Chapter 1
Introduction

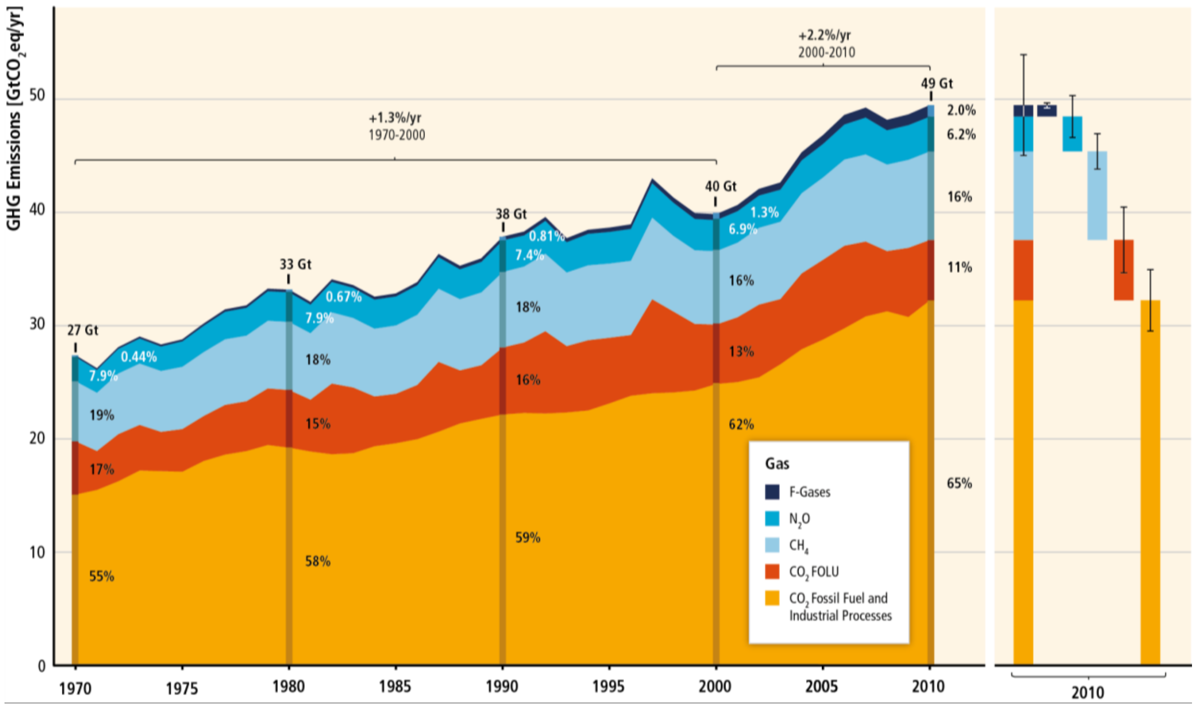
1.1 Background

Climate change is a global concern. Scientists affirm unequivocally that the Earth's atmosphere and oceans have warmed, the sea ice and glaciers have continued to retreat, and sea level has risen. Each of the last three decades has been successively warmer at the Earth's surface than during any preceding decade since 1850 (Stocker et al., 2013). Inter-governmental Panel on Climate Change (IPCC) reports published in 2014 stated that the atmospheric concentrations of greenhouse gases (GHGs) like carbon dioxide, methane, and nitrous oxide had increased to levels unprecedented in at least the last 800,000 years. The increased amount of GHGs in the atmosphere has contributed to positive radiative forcing that has led to surface warming on Earth. Carbon dioxide (CO_2) concentrations largely determine global mean surface warming (IPCC, 2014). CO_2 concentrations have increased by 40% since pre-industrial times, from fossil fuel emissions and land use change emissions (IPCC, 2013).

