. The contribution of FES to poor rural people, particularly those living in developing countries, is imperative as about 75% of poor people in low-income countries are primarily dependent on FES. Forest ecosystems offer approximately 20% of the income for rural households in low-income countries, through both cash and by meeting subsistence needs. Many ecosystems across the globe are degrading despite significant conservation attempts and the depletion of FES is more pronounced in the mountainous regions of developing countries. The lack of attention and priority paid by policymakers and forest managers to recognising and trying to preserve the comprehensive value of forest ecosystems, and the poor rate of adoption of findings by these leaders in the decision-making process can be argued to have contributed to ecosystem degradation.

This thesis adopts a case study approach and employs mixed (both quantitative and qualitative) methods for collating and analysing data from the *Siwalik* mountains of Nepal. This region is locally known as *Chure* and comprises young and fragile mountains ranging from 93-1955 metres above mean sea level, extending over four developing countries: Pakistan, India, Nepal, and Bhutan. This study identifies and evaluates the FES and explores why FES research outcomes are rarely or only partially incorporated into policies and plans in developing countries. More specifically, the study aims to: (1) identify and prioritise major FES based on proximity (nearby vs distant users), socio-economic class (rich vs poor users) and forest management modalities (community forestry vs collaborative forestry); (2) quantify and value focal FES, and (3) design a framework for policy adoption in developing countries. Selected modalities are dominant forest management regimes in developing countries.

Data were collated through a systematic literature review, focus group discussions (n=8), expert consultations (n=47), household survey (n=253), and workshops (n=2). Data were analysed using qualitative content analysis for ecosystem service identification and prioritisation, market prices, substitute goods prices to estimate financial values received by individual households from provisioning services, willingness to pay for non-use values of regulating and cultural services in cash and labour options through generalised linear mixed modelling in Rstudio, and thematic/content analysis to explore why FES research outcomes are not incorporated into forest policies and plans. Finally, we designed a framework for research that can be helpful in adopting the findings of ecosystem research outcomes.

In this study, 42 different forest ecosystem services (16 provisioning, 15 regulating and 11 cultural) were identified. We found that preferences for services among forest users basically differ according to their proximity to forests, socio-economic status and forest management models. All subgroups of forest users placed the highest priority on firewood, water quality improvement, and bequest values, while they assigned the lowest priority to genetic resources, hazard protection, and hunting services.

Results suggest that users living near forests receive the highest economic benefits compared to those living long distances from the forest area, irrespective of the forest management modality for provisioning FES; likewise, rich users generally derive higher benefits than poorer users.

Rich people generally expressed a higher Willingness To Pay (WTP) for all high ranked non-marketed ecosystem services such as flood control, water quality improvement, bequest and aesthetic values of forests, irrespective of the management modality. The generalised linear mixed model analysis revealed that WTP values for these FES differed in both types of payment options (cash and labour). Statistical analysis between dependent variables (WTP) and other socio-economic attributes (economic status, age of the respondent, gender, caste, household size, and distance from the forest) shows that economic status, distance from forests, household income and household size largely shape the WTP values for all four categories of services.

Overall, this study suggests that FES offer benefits for users although the particular benefits differ according to proximity, economic status and management modality. Forest management plans of forest users could be refined to incorporate the aspirations, priorities and needs of the forest subgroups. This could, in consequence, improve ownership of the community-based forest management system, minimise forest degradation, and restore the critical biodiveraity in the *Siwalik* Mountains. These results, if carefully implemented through policy and forest management operational plans, could also add value to positive outcomes for 'President Chure Tarai Management Plan', World Bank 'Tarai-Arc Strategic Plan and REDD+ initiatives' in Nepal. Furthermore, the methods thus developed and policy adoption framework could be used

for similar climatic, edaphic, topographic, and demographic sites nationally and internationally.

CERTIFICATION OF THESIS

This Thesis is the work of Ram Prasad Acharya except where otherwise acknowledged, with the majority of the authorship of the papers presented as a Thesis by Publication undertaken by the Student. The work is original and has not previously been submitted for any other award, except where acknowledged.

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Student and supervisors signatures of endorsement are held at the University.

STATEMENT OF CONTRIBUTION

The following paragraphs brief the agreed share of contributions of the doctoral candidate and respective co-authors (Supervisors) in the journal publications presented in the thesis.

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Journal Articles

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Ripu M. Kunwar, Maria Fadiman, Santosh Thapa, **Ram P. Acharya**, Mary Cameron, and Rainer W. Bussmann, Plant use values and phytosociological indicators: Implications for conservation in the Kailash Sacred Landscape, Nepal, *Ecological Indicators.* Volume 108 (2020), pp. 105679-89. (Q1: Impact Factor 4.229; SNIP 1.75; 94th Percentile).

Roshan Sharma, Bhagawat Rimal, Himlal Baral, Udo Nehren, Kiran Paudyal, Sunil Sharma, Sushila Rijal, Surendra Ranpal, **Ram Prasad Acharya**, Amer A. Alenazy,and Prashid Kandel. Impact of Land Cover Change on Ecosystem Services in a Tropical Forested Landscape, *Resources*, Volume 18 (1) (2019).

Conference Paper

Bhola Bhattarai, Bishnu H. Poudyal, **Ram P. Acharya** and Tek Maraseni, "Policy and governance issues in timber harvesting: a case study of collaborative forest in Nepal", in the proceedings of the International Conference "Wild harvests, governance, and livelihoods in Asia" Kathmandu 30 November to 2 December 2017.

Book Chapter

Ram Prasad Acharya, Rose Shrestha, Ripu M. Kunwar, Hammad Ahmad Jan, Wahid Hussain, Rainer W. Bussmann, and Narel Y. Paniagua-Zambrana. *Asparagus racemosus* Willd. Asparagaceae. Ethnobotany of Mountain Regions. Book Series, Springer, 2020.

Rose Shrestha, **Ram Prasad Acharya**, Rainer W Bussmann and Narel Paniagua Zambrana. Terminalia bellirica (Gaertn.) Roxb. Terminalia chebula Retz. Combretaceae. *Ethnobotany of Mountain Regions.* Book Series, Springer, 2020.

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ABBREVIATIONS

BT	Benefit Transfer
CBFM	Community Based Forest Management
CC	Crown Cover
CE	Choice Experiment
CF	Community Forest
CFM	Collaborative Forest Management
CFUG	Community Forest User Group
CVM	Contingent Valuation Method
DAI	Demonstration, Appropriation, Internalisation
DBH	Diameter at Breast Height
DD	Deforestation and Forests Degradation
DDC	District Development Committee
DFO	Divisional Forest Office
DFRS	Department of Forest Research and Survey
DMCA	Deliberative multi-criteria analysis
DPR	Department of Plant Resources
DOI	Digital Object Identifier
EC	Expert consultation
ES	Ecosystem Services
FES	Forest Ecosystem services
ERP	Emission Reduction Programme
FFI	Face-to-face Interview
FGD	Focus group discussion
FC	Flood Control
GLMM	Generalised Linear Mixed Model
GMF	Government Managed Forest
GoN	Government of Nepal
Ha	Hectare
HH	Household
HHS	Household Survey
HKH	The Hindu-Kush Himalaya
HP	Hedonic Pricing
ICIMOD	The International Centre for Integrated Mountain Development
IPBES	Intergovernmental Platform for Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	The World Conservation Union
KIS	Key informant survey
LDCs	Least developed countries
LL	Leaf Litter
LR	Literature review
MEA	Millennium Ecosystem Assessment
MFSC	Ministry of Forests and Soil Conservation
MP	Master Plan
MOFE	Ministry of Forests and Environment
MS	Market Survey
MASL	Metres Above Sea level

NOAA	National Oceanic and Atmospheric Administration
NP	National Park
NPC	National Planning Commission
NRM	Natural Resource Management
NV	Average annual net value
OLS	On-line survey
OP	Operational plan
PCTMCDB	President *Chure Tarai Madesh* Conservation Development Board
PFA	Production Function Approach
PQL	Penalised Quasi-Likelihood
PS	Provisioning Ecosystem Services
Q	Quarter
REDD+	Reducing emissions from deforestation and forest degradation
RMS	Rapid Market Survey
RP	Revealed Price
SOC	Soil Organic Carbon
Sq. km	Square kilometre
SC	Sediment Control
TAL	Terai Arc Landscape
TC	Travel Cost
TEEB	The Economics of Ecosystem and Biodiversity
TEV	Total Economic Value
TI	Telephone interview
TPV	Total Value of provisioning Services
UK	United Kingdom
TU-CDES	Tribhuvan University-Central Department of Environmental Science
W	Workshop
WQI	Water quality improvement
WTA	Willingness to Accept
WTP	Willingness to Pay

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1 CHAPTER ONE: INTRODUCTION

1.1 Background

The concept of Ecosystem Services (ES) first appeared in the 1980s (Gómez-Baggethun et al. 2010) and gained increased recognition following a seminal paper by Costanza et al. (1997). Ground-breaking work on ES includes the Millennium Ecosystem Assessment in 2005 (MEA 2005), and The Economics of Ecosystem and Biodiversity (TEEB) (TEEB 2010). The concept of ES has entered into the discourses of many disciplines including natural resource management, biodiversity conservation, and environmental policy and accounting (Gómez-Baggethun et al. 2010). Valuing ES can be part of a strategy for nature conservation and resource management for both enhancing sustainable resource use and persuading policymakers of the significance of keeping natural resources intact. Economic valuation, a process of expressing nature's contribution in dollar values (Farber et al. 2002), appraise both use and non-use values. This process allows decision-makers to identify, evaluate, and estimate trade-offs of ES values with other development goals (Balmford et al. 2002; Christie et al. 2012).

Recognition of the values of ecosystem services has increased globally. Costanza et al. (1997) first estimated the world's ES worth at USD33 trillion, almost 1.2 times more than the total global gross domestic product in 1995. In their more recent update, these values increased to USD 145 trillion (Costanza et al. 2014). Total economic value covers many use values (direct and indirect), option values, and non-use values (Admiraal et al. 2013). However, the direct, apparent and salient services which possess market values are more frequently assessed in most of the ecosystem related research and in different forest management regimes (Gomez-Baggethun & Ruiz-Perez 2011; De Groot et al. 2012; Aslaksen et al. 2015). The state of ecosystems, including forests, has, however, significantly decreased at the global scale, thus limiting the provision of forest ecosystem services (FES).

One of the key reasons behind the diminishing of the state of FES is the limited attention of policymakers and forestry managers to incorporation of total economic values of FES in policy and plans. Contemporary discussions of FES have demanded urgent attention and actions to focus on research on FES from local to global scales by all relevant stakeholders including government, international agencies and academics (Paudyal et al. 2016). There are knowledge gaps in the disproportionate scholastic endeavours on FES research in high biodiverse developing countries and this may be contributing to limited realisation of value of FES compared to other sectors. This can ultimately lead to diminishing its ability to supply FES for human well-being especially in many developing countries.

FES have significantly contributed to the livelihoods of people in both developed and developing nations, despite variations in levels of contribution. The contributions to the livelihoods of resource-poor rural people, particularly those in developing countries, are critically important (Christie & Rayment 2012; Bhatta et al. 2014). Recent statistics show that FES provide approximately 20% of the annual income of rural households both through cash and by meeting subsistence needs (Wunder et al. 2014). About 75% of poor people in developing countries are heavily dependent on FES (FAO 2018). However, despite their significant contributions to large populations, the actual social contributions of FES to different categories of users have not been adequately assessed.

Many academic studies have attempted to assess the economic value of FES. These studies have mostly concentrated on government-managed/public land forests (de la Torre-Castro et al. 2017; Murali et al. 2017; Queiroz et al. 2017), private forests (Nordén et al. 2017), protected area systems (Cuni-Sanchez et al. 2016; Peh et al. 2016b; Shoyama & Yamagata 2016b; Affek & Kowalska 2017; Delgado-Aguilar et al. 2017; Mukul et al. 2017; Vauhkonen & Ruotsalainen 2017) and Community-Based Forest Management - CBFM[1] (Lakerveld et al. 2015; Paudyal et al. 2015; Bhandari et al. 2016). The CBFM is

[1] CBFM stands for community-based forest management. In this study, CBFM covers both community forestry and collaborative forest management. CF is a management model by which national forests are handed over to local forest users for protection, utilisation, and management with the objective of fulfilling the forest product and services demands of local communities. Similarly,

the dominant forest management system (almost 15.5% global forest) in developing countries and is owned or managed by local communities (Maraseni et al. 2019; Torkar & Krašovec 2019). The increasing popularity of CBFM has become increasingly popular in developing countries –22% in 2006, 27% in 2010, and >30% in 2015 (Paudyal et al. 2017). The *Siwalik*, the youngest mountain system in the Himalaya region, extends over four countries: Pakistan, India, Nepal and Bhutan. This mountain system is locally known as *Chure* in Nepal and extends over 36 districts. Ecosystem services[2] from the *Chure* region are critically important to large populations in Nepal and the Bihar and Uttar Pradesh provinces of India. Despite the importance of CBFM, prior studies have not comprehensively assessed the economic contribution of FES to different subgroups within the CBFM, including those in the *Chure* mountain region.

One of the objectives of ES valuation research is to include both use and non-use values in the policy process. However, as noted earlier, recognition of FES studies and integration of their findings in forests and ecosystem management policies and plans at the country level has so far been limited. Many seminal works (MEA 2005; TEEB 2010; Bell et al. 2011), and scholars (Pittock et al. 2012; Gatzweiler 2014; Schuhmann & Mahon 2015; Torres & Hanley 2017) have identified the role of ES valuation studies in informing and reshaping policies. Some studies have attempted to identify the level of influence of ES valuation studies' recommendations in policy improvement in high-income countries such as Australia, New Zealand, Germany and the European Union (Dehnhardt 2013; Rogers et al. 2015; Bouwma et al. 2018; Keenan et al. 2019). Despite increased scholarly efforts, little research has been conducted to investigate the use of research outcomes in actual policy and management decisions, especially in low-income countries. To address this mismatch, this study has also made an effort to explore why the research findings on forest ecosystem services have not been

CFM, in contrast, is a partnership model involving the Department of Forests, local governments and local communities whose aim is to manage a patch of national forest to fulfil local needs.

[2] The MEA (2005) classification of ecosystem services was the first attempt to categorise services into four categories (provisioning, regulating, supporting and cultural). Following CICES (2012) (Haines-Young and Potschin 2012), in this thesis, I adopt three categories of ES (provisioning, regulating and cultural) since they are mutually exclusive, to minimise the risk of double counting, and eliminate the probability of overestimation of values (please see details in Section 3.13.

incorporated into policies and plans and finally, it proposes a research framework for policy adoption of ES research outcomes in developing countries.

1.2 Problem statement

The overall problem is that the value of ecosystem services is declining mainly due to few or no market incentives existing for conservation, proliferation of unplanned infrastructure development, as well as the limited appraisal of the services. For instance, globally, 15 out of 24 ecosystem services are deteriorating because of land use change, population growth, and infrastructure development (MEA 2005). Globally, Costanza et al. (2014) estimate that about USD 4.3 trillion in ecosystem services value was lost due to land-use change over 14 years (1997 to 2011). The limited and disproportionate nature of appraisal may have also accelerated resource depletion (TEEB 2010; MEA 2005; Sharma et al. 2015; Ojea et al. 2012). Ecosystems, including forests, have not been fully valued and so policymakers and resource users are unaware of the true scale of FES losses.

Global studies acknowledge that the realisation of the contributions of FES to enhance forest-dependent people's livelihoods and sustaining the nation's economy (FAO 2015; FAO2018) is increasing. Although valuation research in FES 2014 onwards has proliferated (Chaudhary et al. 2015, McDonough et al. 2017) these studies have mostly evaluated the biophysical aspects by modelling and mapping (Akujärvi et al. 2016; Forsius et al. 2016; Langner et al. 2017; Verkerk et al. 2014), or focussed on the monetary values of FES (Verma et al. 2017, Parthum et al. 2017, Turpie et al. 2017a, Kubiszewski et al.2013). Little research has been carried out on how social dimensions, for example, people's perceptions or preferences, affect or play an important role in the identification and prioritisation of FES. Studies have called for urgent actions to incorporate broader stakeholder priorities and aspirations while performing FES valuation research (Garrido et al. 2017; Fagerholm et al. 2016; Nieto-Romero et al. 2014; Vihervaara et al. 2010; Daw et al. 2011).

McDonough et al. (2017) estimate that more than 88.4% of the ES studies conducted between 2005 and 2016 were in high-income or upper middle-income countries such as the European Union (42%), the US (30%), and China (10%). A limited number of valuation studies have been conducted in coastal, marine, dryland and urban ecosystems (Howe et al. 2014). Valuation research in CBFM in polar and fragile mountain regions like the *Chure* area in global literature is lacking.

There also exists a methodological or data problem in that often only salient (use) services are taken into consideration for valuation. Until 2011, half of the publications picked up a single or easily estimated service and only provided a partial account (McDonough et al. 2017). The exclusion of indirect services has created a two-fold problem: (i) it weakens the case for including such contributions in the national accounting systems and indicators, and (ii) conservation has become a lower priority due to its apparently less significant contribution compared to other sectors. This suggests a critical need for valuation research of non-use FES such as flood control, water quality improvement, bequest and aesthetic values in the data-poor regions of developing countries.

Many developing countries have adopted the CBFM modality to overcome problems of resource degradation (Agrawal et al. 2008; Beyene et al. 2015; Paudyal et al. 2017). Currently, about 31% of forests in developing countries are either managed or owned by communities. Within the CBFMs system, there are different modalities. However, the relative importance of different forest management regimes in delivering diverse ecosystem services to the people is poorly understood and policy implications are not clear (Nepal et al. 2017). Moreover, people have different preferences and may place different priorities on the same services based on their proximity to forests and their socio-economic class (Daw et al. 2011). In particular, there is relatively little knowledge about the value and losses of FES in the CBFM systems of developing countries and mountain regions, and this is evident in the case of the *Chure* region of Nepal, which is subject to extensive demand for development.

Overall, this study addresses these knowledge gaps before demonstrating the actual values of FES, mainly from high priority provisioning, regulating and cultural services. This thesis offers the findings of the study and highlights concerns related to the FES of CBFM (Community Forestry and Collaborative Forest Management) considering preferences of forest users, deriving economic benefits based on proximity to forests, socio-economic status and management modalities, and their implications for forest management in both community and collaborative forest management in the *Chure* region of Nepal.

1.3 Research questions, aim and objectives

The overarching question for this study was: "What are the economic contributions of Community Forestry (CF) and Collaborative Forest Management (CFM) regimes in a developing country, Nepal?" More specifically, this study was guided by the following four research questions:

1. What is the state of forest ecosystem services research and the knowledge gap in the global context?
2. How do the different users of both Community Forestry (CF) and Collaborative Forestry Management systems (CFM) prioritise different forest Ecosystem Services (ES)?
3. What is the economic contribution of priority ecosystem services to the various forest subgroups?
4. How can forest ecosystem services research recommendations be better integrated into the policy process in developing countries like Nepal?

Based on these research questions, this research aimed to assess and estimate the economic contribution of CF and CFM in enhancing the livelihood of forest users in Nepal's *Chure* region. In particular, the study expects to capture the ES values of *Chure* forests for the various sub-groups.

1. **Identify and prioritise forest ecosystem services considering population sub-groups and management regimes in the *Chure* mountains of Nepal.** This objective was achieved through field data collection, focus group discussion and

analysis of priorities by subgroups. The detailed methodology, results, and possible implications are described in the journal article published in *Forests*, vol. 10 (no. 421) which is reproduced as Chapter Four in this thesis.

2. **Quantify the economic contribution of priority forest ecosystem services' values to population sub-groups in the fragile *Chure* mountain area of Nepal**. This objective was achieved through field-data collection and analysis considering economic benefits derived from provisioning, regulating and cultural services. Two articles (*Land Use Policy*, vol. 95 and *Annals of Forest Science,* vol. 11, no. 27 Chapter 5.1 and Chapter 5.2) address this objective.
3. **Design a framework of forest ecosystem services research for policy adoption in developing countries (Nepal).** The objective was addressed comprehensively through careful expert consultation and workshops to identify potential reasons why ecosystem services research outcomes are not incorporated into policies and plans. A framework that can help to integrate forest ecosystem services research outcomes in policies and plans is proposed. A paper to this end was published in *Sustainability*, Vol. 12 (Chapter Six).

1.4 Significance of the study

The findings of this thesis can contribute to the UN Sustainable Development Goal 15, which covers protection, restoration and promotion of the sustainable use of terrestrial ecosystems including sustainable management of forests. Forests contribute to the livelihoods of about 1.6 billion people worldwide and are managed by either government, private or CBFM systems. CBFM has become the dominant forest management system, in which local people play a vital role in planning, decision-making, implementing, and benefit-sharing. More than 31% of the forests in developing countries are under some form of CBFM system.

It is hoped that the results of the study will be helpful to researchers, planners and policy implementers. The outcomes of this study can act as a reference for other fragile *Chure* regions in similar settings in Pakistan, India, and Bhutan. The proposed framework could also assist future research on FES and achieve outcomes such as positive policy development processes in a country like Nepal.

The values of FES considering forest user subgroups are beneficial to projects that are already underway in the study area. For example, the GoN has recently formulated a twenty-year Master Plan (MP) for the *Chure* region with an expected investment of US$2385.321 million (PCTMCDB 2017) and has also formulated a *Tarai*-Arc Landscape Strategic Plan (2015-2025) to develop and conserve both the *Tarai* and the *Chure* regions, with a budget of US$ 272.92 mil (MFSC 2015). The research outcomes from this study — priority ES and their monetised values — can assist decision-makers to prioritise the scarce resources in the right way in the right place in the future.

1.5 Structure of the Thesis

Chapter 1: Sets the overall context and background of the study and outlines the statement of the problem, objectives of the study and significance of the research at a global scale in general and for the case study country.

Chapter 2: Describes the study area and presents the overall methodology applied in the study; it sets out the methodological basis for subsequent chapters which are primarily based on published papers that use the specific methods for data collection, compilation and analysis.

Chapter 3: This chapter reviews pertinent literature and investigates the key knowledge gaps in forest ecosystem services valuation studies. The first section presents an overall review of the literature on forest ecosystem services valuation and justifies the study. The second section identifies the forest ecosystem services temporal trends, methodological approaches, the types of services mostly assessed and discusses the spatial distribution of FES valuation studies. This section is presented as a published review article entitled “Global trends of forest ecosystem services valuation – An analysis of publications” in *Ecosystem Services* (https://doi.org/10.1016/j.ecoser.2019.100979). This paper reveals that prior studies are mostly concentrated in high-income countries and government-managed and protected area systems. It adopts an aggregated perspective and identifies the urgent need to explore FES in low-income countries, with a community-based management model while considering different forest users.

Chapter 4: This chapter comprises a published article "Local Users and Other Stakeholders' Perceptions of the Identification and Prioritization of Ecosystem Services in Fragile Mountains: A Case Study of *Chure* Region of Nepal" in the journal *Forests* (DOI: http://doi.org/10.3390/f10050421 and addresses the first research objective of the study.

Chapter 5: This chapter is presented as articles addressing the second objective of the study. The first is a published article entitled "Assessing the financial contribution and carbon emission pattern of provisioning ecosystem services in *Siwalik* forests in Nepal: Valuation from the perspectives of disaggregated users" in the journal *Land Use Policy* (DOI: https://doi.org/10.1016/j.landusepol.2020.104647).

The second article is "Estimating the willingness to pay for invisible ecosystem services from forested Siwalik landscape: Perspectives of the disaggregated users", published in *Annals of Forest Sciences.* The first assesses the financial contribution of provisioning services to different subgroups in two community-based forest management (CBFM) modalities and outlines the carbon emission from the use of provisioning services. The second article particularly estimates the Willingness to Pay of different regulating and cultural services to different subgroups in CBFM.

Chapter 6: Comprises a published article "An Ecosystem Services Valuation Research Framework for Policy Integration in Developing Countries: A Case Study from Nepal" in the journal *Sustainability* (DOI: doi:10.3390/su12198250) and responds to the third research objective of the study.

Chapter 7: Synthesises the overall research outcomes and presents the limitations of the study. It presents a summary of the policies and plans for the benefit of policymakers.

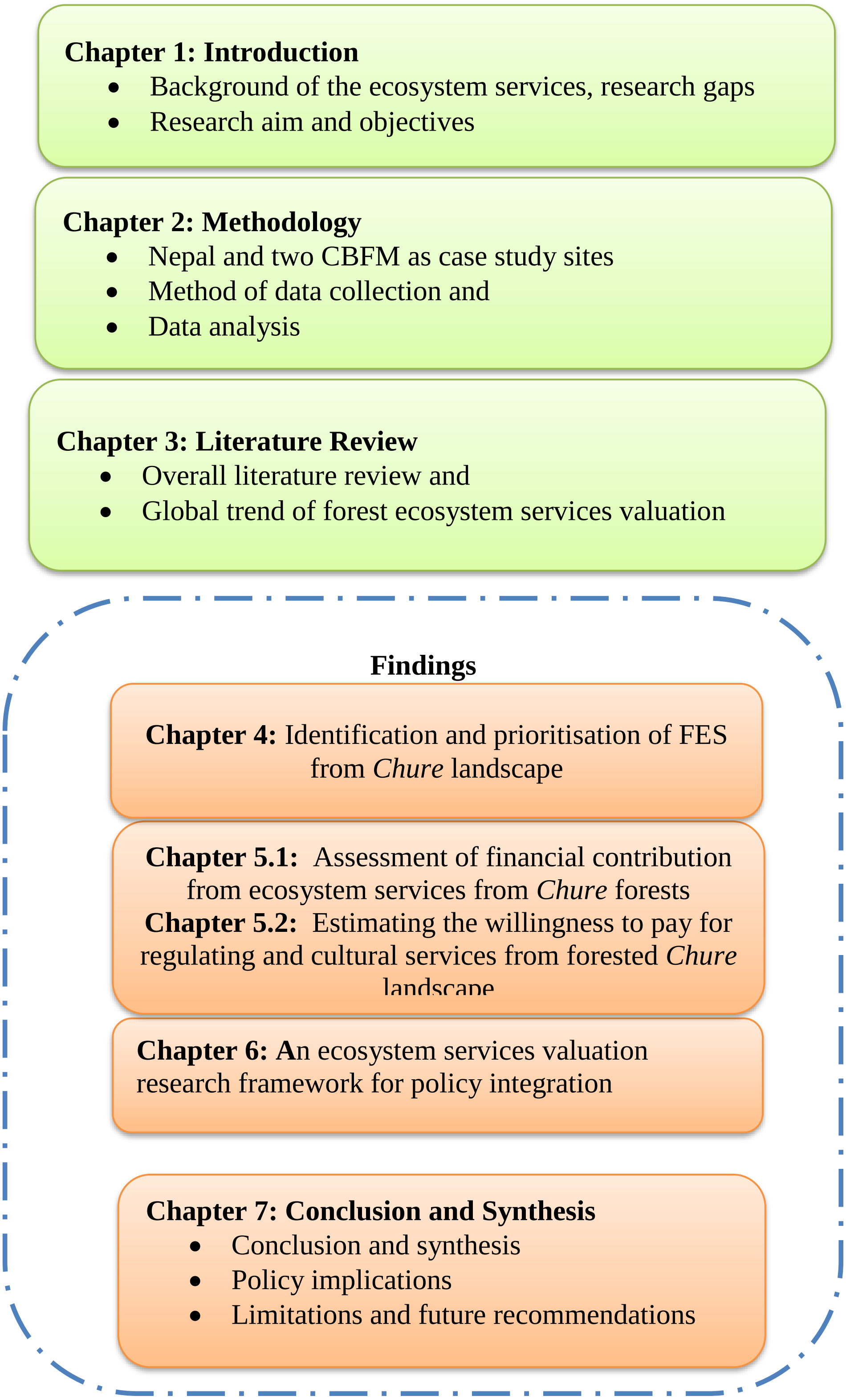

Figure 1-1: Structure of the Thesis

2 CHAPTER TWO: METHODOLOGY

This chapter describes the study location, study area selection criteria, research design, types of data, and methods employed to collect the required information. As each of the objectives and their subsequent chapters are published papers in international peer-reviewed journals, they contain a detailed methodology, therefore, this chapter is a summary of the methods used in the whole thesis.

2.1 Study area

Nepal is selected as a case study site for this study. Nepal has wide climatic and topographic and altitudinal variations and hosts 118 different varieties of ecosystem (MFSC 2014; Acharya et al. 2020). Nepal harbours many forest ecosystems with services ranging from the provision of timber, firewood, fodder and soil and water as well as climate-related services. Nepal occupies about 0.1 per cent of the global area, but ranks 25th in terms of biodiversity, possessing 3.2% and 1.1% percentage of global flora and fauna respectively. Nepal extends from tropical lowlands to snow-capped Himalayan Mountains physiographic zones. These comprise five major physiographic regions extending from East to West including High Himal, High Mountains, Middle Mountains, *Siwaik* (or *Chure*) and Tarai (MFSC 2015).

The Chure region extends parallel to the Lesser Himalaya in the southern part of the Indian subcontinent (Sivakumar et al. 2010) and extends across four countries Pakistan, India, Nepal and Bhutan (Figure 2.1). This area has a sub-tropical climate. The soil comprises deposition of detritus and sediment as a skirt and is composed of unconsolidated loose materials originating from soft rocks such as mudstone, sandstone, siltstone at the southern base of the rising Himalayas (Dahal et al. 2012).

In Nepal, the *Chure* spreads from east to west across 36 districts, covering 12.78% of Nepal; of this area, 72.56% is forest (DFRS 2015). Despite the large forest coverage, the region has witnessed tremendous land-use changes over the last four decades due to a variety of anthropogenic drivers (Dahal et al. 2012).

Moreover, the region faces high soil erosion due to the high precipitation, fragile topography, excessive anthropogenic pressure, and unplanned development activities. This, in turn, has resulted in serious floods, damage to agricultural fields (in *Tarai* and inner *Tarai* areas), expansion of riverbeds, and deposition of sands on farmlands leading to desertification (DPR 2014).

The basis for selecting the *Chure* region *of* Nepal as a case study site was the size, importance and fragility of the region. *Chure* extends 2400 km in total; Nepal's share is more than 36% (885 km) (Joshi et al. 1998) and the forests are managed as various CBFMs (CF, CFM) (Maraseni et al. 2014; Paudyal et al. 2017).

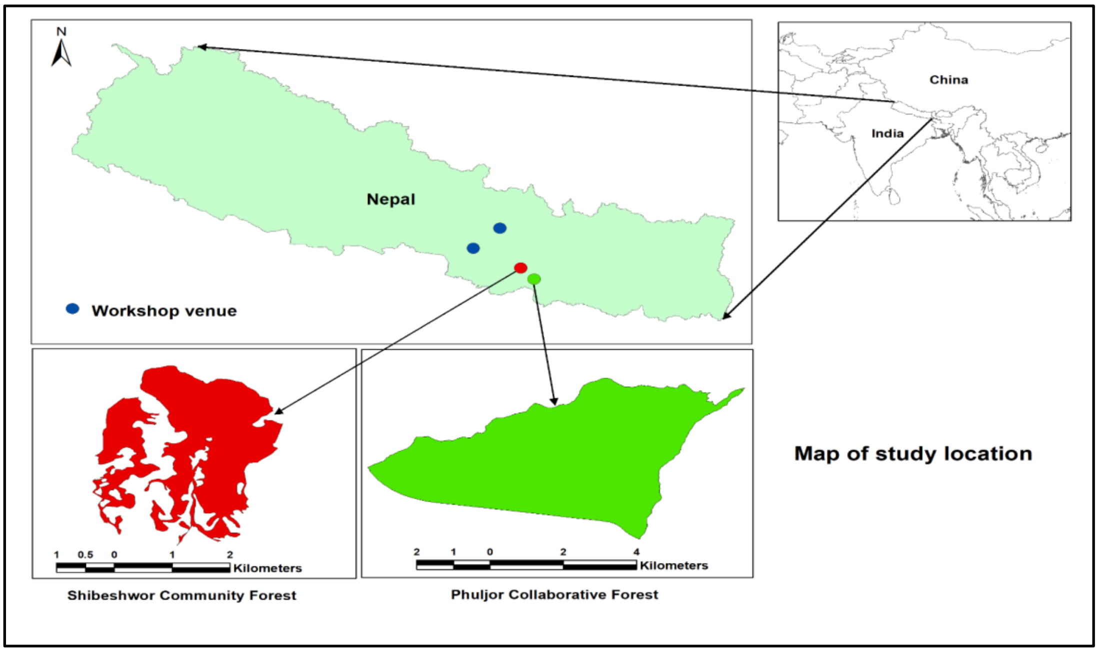

Figure 2-1: Map of Siwalik region and study sites :Shibeshwor Community Forest, left,and Phuljor Collaborative Forest (right) in Nepal and Workshop venue Kathmandu (top) and Hetauda (bottom)

Likewise, the *Chure* comprises almost 12.8% of the land area in Nepal but holds more than 23% of Nepal's forests; it provides various FES for half of Nepal's population as well as for many parts of India. This region also suffers from high deforestation and forest degradation and has lost almost 2.7% of forest area in the last 15 years (DFRS

2015), whereas the forest areas in other parts of Nepal have increased during the same period. As noted, given *Chure's* importance to downstream communities and its degraded situation, the GoN has been giving top priority to its conservation and management by formulating a twenty-year master plan with a budget of US$ 2385.321 million (PCTMCDB 2017).

I carried out the study in *Sarlahi*, the central Tarai district of the Chure-Tarai Landscape, positioned 330 kilometres southeast of Kathmandu, Nepal. The district comprises 125,948 hectares, of which 15.5% is the *Chure* mountains and the remainder is the Bhawar and the Tarai regions. The study sites are in the northern part of the study district. This area displays multiple land uses, including cultivated land 66.6% and forests 23.3% (DFO 2017). Forests in the area are managed through both community (45%) and collaborative forest management (18%). Due to the high elevation, from 60 metres above sea level (masl) to 659 masl (DDC 2016), the region is diverse in climate, vegetation and land-use patterns (DFO 2017; Singh 2017).

Two community-based forest management units were selected (one CF and one CFM) for the case study. *Shibeshwor* community forest is located in the *Hariyon* municipality and *Phuljor* Collaborative Forest Management is situated in the *Ishworpur* municipality, covering 3121 hectares of forest area (*Shibeshwor*: 711 hectares, and *Phuljor*: 2419 hectares) (see Figure 2.1). Sal (*Shorea robusta*) is the dominant tree species in both these CBFM and comprises almost 55% of crown cover in both units. These two CBFM units were chosen for four main reasons: (1) these CBFMs have both nearby and distant users with different degrees of intensity of both direct and indirect use of ES; (2) users have a long history of contribution to forest protection, management and utilization; (3) the areas comprise naturally rich and productive ecosystems; and (4) the landscape faces severe soil erosion and flooding (DPR 2014; PCTMCDB 2017).

2.2 Overview of the research methods

2.2.1 Research design

This study adopted a mixed-methods research design, which combines both qualitative and quantitative methods for data collection, analysis and integration. This method was applied to secure an in-depth and elaborative understanding of phenomena of interest. The method can improve validity through triangulation of information at various levels (Creswell & Clark 2007). It was based on a case study approach, which was considered suitable for a mixed method study (Mills et al. 2010), with focus group discussions (FGD), a household survey (HHS), a key-informant survey (KIS), expert consultation (EC), workshops (W), and a market survey (MS) to collect primary data.

This study aimed to assess forest users' priority in a stratified manner; therefore, data were collected through stratification of the forest users in terms of management regime (CF and CFM), proximity to sites[3], and socio-economic class[4]. Eight FGDs representing different management regimes, proximity and remoteness, and socio-economic classes [(CF: nearby-2 (rich:1, poor:1), distant-2 (rich:1, poor:1) and CFM: nearby-2 (rich:1, poor:1), distant-2 (rich:1, poor:1)] was conducted. Similarly, HHs were also stratified for the survey using the same criteria and the total number of HH from each stratum was identified. Then, 30-33 HHs from each stratum/sub-group were randomly selected. In addition, this study used workshops to gather further primary information before and after the HHs survey. An inception workshop was organised in *Kathmandu* among officials from the Ministry of Forests and Soil Conservation and its Departments, officials from the Planning Commission, and organisational heads working in NRM sectors to share the research objectives, methods, potential contribution/outcomes and identify research problems/gaps. Similarly, after data compilation, a validation workshop was organised in *Hetauda* to share the preliminary

[3] Users living within 5 km distance from forests are considered nearby and beyond 5 km as distant users
4 CBFM classifies users into four categories (Well-off, Medium, Poor and Very-poor). This study considers the first two as Rich and the other two as Poor.

findings and to obtain feedback. The following framework illustrates the flow of the research (Figure 2.2).

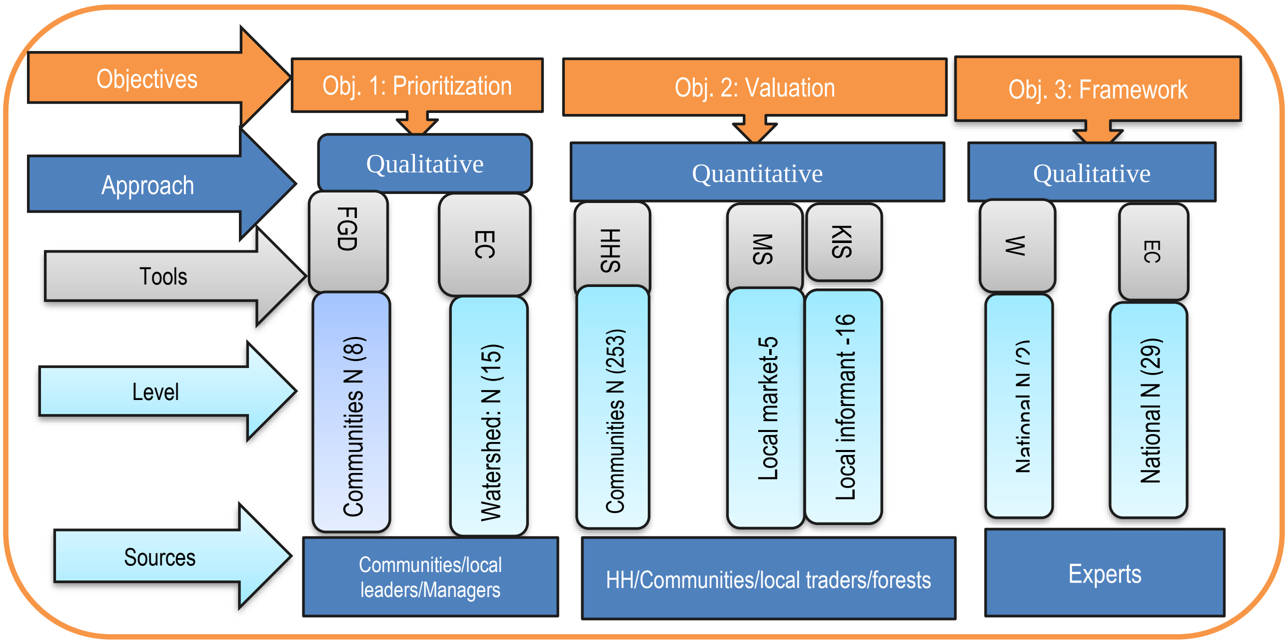

Figure 2-2: Conceptual framework of the research

2.2.2. Data collection methods

Web-mining, consultations, social surveys, and workshops techniquies were employed to collect data for this research. A systematic review of 1156 peer-reviewed journals, eight focus group discussions, face-to-face households survey of 253 households, key-informant interviews was carried out. Moreover, two stakeholders workshops were conducted at Kathmandu and Hetauda.

A list of potential FES was prepared after reviewing the relevant literature, specifically those that were published in peer-reviewed journals in and those adjacent to the *Chure* region (Basnyat et al. 2013; Sharma et al. 2015; Bhandari et al. 2016). The preliminary list of forest ecosystem services available in the *Chure* region was adopted from Bhandari et al. (2016) since the research site is similar to my site. This list was discussed, refined and updated through the Expert Consultations (EC).

Understanding the local forest users' attitudes, considering their needs, aspirations and representing their opinions are important for the successful conservation and sustainable use of FES. To understand of the FES priorities of the forest users, a number of methods including community workshop (Greenhalgh et al. 2017), stakeholder consultation (Baral et al. 2016), household survey (Bhandari et al. 2016), and point system rating (Shoyama & Yamagata 2016a) have been used. However, these methods possess some limitations. In some cases, stakeholders such as government and non-government sectors may not fully understand the reality of communities especially in-terms of socio-economic aspects. Similarly, community workshops may fail to control undue deliberation by elites.

I adopted a qualitative method, the Focus Group Discussion (FGD) to identify the users'priority on forest ecosystem services from both CBFM. This is the appropriate method since it allows participants to express their shared views about many types of social and cultural values on natural resources (Stålhammar & Pedersen 2017). While FGD is designed to explore people's perceptions of a particular area of interest (Kaplowitz & Hoehn 2001), it may sometimes ignore minorities' voices. I, therefore, stratified the forest users into eight different homogeneous groups representing proximity, and remoteness, and all wealth classes, to address these limitations. Information on proximity and the economic class was obtained from CBFM operational plans. The FGD were conducted in a local language and participants were provided with a long list of potential FES. Concept, types, importance of various ESs to their livelihoods, and the implication of ranking exercise were discussed. Adopting the principles of Shoyama and Yamagata (2016a), participants were asked to rate all FESs on a 1-100 scale depending on the importance to their livelihood. A similar exercise was conducted with government officials and various experts working in the natural resource management sectors.

Provisioning services have direct use values and therefore can be quantified using market prices. Some non-market services can be evaluated through cost-based approaches (alternative cost, substitute goods cost and replacement cost), the revealed price approach (travel cost, hedonic pricing, production approach) and the Benefit Transfer (BT) method. Revealed Price (RP) can estimate a low value compared to market value if there is any policy distortion or market failure. A similar situation exists in my case study sites. For example, where users receive forest ecosystem services like timber, firewood, thatching materials at a heavily subsidised price.

Following Sharma et al. (2015), the total value of provisioning FES for the forests (TPV_i) was calculated using an Eq 1.

$$TPVi = \sum_{i=1}^{n}(\%hhi * \mathrm{HH} * \mathrm{NV}i) \text{.................}(1)$$

where *i* is a provisioning service type, i.e. firewood, timber, fodder that could be1-11, $\%hh_i$ is the percentage of household dependent on the *i*th provisioning services (i.e dependency weight). HH is the total number of households in the forest area; and NV_i is the average annual net benefits per user HH, which was calculated by subtracting the extraction and transportation cost of the services to the local market from their respective gross value. Household dependency and average household net benefits was obtained through HHS (see HHs questionnaire in Appendix A). For the HHS, the questionnaire consisted mainly of socio-demographic information and the current use level of provisioning services.

Regulating ecosystem services are the benefits obtained from the regulation of ecosystem service processes such as climate and water regulation, soil conservation, natural hazards minimisation including flood control, and waste management (TEEB 2010). Despite the difficulty of monetising these services, scholars have estimated them by applying replacement cost, avoided damaged costs, defensive expenditure and revealed price methods. These methods are not directly relevant to this study because first, some researchers have benefited from reliable historical data such as total biomass and annual growth rate from “Forest Survey of India” (Ninan & Kontoleon 2016; Verma et al. 2017) and sediment load in each catchment of South Africa (Turpie et al. 2017). No such reliable data were available for my study site. Second, many studies have used the benefit transfer (BT) method to estimate carbon stock/sequestration economic value (Appendix B). BT is cost-effective and can be used if site characteristics are similar. When carrying out studies in a country like Nepal where there are highly diverse climatic, edaphic and topographical conditions, care in using such methods is needed.

As discussed earlier, the *Chure* forest provides a water regulation service to a large population of Nepal and some parts of India. Other potential regulating FES are carbon stock, sediment retention/flood control, water quality improvement, biodiversity conservation, and pollination. This study considered only the two highest-ranked regulating services - namely flood regulation and water quality improvement (WQI), mainly due to limited time and financial resources to monetise the economic values in the CBFM. Similarly, it is interesting to note that, irrespective of forest management modality, all forest users chose WQI service as the top priority. Similarly, *Chure*, which is a fragile mountain range faces flash flooding, one of the major problems in the region, and therefore, flood control service was selected as the second priority.

Contingent valuation method was employed for monetising the regulating (flood reduction, water quality improvement) services. The primary data for both services were collected using a household survey following a stratified random sampling technique. Following the guidelines developed by the National Oceanic and Atmospheric Administration (NOAA) (Arrow et al. 1993) and the best practices proposed by Johnston et al. (2017), I developed scenarios and formulated the questionnaire for the contingent valuation survey.

Face-to-face open-ended contingent valuation survey was conducted with two payment options since forest users, who face cash constraints in developing countries, could express their WTP in terms of labour (Rai et al. 2015). The WTP in terms of labour was the preferred option offered in the focus group discussions. The participants were reminded that while they offered money and labour contribution to forest management, their purchasing power and labour-force would be reduced by the same amount (money/labour). After informing them of the consequences of all situations, they were asked whether they agreed to participate in the process. If the respondent agreed, then he/she was asked what the highest amount in terms of cash as an annual fee or number of annual labour days they would be willing to pay for three different forest recovery scenarios. If he/she did not agree then he/she was asked to state the reason for being unwilling to participate. More than 95% of the participants (n=241) said they would contribute either cash or in-kind for all four services.

Two cultural services i.e. aesthetic and bequest services were most prioritised during a focus group discussion and therefore I selected these two services for economic valuation. Aesthetic value refers to the appealing and inspirational aspect of the landscape (Beza 2010), whereas bequest value is attached by individuals to the fact that future generations will also derive benefits from species and ecosystems (Pascual et al. 2010). Moreover, bequest value is categorised as a non-use value, which is a special case of option value that represents the value (to current users) of being able to bequeath the forest to future generations (Pearce & Turner 1990; Davies & Richards 1999). There is a knowledge gap in the estimation of the bequest value of forests. It is not like existence values which tend to be fuzzy values (Pearce & Turner 1990) and which accrue mainly to people who do not use the forest and may never see it except through media (Davies & Richards 1999). If the bequest is for immediate descendants, preference will be higher than for future generations in general (Pearce & Turner 1990).

Both aesthetic and bequest values were also assessed through the contingent valuation technique. Following Sattout et al. (2007), this study used an open-ended questionnaire, which did not restrict respondents to the specific value of the services (Boyle et al. 1996) to estimate the willingness to pay for aesthetic and bequest values. Three hypothetical scenarios - *Scenario I:* current land-use patterns [55% crown cover with forests land (broadleaf, and conifer), grazing and cropping land]; S*cenario II*: land use as of 15 years ago i.e. % of 70% crown cover along with land use pattern; and *Scenario III:* land use as of 30 years ago with 85% of CC along with land use pattern, was developed. Then, the HH survey was conducted to estimate WTP for aesthetic value in cash for each scenario (See Appendix A).

Many scholars have attempted to identify the state of integration of forest ecosystem services research outcomes in policies and plans and have identified multiple attributes that determine the integration of research recommendations into policies and plans. These attributes include proper communication throughout the research (Rogers et al. 2015), and capacity building and critical training of policymakers (Marre et al. 2016). Likewise, the participation of stakeholders from problem identification to knowledge generation (Spangenberg & Settele 2016), context, process and methods of valuation including involvement of local champions (Waite et al. 2015), and adoption of five steps with the critical engagement of stakeholders (Martinez-Harms et al. 2015) are some factors that guide the uptake of the research outcomes in policy and plans. Appendix C lists the literature that explores the influence of ES research recommendations in policy and plans. This study adopted the views of Spangenberg and Settele (2016), who consider participation, communication and careful targeting to integrate forest ecosystem research outcomes into policy processes particularly exploring forest ecosystem values considering economic classes and proximity of users from the forests. A series of consultations with experts and workshops were employed: to explore why ecosystem services research was not incorporated in the policy process; and to develop an effective framework of FES research in developing countries**.**

Twenty-nine one-to-one meetings were organised with researchers, academics, government officials, and persons working in forest ecosystem conservation and management at a central level. During the consultation, the discussion was concentrated on knowledge/gaps in FES valuation at the individual and organisational level, number, process and methods of FES research they applied, major factors that hinder why research recommendations are not being incorporated into policy and plans and solicited advice for process/framework of FES valuation research recommendations in management and decision making.

2.2.3. Data analysis

Both qualitative and quantitative techniques were used for data analysis. Qualitative information collated from systematic web-mining, key informant interviews and workshops were scrutinised adopting tools such as thematic/content analysis, coding and interpretation. For review works, publications were analysed by origins of publications (low, high income countries), types of ecosystem services and research origin in different management modalities. Ecosystem prioritisation was analysed by a ranking process. For example, users ranked 1-16 (1 is least and 16 is the most important) for provisioning services, 1-15 (1 is the least important and 15 is the most important) for regulating services, and 1-11 (1 is the least important and 11 is the most important). The highest number in the service category being the total number of FES (e.g. 15: total of 15 types of provisioning services) in that category.

Socioeconomic information was analysed employing Excel and SPSS and basic statistical measures such as ANOVA test. The prioritised provisioning services was computed using the market price and substitute price methods as presented in Equation 1. Similarly, to analyse the carbon emission from consumption of ten provisioning services, their quantities were first converted into biomass and then into CO_2 using Eq 2.

$$Carbon\ dioxide\ emssion\ (e) = Total\ biomass\ of\ PS * 0.47 * 3.67\ (equivalent) \ldots\ldots\ldots\ldots (2)$$

Where, CO2e= carbon dioxide equivalent, total biomass of provisioning services in tonnes.

