Mapping Carbon Stocks in Community Forests of Nepal Using High Spatial Resolution Satellite Images

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Increases in the concentration of CO_2 and other greenhouse gases in the atmosphere have raised concerns about global warming and climate change. The Intergovernmental Panel on Climate Change (IPCC) reported that the amount of CO_2 in the atmosphere is increasing by 1.4 parts per million (ppm) per year (IPCC 2007). This increase is closely related to human activity. Over the past two decades, most of the anthropogenic emissions of CO_2 into the atmosphere have been from the burning of fossil fuel. An important way of combating global warming is to reduce carbon emissions from deforestation and forest degradation in developing countries. According to Hunt (2009), 1 tonne of carbon stored in trees is the result of the removal of 3.67 tonnes of carbon dioxide from the atmosphere. Thus, the world's forest 'sinks' hold more carbon than the atmosphere. Recognising the importance of forests as carbon sinks, in 2007 the United Nations Framework Convention on Climate Change (UNFCCC) introduced the new mechanism of Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD).

Field measurement of carbon stock

With forests occupying 40 per cent of its territory, Nepal is an important target for REDD projects. In Nepal, deforestation, forest degradation, and forest fragmentation are affecting forest resource based livelihoods. Following serious deforestation in the 1970s, community forestry was introduced for managing Nepal's forest resources. Over 25 per cent of forests in Nepal are now managed by local Community Forest User Groups (CFUGs).

REDD in Nepal

Nepal was one of the first 14 countries selected by the World Bank for assistance under the Forest Carbon Partnership Facility (FCPF), which helps developing countries address global climate issues under the REDD principles. The Government of Nepal has established a three-tiered institutional mechanism for implementing REDD, consisting of the REDD Multi-sectoral, Multi-stakeholder Coordinating and Monitoring Committee as the apex body, the REDD Working Group at the operational level, and the REDD-Forestry and Climate Change Cell as the coordinating entity. All three bodies have been working together to prepare the REDD National Strategy and implementation plan. The REDD Cell, under the Ministry of Forests and Soil Conservation, is implementing REDD readiness activities in Nepal.

Nepal's REDD strategy is that by 2013 and beyond, greenhouse gas emissions resulting from deforestation and forest degradation will be significantly reduced by forest conservation and enhancement, by addressing the livelihood concerns of poor and socially marginalized forest dependent people, and by establishing effective policy, regulatory, and institutional structures for sustainable development of Nepal's forests under the forthcoming new constitutional framework. One of the key pillars of the strategy is to address poverty and enhance the livelihoods of people who depend on forest resources. The strategy also aims to establish a clear link between carbon ownership rights and land tenure, making it a priority to clarify issues of rights to forests during preparation for REDD.