Continued emissions of GHGs will cause further warming and changes in all components of the climate system. The IPCC fourth assessment report (AR4) warns that average world surface temperature could rise by 3^0C by 2100 and possibly even more, if no measures are taken to reduce GHG emissions to the atmosphere. The latest estimate in the fifth assessment report (AR5) indicated that without more mitigation, global mean surface temperature might increase by 3.7^0C to 4.8^0C. The Earth's oceans will also continue to warm during the 21st century. Heat will penetrate from the surface to the deep ocean and affect ocean circulation. The warming of surface and ocean seawater will affect the global water cycle, resulting in increased extreme events like heat waves, heavy precipitation, drought and cyclones. The AR5 report suggests that more hot days and nights, fewer cold days and nights over most land areas, were virtually certain by late 21st century.

After rigorous and comprehensive review of scientific evidences, the IPCC (2013) concluded that human influence had been the dominant cause of increased greenhouse gas (GHG) concentrations in the atmosphere and the observed warming since the mid-20th century.

The share of anthropogenic GHGs emissions from Agriculture, Forestry and Other Land Use (AFOLU) sector in 2010 was 24% (IPCC, 2014). Earlier estimates suggested that global emissions from deforestation and forest degradation alone contribute between 20 and 25 per cent of all greenhouse gas emissions (Sedjo & Sohngen, 2007; Skutsch et al., 2007; Webb & Sah, 2003). Since the publication of AR4 in 2007, IPCC estimates of emissions from AFOLU sector have remained similar but the share of anthropogenic emissions has decreased in 2010, largely due to increases in emissions in the energy sector (IPCC, 2014). Considering groups of gases, forestry and other land use sector contributed 11% of total anthropogenic GHGs emissions in year 2010 (see figure 1.1).



Source: IPCC, 2014.

Figure 1.1 Total Annual Anthropogenic GHG Emissions by Groups of Gases 1970-2010

The forestry sector is unique among other sectors because it performs as both sink and source of GHG emissions. The mitigation potential of the forestry sector is derived from both enhancement of removal of GHGs (sink), as well as reductions of emissions through management and conservation of forest lands. The forest ecosystems contains 1200 giga tones (Gt) of carbon (C) which represents most of the terrestrial carbon and is more than double the amount of carbon (550 Gt) in the atmosphere (IPCC, 2001). These carbon stocks can be increased by sequestration in biomass and soil. The economic mitigation potential of emissions reductions in the forestry sector, including agriculture and other land use, is estimated to be 7.18 to 10.60 GtCO2e/yr at C prices up to 100 US$/Mg$CO_2$e, about a third of which can be achieved at <20 US$/Mg$CO_2$e (IPCC, 2014).

Limiting climate change and global warming to 2^{0}C by 2100 AD will require sustained reductions of greenhouse gas emissions through long-term commitment of substantial mitigation actions. The design and coverage of financing mechanisms is a key element for successful use of the AFOLU mitigation potential. Considering the size of the global carbon pool in forests, its potential climatic effects on natural and anthropogenic emissions, and cost effective option for mitigation, 'reducing emissions from deforestation and forest degradation, conservation, enhancement of forest carbon stocks and sustainable management of forests (REDD+)' has gained much attention in recent climate change negotiations. The proposed REDD+ financing mechanism which has economic, social, and other environmental co-benefits, is expected to form part of a post-2020 climate regime (Angelsen, Streck, Peskett, Brown, & Luttrell, 2008; IPCC, 2014; Phelps, Guerrero, Dalabajan, Young, & Webb, 2010).