This study performed the generalised linear mixed model (GLMM) to analyse the data of invisible services in RStudio. The maximum wiliness to pay amount was estimated using Boyle 2017 as presented in Eq. 3.

$$Mean\ WTP = \sum_{i=1}^{n} WTPi \ldots\ldots\ldots\ldots\ldots (3)$$

To identify the relationship between dependent variables (i.e. wiliness to pay) and other socio-demographic variables such as economic status, age of the respondent, gender, caste, household size, and distant from the forecast, we analysed the data in

Rstudio following Bolker et al. (2009). A Generalised Linear Mixed Model (GLMM) was used to assess the correlation and estimate the effects of the explanatory variables (economic status, distance from forests, level of education, household size and caste, a fixed variable; age of respondent, gender, a random variable) on response variables. GLMM with PQL (Penalised Quasi-Likelihood) function in R package (Pinheiro et al. 2018) was used for fitting the model. This GLMM was selected because it deals with non-normal data with unbalanced design and cross-random effects.

We used the forward method, that is, we commenced with economic status, age, and gender and put in other variables (distance from forest, caste, income, family size, and livestock) in different combinations (please refer Appendix D for six other combinations). We performed an Anova test between six combination models, (for example first (M1) versus second (M2) and observed whether there was any significant difference among these models. We repeated the same process for all six models one by one. We chose the sixth model, in which three variables (Eco_Status, Edu_lev, Distant_For) as main variables, two (Age_respon, and Total.income, Tot_Fam_memb) as associate variables and Gender and Age_response as random variables exhibited significance for most of the variables as presented in Eq 4. This equation is an example of the prediction of the willingness to pay for flood reduction by 15% of cash option (please see all 24 fitted models for four regulating and cultural services and six different scenarios in Appendix E).

To explore why forest ecosystem services research outcomes are not incorporated in the policies and plans, we employed a qualitative content analysis technique following Poudyal et al. 2020, who categorised the experts‘ opinions and labelling them based on the content. The content analysis software NVIVO v11 was used to identify the major steps and major reasons that experts expressed include five major themes i) limited multiple stakeholders' engagement, ii) lack of proper dissemination mechanism, iii) no actual ground reflection, iv) lack of sound research methods, and v) research conducted in isolation.

In summary, this chapter documented a broader overview of the study area and overall methodology used for the study. Specific methods are intensively discussed and comprehensively covered in published papers.

3 CHAPTER THREE: LITERATURE REVIEW

This chapter is divided into two sections. The first section presents the overall literature review to set a context of the study for the Forest Ecosystem Services (FES) and it explores the concepts of ecosystem services, categorisation of forest ecosystem services, prioritisation, and techniques/processes of FES valuation that help to integrate the forest ecosystem services research outcomes in the policies and plans. The second section is a published reviewed journal article that pinpoints the knowledge gap in the field of forest ecosystem services. In addition, each of the objective-wise published chapters have incorporated the relevant literature appropriate to their study focus of the article.

3.1 Overall Literature Review

3.1.1 Theoretical context of research

This study considers forest ecosystems from communal lands i.e. common pool resources that are either managed by forest users or by a combination of local users and the District/Divisional Forest Office (DFO) under approved rules, regulations and management plan as a common resources. Two pertinent approaches (theory of commons, and environmental economics) are applicable to manage these goods. Common pool services including FES are those services over which users compete for their use and are characterised by subtractability (Ostrom 1990; Paudyal et al. 2016). CBFM as a local institution through collective action addresses such competition and free riding, overuse and other social issues relevant to FES (Ciriacy-Wantrup & Bishop 1975; Ostrom 1990). The theory of commons also explores the perception and evaluates FES values that local people place on the FES, which they receive from CBFM management. Environmental economics includes the systematic undervaluation of the ecological dimension in decision-making provided by forest ecosystems and other natural capital (Costanza et al. 1997; Gómez-Baggethun et al. 2010). All FES are not traded, and therefore, cannot be factored in policies and plans. Many regulating and cultural services are rooted in welfare economics, in which the neoclassical concept of economic value is outlined under the broader framework of individual utility maximisation (Bateman & Turner 1992; Hoyos & Mariel 2010).

3.1.2 Concept and state of ecosystem services

The concept of ES was first introduced in 1981 by Ehrlich and Ehrlich, and gained momentum by the end of the 1980s (Gómez-Baggethun et al. 2010). ES are the contributions made by ecosystem structure and functions (in combination with other inputs) to human well-being (Burkhard & Maes 2017). The proliferation of literature on ESs and their valuation in the past two decades (Chaudhary et al. 2015; Shackleton et al. 2017) reflects the attention paid to this concept and its application on the ground. A recent search conducted by Costanza et al. (2017) in SCOPUS revealed that more than 17,000 articles on the topic 'Ecosystem Services' were published. However, despite this increased scholarly attention, the state of forest ecosystems services and their values are decreasing. For example, about 60% of ESs (15 out of 24) (MEA 2005; Kubiszewski et al. 2017) and values of FES (Costanza et al. 2014) are decreasing globally despite the global commitment to forest conservation. Costanza et al. (2014) have recently estimated that FES values worth US $ 6.8/yr. trillion have been lost due to land-use change. This might be due in part to the limited integration of ES values in decision making especially in developing countries (Christie et al. 2012) and results in both short and long-term impacts on poor and natural resource-dependent people. So, it is imperative to critically analyse why ES research is rarely integrated into the policy process.

3.1.3 Categorisation and prioritisation of ecosystem services (ES)

Studies have categorised ES into four broad types: provisioning, regulating, supporting, and cultural, comprising 17-23 specific services (Costanza et al. 1997; De Groot et al. 2002; MEA 2005). Hein et al. (2006) argue, however, that using the category 'supporting services' like soil formation as a separate item in valuation, may lead to double counting because their value can be realised in the other three types of ES. Later, TEEB (2010) has categorised provisioning, regulating and cultural types into 19 different services. The major differences between the MEA and TEEB classifications lie in the terminology and types enumerated. There are many ecological and chemical processes such as habitat, photosynthesis and soil formation that do not constitute services which, however, underlie the functioning of ecosystems. Therefore, the three categories as proposed by Hein et al. (2006), and followed by others (Haines-Young & Potschin 2012; Iniesta-Arandia et al. 2014) are provisioning, regulation and cultural services appear to be most relevant for ecosystem services assessment. This study adopted the three categories of ES since they are mutually exclusive, minimise the risk of double counting, and eliminate the probability of overestimation of values (Appendix F).

3.1.4 Ecosystem services valuation, emphasis, and gaps

ES are assessed at various scales incorporating single to multiple services and sectors (e.g. agriculture, forestry, watershed, marine etc.). Despite the multi-sectoral coverage, there are still many dimensions that are not explored yet, for example, conventional marketing characteristics and the institutional set up (Costanza et al. 1997; De Groot et al. 2012; Costanza et al. 2014) that is in place to manage the ES. Many ES are considered to be public or common services; therefore, conventional markets and institutions are not helpful to manage these services.

The current valuation trend is particularly focused on modelling and mapping of ES (Bagstad et al. 2013; Brown et al. 2014; Akujärvi et al. 2016; Forsius et al. 2016; Ochoa & Urbina-Cardona 2017; Shoyama et al. 2017), and climate change impact on water (Biao et al. 2010; Bangash et al. 2013; Beniston & Stoffel 2014). Other studies have concentrated on the protected area system (Dinerstein et al. 2013; Ninan & Kontoleon 2016; Cumming & Maciejewski 2017; Verma et al. 2017), the future land-use change scenario (Baral et al. 2014), wetland ES (Adekola et al. 2015), and biodiversity (Christie et al. 2012; Thapa et al. 2014). Despite a broader application in many disciplines, almost 97% of valuation studies have been conducted in developed countries and until 2011, 50% of the studies only focused on single ES (McDonough et al. 2017). In terms of geographical coverage, mountain regions have attracted less attention (Gleeson et al. 2016). Likewise, little research has been conducted on ES and people’s livelihoods (Chaudhary et al. 2015). Economic valuation should consider socio-economic aspects (Plant & Ryan 2013), however, to date, scholars have not considered different CBFM modalities, distant and proximate users and their economic status, while valuing and integrating FES values in policy process (Appendix G).

In the case of Nepal, FES valuation is a relatively new approach. Sixteen studies so far are recorded from various sources and most have concentrated on protected area entry fees (Baral et al. 2008; Baral & Dhungana 2014; Pandit et al. 2015), and wetland ES (Sharma et al. 2015; Baral et al. 2016). Some other studies have focused on CBFM (Paudyal et al. 2015; Paudyal et al. 2016; Paudyal et al. 2017), watersheds (Rai et al. 2015; Van Oort et al. 2015) and, payment for environmental services (Bhatta et al. 2014). These studies have also identified research gaps in capturing non-use values and accounting for these values in a national accounting system (Bhatta et al. 2014) and mainstreaming the ES concept in CBFM through innovative ways (Paudyal et al. 2017). These valuation studies, however, neither cover the *Chure* region nor do they identify various users' priorities in different CBFM modalities, evaluate economic values or integrate the values into the policy process as a bundle (See Appendix H for reviewed literature).

3.1.5 Methodology used for valuation studies

A range of monetary and non-monetary methods have been used to estimate the economic values of FES (Farber et al. 2006). For monetary assessments, approaches that have been included are: i) revealed-preference [revealed price (RP), travel cost (TC), hedonic pricing (HP), and the production approach (PA)], ii) stated preference [contingent valuation and conjoint valuation (CVM)], and iii) cost-based approaches (replacement or avoided) (Pagiola et al. 2004; Christie et al. 2012). These values can be estimated by observing individual consumer behaviour, perceptions (revealed or stated preference), or the actual cost incurred for similar service replacement or avoidance of further damage. Non-monetised valuation includes individual index-based methods (rating and ranking choice and expert opinion) and group opinion methods such as voting mechanisms, focus groups, and citizen juries (Farber et al. 2006; Turner et al. 2016).

The Revealed Price (RP) method is straightforward analyses of markets and is useful for examining provisioning ESs. Those that do not enter into the market can be evaluated through cost-based approaches (alternative cost, substitute goods cost and replacement cost), revealed preference approach (travel cost, hedonic pricing, production approach) and benefit transfer (BT) method. Cost-based methods use the actual cost incurred for similar service replacement or avoided further damage, but this method has been criticised for overestimation (Pagiola et al. 2004; Rasul et al. 2011). The travel cost (TC) method observes the actual cost of travel and time values of visitors and their entry fees to any particular natural resources sites (Pagiola et al. 2004; Christie et al. 2012). The TC approach is mostly used for recreational services (Rasul et al. 2011). Moreover, HP assesses environmental factors and quality and is mostly used in property valuation and with some environmental qualities such as noise, pollution, and aesthetic values. This method is straightforward if data is available, but it requires a large amount of information which may increase the cost of a study if data is not easily available. Moreover, this method cannot capture the non-use values of services (Rasul et al. 2011). CVM is flexible and useful for estimating non-use values of any services but has been criticised by many scholars for invalidity, problems of replicability (Pagiola et al. 2004; Venkatachalam 2004) and differences between hypothetical scenarios and actual behaviour (Bateman et al. 2010; Rasul et al. 2011). To overcome these limitations of CVM, the guidelines developed by the National Oceanic and Atmospheric Administration (NOAA) (Arrow et al 1993) could be followed and survey could be carefully designed. Likewise, the non-monetary valuation method is also useful to prioritise the ES, though this method sometimes faces difficulties in reaching a consensus.

3.1.6 Integration of economic valuation studies in the policy

One of the objectives of FES valuation is to include both use and non-use values in the policy process. Many pivotal works (MEA 2005; TEEB 2010; Bell et al. 2011), and academics (Pittock et al. 2012; Gatzweiler 2014; Schuhmann & Mahon 2015; Torres & Hanley 2017) have explored the role of valuation studies in informing and reshaping policies. Recent studies have attempted to identify the level of influence of valuation studies in many sectors. For example, Waite et al. (2015) have reviewed more than 100 coastal ecosystem studies in the Caribbean region and found that only 17 valuation studies are linked to policy reflection. Other scholars such as Rogers et al. (2015) have estimated the influence of non-market valuation on policy processes in Australia and New Zealand and found that this has little use in decision making due to unfamiliarity with valuation techniques. Similarly, Marre et al. (2016) have categorized information into three levels and measured decision making in marine and coastal area in Australia. They found that most decision-makers believed economic valuation was useful, but it was rarely used. Likewise, Dehnhardt (2013) conducted studies of water management in Germany and found limited applicability of valuation studies to actual policy formulation. Martinez-Harms et al. (2015) have reviewed a long list of studies and identified gaps in the core steps of the decision-making process, and they recommend a deliberative and participatory process for the enabling environment (See Appendix I).

Despite increased scholarly efforts, the use of research outcomes has had limited application in actual policy and management decisions.

3.1.7 Overall research gap on economic valuation

Despite the broader coverage of valuation studies, several gaps, challenges and methodological inconsistencies exist. The underrepresentation of valuation study in the mountain regions of developing countries is one of the most prominent gaps. Likewise, linking direct biophysical estimates with scales of decision, developing methods for evaluating who gets what type of services and benefits for addressing social inequalities are also research needs (Daily et al. 2009). Moreover, valuation research has mainly focused on aggregated perspectives (Daw et al. 2011), which can neglect critical issues of poverty reduction, food security, ethics and rights (Chaudhary et al. 2015). Therefore, concrete steps and framework which can guide to incorporate values of FES in policies and plans are required to improve the knowledge of FESs and their integration into decision making (Pandeya et al. 2016).

Further, several studies have concentrated on either a global or a regional scale and there is limited integrated valuation research of specific CBFM units. Although some studies were conducted at specific sites, they were largely either based on long-term research or used highly sophisticated tools and techniques (Peh et al. 2016a). These require reliable data sets, skilled expertise and huge investment, which is not a high priority in developing countries like Nepal. Moreover, few studies have mapped and prioritised ES in CBFM in the mid-hills and *Chure* (Paudyal et al. 2015; Bhandari et al. 2016) however these studies neglect the socio-economic aspect. Further, no research considers the CBFM regimes, proximity and socio-economic aspects nor integrates FES values in the policy process in the *Chure* region.

In addition, appendices H, I, J and K provide some ES valuation studies from Nepal, global, provisioning, and cultural forest ES respectively.

3.2 Review Article

Global trend of forest ecosystem services valuation – An analysis of publications

Foreword

This section is an exact copy of the published review article in *Ecosystem Services*, vol. 39 (2019), pp. 100979-88.

This paper aims to draw an attention to scholars and forest policymakers in forest ecosystem services by responding the question: 'what is the state of forest ecosystem services valuation globally and what are the ES valuation especially focusing countries economy and management modalities?'. Recognising the importance of ecosystem services valuation research in sustainable forest management, this review article identifies the forest ecosystem services temporal trends, methodological approaches, the types of services mostly assessed, and spatial distribution of ES valuation studies. Using a non-statistical meta-analysis approach, this paper identifies knowledge gaps in the field of forest ecosystem services. As a thorough analysis of 1156 peer reviewed journals in the field of forest ecosystem services, this study confirms that high income western European countries, including the UK, had the highest number of publications (33%) followed by the United States (15%) and China (13%), while countries with lower middle and low income collectively share only about 14% of the total publications, indicating a large gap in ES research in low income nations. More than 80% of studies have consistently assessed multiple functions of forests however these researches largely focus on regulating services (carbon storage/sequestration/climate regulation). Moreover, more than half of the publications (57%) were from the research conducted in public land/government managed forests, whereas only 3% of researches are conducted in community-based forest management system, which share a more than 31% of forest management system in developing countries. Though publication trend is increasing valuation studies particularly, countries with high biodiversity, and forests in mountain regions in low and lower-middle countries are limited.

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Global trend of forest ecosystem services valuation – An analysis of publications

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ABSTRACT

Ecosystem Services (ES) are critically important to human well-being, and sustaining economic growth and livelihoods. Globally, valuation research has increased markedly over the past two decades, partly due to the influence of environmentalism and the notable depletion of ES. Using meta-analysis of 1156 peer-reviewed journal articles from 1994 to 2017, this study assesses forest ES valuation, focusing on temporal trends, methodological approaches, the types of services most frequently evaluated, and the origin of ES valuation research, especially biomes, economy, and management modalities. Findings suggest that western European countries, including the UK, had the highest number of publications (33%) followed by the United States (15%) and China (13%). Countries with lower middle and low income collectively share only about 14% of the total publications, indicating a large gap in ES research in these countries. In terms of valuation methods, monetary valuation was initially popular, while non-monetary valuation using modelling and mapping methods is gaining popularity. The study revealed that more than 80% of studies have consistently assessed multiple functions of forests but largely focus on regulating services (carbon storage/sequestration/climate regulation). Similarly, about 57% of total ES research was carried out on public land, government managed forests and protected areas, whereas less than 3% was on community-based forestry (CBF), which shares more than 15% and 31% of the forests in developed and developing countries, respectively. Whilst ES publications on forestry have seen significant increases, valuation studies in countries with high biodiversity are conspicuously unrepresented; particularly on forests in mountain regions in low to lower-middle income countries. Some reasons for this disparity in ES research under four themes are discussed, in connection with the global climate change, biodiversity policies, and national, bilateral and multilateral initiatives.

1. Context and background

Ecosystem Services (ES) provide a wide range of services that are critically important to human well-being, and to sustaining economic growth, and livelihoods. The benefits that people obtain from nature were first documented in the 1980s (Gómez-Baggethun et al., 2010). The term ES gained increasing popularity following seminal academic efforts (Costanza et al., 1997; Daily, 1997; Costanza et al., 2014) and global initiatives such as the Millennium Ecosystems Assessment (MEA, 2005), and The Economics of Ecosystem and Biodiversity (TEEB) (Pascual et al., 2010). The economic value of ES has been considered within many disciplines including forestry, other natural resource management (NRM), biodiversity conservation and environmental policy and accounting (Costanza et al., 1997; MEA, 2005; TEEB, 2010; Costanza et al., 2017). Economic valuation, a process of expressing nature's contribution in monetary value (Farber et al., 2002), appraises both use and non-use values, and allows decision and policy makers to identify, evaluate, and estimate trade-offs with other development goals (Balmford et al., 2002; Christie et al., 2012). Forest ES valuation can be used for forest resource conservation and management for both enhancing sustainable resource use and persuading policy-makers about the importance of particular forms of management (Baral et al., 2014; Aslaksen et al., 2015; Häyhä et al., 2015; Egarter Vigl et al., 2017). The valuation process offers incentives to managers for sustainable forest management (Deal et al., 2012; Paudyal et al., 2017).

Costanza et al. (1997) first estimated the world's ES worth (US $33 trillion) in 1995, which was almost 1.2 times the total global gross domestic product (GDP), in an update, these values were increased to US $ 145 trillion (Costanza et al., 2014). The state of ecosystems, including forests, have however significantly decreased at the global scale, limiting the provision of forest related services. Scholars and agencies have indicated that human induced pressure (e.g. population

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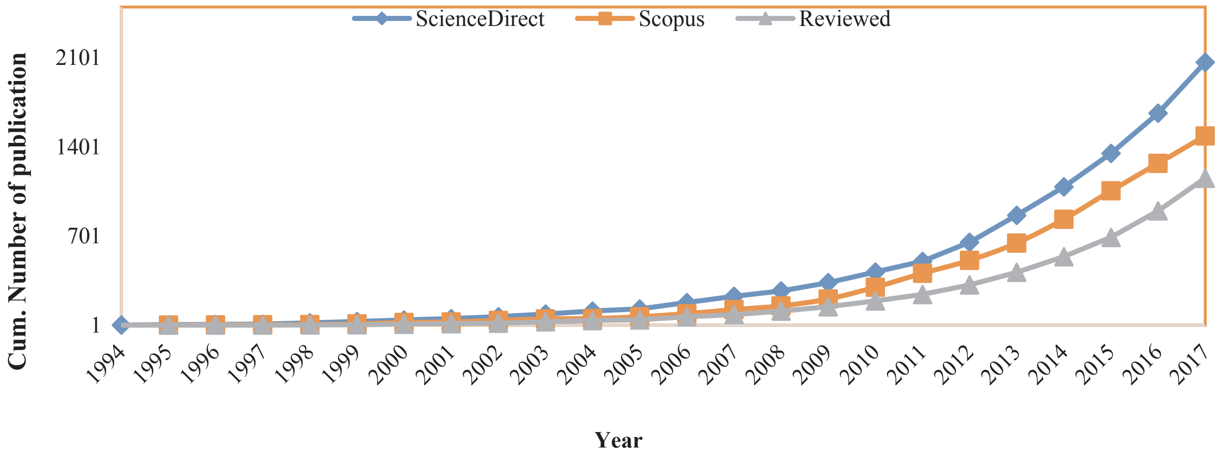

Fig. 1. Global publication trend of forests ecosystem valuation (Cum: Cumulative and n = 2066; 1488, 1156).

growth, increased demand of forest products and climate change) are the key reasons for decreasing the forest values and related ES (MEA, 2005; FAO, 2015; Mutoko et al., 2015; Martin et al., 2016). Between 1990 and 2015, 129 million hectares of forest were depleted, largely in developing countries in the tropical regions (FAO, 2015). Despite the importance of forests being recognised, including global benefits due to watershed and soil protection, climate regulation, and nutrient cycling, they are still underappreciated (Ninan and Kontoleon, 2016).

Valuation research has increased at an exponential rate and scholars have made efforts to assess and review the ES at a global level through: (1) global publication trends analysis (McDonough et al., 2017); (2) discourse analysis (Chaudhary et al., 2015); (3) valuation of biodiversity conservation (Mori et al., 2017); (4) valuation of coastal/marine (Rao et al., 2015; Martin et al., 2016), wetland (Reynaud and Lanzanova, 2017), water (Hackbart et al., 2017) and mountain (Grêt-Regamey et al., 2012; Gleeson et al., 2016) ecosystem services; and (5) review of methods used for valuing ES (Turner et al., 2016). Similarly, studies at regional scale have occurred in Latin America (Balvanera et al., 2012), in European countries (Stürck et al., 2014), in the Caribbean region (Schuhmann and Mahon, 2015), at the national level in Australia (Pittock et al., 2012; Alamgir et al., 2014) and in China (D'Amato et al., 2016). Despite the ongoing effort to advance ES research, there is limited forest-related work at regional and global scales. The distribution of forest ES studies in terms of geography, and of countries related to economic status, and applied methods has been largely stereotypical. The ambiguous classifications of ecosystem services, the question of methodology and validity, the implications and application of monetary valuation for future research have constrained forest ES valuation (Bateman et al., 2010; Ninan and Inoue, 2013; D'Amato et al., 2016; McDonough et al., 2017). This paper assesses and reviews forests ES valuation along the gradients of spatial and temporal scales, geography, forest management regimes, economic state and methods.

We aim to assess forest ES valuation trends focusing on temporal trends, methodological approaches, most evaluated types of services, and the origin of ES valuation research, especially in the contexts of biome, economy, and management modalities. We discuss why ES research trends tend to spike in different periods.

2. Methodology

A non-statistical meta-analysis was conducted using the key words **("Ecosystem Services" AND Valuation* AND "Forests*)** in all the title, abstract, or keywords from reviewed journal articles published from 1994 to 2017. The year 1994 was chosen as the start date, as the concept of forest ecosystem services (ES) was familiarised globally from theory to policy only after the Earth Summit and Convention on Biological Diversity in 1992 (Gomez-Baggethun and Ruiz-Perez, 2011). Since then, the term 'ES' has been consistently and widely used in the literature (Braat and de Groot, 2012; Turpie et al., 2017). Likewise, we explored and finalised the search by the first quarter of 2018 and therefore selected the end of the period as 2017. Articles were sourced from two major data sets *SCOPUS* and *ScienceDirect* (both published by Elsevier). The term "Ecosystem Services" was chosen due to its recognition by many international initiatives and follows the terminology commonly used by academics (Chaudhary et al., 2015). The articles that were shortlisted for review had to be published in English, exclusively focused on forest Ecosystem Services and include empirical data based findings. There were 2066 hits in *ScienceDirect* and 1488 in *SCOPUS*. Almost 43% of articles (n = 907) were judged irrelevant due to either the valuation of ES being based only on biophysical indicators or discussion of the issue of ES by reviewing literature and expanding the theories. Finally, 1156 articles were considered for further review as they would enable exploration of valuation of forest ecosystem valuation. Publications were analysed for: i) trend and magnitude, ii) methodological contribution, iii) country of origin of the study, iv) publication trend in different ecosystem services (provisioning, regulating and cultural services), and v) origin of ES in different management modalities. In addition, we supplemented a thorough review and analysis of many national and international documents to ascertain the possible reasons for key turning points occurring in the publication trends. Lastly, all publications were downloaded and further screened for detailed analysis.

3. Results

3.1. Temporal distribution of forests ES valuation

The number of research articles that assessed forest ES at various scales incorporating single to multiple services has increased (Fig. 1). Although the *SCOPUS* dataset shows a smaller number of published articles, the growth pattern of the two datasets indicates a similar trend in i) no or slight growth i.e. stagnant (1994 and 2005) ii) steady growth from 2006 to 2014 i.e. increasing trend (2006–2014), and iii) exponential growth after 2014. There is a similar trend in the case of reviewed articles (about forest ES valuation) (Fig. 2).

3.2. Methodological contribution to forest' ecosystem valuations

Forest ES can be evaluated using monetary and non-monetary methods. Prior to 2005 these valuation studies were in their infancy and there was little difference between the number of assessments; the number, however, increased slightly until 2010. From 2010 to 2014 the number of monetary valuations was higher; however, in recent years

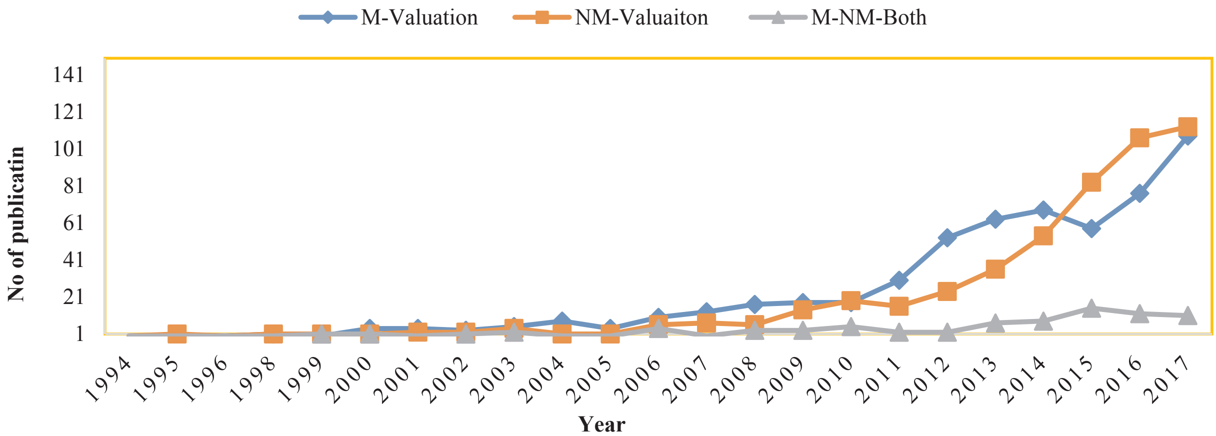

Fig. 2. Trend of monetary (M), non-monetary (NM), both (M-NM) (n = 1156).

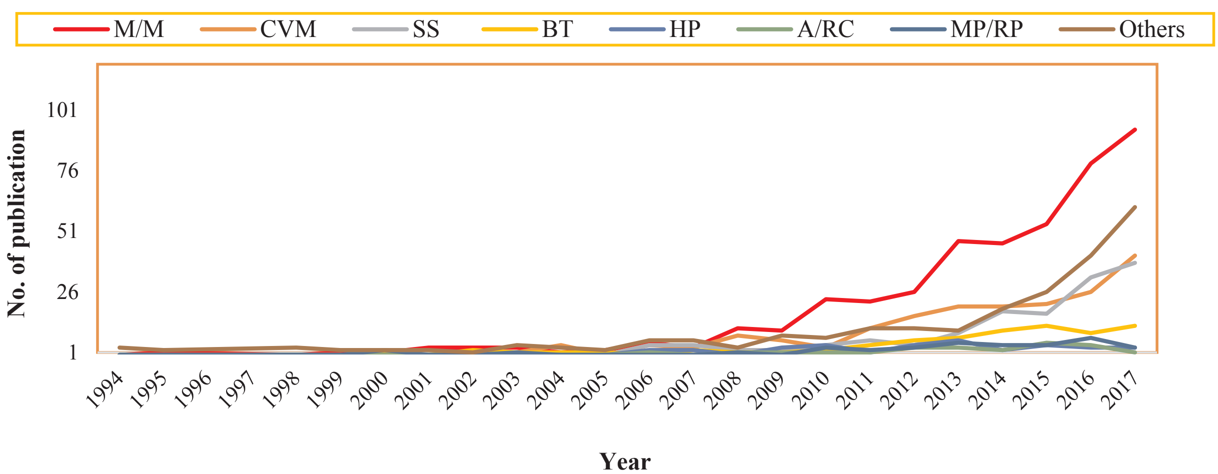

Fig. 3. Major method applied for valuation studies in forestry M/M: Modelling/Mapping, CVM: Contingent Valuation, SS: Social Survey, BT: Benefit Transfer, HP: Hedonic Pricing, A/RC: Avoided/Replacement Cost, MP/RP: Market Price/Revealed Valuation (n = 1156).

the valuation in relation to non-monetary terms has increased rapidly (Fig. 3.).

A range of monetary and non-monetary methods has been used to estimate the economic values of forest ES. Monetary assessment methods include: i) revealed-preference - revealed price (RP)/market price (MP), travel cost (TC), hedonic pricing (HP), and the production approach (PA); ii) stated preference contingent valuation – choice modelling, discrete choice experiment, and conjoint valuation (CVM), and iii) cost-based approaches – replacement and avoided costs (RC/AC), iv) benefits transfer (BT), v) Modelling and mapping through application of GIS (MM) method, and vi) social survey (SS). Non-monetary assessment include: i) individual index-based methods (rating and ranking choice and expert opinion), ii) group opinion methods – voting mechanisms, focus groups, and citizen juries (Farber et al., 2006; Turner et al., 2016).

Between 1994 and 2005, little difference was found between the use of contingent valuation, market price, benefits transfer, mapping/modelling and social surveys methods to elicit forest ecosystems valuation. From 2014 to 2017, forest ecosystems were mostly assessed by modeling/mapping followed by contingent valuation and a social survey (Fig. 3). The hedonic pricing, cost based (replacement/avoided damaged) and market price methods have been consistently stagnant.

3.3. Spatial distribution of ES valuation studies in different economies and countries

Forest ES research has always concentrated on high-income (HI) countries. European countries (EU), USA and other high-income countries such as the UK, Australia and Canada are at the forefront of valuation research. In recent years, forest valuation research from upper middle-income (UMI) countries is also gaining popularity and shows an increasing trend, notably in the case of China (Fig. 4).

Publication trends until 2002 for all economies appeared similar whereas the trend in recent years in HI and UMI increased at an exponential rate. The number of publications in low-income countries and mixed economies (for comparison) has been significantly lower in recent years (Fig. 5). More recently, forest valuation research from UMI countries has also been gaining popularity and shows an increasing trend. For example, the number of publications after 2014 has increased in upper middle income countries including China (Fig. 6).

3.4. Temporal trend of ecosystem services types (provisioning, regulating and cultural)

Global trends on forest ES valuation show increases for a number of services (provisioning, regulating and cultural services), however, within those categories there are particular orientations. The provisioning service includes all physical and biotic energy outputs from ecosystems which can be exchanged or traded, as well as consumed or used directly by people in manufacturing (Haines-Young and Potschin, 2012). Regulating/maintaining services incorporate how ecosystems control or modify biotic or abiotic parameters that define the biophysical environment around the people.

Only 21% of research includes consideration of all three services for

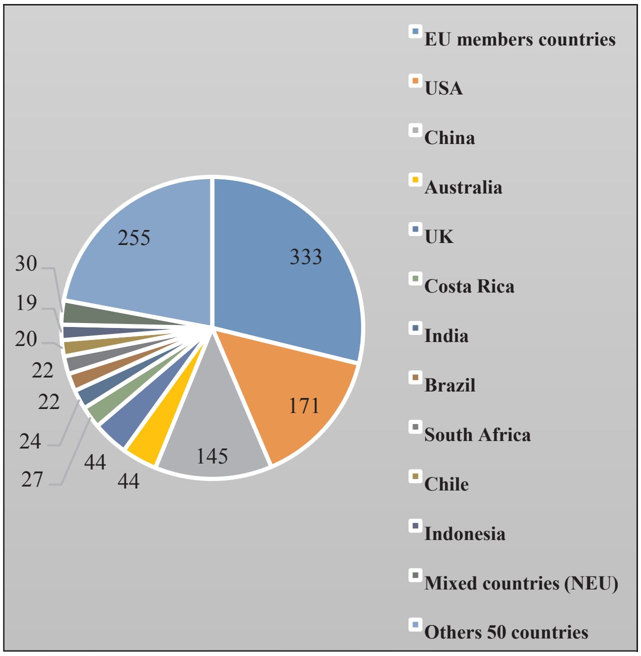

Fig. 4. Top 11 & other countries in ES valuation (n = 1156).

valuation (Fig. 8). Until 2006, ecosystem services (provisioning, regulating and cultural) occurred relatively equal numbers. Regulating services surpassed all services from 2008 to 2017. In recent years, the cultural ecosystem services have gained momentum following a similar trend in provisioning services (Figs. 7 and 8).

In the provisioning services, timber (including wood products and food crop production) is mostly assessed, followed by water provisioning and biomass/raw materials production. NTFPs/MAPs are at the bottom of the evaluation. In the case of regulating services, the carbon storage/sequestration, greenhouse gases (GHG) and climate regulation (CR) at local to global scale, followed by biodiversity and water/water quality services, have been the most commonly assessed services in the forest ES valuation literature. Among the cultural services, recreation, tourism, and aesthetic services are most evaluated (Fig. 9a, b, c).

3.5. Forests ecosystem services studies in different forest types and in management modality

An analysis of forest ES by type of forests revealed that forest other types (i.e. not specified in the sites mentioned in the graph or stated such as river basin/drylands/watershed/catchments/peatlands/historical/cultural/plantation sites) comprised almost half (47%) of the total publications, followed by a focus on coastal/mangroves forests (12%). Valuation of forests from physiographic region (mountains) and urban areas were 10% and 7% respectively (Fig. 10). In terms of management regimes, most of the research is concentrated in protected area (PA) systems followed by public/government managed forests and private land. Little research (n = 28) has been conducted on community based forests management (Fig. 11).

4. Discussion

The following sections discuss: i) the temporal trend (progress) and possible reasons, ii) approach and methods of valuation (monetary vs non-monetary), iii) spatial distribution of ES research across economic status of the countries, iv) state of valuation studies in the different ES types, and v) ES research in various forests types and management modality

4.1. The temporal distribution of publications and possible reasons

Analysis of global publication trends revealed that valuation of

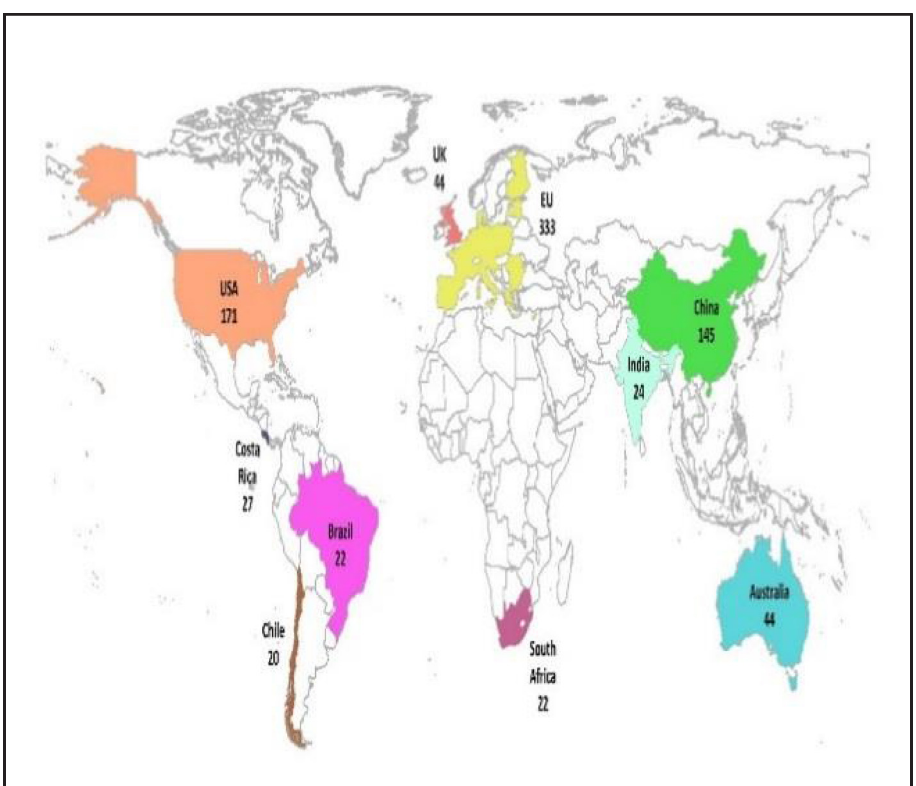

Fig. 5. Map of top ten high ES research countries.

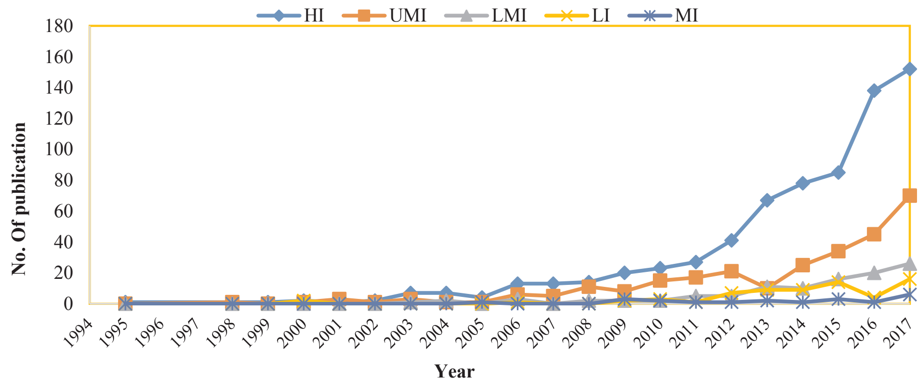

Fig. 6. Forests ES valuation across High Income (HI), Upper Middle Income (UMI), Lower Middle Income (LMI), Lower Income (LI), and more than one income Mixed Income (MI) (n = 1156).

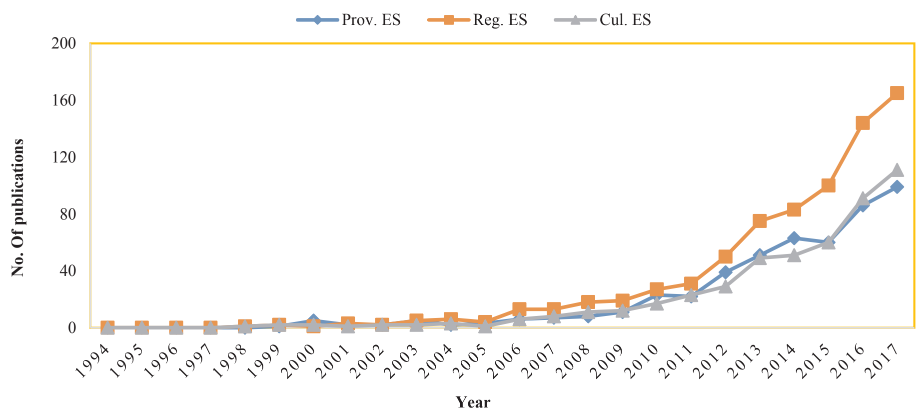

Fig. 7. Publication trend in provisioning (Prov.), regulating (Reg.) and cultural (Cul.) services (L) and Cumulative articles publication (R) (n = 1156).

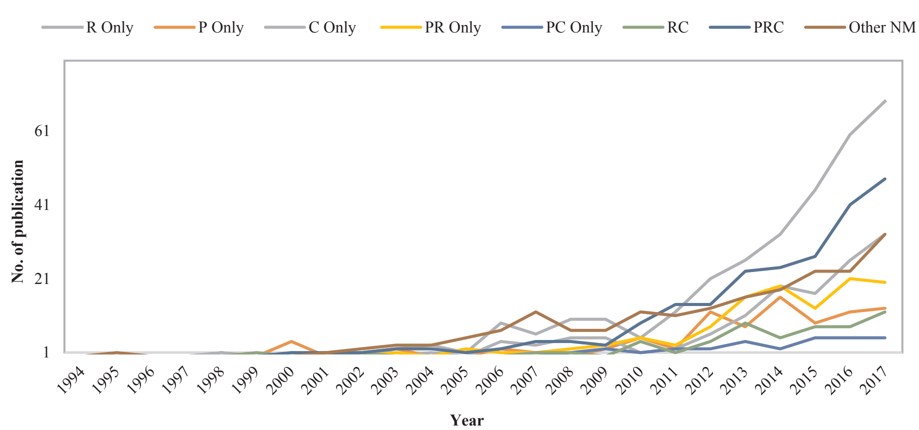

Fig. 8. Valuation trend of various ecosystem services (P: Provisioning, R: Regulating C: Cultural) n = 1156.

forest' ES was static in 1994–2005, gained momentum from 2006 to 2013 (Shoyama et al., 2017) and then grew exponentially after 2014 (2014–2017) (Ruijs and van Egmond, 2017). The seminal publications (Costanza et al., 1997; Daily, 1997), global initiatives on natural resources and the environmental sector (MEA, 2005; TEEB, 2010; Haines-Young and Potschin, 2012), global biodiversity and climate related policies and access to funding, availability of various tools, datasets and increase in investment in NRM and ES have all significantly influenced the publication trend. The forest valuation studies first appeared after the global Earth Summit 1992 and Convention of Biological Diversity 1992 in Rio de Janeiro. Some publications (Costanza et al., 1997; Daily, 1997) have especially influenced research trends. Most of the publications during this period focused on either providing theoretical explanations in favour of monetary valuation or raising concerns around monetary valuation. Forest ES has received considerable attention following the ground-breaking work of the MEA in 2005 (Gómez-Baggethun et al., 2010; Alamgir et al., 2014). With this initiative, ES was established as a policy tool for sustainable natural resource management and has paved the way for gaining momentum for ES valuation studies (Fisher et al., 2009; Alamgir et al., 2014; Costanza et al., 2014).

Our analysis revealed that after 2014, publications proliferated (n = 659). McDonough et al. (2017) associated this with the release of publications through global initiatives such as MEA, TEEB, CICES and IPBES. Shackleton et al. (2017) associated this increase with a stronger research base, the availability of datasets along with growth in the

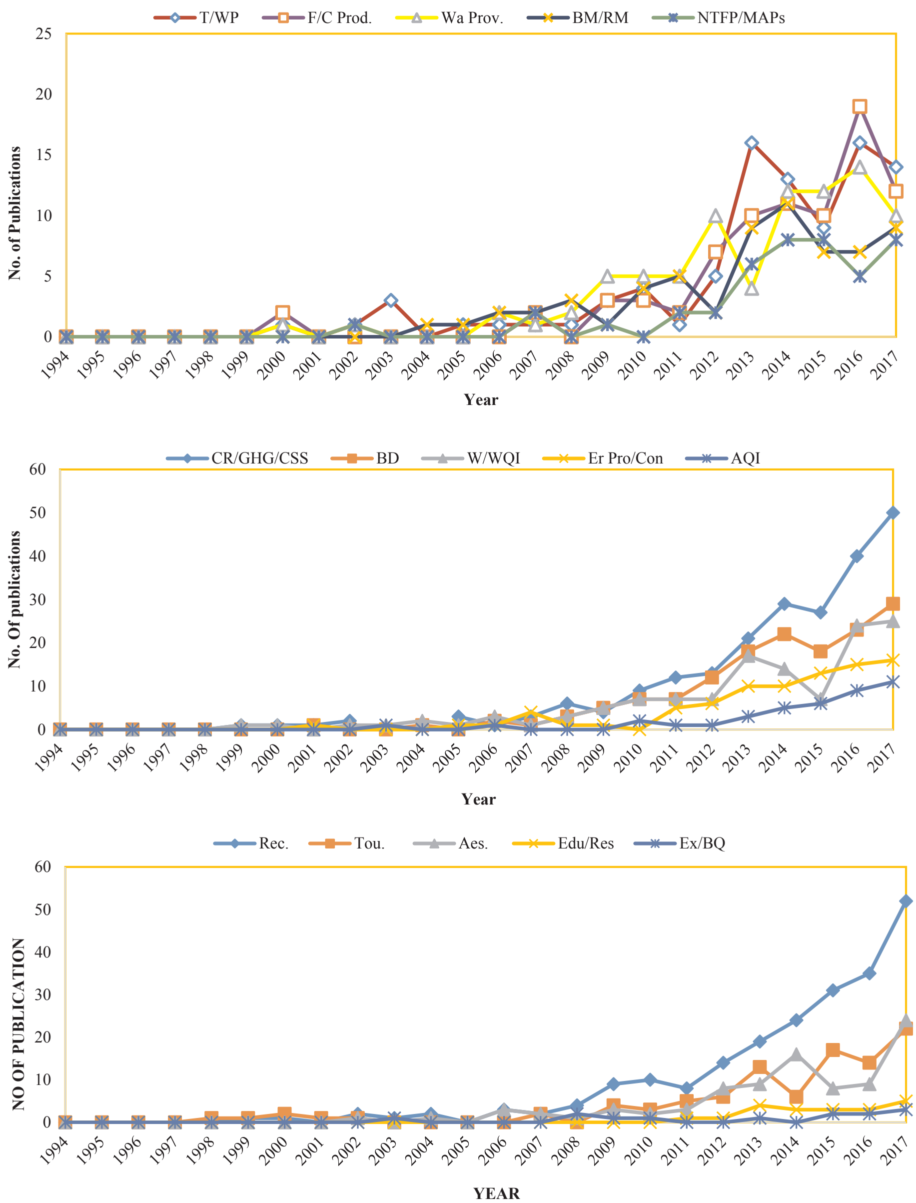

Fig. 9. a, b, c: Top five evaluated forests ecosystem services (1994–2017) a: provisioning b: regulating c: Cultural, T/WP: Timber/wood production, Food/Crop Production, Wa/Prov.: Water Provisioning, BM/RM: Biomass/Raw Materials, NTFPs/MAPs: Non-timber forests products/Medicinal and Aromatic Plants, CR/GHG/CSS: Climate regulation, Green House Gases, Carbon Storage/sequestration, BD: Biodiversity, Water regulation/Water Quality Improvement, Er Pro/Con: Erosion Protection/Control, AQI: Air Quality Improvement, Rec: Recreation, Tourism: Aes: Aesthetic, Edu/Res: Education/Research, Ex/BQ: Existence/Bequest value (n = 1156).

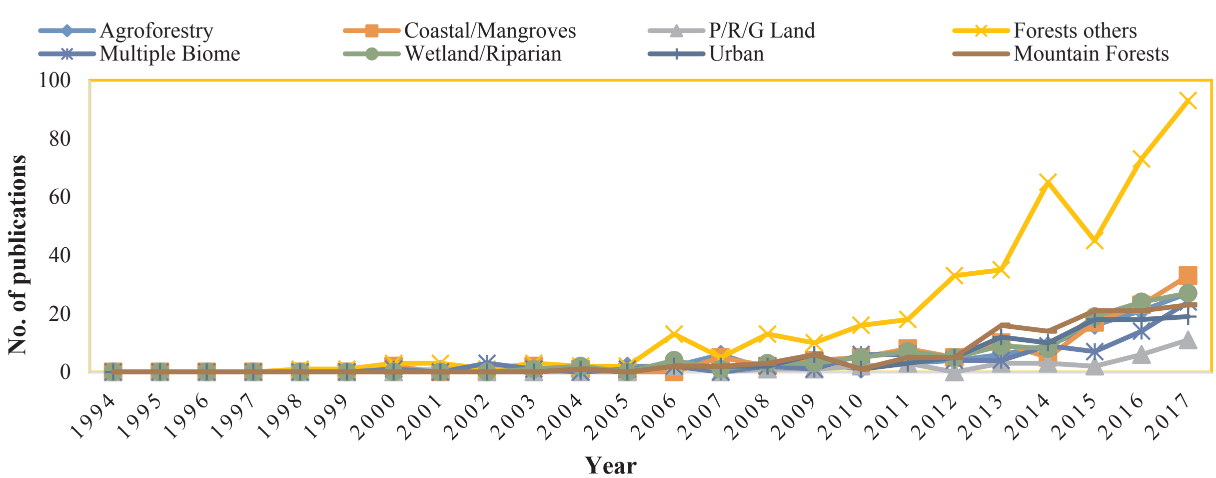

Fig. 10. Proportion of publication in each forests types: PRG: Pasture/Grass/Range (n = 1156).