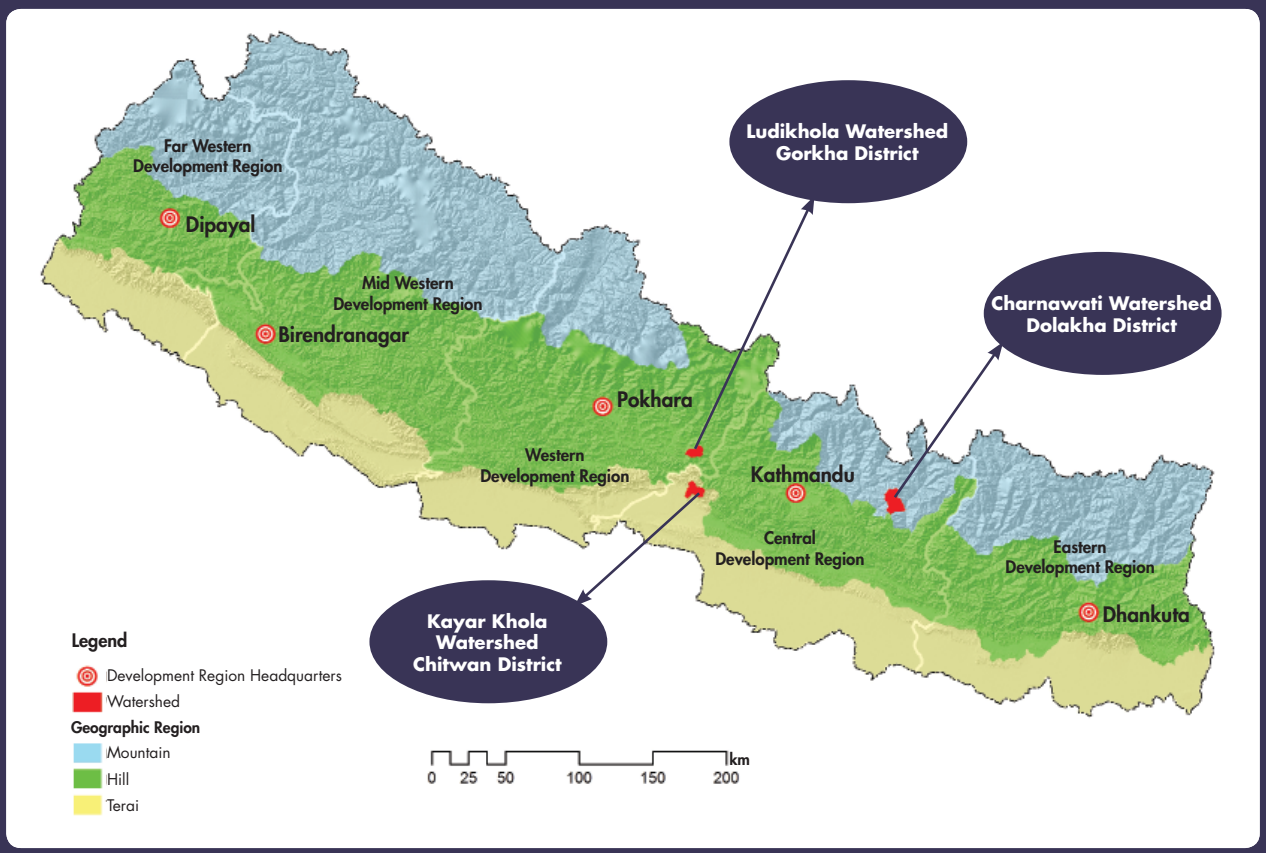
Community mapping of carbon stocks

To support Nepal's REDD activities, ICIMOD, in collaboration with the Federation of Community Forestry User's, Nepal (FECOFUN) and the Asia Network for Sustainable Agriculture and Bioresources (ANSAB), is implementing a project to assist in the design and setting up of a governance and payment system for Nepal's community forest management under REDD. Financed by the Norwegian Agency for Development Cooperation (Norad) under the Climate and Forest Initiative, the project covers over 10,000 ha of community-managed forests in three watersheds (Figure 1) and has an outreach to over 16,000 households with over 89,000 forest-dependent people. It is one of the world's first carbon offset projects involving local communities in monitoring the carbon in their forests and providing the necessary training for them to do so.

Above-ground biomass (AGB) estimation is a key way of quantifying carbon stocks in forests. The carbon stored in the above-ground living biomass of trees is the largest pool of carbon in the world and the most directly affected by deforestation and forest degradation. Accordingly, the estimation of AGB with sufficient accuracy to analyse the amount of carbon stored in a forest is important for emerging mechanisms such as REDD.

The most accurate method for estimating biomass is by cutting the trees and weighing their parts, which is time consuming and expensive for large areas. Instead of this destructive method, the project adopted the use of an allometric equation based on diameter at breast height (DBH), which has proven reasonably accurate and is

Figure 1: **The three watersheds covered under the REDD project**



one of the easiest and least expensive approaches. CFUG members were trained to make the measurements and collect the relevant data.

