Carbon sequestration in community forests: an eligible issue for CDM (A case study of Nainital, India)

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Though community forests have a vital role in environmental services and sustainable development in developing countries such as in India and Nepal, the credit cannot yet to be claimed under the Clean Development Mechanism (CDM). It is due to difficulties of assessing the biomass and carbon storage in the community forests for monitoring and verification. However, forest carbon monitoring is possible by the use of advanced technology such as Leaf Area Index (LAI) that is derived from hemispherical photographs using Gap Light Analyser by establishing the relation with the biophysical characteristics of the vegetation. Therefore, the study stepped towards the assessment of carbon sequestration in community forests using LAI. To meet research tasks, which were to establish the relationship between biomass and LAI and explore environmental benefit of community forest management approach, 70 samples from Dhaili and 73 samples from Guna Chautara community forests were collected using stratified random sampling. The sample data included girth, height and canopy photos. Canopy photographs were taken by use of hemispherical cameras. After biomass was estimated using allometric equations, LAI values from canopy photos were analyzed by the use of Gap Light Analyser. Furthermore, for relationship development, the linear regressions analyses were carried out and CDM criteria were incorporated with forest management practice. Main outputs of the research were carbon sequestration model based on LAI and justification of CDM criteria with community forest management practice.

Keywords: Carbon Sequestration, Leaf Area Index (LAI), Clean Development Mechanism (CDM), Community Forest, Gap Light Analyser, Hemispherical photographs

Globally, deforestation, forest degradation, forest fires and burning of fossil fuel are playing a significant role in producing the Green House Gases (GHGs) (IPCC, 2000). Hence, deforestation and forest degradation, caused by increasing population and land degradation, are major problems in developing countries; whereas burning of fossil fuel from industries is major problem mainly in developed countries. The conversion of forest area into non-forest area, which leads to the additional GHGs in the atmosphere, was recorded as 12.3 million ha between 1990 and 2000 in the tropical countries (FAO, 2004).

The increasing amounts of GHGs adversely affect the global environment. These effects are climate change, global warming, rising of mean sea level, alteration of weather and they threaten the life of living beings. Hence, the relationship between the increasing amount of GHGs in the atmosphere and climate change was taken seriously in 1990 and many efforts were made to create awareness globally. One of the major achievements of such efforts was the third Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), held in 1997 in Kyoto, Japan which issued a protocol, known as Kyoto Protocol (UNFCCC, 1998). Its central concern was how to deal with the mitigation of the climate change for betterment of the global environment.

For mitigation of climate change, the Kyoto Protocol has three different mechanisms. These mechanisms are Clean Development Mechanism (CDM), Emission Trading, and Joint Implementation. Among these, the most important flexible mechanism of Kyoto Protocol is the CDM, which primarily deals with the interest of developing countries. The first aim of the CDM is to account the carbon credit (positive as well as negative) through emission reduction and removal. So, the emission reduction projects primarily deal with energy efficiency and fuel

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substitution. Moreover the emission removal projects also have afforestation, reforestation and deforestation activities. Though community forests have a major activities similar to afforestation and reforestation project, community forests still do not qualify under CDM. The second aim of CDM is to assist the host countries in achieving their sustainable development (Gundimeda, 2004). Thus, the CDM intrinsically helps in achieving the Kyoto Protocol goal as well as helping developing nations. The intention of the Kyoto Protocol is to set legally binding target emission reduction by 5.2% of 1990 emission level. It is the fact that CDM activities under the Kyoto Protocol are restricted only to reforestation and afforestation which contribute in additional carbon sinks (UNFCCC, 1998). Most of the developed nations have welcomed the CDM and approved the Kyoto protocol.

Concept of Carbon Sequestration

Carbon Sequestration in Forest

Carbon dioxide has a vital role in environmental system. Proportional increase in CO_2 results in steadily rising amount of GHGs. So, to check the GHGs is global grave concern and one of the significant measures is to sequester the carbon which is possible by either expanding forest resource or conserving them (Houghton, 1996).

