Chapter 4

Forest Carbon Market and Its Economics

4.1 Background

As discussed in the previous chapters, greenhouse gas emissions continue to rise from most of the countries. India ranks at number three among all countries in the world in terms of total GHG emissions. As studies have indicated and as impacts of climate change become increasingly visible, the consequences of climate change will be very serious for the humanity not in distant future. Nick Stern (2006) in his review has estimated 'that overall costs and risks of climate change will be equivalent to loosing at least 5% of global GDP every year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise up to 20% of GDP[22]. Climate change is a global problem, though the developed countries are responsible for the excessive emissions, now every nation has to contribute towards reduction in emissions and take steps for adaptations according to the projected impacts of climate change. As a global response to the climate change, the countries of the world have come together under the United Nations and a framework convention (UNFCCC) has been signed by over 190 countries. Under UNFCCC, Kyoto Protocol has also been signed by most nations, which assigns legally binding emission reduction targets to the industrialized countries (called Annex I countries). With mounting scientific evidences of the impacts of climate change, governments in every country have awakened to the impending threat of climate change, in many countries the climate change has become

[22] Stern N., (2006), The Economics of Climate Change : the Stern Review

important agenda of the political parties. In global politics, climate change is already an important agenda. In India too, climate change has been taken as a serious issue and as mentioned in the Section 1.9, a National Action Plan on Climate Change (NAPCC) has been launched. India has been fairly successful in CDM projects as well. But, there is scope for much more action in this regard, not only for reducing GHG emission from the country but also to seize opportunities which this problem has opened up. The Emission Trading Scheme can be one of the effective policy tools to promote mitigation actions and along with it, promote ecosystem services and other benefits. Following points deserve attention in support of this argument.

- Besides government sponsored programmes, an enabling mechanism / environment by suitable policy interventions may lead to wider participation of private sector, SHGs, and public at large.
- Developed countries may be largely responsible for the global warming, but its impact will be felt everywhere and developing countries like India with scarce resources will be more vulnerable to the impacts, so adequate efforts are required for adaptation to climate change. Among number of required adaptation actions, sustainable agriculture and strengthening of ecosystem services should be high on priority. Tree planting is a mitigation as well as adaptation measure.
- Several countries have already started emission trading schemes and several of them are on the path of doing so. There is no reason why we should not take advantage of this concept, with appropriate modification and innovation to suit our own problems and priorities.

- As emission or carbon trading is a new area of expertise, management and professionalism, there is a need to build capacity in this field and gain experience, which will happen over a period of time.
- Given the challenges of ecological security, water availability and environment in general, the country needs operational models of payment for ecosystem services not only for greenhouse gas emission reduction but for many other problems too.

4.2 Internalising an Externality - Concept

Greenhouse gas emissions (GHG) is an externality, an industry while producing a good is not concerned about the pollution, because it does not incur any cost in causing the emission which is adding to the problem of climate change which in turn adversely affects the society in so many ways, the society is paying a price for which it is not being compensated by the industry. This is a case of negative externality.