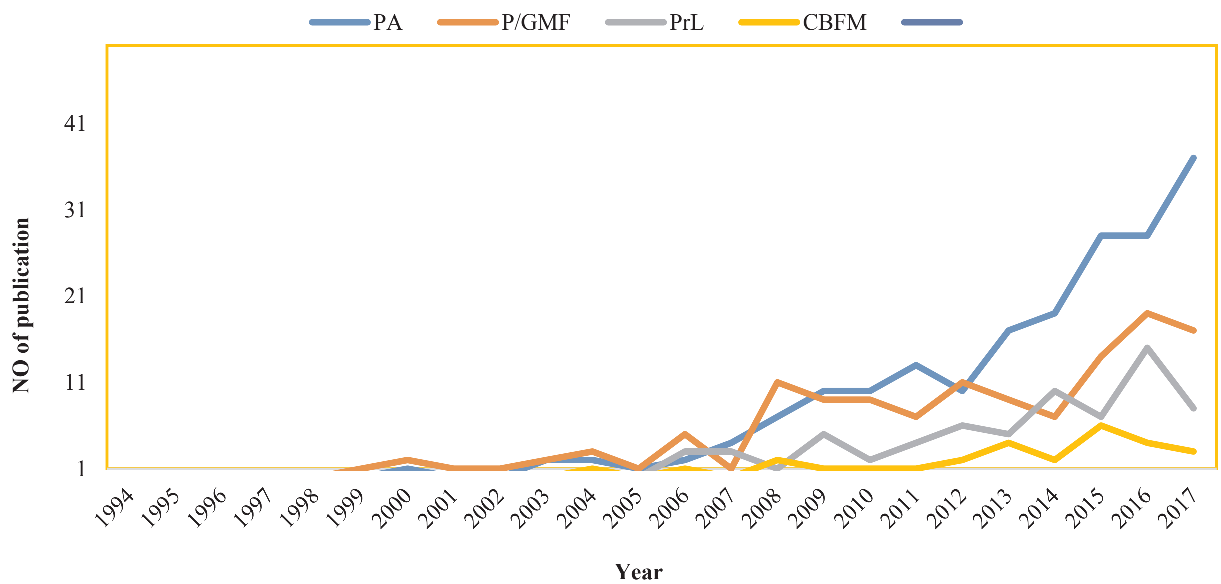

Fig. 11. Ecosystem services valuation in different management modality (PA/PL: Protected Area/Public Land; PrL: Private Land; CFM: community based forest management (n = 1156).

policy environment and capacity building of human resources in ES valuation research. The increase in publications could also be due to the impact of global initiatives that raised awareness regarding the importance of ES, biodiversity and climate concerns, coupled with an increased public investment in ecosystem management and NRM sectors. It could also be the case that this increase in publications could be due to geographic and economic expansions in ES research, the appreciation of the ES approach in various disciplines, the technical advancements in ES application on the ground and dedicated publication journals.

Seminal publications (Costanza et al., 1997; Daily, 1997), global initiatives on natural resources and the environmental sector (MEA, 2005; TEEB, 2010; Haines-Young and Potschin, 2012) have raised awareness of the issue. Initiatives such as TEEB and subsequent publications, Common International Classification of Ecosystem Services (CICES) and Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), attracted new researchers to ES valuation (Chaudhary et al., 2015). The TEEB initiatives engaged a range of stakeholders including media, government officials, scholars and academia, who adopted the findings of these reports. One of IPBES' initial strategies was to engage indigenous groups that have placed the issues firmly in the political arena (Burkhard and Maes, 2017; McDonough et al., 2017). Additionally, the Convention on Biological Diversity (CBD) (United Nations (UN), 1992), coupled with the Strategical Goal of Biodiversity and ES (https://www.cbd.int) and subsequent development such as EU Biodiversity Strategy 2020 (European Environment Agency (EEA), 2015), have grown ES research in Europe. The recognition of the important role that nature plays in climate change adaption, along with interest in mitigation movements such as Reducing Emission from Deforestation and Forests Degradation (REDD Plus) has increased efforts in adopting ecosystem based approaches.

In addition, a large number of projects, e.g. natural capital projects (www.naturalcapitalproject.org), have been developed in approximately sixty countries worldwide. One specific project, led by The Stanford University, Minnesota University and the Chinese Academy of Science, was implemented with more than 200 global partners. These included The Nature Conservancy and World Wildlife Fund for Nature (WWF) showing -high ability to expand ES issues worldwide.

These major projects have provided the opportunity to receive ES research funding and this has invigorated researchers, resource managers and academia which have developed various tools and techniques for ES valuation. For example, natural capital project developed a tool InVEST; this is now one of the most important ES valuation tools globally. These projects have, through research and capacity building in ES mapping and valuation studies, also helped increase the number of publications post 2014.

4.2. Methodological approaches to forest ES valuation

A range of monetary and non-monetary methods (Farber et al., 2006) or a combination of methods (Turner et al., 2016) has been used to estimate economic values of the forests. These values can be estimated either by observing individual consumer behaviour, perceptions (revealed or stated preference) or actual cost incurred for similar service replacement or avoidance of further damage. Non-monetized valuation includes individual index-based methods (rating, ranking choice and expert opinion) and group opinion methods such as voting mechanisms, focus groups and citizen juries. Monetary and non-monetary valuation methods followed similar trends in the early years, whereas monetary valuation methods dominated during 2006–2014, while non-monetary approaches surpassed in the recent years. There has been little application of combined methods (monetary and non-monetary) from 1994 to 2014, however, the numbers of studies gradually increased after 2014.

Vihervaara et al. (2010) indicated that before 2005 there was limited scientific understanding and sharing mechanism in ES valuation issues. There was also limited methodological clarity on how to conduct an ES valuation specially on biological and chemical processes (Pagiola et al., 2004; Kremen, 2005) and from 1994 to 2005 there were limited human resources devoted to economic valuation practices (Wangai et al., 2016). These could be the main causes of the low numbers in both monetary and non-monetary valuations during that period.

Intergovernmental and governmental initiatives, valuation projects in natural capital and ecosystem services assessment commenced after 2005. During the MEA, TEEB, CICES and IPBES process, and subsequent toolkit developments, a large number of stakeholders were involved and many researchers advocated the monetary valuation method as a public awareness tool (Costanza et al., 1997, 2014; Rasul et al., 2011). The researchers made and effort to value forests ES in monetary units so that they could convince and compare the results with cost-benefit analysis. Payments of environmental services (PES) also gained the momentum in many countries that demand monetary valuation especially watershed protection, carbon storage and sequestration (Balderas Torres et al., 2013; Pandey et al., 2016). There was an increasing recognition of ES values on national accounting systems and GDP (Onofri et al., 2017), resulting in policy-makers demanding monetary estimates made by forests and NRM sectors. These initiatives, along with other national natural capital projects, also practised monetary valuation methods (Gómez-Baggethun et al., 2010). These significantly contributed to a large number of monetary valuations between 2005 and 2014.

The trend revealed that after the 2014 peak in forest ES valuation, non-monetary approaches surpassed the monetary approach. The current number of non-monetary valuation methods (qualitative approach) may be due to the establishment of multi-faceted forums at the international level e.g. IPBES, which were lobbied by many researchers to incorporate biodiversity and non-use values, for example cultural aspects, in ES valuation (Christie et al., 2012; Klain and Chan, 2012; Tengberg et al., 2012). In addition, some regulating services, such as sediment retention/erosion control (Bangash et al., 2013; Bogdan et al., 2016), water yield (Jiang et al., 2016) and carbon sequestration (Lauf et al., 2014), were also evaluated by applying non-monetary approaches though the modelling and mapping approach using InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) and other similar tools (Shoyama et al., 2017).

4.3. Distribution of forest ES valuation in all continents and various economies

Valuation research has been conducted all over the world; however, its temporal and spatial distribution is skewed towards Europe and North America. Most of the research was carried out in the developed world (EU member countries and UK, US, Canada and Australia in the late 1990s to early 2000s, whereas the research in ES valuation commenced almost ten years later in the least developed nations. The spatial distribution shows that more than three-quarters of the studies (78%) have been conducted in 11 countries. McDonough et al. (2017) have reported that almost 98% of ES valuations were carried out in high income or upper middle income countries. This study revealed a similar trend with less proportion – 86% (HI: 60%, (EU member countries including UK, USA, Australia – and Chile and high mixed economy (HMI); UMI: 24% (mostly China, Costa Rica, Brazil and South Africa; the lower middle income (LMI) such e.g. India, Indonesia contributed almost 8% of publications and only 6% of publications were from more than 50 other low income countries. The analysis shows that ES research is still concentrated in high income and upper middle income countries, although their proportion significantly decreased compared to previous studies.

An explanation for publication concentration in the high income countries could be due to the ES initiatives, greater funding opportunities, and training/capacity building programme. The initiatives include EU Biodiversity Strategy 2020 and subsequent guidelines and strategies (Hauck et al., 2013; McDonough et al., 2017), President's Council of Advisors on Science and Technology (PCAST) in 1998, Interagency Ecosystem Services working group in 2006, and the Farm Bill 2008 in the USA (Schaefer et al., 2015). Apart from this, most of the EU member countries received research grants through the European Commission; this contributed to institutionalising ES research in EU member countries. Moreover, training/capacity building through many ES and natural capital projects (e.g. natural capital projects) also contributed by adding research opportunities in HI countries. The publication trend in forest ES valuation in developing countries is receiving comparatively low attention except in China. China has implemented a series of programmes e.g. Eco Compensation Schemes, Grain to Green, Natural Forests Protection, Wildlife Conservation and Nature Reserve Development (D'Amato et al., 2016), which have contributed substantially to the proliferation of valuation studies in China.

ES valuation studies commenced almost a decade later (after 2005) in the developing or least developed nations and many mega-biodiverse countries are still underrepresented in forest' ES valuation. For example, ES valuation research in Colombia, Congo, Ecuador, Madagascar, Malaysia, Mexico, Papua New Guinea, Peru and Venezuela is limited. Although it is difficult to specify the reasons behind the dearth of research in these countries, it could be due to the late adoption of the concept, limited funding for this work, limited human resources, and lack of adoption of findings into policy and practice in the ES valuation research in LMI and LI economies (Christie et al., 2012). Further, low-income countries, where many of the world's biological resources are located and which are facing many anthropogenic drivers on forest and biodiversity (Christie and Rayment, 2012), have not institutionalised the valuation research (Pandey et al., 2014). While forests play a critical role in reducing rural poverty through securing food and providing decent livelihoods for lower socioeconomic societies (FAO, 2015) these issues have not been taken into account in forests ecosystem valuation research.

4.4. Valuation studies across the various ES types (provisioning, regulating and cultural)

ES publication trends across various ES types show a distinct feature across our chosen timeframe. Regulating services remained the top priority followed by provisioning and cultural services. Only 20% of studies considered all three services together (provision, regulating and cultural) whereas at least a combination of two services at a time has been evaluated ranging from 2 to 10% (PR = 10, RC = 4, & PC = 2). Only a single service at a time was assessed in 7–27% (R = 27, C = 11, & P = 7). This result is consistent with findings of global surveys that indicated existing forest valuation studies are mostly focused on a limited number of services such as carbon sequestration, soil and water conservation and recreation (Ninan and Inoue, 2013; Ninan and Kontoleon, 2016). In recent years, research on cultural ES has gained momentum, following a similar trend to provisioning services.

Many scholars state that ES valuation either evaluates limited key services or an individual service (Christian et al., 2015; McDonough et al., 2017). However, this study revealed that more than 80% of ES research has been consistently valued the multiple ESs of forests. Many researchers cited that salience and ease of adoption (e.g., market or revealed price) drive the selection of methods of monetary valuation (D'Amato et al., 2016; McDonough et al., 2017). However, modelling and mapping is gaining popularity as a method and has been frequently used since 2010 in the case of forest ES valuation. Explanations for this development include: the lobbying for non-monetary methods for biodiversity and cultural services by various scholars (Chan et al., 2012; Christie et al., 2012); the contribution of various NRM related projects (e.g. natural capital project, WAVES and NCC) and global initiatives e.g IPBES; methodological advancements through ES valuation tools such as InVEST; and easily accessible data sets (e.g. TEEB ES valuation datasets, global land cover datasets).

4.5. Valuation studies in global forest types and management modality

The analysis of valuation studies reveals a similar trend with a unique feature in the various forests types. The publications were almost equal in all types of forests until 2005, with a steady increase until 2014 and rapid growth after 2014. The publications on other forest land (i.e. mixed, river basin, drylands, watershed, catchments, peatlands, historical, cultural, and plantation forests) without specifying these forest types in Fig. 11 throughout the timeframe followed by publications from coastal or mangrove areas and agroforestry. It is difficult to speculate on the reasons behind the trend, however, forests in coastal, or mangrove categories have received considerable attention in recent years (De Groot et al., 2012; Huxham et al., 2015; Barbier, 2016). For example, Costanza et al. (2014) stated that the value of tidal marsh/mangroves increased up to 8 times compared to the 1997 estimate due to the incorporation of new studies (Costanza et al., 2008; De Groot et al., 2012). A similar situation also exists in the case of coral reef forests that contributed larger numbers of publications in that forest type. The valuation studies from mountain regions (Gleeson et al., 2016; Langner et al., 2017; Zarandian et al., 2017) and urban areas (Chen and Hua, 2017; Ives et al., 2017) have gained popularity in recent years; however, these areas are still underrepresented despite their importance.

Despite the large coverage and critical importance of mountain regions (MEA, 2005; Rasul et al., 2011), they have not received the same level of attention in ES literature as have other areas. This study reveals that whilst mountain regions occupy 24% (35.8 million square kilometres) of the Earth's surface, only about 10% of total forests' ecosystem valuation studies (n = 120) were from mountainous regions. Gleeson et al. (2016) documented the state, population and publication trend over the last decade in mountainous areas and found that whilst the research on European mountain regions decreased, they were still overrepresented in comparison to mountainous areas in Asia and Africa. This study revealed that most of the research was concentrated on the Alps, the Rockies or in the Mediterranean Mountains and other mountain regions from the least developed world are disproportionately represented in the forest ES research. It is possible that mountain regions receive the least research priority due to the perception that they are economically non-profitable regions, geographical inaccessible, incur high research costs and are less capable of providing human resources (Grêt-Regamey et al., 2008, 2012). The current modelling and mapping methods can easily capture the ecosystem values through remotely sensed data. However, verification of this data in mountain regions remains challenging and costly.

Almost one in four publications on ES has been conducted at the site-specific level. The forest ES valuations have mostly been conducted in all management modalities and their distributions have been skewed towards public land/government managed forests, while Protected Areas (PA) was the most researched after 2008. Globally, a large area of forests (2969 million hectares) is public and government managed forests (FAO, 2015) along with the protected area systems. PAs are the cornerstone for global biodiversity and constitute an important element of the global tourism industry (Pandit et al., 2015); as of October 2017 this land management category covers more than 200,000 terrestrial and marine PAs worldwide. The large area coverage of government managed and PA systems may have resulted in a higher number of publications and due to this, there may be a continual increase in the future. Community Based Management (CBM), which covers almost 15% of global forests, has seen 31% of the developing countries begin adopting CBM. Despite the wide global coverage, the ES research in CBM seems the lowest between 1994 and 2017.

Despite the increase in coverage, there has continued to be a limited number of publications in Community-based Forest Management (CBF). Many developing countries have adopted the CFM modality to overcome the problems of resource degradation (Agrawal et al., 2008; Beyene et al., 2015; Paudyal et al., 2017) as this approach can reduce individual competition for resources. Despite the increased figures in valuation research as shown by our review, ES valuation research in CFM has been largely ignored. A conclusion cannot be drawn as to the exact causes of this; there could be small patches of forests, low economic scales and less priority in ES valuation in low income countries.

5. Conclusion

This is a case study of the application of an analytical tool that shows how interest and application can increase quite rapidly. In this case, it could be driven by an important and wide-reaching global issue, in the depletion of forests, with strong interest in the problems in global and national institutions. There were some seminal research works that influenced later scholarship, along with funding support, increasingly for work in developing countries. Analytical methods, tools and computer power may have helped drive this trend. The focus of and sites for, the research have shifted over time, with more activity in developing and upper middle income countries and larger collaborative projects having an influence on that. There may however be some limits to the growth of some types of analysis, with monetary evaluations seeming to have peaked.

The meta-analysis of forests ES studies from 1994 to 2017 was executed to identify the major focus of the research into this area. The analysis revealed that ES research has proliferated and may continue to grow in the coming year in peer-reviewed journals. Despite the broader coverage of valuation studies in forestry there are still several gaps, challenges and methodological inconsistencies. One of the prominent gaps is the underrepresentation of valuation studies in countries with high biodiversity and particularly the forests from mountain regions in developing countries and community based forests management. Research needs to link direct biophysical estimates with scales of decision; develop methods for evaluating best type of service delivery and emphasise the benefits of addressing social inequalities. Moreover, valuation research has mainly focused on aggregated perspectives; this can neglect critical issues of poverty reduction, food security, ethics and the rights of many ES dependent communities.

Concrete steps are required to address the gaps through local scale valuations to improve the knowledge of ES and their integration into decision making. Several studies have concentrated on either a global or a regional scale and there is limited integrated valuation research at the level of site-specific management units. Although a small number of studies has been conducted at specific sites, they have been largely either based on long-term research or have used highly sophisticated tools and techniques. These studies require reliable data sets, skilled expertise and huge investment and this is not a high priority in low-income countries. Moreover, ES research should concentrate on the neglected management regimes in low socio-economic state of the local communities.

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4 CHAPTER FOUR: IDENTIFICATION AND PRIORITISATION OF ECOSYSTEM SERVICES IN THE SIWALIK MOUNTAINS

4.1 Local Users and Other Stakeholders' Perceptions of the Identification and Prioritisation of Ecosystem Services in Fragile Mountains: A Case Study of the *Chure* Region of Nepal.

Foreword:

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After presenting an overview of insight and knowledge gap in forest ecosystem services valuation research in chapter 3, this chapter assesses how local users and other stakeholders perceive the importance of FES based on subgroups such proximity (nearby vs. distant users), socio-economic class (rich vs. poor users), and forest management modalities (CF vs. CFM). More explicitly, this article explores how many number and types of forest ecosystem services are in use in the community-based forest management modality in *Siwalik* region of Nepal and is there any difference on their priority of ecosystem services among the subgroups. To capture this information, this study employed eight focused group discussion, 29 in-depth interviews with national experts and workshops. This article finds that local users and other stakeholders in the *Siwalik* region utilises a total of 42 forest ecosystem services. This article also reveals both similarities and differences in prioritisation of the forest ecosystem services among different subgroups, largely influenced by the management modalities, proximities and socio-economic condition. Finally, this article discusses the potential reasons for the priority differences and policy implications for forest ecosystem services management in *Siwalik* region.

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Article

Local Users and Other Stakeholders' Perceptions of the Identification and Prioritization of Ecosystem Services in Fragile Mountains: A Case Study of *Chure* Region of Nepal

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Abstract: Forest-based ecosystem services (ES) play a vital role in improving people's livelihoods, the environment, and the economy. Prior studies have focused on technical aspects of economic valuation such as biophysical quantification through modeling and mapping, or monetary valuation, while little attention has been paid to the social dimensions. Taking case studies of two dominant community-based forest management systems (community forestry—CF and collaborative forestry—CFM) in the *Chure* region of Nepal, we investigate how local users and other stakeholders perceive the valuation of forest-based ecosystem services based on proximity (nearby vs. distant users), socio-economic class (rich vs. poor users), and forest management modalities (CF vs. CFM). We found that local users and other stakeholders in the *Chure* region identified a total of 42 forest-based ecosystem services: 16 provisioning, 15 regulating, and 11 cultural services. While all local users prioritised firewood, water quality improvement, and bequest values as the top three services, genetic resources, hazard protection, and hunting services were valued as having the lowest priority. The priorities placed on other services varied in many respects. For instance, rich users living near a CF showed a strong preference for fodder, grasses, and soil conservation services whereas users living far from forests prioritised timber, fresh water, and flood control services. In the case of CFM, rich users adjacent to forests preferred timber, soil conservation, and carbon sequestration services but those living far from forests chose timber, poles, and flood control as their top priorities. Differences in rankings also occurred among the regional managers, national experts, and forest users. The reasons for these differences and their policy implications are discussed, and ways of reaching consensus between the users are suggested.

Keywords: forests; valuation; community-based forest management

1. Introduction

The concept of ecosystem services (ES) first appeared in the 1980s [1] and gained increased recognition following a seminal paper by Costanza and his team [2]. Costanza et al. [2] first estimated the worth of the world's ES at US $33 trillion, almost 1.2 times more than the total global gross domestic product in 1995. In their 2014 update, this estimate increased to US $145 trillion [3]. Other groundbreaking works on ES include the Millennium Ecosystem Assessment in 2005 [4] and The Economics of Ecosystem and Biodiversity (TEEB) [5]. The concept of ES has now entered the discourse of many disciplines including natural resource management, biodiversity conservation, and environmental policy and accounting [1,6].

Forest-based ES play a vital role in enriching people's livelihoods, enhancing the environment, and developing the economy [7,8]. Valuation research in forest-based ES increased at an exponential rate from 2014 onwards [9,10]. Prior studies explored how forest-based ES contribute to generate value or benefits for people's livelihoods [11,12], the environment, and the economy [13]. However, these studies were constrained by their disproportionate focus on the technical aspects of economic valuation such as biophysical quantification through modelling and mapping [14–17], or by employing purely monetary valuation, of the forest-based ES [18–21]. Little research has been carried out that demonstrates how social dimensions, for example people's perceptions or preferences, affect or play important roles in the identification and prioritization of forest-based ES. Studies have called for urgent action to incorporate the views of broader stakeholders when carrying out forest-based ES valuation research [22–26].

The forest-based ES contribute in both developed and developing nations, although their contributions vary. The contribution to the livelihood of resource-poor rural people, particularly those in developing countries, is critically important [27,28]. Recent statistics show that forest-based ES provide approximately 20% of the income of rural households both through cash and by meeting subsistence needs [29]. About 75% of poor people in developing countries are heavily dependent on forest-based ES [8]. However, despite their significant contributions to large populations, the actual social contributions of forest-based ES to different categories of users have not been adequately assessed.

The community based forest management (CBFM) system is the dominant forest management regime in developing countries. In this system, local people play a vital role in planning, decision-making, implementation, and benefit sharing [30,31]. About 511 million hectares of global forests (almost 15.5%) are either owned or managed by such communities [32]. The trend for adoption of these systems is increasing in developing countries (22% in 2006, 27% in 2010, and >30% in 2015) [30,32]. The CBFM system comprises different users of a forest, both living nearby and distant from the forest and with different socioeconomic backgrounds [33]. Their perceptions of the forest-based ES vary significantly according to their livelihood outcomes [34]. The users are the real managers but are victims of ecosystem degradation, and therefore, there is a need to understand their perceptions and take their views into account for effective implementation of forest policy and plans [35]. Knowing the local people's attitudes, considering the needs of the local context of forest-based ES is imperative since this can create three-fold benefits. First, this will create awareness among different sub-groups at the local level of the identification and prioritization of critical forest-based ES. Second, identification and prioritization of forest-based ES will help policy makers and managers assess the needs and aspirations of the different sub-groups involved so that they can formulate practical and applicable forest-based ES management plans. Such an understanding would also help prioritize scarce resources for the successful implementation of forest and natural resource conservation plans. Third, the international community will gain insights into how forest-based ES vary among the sub-groups in the CBFM under consideration and how these ES can be assessed through reaching a consensus in a complex situation.

Nepal is considered a pioneering country in adoption of the CBFM system and its modality has been replicated in many developing countries around the world [30]. There are two major CBFM systems in Nepal, community forestry (CF) and collaborative forest management (CFM). These two CBFM systems manage over 32% of the total forests in Nepal [36]. The National Forest Strategy Plan 2016–2025 aspires to increase this figure to 39% (6.6 million ha) by 2025 [36]. Taking a case study of these two CBFM systems, we assess how local users and other stakeholders perceive the importance of forest-based ES based on proximity (nearby vs. distant users), socio-economic class (rich vs. poor users), and forest management modalities (CF vs. CFM).

The significance of this study is further enhanced by the selection of case studies from the Siwalic region, locally known as *Chure*, which comprises the youngest mountains ranging from 93–1955 metres above mean sea level (masl), and extends over four developing countries: Pakistan, India, Nepal, and Bhutan [37]. In Nepal, it extends over 36 districts and its ES are critically important to large populations in Nepal and in the Bihar and Uttar Pradesh provinces of India. Given its importance to peoples' livelihoods and socioeconomic development, the Government of Nepal (GoN) has placed high priority on its conservation and management through its US $2.49 billion "President Chure-Tarai Madhesh Conservation and Development Programme" [38,39]. The programme is gathering information on how different types of forest users and other stakeholders perceive and prioritise forest-based ES in order to prepare a master plan for the region [40].

2. A Brief Snapshot of Community Forestry (CF) and Collaborative Forestry (CFM) in Nepal

Although CF and CFM both adopt a CBFM modality, many differences—such as coverage, access to forest ES, use rights, management modalities, exclusion of other users, and alienation of forest areas—exist between them (see Table A1 in Appendix A for details). CF applies to national forests handed over to local forest users for protection, utilization, and management with the objective of fulfilling the forest product and services demands of local communities [41]. About one-third of Nepal's total forest area has been handed over to 22,000 community forest user groups (CFUGs); the National Forest Strategy 2016–2015 aims to add an additional 600,000 hectares by 2025 [36]. CFM, on the other hand, is a partnership model involving the Department of Forests, local governments and local communities for the management of a patch of national forest to fulfil local needs [42]. So far, 28 CFM groups, comprising 3.4 million households, manage nearly 71,000 hectares of forests. By 2025, the Government of Nepal aims for an additional area of 265,000 hectares of forests to be under CFM [36].

CF users can collect and harvest all provisioning ES, whereas CFM users can gain access only for basic forest ES [43]. CF users, through a general assembly, can make all decisions about forest utilization and management, whereas in CFM, mostly the forestry officials and an executive committee make such decisions [43]. In the case of CFM, 50% of forest product revenue goes to the governments (40% to the national government and 10% to the local government) but in the case of CF, all revenue goes to local users. It is widely claimed that although a large percentage of CFM income goes to government, the contribution from the government is inadequate for managing collaborative forests [44]. Similarly, in the case of CFM, 40% of the total community income is allocated to forest management, 50% to poor people and 10% to community development, whereas in CF, these values are 25%, 35%, and 40%, respectively [36]. Although 50% income allocation to poor people seems high in the case of CFM, it is in fact 20% of the total income. Furthermore, in the case of CFM, there is no right to alienate forestland to the poor, whereas in CF, some areas of forest can be allocated to poor people for leasing [36]. Therefore, compared to the CFM model, the CF is a more pro-poor forest management model.

3. Materials and Methods

3.1. Study Area

This study was conducted in *Sarlahi* District. The district hosts both community and collaborative forests with nearby and distant users. The *Sarlahi* district is in the central part of Province No. 2, 350 kilometres southeast of Kathmandu, the capital city. The district covers 125,948 hectares, of which 15.5% are *Chure* ranges and rest is the *Bhawar* and the *Tarai* regions [45]. The elevation of the district ranges from 60 metres above sea level (masl) to 659 masl [46] and consequently it is diverse in climate, vegetation, and land use patterns [37,47].

In the district, the sub-watersheds of the Lakhandehi and Banke rivers were selected for study. The total area of the two watersheds is 15,930 hectares [47]. Cultivated land constitutes almost two-thirds of the area (66.57%) followed by forests (23.31%) and sand/gravel (4.31%) [46,47]. CF and CFM have been implemented in the watershed since the early 2000s with the support of the Biodiversity Sector Programme for Siwalik and Tarai (BISEP-ST), funded by the Government of The Netherlands.

The study investigated two community-based forest management models (one CF and one CFM). These were *Shibeshwor* CF in the *Hariyon* municipality, and *Phuljor* CFM in the *Ishworpur* municipality, which cover a total area of 3121 hectares of forested area (the CF covering 711 hectares, and CFM

2419 hectares) (see Figure 1). The *Shibeshwor* CF comprised 719 households with a population of 4496, while *Phuljor* CFM consisted of 27,953 households with 161,730 residents [48]. Local users were living both nearby and far from the forests. The nearby users in both the CF and CFM live in the foothills. Agriculture and animal husbandry are the mainstays of their livelihoods. The distant users in the CF live in the semi-urban area and have multiple livelihood options including commercial agriculture, services, and small shops. The distant users in the CFM live some distance away from the forest (>5–20 kilometres) and also depend on agriculture and animal husbandry for their livelihoods [48]. The reasons for selecting these two CBFMs are: (1) both of them have both nearby and distant users; (2) they have a long history of community participation in forest management; (3) the areas are endowed with rich ecosystems [49]. The outcomes of the study are highly applicable to the wider *Chure* region and to the CBFM model globally.

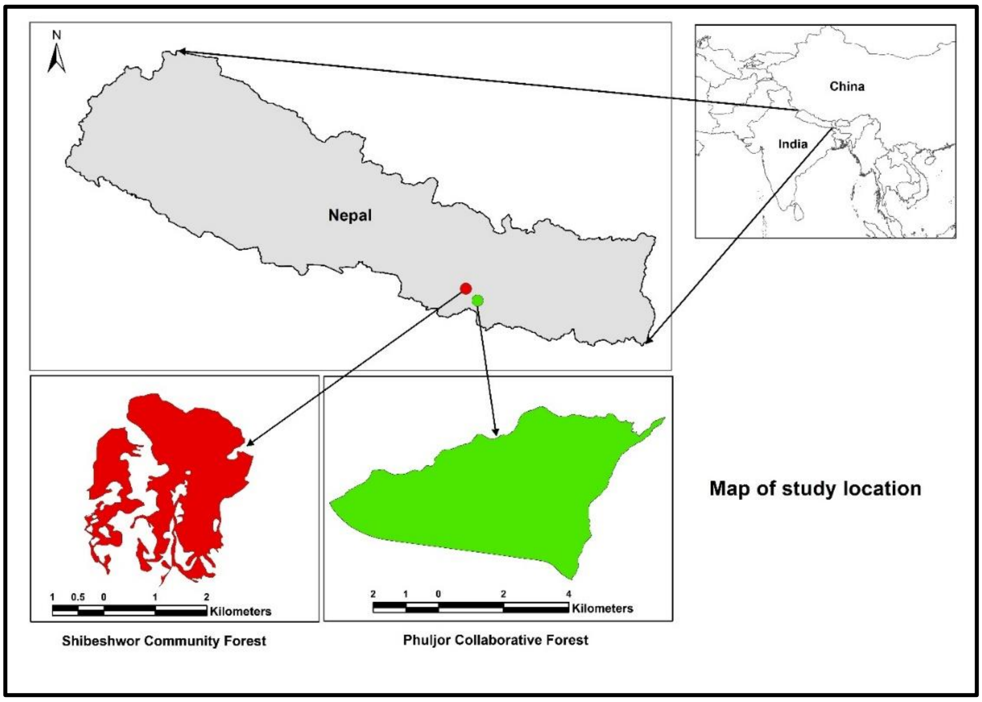


Figure 1. Location map of case study sites (CF and CFM) in Nepal.

3.2. Assessment and Prioritisation of Ecosystem Services

3.2.1. Identification of Ecosystem Services

A list of potential ES was prepared after reviewing the relevant forests and wetland ecosystem literature, particularly studies conducted in and adjacent to the *Chure* region [50–53]. We started with Bhandari et al. [50] for a preliminary list—which included 14 provisioning services, 9 regulating services, and 3 cultural services—since their research site is similar to our site and then expanded the list based on other literature. This list was then further augmented through consultation with 29 national experts (an 'expert' is a person with extensive knowledge or ability in ecosystem-based research, experience, or occupation and in particular, having publications in ES and resource management), 17 regional managers ('regional managers' are provincial and district forest officials working in the *Chure* area directly involved in managing ecosystem services in the *Chure* region), and eight focus group discussions (FGD).

3.2.2. Prioritisation of Ecosystem Services

The primary data was collected from July to October 2018. The names of potential experts and regional managers were obtained from the President Chure-Tarai Madesh Conservation and Development Board and the District Forest Office *Sarlahi*. After that, we consulted some of them for suggestions on selecting case study sites to meet our objectives. Subsequently, we carried out multistage sampling, first selecting the district and then the CBFMs and venues for discussions, after ascertaining that the users' participation was high.

Local users' preferences among the range of ESs were identified through FGD which is considered as a suitable tool for assessing people's perceptions of a particular area of interest [54]. As noted, in order to serve our objectives, users were stratified into different strata (rich and poor and nearby and distant users) (Nearby/distant: In collaborative forest management: users living within 5 km of forests are considered nearby and beyond 5 km as distant users; in CF living within 3 km is considered distant. Rich/Poor: CBFM classifies users into four categories (Well-off, Medium, Poor and Very poor). This study includes the first two as Rich and the other two as Poor). The databases for forming these strata were obtained from the constitutions and operational plans of both CBFMs. These databases were further verified through consultations with executive committees. Eight FGDs were conducted, addressing proximity (nearby and distant) and the socio-economic classes (rich and poor). The FGD were conducted in a local language and between 11 and 18 participants took part in the FGD. The main demographic features of the participants are listed in Table 1. A long list of potential ES—developed through the literature review and preliminary consultations with users, experts and forest managers—for each service type was provided to all participants. ES Concept, types (i.e., provisioning, regulating and cultural), importance of various ES to their livelihoods, and the implication of ranking priorities were also discussed. The discussion also addressed the question of how respondents could reach a consensus if there were any misalignments of priorities. Then, adopting the principles set out in Shoyama and Yamagata [55], participants were asked to discuss and unanimously rank all ESs on within services types on the basis of their importance to their livelihoods. The final list of identified forest-based ES suggested 16 provisioning, 15 regulating, and 11 cultural services. Therefore, in case of provisioning services, regulating services, and cultural services, the ranking goes from 1–16 (1 is the least important and 16 is the most important), 1–15 (1 is the least important and 15 is the most important), and 1–11 (1 is the least important and 11 is the most important), respectively. The respondents agreed that if there is any misalignment among user's priorities, the differences could be settled by a democratic process through a majority vote. They also discussed why they assigned the top score to the particular services in that particular fashion.

4. Results

4.1. Assessment of Ecosystem Services from the Community-Based Forest Management System of Chure Forests

Local users, regional managers, and experts from the national level identified a total of 42 different ES throughout the region. These were classified based on the Common International Classification of Ecosystem Services (CICES) [56] into three categories: provisioning (16), regulating (15), and cultural (11) services (Figure 2A–C; Appendix B: Table A2). ES are either from extractive uses such as timber, firewood, grasses, sand, boulders, and gravel or non-extractive uses such as regulating climate and water related services as well as being linked to social and cultural values of the local communities such as cultural or religious values or landscape beauty.

Table 1. Socio-demographic features of the respondents.

Demographic Features	CF Nearby		CF Distant		CFM Nearby		CFM Distant		Regional Manager (*n* = 17)	National Experts (*n* = 29)
	Rich (*n* = 11)	Poor (*n* = 16)	Rich (*n* = 18)	Poor (*n* = 18)	Rich (*n* = 12)	Poor (*n* = 12)	Rich (*n* = 15)	Poor (*n* = 17)		
Gender	M = 8 F = 3	M = 6 F = 10	M = 13 F = 5	M = 7 F = 11	M = 8 F = 4	M = 9 F = 3	M = 12 F = 3	M = 12 F = 5	M = 14 F = 3	M = 25 F = 4
Median age (years)	41 (19–75)	40 (18–80)	48 (24–79)	48.50 (21–74)	39 (22–68)	45 (20–75)	51 (20–84)	45 (25–77)	46 (31–57)	53.5 (29–69)
Education level	I = 2 P = 4 S = 3 T = 2	I = 3 P = 10 S = 2 T = 1	I = 1 P = 3 S = 7 T = 7	I = 8 P = 3 S = 5 T = 2	I = 1 P = 4 S = 6 T = 1	I = 2 P = 5 S = 3 T = 2	I = 2 P = 4 S = 5 T = 4	I = 4 P = 7 S = 5 T = 1	T = 17	T = 29
Ethnic composition	UC = 8 LC = 3	UC = 2 LC = 14	UC = 16 LC = 2	UC = 4 LC = 14	UC = 5 LC = 7	UC = 3 LC = 9	UC = 11 LC = 4	UC = 10 LC = 7	UC = 10 LC = 7	UC = 17 LC = 12
Religion	H = 9 B = 2	H = 12 B = 4	H = 18	H = 16 M = 2	H = 9 B = 2 M = 1	H = 7 B = 4 M = 1	H = 15	H = 17	H = 14 B = 3	H = 25 B = 4

Data in parentheses denotes a range; Gender: M = Male, F = Female; Education level: I = Illiterate, P = Primary/lower secondary, S = High school educated, T = College & above; Ethnic composition: Higher Caste = Bahun/Kshetri/Dashanami/Madeshi, Lower Caste = Janajati, Janajati/Madhesi, and Dalit; Religion: H = Hindu, B = Buddhist, M = Muslim.

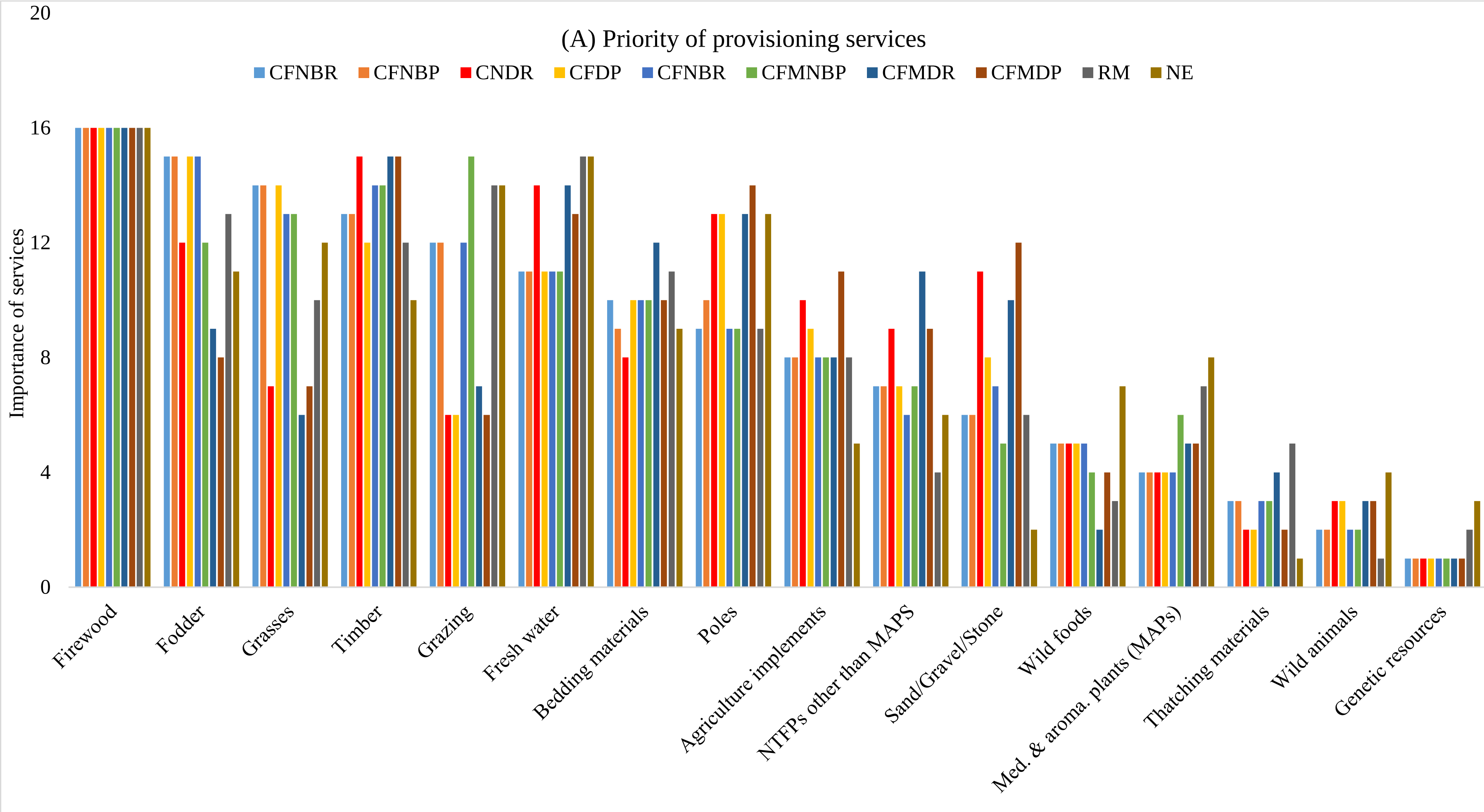
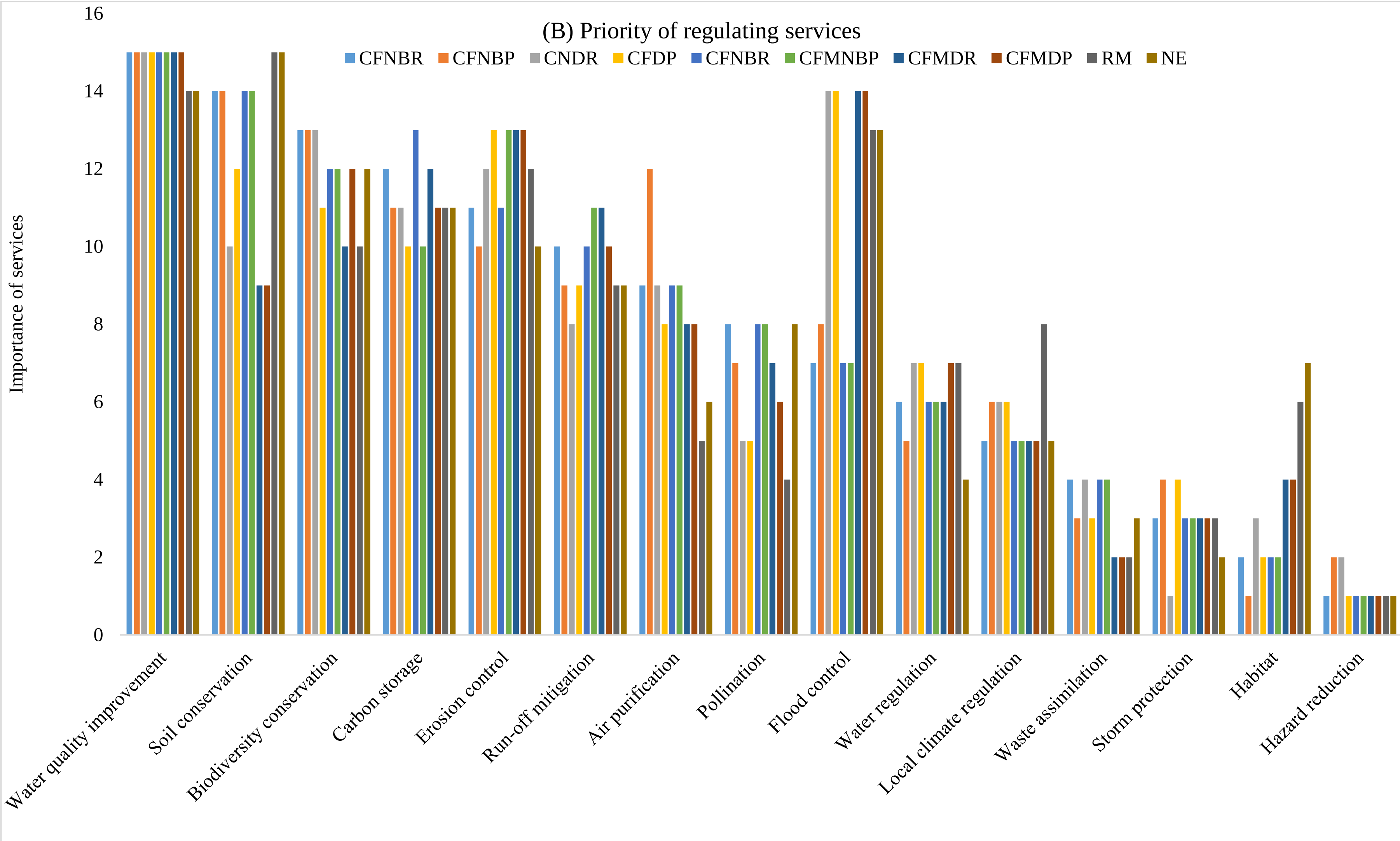


Figure 2. *Cont.*



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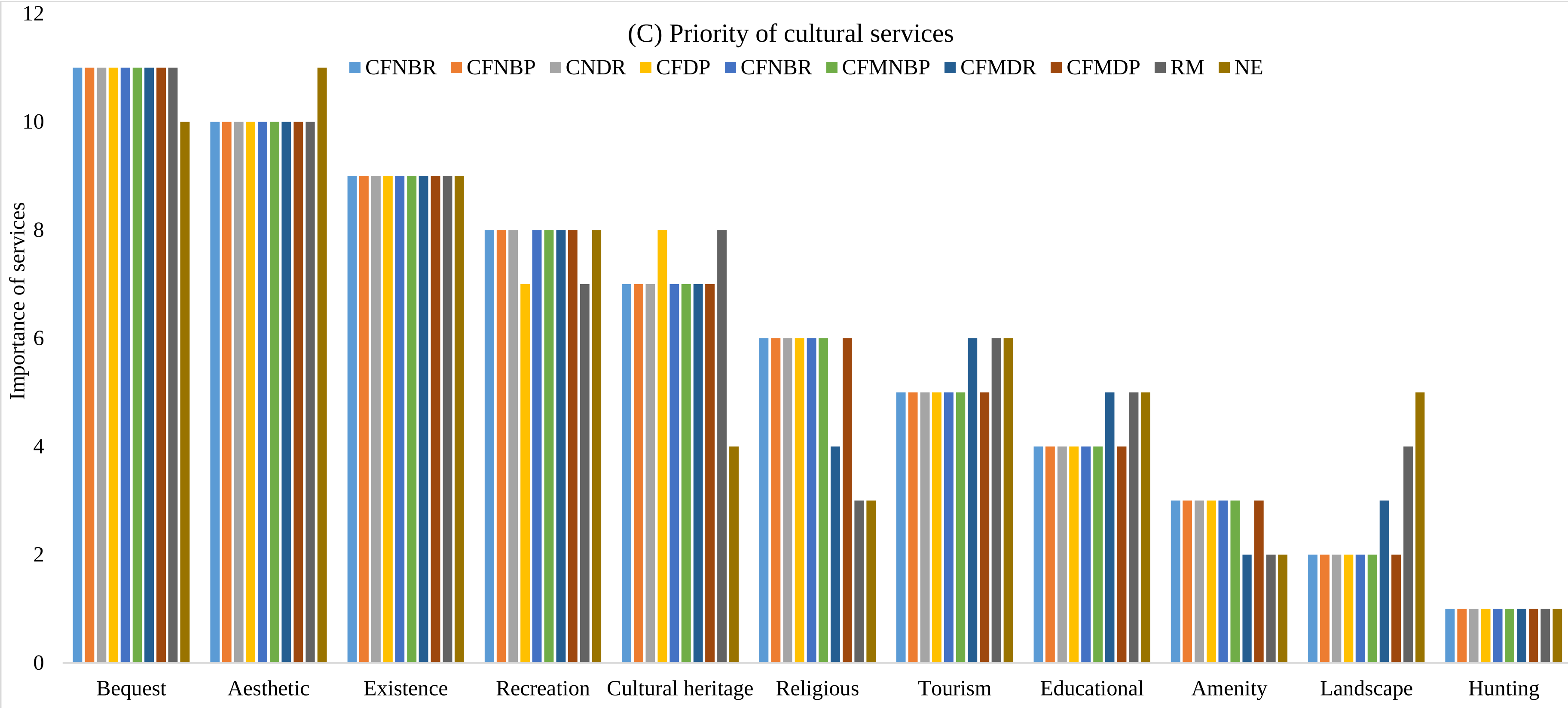

Figure 2. Prioritisation of 16 provisioning (**A**), 15 regulating (**B**), and 11 cultural (**C**) ecosystem services. In the case of provisioning services, regulating services and cultural services, the ranking goes from 1–16 (1 is the least important and 16 is the most important), 1–15 (1 is the least important and 15 is the most important) and 1–11 (1 is the least important and 11 is the most important), respectively. Note: CFNBR = Community Forest Nearby Rich Users, CFNBP = Community Forest Nearby Poor Users, CFDP = Community Forest Distant Rich Users, CFDP = Community Forest Distant Poor Users CFMNBR = Collaborative Forest Management Nearby Rich Users, CFMNBP = Collaborative Forest Management Nearby Poor Users, CFMDR = Collaborative Forest Management Distant Rich Users, CFMDP = Collaborative Forest Management Distant Poor Users, RM = Regional Managers, NE = National Experts.

In the case of CF, the top priorities of all subgroups were found to be: firewood, fodder, grasses, timber, fresh water, water quality improvement (WQI), soil conservation (SC), biodiversity conservation (BD), flood control (FC), erosion control (EC), bequest, aesthetic, and existence. In the case of CFM, top priorities were firewood, fodder, timber, grazing, fresh water, poles, WQI, SC, BD, FC, EC, bequest, aesthetic, and existence ES.

4.2. Prioritisation of Various Ecosystem Services from Community-Based Forest Management by Local Users

Different subgroups had different priorities. Considering all subgroups within the CF, the top three provisioning services were firewood, fodder, timber, grasses, and fresh water. Similarly, the top three regulating and cultural services were WQI, SC, FC, bequest, aesthetic, and existence values.

CFM users, on the other hand, assigned highest priority to firewood, timber, and fresh water as provisioning services, and WQI, carbon, FC, and EC as regulating services. Irrespective of the different management modalities, users placed high priority on bequest, aesthetic, and existence vales as cultural services.

Forest users' priorities on ES differed in relation to their spatial distance from forests. In CF, users living near forests prioritised fodder, grasses, and grazing provisioning services while distant users chose timber, fresh water, and poles. In the case of regulating services, nearby users placed highest priority on SC, and BD services, whereas distant users from the same category placed strong priority on FC and EC services. For cultural services, both nearby and distant users preferred bequest, aesthetic, and existence services and prioritised amenity, landscape, and hunting services least. In the case of CFM, nearby users gave high priority to firewood, fodder and timber while distant users selected firewood, timber, and fresh water provisioning services. Users living adjacent to a forest selected WQI, SC, and carbon sequestration/storage, whereas distant users from the same category nominated WQI, FC, and EC regulating services. Users both nearby and distant from a forest favoured similar cultural services to those selected by the CF users.