In fact, carbon is held in the terrestrial ecosystems as vegetation and in soils. In addition oceans hold a large volume of carbon so does atmosphere. Carbon sequestration is the process of removing additional carbon from the atmosphere and depositing it in other reservoir principally through changes in land use. In practical terms carbon sequestration occurs mostly through the expansion of the forests (Houghton, 1996).Therefore, the terrestrial carbon sequestration is the net removal of CO_2 from the atmosphere and storing it in terrestrial ecosystem (Sedjo *et a*l., 2003). So, the forest expansions and sustainable forests, as mitigation measure, have a significant contribution to the environmental benefit but any shrinkage of forests, as emission, has a long term influence and impact. Therefore, the sustainable forest , as a carbon sinks, is the key factor to balance the GHGs emission (Levy *et al.*, 2004).

The carbon sequestration process involved in individual tree is an important concern in environmental system. The carbon sequestration in tree represents the balance between the process of photosynthesis and respiration which uses and releases CO_2 respectively. The process of carbon sequestration is the most rapid during the early stage of the life of tree while, as tree reaches maturity the above two processes become increasingly similar. Additionally, the rate of carbon sequestration is less particularly in over mature stage of the tree. Hence, the tree or forest expands the capacity of carbon sequestration also increases and vice-versa (Sedjo *et al.*, 2003).

Forest has a prime role in sequestering carbon from the atmosphere. In reality, the forest is a reservoir, a component or components of the climate system where a green house gas is stored, as well as sink, any process which removes a green house gas from the atmosphere (Pearce *et al.*, 2003). Thus the forest is the complement of carbon sequestration.

Conclusively, sustainable forests are reliable sinks of GHGs (Levy *et al.*, 2004). Hence, the sustainable forest and the management system is key concern as sinks. Generally, there are three broad categories of interventions such as management of the existing forest and trees source for instance community forest management in developing countries, expanding the forest area and tree cover for example afforestation and reforestation as well as using the renewable energy sources as a substitute for fossil fuel (Baral *et al.*, 2004). Among these, the community forest management which is a successful example of sustainable forest management, is the preferable option of carbon sequestration, primarily in developing countries (Klooster *et al.*, 2000).

Community forest: yet to be eligible issue under the CDM

The community forest management which is an essential part of life of local people in developing countries such as India and Nepal has a high potential as carbon sink for CDM. In this management system, the local people have been working to transform the unsustainable forests to sustainable ones (Klooster et al., 2000). The purpose of this is to meet their local forest product demands from dead trees and leaf litter and few amounts of medicinal and aromatic products without destroying the living forest biodiversity. In addition, this management system enables them to organise, develop and work institutionally. The institutional mechanism leads them to perform the sustainable development with reputation in their own local environment.

As far as community forest management is concerned globally, it is an accepted fact that community forests are additional carbon sinks for environmental benefit and also support in sustainable development such as in India and Nepal. However, since issues of leakage, permanence and additionality are still under debate and so community forest is not eligible yet under CDM. Infact, the main purpose of the Kyoto Protocol "to think global and act local" will be robust (Skutsch *et al.*, 2003; Garcia-Quijano *et al.*, 2004) possibly by community forests. Therefore, the strategies of expansion of carbon sinks need to be extended towards the forest conservation as community forest management.

Reliable argument of comparison between the community forest management with afforestation and reforestation is that both have a role in additional carbon sinks but extra resources and open lands aren't need for community forests. Therefore if the decision regarding eligibility of forest management under CDM were to be reserved in future, the financial incentive provided by sale of carbon offsets could potentially swing the balance and encourage many communities to engage in this sort of forest management and thus promote the protection of tropical forests and avoidance the deforestation (Skutsch *et al.*, 2003). Obviously, contributions of community forest can help to meet the binding target of emission reduction of Kyoto Protocol (Gundimeda, 2004).