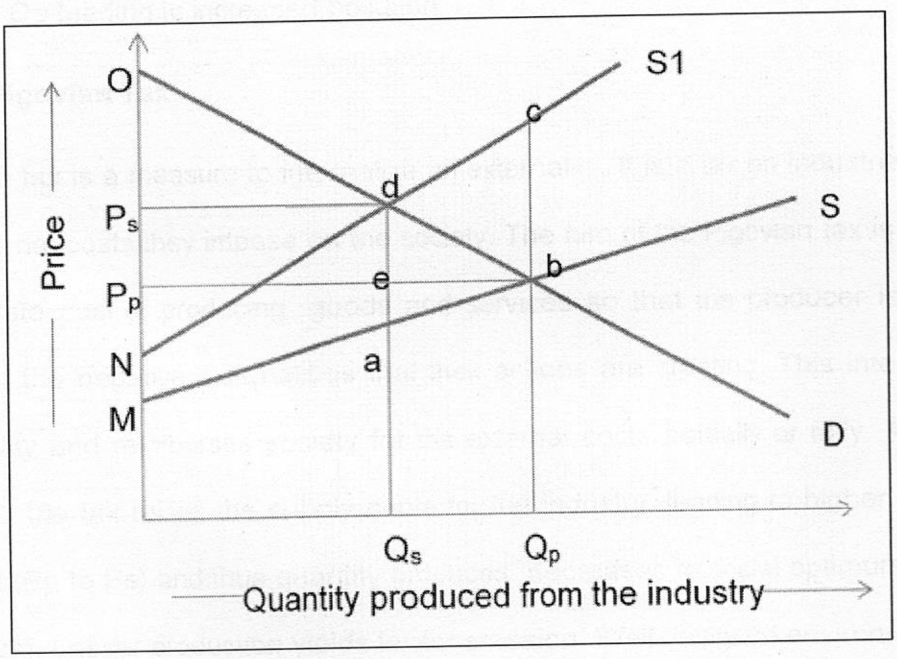

Fig 4.1 Supply Demand Curve showing negative externality

Externality and the social cost can be understood with the help of the Fig 4.1 in which curve D is the market demand curve which shows how much quantity people want to consume at a given price, curve S is the supply curve which shows the summation of marginal private costs for producing the good by the industry – it shows the quantity that industry wants to produce at each price, its height shows the marginal costs incurred by the industry in producing the good. In the market situation, the equilibrium price and quantity of the good will be Qp and Pp. S1 represents the supply curve which also takes in to account the social cost, i.e the damage done by the pollution height of S1 shows the marginal social cost of producing the good i.e. MPC + MEC. Vertical distance between S and S1 is the cost to the society due to pollution. Efficient rate of production with the social marginal cost would be Qs instead of Qp. At this quantity marginal social cost of producing the good will be equal to the marginal benefits of having it produced. If the firm does not have to incur the external cost it will continue to produce the higher quantity Qp leading to increased pollution.

4.2.1 Pigovian Tax

Pigovian tax is a measure to internalize an externality. It is a tax on industries based on the external costs they impose on the society. The aim of the Pigovian tax is to Increase the private cost of producing goods and services so that the producer is paying for some of the negative externalities that their actions are creating. This internalizes the externality and reimburses society for the external costs partially or fully. As shown in Fig 4.2, the tax raises the supply curve for the industry, leading to higher price of the product (Pp to Ps) and thus quantity produced decreases to social optimum level (from Qp to Qs). Lesser production yields lesser emission. Well designed environmental taxes can encourage innovation and the development of new technologies which reduces our dependence on pollution-inefficient forms of energy. Revenue derived from these taxes can be utilized to fund increased spending on environmental projects achieving improved sustainability in natural resource use so as to protect the resources available for future generations ensuring inter-generational equity justification.

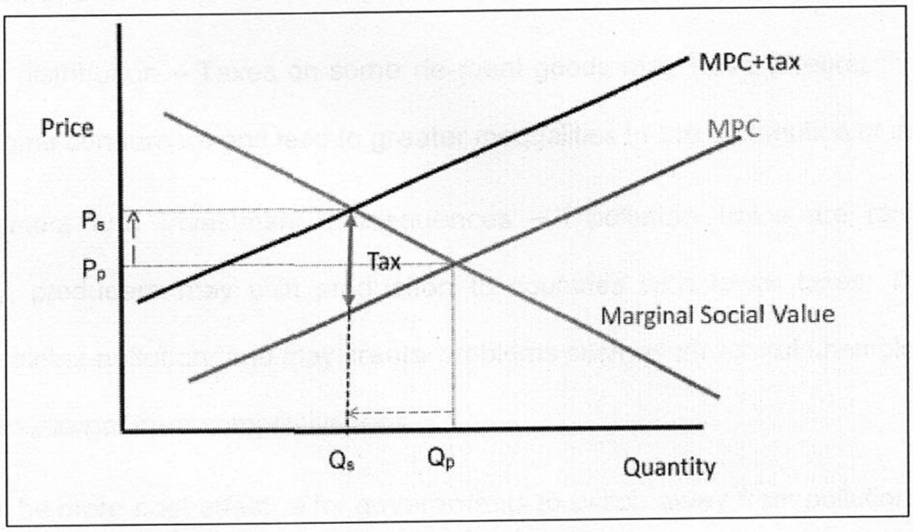

Fig 4.2 Concept of Pigovian Tax

4.2.2 Problems with environmental taxation

The main criticisms of environmental taxes are discussed below:

Valuing the environment – There are problems in setting taxes so that marginal private costs will equate with the marginal social costs. Frequent adjustments of tax levels may be required and this involves substantial organisational costs.

Consumer welfare effects – Taxes reduce output and raise prices and this might have an adverse effect on consumer welfare. Producers may be able to pass on the tax to the consumers if the demand for the good is inelastic and, as a result the tax may only have a marginal effect in reducing demand and final output.

Achieving a target quantity of pollution reduction – Taxes do not lend themselves to the government achieving an accurate reduction in total pollution. This is because no government can ever predict how consumers and / or producers will respond to higher costs and prices. The price elasticity of demand will vary over time.