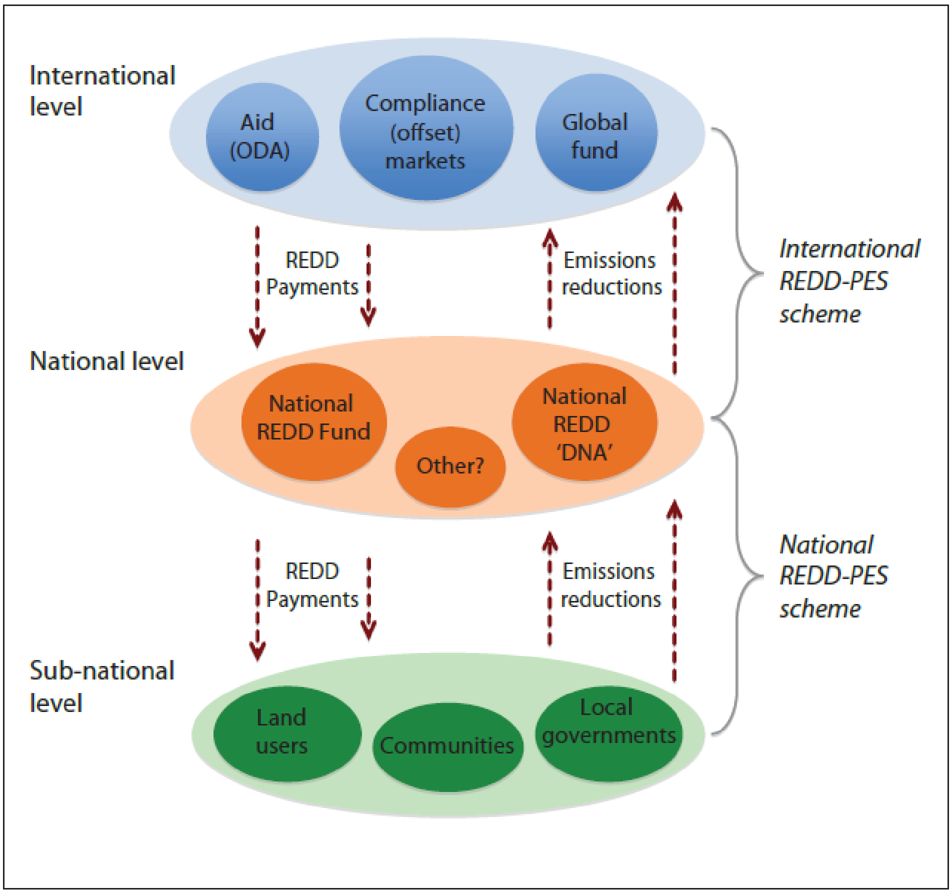
The Copenhagen Accord, the outcome of the Conference of Parties (CoP 15) to the United Nations Framework Conventions on Climate Change (UNFCCC) on December 2009 outlined the importance of REDD+ stating in paragraph 6 – "We recognize the crucial role of reducing emission from deforestation and forest degradation and the need to enhance removals of greenhouse gas emission by forests and agree on the need to provide positive incentives to such actions through the immediate establishment of a mechanism including REDD+, to enable the mobilization of financial resources from developed countries."

1.2 **REDD+ Discourse: Concepts and Designs**

REDD+ primarily refers to an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development (Parker, Mitchell, Trivedi, & Mardas, 2008). It has been considered as a cost-effective approach to climate change mitigation (Phelps et al., 2010), compensating developing countries for even a small portion of the global benefits their forests provide might be sufficient to greatly reduce deforestation (Stern, 2007). Besides its climatic and other environmental benefits, REDD+ appears to offer a feasible option for north-south benefit transfer (Levin, McDermott, & Cashore, 2008).

REDD+ is a broad set of approaches and objective (*see* Fig 1.2) aimed to reduce emissions from deforestation and forest degradation rather than a single action or activity. The mechanism comprises multi-level processes and approaches designed to transfer compensation from international agencies to local resource managers that are willing and able to reduce emissions by addressing underlying causes of deforestation and forest degradation.

Since the evolution of REDD+ (*see* Levin et al., 2008), several proposals put forward by various governments and environmental organizations are currently under discussion. Parker et al. (2009) depicted those proposals in four building blocks of REDD+; *scope*, *reference level*, *distribution of incentives* and *financing approach* in order to determine the overall feasibility including effectiveness, efficiency and equity of the proposal. The scope of REDD+ deals with the activities eligible for the mechanism; reference level is about estimating emissions reductions; financing and distribution categories deal with source and amount of funding and beneficiaries respectively.



Adopted from Angelsen and Wertz-kanounnikoff, 2008.