Conclusively, the community forest management has a global role in reversing the process of deforestation and sequestering carbon, and a local function of promoting rural development activities. These roles of community forests are the prime assurance for eligibility under CDM. However, the assessment of carbon in Community Forests (CFs) is a major difficult task (Skutsch *et al.*, 2003).

Carbon monitoring under CDM

Baseline and criteria for carbon monitoring

CDM has a set of criteria to certify the project related to environmental benefit. So, the certification processes are based on monitoring and recording system of project activities which follow the baseline, additionality, permanence and leakage. Therefore, CDM evaluates the emission and reduction of GHGs using the standard monitoring system.

Base line for a CDM project activity is the scenario that reasonably represents the anthropogenic emission by sources of GHGs. So, in Kyoto term a baseline is not just the state of forest as it is now but it also involves the prediction about what would happen in the future "without a project". Thus it is possible that a standardized baseline might be accepted under UNFCCC guidelines such that for a whole ecological zone and typical managed forest. The standard baseline includes the present status of the emission sink and source as business as usual scenario (Chomitz, 2002).

The addionality is an important criterion of CDM project to monitor a carbon sink. So, additionality deals with a project that can only get CDM status if it is additional, which leads to carbon benefits, above business as usual scenario. Practically, afforestation and reforestation are accounted as additive gain under CDM (Chomitz, 2002). So far in community forests either expansion in areas or biomass is additional carbon sinks.

Permanence is another important criterion of monitoring the carbon for long time mitigation of climate change under CDM. So, the possibility of reliable guarantees of storing the carbon for a long-time (Sathaye *et al.*, 1999).

The last but not least important criterion of monitoring and verification of carbon under CDM is the guarantees of no leakage. Leakage is mainly concerned with the demonstration of the anticipated carbon benefits that do not suffer an unexpected loss due to displacement activities that result in carbon emission. One of the great difficulties in leakage is that carbon saved somewhere may be lost somewhere else. Guarantee for no leakage of carbon is appreciated under CDM (Chomitz, 2002).

Considering the above criteria under CDM different countries have different carbon monitoring, verification and recording mechanism. So, the monitoring and verification of carbon are basically done by field estimation of biomass (carbon), above and below ground of forest trees and soil carbon, as well as remote sensing based method which are described below.

Field based estimation of carbon: adopted by community

Estimation of carbon sequestration of the forest is an important concern for carbon monitoring under CDM. Hence, the field biomass is used for carbon sequestration. Therefore, it requires the delineation of forest area, survey of forest cover and recording of biomass parameter like girth, height and crown cover etc. Moreover, field based techniques are significant for relation development as well as verification purpose of monitoring work. Therefore this technique has still wide use in the developing countries to monitor the carbon.

The communities in India and Nepal have adopted standard method to estimate aggregate carbon in their community forests. So the aggregate carbon collectively includes the above ground biomass, below ground biomass, herb and shrub biomass and soil carbon. For this, the data for biomass quantification are carried by using the standard sampling, mostly stratified technique. Generally, they use the allometric equations, which cover the species wise biomass. The allometric equation, developed by Rawat and Singh, includes the total biomass of branch, twig, leaves, stem and roots (Rawat *et al*., 1988). In this way aggregate carbon has been estimated.

LAI based estimation of carbon:

Leaf Area Index based carbon estimation

LAI is a key variable that supports to understand energy and nutrient (water and carbon) exchange rate between the forest canopy and atmosphere. In addition the LAI values represent characteristics of forest canopy cover and density. Hence, The LAI is related with the photosynthetically active surface (for photosynthesis etc.) which allows the tree to grow and accumulate the biomass. Thus the LAI is widely used as a reliable tool to develop the relationship with forest biomass (Kiniry *et al*., 1999).

Some examples of monitoring the carbon under CDM

The following examples are the demonstration of carbon monitoring scheme of some nations. The purpose of demonstration is to describe the use of technology in Kyoto Protocol.