Users' priorities differed between higher and lower socioeconomic status groups for many services in the CF. For example, rich users from nearby forests ranked fodder as the second most important service while those of the same status living far from the forest area preferred fresh water. Regarding regulating services, both categories placed WQI in the top rank; however, their priority differed regarding SC. SC was ranked in second position by rich nearby users, whereas the same wealth category living far away ranked this service as sixth priority. In the case of CFM, wealthier users living next to the CFM area preferred fodder, timber, grasses, and grazing services while rich users residing far from forests selected timber, poles, and fresh water services. In terms of regulating services, the priorities of the wealthier users living near the CFM area were similar to those living nearby the CF area, whereas wealthier users at a greater distance prioritised FC and EC (Figure 2A–C; Appendix B: Table A2).

4.3. Prioritisation of Various Ecosystem Services by Regional Managers and National Experts in the Chure Region

The priorities placed on ES by regional managers and national level experts were also mixed. Regional managers assigned fresh water and SC services as their top priorities. The national level experts, on the other hand, placed the highest priority on firewood, SC and aesthetic values. Regional managers and national experts also placed high priority on genetic resources, habitat, landscape beauty, amenity services, and hunting, whereas local forest users prioritised these services least (Figure 2A–C; Appendix B: Table A2).

5. Discussion

5.1. Identification of Ecosystem Services

Forest users and other stakeholders identified 42 different ES in the study area which are important to local people's livelihoods and that also contribute to the regional and national economy. These results are comparable with some other studies, both within and outside Nepal. Previous studies have enumerated 19 to 37 different ES from similar localities focusing on forests [35,41,50,53,57–59] and wetlands [51,52].

It has been a challenge to the researchers to explain the high numbers in the results occurring in ES types. For example, a similar study conducted in *Panchase* area in Nepal acknowledged the landscape mosaic as an important factor [58]. Our study site does not comprise the same mosaic, however it still resulted in a high number of ES identified, probably because of the involvement of a large number of diverse forest stakeholders. Moreover, the *Panchase* study was based only on CF while our research covers both CF and CFM systems. Furthermore, their case study site was hilly terrain, whereas our study area is a lowland landscape with diverse flora and fauna, and high ethnic and cultural diversity. Our study site has more than 20 different ethnic groups with resulting diversified demands on forest ES [48]. Similarly, about 1308 species of flora and fauna are found in the *Chure-Tarai* landscape alone [38,60]. The higher the number of species and ethnic and cultural groups, the greater the diversity of all ES [61].

Our study revealed a high number of provisioning ES (16) in comparison to regulating (15) and cultural services (11). The findings of our study both coincide with and contradict other studies. For example, Bhandari et al. [50] documented 14 provisioning and 11 regulating services, which is similar to our findings while Adhikari, Baral, and Nitschke [58] identified 19 regulating services in Nepal. Similarly, Chaudhary et al. [41] identified eight provisioning, four regulating, and seven cultural services in *Mai Pokhari* Ramsar site, Nepal. A study conducted in Sweden in private forests also reported a high number of provisioning services (n = 23) [22]. The difference between cases might be due to differences in landscape and ethnicity. The first case study site is similar to our site and revealed similar findings, whereas the second and third study sites have different landscapes and different management modalities. In addition, our study site comprises production forests while the other two sites studied (i.e., *Panchase* and *Mai Pokhari*) comprise protection forests with limited use of provisioning services.

5.2. Differences in Priority of Ecosystem Services among Forests Users, Regional Managers, and National Experts

5.2.1. Differences among Different Sub-Groups of Community Forests and Collaborative Forest Management

The findings revealed that, irrespective of management modalities, all users ranked firewood, water quality improvement (WQI), and bequest values as top priority. Some of the possible reasons behind these preferences could be similarity in the use pattern, an increased need for these services as well as the socio-cultural beliefs of those sub-groups. More than 80% of the households in the *Chure* region use firewood for cooking [38] and the total demand for firewood in both CBFMs is 403,112 (35,512 *bhari* required by CF and 367,600 *bhari* by CFM) *bhari* (*Bhari* is a local unit of measurement. One *bhari* is a head load carried by an individual, approximately equivalent to 25 kg) [48]. Rich-distant users employ an energy mix such as liquefied petroleum gas (LPG) and bio-gas, however, most of the population regardless of their economic status rear cattle and firewood is necessary for cooking cattle feed, locally called *Khole*. In addition, all sub-groups use firewood for heating in winter. According to FAO about 2.4 billion people make use of fuelwood for cooking, boiling water, and heating globally [8]. In the case of developing countries, fuelwood is the prime source of energy. Our case study sites concur with the findings of others studies [8,35,62]. Likewise, both water quality and quantity are of serious ongoing concern for inhabitants of *Chure* and *Tarai*, mainly due to the influx of hill migrants and increased water use coupled with the fragile topography and the low water holding capacity of the landscape [37,38,63]. Similar results have been recorded in other parts of the world e.g., in the dry northern region of Kenya [61] and the Chittagong Hill Tracts in Bangladesh [62]. Similarly, bequest value is categorised as a non-use value, which is a special case of option value that represents the value (to current users) of being able to bequeath the forest to future generations [64,65]. As the local users of the study area strongly believe in reincarnation and saving for future generations, forest users may have prioritised bequest services for their children and grandchildren [66]. Therefore, all sub-groups ranked these services amongst their top priorities.

Regardless of their economic status and management modalities, all users from both CBFMs regarded many critical services, for example genetic resources, hazard protection, and hunting services as least priority. The reason for this might be associated with the level of awareness of the importance of many ES. Although the landscape approach in the Tarai-Arc Landscape (TAL) programme was implemented in the Chure and Tarai regions in 2004, their focus has only been on 13 western districts [63]. The TAL excludes the eastern Tarai region, where our study area is located. Furthermore, both CBFM have completely prohibited the hunting of any wild animals [48,67]. This could be why hunting services were given lowest priority.

The findings indicated a clear difference in the priority rankings among nearby and distant users in CFM; such difference might be influenced by number of factors, primarily the benefits accruing from the forests [26,41]. In general, local users from the CFM placed highest priority on the ES based on the benefits that they would have to their individual livelihoods. For example, the nearby users of both socioeconomic groups prioritised grasses 4th while distant users in same category placed grasses 8th and 10th. This is comparable with communities' priorities in other empirical studies [35,68,69]. Nearby forest users, show a greater preference for direct use services as they receive higher benefits from these as compared to more distant users. Hence, the level of tangible benefits received by the users could be one of the primary determinants of prioritising the ES.

In our study, proximity to a forest area also influenced the prioritisation of the ES. Users living nearby forests under CF preferred daily use services such as fodder, grasses, and grazing, whereas users living farther from the forest area prioritised timber and fresh water. The possible reasons for variation in priority among these sub-groups might be differences in location, occupation, demand, price, and use pattern of the services. For instance, as previously mentioned when discussing our methodology, the nearby users in CF live in the hills and rely solely on agriculture and animal husbandry for their livelihoods. About three quarters of these households raise cattle ranging in number from one to seven head and total demand for fodder and grasses is almost 21,256 *bhari* [67]. The more distant users of a CF, on the other hand, live in semi-urban areas and have multiple livelihood options including cash crop cultivation, government and other jobs, and small businesses. They prioritised timber and poles, since the market price of timber in the semi-urban area is high. Comparable findings were reported in Java, Indonesia, where location of residents and livestock holdings determined the selection of forest-based ES [35]. Purchasing timber and poles from the market is almost 10 times more expensive than obtaining these services from the CF. In addition, fresh water is of special interest for distant rich users since large farmers cultivate sugarcane [70] and irrigate their sugarcane farms. These might be key reasons behind the differences in priority placed on provisioning services among CF users.

In the case of CFM, the nearby users favoured fodder, timber, and grasses while distant users selected timber, poles and fresh water services. Access to benefit sharing, distance to the forest area, and demand for scarce services could be potential reasons for selecting these services. As noted, CFM is a partnership model among national and local governments and local communities for the management of a block of national forest to fulfil the needs of local people [42]. In CFM, the level of access to benefit sharing by users distant to a forest area is different to that of CF [43]. In the case of CFM, 50% of forest product revenue goes to the governments (40% to national government and 10% to the local government) but there is no such provision in CF [43,44]. CF users reside near forests (nearby users live adjacent to the forest area and distant users live almost two to three km from a forest) while under CFM, distant users reside over five km away [33]. As the nearby users raise livestock (average of four to eight head of cattle per livestock-keeping household (HHs)) and require substantial amounts of forage, their priority is fodder and grasses. Likewise, as many users in the CFM system live 5–20 kilometres away from the forest area [48], they cannot collect daily use services such as fodder and grasses [33]. A study conducted in Tanzania reported contrasting findings [71], suggesting that most of provisional ES were utilized within one km radius of the forest, but in our case, many ES such as timber, poles and firewood are used up to 20 km away from the forests. Users do, however, consider forests as the source of timber, poles, and the fresh water and therefore prioritise these services accordingly.

Likewise, socio-economic and topographic factors play important roles in prioritising regulating services. The wealthier users adjacent to both CBFMs assigned top priority to SC, BD, and carbon sequestration services while users within the same wealth group living far from forests assigned high priority to FC and EC services. The *Chure* region is highly susceptible to soil erosion [39,72] and the Dun and *Tarai-Madesh* regions are susceptible to flooding [38,40]. Users living nearby the *Chure* forests face acute soil loss problems in the region [38–40]. On average, 16 to 64 tonnes of soil are lost every year [72,73]. The Tarai/distant region, on the other hand, faces frequent flooding: in 2017 flooding caused severe losses in 18 Tarai districts worth US $584.7 million [74]. Due to experiencing recent flood damage, distant users might have been influenced to select FC services as the top priority.

As presented in the study results, all sub-groups in both management modalities recognised the benefits of carbon storage and sequestration services (CSS) and ranked these fourth to sixth. Surprisingly, they currently receive no benefit from CSS though still choose this as a high priority. However, they have heard about the Reducing Emissions from Deforestation and Forests Degradation (REDD+) pilot projects implemented in nearby districts (*Chitwan, Dolakha*, and *Gorkha* districts). These projects have provided many financial benefits to the local users in accordance with their contribution to social and environmental safeguards [31,75]. Similarly, the Nepalese government, along with World Wildlife Fund for Nature (WWF) recently initiated REDD+ projects in 12 TAL districts, adjacent to our study site [36,76]. With a total budget of US$ 177.1 million, 14 metric tonnes of carbon dioxide equivalent ($MtCO_2$ e) (A metric measure used to compare the emissions from different greenhouse gases based upon their global warming potential. The carbon dioxide equivalent for a gas is derived by multiplying tons of the gas by its associated global warming potential) will have been credited to the World Bank Carbon Fund [36]. Although users in our research site have not received any carbon benefits so far, these initiatives in nearby districts may have created some awareness about them and users might have been more optimistic at the time of the study about the carbon benefits coming in the near future.

5.2.2. Differences between Regional Managers and National Experts

Regional and nation stakeholders share many similarities, although they have slightly different priorities for bequest services. Regional managers regard bequest value as the top priority, whereas the national stakeholders ranked this in second position. Regional managers stayed longer in the region and have a more in-depth understanding of the current field situation than national stakeholders. Studies conducted in Israel and Slovenia concur with this finding [77,78]. Practical and field experience can enhance identification and better prioritization of the ES. Consistent with this, regional managers tend to see with the eyes of local users whereas the national experts' input reflects national perspectives. The national experts, however, have more international exposure and have more knowledge of the global literature, which might have influenced their perceptions.

5.3. Policy Implications of the Study

This study identified and prioritized a wide range of forest-based provisioning, regulating, and cultural ecosystem services. Many of these services are not documented in the operational/management plans of both forests management systems [79]. Considering the increasing tendency toward valuing such services, it is essential to document them in management plans for CBFM projects. Furthermore, our study revealed the differences in priorities between sub-groups in both CF and CFM, however, up until now the plans of CBFM have not internalized these issues. In the CF, for instance, users living nearby prioritised fodder and grass services as highest priority but the current management plans do not incorporate ways of optimizing the values of these services. In the case of CFM, the operational plan largely focuses on timber production, while high priority is placed on firewood by distant users. Moreover, poor users living nearby also need a substantial amount of fodder, grasses, and grazing services but the management plan does not consider these pertinent issues. Users acknowledged that it is not possible to include all prioritized ecosystem services from all sub-groups in the management plans but it is crucial to consider at least the top five priorities from each sub-group. This provision would make all users feel that their interests and priorities are included. As a result, they will be motivated for to act for conservation and sustainable management of their forests. At the same time, mismatches of different groups should be equally considered for managing potential areas of conflict in the long run.

How we can include the provision of forest-based ecosystem services in an operational plan could raise some issues. As noted, in the CBFM system, part of the national forest is legally handed over to the local community for protection, management and utilization [80]. The process is supported by government policies, rules, and regulations. In the case of Nepal, Forest Act 1991, Forest Regulations 1995, and National Forest Strategy Plan 2016–2025 provide a roadmap and clearly specify the possible roles, responsibilities and inputs of communities, government, and non-government facilitators [36,81]. Once the user group's constitution and working plan are negotiated and signed by the users and government department—in the case of Nepal, the Divisional Forest Officer (DFO) —a given patch of national forest legally becomes a community forest. The operational plan of a CBFM system must be renewed at regular intervals for its perpetuity. The process and provision of securing prioritized forest-based ES could be incorporated into the revised operational plan for full-fledged implementation.

6. Conclusions

This study assesses and prioritizes key forest-based ecosystem services in community and collaborative forests in the *Chure* region of Nepal. The findings show that the *Chure* landscape provides approximately 42 ecosystem services for local, regional, national, and international users. This high number of ecosystem services is attributed to the high diversity of flora and fauna, and to the cultural and ethnic diversity in the study areas. Results also show both similarities and differences in the prioritization of the ecosystem services among different user groups, largely influenced by their forest management modalities (community forests and collaborative forests), proximity to forest area (nearby and distant) and socio-economic status (rich and poor). The similarities can determine common areas of interest among larger stakeholders, while the differences can indicate potential areas of conflict when implementing the management plans.

The mismatches in prioritization of ecosystem services among the subgroups of users generates complexities for forest management. Although obtaining consensus among different subgroups is not possible in such a large and socio-economically and culturally diverse landscape, it is imperative for better management of forest resources. Considering the priorities of regional managers and national experts is equally important, despite adding further complexity. Therefore, promoting the culture of multi-stakeholder consultation process towards achieving consensus among them is necessary. Once the interests of all stakeholders are negotiated and agreed upon, the process and provision of securing those ecosystem services should be included in the forest operational plans during their revision.

The outcomes of this research could be useful for a number of purposes: (1) two ongoing large programmes in Nepal—“President Chure-Tarai-Madhesh Conservation and Development Programme” and “Tarai Arc Landscape Programme”—could consider the users’ priorities for channeling and prioritizing their scarce resources; (2) the priority of ecosystem services for different users may change over time. This study provides benchmark data for change assessment; and (3) the research-sampling framework developed in this study can be applied in any community-based forest management (CBFM) system in developing countries.

Due to the scarcity of resources, this study was not able to cover all forest user groups. Therefore, more research across a larger number of community and collaborative forests is required to determine whether these results are indicative of the entire *Chure* region.

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Conflicts of Interest: The authors declare that there is no conflict of interest.

Appendix A

Table A1. Difference between Community Forests and Collaborative Forest Management in Nepal.

Features	Community Forests	Collaborative Forests
Concept	CF are national forests handed over to forest users for protection, utilisation and management of forests with the objective of fulfilling forest product and services demands of the local communities	CFM is a partnership model between Department of Forests (DoF), local government and local communities for the management of a patch of national forest to fulfil the local needs (both nearby and distant users) of many ecosystem goods and services such as timber, firewood and other non-timber forest products
History	Initiated in late 1980s	Initiated after 2000s
Coverage	1.81 million hectares of forests among 19,361 CFUG groups across Nepal Tarai, Chure, Midhills, and High Mountain regions	0.071 million hectares of forests area managed by 28 CFM groups (3.4 million HHs) in *Tarai* and *Chure* regions
Access	Each member has access rights as per the prescribed management plan	Forest users have rights to enter the forest within specified times and months
Use/management right	Users can decide and extract, collect and harvest all provisioning ES	Users can get regular access only for basic forest services such as fodder, grasses, and other non-timber forests products
Exclusion of non-users	Users have rights to include and exclude users, and utilisation of forests services	Forestry officials and executive committee mostly decide about the users, utilisation and management of forest services
Sharing of Revenue	100% of income goes to local users but 15% of revenue from commercial transactions of *Acacia catechu* and *Shorea robusta* goes to central government.	50% of all timber income goes to central and local governments and another 50% to the local government.
Provision on forest management	Allocation of 25% of total income of CF for forest management	Allocation of 40% of total income of CFM for forest management
Alienation of land forest land	CF can decide to allocate a piece of land to poor groups	There is no such provision in CFM

Appendix B

Table A2. Relative importance of different forest-based ecosystem services to sub-groups and other stakeholders.

Service Types	Category	CF Nearby		CF Distant		CFM Nearby		CFM Distant		Regional Managers	National Experts
		Rich	Poor	Rich	Poor	Rich	Poor	Rich	Poor		
Provisioning Services	Firewood	16	16	16	16	16	16	16	16	16	16
	Fodder	15	15	12	15	15	12	9	8	13	11
	Grasses	14	14	7	14	13	13	6	7	10	12
	Timber	13	13	15	12	14	14	15	15	12	10
	Grazing	12	12	6	6	12	15	7	6	14	14
	Fresh water	11	11	14	11	11	11	14	13	15	15
	Bedding materials	10	9	8	10	10	10	12	10	11	9
	Poles	9	10	13	13	9	9	13	14	9	13
	Agriculture implements	8	8	10	9	8	8	8	11	8	5
	NTFPs other than MAPS	7	7	9	7	6	7	11	9	4	6
	Sand/Gravel/Stone	6	6	11	8	7	5	10	12	6	2
	Wild foods	5	5	5	5	5	4	2	4	3	7
	Med. & aroma. plants (MAPs)	4	4	4	4	4	6	5	5	7	8
	Thatching materials	3	3	2	2	3	3	4	2	5	1
	Wild animals	2	2	3	3	2	2	3	3	1	4
	Genetic resources	1	1	1	1	1	1	1	1	2	3
Regulating Services	Water quality improvement	15	15	15	15	15	15	15	15	14	14
	Soil conservation	14	14	10	12	14	14	9	9	15	15
	Biodiversity conservation	13	13	13	11	12	12	10	12	10	12
	Carbon storage	12	11	11	10	13	10	12	11	11	11
	Erosion control	11	10	12	13	11	13	13	13	12	10
	Run-off mitigation	10	9	8	9	10	11	11	10	9	9
	Air purification	9	12	9	8	9	9	8	8	5	6
	Pollination	8	7	5	5	8	8	7	6	4	8
	Flood control	7	8	14	14	7	7	14	14	13	13
	Water regulation	6	5	7	7	6	6	6	7	7	4
	Local climate regulation	5	6	6	6	5	5	5	5	8	5
	Waste assimilation	4	3	4	3	4	4	2	2	2	3
	Storm protection	3	4	1	4	3	3	3	3	3	2
	Habitat	2	1	3	2	2	2	4	4	6	7
	Hazard reduction	1	2	2	1	1	1	1	1	1	1
Cultural Services	Bequest	11	11	11	11	11	11	11	11	11	10
	Aesthetic	10	10	10	10	10	10	10	10	10	11
	Existence	9	9	9	9	9	9	9	9	9	9
	Recreation	8	8	8	7	8	8	8	8	7	8
	Cultural heritage	7	7	7	8	7	7	7	7	8	4
	Religious	6	6	6	6	6	6	4	6	3	3
	Tourism	5	5	5	5	5	5	6	5	6	6
	Educational	4	4	4	4	4	4	5	4	5	5
	Amenity	3	3	3	3	3	3	2	3	2	2
	Landscape	2	2	2	2	2	2	3	2	4	5
	Hunting	1	1	1	1	1	1	1	1	1	1

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5 CHAPTER FIVE: ASSESSMENT OF THE FINANCIAL CONTRIBUTION OF ECOSYSTEM SERVICES FROM THE SIWALIK MOUNTAINS

5.1 Assessing the financial contribution and carbon emission pattern of provisioning ecosystem services in Siwalik forests in Nepal: Valuation from the perspectives of disaggregated users.

Foreword:

This section of Chapter Five is an exact copy of the published research article in *Land Use Policy,* vol. 95 (2020), pp. 104607-18.

This section of chapter five assesses how local users derive benefits and emits carbon from the use of provisioning services. More precisely, this article estimates financial benefits from the utilisation of different provisioning services in two dominant community-based forest management systems (community forestry—CF and collaborative forestry—CFM) based on proximity (nearby vs. distant users) and socio-economic class (rich vs. poor users) in the *Siwalik* region, Nepal. Applying a market price and substitute goods price methods, this article evaluates the financial contribution of different provisioning services for different subgroups in community-based forest management system in Nepal. The socio-economic status of the users and proximity to forests play a key role for the amount of financial benefits generated from the use of forest provisioning services. For example, users living near forests receive the highest financial benefits compared to those living long distant from the forest area. Users from community forestry, on typically, derive higher benefits that users from collaborative forest management and rich users receive higher monetary benefits compared to poor households living in the same area. In terms of carbon emission, CF users, on an average, emit (7.4 tCO2/HH/year) from the use of provisioning services, with almost 50% more carbon compared to users from collaborative forests (5 tCO2/HH/year) in the study areas.

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Assessing the financial contribution and carbon emission pattern of provisioning ecosystem services in *Siwalik* forests in Nepal: Valuation from the perspectives of disaggregated users

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ABSTRACT

Provisioning Ecosystem Services (PS) from the forests contribute much to peoples' livelihoods as well as to the national economy. Previous studies have been constrained by their primary focus on biophysical quantification of PS through modelling and mapping or aggregated monetary valuation, while little attention has been paid to the issues of the distribution of financial benefits among the different forest subgroups. Using market price and substitute good price methods, this paper assesses how local users exploit financial benefits and emit carbon from the use of PS in two dominant community-based forest management systems (community forestry—CF and collaborative forestry—CFM) based on proximity (nearby vs. distant users) and socio-economic class (rich vs. poor users) in the *Siwalik* region, Nepal. Results indicated that the wealth level of the users plays a key role in the amount of financial benefits generated from the use of PS: (1) users living near forests receive the highest economic benefits compared to those living long distances from the forest area. However the distribution of benefits differs according to management modality and socioeconomic status; (2) CF users, on average, receive higher economic benefits than CFM users; and (3) compared to poor households, rich households receive higher benefits. On average, a rich household adjacent to CF receives USD 1214/year while a poor household living in the same area receives almost half of that (USD 630/year). Similarly, a poor household living far from a forest area generates USD 189/year, slightly higher than that of a rich household in the same area (USD 109/year); and (4) an average CF user emits more carbon (7.4 tCO_2/HH/year) from the consumption of PS than an average CFM user (5 tCO_2/HH/year). Finally, we discuss the reasons behind these differences and draw policy implications for developing and refining constitutions and operational plans of forest user groups.

1. Background

Forest ecosystem services (hereafter FES) play a vital role in sustaining people's livelihoods, the environment, and the economy. These services are critically important in both developed and developing nations, but are more critical for resource-poor, rural people, particularly those in developing countries where dependency on these services is higher (Christie and Rayment, 2012; Bhatta et al., 2014; Paudyal et al., 2016, 2017). Recent statistics show that FES provide approximately 20 % of the income for rural households both through cash and by meeting subsistence needs (FAO, 2018). About 75 % of poor people in developing countries are heavily dependent on FES (FAO, 2018; Acharya et al., 2019a). However, despite their significant contribution to a large number of people, the actual contributions of FES to different types of forest users have not been fully evaluated (Daw et al., 2011; Lakerveld et al., 2015).

FES valuation research has proliferated at an exponential rate. Earlier studies primarily assessed how FES contribute to generating value or benefits for people's livelihoods (Ninan and Inoue, 2013), the environment, and the economy. These studies are however constrained by a primary focus on biophysical quantification through modelling and mapping (Baral et al., 2014; Verkerk et al., 2014; Akujärvi et al., 2016; Forsius et al., 2016; Langner et al., 2017), or purely aggregated monetary valuation (Maraseni et al., 2006; Kubiszewski et al., 2013; Parthum et al., 2017; Turpie et al., 2017; Verma et al., 2017). There exists little research that demonstrates how these contributions, for example the economic benefits of FES, are distributed among different sub-groups in a community-based forest management (CBFM) system. Some studies have called for urgent action to demonstrate the financial benefits of various sub-groups while performing FES valuation research

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(Vihervaara et al., 2010; Daw et al., 2011; Nieto-Romero et al., 2014; Fagerholm et al., 2016; Garrido, Elbakidze, et al. 2017; Chaudhary et al., 2018).

Some scholarly works have attempted to assess the economic contribution of FES. These studies have mostly concentrated on government-managed/public forests (de la Torre-Castro et al., 2017; Murali et al., 2017; Queiroz et al., 2017), private forests (Nordén et al., 2017), protected area systems (Cuni-Sanchez et al., 2016; Peh et al., 2016; Shoyama and Yamagata, 2016; Affek and Kowalska, 2017; Delgado-Aguilar et al., 2017; Mukul et al., 2017; Vauhkonen and Ruotsalainen, 2017), and community forests (Lakerveld et al., 2015; Paudyal et al., 2015; Bhandari et al., 2016). However, these studies have not comprehensively assessed the financial contribution of provisioning ecosystem services (PS) to different subgroups within the CBFM (Acharya et al., 2019b; Torkar and Krašovec, 2019).

Community-based forest management (CBFM) is a management model in which local people play a critical role in planning, decision-making, implementation, and benefit sharing. CBFM normally includes users living both near to and distant from forest areas and with different economic backgrounds (Rai et al., 2017; Bhattarai et al., 2018). The different groups have different needs and demands for different PS, while most studies have concentrated on aggregated values (Martín-López et al., 2012; Garrido et al., 2017a, 2017b). The users, who are the key stakeholders, resource managers and at the same time the victims of ecosystem degradation, need to understand the overall and specific use patterns of PS. Prior research has focused on carbon emissions from forest cover loss (Harris et al., 2012; Sharma et al., 2019), fuelwood consumption (Baral et al., 2019) and household emissions (Kenny and Gray, 2009; Qu et al., 2013). As differences in the use of PS among different users exist, the carbon emission patterns from the consumption of PS vary (Muhamad et al., 2014). However, no previous studies have investigated the carbon emission pattern resulting from the use of PS for different subgroups in the CBFM.

An understanding of the use patterns of different PS from forests, their financial contribution to the different users and carbon emission patterns from the consumption of PS can contribute in various ways. First, such study helps in designing appropriate policies, strategies and plans for resource use. Second, it creates a heightened awareness of the most economically important services to local people that can be helpful in improving livelihood of the forest dependent communities. Third, study findings help to refine and update constitutions and operational management plans of the CBFM units for more sustainable management of the forests. Finally, this study can contribute in refining the national accounting system of the forestry sector so that the contribution of forestry can be better visualised by the policymakers.

Using market price and substitute good price methods, this paper assesses how local users exploit financial benefits and emit carbon from the use of PS in two dominant community-based forest management systems (community forestry—CF, and collaborative forestry—CFM) based on proximity (nearby vs. distant users), socio-economic class (rich vs. poor users) in the *Siwalik* region, Nepal.

2. Methodology

2.1. Study area

This study was carried out in *Sarlahi* district, the central part of Province 2, 350 km southeast of the capital city of Nepal, Kathmandu. The district covers 125, 948 ha, of which 15.5 % is *Siwalik* and the rest is the *Bhawar* and the *Tarai* regions. The *Siwalik* region, is parallel to the Lesser Himalaya in the southern part of the Indian subcontinent (Sivakumar et al., 2010) and extends 2400 km across four countries *Pakistan, India, Nepal* and *Bhutan.* The study sites are located in part of the *Siwalik* region in the northern part of the study district. This district hosts both community and collaborative forests with nearby and distant users (Acharya et al., 2019a). The elevation of the district ranges from 60 m to 659 m (DDC, 2016) and resulting in diversity of climate, vegetation and land-use patterns (Singh, 2017; Acharya et al., 2019a). CF and CFM have been implemented in the district since the early 2000s with the support of the Biodiversity Sector Programme for *Siwalik* and Tarai (BISEP-ST), funded by the Government of The Netherlands.

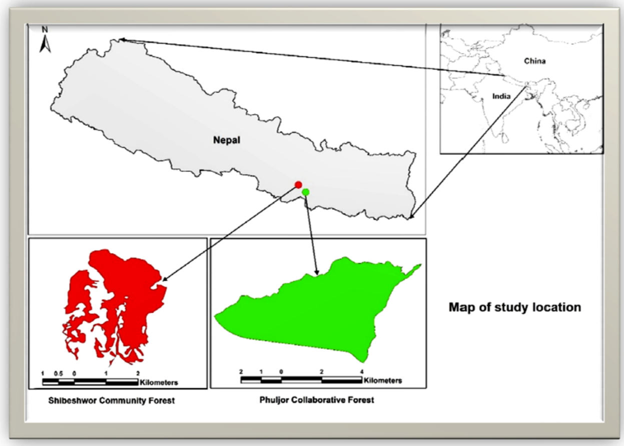

Fig. 1. Map of Siwalik region and study sites (*Shibeshwor* Community Forest left) and *Phuljor* Collaborative Forest (right) in Nepal.

We investigated two community-based forest management models, one CF and one CFM. These CBFM were *Shibeshwor* CF in the *Hariyon* municipality, and *Phuljor* CFM in the *Ishworpur* municipality covering a total area of 3130 ha of forest (CF: 711 ha, and CFM: 2419 ha) (see Fig. 1).

The CBFM group, comprising members from different socio-economic backgrounds, some living close to the forest area and some from distant villages, are responsible for the protection, management and use of these forests. The nearby users in both the CF and CFM live in the *Siwalik* foothills. Agriculture and animal husbandry are the mainstays of their livelihoods. The distant users live within 5 km of the CF in the semi-urban (small town) area and have multiple livelihood options including commercial agriculture, services and small shops. The nearby users in both CBFM utilize many forest services such as firewood, fodder, grazing, timber, poles, agriculture implements, medicinal and aromatic plants (MAPs), and wild foods for their daily uses. The distant users in the CFM live a fair distance away from the forest ($> 5-20$ km) and depend on agriculture and animal husbandry for their livelihoods (GON, 2016). The distant users receive services mainly in terms of firewood, timber, sand/boulders/gravel and poles. Table 1 provides socio-demographic information (gender, age, household size, education level, ethnic, religion, income, expenditure, the status of private forest and household dependency on CBFM) for the CBFM. The reasons for selecting these two CBFMs are: (1) they comprise both nearby and distant users with different degrees of intensity of use; (2) they have a long history of community participation in forest management; and (3) the areas are endowed with rich and productive ecosystems (DPR, 2014).

2.2. Valuation of ecosystem services

2.2.1. Prioritisation of provisioning ecosystem services (PS)

In general, *Siwalik* forests provide firewood, timber, grass, fodder, bedding material, medicinal plants, sand/stone/boulders, and grazing services (PCTMCDB, 2017). Through a rigorous consultation process involving eight different focus group discussions (FGD) which

Table 1
Sociodemographic information for the respondents.

Demographic features	CF Nearby		CF Distant		CFM Nearby		CFM Distant	
	Rich (n = 32)	Poor (n = 31)	Rich (n = 31)	Poor (n = 31)	Rich (n = 32)	Poor (n = 31)	Rich (n = 33)	Poor (n = 32)
Gender (Number)	F = 20 M = 12	F = 20 M = 11	F = 6 M = 25	F = 10 M = 21	F = 10 M = 22	F = 11 M = 20	F = 5 M = 28	F = 6 M = 26
Median age of the respondents range (years)	41 (19−75)	40 (18−80)	48 (24−79)	48.50 (21−74)	39 (22−68)	45 (20−75)	51 (20−84)	45 (25−77)
Average family size and standard error of mean	6.10 (0.46)	5.33 (0.37)	6.3 (0.5)	5.67 (0.41)	6.27 (0.40)	5.83 (0.53)	6.10 (0.46)	7.43 (0.55)
Education	I = 6 P = 6 S = 16 T = 4	I = 9 P = 12 S = 8 T = 2	I = 1 P = 4 S = 15 T = 11	I = 13 P = 5 S = 12 T = 1	I = 6 P = 9 S = 15 T = 2	I = 7 P = 12 S = 12 T = 0	I = 10 P = 5 S = 17 T = 1	I = 18 P = 7 S = 6 T = 1
Ethnic composition (Number)	UC = 4 LC = 28	UC = 2 LC = 29	UC = 24 LC = 7	UC = 8 LC = 23	UC = 14 LC = 18	UC = 7 LC = 24	UC = 28 LC = 5	UC = 17 LC = 15
Religion of Respondents	H = 24 B = 6	H = 24 B = 7	H = 31	H = 28 M = 3	H = 23 B = 7 M = 2	H = 21 B = 9 M = 1	H = 33	H = 32
Average Income/HHs (USD) (Standard Dev.)	3532 (± 2172)	1395 (± 794)	6515 (± 3767)	1421 (± 935)	4933 (± 2520)	1463 (± 708)	3684 (± 1785)	1671 (± 985)
Expenditure/HHs (USD)	2026	1091	6161	1302	2672	1319	2321	1470
% of private forests owners	66	50	40	37	28	16	64	41
%of dependency on CBFMs	56	46.28	6%	14	65	68	6	11

Data in parenthesis are standard deviation; Gender: M: Male, F: Female; Education level: I = Illiterate, P = Primary/lower secondary, S = High school educated, T = College & above; Ethnic composition: Upper Caste: Bahun/Kshetri/Dashanami/Madeshi, Lower caste: Janajati, Janajati/Madhesi, and Dalit; Religion: H = Hindu, B = Buddhists, M = Muslim.
Incomes are derived from agriculture, horticulture, livestock, daily wages, foreign employment, different types of salaries, small businesses, fisheries, NTFP/medicinal plants, and firewood collection.
1 USD = NPR 110.52.
Expenditure includes foodstuff, clothing, education, health, agriculture, purchasing land, livestock, paying interest.

considered each subgroup (modality: CF/CFM, economic class: rich/poor, spatial distance: nearby/distant), a total of 16 PS were identified (Acharya et al., 2019a). Their priorities differed according to management modality, spatial distance and economic class. However, four provisioning ecosystem services genetic resources, wild animals, thatching materials, and medicinal and aromatic plants (MAPs) were least important for all groups. This was verified through FGD and CBFM records, and therefore, these were not further considered in this study. Overall, the top ranking 11 PS for all sub-groups were firewood, fodder, timber, poles, grasses, grazing, sand, boulders and gravel, non-timber forest products (NTFPs) other than MAPs, and wild foods (see Acharya et al. (2019a) for details on the prioritisation of all PS).

2.2.2. Valuation of provisioning ecosystem services (PS)

Many researchers have estimated PS using the revealed price (RP) approach (Sumarga et al., 2015; Baral et al., 2016; Verma et al., 2017). The revealed price (RP) method estimates low value compared to actual market value if there is any policy distortion (Pagiola et al., 2004; Rasul et al., 2011). For example, the *Sal* timber (*Shorea robusta*) royalty to the CF users is fixed at USD 0.2 – 0.55/cft (Poor: USD 0.2/cft, rich: USD 0.55/cft), while *Sal* timber sells for USD 31.7–40.7/cft in the nearby market. Considering a similar market distortion situation in the study sites, we employed market prices and substitute goods prices for the various categories of prioritised PS, as detailed in Table 2.

Sampling techniques and data collection: A pilot survey was conducted with 20 randomly selected households in four villages drawn from nearby and distant users in both CBFM to determine a proportion (*p*) of householders who benefit from PS. The sample size was estimated, following Eq. 1 as suggested by (Köhl et al., 2006);

$$n = [\frac{1}{e^2}\left(p(1-p)U^2 1 - \frac{\alpha}{2}\right)] \tag{1}$$

where n is the estimated sample size, U is the value of normal random variable (1.96 for α = 0.05) and e, the allowable margin of error from this survey, held to be 5%. According to the formula developed by Köhl et al. (2006), 240 households (p = 80 %) were required for survey. Households in both CBFM are relatively homogenous in-terms of their demographic and socio-economic features. Being users of CBFM, all households are governed by the same Forest Act and Forest Regulations. Therefore, their forest use rights are more or less similar. In addition, we categorised the whole population into eight homogenous strata based on management modality (CF/CFM), economic class (rich/poor) and spatial distance (nearby/distant[1]) from the forests (Acharya et al., 2019a). Therefore, we argue that our sample size (253 households) truly represents the population.

The field data for the study were collected from July to October 2018. A 45-minute face-to-face interview with each household head was conducted in their house. The household questionnaire consisted of three sections. The first section focuses on general information of the household. The second section elicits about the basic household information such as gender, age, caste, religion, ethnicity, livestock, education, occupation, income and expenditure of the respondents while the third section records about quantity of PS used and sold and their market prices.

One-year data could be influenced by some local factors (such as flood, drought, earthquake) and therefore the distribution could be skewed. Therefore, we collected data for three years of use patterns of PS and then averaged these to provide more reliable use patterns of PS. Household data were independently verified with the executive members and minutes/records of users' committees and therefore the data are reliable.

Socioeconomic data were analysed using basic statistical procedures

[1] **Nearby/distant:** In collaborative forest management (CFM): Users living within 5 km from forests are considered nearby and beyond 5 km as distant users; in CF users living 3 km from forests are considered distant users. **Rich/Poor:** CBFM classifies users into four categories (Well-off, Medium, Poor and Very -poor). This study considers the first two as Rich and the other two as Poor.

Table 2
Methods used to estimate values of provisioning ecosystem services.

Category	Valuation method	Valuation procedure
Firewood	Market price	Average firewood quantity and benefits obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of firewood
Grazing	Market price	Average livestock unit raised by sample user households from CBFM area in the last three years multiplied by dependency ratio on forest forage and local market price of substitute goods or their equivalent
Fodder	Market price	Average fodder quantity and benefits obtained by sample user households from CBFM area in last three years multiplied by dependency weighting and local market price of fodder
Timber	Market price	Average timber quantity and benefits obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of timber
Grasses	Substitute goods price	Average quantity and benefits of grasses derived by sample user households from CBFM area in last three years multiplied by dependency weighting and local market price of substitute goods or their equivalent
Sand/boulder/gravel (SBG)	Market price	Average SBG quantity and benefits derived by sample user households from CBFM area in the last three years multiplied by dependency weighting and market price of SBG
Poles	Market price	Average quantity of poles and benefits obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of poles at local level
Bedding materials	Substitute goods price	Average quantity and benefits of bedding materials obtained by sample user households from CBFM area in last three years multiplied by dependency weighting and local market price of substitute goods or their equivalent
Agricultural implements	Market price	Average number and benefits of agricultural implements obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of agricultural implements at local level
NTFPs other than MAPs	Market price	Average NTFPs quantity and benefits obtained by sample user households from CBFM area in the last three years multiplied by dependency weighting and local market price of NTFPs at local level
Wild foods	Substitute goods price	Average quantity and benefits of wild foods obtained by sample user households from CBFM area in last three years multiplied by dependency weighting and local market price of substitute for wild goods or their equivalent

CBFM: Community-based forest management, NTFPs: Non-timber Forest Products, MAPs: Medicinal and Aromatic Plants.

and analysis of variance (ANOVA) to compare the means. Similarly, the total values of prioritised services (TPV_i) were computed using Eq. 2, following Sharma et al. (2015).

$$TPV_i = \sum_{i=1}^{n} (\%hhi*\text{HH}*NV_i) \quad (2)$$

Where i is a PS category, for example firewood, timber, fodder that could be 1–11, $\%hh_i$ is the percentage of households dependent on the ith PS (i.e dependency weightage). HH is the total number of households in the forest area; and NV_i is the average annual net benefits per user HH, which was calculated by subtracting the extraction and transportation cost of the services from their gross value in the local market. Household dependency and average household net benefits were obtained through the household survey (HHS) as discussed above. Table 2 above provides the details of the method used for the prioritised services.

2.3. Carbon emission from consumption of provisioning ecosystem services (PS)

Forest users harness economic benefits by consuming different provisioning services, but at the same time, while consuming these services they emit carbon into the atmosphere. In order to estimate this emission, we used the same household consumption data for all PS (except sand, boulders and gravel). These data were converted into biomass, carbon mass, and then converted into CO_2 emissions following the standard IPCC (2006) process and conversion factor (Eq. 3; (Pandey et al., 2014, 2016)). Please see Annex 3 for the biomass of all consumed PS.

$$\text{Carbon dioxide emission } (CO_2\text{e}) = \text{Total biomass of PS}*0.47\ (\text{carbon})*3.67\ (CO_2 \text{ equivalent}) \quad (3)$$

Harvested or consumed PS can store carbon for a number of years depending on their use and half-life period (Maraseni and Cockfield, 2011). For example, an item of wooded furniture or an electricity pole can store carbon for many years. However, in this analysis, we assumed that the harvested/consumed products emit carbon immediately into the atmosphere. This is a realistic assumption as about 90 % of the carbon emissions from PS is attributed to firewood, fodder, grasses, and grazing services.

In order to estimate the cost of carbon emissions, we used US dollar five per tonne carbon dioxide equivalent (USD 5/tCO_2e) following the World Bank Carbon Fund project in Nepal (GON, 2019).

3. Results

3.1. Economic valuation of PS

The overall annual values of 11 different PS harvested in both CBFM are summarised in Fig. 2. A household, on average, generated USD 231/year from these services. Among the PS, firewood constituted the highest financial benefits (USD 61/HH/year) followed by timber (USD 45/HH/year), and grazing services (USD 42/HH/year). Other PS such as agricultural implements (AI), NTFPs other than MAPs, and wild foods on average generated low financial values ranging from USD 2.0 to USD 1/HH/year. The utilisation patterns vary by management

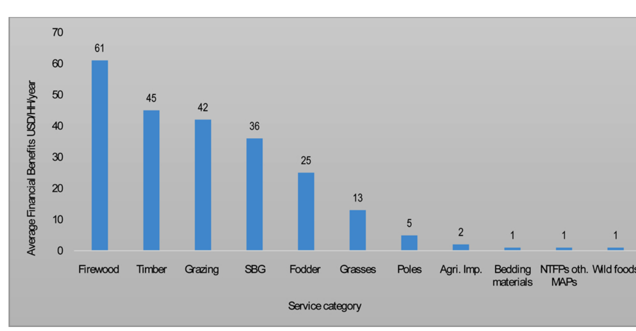

Fig. 2. Average value of different provisioning ecosystem services (USD/HH/year) (SBG: Sand/Boulder/Gravel; Agri. Imp.: Agricultural Implements).

Table 3
Average contribution of provisioning ecosystem services by relative wealth and distance from forest (in USD/HH/year).

Category	CF Nearby		CF Distant		CFM Nearby		CFM Distant	
	Rich (n = 32)	Poor (n = 31)	Rich (n = 31)	Poor (n = 31)	Rich (n = 32)	Poor (n = 31)	Rich (n = 33)	Poor (n = 32)
Firewood	150	136	25	82	161	158	5	14
Grazing	217.4	214.2	3	31	121	121	0	0
Fodder	170	131	4	41	76	63	0	0
Timber	499	20	40	0	140	40	40	0
Grasses	85	74	0	11	33	40	0	0
Sand/boulder/gravel	0	0	25	0	74	49	25	25
Poles	36	27	9	18	5	5	9	0
Bedding materials	43	22	1	5	2	2	0	0
Agricultural implements	4.26	3.75	1.95	0.5	4.4	9.7	0.1	0.1
NTFPs other than MAPs	7	2	1	0	1	0	1	1
Wild foods	1	1	0	0	1	1	0	0
Total (USD/HH/year)	1214	630	109	189	617	488	80	39

CF: Community Forest, CFM: Collaborative Forest Management, NTFPs: Non-timber Forest Products, MAPs: Medicinal and Aromatic Plants.

modality, users' socio-economic situation and proximity to forest area.

Among the management modalities, average benefits to the CF users are much higher than for CFM. For example CF users derive USD 402/HH/year from the use of PS, while CFM users generate almost half that (USD 227/HH/year) from provisioning ecosystem services. In the CF, wealthier users living near forests receive the highest financial benefits from all PS (USD 1214/HH/year) followed by poor people living in the same area (USD 630/HH/year) (see Table 3). The biggest difference is in the values derived from timber, but the rich users derive greater benefits in all categories. People living farther from a CF area show the opposite trend. The distant poor users obtain higher financial benefits (USD 189/HH/year) compared to the distant rich users (USD 109/HH/year).

Similarly, the difference between net benefits for the nearby rich and nearby poor is much less for CFM than for CF. The distant rich do, however obtain more benefits from CFM, which is the reverse of the situation with CF. Wealthier users at farther distance receive higher benefits from the PS, (USD 80/HH/year) compared to poor users (Table 3).

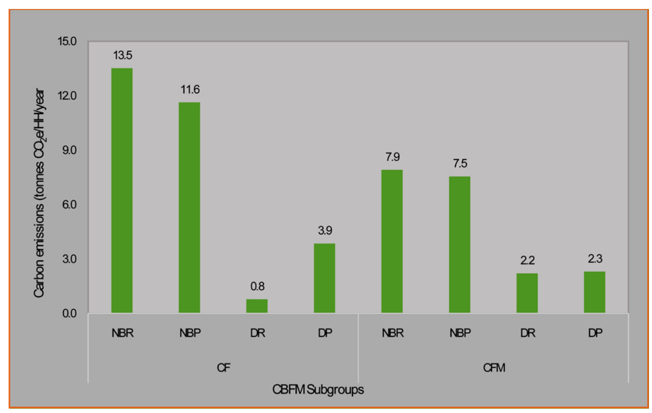

Fig. 3. Household carbon emissions (tonnes CO_2 /HH/year) from consumption of 10 different provisioning ecosystem services, CF: Community Forest, CFM: Collaborative Forest Management and CBFM: Community Based Forest Management Systems, NBR: Nearby Rich, NBP: Nearby Poor, DR: Distant Rich, DP: Distant Poor.

3.2. Carbon emission from the consumption of provisioning services

In our study, an average household, regardless of their modality and spatial distribution, emits 6.2 tCO_2 per year from the consumption of all 10 different PS (Table 4 and Fig. 3). As expected, the emission pattern from the consumption of all PS varies by CBFM modality, socio-economic status and spatial distance from forests.

A household in CF emits one and half times higher carbon (7.5 tCO_2/HH/year) than a household in CFM (5.0 tCO_2/HH/year) from the consumption of PS. Similarly, a rich household living near a CF area

Table 4
Household carbon emissions (kg CO_2/HH/year) from consumption of 10 different provisioning ecosystem services.

Category	CF Nearby		CF Distant		CFM Nearby		CFM Distant	
	Rich (n = 32)	Poor (n = 31)	Rich (n = 31)	Poor (n = 31)	Rich (n = 32)	Poor (n = 31)	Rich (n = 33)	Poor (n = 32)
Firewood	2307	2097	378	1258	2475	2433	84	629
Fodder	2785	2685	84	839	1552	1300	965	755
Timber	1074	43	86	0	301	86	86	0
Grazing	2396	2685	101	805	1732	1920	0	0
Grasses	2517	2727	0	420	1217	1468	881	881
Poles	347	258	86	172	43	43	86	0
Ag. Imp.	195	191	7	123	485	230	0	0
NTFPs other than MAPs	15	3	2	0	2	0	2	2
Bedding materials	1879	940	34	235	101	67	104	34
Wild foods	3	2	0	0	3	2	0	0
Total (kg CO_2/HH/year)	13,515	11,630	776	3852	7909	7549	2207	2300

CF: Community Forest, CFM: Collaborative Forest Management, NTFPs: Non-timber Forest Products, MAPs: Medicinal and Aromatic Plants; Ag. Imp: Agricultural implements.

releases the highest amount of carbon (13.52 tCO_2/year) followed by a poor household living in the same area (11.63 tCO_2/HH/year). In contrast, a rich household living a greater distance from a forest area releases the least (< 1 tCO_2/HH/year). In the case of CFM, the trend is similar to that of CF although the emission rate for all households in a CFM is lower in both rich and poor categories (Rich: 8 tCO_2/HH/year and poor: 7.5 tCO_2/HH/year).

4. Discussion

4.1. Economic contribution of PS in different sub-groups

Our results suggest that PS from CBFM of *Siwalik* region contributed significant financial benefits to different sub-groups. Results revealed that firewood contributed the highest financial benefits in both types of CBFM. The results reflect a trend in developing countries where fuelwood is the prime source of energy irrespective of household well-being. As substantiated by FAO (2018) about 2.4 billion people globally use fuelwood for cooking and heating purposes, similar to the results of our study. Other studies also report similar findings for fuelwood use (Angelsen et al., 2014; Ahammad et al., 2019).

None of the previous studies performed disaggregated assessments of PS considering rich/poor and nearby/distant users in CBFM (CF/CFM). Therefore, we compare our overall results with aggregated results from other global research. For instance, our results (USD 231/HH/year) are similar to those reported by Sumarga et al. (2015) (P = USD 224) in a study conducted in Central Kalimantan, Indonesia. Some studies estimated lower economic values ranging from USD 31–162 (Kunwar et al., 2010; Basnyat et al., 2012; Lakerveld et al., 2015; Mukul et al., 2016; Chauhan et al., 2017; Rai et al., 2017), while other studies estimated higher financial returns ranging from USD 359 to USD 6045 (Sapkota and Odén, 2008; Pant et al., 2012; Schaafsma et al., 2014; Mutoko et al., 2015; Ninan and Kontoleon, 2016; Tilahun et al., 2016; Kibria et al., 2017; Chaudhary et al., 2018) from the PS.