Figure 1.2 Conceptual model of multi-level REDD+ mechanism

Considering the magnitude of emissions coming from deforestation, the initial focus on *scope* of the mechanism was to achieve reductions of carbon emissions from deforestation (RED). Inclusion of forest degradation (the second D) at COP 13 in Bali is recognition of forest degradation as a major source of greenhouse gas emissions (Asner et al., 2005; Lambin, Geist, & Lepers, 2003; Marklund & Schoene, 2006) and aimed to provide opportunities for countries with less pristine forests from the dry tropics where opportunity costs are often lower (Campbell, 2009). The proposals have moved on and the additional components are added in terms of "+" in REDD+. This component includes "role of conservation, sustainable management of forests and enhancement of forest carbon stocks". The mechanism has potential to deliver much more co-benefits in terms of alleviating poverty, improving governance, conservation of biodiversity and sustaining vital ecosystem services (Parker et al., 2008).

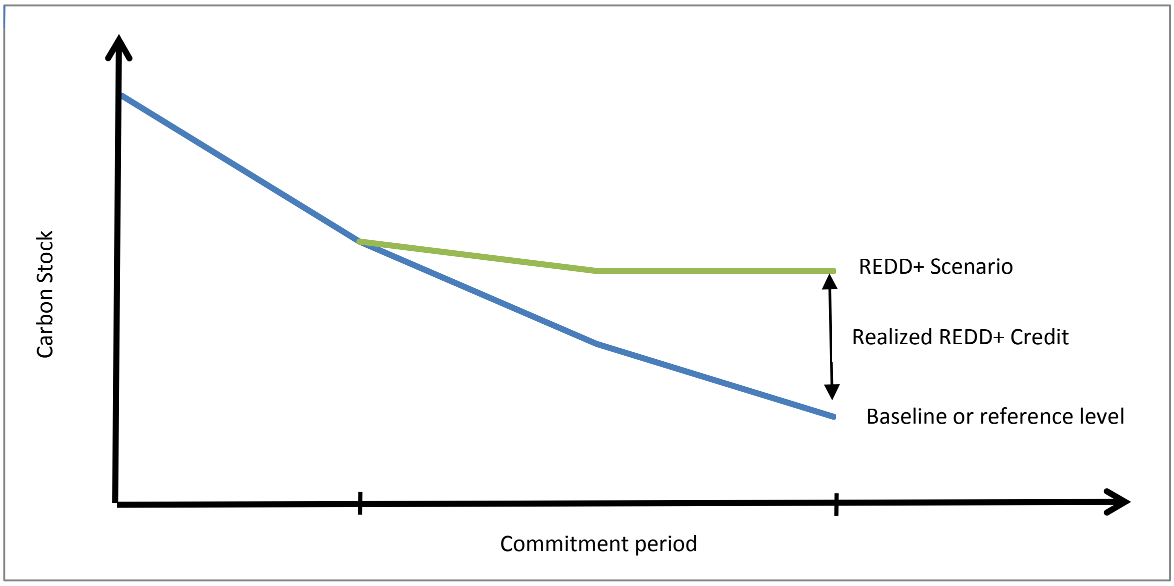


Figure 1.3 An example of comparison between reference level and REDD+ scenario

To make payment of reduced emissions under the REDD+ mechanism net emissions reductions have to be compared with a reference level (Angelsen et al., 2008; Mattsson, Persson, Ostwald, & Nissanka, 2012). Reference level refers to the benchmark scenario against which future emissions reductions can be measured and potentially rewarded (Parker et al., 2008). The benchmark scenarios are used to determine the quantity of emissions reduced because of the implementation of REDD+ mechanism in addition to what would have otherwise happened (See fig 1.3). It has great implications for overall reductions in emissions (effectiveness), the efficiency in terms of costs of obtaining the reductions, and the distribution of incentives across the regions and countries (equity) (Busch et al., 2009; Cattaneo et al., 2010; Mattsson et al., 2012).

Current debate on types of reference levels includes either historical or projected reference level. A historical reference level uses past rates of deforestation as a proxy for future deforestation. On the other hand, a projected reference level predicts future deforestation through econometric models by analysing drivers of deforestation and forest degradation. Unavailability of historical deforestation and forest degradation data, especially in developing countries is one of the major limitations of using a historical reference level. Such reference level does not recognize potential changes in the country's circumstances and the underlying causes or drivers of deforestation and forest degradation (Parker et al., 2008). The projected reference level is arguably a more robust approach to estimate future deforestation and forest degradation as it incorporates a wide range of socio-economic variables rather than just historical behaviour.