Verification by remote sensing

At the same time, the project sought to develop a methodology to verify the carbon stock measurements using remote sensing. The advantage of using remote sensing data is that the spatial distribution of forest biomass can be obtained at a reasonable cost and with acceptable accuracy. ICIMOD, together with a group of researchers from the Faculty of Geo-Information Science and Earth Observation (ITC) at the University of Twente in the Netherlands, used high resolution satellite imagery (GeoEye-1 & WorldView-2) together with object based image analysis (OBIA) techniques to delineate and classify crown projection area (CPA) of individual trees for improved AGB estimation (Figure 2). The relationship between stem DBH and the CPA of a tree allows the calculation of AGB using high-resolution optical imagery in which each tree is identifiable.

Three kinds of segmentations (multi-resolution segmentation, region growing segmentation, and valley following segmentation) were performed in three watersheds to assess overall as well as individual accuracies. Nearest neighbour and fuzzy rule classification were applied for tree species classification.

The fieldwork was conducted in the three watersheds by eight Master of Science students from ITC, who produced theses based on the fieldwork (see Box above). The fieldwork was organised and financially supported by ICIMOD.

Overall, 80 per cent accuracy was achieved. Carbon stock maps were produced as the final output (Figure 3).

Topics of Masters Theses Resulting from the Joint Work between the University of Twente (Netherlands) and ICIMOD

- Mapping carbon stock using high-resolution satellite images in sub-tropical forest of Nepal
- Comparison of individual tree crown delineation method for carbon stock estimation using very high-resolution satellite images
- Modeling the relationship between tree canopy projection area and above-ground carbon stock using high-resolution Geo-eye satellite images
- Carbon stock estimation using very high-resolution satellite imagery and individual crown segmentation: A case study of broadleaved and needle leaved forest of Dolakha
- Object based image analysis of Geo-eye VHR data to model above-ground carbon stock in Himalayan mid-hill forests, Nepal
- Assessment of REDD and its effect on the livelihood of local people at CFUGs: A case study of Gorkha, Nepal
- Modeling forest fire behavior and carbon emission in the Ludikhola watershed, Gorkha district, Nepal
- Development of a spatial, dynamic, fuzzy fire risk model for Chitwan district, Nepal

Figure 2: **Crown projection area**

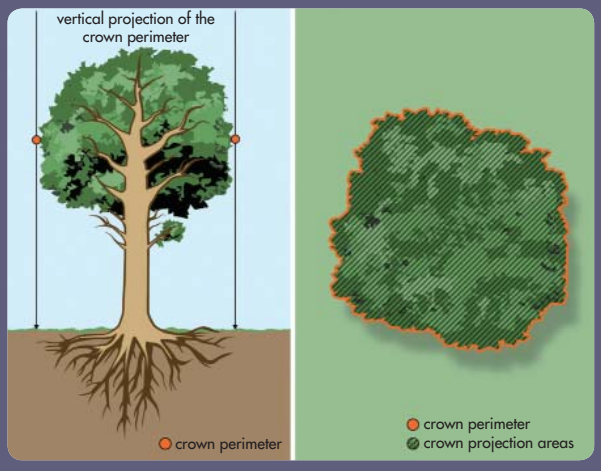
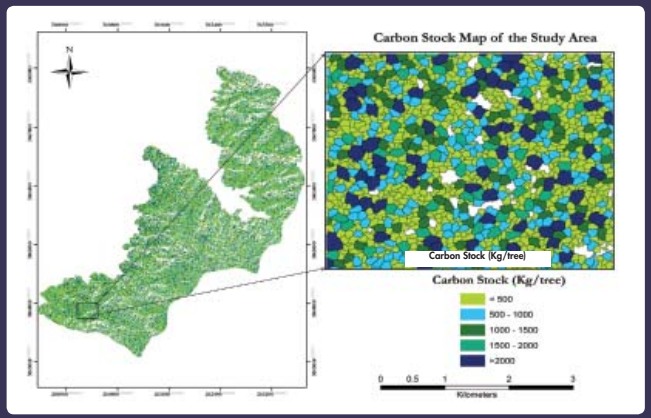


Figure 3: **Map of carbon stock in Chitwan area**



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