Income distribution – Taxes on some de-merit goods may have a regressive effect on low-income consumers and lead to greater inequalities in the distribution of income.

Employment and investment consequences – If pollution taxes are raised in one country, producers may shift production to countries with lower taxes. This will not reduce global pollution, and may create problems such as structural unemployment and a loss of international competitiveness.

It might be more cost effective for governments to switch away from pollution taxation to direct subsidies to encourage greater innovation in designing cleaner production technologies. The impact of green taxes depends crucially on what is done with the revenues. If they are balanced by reducing other taxes through 'revenue re-cycling', research suggests that green taxes could result in an overall economic improvement

4.2.3 Command & Control

The government can respond to externalities through command-and-control policies. Command-and-control regulation can come in the form of government-imposed standards, targets, process requirements, or outright bans. In practice, implementing regulation effectively is difficult. Advocates of market-based policies for reducing negative externalities point to the difficulty of creating and enforcing effective regulation for reasons why the government should create systems of incentives and disincentives instead of using the force of regulation.

Command & control can succeed only if there is a very effective monitoring system and the regulating authority has in-depth knowledge of all the factors leading to pollution. This is also criticized for inducing corruption in the system and thus the very purpose of creating control and command authority is defeated.

4.2.4 Coase Theorem

As explained in the section 1.4.5, Coase theorem offers solution to the externality by assigning property rights. If the well defined property rights exist then in absence of transaction cost the parties can bargain to a mutually beneficial and efficient outcome. In the context of emission of GHGs, the property right signifies the emission allowance assigned to a particular industry i.e. the limit to which it is permitted to emit. The concept of property right lays down foundation of emission trading, as an industry which is holding emission allowance may sell the unutilized emission allowance to some other industry which has exhausted its allowance and wants to emit more.

Application of Coase theorem in real life situation is not always possible for the following reasons

- transaction cost in bargaining a solution is never zero
- Coase theorem can work if there are only two or very few parties trying to bargain a solution but in many situations large number of stakeholders are involved. Bargaining a solution in such situations may not be possible.

- monitoring the property rights, emission allowances in case GHG emissions is difficult and costly affair.

Coase theorem however, lays down principles and suggests an approach by which emission can be reduced in a cost effective and efficient by way of emission trading.

4.3 Transaction Cost

Mitigation projects will differ in terms of cost per unit of carbon emissions avoided or carbon sequestered, and they will also differ in terms of other environmental and social benefits provided. For example an agroforestry project will be very different from an energy efficiency project though both may be leading to similar amount of mitigation (former by sequestration of carbon and the later by avoidance of fossil fuel). Agroforestry is considered as an efficient use of family labour in generating additional income, leads to higher biodiversity and also provides many environmental benefits including soil improvement.