The *reference level* consists of recent forest carbon stock against which future performance can be measured (Mattsson et al., 2012). The science of forest carbon accounting and assessment of business as usual scenario within forests is still imprecise (Betts et al, 2008), a major challenge en-route to an effective REDD+ mechanism and as such both historical and projected baselines have a large element of uncertainty (Gibbs, Brown, Niles, & Foley, 2007; Parker et al., 2008) . Angelsen (2010) insisted that researchers need to investigate the drivers of deforestation and forest degradation to determine reliable baseline as well as to estimate the cost of emission reductions. Likewise, the accurate quantification of carbon stocks retained in forests and the carbon dioxide emissions avoided through REDD+ for the compensation payment, is another technical challenge (Ghazoul, Butler, Mateo-Vega, & Koh, 2010). In this way, understanding the drivers of deforestation and forest degradation has assumed renewed importance (Kanninen et al., 2007) due to their newly-appreciated role in the REDD+ mechanism.

The component *distribution* is about allocation of financial incentives to countries that might not directly benefit from emissions reductions based on reference level approach to REDD+. The discussion is focused on how to reward countries with high forest cover and low rate of deforestation for their standing forests or carbon stocks. The argument is if these countries are not rewarded for conserving the carbon stocks, there will be perverse incentive to clear their forests for more profitable businesses. Redistribution of REDD+ incentives or additional sources of funding are the two types of mechanism under discussion in order to address the distributional equity issues. Redistribution mechanism, "combined incentives" for example [see (Strassburg, Turner, Fisher, Schaeffer, & Lovett, 2009)], uses a global baseline against which a proportion of incentives are allocated. Proposals on additional funding advocate establishment of a 'stabilisation fund' coming from voluntary or other sources that would use additional funding to address leakage and equity concerns in those countries having low deforestation but high carbon stocks (Parker et al, 2009).

The *financing* component of REDD+ refers to the sources of funding that would be used to provide incentives. Finance for REDD+ can be grouped into three main categories; direct-market based, market-linked or voluntary funding mechanisms (Boucher, Movius, & Davidson, 2008). Under the market based mechanism, emissions reduction, in terms of certified emissions reductions (CERs) units could be traded to meet emissions reduction targets of companies and governments. Market-linked approach would generate revenues through auction processes. Voluntary funding mechanism is an additional contribution through official development assistance (ODA). Considering the strength and weaknesses of these mechanisms, discussion on combinations of these mechanisms is emerging as a phased-approach (Boucher et al., 2008; Parker et al., 2008).

1.3 Motivation and research context

The aforementioned building blocks of REDD+ and design options seek to reduce GHG emissions at a minimum cost. Therefore, debate over the magnitude of REDD+ cost is intense (Viana, Grieg-Gran, Della Mea, & Ribenboim, 2009). While all agree that emission reductions must be effective and efficient, there is less consensus on the amount of compensation. Will a low carbon price of US$ 5/MgCO2e, as used in the Stern (2007) review, provide sufficient incentives to forest stewards to change behaviours on the ground? Research literature suggests that payments to resource managers are only likely to work where the value of compensation payment exceeds all the costs of the forest conservation (Wunder, 2000). Some argue that without fully covering the opportunity costs of forest conservation, mitigation measures would be less attractive compared to returns from other land uses in developing countries (Angelsen, 2008).

REDD+ is likely to be affected by three broad categories of costs: i) Transaction costs including costs of monitoring, reporting and verification (MRV), ii) costs of implementing policies and activities to address drivers of deforestation and forest degradation and iii) opportunity costs (Angelsen, 2008; Pagiola & Bosquet, 2009). Opportunity cost is the foregone profits from cutting down the trees or converting forest land into other land use, if owners choose to keep the trees standing. Opportunity cost seems to be the largest single cost component of any REDD scheme (Pagiola & Bosquet, 2009).