The Netherlands government is very sincere and active in the Kyoto Protocol concern despite it's own a small biosphere option. Remote sensing techniques are used to monitor the carbon. The remotely sensed imagery is basically used to find the vegetation cover and land cover change. The carbon sequestration and reporting are frequently maintained by regularly updated data. The reporting includes the yearly increase of biomass in the forest and tree outside forest, corrected by yearly extracted wood (Nabuurs *et al*., 2000). In this way, the recording is annually carried out for monitoring the carbon in The Netherlands under Kyoto Protocol. Similar system has been adopted by Canada, New Zealand (Kurz, 1999). The one of the useful tool is LAI which can be also used as a monitoring the carbon.

India has some proposed criteria under the CDM like using the field base estimation method of forest biomass estimation and remotely sensed data for the land cover estimation (Gundimeda, 2004). Similarly, Nepal has been also initiating same methods of carbon estimation for carbon monitoring (Sharma *et al*., 2004).

Research Methods

Study Area

Some community forest users groups in Nainital, India have been working for mitigation of climate change. In addition, this management practice has main strategies to increase the carbon sinks capacity of community forests. This is the purpose of selection of study area in Nainital, India.

Two community forests were selected for this research. These community forests are Dhaili and Guna Chautara. The geographical position of Dhaili community forest is 29^0 32' 52" N to 29^0 33' 16" N and 79^0 43' 54" E to79^0 44' 22" E. The estimated area under this community forest is 24.01 ha. Similarly geographical location of Guna Chauta community forest is 29^0 33' 54" N to 29^0 34' 13" N and 79^0 41' 24" E to79^0 42' 01" E. This forest covers 22.8 ha area. The altitude varies from 1500 m to 2000 m. The aspect of the study area is south west.

The dominant tree species is *Quercus leucotrichophora.* The associate species are *Rhododendron arborem, Myrica nagi Pinus roxburghii, Pyrus pashia,*etc. and other non-timber forest species are *Daphne volua, Daphne paparaceae, Delphinium himalayens, Paris polyphylla, Rheum arstrale, Nordostachys grandiflora, Valariana wallichii, Morchella esculenta* etc. But *Pyrus pashia* is not common in Guna Chautara community forest. Moreover, Due to the major dominancy of *Quercus leucotrichophora*, Guna Chautara CF characterized like a Pure Oak forest.

Sampling design and allocation

Stratified random sampling was carried in sampling purpose. But in case of Guna Chautara (Pure Oak) Community forest, sample plots were randomly selected.

Generally, the circular plot is preferred because it is easy to establish and has less number of boarder line trees. The radius of sample plot was fixed to 5.64 (100 m^2) from the centre. Sample plots were allocated with the help of Global Positioning System (GPS) finding coordinates.

Field data collection

The field data collection was done in two steps which are followed, firstly recording the tree measurement and secondly taking the canopy photographs. As tree measurement, girth of trees were taken at breast height and secondly the canopy photographs were recorded with hemispherical camera. For this task, the camera, with fisheye lens, was set beneath the forest canopy in the centre of the sample plot at 1m height above ground. The canopy photos were recorded by the researcher. The photo number, ground feature and crown condition as well as weather condition in the beginning of the work were also included in record sheet. the This part answer how relation can be derived using LAI with above ground biomass.

Data preparation for relation development

The careful visual observation of data spread in a scatter plot can provide a fundamental base develop the relation. Seven observations were found out of trend in both community forests plotting the LAI against field biomass in both community forests. Therefore only 63 and 66 observations in Dhaili and Guna Chautara respectively, were used in study. Half data set was used for relation development and remaining half was used for validation purpose.

Indeed the linear equation has benefits such as easy to estimate in simple computers or calculators (Vanclay, 1999). Therefore, in case of this study the linear model, which showed the better relationship, was used.

Data regarding forest management practice

Adopted some forest management practice in Nainital, India can support to meet the criteria CDM. So, data regarding baseline, addionality, no leakage and permanency were collected from user group records. This answer the problem related to how these management practices assure and assemble the CDM criteria.