Despite the higher priority and the financial contribution of timber to the national economy, this study found that timber contributed the second-highest financial benefits only for a small section of the sub-groups. For example, the wealthier users living near a CF derived an average income of USD 499 from timber, which is almost 15 % of their total income (annual income USD 3532), whereas the poor households living in the same area derived USD 20/HH/year that is 1.5 % of their annual income (USD1395). Several studies globally recognised a wide range of financial benefits deriving from timber services. Other global studies found similarly low and high economic benefits from timber services. For instance, Sharma et al. (2015) reported only USD 5.4/HH/year from timber in the *Koshi Tappu* area of Nepal, which is significantly lower than our findings. Other studies reported similar findings to our study, of USD 56–69/HH/year (Pant et al., 2012; Sumarga et al., 2015; Tilahun et al., 2016), while some studies estimated a higher financial benefit from timber services ranging from USD 85 to USD 6045/HH/year (Adekola et al., 2015; Chauhan et al., 2017; Rai et al., 2017).

Our study suggests that the financial benefits of PS vary based on management modality, socio-economic status and spatial distance from a forest area. Average benefit derived from the use of PS to CF is higher than for CFM. This could be ascribed to the differences in access/control over resources, use/management rights, forest-HH ratio, benefit sharing arrangements, and distance from forest area (Jhaveri and Adhikari, 2015; Acharya et al., 2019a). For example, forest users in a CF can access and harvest PS throughout the year as per their management plan, while CFM users can only access these services during specified times within certain months. Similarly, there is a huge difference in forest-HH ratio among these two management modalities. In the CF, forest-HH ratio is almost 0.99 (GON, 2006-, 2016) whereas the ratio in the CFM is 0.087 (GON, 2016). High forest-HH ratio means that there will be potential for higher forest service extraction, collection and use which in -turn derives high financial returns. Furthermore, the benefit sharing arrangements also differ between these two modalities. For instance, all incomes of the CF from all PS go directly to local users except for a few commercial transactions of *Acacia catechu* and *Shorea robusta*; in contrast, in the case of CFM, 50 % of timber income goes to national and local government (Acharya et al., 2019a).

Similarly, rich households living near a CF area receive the highest PS (USD 1214/year) followed by poor household living in the same area (USD 630/year). We observed significant differences in the financial benefits among sub-groups living in the same area, mainly due to their differences in timber consumption. Rich households living near forest areas utilised more timber in comparison to poor households, mainly due to adverse land tenure problems experienced by poor household and their housing costs and requirements. More than 80 % of poor households do not hold a secure land ownership certificate or an official land entitlement in *Sarlahi* district including in the study site (DPR, 2014; Singh, 2017). Moreover, as noted in Table 1, average household income of poor households, regardless of forest management modality and distance from forests, is less than half that of rich households. Therefore, poor households cannot build permanent and multi-storeyed houses. In contrast, rich users have secure land tenure and can easily build multi-storeyed houses and therefore consume more timber.

4.2. Carbon emission from consumption of PS

In our study area, an average household emits 6.2 tCO_2e annually from the use of all 10 different PS. As expected, the users from CF emit higher amounts of CO_2e compared to users from CFM, as the community forestry rules and regulations allow them to consume more forest products compared to the users of CFM. Most of the carbon emissions of all subgroups come from the consumption the four PS, namely, firewood, fodder, grasses, and grazing services. Because of their heavy daily use, these services account for higher amounts of biomass being used, resulting in higher carbon emissions from their consumption. To our knowledge, no previous study has considered the disaggregated emissions from the use of PS in the CBFM. That is why no comparable findings/results are available for evaluation and discussion.

In total, consumption of these four services constituted almost 90 % of total emissions from PS. If these services could be completely replaced or substituted by other means, up to USD 27.9/HH/year (90 % of 6.2 tCO_2@USD 5/ tCO_2) could be earned at the current carbon price of the World Bank (GON, 2019). However, the carbon emissions vary by the wealth class and distance from the forest area. Users living near forest areas emit the highest amount of CO_2, compared to users living farther from a forest. Similarly, in CF, rich users living adjacent to a forest emit almost 14 tCO_2/HH/year while rich users living far from a forest emit 1 tCO_2/HH/year. These two user types can earn up to USD 63/HH/year and USD 4.5/HH/year respectively, because of not consuming the four main PS. However, producing less emission from distant forests users does not necessarily mean that they are environmentally friendly global citizens. They might have been meeting their consumption demands from some other private sources.

4.3. Policy implications of the study

The results of this study could be useful in guiding the future of the CBFM system considering the complex socioeconomic situation of the landscape promoting multifunctional *Siwalik* landscapes. Since all users in the CF are equally responsible for protection, management and use of the forests' ES, their contributions are not equally reflected in the distribution of benefits from these services to different subgroups due to the unequal use of timber services. One can argue that there is a different level of levies charged for different categories of users (i.e. for different species of timber: rich USD 0.15 – USD 0.55/cft, poor: 0.1 − 0.25/cft). Despite the difference in the levels of levies charged, this might not be sufficient to sustain the forest ecosystem services in the long run. Therefore, it is imperative to incorporate equity issues based on the contribution to ecosystem services management in the forests.

Likewise, the Ministry of Forests and Environment (MOFE) is currently focusing on timber management through Scientific Forest Management (Government of Nepal 2016). However, the current valuation exercise revealed that services derived from timber do not generate high financial returns for many subgroups in the studied CBFM. Therefore, it is essential to revise the CBFM management plan considering the needs, financial returns and aspirations of all subgroups, and to focus on fuelwood, fodder, grasses and grazing services demand. For this, CBFM can: i) promote cultivation of fuelwood species in the CBFM and other public lands; ii) make a plan focusing on fuelwood enrichment plantations in the forest area; iii) promote agroforestry practices through extension services; iv) reduce, replace and switch over the fuelwood demand through supplying improved stoves, and instituting biogas and hydroelectricity programmes as suggested by the ERPD or the President Chure Terai Madesh Conservation and Development Board (PCTMCDB, 2017; GON, 2019).

Moreover, reducing emissions from CBFM remains a key concern in Nepal. MOFE has aimed to reduce, replace and switch over the demand for these services through policies, strategies and programmes (MFSC, 2015, 2016; GON, 2019). For instance, the REDD Implementation Centre (REDDIC) under the Forest Carbon Partnership Facility (FCPF) is currently implementing an Emissions Reduction Programme (ERP) in 13 Western Terai Districts. The programme's aim is to reduce the total 35.6 $MtCO_2e$ through seven different strategic interventions. Out of these, three interventions first, improve management practices of existing CBFM, second expanding access to alternative energy with biogas, third, through supply of improved stoves are planned to reduce 21.6 million tonnes carbon dioxide equivalent ($MtCO_2e$) in districts adjacent the study sites (Acharya et al., 2015; GON, 2019). Similarly, the President Chure-Tarai-Madhesh Conservation and Development Programme (PCTMCDB) has proposed i) promotion of private plantations on private and public lands; ii) promotion of alternative energy through biogas, solar and micro-hydro; and iii) the extension of access to national hydro-electricity (PCTMCDB, 2017). Recently, the Nepal Electricity Authority requested the public to use hydroelectricity instead of other types of fuel for cooking purposes. These activities (i-iii) could be helpful in reducing carbon emissions resulting from the burning of fuelwood. Moreover, PCTMCDB has also planned: i) to control or manage grazing in the CBFM; and ii) to promote commercial animal husbandry (PCTMCDB, 2017). These activities can be promoted through planting multipurpose indigenous fodder species such as Badahar (*Artocarpus lakoocha*), Tanki (*Bauhunia purpurea*), Koiralo (*Bauhinia variegata*) and some exotic leguminous species such as Bhatmase (*Flemingia congesta Roxb*.), and Gliricidia (*Gliricidia sepium*). This could be a helpful strategy for reducing carbon emissions from the consumption of fodder, grazing and grasses in the CBFM.

5. Conclusion

This study estimated the financial benefits accruing from the prioritised provisioning ecosystem services (PS) in the *Siwalik* landscape of Nepal for different subgroups in two dominant community-based forest management systems (CBFMS). The findings reveal that a household, on average, receives the equivalent of USD 231/year from 11 different provisioning ecosystem services, generating a total of USD 5.30 million by managing 3130 ha of forests. Community Forestry (CF) users on average generate the highest financial returns compared to collaborative forestry (CFM) users, mainly due to differences in the level of access, rights, forest-household ratio, benefit sharing arrangements and distance from a forest area. Irrespective of the management modality, forest users living near the forests accrue the highest financial benefits compared to those living more distant from a forest. This difference can be mainly attributed to high amount of firewood, grazing, timber and fodder used.

Consumption of 10 PS accounts for an average of 6.2 tCO_2 emissions per household per year. Average CF users emit about 1.5 times more carbon than CFM users. About 90 % of carbon emissions is attributed to four PS, namely, firewood, fodder, grasses, and grazing services. Therefore, fulfilng the demand of these four services by other means could be instrumental in reducing carbon emissions from CBFMS.

The findings also suggest that there is some disparity in financial benefits and carbon emissions among the different subgroups. As time and effort expended by all these sub-groups in the conservation and management of forests are almost similar, this disparity can lead to disputes, thereby giving rise to unsustainability in forest management. Various sub-groups in the CF are charged levies with different rates for goods and services, but these differential rates cannot adequately sustain the forest ecosystem services. Therefore, incorporating the carbon issue and forest management costs of different subgroups in designing levies could generate more sustainable environmental and financial outcomes.

Author contributions

Author Contributions: R.P.A., conceptualisation and writing; T.N.M., overall guidance and framing the concept; G.C., overall guidance and framing the concept.

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Declaration of Competing Interest

The authors declare no conflicts of interest.

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Appendix A

Total households and sample households in the studied CBFM

CBFM Types	Rural/Municipality	Total HH in the CBFM				Sampled HH			
		Nearby		Distant		Nearby		Distant	
		Rich	Poor	Rich	Poor	Rich	Poor	Rich	Poor
CF	1	120	114	249	236	32	30	31	31
CFM	21	4794	4699	9322	9138	32	31	33	32

CF: Community Forest, CFM: Collaborative Forest Management, HH: Households

Appendix B

Questionnaire for household survey

A General information:	
CBFM name:	Code:
Full name of Respondent:	Date: / /2018
HH GPS Coordinates: Latitude:	Longitude: HH Number:
Address:	Sex/Age:
Family size:	Education (No of years):

(Please tick (√) answer or write the answer in the given field)

B.	Socio-economic information						
1.1	Name of household head			Male			Female
1.2	Name of district:						
1.3	Name of VDC			Ward No.			
1.5	Name of settlement/Tole:						
1.6	Age:						
1.7	Sex:	Male		Female			Other
1.8	Marital status:	Married	Unmarried	Separated	Widowed		Other
1.9	Caste/Ethnicity:		Brahmin/Chhetri /Dashnami	Janajati	Dalit		Other
1.10	Religion:	Hindu	Buddhist	Muslim	Christian		Other
1.11	Details of family members:			HH size:			
	Name	Age*	Sex	Education*	Occupation		Relation with HH head
1							
2							
3							
	Please add						
	* Illiterate = 1, Literate but not school educated = 2, Primary/lower secondary = 3, High school educated = 4, College & above = 5						
	* Child < 5 year = 1, Young 6 − 14 = 2, Adult 16 − 59 = 3, Old 60-above = 4						
1.12	Who is mostly involved in economic decisions in your house?			Female		Male	Both
1.13	Are female members of your household represented in groups/organization?					Yes	No
1.14	Sources of income and expenditure in the family						
	Sources of Income			Expenditure			
	Sources		Amount (NRs)	Items		Amount (NRs)	
	Ag product sell			Food			
	Horti. product sell			Clothing			
	Livestock rearing			Education			
	Other animal products			Health			
	Daily labour			Agriculture purpose			
	Remittance			Festivals			
	Salary (private/govt/pension/social grants			Land purposes			
	Own business			Purchase of livestock			
	Fishing			Buying other physical assets			
	Selling of NTFPs/MAPs			Setting of own business			
	Selling firewood			Interest paid			
	Others specify			Others (specify)			
C.1	**Information related to provisioning services**						
1.15	**Do you have private forests? If yes:**			**Yes**	**No**		
	How many trees/ha?						
	What percentage of your forest product demand is filled by your own private forests?						
Are you or your family members involved in forest products or services collection from CF? If Yes? Please answer 1.15.							
1.16	Which of the following services do you receive from forests?						

S.N	Sources	Amount (in local unit)/year (average of last 3 years)	How much of that is sold/ year (average of last 3 years)	Average local market price (average of last 3 years)	If sold, where and to whom you sold these items.
1	Timber (cft)				
2	Poles (No)				
3	Firewood (*Bhari*)				
4	Fodder (*Bhari*)				
5	Thatching materials (*Bhari*)				
6	Grasses (*Bhari*)				
7	Bedding materials (*Bhari*)				
8	Thatching materials (*Bhari*)				
9	Leaf litter (*Bhari*)				
10	Agricultural implements (No)				
11	Medicinal and aromatic plants -MAPs (kg)				
12	NTFPs other than MAPs (kg)				
14	Sand boulders gravel (truck loads)				
15	Wild foods (kg)				
16	Wild animals (kg)				
17.	Others (specify)				

C.2 Information related to grazing animals

1.17 Are you or your family members do take your animals in forests? If Yes, please provide these information?

SN	Animals	In last 3 years						
		No	Total feed demand (*Bhari*)	Price/*Bhari at local market*	% from CF	% from Private	% buy from other source	Grain and others %
1	Cow							
2	Ox							
3	Male buffalo							
4	Female buffalo							
5	Goat							
6	Horse/donkey							
7	Sheep							
8	Pig							
9	Others specify							

Thank you very much for your response and time!!!!

Appendix C

Table A1

Table A1
Procedure of Conversion of harvested provisioning ES into dry biomass (in kg).

Category	Local unit	Conversion	Biomass conversion procedure	Estimation of carbon	Conversion in CO_2 equivalent
Firewood	*Bhari*	*kg*	*Bhari* is converted into biomass multiplied by 25.	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Grazing	*Bhari*	*kg*	First total grasses required for each category of livestock calculated in *Bhari*. Then dependency ratio of forage on CBFM was calculated. The forage (Bhari) is converted to biomass multiplied by 20	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Fodder	***Bhari***	*kg*	Average of fodder quantity harvested by sample user households from CBFM area in last three years multiplied by 20	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Timber	Cubic feet	*kg*	Average timber quantity obtained by sample user households from CBFM area in the last three years multiplied by 25.6	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Grasses	*Bhari*	*kg*	Average quantity of grasses harvested by sample user households from CBFM area in last three years multiplied by 20	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Poles	No	*kg*	Average quantity of poles harvested by sample user households from CBFM area in the last three years multiplied by 25.6	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Bedding materials	*Bhari*	*kg*	Average quantity of bedding materials collected by sample user households from CBFM area in last three years multiplied by 20	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Agriculture implements	No	*kg*	Average number and benefits of agriculture implements derived by sample user households from CBFM area in the last three years multiplied by weights of each of the agriculture implements	Biomass multiplied by 0.47	Carbon multiplied by 3.67
NTFPs other than MAPs	kg	*kg*	Average NTFP quantity obtained by sample user households from CBFM area in the last three years	Biomass multiplied by 0.47	Carbon multiplied by 3.67
Wild foods	kg	*kg*	Average quantity of wild foods obtained by sample user households from CBFM area in last three years	Biomass multiplied by 0.47	Carbon multiplied by 3.67

Appendix D. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104647.

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5.2 Estimating the willingness to pay for regulating and cultural ecosystem services from forested Siwalik landscape: Perspectives of the disaggregated users.

Foreword:

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This section of Chapter five provides an estimation of how forest users perceive the benefits from particular community-based forest management in developing countries. Since forest ecosystem services contribute to sustaining people's living, the national economy and the global environment, there is little research on the distributional issues of willingness to pay (WTP) of many high-priority regulating and cultural services such as water quality improvement (WQI), flood reduction (FR), or bequest and aesthetic values among different forest user subgroups. Recognizing the contribution of these invisible forest ecosystem services, we examine assess two prime community-based forest management systems (community forestry—CF and collaborative forestry—CFM) in the *Siwalik* landscape, Nepal, and estimate how forest users derive economic benefits from these invisible services based on socio-economic status (rich vs. poor users), proximity (nearby vs. distant), and forest management modalities (CF vs. CFM). The contingent valuation of 253 households reveal that socio-economic status of forest users and spatial distant to forest area play vital roles for offering the willingness to pay for these invisible services. The statistical analysis of generalised linear regression model indicates that willingness to pay differs in-terms of payment options (i.e. cash and labour). In general, economic status, distance from forests and income level of the respondent in cash and economic status and distance from forests in labour format significantly influence the willingness to pay for these services. Irrespective of the management modality, rich users usually offered a high willingness to pay for all services. Finally, potential reasons behind the differences in willingness to pay for these invisible services are discussed.

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RESEARCH PAPER

Estimating the willingness to pay for regulating and cultural ecosystem services from forested *Siwalik* landscapes: perspectives of disaggregated users

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Abstract

Key message **We assessed forest users' willingness to pay (WTP) for regulating and cultural forest services based on their socio-economic status (rich vs. poor), proximity to forests (nearby vs. distant), and forest management modalities (community forestry vs. collaborative forest management). As expected, a huge variation was found in WTP among these sub-groups. The wealthier households (HH) preferred 'cash' whereas poor HHs preferred 'labour' as a payment option.**

• ***Context*** Forest's ecosystem services (FES) research have largely concentrated on aggregated economic valuation, while minimal consideration has been paid to distributional issues of willingness to pay (WTP) of many regulating and cultural services such as water quality improvement (WQI), flood control (FC), and bequest and aesthetic values.

• ***Aims*** We assessed WTP of high-priority FES to the various sub-groups (nearby/distant, rich/poor and community/collaborative forest users) and explored the preferred payment options among the sub-groups in the Siwalik landscape of Nepal.

• ***Methods*** We carried out contingent valuation survey of 253 households (ranging from 31 to 33 households from each of the sub-groups). We performed the generalised linear mixed model (GLMM) to analyse the data in RStudio.

• ***Results*** Spatial distance and wealth levels of the respondents play a crucial role in WTP of FES. GLMM analysis indicated that WTP of non-marketed FES differed in terms of cash and labour format. Generally, the WTP is higher in wealthier sub-groups as a cash option. WTP in-terms of labour is a better option for poor HH.

• ***Conclusion*** Disaggregated WTP should be considered while designing future forest management interventions.

Keywords Valuation · Economic contribution · Flood control · Water quality improvement · Bequest value · Aesthetic value

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Contributions of the co-authors RPA, conceptualization, design, fieldwork, analysis and writing; TNM, overall guidance and framing the concept; GC, overall guidance and framing the concept.

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1 Introduction

1.1 Background of the study

Forest ecosystem services (FES) play critical roles in people's daily lives, their environments and national income. Forest ecosystem services contribute to livelihoods in both high-income and low-income countries, although the contributions from the services often vary widely. The contribution to resource-poor rural people, particularly those in low-income countries, is critically important (Christie and Rayment 2012; Bhatta et al. 2014), as about 75% of poor people in low-income countries are primarily dependent on forest ecosystem services. Recent statistics show that forest ecosystems provide approximately 20% of the income for rural households in low-income countries, both through cash and by meeting subsistence needs (FAO 2018). However,

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despite the significant contribution made by the ecosystem to the population, the actual contributions of forest ecosystem services to different categories of forest users have not been assessed adequately.

While research on the valuation of forest ecosystem services has increased at an exponential rate, most of these studies are constrained by their disproportionate focus on aggregated economic valuation such as biophysical quantification through modelling and mapping (Verkerk et al. 2014; Akujärvi et al. 2016; Forsius et al. 2016; Langner et al. 2017) or purely aggregated monetary valuation of the FES (Kubiszewski et al. 2013; Parthum et al. 2017; Turpie et al. 2017; Verma et al. 2017). There exists little research that demonstrates how these contributions, for example the economic benefits of forest ecosystem services, are distributed among different sub-groups in community forest-based ecosystems, although some studies have called for urgent action to demonstrate the economic values of various sub-groups while performing forest-based ecosystem services valuation research (Vihervaara et al. 2010; Daw et al. 2011; Nieto-Romero et al. 2014; Fagerholm et al. 2016; Garrido et al. 2017; Chaudhary et al. 2018; Acharya et al. 2020b).

Some researchers have attempted to fill this gap, but they have mostly focused on forests on government-managed/public land (de la Torre-Castro et al. 2017; Murali et al. 2017; Queiroz et al. 2017), private forests (Nordén et al. 2017), protected area systems (Cuni-Sanchez et al. 2016; Peh et al. 2016; Shoyama and Yamagata 2016; Affek and Kowalska 2017; Delgado-Aguilar et al. 2017; Vauhkonen and Ruotsalainen 2017; Adhikari et al. 2018), and community forests (Lakerveld et al. 2015; Paudyal et al. 2015; Bhandari et al. 2016). Similarly, researchers have explored regulating services including insurance values of forests and wetlands (Brander et al. 2013; Ninan and Inoue 2013; Acharya et al. 2019b; Dallimer et al. 2020) or analysed various functions, values, demand and supply and management implications of forests (Olschewski 2013; Müller et al. 2020; Unterberger and Olschewski 2021). However, these studies have not comprehensively assessed the economic contribution of the forest ecosystem services or compared the different community-based management modalities among groups with different socio-economic rankings when focusing on regulating and cultural services. Community-based forest management (CBFM) is a management model which places people at the forefront of planning, decision-making, implementation and benefit-sharing (Maraseni et al. 2005). This model is applied to around 511 million hectares of global forests (almost 15.5% of global forests) and has been gaining popularity in recent years. The adoption of these systems is an increasing trend in developing countries (2006, 22%; 2010, 27%; 2015: > 30%) (Maraseni et al. 2014, 2019; Paudyal et al. 2017). This model comprises different users living close to and far away from a forest area and includes people of different economic and social backgrounds (Rai et al. 2017). Such differences imply diverse needs and demands on forest ecosystem services. Therefore, the benefits derived from these regulating and cultural forest ecosystem services vary significantly based on their livelihood outcomes.

The users, who are not only the key stakeholders and the real managers but also the victims of ecosystem degradation, need to understand the real economic contribution of regulating and cultural forest services for effective implementation of policy and management plans (Muhamad et al. 2014). Knowing local people's needs, their demands and the distribution patterns of economic benefits to different segments of the societies is imperative and can create threefold benefits. First, such knowledge can create awareness among different sub-groups at the local level of the real economic contributions of critical but non-marketed forest ecosystem services. Second, the monetary valuation of those forest ecosystem services in a disaggregated manner will help policymakers and managers understand the needs and inspirations of the different sub-groups so that they can formulate practical and applicable forest ecosystem management plans. This also helps to prioritize the use of scarce capital for the effective implementation of forest management plans. Third, the global community will gain insights into how the economic contribution of forest ecosystem services varies among the sub-groups involved in community-based forest management, which has become a world-renowned model of forest management.

In this paper, we quantify the economic contribution of high-priority regulating (flood control and water quality improvement) and cultural (bequest and aesthetic value) forest ecosystem services disaggregated according to proximity (nearby/distant forest users), economic status (rich/poor users) and forest management modalities (community forestry (CF)/collaborative forestry management (CFM)) in the fragile mountain area of the *Siwalik* of Nepal.

2 Methodology

2.1 Description of study sites

This study was carried out in *Sarlahi*, the central *Terai* district of the *Chure-Tarai* Landscape, situated 330 km southeast from Kathmandu, Nepal. The total area of the district is 125,948 ha, of which 15.5% consists of the *Siwalik* mountains and the remainder comprises, the *Bhawar* and *Tarai* regions. The *Siwalik* region lies parallel to the Lesser Himalayas in the southern part of the Indian sub-continent (Sivakumar et al. 2010) and extends 2400 km across four countries, Pakistan, India, Nepal and Bhutan. Our study sites are located in part of the *Siwalik* region in the northern part of the study district.

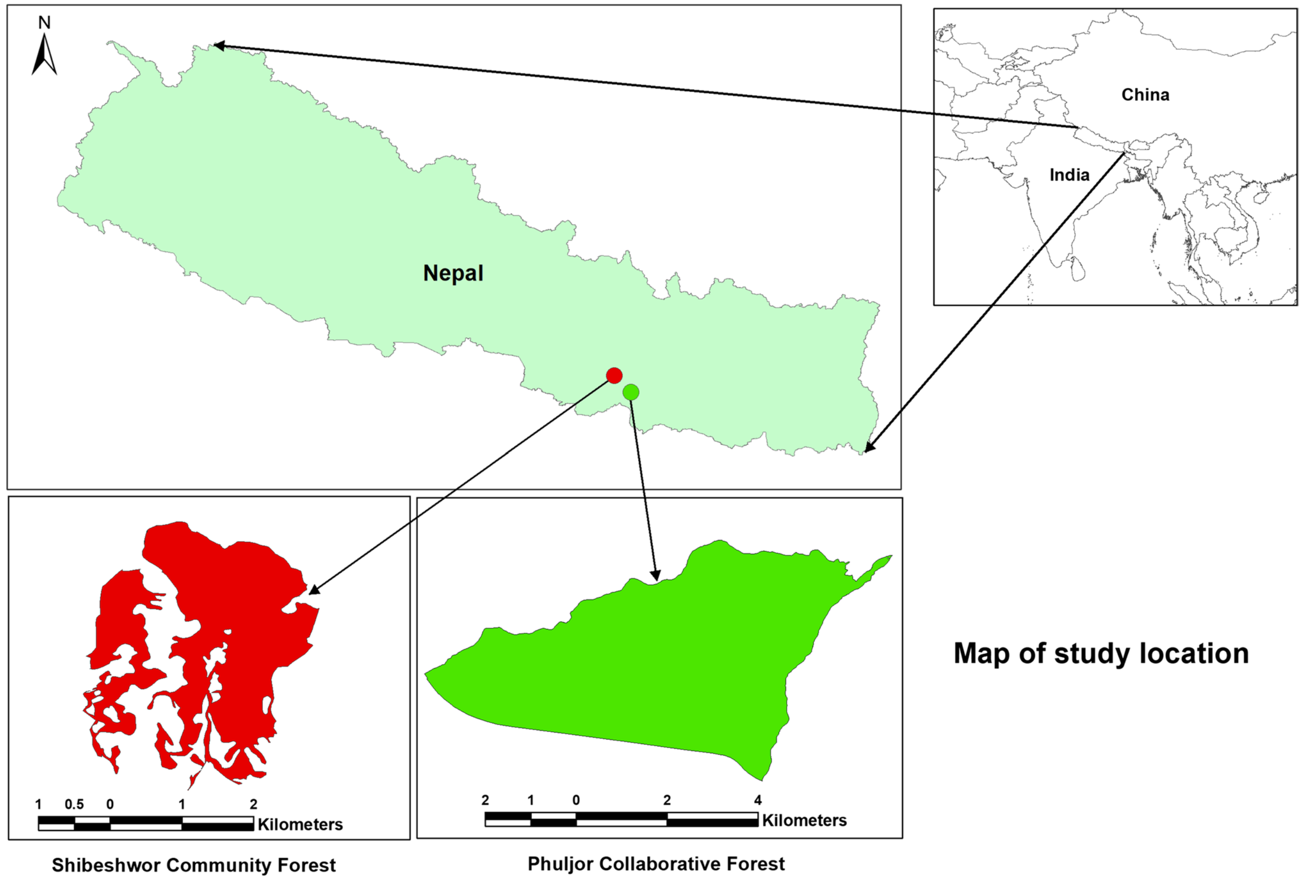


Fig. 1 Location map of study sites (Shibeshwor CF to the left and Phuljor CFM to the right) in Nepal

This area displays multiple land uses. Cultivated land constitutes the highest percentage (66.57%) of land use, followed by forests (23.31%) and sand/gravel extraction (4.31%) (DFO 2017). Forests in the area are managed through both community (45%) and collaborative forest management (18%). Due to the high elevation range, from 60 m above sea level (masl) to 659 masl (DDC 2016), the region is diverse in climate, vegetation and land use patterns (DFO 2017; Singh 2017).

We chose two community-based forest management units (one CF and one CFM) for the case study. *Shibeshwor* community forest is located in the *Hariyon* municipality and *Phuljor* CFM is situated in the *Ishworpur* municipality, covering 3121 hectares of forest area (*Shibeshwor*: 711 hectares, and *Phuljor*: 2419 hectares) (see Fig. 1). Sal (*Shorea robusta*) is the dominant tree species in community-based forest management and comprises almost 55% of crown cover in both units.

Members of the community-based forest management groups, which are made up of people from different socioeconomic backgrounds, are responsible for the protection, management and use of these forests. Those users living nearby both the community forests and collaborative forest management areas live in the *Siwalik* foothills. They rely mainly on agriculture and animal husbandry for their livelihoods. Forest users who are more distant from the community forest live within 5 km of the forests in a semi-urban (small town) area and are engaged in multiple occupations including commercial agriculture, services and small shops. The nearby users in both community-based forest management units take advantage of the many services provided by the forests such as firewood, fodder, grazing, timber, poles, agriculture implements, medicinal and aromatic plants (MAPs), and wild foods for their daily use. Similarly, they benefit from regulating services such as flood control (FC), water quality improvement (WQI) and cultural services, namely the aesthetic and bequest values of the forests. The distant users of the collaborative forest live further away from the forest (> 5–20 km) (Bhattarai et al. 2018; Acharya et al. 2020a) and depend on agriculture and animal husbandry for their livelihoods (GON 2016). These distant users receive services mainly in terms of firewood, timber, sand/boulders/gravel, and poles as provisioning services, and also derive benefits from regulating and cultural services. We selected these two community-based forest management areas for the following reasons: (1) they comprise both nearby and distant users with different degrees of intensity of both direct and indirect use of the forests' ecosystem services; (2) users have a long history of public contribution to forest protection, management and utilization; (3) the areas comprise naturally rich and productive ecosystems; and (4) the landscape faces severe soil erosion and flooding (DPR 2014; PCTMCDB 2017).

2.2 Data and methods

Many methods have been used to estimate monetary values of regulating and cultural forest services, which include revealed price (e.g. revealed price, travel cost and the production approach), stated preference (e.g. contingent valuation method (CVM)) and a cost-based approach (replacement or avoided) (Pagiola et al. 2004; Farber et al. 2006; Christie et al. 2012). Contingent valuation methods can (in principle) estimate both use and passive-use values and can be employed to estimate the non-marketed ecosystem services, those are not traded in the markets (Bateman and Turner 1992; Segerson 2017). In contingent valuation, an investigator generally asks people to indicate how much they would be willing to pay (WTP) for non-marketed ecosystem services if they were in a hypothetical situation. The method is called contingent valuation because the values revealed by respondents are contingent upon the constructed or simulated market presented in the scenario.

Based on the elicitation questionnaire format, the stated preferences can be categorized as discrete choice experiment (DC), bidding game (BG), choice-based conjoint analysis (CBC) and open-ended questionnaire (OE). The theoretical background of the open-ended contingent valuation of regulating and cultural ecosystem services is rooted in welfare economics, in which the neoclassical concept of economic value is outlined under the broader framework of individual utility maximization (Bateman and Turner 1992; Hoyos and Mariel 2010). If anybody perceives a utility from the use of any non-marketed ecosystem services, he/she can offer a maximum monetary amount to utilize these services. Contingent valuation methods are capable of directly obtaining a monetary (Hicksian) value of welfare associated with changes in the provision of a particular ecosystem service such as flood control or water quality improvement (Bateman and Turner 1992). Theoretically, we specified the open-ended willingness to pay model as described in Jala and Nandagiri (2015),

$$WTP = f(\mathrm{ES,\ DF,\ EL,\ HS,\ TI,\ C,\ G,\ AR}) \quad (1)$$

where WTP means Hicksian compensating measures of welfare, ES refers to economic status of respondent, DF denotes distance from forests, EL refers to educational level of the respondent; HS refers to household family size (No); TI refers to household yearly income (NRs), C refers to caste; G refers to gender; and AR refers to age of the respondent (years).

As discussed earlier, there exists a variety of stated preferences techniques and each of them has merits and demerits. DC format is complex for designing their choices and scenarios, and CBC rarely estimates an individual's WTP; rather, data from groups are aggregated for analysis. The bidding game is lengthy and criticized for its starting bias. The OE method, on the other hand, is flexible, easy to understand and analyse, and produces direct continuous individual WTP. This method has also been criticized by some scholars on the grounds of hypothetical bias, strategic bias (Pagiola et al. 2004; Venkatachalam 2004) and incentive incompatibility (Bateman et al. 2010; Rasul et al. 2011). Some of these criticisms could be addressed if hypothetical scenarios and questionnaire are properly designed and implemented.

2.2.1 Valuation of regulating and cultural ecosystem services

In general, Siwalik forests provide both direct and indirect ecosystem services. The direct services include firewood, timber, grass, fodder, bedding material, medicinal plants, sand/stone/boulders and grazing services, while indirect services comprise soil conservation, water quality improvement, erosion control, run-off mitigation, flood regulation, bequest, aesthetic existence, recreation, cultural heritage, tourism and educational services (Basnyat et al. 2012; Sharma et al. 2019). We categorised forest users into eight homogeneous sub-groups (4 sub-groups from community forests and another four sub-groups from collaborative forest management). The databases used to create the different strata were obtained from the forest constitutions and forest operational plans of the community/collaborative management groups (see Appendix 1 for locally adopted criteria for rich and poor). These databases were further verified with their executive committees and district forest officials. Eight different focus groups were set up representing each sub-group (Community Forest: nearby[1]-rich/poor,[2] distant-rich/poor; Collaborative Forest: nearby-rich/poor, distant[3]-rich/poor). In each focus group, 11–18 sub-group members participated in the discussion and a total of 15 regulating and 11 cultural services were documented (Acharya et al. 2019a). The priorities recorded for the different groups contrasted for the different forest management

[1] Nearby users live adjacent to the forest areas (within 3 km) in CF areas whereas in the collaborative forest system, the nearby users live up to five km from the forest area.

[2] Rich/poor: CBFM classifies users into four categories (well-off, medium, poor and very poor). This study considers the first two as rich and the other two as poor.

[3] Distant users live from three to five km away from the CF area, while distant users live 5–20 km away from the CFM area.

modalities, spatial distance from forests and economic classes. Overall, the four top ranking FES (two regulating and two cultural services) for all sub-groups were flood control, water quality improvement, bequest and aesthetic services: these became the bases for this study. See Acharya et al. (2019a) for details of prioritisation of all the forest ecosystem services in the study area.

Method of data collection. The primary data for the study was collected from July to October 2018 using a household survey following a stratified random sampling technique. Local users were stratified based on management modality (community forest/collaborative forest), economic class (rich/poor) and spatial distance (nearby/distant) from the forests. A total of 253 households ranging from 31 to 33 households from each sub-group was surveyed from both community-based forest management types. Socioeconomic data for households, for the classification of poor and rich, was obtained from the records of forest users' meeting minutes and was verified with key informants and community-based forest management executives. In order to address the issues raised by the 'open-ended questionnaire' discussed above (Sect. 2.2), we followed the guidelines developed by the National Oceanic and Atmospheric Administration (NOAA) (Arrow et al. 1993) and 'incentive compatible conditions' suggested by Vossler and Holladay (2018). In order to meet incentive compatible conditions, we suggested that respondents: (1) take care about the outcomes; (2) that the authority can enforce the payment they themselves indicated; (3) that there are 'yes' and 'no' options for each scenario; and (4) that there is high chance of project execution if the proportion of the 'yes' response is high.

Following suggestions offered in focus group discussions, we designed our questionnaires to comprise the baseline condition of forest crown cover, mechanisms of forest condition improvements, changes to be valued and price information. Accordingly, the household questionnaire consisted of five main sections. The first section comprised basic household variables of gender, age, caste, ethnicity and livestock numbers while the second, third, fourth and fifth sections were intended to elicit detailed information on flood control and water quality, bequest and aesthetic services in three different hypothetical scenarios—increasing crown cover by 15%, 30% and 45% from current crown cover (baseline) of 55% to elicit users' willingness to pay (WTP) in either cash or labour for different management interventions (Table 1). As noted earlier, we conducted eight focus group discussions, in which we discussed forest degradation issues and their implications for high priority ES, the concept of WTP and its implications for the outcomes and uncertainty about the actual cost of improving the forest condition, preferred payment vehicle (cash or in-kind) and potential authority to enforce the payment fees/levies (e.g. by executive committee) and methods of expressing their WTP. We also carried out a small pilot testing of the questionnaire before proceeding to the actual household survey as suggested by many studies (Bateman and Turner 1992; Adamowicz 2004).

We employed the face-to-face open-ended contingent valuation method with two payment options since many forest users face cash constraints, and thus could express their WTP in terms of labour (Rai et al. 2015). This method was the preferred option proposed in the focus group discussions and has many advantages. To control hypothetical bias, we created the scenarios in the questions to allow the respondents feel they were paying the agreed amount of money. The participants are forest users and use many FES in their daily lives, consequently they are concerned about the imposition of any rules and regulations that would lead to the improvement/degradation of forest conditions. They were reminded that while they offered money and labour contribution to forest management, their purchasing power and labour-force would be reduced by the same amount (money/labour). After informing them of the consequences of all situations and highlighting the uncertainty about the actual cost of forest management, to control strategic bias and informing them of the probability of executing the project if they agreed, they were asked whether or not they agreed to participate in the process. If the respondent agreed, then he/she was asked what would be the highest amount in terms of cash as an annual fee to CBFM or the number of annual labour days they would be willing to pay for each of the three scenarios. If he/she did not agree then he/she was asked to state the reason for being unwilling to participate. More than 95% of the participants ($n = 241$) agreed to contribute either cash or in-kind for all four services. Table 1 provides details of the methods used to elicit the willingness to pay for regulating and cultural services.

Method of data analysis. The maximum willingness-to = pay amount for each sub-group was estimated following Boyle (2017) as expressed in Eq. 2.

$$Mean\ WTP = \left(\sum_{i=1}^{n} WTP_i\right)/n \quad (2)$$

where WTP is the maximum willingness to pay expressed by individual households, and n is the number of observations.

While contingent valuation undertakes to elicit maximum willingness to pay for a household, it is essential to identify the contribution of different social attributes, e.g. age, income etc. to willingness to pay of the respondents. To observe the relationship between maximum willingness to pay amount and social attributes, we specified the following econometric model for the data analysis as shown in Eq. 2.

$$y_i = \beta' X_i + \varepsilon_i \quad (3)$$

where y_i is the dependent variable, in our case willingness to pay, in monetary terms or labour days, which a respondent offers during the questionnaire survey, β is the vector of unknown parameter, X is the set of independent variables,

Table 1 Contingent valuation method to estimate regulating and cultural services

FES category	Background information	Hypothetical scenario
Flood control	You have witnessed floods and sediments for a long time in your area. You know better than I do about the causes which could be deforestation/degradation, land use changes and unmanaged infrastructure development. You are aware of the impacts of sediment and flood damage to public and private properties like agriculture land (144,724 ha), livestock (US$ 96.50 million), houses (192,510), irrigation (961 schemes), transport—local roads, bridges, culverts (26.60 mil) and human casualties (almost 134 lives) including more than US$ 552 million loss) in Tarai-Madesh area in last August 2017 (NPC 2017). You might still remember or have heard about- worse past incidents in your area	Considering the current situation, GON is going to implement various forests management activities under Chure management to reduce the risk of human casualty, and loss of private property through unsustainable management of forests. GON wants to reduce the impacts of the deposition of sediment and flood, which you are frequently suffer from. Particular forest management activities can increase tree and ground cover that can control the problem of frequent flooding in your area. Currently, you know that the forest crown cover is almost 55%. As a resident of several years, you know better than me about the "flood control benefits" of increased crown cover of the forests on your private property only. Here, we are proposing three hypothetical scenarios (increasing CC by 15%, 30% and 45%). This will not totally mitigate the whole flood problem, however, it can reduce the losses on your private property significantly. Considering the impacts and potential mitigation measures to protect your private property, and remembering that this will reduce your purchasing power or labour force, and implications of the outcomes and uncertainty about the actual cost to improve the forest condition, would you vote in favour of reducing such loss of private property? Yes No Yes No Yes No If yes, what would be the highest amount in cash or labour days of contribution as an annual fee/labour contribution to each of the three scenarios (15%, 30% and 45%) improvements in CC? Increase CC by 15% / Increase CC by 30% / Increase CC by 45% In cash NRs....../Year / In cash NRs....../Year / In cash NRs....../Year Labour days ...../Year / Labour days ...../Year / Labour days ...../Year If no, why do you say no? What would be the least amount of cash/labour contribution in all three scenarios? In cash NRs....../Year Labour days ...../Year

Table 1 (continued)

FES category	Background information	Hypothetical scenario
Water quality improvement	You have witnessed situations, problems, and causes of poor water quality in your area. You know better than I do the causes which could be deforestation/degradation, intensive agriculture and unmanaged infrastructure development. You are aware of the impacts of WQ on your family especially increase in maintenance cost of water pipe clogging/plumbing, cost of additional pipes for your pump to access good quality water compared to several years ago, and ultimately problems in human health. This also demands additional maintenance and consequently increased water maintenance and treatment costs like chemicals, filtering and boiling. At the same, you are also interested in receiving good quality water through a long-term solutions. Considering your current situation, GON is going to implement various forest management measures to improve the water quality and help reduce the risks to human health through sustainable management of forests	GON wants to provide quality water, which you also want to receive. These forest management activities can increase tree and ground cover and thus improve water quality in your area. Currently, you know that the forest crown cover is almost 55%. As a resident of several years, you know better than me the "water quality improvement benefits" derived through increased crown cover of the forests: decrease water treatment costs and gaining health benefits for you and your family. Here, we are proposing three hypothetical scenarios (increasing CC by 15%, 30% and 45%). This will not totally mitigate all water related problems; however, it can decrease the cost of achieving quality water and can also significantly moderate risks to human health. Considering your impacts and potential mitigation measures to decrease water treatment cost and gaining health benefits for you and your family, and also remembering that this will reduce your purchasing power or labour force, implications of the outcomes and uncertainty about the actual cost to improve the forest condition, would you vote in favour of water quality improvement through forest management activities? Yes No Yes No Yes No If yes, what would be the highest amount in-terms of cash or labour days contribution as an annual fee or labour contribution of all three 15%, 30% and 45% CC improvement? Increase CC by 15% — In cash NRs……/Year; Labour days …../Year Increase CC by 30% — In cash NRs……/Year; Labour days …../Year Increase CC by 45% — In cash NRs……/Year; Labour days …../Year If no, why do you say no? What would be the least amount of cash/labour contribution in all three scenario? In cash NRs……/Year Labour days …../Year

Table 1 (continued)

FES category	Background information	Hypothetical scenario
Aesthetic	You have witnessed situations, problems, and causes of aesthetic quality decreasing in your forests area. You know better than I do the causes which could be deforestation/degradation, other land use changes and unmanaged infrastructure development. You are also aware of the impacts on aesthetic values in you and your family especially loss of greenery or changing one land use system to other compared to several years back, and ultimately your decrease in satisfaction from the aesthetic values of the forests. At the same time, you are also interested in receiving aesthetic quality through a long-term solution	Considering your current situation, GON is going to implement various forests management activities to maintain or improve the aesthetic value of forests through sustainable management of forests. GON would like to assure you of providing aesthetic quality, which you are also interested in receiving. These forest management activities would increase tree and ground cover and thus improve the situation of aesthetic value in your forest area. Currently, you know that the forest crown cover is almost 55%. As a resident of several years, you know better than I do the "aesthetic improvement benefits" through increased crown cover of the forests to you and your family. Here, we are proposing three hypothetical scenarios (increasing CC by 15%, 30% and 45%). This will not totally improve the whole aesthetic issue; however, it can significantly increase satisfaction. Considering your satisfaction from increased forest cover and gaining personal benefits for you and your family, and also remembering that this will reduce your purchasing power or labour force, implications of the outcomes and uncertainty about the actual cost to improve the forest condition how would you vote in favour of aesthetic quality improvement through forest management activities? Yes No Yes No Yes No If yes, what would be the highest amount of cash or labour days contribution as an annual fee or labour contribution to all three 15%, 30% and 45% CC improvements? Increase CC by 15% / Increase CC by 30% / Increase CC by 30% In cash NRs……/Year Labour days …../Year / In cash NRs……/Year Labour days …../Year / In cash NRs……/Year Labour days …../Year If no, why do you say no? What would be the least amount of cash/labour contribution to all three scenarios? In cash NRs……/Year Labour days …../Year

Table 1 (continued)

FES category	Background information	Hypothetical scenario
Bequest	You have witnessed current bequest value in your forest area. You know better than I do the causes which could be deforestation/degradation, land use changes and unmanaged infrastructure development that impact the BV of your forests. BV is a non-use value that denotes a special case of option value representing the value (to current users) of being able to bequeath the value of FES to coming generations. It is not like existence values which are fuzzy values and which accrue mainly to people who do not use the forest, and may never see it except in books. In countries like Nepal, where people are more religious, are immersed in traditional culture and believe in incarnation, and earn and save everything for the future generation; forest users may agree to amount of WTP to bequeath the forest to your children and grandchildren. You are also aware that our society believes in incarnation and is conscious of future benefits to your off-spring in your future generation	Considering your current situation, GON is going to implement various forests management activities to improve the bequest value through a variety of management activities in forests. GON would like to improve forest quality, which you are also interested in improving. Such forest management activities can increase tree and ground cover that can improve the value of your forest area. Currently, you know that the forest cover is almost 55%. As a resident of several years, you know better than I do about the bequest value of forests derived through forests management. Here, we are proposing three hypothetical scenarios (increasing CC 15%, 30% and 45%). This will not only determine the total bequest value, but will also significantly increase bequest value. Considering your ability to protect the forests for future generations, and also remembering that this will decrease your purchasing power or labour force, implications of the outcomes and uncertainty about the actual cost to improve the forest condition would you vote in favour of BV? Yes No Yes No Yes No If yes, what would be the highest amount in-terms of cash or labour days contribution of all three 15%, 30% and 45% CC improvements? Increase CC by 15% / Increase CC by 30% / Increase CC by 30% In cash NRs……/Year / In cash NRs……/Year / In cash NRs……/Year Labour days …../Year / Labour days …../Year / Labour days …../Year If no, why do you say no? What will be the least amount of cash/labour contribution as an annual fee or labour contribution to all three scenarios? In cash NRs……/Year Labour days …../Year

CBFM community-based forest management, *GON* Government of Nepal, *NRs* Nepalese rupees, *CC* crown cover, *FES* forest ecosystem services, *WTP* willingness to pay and ε is the random error term which is normally distributed with a zero mean and constant variance. To identify the relationship between maximum willingness to pay and social attributes, we used a mixed effect model, which deals with both fixed and random effects.

To explore the relationship between key independent variables and forecast WTP based on selected variables, we analysed the data in Rstudio as suggested by Bolker et al. (2009). A generalised linear mixed model (GLMM) was used to assess the correlation and estimate the effects of the explanatory variables (economic status, distance from forests, level of education, household size and caste, a fixed variable; age of respondent, gender, a random variable) on response variables. GLMM with PQL (penalized quasi-likelihood) function in R package (Pinheiro et al. 2018) was used for fitting the model. This GLMM was selected because it deals with non-normal data with unbalanced design and cross-random effects.

We checked multicollinearity among the independent variables through one-on-one correlation among independent variables and through variance inflation factors (VIF). Correlation between income and economic status and income and caste are 0.59 and 0.26, respectively. Among the independent variables the VIF value is less than 2.06, which indicates no multicollinearity was found (please see test results in Appendix 2). Further, we employed the forward method, that is, we started with economic status, age, and gender and added other variables (distance from forest, caste, income, family size and livestock) in different combinations (see Appendix 3 for six different combinations).

To select the best models among six different combinations, we calculated adjusted R^2 values of these models and checked their p values. The first two models yielded adjusted R^2 values less than 0.3, which means the model does not provide a reliable prediction. The third model yielded R^2 0.36, which also predicts moderately. Models four and five produced R^2 values 0.74 and 0.75, respectively, showing good predictive capacity. We chose the sixth model (adjusted R^2 equal to 0.8, the highest among the models), in which three variables (Eco_Status, Edu_lev, Distant_For) were the main variables, three (Total.income, Tot_Fam_memb and Caste) were associated variables and Gender and Age_response were random variables (please see adjusted R^2 value for all models in Appendix 4). In addition, we also checked the Pearson's residuals for all models and found that neither does any model indicate a lack of fit nor provide evidence of over-dispersion of the fitted value (p values greater than 0.05). From these two different tests, it is clear that the sixth model exhibits the best fit since it produces significance for most of the variables.

In addition, we further tested the selected model using other criteria. For example, we plotted fitted values with standard residuals for our observation of total incomes, age of the respondents, and household size and found that the residual values were mostly distributed near to zero, which means the sum of residuals is almost zero and predicted value is fitted well with our observed values. Moreover, we performed an ANOVA test between observed mean and predicted mean and found no significant difference among them. Therefore, we concluded that the model can predict with selected observed variables. We repeated the same process for all four regulating and cultural services and six different scenarios for both the cash and labour payment options.

3 Results

3.1 Sociodemographic information and fitted generalised linear mixed model

Table 2 provides relevant socio-demographic information on gender, age, household size, education level, ethnic, religion, household income, expenditure, status of private forest and dependency on forests for the sampled households. Overall, the median age of the respondents is 45 years. A majority of the respondents were of mixed ethnic composition and follow either Hinduism or Buddhism. The average household income was US\$ 2884, while expenditure is US\$ 2142, which reflects almost similar national income figure of US\$ 2987 and expenditure of US\$ 2152 in rural settings (CBS 2015).