A growing amount of literature (Boucher et al., 2008; Stern, 2007; Viana et al., 2009) on the economics of climate change noted that REDD+ could be a cost-effective route to address climate change, would be economically viable for suppliers and at the same time attractive to demanders looking for cost-efficient emission abatement opportunities. However, a large degree of variation both within and between countries exists, depending on the direct and indirect drivers of deforestation and carbon content of forests (Caravani & Nakhooda, 2011). On the other hand, due to the significant variation in the carbon content of forest at sub-national scale because of the differences in local conditions, the usefulness of national and global average carbon data are limited (Gibbs et al., 2007). Therefore it is critical to carry out disaggregated research on local or sub-national drivers, carbon stock per unit of forest area and opportunity cost of avoiding emissions so as to determine the feasibility of REDD+ in a particular landscape or region before embarking into the newly proposed mechanism.

Nepal has observed one of the highest deforestation rates in the world. According to the last National Forest Inventory carried out in the early 1990s, the rate of forest area decrease was 1.7% per annum during 1978/79 to 1994. The drivers of deforestation and forest degradation, however, vary according to the geographic regions; viz. high hills (Himalaya), mid hills and plain area (Terai). Until the 1960s, the fertile plains of Nepal, which still has the largest commercially exploitable forests of Nepal, were sparsely inhabited due to the vector borne malaria disease. The eradication of this deadly disease resulted in extensive deforestation and increased human encroachments for settlements and agricultural land. However scientific research on the drivers of deforestation and forest degradation using econometric variables, and on the carbon content in the forests, that together determine the cost of emissions reduction are both lacking in this region. As a result, an economic viability of REDD+ mechanism for the region is still unknown.

1.4 Research Objectives

The study aimed to assess the feasibility of REDD+ in the Terai Arc Landscape by analysing the ecological features of the forests and the economic influences on them. The study calculated cost of emissions reduction at the sub-national or landscape scale using estimates derived from district-disaggregated data sets, and subsequently compared them to cost estimates that use global-scale approaches. The specific objectives of the study were;

- To define the drivers of deforestation and forest degradation in the Terai Arc Landscape
- To estimate the carbon stock and emission reduction potential of the forests of the region
- To quantify the opportunity costs of emissions reductions from avoided deforestation and forest degradation in the landscape

1.5 Research Framework

Amount of compensation payment against the cost of per unit emission reductions under the proposed incentive mechanism determines economic feasibility of REDD+ in the participating countries. This research examines economic viability of REDD+ in the Terai Arc Landscape of Nepal by comparing opportunity costs estimates of emissions reductions derived from bottom-up approach with earlier top-down global estimates. The drivers of deforestation and forest degradation were identified and carbon stock was estimated to derive opportunity costs of emissions reduction in the Terai Arc Landscape of Nepal. Figure 1.4 shows the framework of the research.

The study uses multiple methods and analytical techniques. The detailed methodologies are discussed in each self-contained essay. An econometric strategy is adopted to identify drivers of deforestation and forest degradation in chapter 2. The study applied panel analysis of time series cross sectional data of deforestation and forest degradation variables using Stata software. For the estimation of carbon stocks in the forests, the research applied a ground-based inventory or field measurement approach as described in detail in chapter 3. For the third essay in chapter 4, opportunity costs of emissions reductions are estimated using a bottom-up approach.