Results and Discussion

LAI versus field based above ground forest biomass

To meet the research task related to how relation can be derived using LAI with above ground biomass for Guna Chautara and Dhaili community forest, independently.

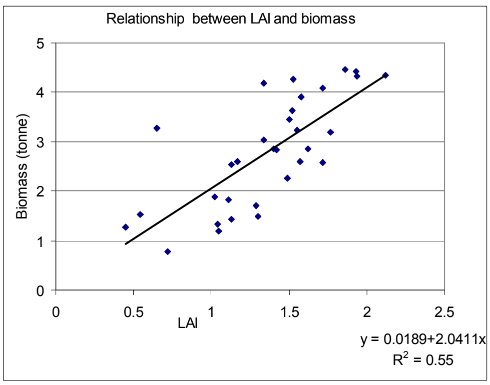
Analysis of Forest Canopy

Figure 1 Canopy Photo of Sparse Area

Figure 2 A Canopy Photo of Dense Area
Figure 3 Analysed Photo of Sparse Area
Figure 4 Analysed Photo of Dense Area

The result from the canopy analysis showed that the higher and the lower values of LAI (2.27 and 0.45 in figure 3 and 4 respectively) were caused by high and low forest tree densities respectively. Basically, the good indicator of forest biomass is the crowns cover i.e. the proportional ground covered by the forest canopy on which the LAI depends upon. Hence, the importance of LAI is not only to generate the relationship with the canopy, but also with the ecological processes such as rates of photosynthesis, transpiration and evapotranspiration. Studies have indicated that the larger the canopy cover, the higher the rate of ecological processes (Gong *et al.*, 2003). It follows that, the larger the canopy cover, the higher the value of LAI hence the more amount of forest biomass.

Relationship between Biomass and LAI in Guna Chautara



Scatter plot of LAI and biomass in Guna Chautara CF(Pure oak forest)

Figure 5 : Scatter Plot of LAI and Biomass in Guna Chautara CF

A total of 33 sample plots of the above ground biomass estimated from the field and their corresponding LAI values were used to co-relate between them for Guna Chautara CF. A positive correlation was observed between them. Further, a linear model was fitted which revealed significant relationship with R^2 of 0.55 as shown in Figure 5. The linear model is represented by, $y = 0.0189+2.0411x$

Where, y is for above ground biomass and x is LAI values.

Predicted over observed biomass in Guna Chautara CF

The validation test equation obtained by plotting the predicted over observed (n = 33) biomass supported the LAI-biomass model because R^2 value was 0.525. It indicated that the LAI-biomass model represents 52.5 % of observed biomass. In addition, the standard error was 0.43 while accuracy (-0.07) showed within the standard error.

Relationship between Biomass and LAI in Dhaili CF

LAI over Biomass in Dhaili CF (Adense mixed forest)

A total of 32 sample plots of the above ground biomass estimated from the field and their corresponding LAI values were used to derive the relate between them for Dhaili CF. A positive correlation was observed between them. Further, a linear model was fitted which revealed significant relationship with R^2 of 0.54. The linear model is represented by, $y = -0.6168+2.2928x$.

Where, y is for above ground biomass and x is LAI values.

Predicted versus Observed Biomass in Dhaili CF

The validation test of linear equation (n = 31) predicted versus observed biomass supported the LAI-biomass relation because R^2 value was 0.52. It indicated that the LAI-biomass model can predict 52 % of field data. In addition the standard error was 0.37 and accuracy which had a value -0.07 showed within the standard error.

Canopy analysis results showed that there was a better positive relationship between LAI and forest biomass in both pure and dense mixed forest. The estimated values of LAI have been used to predict the future growth and yield including the carbon sequestration by using the forest canopy closure (Houghton, 1996). Therefore, the forest canopy is related with the individual tree crown characteristics. In this circumstance, the major tree characteristics are size, shape and structure of tree crown. The canopy of green leaves and branches forms the trees crown in a forest. In addition, relationships that exist among the tree crown, diameter and height. A group of trees collectively form the forest canopy, which is related with the above ground forest biomass. However presence of stems, tree leaning also, weather condition affects the LAI values.