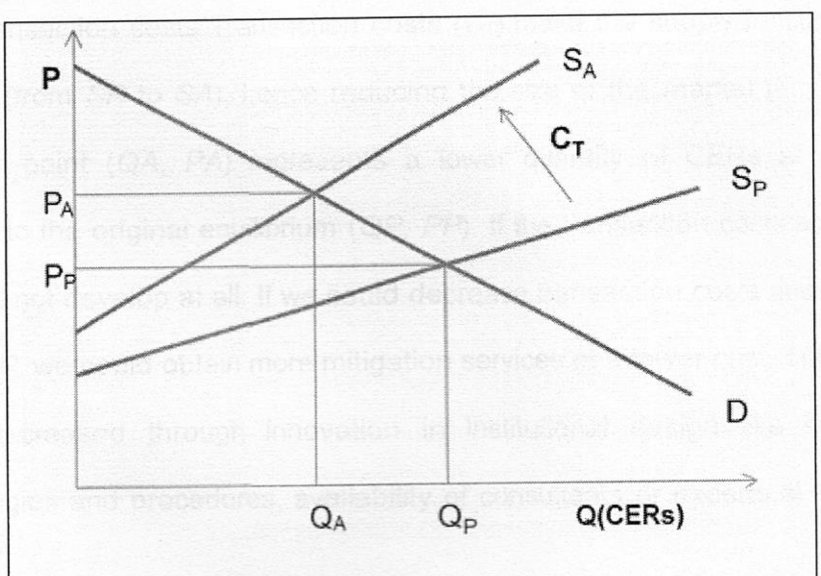

Fig 4.3 Explaining Transaction Cost

The supply of CERs depends on availability and costs of different technologies and resource endowments, and these will be partly determined by location. For a given supply function, as determined by current technology and land availability, the equilibrium levels of price and quantity (Q_P, P_P) depend on the demand function (D). The position and slope of the demand function will depend to a large extent on the regulations imposed by governments (international regulations in case of international carbon market), channeling of overseas funds, and the extent to which the private sector is required to offset emissions. One can expect a downward sloping demand function. The transformation costs of producing GHG mitigation can therefore be regarded as abatement cost, which means the total cost incurred in the activity for mitigation in terms of per unit of CER. The curve S_P shows the prices that would be required to motivate different levels of abatement, or mitigation, in a world of zero transaction costs, where supply decisions depend simply on abatement, or transformation costs. However, In order to participate in the market, suppliers will have to incur transaction costs Transaction costs (C_T) make the supply function shift up and to the left (from *SP* to *SA*), hence reducing the size of the market (Fig 4.3). The new equilibrium point (*QA*, *PA*) represents a lower quantity of CERs at a higher price compared to the original equilibrium (*QP*, *PP*). If the transaction costs are too high, the market will not develop at all. If we could decrease transaction costs and move from *SA* towards *SP*, we could obtain more mitigation services at a lower cost. Transaction costs can be decreased through innovation in institutional design like simplification in methodologies and procedures, availability of consultants or experts at lesser cost etc.

Transaction costs will differ between projects, affecting their market shares and even possibly driving some projects out of the market.

The market supply is an aggregation of the individual supply functions of the market participants. Fig 4.4 shows this with an illustration of two suppliers with supply functions s_1 and s_2. The market supply function Sp is the horizontal summation of the individual supply functions. First, it is assumed that there is no transaction costs to the suppliers. This is also assumed that the demand of the CERs is perfectly elastic at a fixed price P. This results in an equilibrium quantity $Q_P = q_1 + q_2$, with q_1 CERs supplied by first supplier and q_2 CERs supplied by the other one. It may be noted that this is a situation with no transaction cost. Therefore individual supply curves are also the marginal abatement cost curves i.e the pure mitigations actions only, and thus will shift with changes in abatement technologies and innovations.