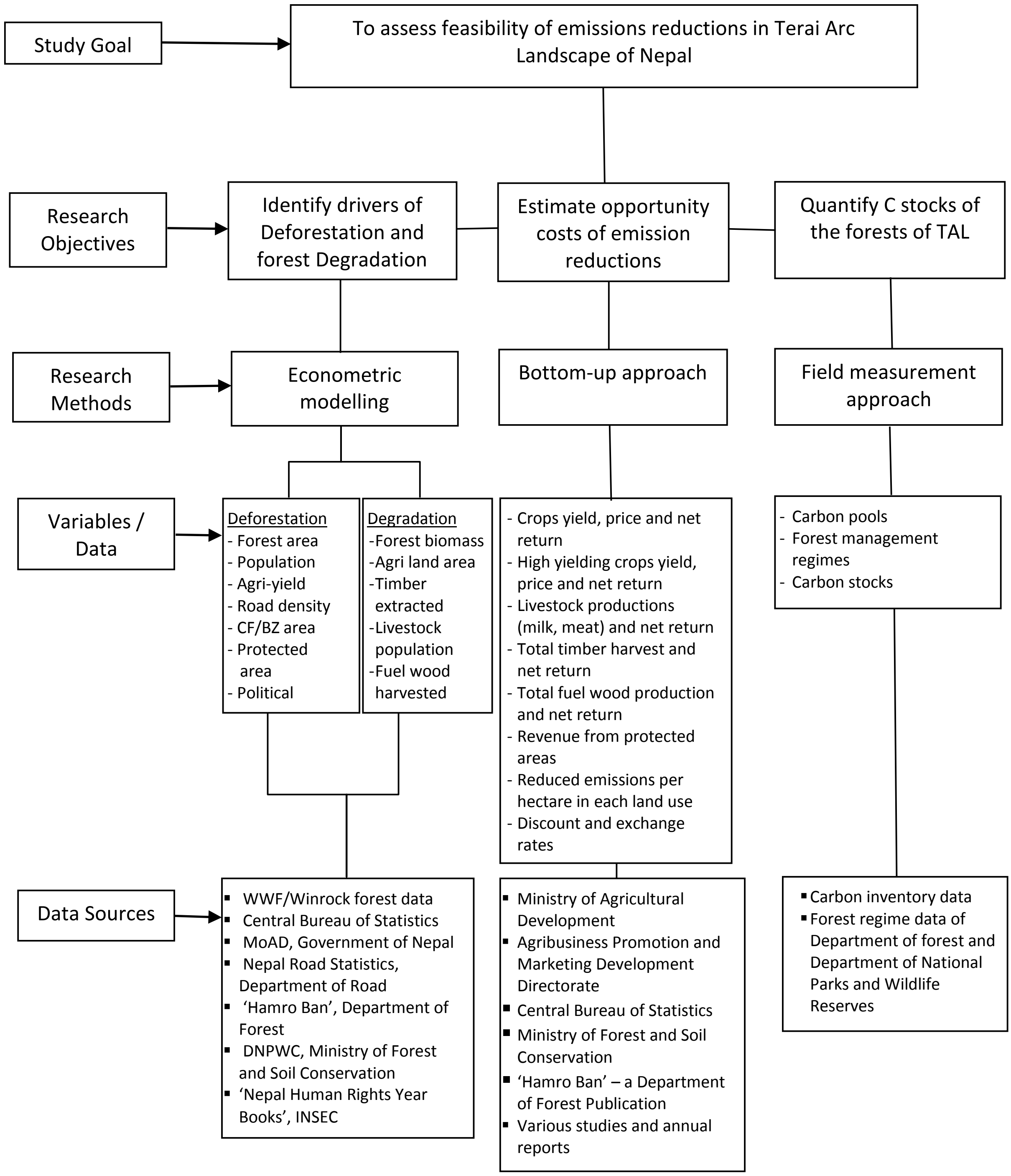


Figure 1.4 Research Framework

The study is based on biophysical and socio-economic data sets collected from primary and secondary sources. Detailed descriptions, sources and properties of data are mentioned in each individual essay. The first essay on drivers of deforestation and forest degradation uses time series cross-sectional data of 12 different variables over the period of 1990 to 2009. These data sets were extracted from governmental and non-governmental organization statistics. The second essay on carbon stock of the forest uses forest biomass data collected from 113 sample plots across the forests of the landscape. The third essay on opportunity costs of emissions reductions is based on the agriculture and forestry production, price and net return data collected from various sources.

1.6 **Structure of the Thesis**

This thesis consists of six chapters. The first chapter introduces the concept of REDD+ and explains the background of the study. Chapters 2 to 6 are each self-contained but related essays written in journal article style. Chapter 2 identifies drivers of deforestation and forest degradation in the Terai Arc landscape. Chapter 3 deals with the second determinant of REDD+ cost, the carbon stock in forested areas. The chapter also examines distributions of carbon stocks across different forest management regimes. Chapter 4 estimates opportunity costs of emissions reduction through avoided deforestation and forest degradation. Chapter 5 is an overview of findings in the previous three chapters and assess feasibility of REDD+ in the Terai Arc Landscape. The final chapter draws overall conclusions and discusses relevant policy implications of the study.