Forest Management Practice for Environmental Benefit

To meet the research task how the management practices assure and assemble the CDM criteria the community activities and their steps for environmental benefits are essential parts. Both communities have adopted the same type of forest management practice. The major works are presented as follows:

Protection Approach in Community Forest

The communities themselves had been involved in protection against deforestation and forest degradation. For this purpose, they followed the daily calendar (Unwritten) which was prepared by the committee monthly meeting. The calendar included person's name and date of watching the forest. So, probably they had a rotation once a month to watch the forest. Additionally, they had some rules to protect the forest for example they strictly prohibited any destructive activities such as grazing, cutting the tree, fuel wood and fodder collection, burning and other any damaging activities. If the people violated the community rules they were punished. Therefore, these protection activities are the evidence of guarantees of permanence and no leakage.

Plantation Work in Community Forest

As a plantation work, community had planted some trees in open patch of the forest. For this purpose, seedlings were available free of cost from the Central Himalayan Environmental Association (CHEA) project. The record showed that they had planted 2.5 ha in open areas in their forest in 2004. Before the plantation, the present status of community forest considered as base line (business as usual scenario). In addition the annual increment in community forest and plantation activities are additional carbon sinks which are the indications of additionality.

Utilization of Forest Products

The community had strictly prohibited removing the live trees, leaves, firewood and fodder but people have a requirement of firewood, fodder and timber etc. Therefore, they used the private forest to meet the demand of forest products. However the dead trees were collected and open auctions were called to sell them. If there is an emergency for users, the logs (dead logs) are freely available. This is the supportive role for the local community.

Conclusion

The first research output was the method produced by the combination of LAI and biomass. The remarkable fact in this relationship was the use of LAI which was extracted from the canopy photos, taken by hemispherical camera and analysed by the use of Gap Light Analyzer. Therefore it can be concluded that the hemispherical photography techniques and GLA software are the additional devices in assessment of biomass in community forests.

Another research outcome, i.e. forest management practice in India in Uttaranchal, Nainital have a successful example. The protection, plantation and management have effective efforts for environmental benefit. This management practice is not only contributing in increase in carbon sinks but also to prevent the deforestation and forest degradation. Therefore, it can be concluded that community forest management practice will be one of the important concern of CDM.

Relevance

Forest management is an important carbon mitigation strategy in developing countries such as India and Nepal. One of the effective forest management approaches is community forest management because it offers tangible local benefits while converting forests for carbon sequestration. According to Central Himalayan Environmental Association (CHEA) in Uttaranchal, India project records, most of the communities involved in community forest management have been concerned with carbon storage. The record showed that there are 6777 community forests (Tolia, 2004) in Uttaranchal state only. Similarly in Nepal, According to record of Community Forest Division 13,238 users groups have been involved managing 10, 82,165 ha forests. In this contest also community forests have been recorded as improving the forest stocks. This means that these community forests are capable to sink carbon and that the community forest management is a useful practice in carbon mitigation from the environment.

Though communities in both India and Nepal have been started to assess the forest carbon, their methods and skills are still at an infancy level. However on the other hand, community forests are still not qualified under the CDM. This is due to the difficulties of assessment of carbon by the concerned community. It is expected that the assessment of forest carbon will be adopted as a regular process by the communities and will archive their records of forest carbon for monitoring. The success of this process has been due to training support to the community by CHEA , and King Mahendra Trust for Nature Conservation (KMTNC) in Nepal (Sharma et al., 2004). More forest area (than afforestation and reforestation), the community forests offer an easy and accessible alternatives for carbon sequestration. Therefore, the community forest management practice will be a possible global key concern for Kyoto Protocol.

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