From the GLMM analysis, we found the following model showed the best fit; most of the socio-economic and demographic attributes were significant for both cash and labour. We also plotted fitted values with standard residuals for total incomes, age of the respondents, and household size and found that the values were mostly distributed near to zero (see Appendix 5 for fitted model for all four services in different scenarios). In addition, no significant difference among observed and predicted mean in the ANOVA test, which suggesting that the model is fitted our observed values. We present here a sample of a predicted model for flood control services (15%) for the cash option as in Eq. 3 (please see Appendix 6 for the 24 fitted models in total, for four forest ecosystem services and six different scenarios).

$$
\begin{aligned}
\textit{Average of flood control value } (15\%) = & \, 6.657 - 0.623 \\
& * AF(Eco\_Status2) \\
& + 0.888 * AF(Edu\_Lev2) \\
& - 0.573 * AF(Dis\_For2) \\
& - 0.0638 * HHsize + 0.000001 \\
& * Tot\_Inc - 0.492 \text{ Caste2}
\end{aligned}
\tag{4}
$$

Table 2 Sociodemographic information of the respondent

Demographic information	CF nearby		CF distant		CFM nearby		CFM distant	
	Rich ($n=32$)	Poor ($n=31$)	Rich ($n=31$)	Poor ($n=31$)	Rich ($n=32$)	Poor ($n=31$)	Rich ($n=33$)	Poor ($n=32$)
Gender (%)	F = 63 M = 37	F = 65 M = 35	F = 19 M = 81	F = 32 M = 68	F = 31 M = 69	F = 35 M = 65	F = 15 M = 85	F = 19 M = 81
Median age with range (years)	41 (19–75)	40 (18–80)	48 (24–79)	48.50 (21–74)	39 (22–68)	45 (20–75)	51 (20–84)	45 (25–77)
Family size (std. error of mean)	6.10 (0.461)	5.33 (0.37)	6.3 (0.5)	5.67 (0.413)	6.27 (0.401)	5.83 (0.525)	6.10 (0.461)	7.43 (0.545)
Educational status (%)	L = 38 U = 62	L = 68 U = 32	L = 16 U = 84	L = 58 U = 42	L = 47 U = 53	L = 61 U = 39	L = 45 U = 55	L = 78 U = 22
Ethnic composition (%)	HC = 13 LC = 87	HC = 6 LC = 94	HC = 77 LC = 23	HC = 26 LC = 74	UC = 44 LC = 56	UC = 23 LC = 77	UC = 85 LC = 15	UC = 53 LC = 47
Religion (%)	H = 75 B = 25	H = 77 B = 23	H = 100	H = 90 M = 10	H = 72 B = 22 M = 6	H = 68 B = 29 M = 3	H = 100	H = 100
Average annual income[a]/HHs (US$[b]) (std. dev.)	3532 (±2172)	1395 (±794)	6515 (±3767)	1421 (±935)	4933 (±2520)	1463 (±708)	3684 (±1785)	1671 (±985)
Average annual expenditure[c]/HHs (US$)	2026	1091	6161	1302	2672	1319	2321	1470
Private forests owners	66%	50%	40%	37%	28%	16%	64%	41%
Dependency on CBFMs	56%	46.3%	6%	14%	65%	68%	6%	11%

Data in parenthesis is standard deviation; gender: M: male, F: female; lower education level (L) (I = illiterate, P = primary/lower secondary), upper (U) = (high school and college above); ethnic composition: higher caste (HC): Bahun/Kshetri/Dashanami/Madeshi, lower caste (LC): Janajati, Janajati/Madhesi, and Dalit; religion: H = Hindu, B = Buddhists, M = Muslim

[a]Incomes are derived from agriculture, horticulture, livestock, daily wages, foreign employment, different types of salaries, small businesses, fisheries, NTFP/medicinal plants and firewood collection

[b]One US$ = NPR 110.52

[c]Expenditure includes foodstuff, clothing, education, health, agriculture, purchasing land, livestock, paying interest, etc.

where ES refers to economic status of respondent (1 rich, 2 poor), DF refers to distance from forests (1 nearby, 2 far from forests), EL refers to educational level of the respondents (1 high school and below, 2 college and above); HS refers to household family size (number); TI refers to household yearly income (NRs), C refers to caste (1 upper, 2 lower); G refers to gender (male 1, female 2); and AR is age of the respondents (years)..

3.2 Valuation of regulating services

We calculated average willingness to pay of all eight sub-groups: the sum of willingness to pay divided by the total number of respondents in each sub-group. We also included the standard deviations of willingness to pay values in the results.

3.2.1 FC values

The average willingness to pay for flood control services differs according to management modality, economic status, and proximity to forest area (Table 3).

In the community forest, rich-distant users expressed the highest willingness to pay for flood control services (US$4.95 to US$13.5/HH/year) followed by rich-nearby users (US$3.2 to US$7.2/HH/year) for all three scenarios. Irrespective of spatial distance to forests, poor households expressed low willingness to pay (US$1.5 to US$3.3/HH/year). In terms of labour contribution, rich-nearby users offered the highest number of labour days (2.2 to 7.2 man-day/HH/year) followed by rich-distant users for all scenarios. Poor households (both nearby and distant) offered a lower labour contribution for the same scenario (1.5 to 3.5 man-day/HH/year).

In the case of collaborative forest management, wealthier-nearby users showed the highest willingness to pay for flood control services (US$3.5 to US$10.10/HH/year) followed by poor users from the same area. Poor users in both nearby and distant forest areas expressed the minimum (US$0.4 to US$1.1/HH/year) willingness to pay for all scenarios. Regarding labour contribution, the poor for all groups showed similar willingness to pay compared to a cash contribution for all scenarios (Table 3).

Table 3 Average willingness to pay (WTP) for flood control by different sub-groups per households per year (in US$ and labour days)

Services types	Category	CF nearby		CF distant		CFM nearby		CFM distant	
		Rich, $n=30$	Poor, $n=31$	Rich, $n=30$	Poor, $n=30$	Rich, $n=30$	Poor, $n=30$	Rich, $n=30$	Poor, $n=30$
Flood control	FCC_15%	3.2 (1.9)	1.8 (1.4)	4.9 (4.1)	1.5 (1.1)	3.5 (2.5)	1.7 (1.3)	1.1 (0.7)	0.4 (0.2)
	FCL_15%	2.2 (1.7)	2.0 (1.6)	2..0 (1.6)	1.5(1.2)	2.0 (1.5)	1.8 (1.2)	0.5(0.2)	0.4 (0.3)
	FCC_30%	4.9 (3.1)	2.5 (1.7)	9.4 (8.2)	2.8 (1.5)	6.5 (5.2)	2.8 (2.1)	2.0 (1.3)	0.7 (0.4)
	FCL_30%	3.0 (2.1)	2.9 (2.3)	3.0 (2.2)	2.9 (2.3)	3.8 (2.1)	3.5 (1.5)	1.0 (0.6)	0.8 (0.5)
	FCC_45%	7.2 (4.7)	3.3 (2.1)	13.5 (11.0)	5.3 (3.5)	10.1 (5.2)	3.9 (2.7)	3.0 (2.2)	1.1 (0.6)
	FCL_45%	3.6 (2.1)	3.5 (2.2)	4.5 (3.1)	4.5 (3.1)	5.9 (4.3)	4.0 (1.9)	1.6 (1.1)	1.0 (0.7)

FCC flood control value in cash, *FCL* flood control value in labour days (standard deviation in parenthesis)

The generalised linear mixed model (GLMM) employed confirmed that economic status, educational level, distance from forests, household size and caste have a significant correlation with willingness to pay for flood control services (see Table 4 for test results for all variables with Pearson's chi-square residual p value of the model).

3.2.2 Water quality improvement values

The average willingness to pay values for water quality improvement (WQI) services for the different sub-groups varied by spatial distance and socio-economic status (Table 5).

In community forest, rich-nearby households expressed the highest willingness to pay for water quality improvement services (US$6 to US$18/HH/year) for increased forest cover (15% to 45%), while poor households stated low willingness to pay (US$2.5 to US$4.5/HH/year) for different water quality improvement scenarios. Rich-distant users expressed a similar desire for WQI as rich-nearby users; however, poor-distant users offered somewhat higher (US$3 to US$4.5/HH/year) for the different scenarios. Referring to labour days, rich users in the community forest offered the highest man-days (2.0 to 7.5 man-day/year) irrespective of their proximity to a forest area. Poor-distant users showed similar man-day contributions, while the nearby-poor households offered the least labour contribution (1.2 to 3.6 man-day/year).

In the case of collaborative forest management, rich-nearby households were willing to pay the highest amount (US$6.5 to US$17/HH/year) followed by poor households living in the same area (US$3 to US$7.40/HH/year). Both types of users (rich and poor) living a long distance from forests expressed a low willingness to pay ranging from US$ 1.0 to US$4.0/HH/year. For labour contribution, rich-nearby users offered the highest number of days (2.7 to 7.6

Table 4 Effect of different socio-demographic characteristics on willingness to pay for flood control service under different conditions (15%-45%)

Fixed effects	Coefficient	Std. err	p value	Coefficient	Std. err	p value	Coefficient	Std. err	p value
FRC	FRC_15%			FRC_30%			FRC_45%		
Intercept	6.75775	0.3596270	0.0000	7.012494	0.3436474	0.0000	7.364783	0.3379891	0.0000
AF (Eco_Status)2	− 0.62381	0.1696527	0.0003	− 0.533945	0.1644978	0.0015	− 0.547819	0.1610087	0.0009
AF (Edu_lev)2	0.88823	0.1601841	0.0000	0.821379	0.1532963	0.0000	0.718067	0.1516314	0.0000
AF (Distant_For)2	− 0.57345	0.1641240	0.0006	− 0.477084	0.1579875	0.0030	− 0.498803	0.1539332	0.0015
Household size	− 0.06386	0.0281076	0.0246	− 0.051607	0.0265135	0.0536	− 0.040750	0.0256047	0.1137
Total Income	0.00000	0.0000002	0.0004	0.000001	0.0000002	0.0000	0.000001	0.0000002	0.0000
Caste2	− 0.49243	0.1528783	0.0016	− 0.502633	0.1465624	0.0008	− 0.539571	0.1425283	0.0002
Pearson's χ^2 residuals	0.001			0.0009			0.0001		
FRL	FRL_15%			FRL_30%			FRL_30%		
Intercept	0.89085	0.2952606	0.0030	1.3863187	0.282	0.0000	1.7982	0.2968	0.0000
AF (Eco_Status)2	− 0.10243	0.131801	0.4383	− 0.194487	0.124456	0.1203	− 0.2540676	0.12947892	0.0500[1]
AF (Edu_lev)2	0.5524099	0.1246256	0.0000	0.5225054	0.1184	0.0000	0.5753	0.1224	0.0000
AF (Distant_For)2	− 0.4673833	0.1216811	0.0002	− 0.48405	0.1159	0.0001	− 0.4533	0.1220	0.0003
Pearson's χ^2 residuals	0.0003			0.0001			0.001		

Eco_Status economic status, *Edu-lev* education level, *Distant_For* distant for, *Age_respon* age of the respondents, *Tot_Inc* total income, *AF* as a factor, *FRL* flood control in labour days

Table 5 Average—willingness to pay for water quality improvement by different sub-groups per HHs per year (in US$ and labour days)

Services types	Category		CF nearby	CF distant		CFM nearby		CFM distant	
		Rich, $n=30$	Poor, $n=31$	Rich, $n=30$	Poor, $n=30$	Rich, $n=30$	Poor, $n=30$	Rich, $n=30$	Poor, $n=30$
Water quality improvement services (WQI)	WQIC_15%	6.0 (3.9)	2.5 (1.1)	6.0 (4.0)	3.0 (1.2)	6.5 (4.2)	3.0 (2.0)	2.0 (1.0)	1.0 (1.0)
	WQIL_15%	2.4 (1.5)	2.0 (1.3)	2.0 (1.3)	2.0 (1.0)	2.7 (2.0)	1.5 (1.1)	1.0 (0.7)	0.5 (0.2)
	WQIC_30%	11.9 (8.0)	5.0 (2.9)	9.0 (6.0)	4.0 (2.7)	13.0 (9.4)	5.7 (3.2)	3.0 (1.8)	1.8 (1.0)
	WQIL_30%	4.7(3.2)	4.0 (2.0)	3.5 (2.4)	3.8 (2.0)	4.8 (2.0)	3.0 (1.6)	1.9 (1.1)	1.0 (0.6)
	WQIC_45%	18.0 (7.9)	7.4 (5.0)	11.9 (7.8)	5.0 (3.9)	17.0 (12.0)	8.4 (5.0)	4.0 (2.0)	2.9 (1.0)
	WQIL_45%	7.5 (5.0)	6.5 (5.0)	6.5 (4.5)	6.5 (3.0)	7.6 (4.0)	4.5 (2.0)	2.7 (1.0)	1.5 (0.5)

WQIC water quality improvement value in cash, *WQIL* water quality improvement value in labour day (standard deviation in parenthesis)

man-day/HH/year) followed by poor users in the same area. Poor-distant users offered the lowest labour contribution (0.5 to 1.5 man-day/year).

Of all attributes tested, total income and education level are positive, and household size, economic status and caste are negatively associated with willingness to pay for water quality improvement as a cash option, while education is positive, and economic status and distance from the forests are negatively correlated with labour contribution (Table 6).

3.3 Valuation of cultural services

3.3.1 Bequest values

The average willingness to pay for bequest value (BV) also differed according to socioeconomic condition and distance to the forest (Table 7).

Referring to the community forest, the rich-nearby users offered the highest willingness to pay (US$7 to US$14/HH/year) followed by rich-distant users for three different scenarios of bequest value. In contrast, poor-distant users offered the lowest willingness to pay (US$1 to US$3/HH/year). A similar trend to that indicated for willingness to pay cash is shown for labour contribution. Well-off users were ready to invest the highest number of man-days (2 to 5.5 man-day/HH/year), while poor users offered slightly lower numbers (1.5 to 4.2 man-day/HH/year) for the different scenarios.

In the collaborative forest management FM area, the rich-nearby users offered the highest amount (US$8 to US$ 15/HH/year) for bequest value, while distant users from the same category offered almost one-fourth that. The labour contribution offered, on the other hand, was highest (2.5 to 6 man-day/HH/year) for rich users living near the forests followed by poor users from the same area.

Similar to FC and WQI, income is positively associated with level of willingness to pay for bequest value (BV), suggesting that increases in unit level in income increases WTP

Table 6 Effect of different socio-demographic characteristics on willingness to pay for water quality improvement under different conditions (15–45%)

Fixed effects	Coefficient	Std. err	p value	Coefficient	Std. err	p value	Coefficient	Std. err	p value
WQIC	WQIC_15%			WQIC_30%			WQIC_45%		
(Intercept)	7.234446	0.275954	0.0000	7.054326	0.3692724	0.0000	7.325048	0.3367777	0.0000
AF (Eco_Status)2	− 0.742254	0.140987	0.0000	− 0.619699	0.1866758	0.0011	− 0.642210	0.1644233	0.0001
AF (Edu_lev)2	0.494297	0.12479	0.0001	0.467985	0.1602609	0.0041	0.293649	0.1529548	0.0569
AF (Distant_For)2	− 1.20822	0.140534	0.0000	− 0.920797	0.1771162	0.0000	− 0.772341	0.1565443	0.0000
HH size	− 0.05549	0.02285	0.0164	− 0.035823	0.0283771	0.2089	− 0.042591	0.0264820	0.1100
Total Income	0.000001	0.000000	0.0033	0.000001	0.0000002	0.0062	0.000001	0.0000002	0.0001
Caste	− 0.25622	0.12563	0.0433	− 0.02722	0.1697772	0.8728	0.007228	0.1481291	0.9611
Pearson's χ^2 residuals	0.0001			0.00001			0.0002		
WQIL	WQIC_15%			WQIC_30%			WQIC_45%		
(Intercept)	1.4674236	0.24166894	0.0000	1.9493200	0.24927453	0.0000	2.3076056	0.25315178	0.0000
AF (Eco_Status)2	− 0.2356257	0.11145401	0.0362	− 0.2572740	0.11644421	0.0287	− 0.2948412	0.11909439	0.0145
AF (Edu_lev)2	0.4014262	0.10432512	0.0002	0.4421669	0.10840738	0.0001	0.4228179	0.11096201	0.0002
AF (Distant_For)2	− 0.6641104	0.10509946	0.0000	− 0.7061746	0.10958154	0.0000	− 0.6286190	0.11132355	0.0000
Pearson's χ^2 residuals	0.000006			0.00001			0.00003		

Eco_Status economic status, *Edu-lev* education level, *Distant_For* distant for, *Age_respon* age of the respondents, *Tot_Inc* total income, *AF* as a factor

Table 7 Average willingness to pay for bequest value by different sub-groups per HHs per year (in US$ and labour days)

Service types	Category	CF nearby		CF distant		CFM nearby		CFM distant	
		Rich, $n=30$	Poor, $n=31$	Rich, $n=30$	Poor, $n=30$	Rich, $n=30$	Poor, $n=30$	Rich, $n=30$	Poor, $n=30$
Bequest value	BVC_15%	7.0 (5.2)	2 (0.5)	5 (2.3)	1 (0.4)	8 (6.0)	2 (1.5)	2 (1.0)	1 (0.4)
	BVL_15%	2.3 (1.2)	1.9 (1.3)	2.3 (1.3)	1.9 (1.1)	2.3 (1.7)	1.9 (1.2)	2.0 (0.3)	1.6 (0.6)
	BVC_30%	11 (7.8)	4 (1.9)	9 (5.8)	2 (1.2)	12 (7.8)	3 (1.8)	3 (1.4)	1(0.5)
	BVL_30%	4 (2.7)	3.5 (2.1)	4.1 (2.5)	3.4 (2.1)	4.4 (2.2)	3.4(1.6)	3.5 (0.6)	3 (0.9)
	BVC_45%	14 (9.5)	5 (3.5)	13 (8.0)	3 (1.3)	15 (10.8)	5 (2.4)	4 (1.9)	2 (0.9)
	BVL_45%	5.9 (2.9)	4.9 (2.2)	6.0 (3.3)	4.8 (2.1)	6.0 (3.5)	4.9 (1.7)	4.3 (0.8)	4.0 (1.2)

CF community forest, *CFM* collaborative forest, *BVC* bequest value in cash, *BVL* bequest value in labour day (standard deviation in parenthesis)

of all three scenarios, while economic status, distance from forests, and household size of the respondents are negatively associated with willingness to pay for bequest value (Table 8).

3.3.2 Aesthetic values

Table 9 shows the average willingness to pay values for aesthetic value (AV) for the different sub-groups in both community-based forest management types.

Rich-distant users of community forests offered the highest willingness to pay (US$4 to US$10/year) followed by nearby-users in the same economic category. Poor users from both nearby and at a distance expressed a lower willingness to pay (US$1 to US$5/HH/year). Considering the labour contribution, rich-distant users offered a high number of man-days followed by nearby users from same the category living adjacent to a forest area. Poor users living nearby and at a distance from a forest offered a low labour input (1–3 man-days/HH/year) for the scenario of aesthetic services.

Total income and education of the respondents are positively associated with willingness to pay for AVs while distance from forests, household size and caste of the respondents are negatively associated with willingness to pay for aesthetic value in cash (Table 10).

4 Discussion

The open-ended contingent valuation method is flexible, easily understood by the users and useful for estimating many non-use ecosystem services. This method is easy to analyse and does not rely on distributional assumptions and is statistically more efficient than the dichotomous contingent approach because it identifies continuous individual WTP and does not suffer from "yea-saying" (Gordillo et al. 2019). Despite many researchers' concerns about the CVM method in relation to invalidity and replicability (Pagiola et al. 2004; Venkatachalam 2004) and differences between hypothetical scenarios and actual behaviour (Bateman et al. 2010; Rasul et al. 2011), many studies have applied this method to elicit

Table 8 Effect of different socio-demographic characteristics on willingness to pay for bequest value under different conditions (15–45%)

Fixed effects	Coefficient	Std. err	p value	Coefficient	Std. err	p value	Coefficient	Std. err	p value
BVC	BVC_15%			BVC_30%			BVC_45%		
(Intercept)	6.854291	0.3239501	0.0000	7.080303	0.3268791	0.0000	7.320905	0.31004869	0.0000
AF (Eco_Status)2	− 0.861778	0.1698299	0.0000	− 0.91685	0.1642297	0.0000	− 0.804582	0.15461807	0.0000
AF (Edu_lev)2	0.165754	0.1543238	0.2846	0.04950	0.1519552	0.7449	0.106384	0.14372103	0.4604
AF(Distant_For)2	− 0.970307	0.1628313	0.0000	− 0.74175	0.1582851	0.0000	− 0.696427	0.14852181	0.0000
HH size	− 0.053368	0.0265950	0.0467	− 0.05271	0.0260378	0.0448	− 0.051601	0.02447466	0.0367
Total Income	0.000001	0.0000002	0.0003	0.000001	0.0000002	0.0002	0.000001	0.00000019	0.0000
Caste	− 0.169950	0.1467619	0.2488	− 0.07057	0.1453976	0.6282	− 0.099055	0.13743103	0.4722
Pearson's χ^2 residuals	0.0001			0.0004			0.0005		
BVL	BVL_15%			BVL_30%			BVL_45%		
(Intercept)	1.086001	0.26701764	0.0001	1.349592	0.26088434	0.0000	1.6574205	0.25414627	0.0000
AF(Eco_Status)2	0.273467	0.1182	0.0222	0.293619	0.11483012	0.0116	0.3533008	0.11204596	0.0020
AF(Distant_For)2	− 0.461914	0.1116179	0.0001	− 0.446919	0.10969181	0.0001	− 0.4060569	0.10694301	0.0002
Pearson's χ^2 residuals	0.0001			0.00002			0.0002		

Eco_Status economic status, *Edu-lev* education level, *Distant_For* distant for, *Age_respon* age of the respondents, *Tot_Inc* total income, *AF* as a factor

Table 9 Average willingness to pay of aesthetic value by different sub-groups per HHs per year in US$ & labour days

Service types	Category	CF nearby		CF distant		CFM nearby		CFM distant	
		Rich, $n=30$	Poor, $n=31$	Rich, $n=30$	Poor, $n=30$	Rich, $n=30$	Poor, $n=30$	Rich, $n=30$	Poor, $n=30$
Aesthetic value	AVC_15%	3 (1.6)	1 (0.3)	4 (2.1)	1 (0.3)	4(1.7)	1(0.5)	1 (0.2)	0.3(0.1)
	AVL_15%	2(1.1)	2 (1.2)	2 (1.3)	1 (0.7)	2(0.8)	2(1.0)	1(0.5)	0.2(0.07)
	AVC_30%	4 (2.3)	2 (1.1)	7 (4.5)	2 (1.4)	5(3.3)	2(1.1)	1(0.6)	0.4(0.2)
	AVL_30%	3 (1.5)	3(1.7)	3.2 (2.1)	1 (0.6)	3 (1.4)	3(1.1)	1(0.4)	0.2 (0.1)
	AVC_45%	6 (2.5)	3 (1.1)	10 (6.8)	3 (1.6)	7 (4.4)	3(1.8)	2 (1.1)	1(0.4)
	AVL_45%	4(2.1)	3 (2.2)	4.2 (3.2)	2 (1.1)	4(3.1)	3(1.3)	1(0.7)	0(0.0)

CF Community Forest, *CFM* Collaborative forest, *AVC* Aesthetic Value in Cash, *AVL* Aesthetic Value in Labour Days (standard deviation in parenthesis)

information for flood control, water quality improvement, bequest and aesthetic value of forest. As noted, they have overcome the limitations by utilising the guidelines developed by the National Oceanic and Atmospheric Administration (NOAA) (Arrow et al. 1993) and fulfilling the conditions OE contingent valuation required to be incentive compatible as suggested by (Vossler and Holladay 2016).

The results of FES research have to date played a limited role in discussions of the management of ecosystems to achieve combined social and ecological objectives. The lack of consideration and poor integration of social sciences in ecological or economic studies have resulted in limited progress in understanding the socio-ecological complexities inherent in these areas (Reyers et al. 2010; Lele et al. 2013; Lele and Srinivasan 2013). This could be improved by incorporating socially disaggregated economic values of many high-priority FES to enrich our understanding of how people place values on FES (Polishchuk and Rauschmayer 2012; Forsyth 2015). Although we have analysed our data in a disaggregated manner, we could not compare our results with other studies due to the lack of such studies, and therefore, we compared our overall results with other global literature.

Above 95% of the respondents are willing to pay either in cash or in kind for all four services. These results are consistent with many studies conducted in developing countries (Maraseni et al. 2008; Rai et al. 2015; Atinkut et al. 2020) and also indicate a clear a demand for those non-marketed forest ecosystem services. The reasons behind the high response rate in our case are as follows: (1) the use of face-to-face interviews; (2) flexibility of our interview times (we usually conducted interviews in respondents′ leisure time, either early in the morning or late evening); (3) the research issues are of interest to forest users and they care about the outcomes of the research; and (4) offering the opportunity to express willingness to pay as two different options (labour days and cash).

Table 10 Effect of different socio-demographic characteristics on willingness to pay for aesthetic value under different conditions (15%-45%)

Fixed effects	Coefficient	Std. err	p value	Coefficient	Std. err	p value	Coefficient	Std. err	p value
AVC	AVC_15%			AVC_30%			AVC_45%		
(Intercept)	6.182200	0.3536673	0.0000	6.429598	0.3281168	0.0000	6.445659	0.3254425	0.0000
AF (Eco_Status)2	− 0.502158	0.1801870	0.0060	− 0.482245	0.1671861	0.0045	− 0.553733	0.1655559	0.0011
AF (Edu_lev)2	0.105608	0.1676143	0.5297	0.151627	0.1551772	0.3302	0.121634	0.1534932	0.4294
AF (Distant_For)2	− 0.639470	0.1652191	0.0002	− 0.619360	0.1516574	0.0001	− 0.483271	0.1485676	0.0014
Household size	− 0.046442	0.0274386	0.0927	− 0.028393	0.0248149	0.2545	− 0.010959	0.0240763	0.6497
Total Income	0.000001	0.0000002	0.0001	0.000001	0.0000002	0.0000	0.000001	0.0000002	0.0000
Caste	− 0.287061	0.1607573	0.0763	− 0.302449	0.1480634	0.0429	− 0.178681	0.1457123	0.2221
Pearson's χ^2 residuals	0.0002			0.00008			0.0002		
AVL	AVL_15%			AVL_30%			AVL_45%		
(Intercept)	1.0270129	0.4015267	0.0116	1.409633	0.3876668	0.0004	1.7582509	0.4006866	0.0000
AF (Eco_Status)2	− 0.3862142	0.1850431	0.0386	− 0.391073	0.1757758	0.0277	− 0.3935216	0.1879756	0.0381
AF (Edu_lev)2	0.6070391	0.1708090	0.0005	0.686339	0.1634834	0.0000	0.6779231	0.1689266	0.0001
AF (Distant_For)2	− 0.6752174	0.1768470	0.0002	− 0.719352	0.1700438	0.0000	− 0.6658728	0.1775134	
Pearson's χ^2 residuals	0.0004			0.00006			0.00004		

Eco_Status economic status, *Edu-lev* education level, *Distant_For* distant for, *Age_respon* age of the respondents, *Tot_Inc* total income, *AF* as a factor

Our results suggest that users' wealth level, proximity to a forest area, income and size of the household generally govern the WTP values of all four services, which is consistent many global studies. For example, as income increases, the WTP value for the water quality improvement scenario and flood control also increases in USA (Nelson et al. 2015; Aguilar et al. 2018). Furthermore, our study revealed that the WTP value of three services, namely flood control, water quality improvement and aesthetic values, is consistent for both cash and labour payment options. In contrast, poor households offered a higher WTP in the case of bequest value in both labour and cash options, suggesting that they are more concerned to preserve the forests for future generations. This is very logical as they do not have many things to leave for their future generations, except their forests.

Many researchers suggest that the payment option is critical for exploring the WTP value and suggest that labour input is a better option in the case of low-income countries (Vondolia et al. 2014; Rai et al. 2015; Owuor et al. 2019), as their opportunity cost of time is low. However, our finding reveals that such a wholesale approach needs to be critically weighed. Our case study country, Nepal, is a low-income country, however, most of the well-off households offered fewer labour-days compared to their offer of cash, whereas the opposite was true for poor households. This is because the opportunity cost of time for rich people is higher than that for poor people. This provides evidence that the willingness to pay in the form of labour could be a better option mainly for poor households, regardless of their country of origin or location.

We have also predicted the WTPs for all four services and six different scenarios using 24 fitted models along with other socio-economic attributes. Details of the discussion are in Sect. 4.1.

4.1 Economic contribution of regulating services by different sub-groups

4.1.1 Willingness to pay for flood control service

Forest users offered an overall WTP of US$3.2 to US$7.2/HH/year for different scenarios of flood control service. This WTP value is both similar to (US$ 6.2/HH/year) (Birol et al. 2009) and higher than (US$23 to US$620/HH/year) the results of other global studies (Ryffel et al. 2014; Soy-Massoni et al. 2016; Aguilar et al. 2018). A possible reason for the low value placed on flood control in our study could be due to the level of average annual income of the respondents. For example, Ryffel et al. (2014) assessed the flood control value in the Kleine Emme catchment in Switzerland, a high-income country with an average annual income of US$57,119 in contrast with the average annual income of our respondents of US$2884.

The WTP for the FC service differs according to users' economic status. As presented in the results, distant-rich users in CF offered almost one and a half to two times more willingness to pay compared to nearby-rich users. Another potential reason for the high WTP of the rich-distant users in our study could be the price of private property (e.g. house and land) and the type of farming system. For instance, the rich distant users in the CF live in a semi-urban area, where the price of land is almost five to six times higher than the price of land in the nearby community forest area. Similarly, the distant users in the community forest mostly engage in commercial sugarcane cultivation (Neupane et al. 2017; Acharya et al. 2019a), which yields high profits from agriculture in comparison to the subsistence farming of the nearby users. In terms of labour contribution, rich users offered a low number of labour-days compared to a cash contribution for all scenarios. Rich users in our study area engage in multiple livelihood options such as commercial agriculture, small shops and professional occupations and unsurprisingly could not offer high numbers of labour days.

Statistical analysis for income and education are positively associated, and economic status, distance from forests, HH size and caste are negatively associated with the cash option, while education is positive and distance from forests is negatively correlated with the labour payment option. The higher the annual income and education of the respondents, the higher the WTP in all scenarios, which is consistent with the findings of global studies (Lehtonen et al. 2003; Devkota et al. 2014; Nyongesa et al. 2016). In contrast, as household size increases, the WTP for FC value decreases, which is also consistent with some other studies (Rai et al. 2015; Nyongesa et al. 2016).

4.1.2 Willingness to pay for water quality improvement

Our overall results for water quality improvement as presented in Table 9 (US$ 3.8 to US$ 9.0/HH/year) for different scenarios both concur with and contradict other global studies. The results are similar (US$2.0 to US$12.64/HH/year) to the findings of some studies (Johnson and Baltodano 2004; Roesch-McNally and Rabotyagov 2016; Chaikaew et al. 2017), while they are higher than those (US$19.5 to US$107/HH/year) reported in other studies (Milon et al. 1999; Shrestha and Alavalapati 2004; Tao et al. 2012; Dauda et al. 2014; Aguilar et al. 2018) (Table 9). Since WTP is influenced by attitude towards the type of service and the level of awareness of forest conservation, the results revealed relatively low WTP for WQI. Scholars accept that all non-marketed FES, including WQI benefits from forests, are supposed to be free services (Bhatta et al. 2014; Aguilar et al. 2018), which could influence the low WTP in our study site. Some researchers have claimed that low WTP for forest conservation is associated with a lower level of conservation

Table 11 Overall results and global literature on water quality improvement services (US$/Year). WQIC = water quality improvement value in cash

Category	Our study	Other global references									
		(Shrestha and Alavalapati 2004)	(Chaikaew, Hodges et al. 2017)	(Aguilar, Obeng et al. 2018)	(Tao, Yan et al. 2012)	(Johnson and Baltodano 2004)	(Dauda, Yacob et al. 2014)	(Roesch-McNally and Rabotyagov 2016)	(Milon, Hodges et al. 1999)	(Mueller 2014)	(Mueller et al. 2019)
	Country										
	Nepal	USA	USA	USA	China	Nicaragua	Nigeria	USA	USA	USA	USA
WQIC	US$ 3.8–US$ 9.0	30.24–71.17/HH/year	US$ 2/HH/year	US$ 42–73/HH/year	US$ 34.44/HH/year	US$ 4.5/HH/year	19.5–107/HH/year	4.71–12.64/HH/year	US$ 60–70/HH/year	US$ 59/HH/year	US$ 59/HH/year

awareness about the resources (Baral et al. 2016) and this could lead to an acute problem of deforestation in Siwalik landscape (DFRS 2015; Singh 2017; GON 2019) (please see Table 11).

Our results revealed that the economic background of the respondent plays a key role in WTP for WQI service. For instance, rich users in both CBFM types are willing to pay a large amount of money for WQI service, compared to poor users. The difference in WTP in both sub-groups could be attributed to education and awareness among the respondents. Rich users in the study site have a higher education level (> 63% attended college and above). Moreover, rich users may have greater exposure to information about WQI service of forests through participating in a variety of training and interactions (Bhandari et al. 2016; Torkar and Krašovec 2019). This could be one reason for showing a higher WTP to pay for WQI service.

While carrying out modelling with different socio-economic variables, forest users with higher income and higher education offer higher WTP in cash for WQI in both CBFM arrangements, which is similar to the findings of other studies (Shrestha and Alavalapati 2004; Genius et al. 2008; Bhandari et al. 2016). In contrast, as the HH size increases, WTP for water quality decreases, contradicting the results of other studies (Tao et al. 2012). This could be attributed to the many competing interests for cash in a large family-household to fulfil the demand of food, clothing, and education reducing he disposable income for various purposes including forest conservation for WQI service.

4.2 Willingness to pay for cultural services in different sub-groups

4.2.1 Willingness to pay for bequest values

The overall mean WTP for bequest value (BV) ranged from US$ 3.5 to US$ 8.0/HH/year for all scenarios; these results are congruent with those of Kriström et al. (2001) who estimated US$10 to US$20/HH/year in Sweden. Other studies revealed rather higher (US$25.2 to US$ 107/HH/year) bequest values of the forests (Sattout et al. 2007; O'Garra 2009; Diafas et al. 2017).

The results revealed that irrespective of the spatial distance and economic category, forest users generally offered a high WTP in labour compared to cash for BV. The WTP results clearly indicate that they want to save forest resources for coming generations despite their economic status.

Our statistical analysis reveals that income is positively associated whereas distance from forest and household size is negatively associated with WTP of BV in the case of cash. Our findings are consistent with the findings of many other studies of income and household size (Togridou et al. 2006).

4.2.2 Willingness to pay for aesthetic values

AV refers to the appealing and inspirational aspects of the landscape (Beza 2010) and the pleasure (positive value) derived by human beings from forests. These benefits are highly appreciated. Studies on valuing the AV of forest landscapes are scarce especially in Nepal. Prior studies in Nepal are mostly related to tourism (Baral et al. 2016), ecotourism (Baral et al. 2008; Sharma et al. 2015) and recreational services (Birch et al. 2014; Sharma et al. 2019).

Overall, respondents on average were willing to pay US$ 2.2 to US$4.6/HH/year for AV service under different scenarios, which are similar to those reported by studies conducted in the USA, China and Spain (US$2.4 to US$7.0/HH/year) (Grala et al. 2012; Dou et al. 2017; Torres-Miralles et al. 2017). Other study results were high compared with our results (US$8.5 to US$24.5/HH/year) (Soy-Massoni et al. 2016; Aguilar et al. 2018).

Irrespective of the management modality and distance from forests, poor households in general offered almost eight times lower WTP compared to households in the rich category. One possible explanation for this relatively low WTP may be the respondents' other pressing needs such as housing, education of children and food requirements.

We have discussed some limitations of using the open-ended contingent valuation format and reviewed the ways suggested to overcome them, which we followed in this study. After in-depth assessment, we observed that (1) WTP increased with increasing quality of the forests and therefore there is consistency with rational choice; (2) variation in their responses in terms of cash and labor-based payment options showed that they are serious about the limitations of their disposable income; and (3) being long-term FES users, they are familiar with all the governing policies, rules and regulations of CBFM system, and therefore, they have a strong ability to assimilate and evaluate information provided to them. The logical WTP values for different forest conservation scenarios show that they valued the given environmental services wisely and meaningfully.

There are some more limitations to our study. As noted, we have estimated the value of high priority ES, i.e. flood control, water quality improvement, bequest and aesthetic values, through open-ended contingent valuation. Application of other methods such as the damage cost method for flood reduction and the replacement cost method for water quality improvement to estimate these values present alternative options to verify the WTP values of the respondents. These methods might have provided more accurate estimates. Moreover, due to the limitations of time and financial resources, this study has depended on a small sample size and focussed on one particular region of the Siwalik landscape. A large sample size covering a broad geographical area could provide more credible suggestions.

5 Conclusion

This study estimated the willingness to pay of four non-marketed ecosystem services (with six different scenarios) by members of households in community forestry and collaborative forest management systems in the *Siwalik* region of Nepal. The key conclusions of the study are:

- A large number of forest users (about 95%) from both community and collaborative forest management systems were willing to pay cash and labour for improvements in forest conditions.
- Willingness to pay for all four services is mostly shaped by economic status, distance from forests, household income and household size. For example, rich users living near a community forest showed a willingness to pay almost double for flood control compared to poor users living in the same area. These factors should be taken into account when estimating the willingness to pay for values arising from non-marketed ecosystem services.
- Researchers advocate that elicitation of willingness to pay for labour contribution is a better option in developing countries as people's opportunity cost of time is low. However, our research suggests such a blanket approach needs to be considered carefully. Nepal is a least developed country (LDC) and in our case study area, most of the rich households offered fewer labour-days compared to their cash offer, whereas the opposite was true for poor households. This is because the opportunity cost of time for rich people is higher than that of poor people. This suggests that the willingness to pay in the form of labour could be a better option only for poor households, regardless of their location.
- Although forest sub-groups from both community-based forest management arrangements offered willingness to pay for flood control and water quality services, these services are either not documented or not internalised in the existing forest operational plans. For instance, forest operational plans in Nepal nominate soil and water conservation services of forests as important ecosystem services, however, both forest management systems have implemented an irregular shelter wood system that massively opens up the canopy, leaving only a few trees, and undermining these services. Therefore, there is an urgent need to incorporate these services in the forest users' constitutions and operational plans during the revision of these documents.
- We have developed 24 different models for eliciting average WTPs from different regulating and cultural ecosystem services. The predicted WTP values using these models closely approximate those of observed WTP values. Therefore, researchers can use these models with confidence in similar socio-economic, biophysical, demographic and climatic settings.

Appendix 1. Locally adopted criteria to classify the four categories of users

Criteria	Rich	Medium	Poor	Very poor
Land holding (ha)	> 2	1–2	0.5–1	< 0.5
Occupation	> 2	2	1–2	Only 1
Food sufficiency from their own production	More than 12 months	9 to 12 months	6 to nine months	Less than six months
Livestock no	More than 5	3–5	2–3	Less than 2
Education level	College or above	SLC and above	Primary or above	Literate or illiterate
House types	Two or more storeyed/with concreted roof	Single or more storeyed/with stone or galvanised sheet roof		Single or more storeyed/with stone or galvanised sheet roof
Membership in social groups (e.g. cooperative members)	More than four	More than three	2–3	No or single

Appendix 2. Multicollinearity test using correlation among independent variables and through variance inflation factors

Example 1: Correlation among independent variables

Mag_Model Eco_Status Distant_For Gender Age_respon

Mag_Model 1.000000000 -0.004132231 0.004132231 0.23422051 0.12027882

Eco_Status -0.004132231 1.000000000 -0.004132231 -0.07610526 0.06922862

Distant_For 0.004132231 -0.004132231 1.000000000 0.30449395 0.23592988

Gender 0.234220507 -0.076105263 0.304493949 1.00000000 0.11965283

Age_respon 0.120278816 0.069228619 0.235929878 0.11965283 1.00000000

Tot_Fam_memb 0.106424115 -0.150165736 0.093926509 0.07964491 0.20294099

Edu_lev -0.236169147 -0.355520892 0.145566362 0.13136066 -0.16336161

Caste -0.198015272 0.299550763 -0.418008835 -0.27945908 -0.17506185

Inc_Ag_AH -0.066142236 -0.393592271 0.283632062 0.16897604 0.01903213

Tot_Inc -0.049706841 -0.599599531 0.095077437 0.10355071 0.03315137

Tot_Fam_memb Edu_lev Caste Inc_Ag_AH Tot_Inc

Mag_Model 0.10642411 -0.23616915 -0.19801527 -0.06614224 -0.04970684

Eco_Status -0.15016574 -0.35552089 0.29955076 -0.39359227 -0.59959953

Distant_For 0.09392651 0.14556636 -0.41800884 0.28363206 0.09507744

Gender 0.07964491 0.13136066 -0.27945908 0.16897604 0.10355071

Age_respon 0.20294099 -0.16336161 -0.17506185 0.01903213 0.03315137

Tot_Fam_memb 1.00000000 0.01223982 -0.09214273 0.07831156 0.26737239

Edu_lev 0.01223982 1.00000000 -0.26170423 0.37192634 0.41137370

Caste -0.09214273 -0.26170423 1.00000000 -0.41580778 -0.26424912

Inc_Ag_AH 0.07831156 0.37192634 -0.41580778 1.00000000 0.52744159

Example 2: Variance inflation factor (VIF) among independent variables

Mag_Model Eco_Status Distant_For Gender Age_respon Tot_Fam_memb

1.247215 1.710172 1.406110 1.216962 1.183831 1.147717

Edu_lev Caste Inc_Ag_AH Tot_Inc

1.479690 1.610020 1.673635 2.063163

Appendix 3. Six different model specifications to select fitted model

1) M1: Depedent variable (e.g.FR). ~ as.factor(Eco_Status) + # main variable (1|Caste) + (1|Distant_For) + (1|Gender) , # random variabledata=a.df,family="poisson")……………(1)
2) M2: Depedent variable ~ as.factor(Eco_Status) * as.factor(Caste) + as.factor(Gender) + # main variable (1|Distant_For), # random variable data=a.df,family="poisson")……………………(2)
3) M3: Depedent variable ~ as.factor (Eco_Status) + Tot_Fam_memb + Caste + Tot_Inc + as.

factor(Edu_lev),random = ~ 1|Distant_For/Gender,data = dt,family = "poisson")..................(3)

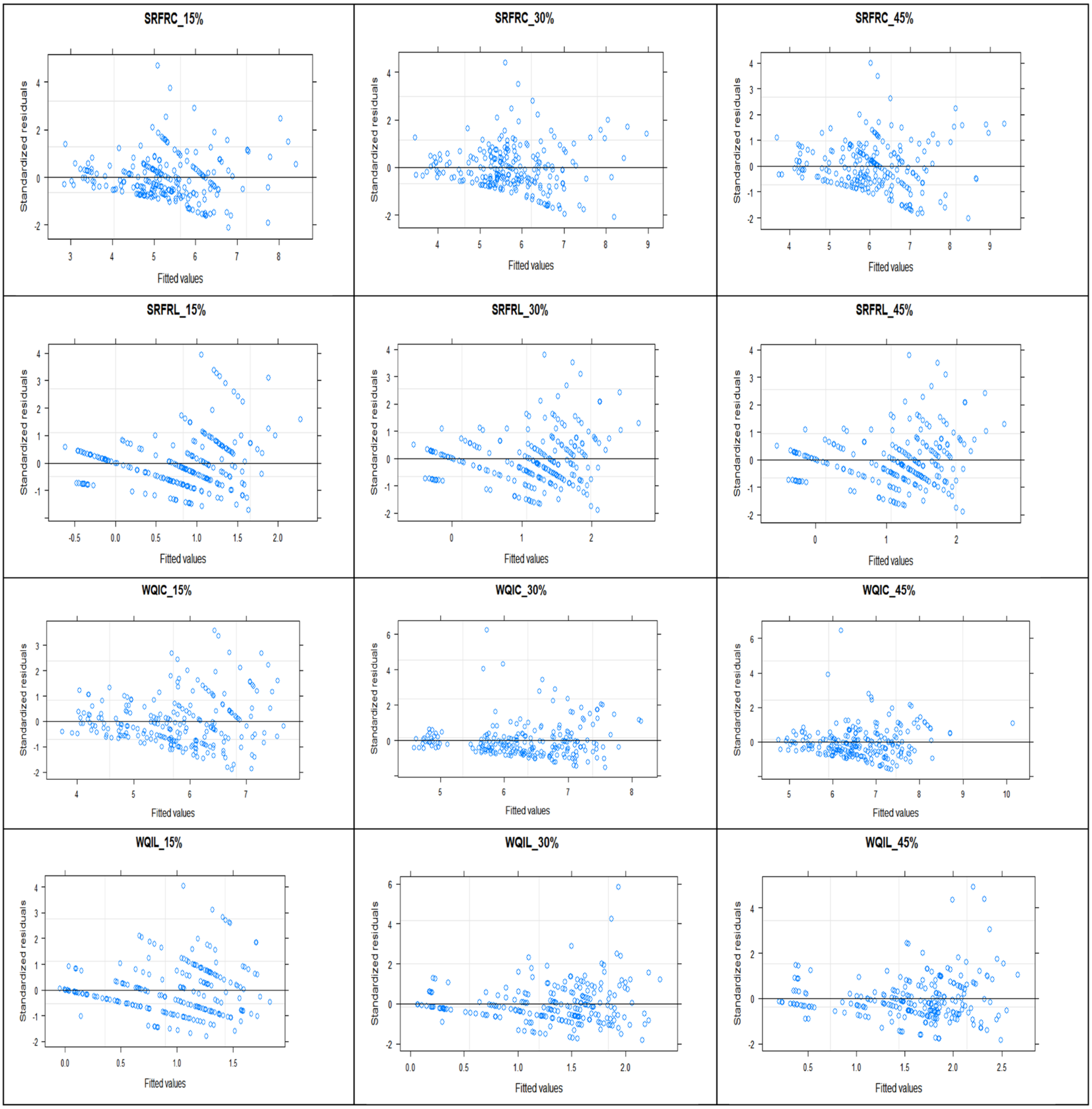
4) M4: Depedent variable ~ as.factor (Eco_Status) + as.factor(Edu_lev) + + As.factor(Distant_For)+as.factor(Tot_Fam_memb)+Tot_Inc+Caste+Gender, + random = ~ 1|Age_respon,data = dt,family = "poisson")........................(4).
5) M5: Depedent variable. ~ as.factor(Eco_Status) + Edu_lev + * as.factor(Distant_For) + Tot_Fam_memb + as.factor(Age_respon) # main variable (1|Caste/Gender), # random variable data = a.df,family = "poisson")..................(5)
6) M6: Dependent variable ~ as.factor(Eco_Status) + as.factor(Edu_lev) + as.factor(Distant_For) + Tot_Fam_memb + Tot_Inc + Caste, random = ~ 1|Gender/Age_respon, data = dt,family = "poisson")...................(6)

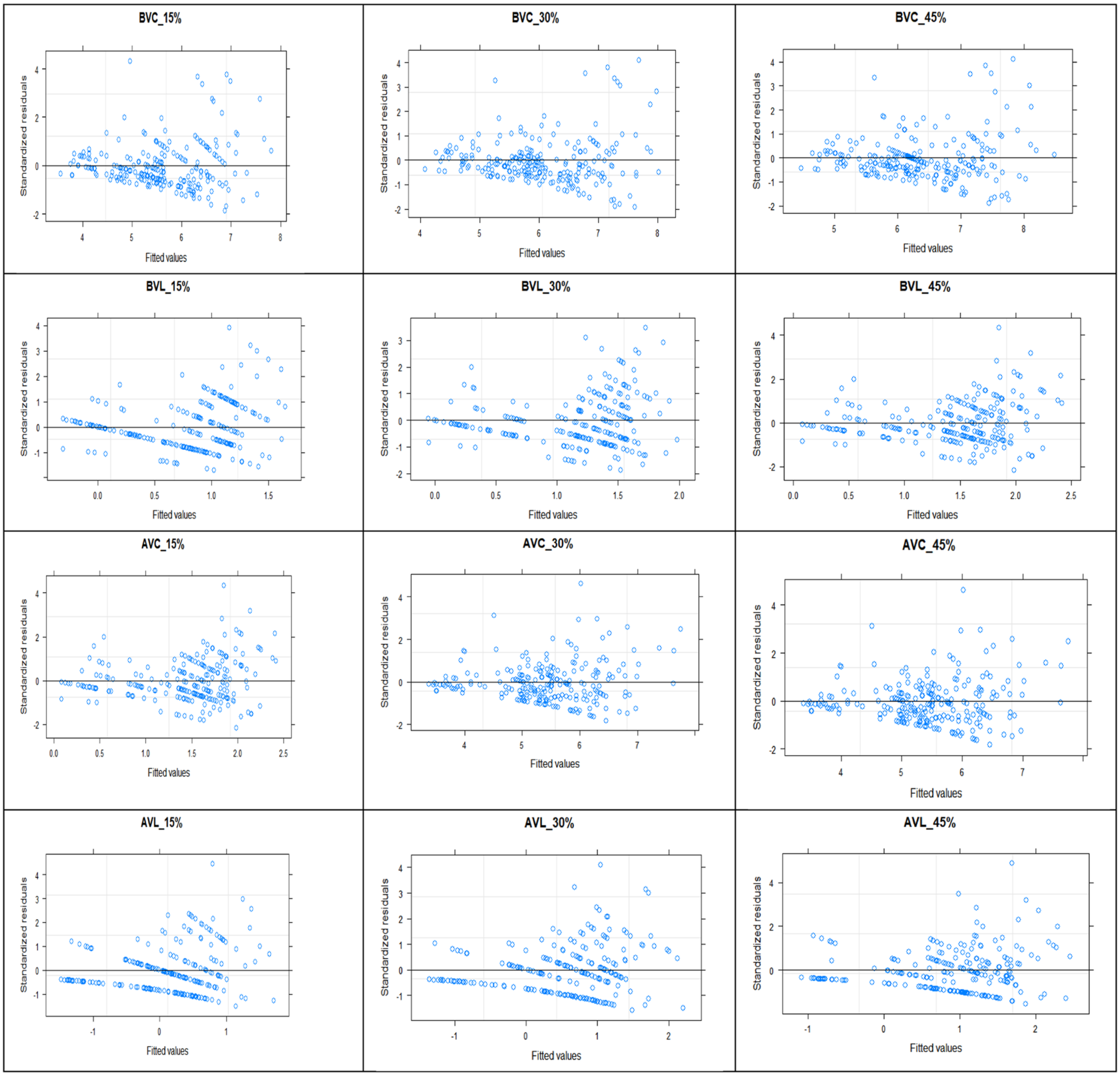
Appendix 4. X^2 Pearson's residual and adjusted R^2 values for all models

Model No	X^2 Pearson's residual	Adjusted R square	p value	Remarks
M1	1.02	0.097	4.94e−07	In M7, total income is drop from model
M2	1.025	0.11	6.44e−08	
M3	1.09	0.36	< 2.2e−16	
M4	1.093	0.74	< 2.2e−16	
M5	1.35	0.76	< 2.2e−16	
M6	1.85	0.80	2.2e−16	
M7	1.86	0.75	2.2e−16	

- The Pearson's residuals from neither model indicate a lack of fit or evidence of over dispersion of the fitted value (p values greater than 0.05).
- p Value is always less than 0.05 shows the significance of the fitted model.
- Adjusted R^2 value increases with progressive forward modelling.

Appendix 5. Standardised residuals and fitted values of all 24 selected fitted models





Appendix 6. Models for four high priority forest ecosystem services and six different scenarios

Model for flood control service prediction

1) Average of WTP of flood control value in cash (15%) = 6.757–0.623*AF(Eco_Status$_2$) + 0.888*AF(Edu_Lev$_2$)—0.573*AF(Dis_For$_2$)-0.0638*HH size + 0.000001* Tot_Inc—0.492 Caste2 ....(1)
2) Average of WTP of flood control value in cash (30%) = 7.01–0.533* AF(Eco_Status$_2$) + 0.821*AF(Edu_Lev$_2$)- 0.477*AF(Dis_For$_2$) + 0.000001*Tot_Inc – 0.526*Caste2 .... (6)
3) Average of flood control value in cash (45%) = 7.36–0.547* AF(Eco_Status$_2$) + 0.718*AF(Edu_Lev$_2$)—0.498*AF(Dis_For$_2$) + 0.000001*Tot_Inc – 0.539*Caste2 ....(3)
4) Average of flood control value in labour day (15%) = 0.89 + 0. 0.552*AF(Edu_Lev$_2$) – 0.467*AF(Dis_For$_2$) .... (4)
5) Average of flood control value in labour day (30%) = 1.38 + 0. 0.52*AF(Edu_Lev$_2$) – 0.484*AF(Dis_For$_2$) ....(5)
6) Average of flood control value in labour day (45%) = 1.80 + 0. 0.57*AF(Edu_Lev$_2$) – 0.122*AF(Dis_For$_2$) ....(6)

Model for water quality improvement services prediction

7) Average of WTP of Water Quality Improvement value in cash (15%) = 7.234 − 0.742*AF(Eco_Status_2) + 0.494*AF(Edu_Lev_2) − 1.208*AF(Dis_For_2)- 0.055*HH size + 0.000001* Tot_Inc − 0.256 Caste ....*(7)*
8) Average of WTP of Water Quality Improvement value in cash (30%) = 7.054 − 0.619*AF(Eco_Status_2) + 0.160*AF(Edu_Lev_2) − 0.920*AF(Dis_For_2)- 0.035*HH size + 0.000001* Tot_Inc − 0.027 Caste.........(8)
9) Average of WTP of Water Quality Improvement value in cash (45%) = 7.325 − 0.642*AF(Eco_Status_2) + 0.293*AF(Edu_Lev_2) − 0.77*AF(Dis_For_2) + 0.000001* Tot_Inc.......(9)
10) Average of WTP of Water Quality Improvement value in labour day (15%) = 1.467 − 0.235*AF(Eco_Status_2) + *0.40**AF(Edu_Lev_2) − 0.66*AF(Dis_For_2)...........(10)
11) Average of WTP of Water Quality Improvement value in labour day (30%) = 1.949 -0.257*AF(Eco_Status_2) + 0.442*AF(Edu_Lev_2) − 0.706*AF(Dis_For_2)...............(11)
12) Average of WTP of Water Quality Improvement value in labour day (45%) = 2.307- 0. 0.294* AF (Eco_Status)2 + 0.422*AF(Edu_Lev2)—0.628*AF(Dis_For2).......(12)

Model for bequest value prediction

13) Average of WTP of Bequest value in cash (15%) = 6.854 − 0.861*AF(Eco_Status_2) − 0.970*AF(Dis_For_2)—0.053*HH size + 0.000001* Tot_Inc ....*(13)*
14) Average of WTP of Bequest value in cash (30%) = 7.080 − 0.916*AF(Eco_Status2) − 0.741*AF(Dis_For2)—0.052*HH size + 0.000001* Tot_Inc...............(14)
15) Average of WTP of Bequest value in cash (45%) = 7.325 − 0.80*AF(Eco_Status2) − 0.69*AF(Dis_For2)—0.051*HH size 0.000001* Tot_Inc ....(15)
16) Average of WTP of bequest value in labour day (15%) = 1.08 + 0.273*AF(Eco_Status2) − 0.461*AF(Dis_For2)........(16)
17) Average of WTP of bequest value in labour day (30%) = 1.34 + 0.353*AF(Eco_Status2) − 0.446*AF(Dis_For2)........(17)
18) Average of WTP of bequest value in labour day (45%) = 1.65 + 0.293*AF(Eco_Status2) − 0.406*AF(Dis_For2)........(18)

Model for aesthetic value prediction

19) Average of WTP of Aesthetic value in cash (15%) = 6.182 − 0.502*AF(Eco_Status2) − 0.639*AF(Dis_For2) + 0.000001* Tot_Inc .... (19)
20) Average of WTP of Aesthetic value in cash (30%) = 6.429 − 0.482*AF(Eco_Status2) − 0.619*AF(Dis_For2) + 0.000001* Tot_Inc .... (20)
21) Average of WTP of Aesthetic value in cash (45%) = 6.445 − 0.553*AF(Eco_Status2) − 0.483*AF(Dis_For2) − 0.010*HH size 0.000001* Tot_Inc ....(21)
22) Average of WTP of Aesthetic value in labour day (15%) = 1.02 − 0.386*AF(Eco_Status2) + 0.607*AFEdu_lev2 − 0.675*AF(Dis_For2)........(22)
23) Average of WTP of Aesthetic value in labour day (30%) = 1.40 − 0.391*AF(Eco_Status2) + 0.686*AFEdu_lev2 − 0.719*AF(Dis_For2)........(23)
24) Average of WTP of Aesthetic value in labour day (45%) = 1.75 − 0.393*AF(Eco_Status2) + 0.677*AFEdu_lev2 − 0.665*AF(Dis_For2)........(24)

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical statement The authors declare that they obtained the approval of the USQ Human Research Ethics Committee (Approval No. H18REA127) for conducting the present study based on Interviews/survey.

Conflict of interest The authors declare that they have no conflict of interest.

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6 CHAPTER SIX: AN ECOSYSTEM SERVICES VALUATION RESEARCH FRAMEWORK FOR POLICY INTEGRATION

6.1 An Ecosystem Services valuation research framework for policy integration in developing countries: A case study from Nepal.

Foreword:

This chapter is an exact copy of the published research article in *Sustainability,* vol. 12, No 19 (2020), pp. 8250-65.

As one of the key ecosystems, research on forest ecosystem services play an important roles and adoption of recommendations in the policies and plans needs to be explored. Recognising the broader aspect of forest ecosystem services research implication in developing countries, this chapter explores why FES research outcomes are not incorporated in policies and plans and proposes a framework for FES research which is believed to be helpful for policy integration in developing countries. Taking case study from Nepal and employing in-depth experts interviews and workshop methods, this article explores that limited stakeholder engagement is the key factor hindering incorporation of FES related research outcomes in policies and plans. The framework comprises four components (inputs, actors, outcomes and impacts) and sets out seven major steps. Effective engagement of relevant stakeholders in each step is critical, while it demands high financial resources and requires a lengthy timeframe. Such engagement would create an environment of trust that enhances the acceptability of research outcomes among stakeholders. ultimately yielding a desired outcome in the forest ecosystem services.

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Article

An Ecosystem Services Valuation Research Framework for Policy Integration in Developing Countries: A Case Study from Nepal

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Abstract: Forest ecosystem services (ES) valuation research has increased exponentially in recent years, and scholars accept that such research could be useful in reshaping governments' policies. Despite such scholarly efforts, the research outcomes have had limited application in actual policies and plans. This study explores reasons why ES valuation research recommendations are not reflected in policy processes and proposes a research framework which, when appropriately applied, would lead to the adoption of research findings. Literature review, semi-structured expert interviews (N = 29), and a workshop (N = 2), were used to achieve these objectives. Experts expressed that limited stakeholder engagement is the key factor hindering incorporation of ES research outcomes in policies and plans. We developed a framework that comprises four major components (inputs, actors, outcomes, impacts) and sets out the seven major steps involved in implementing this framework. Effective engagement of relevant stakeholders in each step is critical to integrate the ES research outcomes in policy and plans although this will demand a lengthy timeframe and a high investment requirement. Such engagement would create an environment of trust that enhances the acceptability of research outcomes among stakeholders. The acceptability of the research outcomes can increase ownership leading to more informed decision making, and ultimately yield desired outcomes in ES conservation.

Keywords: forest ecosystem services; research; framework; policy adoption

1. Introduction

Forests, the Earth's largest terrestrial ecosystems, provide a myriad of important services to human society. Forest ecosystem services (hereafter ES) play a crucial role in sustaining people's livelihoods, the environment, and the economy [1,2]. Many ecosystems including the forests across the globe are degrading despite significant conservation efforts; the extent of this depletion is more pronounced in developing countries [3–6]. Limited knowledge about the values of ES and poor adoption of findings in the decision-making processes are the main reasons for this depletion.

In recent years, ES valuation research has proliferated at an exponential rate. One of the objectives of ES valuation research is to include both use and non-use values in the policy process. Many seminal works [7–9] and scholars [10–13] have identified the role of ES valuation studies in informing and reshaping policies. Some studies have attempted to identify the level of influence of ES valuation studies' recommendations in policy improvement in high income countries such as Australia, New Zealand, USA, and the European Union, including Germany [14–19]. Despite increased scholarly efforts, little research has been conducted to explore the use of research outcomes in actual policy and management decisions, especially in low-income countries.

Some studies have explored the state of integration of ES values in policies and plans and have acknowledged multiple attributes that can govern the integration of research recommendations into policies and plans. Common attributes include proper communication with and meaningful participation (critical engagement) of relevant stakeholders throughout the research process [15,20–22], and capacity building including training of policymakers [23]. However, no previous studies have investigated the reasons behind the limited integration of outcomes of ES research in policy and plans focusing on low-income countries [13].

Drawing on insights gained through one-on-one expert consultations, and in workshops at local to national level in a low-income country, Nepal, this paper explores why ES research findings have not been incorporated into policies and plans. We propose a research framework for policy adoption of ES research outcomes in developing countries.

An understanding of the state of ES research and resultant policy uptake can contribute to the design of future ES research in such a way that policies acknowledge the findings and mainstream the outcomes. Potential contributions include: (i) it helps in designing appropriate research frameworks in developing countries; (ii) it creates an in-depth knowledge base highlighting the importance of ES to relevant stakeholders that can be helpful in improving livelihoods of forest-dependent communities; (iii) study findings help reform policies and plans of the natural resource management sector to ensure sustainable management of the forests; (iv) it will help to refine the national accounting system of the forestry sector so that the contribution of forestry can be better visualised by the different stakeholders including policymakers.

2. Materials and Methods

2.1. Selection of Case Study Site

Nepal was chosen for the case study site from the low-income countries. Nepal, a beautiful mountainous country with unique and diverse geography, hosts 118 different types of ecosystems and natural habitats and harbours many critical forest ES, ranging from provision of timber, firewood, fodder and conserving soil and water to climate-related services [24,25].

The country is relatively small, occupying about 0.1 percent of the global area, but ranks 25th in terms of biodiversity [24]. It possesses 3.2 percent and 1.1 percent of the world's known flora and fauna, respectively [26,27]. Similarly, Nepal is renowned for community-based forest management modalities globally, with more than 2.5 million hectares of forests under the community-based forest management (CBFM) system [28]. Nepal has witnessed many shifts in policies and plans, from state control to community-based management, and faces serious threats to its rich ecosystems. Moreover, Nepal recently inaugurated a federal political structure authorising the seven provincial states to manage their existing CBFM modalities. There is growing fear among forest users that this may de-establish the CBFM system and further degrade forest ES [29].

2.2. Data Collection Methods

We employed both primary and secondary sources for data collection. Systematic reviews of published literature [3], syntheses of policies and plans related to forest ES, expert consultations, as well as stakeholder workshops, were the main methods for data collection. We employed qualitative methods such as content analysis, expert consultation and workshops. A list of the pertinent literature that deals with how to incorporate research outcomes in policies and plans is provided in Supplementary Material 1.

2.3. Expert Consultation

Twenty-nine semi-structured in-depth interviews were conducted one-on-one with policymakers, researchers, academics, government officials, and persons working in ES conservation and management and their details are provided in Table 1. Policymakers and other respondents were chosen since they represent the government and public institutions and, at the same time, they were engaged in ES research and publications. We devised a semi-structure questionnaire based on a review of the extant literature on ES. The questionnaire consisted of two sections. The first section records personal data: name, gender, age, education level, affiliation, experience in ES research and publications, and the major area of expertise of the respondents. The second section of the questionnaire covers knowledge/gaps in ES valuation at an organizational and individual level, application of research knowledge in management and decision making, methods applied to conduct the research and a number of policy recommendations. The section also investigates why more of the research recommendations have not been incorporated into the policies/plans and steps and issues that can be crucial for policy adoption (see Supplementary Material 2 for details).

Table 1. Types of experts, institutions and expertise consulted during the consultation (N = 29).

Affiliation	Types of Expertise	No. of Respondents
Government (9)	Biodiversity/Wildlife	1
	Economics	-
	Forestry	4
	Soil conservation	3
	Research/policy	1
Non-government organisation (12)	Biodiversity/Wildlife	2
	Economics	3
	Forestry	4
	Soil conservation	1
	Research/policy	2
Academic (3)	Biodiversity/Wildlife	1
	Economics	1
	Forestry	-
	Soil conservation	-
	Research/policy	1
Private (5)	Biodiversity/Wildlife	1
	Economics	1
	Forestry	1
	Soil conservation	1
	Research/policy	1

Table 2 provides socio-demographic information (gender, age, education, expertise, experience and number of publications) of the experts. Overall, the median age of the respondents is 52 years. The majority of the respondents had attained a PhD degree in forestry or environmental economics; the second highest number had a masters level education in forestry. The respondents had an average of more than 25 years of experience in the fields of biodiversity, forestry, economics and soil conservation. Moreover, all the participants were familiar with the concepts of ES and had been involved in planning, implementation and research on ES-related activities.

Table 2. Demographic characteristics of the respondents.

Demographic Characteristics	Respondents	Research Outcomes Adoption %
Gender (number of respondents)	Male (26) Female (3)	15 13
Age (median age year)	52	-
Education (number)	PhD (16) Masters (12) Graduate (1)	16 12 9
Expertise	Biodiversity/WL (5) Economics (5) Forestry (10) Soil conservation (5) Research/policy (4)	14 12 12 17 8
Experience (year)	25	-
Number of publications (average and range)	25 (8–195)	-

2.4. Workshops

The research framework was developed by first reviewing relevant literature, then consulting with local, regional, national and international level experts, and finally an in-depth analysis of the information. Then, two day-long workshops (N = 2) were conducted at national and regional levels to refine and receive feedback on the framework developed. The first workshop was organised in Kathmandu, where many policymakers such as members of national planning commissions, departmental heads, members of the President Chure-Tarai Conservation and Development Board, Academia and other experts were present. In the workshops, we presented the state of ES research globally, categorised the research gaps in forest ES, and speculated on reasons for non-adoption of forest ES research recommendations. We also shared the proposed research methods to obtain feedback on how forest ES research recommendations could be better integrated into policies and plans. The second workshop was organised at the Institute of Forestry, *Hedauda*, where members of the Bagmati Province Planning Commission, the Dean of the Institute of Forestry, faculty members of the Economics, Environment, and Botany Departments and students attended. During the workshop, we shared the preliminary findings from the literature about the reasons for not adopting ES research outcomes in policies and plans and elicited from participants the key challenges they perceived in ES research. The researcher presented the draft preliminary framework to receive participants' feedback. After intensive discussion, these workshops refined the draft research framework.

2.5. Data Analysis

The data were analysed using qualitative analysis techniques such as thematic/content analysis, coding and interpretation techniques. We followed the stepwise techniques of content analysis following Poudyal, Maraseni [30], which consist of categorisation of experts' opinions and views, labelling them based on the content. Qualitative data analysis software NVIVO v11 was used to analyse the major steps that the experts emphasised during their interviews. The views expressed by the experts regarding the reasons behind the lack of integration of research outcomes in policies were categorised into five major groups: (i) limited multiple stakeholders' engagement; (ii) lack of proper dissemination mechanisms; (iii) no actual reflection of on-the-ground reality; (iv) lack of appropriate and sound research methods; (v) research conducted in isolation.

2.6. Framework Finalization

During the workshop, we drafted a research framework that consists of four major components (inputs, actors, outcomes, impacts) and detailed the seven major steps in the research process: (i) conceptualisation, (ii) planning, (iii) data collection, (iv) triangulation, (v) analysis and reporting,

(vi) policy recommendation, and (vii) policy adoption. The workshop participants also provided some general guidelines for each step. After the workshop, we documented all the suggestions of participants and experts, and then shared with them to confirm: (i) that their views are clearly reflected in the framework; (ii) the explanation for each step is satisfactory. Their feedback was incorporated when finalising the final framework and its key explanations.

3. Results and Discussion

3.1. Reasons for Non-Adoption of Forest Ecosystem Services Research

Experts working in ES research identified many reasons that hinder the research outcomes from being incorporated into the ES policies and plans. Four out of five respondents suggested that limited stakeholder engagement is the key factor hindering incorporation of ES research recommendations. The second main reason identified was the lack of appropriate mechanisms for disseminating outcomes of ES research. Figure 1 presents the reasons suggested for why ES research recommendations are not incorporated into forestry-related policies and plans.

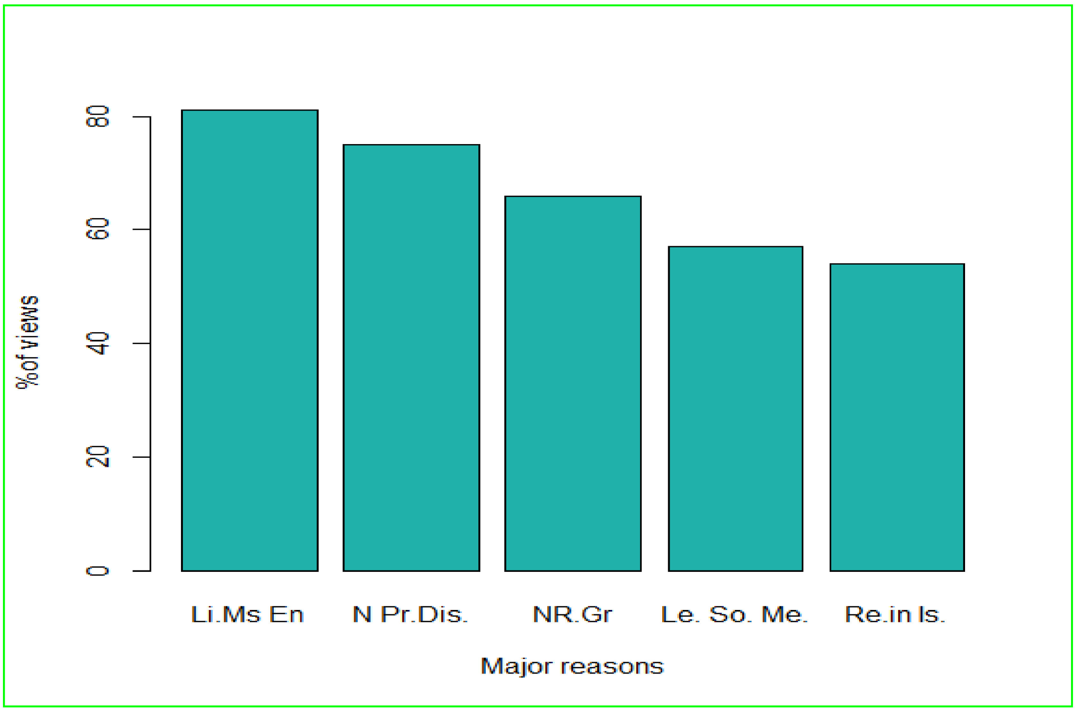

Figure 1. Reasons for non-adoption of forest ecosystem services research outcomes in Nepal; Li. Ms En. = Limited Multi-stakeholder engagement; N Pr. Dis. = Lack of proper dissemination mechanisms; NR Gr. = No actual reflection of on-the-ground reality; Le So Me = Lack of appropriate and sound methods adopted; Re. in Is. = Research conducted in isolation.

Many researchers report similar findings in relation to ES research in Nepal and in other countries about stakeholder engagement. For example, Ojha and his team [31] emphasized that strong engagement of stakeholders for collaborative enquiry is essential for influencing better policy outcomes in Nepal; they argue that this is still a crucial issue in the policy–research interface. Similarly, some authors [15,32] highlighted that critical stakeholder engagement is one of the main issues in the policy process, while another study [33] stressed that poor access and the limited capacity of the stakeholders to be involved in the policy process is the key issue to be addressed.

Twenty-one respondents identified the lack of a proper mechanism to disseminate research outcomes as the key reason hindering uptake of ES research findings in the policies and plans in Nepal. Global studies support this finding. For example, Keenan and his team [17] explore the key impediments to integration of the ES research outcomes in the context of Australia; they argue that no appropriate mechanism has been devised to encourage uptake of ES research outcomes. Similarly, three out of five respondents agreed that lack of appropriate and sound methods of data collection impede the integration of relevant ES research into policies and plans. They further elaborated that ES research requires reliable and trustworthy data to convince the policymakers, concurring with the findings of other scholars who advocated for presentation of pertinent and reliable data to persuade the policymakers [22,32,34].

3.2. Proposed Framework of Research in Forest Ecosystem Services Research

The proposed research framework consists of four major components and seven major steps. In each step, the inputs, actors involved, outcomes and the expected impacts are also detailed in the framework (see Figure 2).

3.2.1. Conceptualisation

The conceptualisation of research needs, and identification of the problems comprise the first key step in ES research. Most of the experts held that the research needs/problem identification should be carried out among a set of stakeholders such as researchers, government officials, rights-holders/stakeholders, forest users and experts to make research outcomes able to be adopted in the policy process.

Many researchers globally acknowledged that who leads and who is involved in the ES research conceptualisation is the key step for integration of the research outcomes into policies and plans [15,21,22,35,36]. In the conceptualisation of the ES research, there is a need to brainstorm the potential research and policy actors while developing the ES research problem. If the ES researcher makes an effort to engage a range of stakeholders from local to national level including forest users, representatives of different sub-groups, users, executive committee members, local authorities, local leaders, regional managers, national stakeholders and rights-holders during the process of conceptualisation, this step can certainly underpin the credibility of the research, provide opportunities for better reflection of context and visualise the problems and issues [15,21,37]. In addition, the engagement of stakeholders in conceptualisation can aid the in-depth analysis of the problems from many angles and empower stakeholders in the forest ES-related issues [20,33,38].

Before finalisation of the problem, the researcher should make a field visit to assess the on-the-ground reality. One of the experts stressed that the field visit is necessary to communicate the whole process to the local stakeholders so that local people can formulate and collaborate in the development of the research problem and also own the research processes from the very beginning.

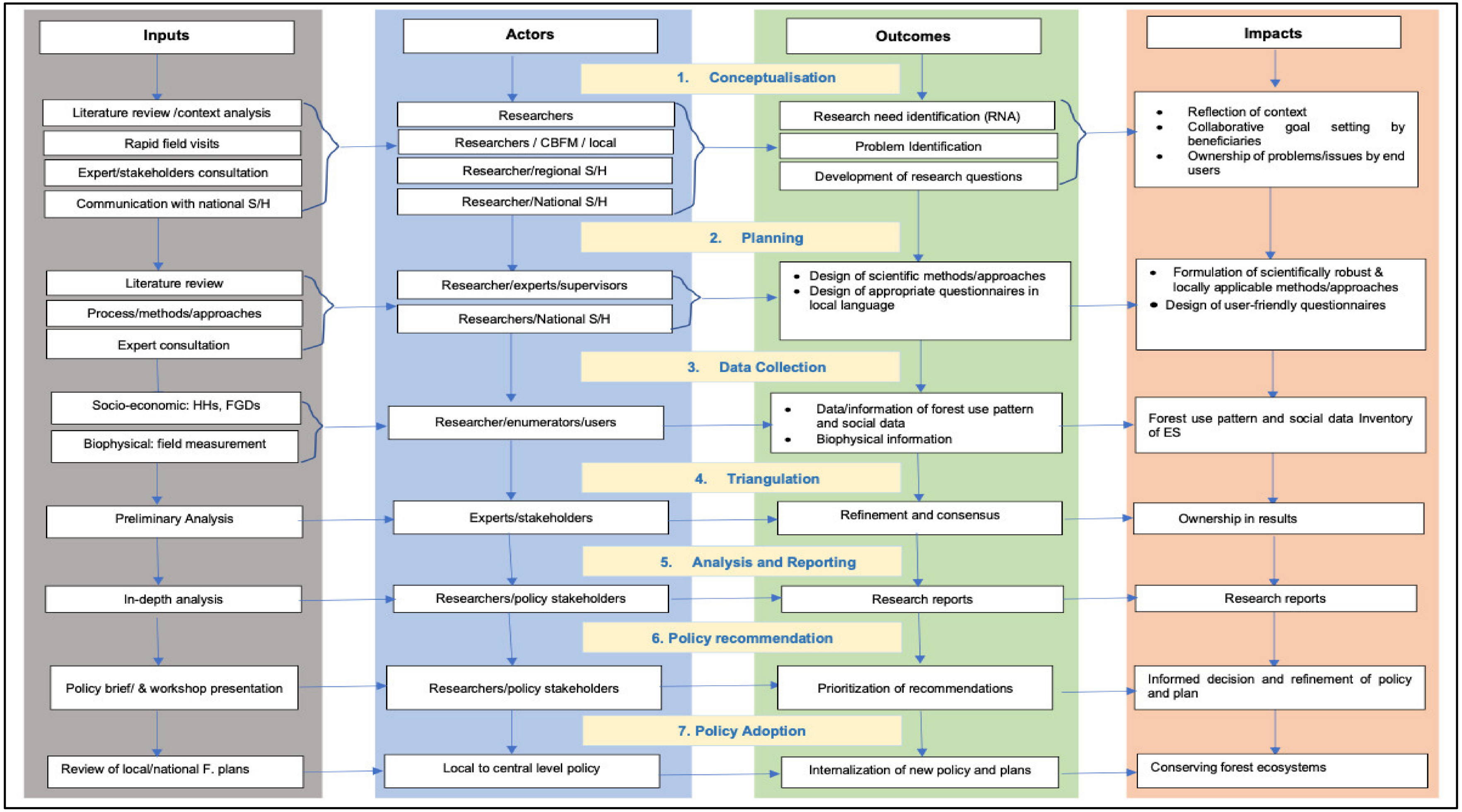

Figure 2. Proposed framework of ecosystem services (ES) research outcomes for policy adoption in developing countries. S/H: Stakeholders; HH: Households; FGD: Focus Group Discussion; F. plans: Forest management plans; CBFM: Community based forest management.

3.2.2. Planning

The second step of the framework is planning the ES research. The planning process comprises mainly the development of the research approach, the methods, and the processes. Experts in Nepal recommended that a range of stakeholders needs to be engaged to make the research process trustworthy and transparent. They reasoned that the potential stakeholders for the planning step should include researchers, experts, forest officials, political opinion leaders, local authorities, representative of forest users, rights-holders and representatives of the media.

Scholars globally acknowledge that ES research needs to involve various stakeholders in the planning process [20,32,39,40]. How we can engage different stakeholders in the planning process is the key issue in the ES research. Paudyal and his team [41] stressed that this can be achieved either through regular meetings and interactions, such as national workshops or one-on-one consultation meetings among the stakeholders. Experts recommended a national level stakeholder workshop as an effective avenue where researchers can share approaches, methods, and key processes of the ES research. This workshop would ensure improved communication among the key policy-level players and practitioners and could be helpful in bringing about a consensus on the methods to be used among stakeholders and rights-holders. Moreover, this type of consultation may generate a sense of ownership among key stakeholders and scientists on the process, approaches and methods of the research, which would ultimately improve the quality of the research processes [40].

Some researchers identified a clear gap in empowering the stakeholders in the ES research process [33,42]. These studies suggested that stakeholders from the local level, for example, forest users and executive members and local keypersons working in forest management and ES and rights-holders, as well as experts, should be involved in the process of any ES research planning process. If the ES research involves these stakeholders in the design and development of the approaches and methods, this can be helpful in formulating scientifically robust and locally applicable methods. Furthermore, the research can develop a questionnaire and other tools in a local language so that it is easy to explain the issues at the local level.

3.2.3. Data Collection

One of the crucial steps in ES research is to generate reliable data and persuade policymakers about the value of the ES. Respondents expressed that ES research demands both biophysical and social information to estimate the reliable economic contribution of forests. They added that all ecological data, such as forest condition, canopy cover and soil erosion, are examples of biophysical data, while socio-demographic information, for example, household size, demand for forest services, livestock holdings, and income are social information.

Prior studies agree that reliable data are required to persuade the policymakers about the ES research outcomes [31,34] and other scholars acknowledge that ES research demands both social and ecological information to produce acceptable ES research outcomes that are applicable to policy [22]. Records of ES use patterns, especially provisioning services, are, however, not adequately recorded in the developing countries [39,43]. Moreover, regulating services such as water quality improvement, flood reduction, and soil conservation from forest management require complex and long-term observations, records and data. These types of data are not easily available in data-poor regions such as Nepal [44–46]. Therefore, researchers in developing countries must rely on social and participatory methods of data collection.

Experts indicated that due to the limited availability of reliable biophysical data, the research team must employ participatory data collection methods from national to local level in developing countries. For this, we need a trustworthy network at national, regional, and local level. The research team can and should develop good relationships at local level so that local forest users can share real information related to ES resource use. Experts further suggest that this process can be fostered either by building good rapport with local people or by hiring local enumerators to collate the social information, or both. Many regulating services require a body of long-term biophysical data. For example, if we want to evaluate the soil retention benefits from forest conservation, we need to find soil erosion rates and quantify the soil nutrients in the area over the long term. These types of information are usually not available in developing countries like Nepal. However, soil conservation is one of the most important values and, therefore, should not be neglected. These values might have to be inferred from some other local practices, methods and data [47].

Social data collection methods (for example, household surveys and focus group discussions) are among the key methods that can be used where the ES use patterns have not been adequately recorded. These methods encourage social interactions and have potential for positive direct communication with local level stakeholders including local forest users [34]. The use patterns among particular local sub-groups could also be different and depend on a range of factors [48,49]. Thus, using stratified random sampling, researchers should collect information on the ES use among different sub-groups focusing on proximity to a forest, socio-economic status and forest management modalities in the local area [50].

3.2.4. Triangulation

Triangulation is the process of validating data collected from various sources such as household survey, focus group discussion, records from forest users and other records from forest offices. Triangulation helps to ensure high quality, transparent and reliable data, from trustworthy sources. Multiple data collection techniques and data sources can be used to generate high-quality data. For this, the data generated should be triangulated, from local to national level, to ensure the results are credible.

Experts suggest multiple methods to triangulate ES use data at local level in the context of Nepal. For example, if we assessed the timber collection and use through a household survey of each household, the household information on timber use at the local level could be verified with executive members and minutes/records of the forest users' committees. Other possible ways of triangulation could include focus group discussions at local level to elicit the same information or triangulate from district forest offices' records. Some biophysical data are not easily available and could not be verified due to lack of recorded data. To estimate the flood reduction (FR) benefits at household level, for instance, there would be no data available at the local level. In many cases, scholars calculate the FR value through contingent valuation methods [47,51,52]. In such situations, we can validate the data using the damage cost method, to verify the reliability of the willingness to pay of the users.

Such triangulation can be helpful in refining the available data. This could be useful to achieve consensus among the results and can increase the ownership of the findings among the stakeholders. If the data are reliable and results are produced on a consensus basis, this could create a trust situation that would convince the policymakers and might lead to adoption in policy of the ES research outcomes.

3.2.5. Analysis and Reporting

The data analysis involves in-depth collation, tabulation, synthesis and interpretation of both biophysical and social data. ES research demands much sophisticated software and hardware to analyse the data. These methods should be both easy to understand and cost effective. The data should be analysed and presented in an appropriate way so that the policymakers and other stakeholders can trust the outcomes of the research.

One way of making the results trustworthy and achieving consensus is involving many policymakers and other potential stakeholders in the in-depth analysis. While it is time-consuming and costly, this requires intensive and extensive interactions and dedication of the researchers [53], as practised in our research. If the research process ensures the sincere engagement of the stakeholders even in data analysis and reporting, this can create a trustworthy environment. Such engagement can build ownership in the research outcomes among policymakers and other stakeholders; however, it is not always possible to involve them in the process because they are always busy with many other activities. In addition, many data analysis processes demand technical and specific expertise in which there is no possibility to involve stakeholders and policymakers in every step. In such cases, the researcher needs to share at least the process of data analysis, in order to help convince policymakers and resource managers of the benefits of the potential research outcomes [53–55]. Several rounds of restatement of the outcomes among the stakeholders can increase the chances of acceptability of the outcomes by the policymakers [32].

The experts opined that ES researchers should decide how the results should be used. If results are targeted to policy inferences, there should be a detailed analysis and they should produce accurate outcomes [21]. The results could be compared with the national gross domestic or highly influential communicable indicators so that policymakers can compare the investment with the potential losses and gains [21,36]. In addition, the outcomes should be reported in a pictorial mode as graphs, histograms and other appealing forms to convince the local people.

The researchers often face two types of criticism from the stakeholders. First, research outcomes are not properly disseminated among the stakeholders, including policymakers and/or managers. Second, most of the research outcomes do not reflect on-the-ground reality. That is probably the main reason why policy players often reject the outcomes of the ES-related research in developing countries.

3.2.6. Policy Recommendations

Based on the outcomes of the analysis carried out in this study, ES research can offer a set of recommendations. Respondents emphasised that ES research recommendations should be categorised based on cost and required resources for implementation, the urgency of the research outcomes, and a timeframe to implement such recommendations. To implement the ES research recommendations properly, we should identify the role of different stakeholders including the role of the private sector which is engaged in ES management. If we prioritise the recommendations, clearly stating the roles of stakeholders, the likelihood of ES research adoption is high.

These recommendations could be presented in several different forms such as policy briefs, workshop presentations or in the form of journal articles based on the target audiences. If the recommendations are targeted to particular scientific communities, the policy recommendations could be published in high impact journals, in appropriate, peer-reviewed publications. Similarly, if the target of the recommendations is policymakers, the most effective recommendations could be policy briefs or policy-related presentations. Experts recommended that effective communication should be established within every step 1–5 (Conceptualisation, Planning, Data collection, Triangulation, Analysis and reporting) so that policymakers can take up the policy recommendations. They added that a policy brief could be effective if there were numerical and easily understandable indicators. Therefore, we need to use maximum relevant figures and graphs in the policy briefs.

While the recommendations are targeted to local level users, the recommendations could be incorporated in action plans. The content and language of the recommendations point to another major issue when targeting local users. Complex, scientific jargon and heavily weighted language can impede the uptake of the ES research outcomes [56,57]. Pictorial presentation, use of different colours for quantification, and using the local language could be helpful in persuading people to adopt the action plans [58]. For example, if the researchers would like to adopt the conservation or ecosystem restoration projects in the Chure and Tarai landscape in Nepal, an action plan should be formulated in *Maithli, Bhokpuri, Abadhi* and *Tharu* languages, so that the local people can appreciate and integrate the recommendations.

The experts also suggested that both the process and venue of policy discussion could impact the integration of the policy recommendation. One recent study conducted in Nepal on the science–policy interface concluded that policy processes were often led either by government, civil society or donor agencies. These agencies are rarely able to agree with each other and policymakers mostly ignore their recommendation although the recommendation could be very useful [31]. To overcome this impasse, the researchers can facilitate several small-group discussions rather than organising one big meeting that includes many stakeholders. If the deliberations are conducted in small groups and presented in calm, neutral language, a small group can discuss and take up recommendations, which in turn can help inform decisions, policy and plan refinement and prioritisation of scarce resources. However, such groups should still include all relevant stakeholders.

3.2.7. Policy Adoption

Based on the ES research information and recommendations, decisionmakers and resource managers can compare the different recommendations and can select the appropriate recommendations. The recommendations can be integrated into policy and plans through inclusion in policy, plans or institutional arrangements. Similarly, the policies or plans are typically operationalised and the interventions could be designed as some form of regulation or incentives proposed in a variety of different forms.

Our experts indicated that the policy adoption could be on two different scales. First, it could be internalised at the national level, where the policymakers can review the relevant forest and other land use policies and plans and accordingly initiate the internalisation of the recommendations by improving, reframing, or redirecting these documents in line with the new recommendations. Second, regional and local level management bodies can review and formulate actions/activities at landscape or management unit levels as per the recommendations to restore or enhance the impaired ES that was also reinstated, as suggested by Bagstad and Johnson [59].

Some of the challenges to internalise the ES research outcomes in policy and plans are a mismatch of the timeframe, availability of windows of opportunity and the mechanisms adopted in the communication of such recommendations [22,32]. Likewise, limited regular monitoring and evaluation of the policy adoption process further hinders integration of the research outcomes in the context of the developing countries.

4. Conclusions

The volume of forest ecosystem services (ES) valuation research has expanded at an exponential rate and its role in informing and reshaping policies has been unanimously accepted by scholars. This study finds that ES researchers do not follow the fundamental steps that can help to incorporate the outcomes of research in policies and plans and that this is mainly due to limited research resources. In this study, we identified seven major steps: (i) conceptualisation, (ii) planning, (iii) data collection, (iv) triangulation, (v) analysis and reporting, (vi) policy recommendation, and (vii) policy adoption, which, if followed appropriately by the researchers can add value if incorporated into the research recommendations in the policy process in Nepal and developing countries.

Application of the deliberative and participatory approach in each step is critical. Although this demands a long-term and high investment to generate policy-relevant research outcomes, these steps are unavoidable to render the environment for research outcomes acceptable. If we follow these steps, the outcomes can create a trustworthy environment among the stakeholders, a feeling of ownership of the process, and acceptance of the results by policymakers. This can lead to informed decision making, and ultimately generate sustainable "win–win" scenarios for all stakeholders.

The outcomes of forest ecosystem research should match the level and objectives of target audiences. A proper communication strategy, timing, and language of the research outcomes need to be considered while aiming to influence policy through results of ES research. For example, if we wish to incorporate ES recommendations in forest management plans at local level, those recommendations should be site-specific and delivered in a local language. Likewise, if the target is for broader audiences and policymakers, a well-developed communication and outreach strategy is a must. Such strategies should be able to utilise diverse media platforms, such as traditional and social media, that allow for both widespread and targeted communication of the results.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/19/8250/s1, Supplementary Material 1: Some relevant reviewed literature for the adoption of research outcomes in policies and plans; Supplementary Material 2: Checklist for national level expert consultation.

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7 CHAPTER SEVEN: CONCLUSIONS, POLICY IMPLICATIONS AND RECOMMENDATIONS

7.1 Conclusions and synthesis

Ecosystem Services (ES) are rapidly depleting across the globe with the deterioration of the ecosystems which are their sources. Being one of the major ecosystem services, Forest Ecosystem Services (FES), which are crucial for sustaining people's livelihoods, are also reducing, and the extent of that depletion is more noticeable in low-income countries. Insufficient knowledge about the values of FES and poor adoption of research findings in policies and plans could be contributing to FES depletion. With one aim being expanding knowledge of forest ecosystem valuation research, this study investigated the global tendencies and patterns of FES research, identified the FES research gap, and then identified the major FES and the different priorities placed on them by different forest users from two dominant community-based forest management (CBFM) in Nepal. This study has also assessed the economic values of provisioning, regulating and cultural services for different subgroups in two prime CBFM systems in Nepal and explored why FES research outcomes are not incorporated into policies and plans.

The objectives as stated in Chapter One were achieved through (i) a systematic non-statistical meta-analysis of global publications in FES; (ii) a review, focus group discussion, and in-depth interviews with key stakeholders to enable FES identification and prioritisation; (iii) investigation of market price, substitute goods price, contingent valuation for provisioning services, regulating and cultural services, respectively; and (iv) an exploration of potential reasons for not incorporating the outcomes in policies and plans and frameworks. This was approached by carrying out in-depth interviews with experts, and workshops and content analysis.

7.1.1 State of FES research and knowledge gaps

As noted in Chapter One, the first gap was critically examined following a systematic review approach, which established the knowledge gaps in the existing FES research despite the current global FES research endeavour. Applying a meta-analysis by way of a systematic review of a *ScienceDirect* database, which provides the full text of journal papers, the study identified the historical trends, the origins of forest valuation research, especially biomes, countries' economies, and forest management modalities. One of the key findings in terms of management modalities was that the FES studies have mostly been carried out on public land/government-managed forests and protected area systems, whereas limited research (<3%) was directed to CBFM, which shares more than 15% and 31% of the forests in developed and developing countries, respectively.

7.1.2 Identification and prioritization of FES in CF and CFM

The detailed cataloguing of the published literature on FES revealed that scholarly and academic endeavours in FES valuation were mainly focused on high and middle-income countries in the European and northern American continents. Countries with high forest biodiversity and low incomes, where forest ecosystems are critical for the livelihoods of many forest-dependent communities, were given less attention. Furthermore, the review showed that the FES valuation of CBFM that considers the different subgroups of users is almost lacking, thus substantiating the rationale behind the present study.

From the review of the literature and Focus Group Discussion (FGD) in both CF and CFM, this study identified a total of 42 different FES and their priorities to local users, based on management modalities (CF vs CFM), economic status (rich vs poor) and spatial distance from a forest (nearby vs distant) in the *Chure* region. The FGD and in-depth interviews with key stakeholders revealed that the priorities placed on individual FES differ among different subgroups. From these different priorities among subgroups, it can be concluded that nearby users placed high priority to subsistence use direct FES (firewood, fodder, grasses, and grazing services), while distant users chose high price and indirect FES (timber and freshwater services, flood reduction services). In the case of economic class, rich users mostly placed highest value on the high marketed economic FES (e.g. timber), whereas poorer people chose daily use FES (e.g grasses). From these differences, it was concluded that there are differences and mismatches in prioritisation of FES among subgroups. These mismatches pose a great challenge, creating complexity in the management of forests. Although building consensus among different subgroups is not possible in such a large and socio-culturally varied landscape, achieving such agreement is imperative for better management of forest resources. Therefore, the promotion of multi-stakeholder consultation processes towards achieving consensus for prioritisation among them is necessary. Once the interests of all subgroups are negotiated and agreed upon, the process of securing those FES should be included in the forest operational plans during their revision.

7.1.3 Economic contribution of priority FES to the various subgroups

Household surveys of forest users in the two CBFM systems revealed that financial benefits from provisioning services (PS) were different under the different management models and subgroups. Users from community forests received almost twice the amount of financial benefits compared to users of forests under the Collaborative Forest Management system. Therefore, this study concludes that forest management modality has implications for deriving benefits among the forest users. These differences can be attributed to policy disparity among the two models. The differences between these two models are: access/control rules over resources, use/management rights, benefit-sharing arrangements, and distance from the forest area. As time and effort expended by all users from both CBFM in the conservation and management of forests are almost similar, this disparity can lead to disputes, thereby giving rise to unsustainability of forest management. The issue of the benefits accruing from the use of provisioning FES among CBFM should be considered while designing any CBFM benefit-sharing mechanisms

Likewise, rich users usually derived 60% higher financial benefit as compared to poor users from the use of PS in the CBFM. Results of our household survey suggest that this discrepancy was mainly due to their differences in timber utilisation. For instance, a rich user on average utilised 13cft of timber per year, while poor households used less than one cubic foot of timber in the same period. Many of the poor households do not have a land-ownership certificate, so derive less annual income. Therefore, they live in simple, easily disposable houses and do not build multi-storied buildings. However, these are the people who largely depend on forests for other minor services (grazing, fuelwood etc.). Current CBFM Plans are timber-centric. Therefore, it is essential to revise these plans considering the needs, financial returns and aspirations of all subgroups.

Furthermore, the financial benefits derived from the use of provisioning FES also varied between subgroups within CF. The rich users living near a CF area, for example, derived higher economic benefits compared to those living far from the same CF. By contrast, a poor household living far from a forest derived almost 57% additional financial benefits compared to a rich household residing in the same area. Since all users in the CF are equally responsible for the protection, management and use of the FES, benefits derived from these services are not equal even within the same category of subgroup due to the unequal use of timber, firewood and fodder services among the subgroups. This implies that the socio-economic profile alone of the user is not a sufficient criterion to charge a levy or other type of fee to protect and manage the forests. Hence, it is equally imperative to include equity issues based on the contribution to ecosystem services management and the utilisation pattern of the FES.

The consumption patterns of provisioning services concluded that a household from CF emits almost 50% more carbon than a user from a collaborative forestry area. Consumption of four different FES (firewood, fodder, grasses and grazing) accounted for more than 90% of carbon emissions from the forest. Existing community forestry rules and regulations allow them to consume more FES compared to the users of CFM. This infers that CF users enjoy more forest services although both CBFM operate under the same Forest Act/Regulations. There could be two types of solutions to reduce emissions from the use of provisioning FES in CBFM: either reducing the demand or increasing the supply of these services. The CF can reduce the demand by promoting more efficient cooking stoves and the use of hydroelectricity for cooking purposes, while promotion of planting of fuelwood species in CBFM and public lands, enrichment plantation in the forest area, and promotion of agroforestry practices would increase the supply in these FES.

The contingent valuation of 253 households in two different CBFMs underscored that spatial distance from forests and wealth levels of the respondents play crucial roles in Willingness to Pay (WTP) for regulating and cultural services. Irrespective of the management modality, rich users usually offered a high WTP for both regulating and cultural services. For example, a well-off user living close to a CF area offered two to three times higher WTP for water quality services (US$6 – US$18/HH/year) compared to a poor household living in the same zone (US$2.5 – US$7.4/HH/year). Rich distant users in CF offered almost one and a half to two times more WTP for flood control services compared to nearby-rich users. This contrasts with the values of provisioning services received by rich distant users in the CF. One potential reason for offering higher WTP could be higher average annual income, the price of private property (e.g. house and land) and the type of farming system practised. From this analysis, it become apparent that forest users of both nearby and distant forests are interested in being a part of forest management if the DFO and forest executive committees can include their priority FES in the management plans. Therefore, all top priority FES of all sub-groups should be included in forest management plans while revising them.

Results from Generalised Linear Mixed Model (GLMM) analysis restate that wealth level, proximity to a forest area, income, and size of the household generally govern the WTP values of three services, namely flood control, water quality improvement and aesthetic values, which is consistent for both cash and labour payment options. In contrast, a poor household offered a higher WTP in the case of bequest value in both payment options, suggesting that they are more concerned with preserving the forests for future generations. This is logical as they do not have many things to leave for future generations, except their forests.

GLMM model analysis also suggested that economic benefits from both services differed in terms of payment options (cash and labour). Researchers globally advocate that elicitation of WTP for labour contribution is a better option in developing countries as their opportunity cost of time spent is low. However, this research recommends that such a blanket approach needs to be considered carefully. Nepal is one of the world's Least Developed Countries (LDC), and in our case study area most of the rich households offer fewer labour-days compared to their cash offer, whereas the opposite is true for the poor households. This is because the opportunity cost of time for rich people is higher than that of poor people. This finding indicates that the WTP in the form of labour could be a better option only for poor households, regardless of their location. Thus, a labour payment option for elicitation of WTP of such services could be promoted where poor people, with a lower opportunity cost of their time, are in a majority.

7.1.4 Framework of FES research recommendations policy process in developing countries.

Finally, exploration of why the findings of FES research in developing countries have not been adopted in policies and plan underlined that limited stakeholder engagement in the research process hinders the integration of research recommendations in policies and plans. This study proposed a framework comprising four major components and set out seven major steps that can facilitate the adoption of research outcomes in policies and plans. This study disclosed that effective engagement of all relevant stakeholders in all seven steps is the key to the integration of the findings of research in policies and plans. Stakeholders such as the Ministry of Forests and Environment (MOFE), the National Planning Commissions (NPC), and Representatives of the Ministry of Finance are key since they have the authority to plan, manage, disburse, and approve the plans and funds for forest ecosystem management. The current way of conducting policy research in isolation is a waste of time and resources. A research study is useless if no-one reads it and no-one applies it in the field. This is what is actually happening in many developing countries. Therefore, a robust mechanism and a supportable code of conduct are necessary to engage all the relevant stakeholders. Despite demanding a lengthy time-period and high resources for the research process to engage all relevant stakeholders, such engagement can create a more trustworthy environment that can improve the chances of adoption of research outcomes in policies and plans. The acceptability of the research outcomes can increase a sense of ownership, leading to more informed decision making, and ultimately yield desired outcomes in forest ecosystem conservation.

There exist key differences in access and control, and in decision making as well as in the utilisation of forest ecosystem services, revenue sharing, prioritisation of ecosystem services among stakeholders in Community Forestry (CF) and Collaborative Forest Management (CFM) in Nepal. In addition, users from both CBFM models derive different economic values from provisioning, regulating and cultural services. The detailed values from these services are provided in Appendix L.

7.2 Policy Implications

Being a prime ecosystem contributing to the national economy and local livelihoods, research outcomes of forest ecosystem services have wider implications for CBFM policies and practices. Results of research on identification, prioritisation and assessment of economic values of such ecosystem services have the potential to be extremely useful in prioritising scarce resources. This study has emphasised the urgency of analysing the needs and aspirations of different forest subgroups for better management of FES, and broadening of research focus, to include all four FES while examining their values. A full accounting of all FES and mainstreaming them into the policy process and forest management plans would accrue multiple financial and environmental benefits to all forest stakeholders. The scholarly efforts to date have mostly been focused on aggregated valuations of FES, with a rare exploration of why FES research findings are not reflected in policies and plans. Therefore, there is an acute need to draw the attention of policymakers and researchers on this issue.

The results indicate that narrow timber and fuelwood focused CBFM practices in Nepal need to be improved and hence holistic views on the various types of forest ecosystem services need to be adopted. For this revision/improvement of forest management plans to incorporate all forest ecosystem services at the local level would be the first essential step in improving the condition of forest degradation. This will recognise the different forest users' real need and encourage all users to feel that their interests and aspirations are included at the local level. Addressing the needs of the different subgroups will have a beneficial impact on the sustainable supply of forest ecosystem services to local forest users and at the same time help to conserve forest ecosystems in a large, and socio/economically and culturally diverse landscape. An increase in FES will help sustainable *Chure* management, with positive impacts on other sectors such as soil conservation, income generation, and employment opportunities at local level. The results may contribute specifically to Nepal's REDD+ Readiness Programme (RPP) in Nepal. As Government of Nepal (GoN), entered into the agreement between GoN and World Bank to trade large-scale carbon credits coming out of the World Bank's Emissions Reduction Programme (ERP) in 14 Western Terai districts of Nepal. To tap these potentials, some key aspects are recommended to take into consideration while improving forest management policies and plans in Nepal's *Chure* and *Tarai* regions.

1. Nepal has been placing a high priority on CBFM practices, which aim to protect, manage, collect, distribute and sell timber, firewood and other non-timber forest products. Our study suggests that CBFM equally generates many regulating (water quality improvement, flood control, soil conservation, biodiversity conservation, etc.) and cultural (bequest, aesthetic, existence, recreation, tourism, etc.) services. However, the current forest act and other forest regulation are silent in these regulating and cultural services. Provision of such regulating and cultural FES including water quality improvement, erosion control, bequest value and aesthetic services in the forest act and regulations will enhance the understanding of managers and forest users.
2. The forest management plan is the key document for translating policy relating to FES into actions. Such a document currently lacks the provision of a full range of FES. If this document makes a mandatory provision to include the full range of these services, then forest management plans can translate into actions. Documenting the full range of FES including regulating and cultural services in forest management plans are urgently needed. To some extent, with the initiation of executive committees and divisional forest offices, these services can be included in the forest management plans. This can be considered as a short-term strategy until this provision is incorporated in the Forest Act/Regulations.
3. CBFM systems normally comprise those living both near and distant from forests and comprising households in different wealth class. These users have different demands, aspirations, and priorities for different types of FES. However, currently, both CBFM management types mostly focus on a single service, which is timber harvested under scientific forest management. This study reveals that most of the subgroups do not derive substantial financial returns from the timber service. CBFM subgroups nonetheless suffer mismatches in their interests in many FES including timber; this can lead to conflicts while using these FES in the future. Respecting all subgroups' expectations, requirements, and monetary benefits, it is, therefore, essential to revise the CBFM management plans focusing on top priority FES such as fuelwood, fodder, grasses and grazing services. Furthermore, the plan should consider at least four to five top-ranked forest ES for all groups so that they

all feel some level of ownership over the management plans. In addition, the provision of conflict management procedures to address the potential conflicts and mismatches among the CBFM subgroups needs to be included in the forest management plan.

4. All forest users in CBFM models are currently supposed to provide equal contributions to the protection and management of forests and expected to receive equal benefits. However, both contributions to and benefits from forests seem unequal among the subgroups. Thus, an equitable benefit sharing mechanism should be formulated based on their contribution to the protection and management of forests.
5. Nepal is implementing the REDD+ mechanism covering different type of management models including CBFM in Tarai Arc Landscape (TAL). One of the concerns of the emission reduction programme in TAL is the utilisation of forest ecosystem services including firewood and fodder. Different forest users utilise these FES to different degrees accordingly, they emit carbon dioxide at a different rate. Our findings conclude that there is inequality in the emission of carbon among the subgroups. Thus, there is an urgent need to revise the forest management levies according to their contribution to forest management costs and emissions from the consumption of FES.
6. Our study suggests that consumption of four different FES (firewood, fodder, grasses, and grazing) accounted for more than 90% of carbon emissions from the forest. In order to reduce their emissions, this study strongly suggests both the demand and supply-side management of these services, by: (1) promoting more efficient cooking stoves; (2) using hydroelectricity for cooking purposes; (3) promoting the planting of fuelwood species in CBFM and public lands; (4) enhancing enrichment plantation in the CBFM area; and (5) promoting agroforestry practices.
7. Forests contribute to both local and national economies as well as to environmental conservation. This study reveals that a small patch of forests (3130 hectares) generates USD 1597/ha totalling more than five million dollars per year, while the Ministry of Forests and Environment (MOFE) records show that the revenue generation from CBFM is negligible USD 53/ha (total USD 11.66 million dollars from 223,000 hectares. This suggests that there is a lack of a proper accounting system in the forestry sector. It is, necessary to establish a ground-based

accounting system that can take into account the real contribution of forest ecosystems to both local and national level. Such a comprehensive accounting system would help in estimating the real economic contribution of the forestry sector which eventually can place forestry as a 'priority sector', and thereby attract the attention of policymakers for allocating more resources into its sustainable management of forests.

7.3 Limitations of the study and recommendations for future research

This study has identified, prioritised and evaluated the economic contribution of principal FES to different forest users in the two leading CBFM models in use in Nepal. Based on this research, five peer-reviewed international journal articles are produced. Despite its considerable contribution to national policy makers and global scientific communities, this research has some limitations stemming from the limited time and resources available for the project. Here we have highlighted some limitations and indicate the way forward.

1. While estimating FES financial contribution and carbon emissions from the consumption of provisioning services, this study has explored only the models of community and collaborative forest management in the *Chure* and *Tarai* regions of Nepal. Comparison of financial contributions from FES covering all other types of CBFM models (e.g. leasehold, protection, buffer-zone community forests) along with community and collaborative forest management systems could be potential topics for future research.
2. The study documented and prioritised the different FES types and evaluated their economic benefits in two major CBFM models in *Sarlahi* district of central *Chure* and *Tarai* region. Replication of this study in three regions of each province (Tarai, Middle hill and mountain regions) could suggest whether our findings have a broader application or not.
3. Whilst assessing provisioning ES, we collected data for three years consumption of different FES by asking households and we relied on 'recall method' for their answers and estimations. Future research may consider collecting multi-year

primary data in different seasons so that the results may enhance the accuracy and validate our findings.

4. The value of regulating and cultural FES (flood reduction, water quality improvement, bequest and aesthetic values) remains a key issue. We have estimated these values through contingent valuation. Application of other methods such as damage cost method for flood reduction and replacement cost method for water quality improvement to estimate these values may be better alternatives. Future research in these areas could add value to the current study.

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Please note that the references presented here do not include the references from the published articles (Chapters 3.2 to 6). These references are provided in the reference sections of the respective articles.

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List of Appendices

Appendix A: Questionnaire for household survey

A. General information:

CBFM name:		Code:
Full name of Respondent:		Date: / /2018
HH GPS Coordinates: Latitude:	Longitude:	HH Number:
Address:		Sex/Age:
Family size:		Education (No of year):

(Please tick (√) answer or write the answer in the given field)

B.	***Socio-economic information***					
1.1	Name of household head		Male		Female	
1.2	Name of district:					
1.3	Name of VDC		Ward No.			
1.5	Name of settlement/Tole:					
1.6	Age:					
1.7	Sex:	Male	Female		Other	
1.8	Marital status:	Married	Unmarried	Separate	Widow	Other
1.9	Caste/Ethnicity:	Brahmin/Chhetri /Dashnami	Janajati	Dalit	Other	
1.10	Religion:	Hindu	Buddhist	Muslim	Christian	Others
1.11	Details of family members:		HH size:			
	Name	Age*	Sex	Education*	Occupation	Relation with HH head
1						
2						
3						
	Pls add					
	* Illiterate = 1, Literate but not school educated = 2, High school educated =3, College & above = 4 * Child <5 year=1, Young 6-14=2, Adult 16-59=3, Old 60-above=4					

1.12	Who is the mostly involve in economic activities of household?	Female	Male	Both
1.13	Do female members of your household represent in group/organization?		Yes	No
	If yes, please provide details of female members representation in functional groups (for each individual maximum three groups)			

	Name	Group/Organization	Position	Remarks

C.1	***Information related to provisioning services***			
Are you or your family members are involved in forest products or services collection? If Yes? Please answer 1.14.				
1.14	Which of the following services do you receive from forests?			
S.N	**Sources**	**Amounts (in local unit)/month**	**Sales? (amount)**	**Sales price**
1	Firewood (Bhari)			
2	Timber (cft)			
3	Fodder (Bhari)			
4	Thatching materials (Bhari)			
5	Wild fruits/foods (kg)			
6	Medicinal plants (kg)			
7	Poles (No)			
8	Agriculture implements (No)			
9	Construction materials (cft)			
10	Leaf-litter (Bhari)			
11	Others (specify)			

C.2	***Information related to grazing animals***										
Are you or your family members do take your animals in forests? If Yes, please provide these information?											
	Animals	Last 3 years					Within 1 year				
		No	If bu	Price/	Sell	Price/ unit	Self-consumption	Other	Amount	Sales	Price/ unit	Remarks

			yno	unit	no			products				
1	Cow							Dairy product				
2	Ox											
3	Male buffalo											
4	Female Buffalo											
5	Goat											
6	Horse/donkey							Service				
7	Sheep							Wool				
8	Pig											
9	Others specify											

If you are not taking your animals in the forests, how do you feed them?

A. Stall feeding B. feeding in your own land or C. others

D.1 Do you produce any of the following cross-pollinated crops? If Yes, please provide these information?				
Crops name	Production (KG)	Sales (KG)	Selling Price (NRs)	Remarks
1				
2				
3				
4				
5				

E.	***Information related to Sediment retention and flood reduction at off-site***
	The following background and impacts of sedimentation/flood will be presented to each of the respondents. "You have witnessed floods and sediments for a long time in your area. You know better than me the causes which could be deforestation/degradation, land use changes and unmanaged infrastructure development. You are aware of the impacts of sediment and flood damage to public and private properties like agriculture land (144724 ha), livestock (NRs. 10670.4 million), houses (192,510), irrigation (961 schemes), transport - local roads, bridges, culverts (2937.8 mil) and human casualties (almost 134 lives) including almost than NRs 61 billion loss) in *Tarai-Madesh* area in last August 2017 (NPC 2017). You might still remember or have heard about worst past situation in your area. Therefore, you know better than me about the impacts of deposition and flood. At the same, you are also interested in protecting your private and public properties through a long-term solution. Considering your current situation, GON is going to implement various forests management activities to reduce the risk of human casualty, and loss of private and public property through sustainable management of forests. GON would like to assure to reduce the impacts of deposition of sediment

	and flood, which you are largely suffer them. The forest management activities can increase tree and ground cover that can control the problem of sediment and floods in your area. Therefore, three potential and practical forests CC and GC will be proposed like 10%, 15% and 20%. This will not totally mitigate whole problem, however, it can reduce the impacts significantly. Considering your impacts and potential mitigation measures to protect your private and public property, would you vote in favour of reducing loss of private and public property?		
1.17	Yes No If yes, what would be the highest amount in-terms of cash or labour days contribution of all three 15, 30 and 45% CC improvement?		
	15%	30	45%
	In cash NRs.. Labour days …..	In cash NRs.. Labour days …..	In cash NRs.. Labour days …..
1.18	If no, why do you say no? What will be the least amount of cash/labour contribution in all three scenario? In cash NRs.. Labour days …..		

F.	***Information related to Water Quality Improvement (WQI)***		
	The following background and impacts of poor water quality will be presented to each of the respondents. "You have witnessed current situation, problems, and causes of current water quality in your area. You know better than I do the causes which could be deforestation/degradation, intensive agriculture and unmanaged infrastructure development. You are aware of the impacts of WQ your family especially increase in maintenance cost of water pipe clogging/plumbing, cost of additional pipe in your pump to access good quality water compared to few years back, and problems in human health. This also demands additional maintenance and consequently increase water maintenance and treatment cost like chemical, filtering and boiling. At the same, you are also interested in protecting your private and public properties through a long-term solution. Considering your current situation, GON is going to implement various forests management activities to improve the water quality and reduce the risk on human health through sustainable management of forests. GON would like to assure to provide quality water, which you are also interested to receive. The forest management activities can increase tree and ground cover that can improve the water quality in your area. Therefore, three potential and practical forests CC and GC will be proposed like 15%, 30% and 45%. This will not totally mitigate whole problem, however, it can reduce the impacts significantly. Considering your impacts and potential reduction to in your water quality issue, would you vote in favour of WQI?		
1.17	Yes No If yes, what would be the highest amount in-terms of cash or labour days contribution of all three 15, 30 and 45% CC improvement?		
	15%	30	45%
	In cash NRs.. Labour days …..	In cash NRs.. Labour days …..	In cash NRs.. Labour days …..

1.18	If no, why do you say no? What will be the least amount of cash/labour contribution in all three scenario? In cash NRs.. Labour days …..

G.	***Information related to aesthetic value***		
	The following background on aesthetic aspect of forests will be presented to each of the respondents. “You have witnessed current land use with % of forests with mainly Sal species. You know better than me the current situation as well as situation of 15 years or 30 years back with proportion of forests and agriculture land in your area. You also know the causes that could be deforestation/degradation, intensive agriculture and unmanaged infrastructure development. You also see the impact on appealing value of your forests. Considering your impacts and potential reduction to in the aesthetic value which do you prefer the current one, as of 15 years or as of back 30 years?		
	Current situation	As of 15 years back	As of 15 years back
	In cash NRs..	In cash NRs..	In cash NRs..

H.	***Information related to Bequest value (BV)***		
	The following background, causes, impacts of bequeath situation will be presented to each of the respondents. “You have witnessed current bequeath appeal in your area. You know better than I do the causes which could be deforestation/degradation, intensive agriculture and unmanaged infrastructure development that impact the BV of your forests. As a social and conscious for future generation of your off-springs. At the same, you are also interested in protecting your forests for your future generation. Considering your current situation, GON is going to implement various forests management activities to improve the bequeath value through various forests management activities forests. GON would like to assure to increase forest quality, which you are also interested to receive. The forest management activities can increase tree and ground cover that can improve the greenery in your area. Therefore, three potential and practical forests conditions will be proposed like as of current situation, forests condition as of 15 years back and forests coverage as of 30 years will be achieved. This will not totally solve the whole problem, however, it can reduce the impacts significantly. Considering your impacts and potential reduction to in your bequest issue, would you vote in favour of BV?		
1.17	Yes No If yes, what would be the highest amount in-terms of cash or labour days contribution of all three current, as of 15 years or as of 30 years back situation?		
	Current bequest	Bequest as of 15 years back	Bequest as of 30 years back
	In cash NRs.. Labour days …..	In cash NRs.. Labour days …..	In cash NRs.. Labour days …..
1.18	If no, why do you say no? What will be the least amount of cash/labour contribution in all three scenario? In cash NRs..		

	Labour days …..

Appendix B: Literature estimating regulating services (including benefit transfer (BT)

Author/s	Coverage	Applied methods
(Verma et al. 2017)	Six tiger reserves, India: i) carbon storage (CS) ii) C Sequestration (CSq) iii) Water purification (WP) iv) Soil cons/erosion retention (SC/ER) v) pollination	i-ii) BT iii) RC , iv) AOC v) BT
(Turpie et al. 2017)	South Africa: i) C Sq and storage ii) Ag support iii) Fisheries iv) Erosion control v) Flow regulation vi) water quality	i)SDC ii) AIC iii) BT iv) BT/InVEST v) RC vi) BT
(Kibria et al. 2017)	Veun Sai-Siem Pang NP, Cambodia: i)CSq ii) water storage iii) erosion prevention iv) Soil fertility improvement v) air purification	i)BT ii) RC iii) RC iv) RC v) RC
(Ochoa & Urbina-Cardona 2017)	Review paper i) 9 different tools – InVEST, SWAT, ARIES, FIESTA, MIMES, Co$sting Nature, EcoAIM, ECONOMETRIX, GUMBO	-
(Turner et al. 2016)	Methodological review: i) Gas regulation ii) climate regulation iii) disturbance iv) biological v) water	i)CV/AC/RC ii) CV iii) AC iv) AC/P v) M, AC, RC, H, P
(Ninan & Kontoleon 2016)	*Nagarhole* NP, India: i) Water con (WC) ii) SC iii) CSq iv) Pollination (P) v) Biodiversity (BD) vi) Air purification (AP)	i)AC ii) H/OP iii) M/DC iv) BT v) CVM v) AlC
(Peh et al. 2016a)	*Shivapuri Nagarjun NP, Nepal:* i) carbon regulation ii) water services	i)M/SDC, ii) BT
(Baral et al. 2016)	*Jagadishpur reservoir, Nepal: i) carbon sequestration ii) biodiversity*	i)BT ii) RV
(Yu & Han 2016)	*Changbai Mountain, China:* i) C fixation ii) Oxygen release iii) Soil con. Iv) water Con	i-ii) SP iii-iv) RC
(Sumarga et al. 2015)	*Central Kalimantan, Indonesia:* i) CSq ii) Orang-utan habitat	i)SDC, ii) DEM
(Sharma et al. 2015)	*Koshi Tappu WR, Nepal:* i) Flood control ii) Carbon sequestration	i)BT/RC ii) BT

(Rai et al. 2015)	*Jhikhu Khola-watershed, Nepal:* i) drinking water ii) irrigation	i-ii) DCE
(Hanley et al. 2015)	*Review articles i) market values/pollination ii) non-market/pollination*	i)P Ii) WTP
(Birch et al. 2014)	*Phulchoki* Nepal : i) Climate regulation ii) water	i)BT, ii)TESSA/BT
(Bangash et al. 2013)	Llobregat basin, Spain: i)water provisioning ii) erosion control	i-ii) InVEST
(Kubiszewski et al. 2013)	*Bhutan:* i) Air purification ii) BD iii) biological control iii) climate regulation iv) erosion v) disturbance vi) WP vii) WR	i-vii) BT
(Basnyat et al. 2013)	*Bardia National Park, Nepal:* i)Carbon sequestration ii) biodiversity iii) soil conservation	i)BT, ii) RV iii) BT
(Pant et al. 2012)	*Kanchanjunga Landscape Nepal:* i) Carbon sequestration	i)BT
(Christie et al. 2012)	*England/Wales i) Sites of Special Scientific Interest (SSI)*	i)Choice experiment
(Biao et al. 2010)	*Beijing, China:* i) rainfall interception ii) soil water storage iii) fresh water provision	i-iii) M
(Möller & Ranke 2006)	*Kabupaten Sleman*, Indonesia: i)Soil erosion	i) RC/PC
(Maraseni et al. 2005)	*Nepal:* i) CSq ii) BD iii) Soil protection	i)FM ii) SBG/CVM iii) RC
(Van Beukering et al. 2003)	*Leuser NP,Indonesia:* i)Biodiversity ii) CSq iii) Fire prevention iv) flood/drought prevention	i)RV ii) MDC iii) ADC, iv) ADC
(Xue & Tisdell 2001)	*Changbishan MBR, China:* Four *services*	AlC, OC, PC

M=Market price, BT=Benefit transfer, SGP=substitute goods price, MP=marginal productivity, RC=replacement cost, TC=Travel cost, P=production approach, H=hedonic pricing, AlC=Alternative cost, AOC=Avoided offset cost, AIC=additional input costs, SDC=Social damage cost, RV=Revealed valuation, SP=Shadow Price, DEM=Defensive expenditure method, DCE=discrete choice experiment; OC=opportunity cost, PC=production cost, DC=Damage cost,

Appendix C: Some relevant reviewed literature for valuation studies for policy adoption

Author/s	Coverage
(Torres & Hanley 2017)	Review articles: Marine and Protected Area
(Marre et al. 2016)	Australia: coastal and marine management
(Martinez-Harms et al. 2015)	Review articles: five filters
(Rogers et al. 2015)	Australia and New Zealand: non-market goods valuation and policy reflection
(Waite et al. 2015)	Caribbean region: Marine ecosystem
(Dehnhardt 2013)	Germany: attitude towards economic valuation for water management
(Raymond et al. 2009)	Myponga Reservoir, Australia. Identification of policy mix for agriculture pollution

Appendix D: Six different model specifications to select fitted model

1) M1: Depedent variable (e.g.FR).~ as.factor(Eco_Status) + # main variable

(1|Caste) + (1|Distant_For) + (1|Gender) , # random variable
data=a.df,family="poisson")……………(1)

2) M2: Depedent variable ~ as.factor(Eco_Status) * as.factor(Caste) + as.factor(Gender)+ # main variable (1|Distant_For) , # random variable

data=a.df,family="poisson")…………………….(2)

3) M3: Depedent variable~as.factor (Eco_Status)+Tot_Fam_memb+Caste+Tot_Inc+as.factor(Edu_lev),random=~1|Distant_For/Gender,data=dt,family="poisson")………………(3)

4) M4: Depedent variable ~ as.factor (Eco_Status)+as.factor(Edu_lev)+

+

As.factor(Distant_For)+as.factor(Tot_Fam_memb)+Tot_Inc+Caste+Gender,
+ random=~1|Age_respon,data=dt,family="poisson")…………………….(4)

5) M5: Depedent variable.~ as.factor(Eco_Status)+Edu_lev+* as.factor(Distant_For)+Tot_Fam_memb+ as.factor(Age_respon) # main variable (1|Caste/Gender) , # random variable data=a.df,family="poisson")………………(5)

6) M6: Dependent variable~as.factor(Eco_Status)+as.factor(Edu_lev)+ as.factor(Distant_For)+Tot_Fam_memb+Tot_Inc+Caste, random=~1|Gender/Age_respon, data=dt,family="poisson")………………..(6)

Appendix E: Models for four high priority forest ecosystem services and six different scenarios

Model for Flood Control Service Prediction

1) **Average of WTP of flood control value in cash (15%) = 6.757- 0.623*AF(Eco_Status$_2$) +0.888*AF(Edu_Lev$_2$) - 0.573*AF(Dis_For$_2$)- 0.0638*HH size+0.000001* Tot_Inc - 0.492 Caste2 …………….(1)**
2) **Average of WTP of flood control value in cash (30%) = 7.01-0.533* AF(Eco_Status$_2$)+0.821*AF(Edu_Lev$_2$)- 0.477*AF(Dis_For$_2$) +0.000001*Tot_Inc - 0.526*Caste2 …………….(6)**
3) **Average of flood control value in cash (45%) = 7.36-0.547* AF(Eco_Status$_2$)+0.718*AF(Edu_Lev$_2$) - 0.498*AF(Dis_For$_2$) +0.000001*Tot_Inc - 0.539*Caste2 …………….(3)**
4) **Average of flood control value in labour day (15%) = 0.89+0. 0.552*AF(Edu_Lev$_2$) - 0.467*AF(Dis_For$_2$) …………… (4)**
5) **Average of flood control value in labour day (30%) = 1.38+0. 0.52*AF(Edu_Lev$_2$) - 0.484*AF(Dis_For$_2$) …………….(5)**
6) **Average of flood control value in labour day (45%) = 1.80+0. 0.57*AF(Edu_Lev$_2$) - 0.122*AF(Dis_For$_2$) …………….(6)**

Model for Water Quality Improvement Services Prediction

7) **Average of WTP of Water Quality Improvement value in cash (15%) = 7.234 - 0.742*AF(Eco_Status$_2$) +0.494*AF(Edu_Lev$_2$) – 1.208*AF(Dis_For$_2$)- 0.055*HH size+0.000001* Tot_Inc - 0.256 Caste …………….(7)**
8) **Average of WTP of Water Quality Improvement value in cash (30%) = 7.054 - 0.619*AF(Eco_Status$_2$) +0.160*AF(Edu_Lev$_2$) – 0.920*AF(Dis_For$_2$)- 0.035*HH size+0.000001* Tot_Inc - 0.027 Caste………(8)**
9) **Average of WTP of Water Quality Improvement value in cash (45%) = 7.325 - 0.642*AF(Eco_Status$_2$) +0.293*AF(Edu_Lev$_2$) – 0.77*AF(Dis_For$_2$)+0.000001* Tot_Inc…….(9)**
10) **Average of WTP of Water Quality Improvement value in labour day (15%) = 1.467 – 0.235*AF(Eco_Status$_2$) + 0.40*AF(Edu_Lev$_2$) - 0.66*AF(Dis_For$_2$)…………(10)**
11) **Average of WTP of Water Quality Improvement value in labour day (30%) = 1.949 -0.257*AF(Eco_Status$_2$)+0.442*AF(Edu_Lev$_2$) - 0.706*AF(Dis_For$_2$)…………….(11)**
12) **Average of WTP of Water Quality Improvement value in labour day (45%) = 2.307- 0. 0.294* AF (Eco_Status)2+ 0.422*AF(Edu_Lev2) - 0.628*AF(Dis_For2)…….(12)**

Model for Bequest Value Prediction

13) **Average of WTP of Bequest value in cash (15%) = 6.854 - 0.861*AF(Eco_Status$_2$) – 0.970*AF(Dis_For$_2$) - 0.053*HH size+0.000001* Tot_Inc …………….(13)**

14) **Average of WTP of Bequest value in cash (30%) = 7.080 - 0.916*AF(Eco_Status2) – 0.741*AF(Dis_For2) - 0.052*HH size+0.000001* Tot_Inc……………(14)**

15) **Average of WTP of Bequest value in cash (45%) = 7.325 - 0.80*AF(Eco_Status2) – 0.69*AF(Dis_For2) - 0.051*HH size 0.000001* Tot_Inc ……….(15)**

16) **Average of WTP of bequest value in labour day (15%) = 1.08 + 0.273*AF(Eco_Status2) - 0.461*AF(Dis_For2)……..(16)**

17) **Average of WTP of bequest value in labour day (30%) = 1.34 + 0.353*AF(Eco_Status2) - 0.446*AF(Dis_For2)……..(17)**

18) **Average of WTP of bequest value in labour day (45%) = 1.65 + 0.293*AF(Eco_Status2) - 0.406*AF(Dis_For2)……..(18)**

Model for Aesthetic Value Prediction

19) **Average of WTP of Aesthetic value in cash (15%) = 6.182 - 0.502*AF(Eco_Status2) – 0.639*AF(Dis_For2) +0.000001* Tot_Inc …………….(19)**

20) **Average of WTP of Aesthetic value in cash (30%) = 6.429 - 0.482*AF(Eco_Status2) – 0.619*AF(Dis_For2) +0.000001* Tot_Inc ……………(20)**

21) **Average of WTP of Aesthetic value in cash (45%) = 6.445 - 0.553*AF(Eco_Status2) – 0.483*AF(Dis_For2) - 0.010*HH size 0.000001* Tot_Inc ……….(21)**

22) **Average of WTP of Aesthetic value in labour day (15%) = 1.02 - 0.386*AF(Eco_Status2) + 0.607*AFEdu_lev2 - 0.675*AF(Dis_For2)……..(22)**

23) **Average of WTP of Aesthetic value in labour day (30%) = 1.40 - 0.391*AF(Eco_Status2) + 0.686*AFEdu_lev2 - 0.719*AF(Dis_For2)……..(23)**

24) **Average of WTP of Aesthetic value in labour day (45%) = 1.75 - 0.393*AF(Eco_Status2) + 0.677*AFEdu_lev2 - 0.665*AF(Dis_For2)……..(24)**

Appendix F: Literature related to Categorisation, assessment and prioritization of ecosystem services

Author/s	Coverage
Categorization at global scale	
(Haines-Young & Potschin 2012)	*Three categories:*
(TEEB 2010)	*Three categories: 23 services*
(MEA 2005)	Global: 17 ecosystem services
(De Groot et al. 2002)	Global: 4 functions and 23 types of services
(Costanza et al. 1997)	Global: 17 ecosystem services
Assessment and prioritisation	
(ICIMOD 2017)	*Barshong*, Bhutan: 46 ecosystem services
(Bhandari et al. 2016)	*Surkhet*, Nepal: 26 ecosystem services
(Shoyama & Yamagata 2016a)	*Kushiro* watershed, Japan: 18 ecosystem services
(Baral et al. 2016)	*Jagadishpur*, Nepal: 24 use/non-use ecosystem services
(Sharma et al. 2015)	*Koshi Tappu, Nepa*l: 13 ecosystem services
(Iniesta-Arandia et al. 2014)	*South-eastern* Spain: Identification and valuation of important/vulnerable services
(Basnyat et al. 2013)	*Bardia* National Park, *Nepal:* 21 ecosystem services
(Pant et al. 2012)	*Kanchanjunga Landscape:* 23 ecosystem services: economic scale of ecosystem services
(Raymond et al. 2009)	South Australian: 32 ecosystem services

Appendix G: Some relevant reviewed literature for valuation studies for policy adoption

Author/s	Method used
(Marre et al. 2016)	OLS: *online survey for researchers/academics*
(Spangenberg & Settele 2016)	Review
(Rogers et al. 2015)	OLS/TI: *Telephone interview*
(Waite et al. 2015)	LR/EI: *LR: literature review/EI: expert interview*
(Dehnhardt 2013)	OLS/LS: 4 point *Likert scale*
(Bryan & Kandulu 2010)	FFI-DMCA: *Face-to-face interview/Deliberative multi-criteria analysis*

Appendix H: Some of economic valuation in Nepal

References	Services & coverage /	Methodology	Major Findings
(Paudyal et al. 2017).	Review article CBF Nepal	Review/ stakeholders workshop	The study has illustrated that CBF provides many ES from local to global benefits as result of forest restoration. This paper does not provide any direct monitory value of ES, rather it give some lists of ecosystem services which are augmented by the CBF such as i) increased economic benefits ii) social benefits and empowerment of local communities iii) iv) environmental benefits v) freshwater provision and regulation vi) habitat conservation and biodiversity.
(Baral et al. 2016)	*Jagadishpur* Nepal	RP, BT	This study provides the total economic values of to local to regional scale for six categories of wetland goods and services. The total annual economic value of the reservoir as NRs 94.5 million, where option/existence value remains main contributor followed by direct use value.
(Peh et al. 2016a)	*Shivapuri - Nagarjun* National Park (ShNNP)	Used TESSA and participatory tools	This study calculates US 11 million as a net benefit from the park and per ha contribution to society was estimated at NPR 69182.39/year and has indicated that various ES have noticeably declined.
(Bhandari et al. 2016)	*Surkhet*, 94.27 Sq km	Qualitative and quantitative approach HH survey, FGD and field observations	This paper gives an overview of some services in *Chure* region, highlighting the major landuse, their potential services with ranking. People realized 10 different ES from the forests and drinking water comes in first place. This study captures the some ecosystem services values in-terms of economic sense but does not provide much information on ecosystem services research gaps as well as monetary value of the services.
(Pandit et al. 2015)	*Chitwan* National Park (CNP), Nepal (932 km2)	CVM with 222 non-South Asian, 48 South Asian, and 40 domestic visitors	The paper captures the international (Non-SAARC and SAARC) and domestic visitors' willingness to pay (WTP) to access to - CNP in Nepal. The study reveals that the visitors have a substantially higher WTP than the current entry fees. This paper also suggests some further research on i) seasonal effect on entry fee ii) differential entry fees for different seasons and parks iii) visitors' experiences of infrastructure quality iv) strategic visitor management as aim of the park and revenue
(Sharma et al. 2015)	TEV of *Koshi* Tappu Wildlife Reserve-KTWR	M, BT, and net revenue or net factor income	This study evaluated the ES values of wetland provided by KTWR with five policy recommendation i) increase investment in natural resource management ii) promotion of alternative livelihood options iii) planning community based tourism iv) trade-offs on different services v)

References	Services & coverage /	Methodology	Major Findings
			coherence in different policy and practices with informed decision making.
(Rai et al. 2015)	*Jhikhu-Khola* sub-watershed for watershed services	DCE for cash and labour contribution	This study identifies water for irrigation purpose received highest demand followed by leaf litter production in the sub-watershed.
(Bhatta et al. 2014)	10 case studies across Nepal	Literature review, in-depth interview and some FGD.	This paper assesses whether any of the existing PES mechanisms can be adopted as part of a long-term and sustainable strategy that will minimize impacts on ecosystems in the context of Nepal. This paper highlights the gaps on limited focus on ES value in the management approaches, in particular to the non-use value of ES, and the national accounting system merely based on the contribution of provisioning services from ecosystems and a concrete regulatory instrument is lacking in Nepal. Standardized methodology and tools for non-market goods and services assessment is lacking or limited. PES and ecosystem based adaptation is another area for further research.
(Baral & Dhungana 2014)	Annapurna Conservation Area in Nepal (7629 km2)	CVM and administered a random of 401 visitors in 2012.	This study reveals that visitors' WTP is higher than prevailing entry fee. This study depicts that a total gross economic impact of ACA is $26,181,569.
(Basnyat et al. 2013)[5]	TEV *Bardia* National Parks, Nepal (968 km2 core area); buffer zone 507 km2	TEV: CE, TC, M and BT	The paper identified and prioritized services. The total economic values include provisional service: NRs: 95.039 mil. Recreational service: 124 mil; biodiversity: 49.6 mil; carbon sequestration value: 89 mil; soil conservation value: 16.54 mil; option value: 4.51 mil; and total economic value of is NRs 379 mil. Current revenue was less than 3% of the total economic value.
(Baral et al. 2008)	*Annapurna* Conservation Area (7629 km2) Nepal	CVM surveys to 315 foreign visitors	It does not calculate any per ha value but provides some revenue calculation over the period and expenditure. Some future projections of revenue generation are based on optimistic and pessimistic scenario. Total projected monetary value is small compared to other values (NRs 16.114 mil) impacts for large area.

[5] *This paper was published in Banko Jankari, which is not a high impact factor journal*.

Refer ences	Services & coverage /	Methodology	Major Findings
(Adhikari et al. 2005)	*Chitwan* National Park, Nepal (932 km2)	Stakeholder analysis; DCE HHs survey (444) in BZ	This paper highlights the linkages between stakeholders and their roles in one-horned rhinoceros with cost and benefits implication from local to global scale.
(Brown 1997)	*Bardia* NP Nepal	Grassland management issues	This study explores some of the difficulties posed by biodiversity coverage. This study further utilizes political ecological perspectives in analysing the issues.

Appendix I: Reviewed of selected articles on ecosystem services valuation in global scale

Reference	Services/coverage	Methodology	Major Findings/Gaps
(McDonough et al. 2017).	All at global scale	Meta-analysis	High concentration on developed nations USA-30%, EU-45%, China-12%, Canada-5%, Australia-7% and Brazil-3%. Up to 2011, 50% of valuation studies examined a single service, failing to consider other services or interactions between them. It recommends further research on terminology, classification methods or schemes with applicability.
(Chaudhary et al. 2015)	Global scale	Review articles	This paper has categorized published articles based on subject areas. Majority of papers are from ecological economics and ecological biology. This paper has also identified minimum research on poverty reduction, food security, livelihood justice, commodification, governance, ethics, and rights etc.
(Costanza et al. 2014)	17 ES from 16 biomes at global scale	Meta-analysis	The authors' updated the estimate of world's ES valuation of US $125 trillion (based on global estimate of 2011) and for 2014 is US $145 trillion and also estimated loss of ES values US $4.3 to 20.2 trillion between/year in 1997 to 2011 due to land use change. This study has clearly indicated that ES are public goods or common pool resources and conventional markets and institutional set up is not right framework to account them.
(De Groot et al. 2012)	Meta-analysis of ES of 10 main biomes	Meta-analysis	This paper particularly accepts that most of the valued goods are public in nature and out of market situation. Over-exploitation of these ecosystem services will pose serious threats to livelihood of the poor in future generation.
(Daily et al. 2009)	Tools/*Hawaii* USA	Review and a new tool InVEST	This paper has outlined a framework and highlighted some future further research in carbon sequestration and ground water recharge. Particularly, focus should be on i) combining direct biophysical estimates with economic contribution at the scale of decision ii) developing non-monetary services iii) developing methods for identifying

			who benefits from what types of services. The paper has also cautioned to risks of creating further exacerbation of social inequalities.
(MEA 2005)	24 ES and Global coverage	Long-term assessment	MEA 2005 has identified four major findings, which are: i) ES were substantially changed in their qualities over last 50 years. ii) Some human well-being are observed, however it has a significant cost of non-linear on ES, iii) ES degradation is one of the barrier to achieve millennium goal. iv) To reverse the degradation of ES, a massive change on policies, institutions, and practices are needed.
(Costanza et al. 1997)	17 ES from 16 biomes at global scale	Meta-analysis	The authors' first estimated world's ES valuing US $33 trillion (ranging from US $16-54 trillion and almost 1.2 times more than total gross domestic product (GDP of 1995 in US dollar).
(Schuhmann & Mahon 2015)	Review article for WCR (37 countries)	Review	They identified major gaps for future valuation work such as i) economic impacts of overfishing ii) opportunities cost of what is lost in society iii) the economic practicabilities of fisheries subsidies in terms of the relative values of contemporaneous support to livelihood and future economic costs of overfishing.
(Balvanera et al. 2012)	9 Latin American countries	Review	This paper highlights the historical initiation, growth of ES in these countries. There is still several gaps especially on systematic and complete suite of assessment of supply, delivery and values. It needs a research on sharp trade-offs between increasing supply of agriculture commodities, maintenance of other service flow and livelihood of poor section and their assessment in current and future alternative scenario.
(D'Amato et al. 2016)	Review ES China	Review	This study suggests conducting a comprehensive methodological study in the future as well as highlighting potential of plantation forests and their services for valuation in the future.
(Plant & Ryan 2013)	Australia	Literature review and pilot survey	The ES concept is getting way into Australian NRM, however the term is sometimes not clear among stakeholders. Well-facilitated participatory process will get the convergence of the true value.
(Alamgir et al. 2014)	All ES Australia	Literature review	This paper has identified ES status, time frame, their distribution across states. This study has also indicated no study focused on future trends of ES under different climate change scenario and their impacts.
(Willemen et al. 2013).	3 ES in DRC	Spatial indicators	This paper focuses on how PAs influence the continuous flow of ES to different members of society and offers ES map as a useful tool to apply for trade-offs.
(Adams et al. 2008).	Existence value. MDSP Brazil	CVM	The results indicate that the conservation value is strongly associated with people's ability to pay, increasing with income levels and qualitative research questions showed that the population considered PA very important. There is budget deficiency compared to public value to MDSP.

Appendix J: Literature estimating provisioning services

Author/s	Coverage	Method used
(Verma et al. 2017)	Six tiger reserves, India: i) Employment (E), Agriculture (Ag) iii) Fishing (Fi) iv) Fuelwood (F) v) Fodder/grazing (Fd/Gz) vi) timber (T) vii) Non-wood forest produce (NWFP) viii) Gene-pool protection (GPP)	i)M ii)BT iii) M, iv) M v) M, Vi) M VII) M, Viii) BT
(Turpie et al. 2017)	South Africa i) livestock fodder-Fd ii) harvested renewable resources-HRR	i)RC ii) BT
(Turner et al. 2016)	Methodological review: i) Water supply (SP) ii) Food iii) raw materials iv) Genetic resources v) medicinal v) ornamental	i)AC/RC/M/TC ii)M/P iii) M/P iv) M/AC v) AC/RC/P vi) AC/RC/H
(Ninan & Kontoleon 2016)	*Nagarhole* NP, India: I) NWFP ii) Grazing	i)M/AlC
(Peh et al. 2016a)	*Shivapuri-Nagarjun NP, Nepal* i) water provisioning ii) cultivated goods	i)no monetary value ii) M
(Baral et al. 2016)	*Jagadishpur reservoir, Nepal:* i) wetland goods ii) water supply iii) tourism	i)RP ii) RP iii) TC
(Sharma et al. 2015)	*Koshi Tappu WR, Nepal.* i) Floodplain Ag ii) Livestock (L) iii) Fishery (Fy) iv) Forests products (Fp) v) drinking water	i)M/BT ii) M/BT iii) M/BT iv) M v) BT
(Adekola et al. 2015)	*Niger Delta, Nigeria: i) material collection ii) Fishing iii) Crop production iv)hunting v)logging*	M
(Kubiszewski et al. 2013)	*Bhutan:* i) bioprospecting ii) energy iii) food iv) genetic resources v) other raw materials vi) T vii) W	i-vii) BT
(Basnyat et al. 2013)	*Bardia NP, Nepal:* i) Fp ii) sand boulders, penalties	i)BT, ii) RP
(Pant et al. 2012)	*Kanchanjunga Landscape Nepal:* i) timber/wood ii) MAPs iii) biomass farming iv) subsidiary food	i-iv) M

M=Market price, BT=Benefit transfer, SGP=substitute goods price, MP=marginal productivity, RC=replacement cost, TC=Travel cost, P=production approach, H=hedonic pricing, AlC=Alternative cost, RP=revealed price

Appendix K: Some relevant reviewed literature for cultural services valuation

Author/s	Coverage	Method used
(Verma et al. 2017)	i) Cultural heritage ii) Recreational iii) spiritual iv) research/education	i)RV ii) TC iii) Q iv) Q
(Turpie et al. 2017)	South Africa i) Amenity value ii) Existence value	i)RE/H ii) SP
(Turner et al. 2016)	Methodological review: i) Recreational ii) Aesthetic iii) Science/Education iv) spiritual/historic	i) TC/CV/R ii) H/CV/TC iii)CV/R
(Ninan & Kontoleon 2016)	*i) Recreational*	i) TC/BT

(Peh et al. 2016a)	*Shivapuri-Nagarjun NP*, *Nepal* i) nature based recreation and tourism	i) RE
(Baral et al. 2016)	i) Existence/options value	i)CV/WTP
(Jónsson & Davíðsdóttir 2016)	Review article i) Heritage ii) Recreation iii) Cognitive	i)NF ii) DC iii) No data
(Sharma et al. 2015)	*Koshi Tappu WR, Nepal.* i) ecotourism	i) NR
(Pandit et al. 2015)	*Chitwan Nepal i) Access to park*	i)CVM
(Birch et al. 2014)	*Phulchoki* IBA, Nepal i) Nature based tourism	i)RE
(Kubiszewski et al. 2013)	*Bhutan:* i) landscape ii) cultural iii) education iv) science/research v) tourism/recreation	i-v) BT
(Basnyat et al. 2013)	*Bardia NP, Nepal:* i) Recreation ii) option/existence value	i)TTE, ii) CV
(Uddin et al. 2013)	*Sundarban Reserve Forest, Banladesh:* i) cultural services	i)RE/WTP
(Van Beukering et al. 2003)	*Leuser NP,Indonesia:* i)Tourism	i)RE/WTP

TC=Travel cost, H=hedonic pricing, RV=Revealed valuation, SP=Shadow Price, OC=opportunity cost, PC=production cost, DC=Damage cost, MDC=marginal damage cost, Q=Qualitative NR=Net revenue approach RE=Revealed expenditure SP=stated preference, TTE=Total tourism earnings, R=ranking, NF=Net factor

Appendix L: Key differences among the community forestry (CF) and collaborative forest management (CFM) in Nepal

SN	Key Features	CF		CFM		Remarks
1.	Access and control in FES	Users can collect and harvest all provisioning ES		Users can gain access only for basic forest ES		
2.	Decision on utilisation of FES	Use can make decision about the forest utilisation through general assembly		Forestry official and EC member can make decision about the forest utilisation		
3.	Revenue sharing	All revenue goes to local user's fund		Revenue of CFM, 50% of forest product goes to the governments		(40% to the national government and 10% to the local government)
4.	Area (studied)	Small patch of forests (711 ha)		Large patch of forests (2419 ha)		
5.	Forest users	Small number of households (719)		Large number of HH (27953)		
6.	Forest/HH	0.99 ha		0.087		
7.	Priority of FES	Firewood, fodder, timber, grasses		Firewood, timber, and fresh water		Mainly difference in timber and fresh water
8.	Priority of FES	Nearby: Firewood, fodder, grasses, grazing		Nearby: Firewood, timber, fodder, grasses		
Provisioning Services						
9.	Financial contribution (Fin.Con.) of PS	US$ 402/HH/year		US$ 227/HH/year		Contribution of 11 major FES
10.	Fin. Con of PS USD	Rich	Poor	Rich	Poor	
11.		468	332	262	191	
12.	Fin. contribution of PS/HH/year	Nearby	Distant	Nearby	Distant	
13.		929	147	553	59	

Regulating services (RS)-Flood Control (FC)						
For cash option						
14.	WTP for FC C15%-45% (USD/HH/year)	USD 4.35-8.15		1.60-3.75		
15.	**Economic status**	**Rich**	**Poor**	**Rich**	**Poor**	
16.	WTP for FC C15%-45% (USD/HH/year)	4.3-11.45	1.6-4.65	1.9-5.4	0.85-2.05	
17.	**Proximity**	**Nearby**	**Distant**	**Nearby**	**Distant**	
18.	WTP for FC C15%-45% (USD/HH/year)	2.5-5.3	3.25-9.5	2.6-7.0	0.75-2.05	
For labour option						
19.	WTP for FC L15% -45% (day/HH/year)	1.9-4.2		0.9-2.5		
20.	**Economic status**	**Rich**	**Poor**	**Rich**	**Poor**	
21.	WTP for FC L15%-45% (USD/HH/year)	2.05-4.2	1.6-4.1	1.0-3.0	0.90-2.0	
22.	**Proximity**	**Nearby**	**Distant**	**Nearby**	**Distant**	
23.	WTP for FC L15%-45% (USD/HH/year)	2.1-3.55	3.2-4.5	1.9-4.95	0.7-1.3	
Regulating services (RS)-Water Quality Improvement						
For cash option						
24.	WTP for WQI C15%-45% (USD/HH/year)	USD 4.5-10.0		2.60-6.6		
25.	**Economic status**	**Rich**	**Poor**	**Rich**	**Poor**	

26.	WTP for WQI C15%-45% (USD/HH/year)	6.0-13.9	2.9-5.8	3.5-8.4	1.7-4.8	
27.	**Proximity**	**Nearby**	**Distant**	**Nearby**	**Distant**	
28.	WTP for WQI C15%-45% (USD/HH/year)	4.3-12.9	4.5-9.0	4.7-12.7	1.5-3.5	
For labour option						
29.	WTP for WQI L15% -45% (day/HH/year)	2.0-6.6		1.2-3.4		
30.	**Economic status**	**Rich**	**Poor**	**Rich**	**Poor**	
31.	WTP for WQI L15%-45% (USD/HH/year)	2.1-6.8	2-6.5	1.6-4.4	0.8-2.5	
32.	**Proximity**	**Nearby**	**Distant**	**Nearby**	**Distant**	
33.	WTP for WQI L15%-45% (USD/HH/year)	2.2-7.0	2-6.5	2.0-6.0	0.75-2.1	
Cultural Services (CS)-Bequest Value (BV)						
34.	**For cash option**					
35.	WTP for BV C15%-45% (USD/HH/year)	USD 3.5-8.6		2.7-5.4		
36.	**Economic status**	**Rich**	**Poor**	**Rich**	**Poor**	
37.	WTP for BV C15%-45% (USD/HH/year)	5.6-13.2	1.3-3.65	4.05-7.80	1.35-3.0	
38.	**Proximity**	**Nearby**	**Distant**	**Nearby**	**Distant**	
39.	WTP for BV C15%-45% (USD/HH/year)	4.6-9.7	3.0-8.1	5.05-10.05	1.50-3.0	
For labour option						

40.	WTP for BV L15% -45% (day/HH/year)	2.1-5.4		1.9-4.6		
41.	**Economic status**	**Rich**	**Poor**	**Rich**	**Poor**	
42.	WTP for BV L15%-45% (USD/HH/year)	2.3-6.0	1.9-4.8	4.0-7.7	1.7-3.0	
43.	**Proximity**	**Nearby**	**Distant**	**Nearby**	**Distant**	
44.	WTP for BV L15%-45% (USD/HH/year)	2.1-5.4	3.05-5.4	2.1-5.5	1.8-4.1	
Cultural Services (CS)-Aesthetic Value (AV)						
For cash option						
45.	WTP for AV C15%-45% (USD/HH/year)	USD 2.4-5.9		1.2-2.7		
46.	**Economic status**	**Rich**	**Poor**	**Rich**	**Poor**	
47.	WTP for AV C15%-45% (USD/HH/year)	3.7-8.9	1.0-3.0	2.0-3.7	0.5-1.7	
48.	**Proximity**	**Nearby**	**Distant**	**Nearby**	**Distant**	
49.	WTP for AV C15%-45% (USD/HH/year)	2.0-4.5	2.5-6.6	2.5-5.0	0.6-1.5	
For labour option						
50.	WTP for AV L15% -45% (day/HH/year)	1.7-3.3		1-1.5		
51.	**Economic status**	**Rich**	**Poor**	**Rich**	**Poor**	
52.	WTP for AV L15%-45% (USD/HH/year)	2.0-4.0	1.3-2.3	1.3-2.0	0.8-1.1	
53.	**Proximity**	**Nearby**	**Distant**	**Nearby**	**Distant**	

54.	WTP for AV L15%-45% (USD/HH/year)	2.0-3.5	1.5-3.1	2.0-3.0	0.6-1.0	