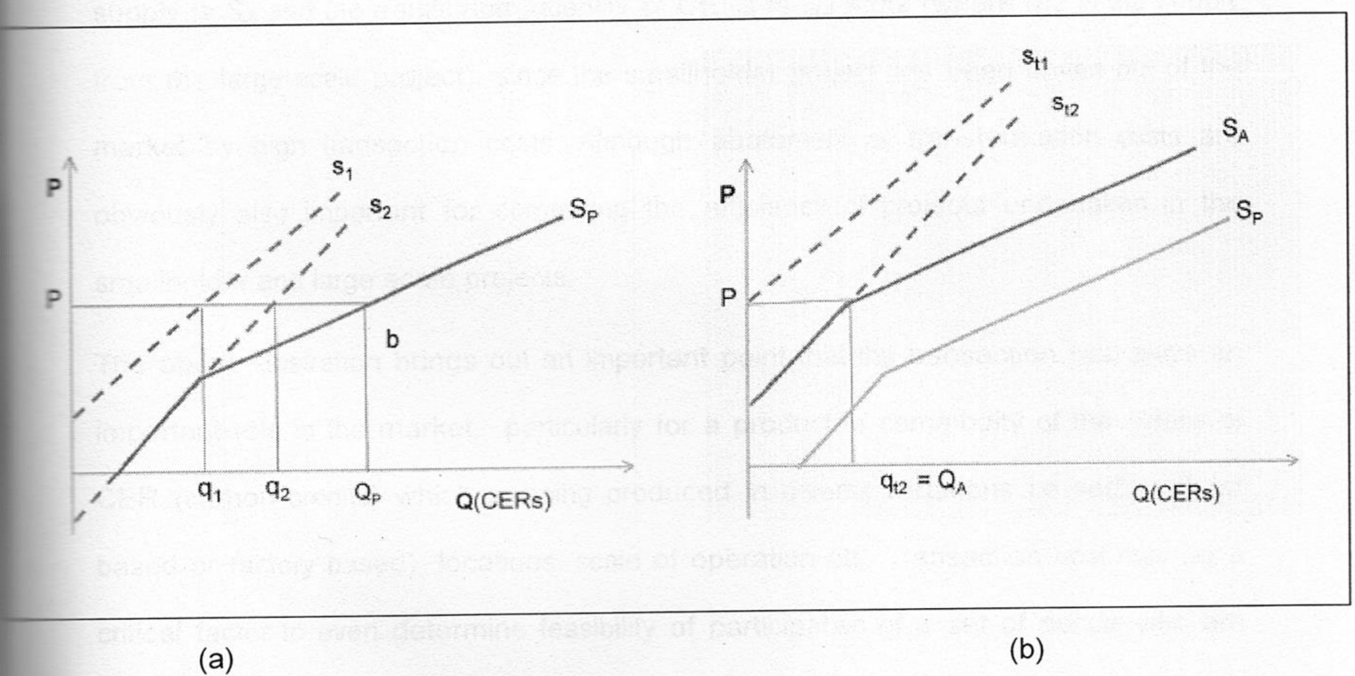

Fig 4.4 Impact of high transaction cost on small holder

In this example, there is scope for both types the projects to participate in the market though both having different marginal abatement cost function. But this analysis accounts only for abatement costs. Now to understand the implication of transaction cost let us assume different transaction cost to the two suppliers. This assumption could be the cases of one small scale project and the other one large scale project or one land based project where transaction cost is high and the other one may be an energy efficiency project involving lesser transaction cost, the transaction cost of the two projects could also be different due to their locations being in two different countries. Fig b shows this situation where due to different transaction costs supply functions shift to *st1* and *st2*, respectively. Transaction cost in case of the first project is higher (let us assume this be the small holder i.e small scale project) than the second project (assumed to be the large holder or large scale project). The new (actual) aggregate supply is S_A and the equilibrium quantity of CERs is $Q_A = qt2$ (where *qt2* is the supply from the large scale project), since the smallholder project has been driven out of the market by high transaction costs. Although abatement or transformation costs are obviously also important for comparing the efficiency of projects undertaken in the smallholder and large scale projects.

The above illustration brings out an important point that the transaction cost plays an important role in the market, particularly for a product or commodity of the nature of CER (carbon credits) which is being produced in diverse situations i.e sectors (land based or factory based), locations, scale of operation etc. Transaction cost may be a critical factor to even determine feasibility of participation of a set of people who are producing a commodity with much higher transaction cost than the others producing the same commodity with lesser transaction cost.

Transaction cost has policy implications. For example, take the case of carbon sequestration by agroforestry in India with multiple objectives of income generation to the farmers, agroecology improvement and greenhouse gas mitigation. Average land holding of agriculture farmers in India is 1.32 ha[23]. Agroforestry on small farm lands will not have much disadvantage as far as marginal abatement cost is concerned but to earn carbon credits from that will involve transaction cost which will be very high for small holder projects compared to alternative abatement projects. With suitable policy interventions, it is possible to bring down transaction cost. Simplification of the methodologies of various steps in project preparation would reduce the transaction cost significantly. Another policy intervention could be to assure the farmers of a minimum support price of the carbon credits. The following figure (Fig 4.5) explains how transaction cost is an essentiality for generating carbon credits from a GHG abatement activity but keeping it as low as possible would be important for the carbon credit market to be sustainable and in ensuring wider participation in the market including the small holders. Various transaction costs involved in generating carbon credits from a an abatement activity are mentioned in the table 4.1

23 Agricultural Land Degradation in India: Trend, Causes and Impacts, G. Mythili (2013)

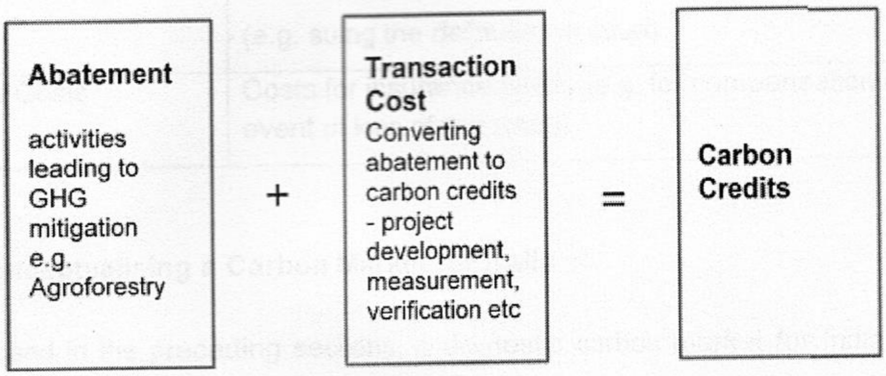

Fig 4.5 Abatement, Transaction Cost and Carbon Credits

Table 4.1 Transaction Costs

Cost Category	**Type of Costs**
Search Costs	- Costs of finding interested partners to the transaction (e.g. advertisements and brokers) - Costs for communication (e.g. expenses for telephone and sales representatives) - Costs for price information and quality control (e.g. agents)
Project Preparation Cost	Developing Project Design Document (PDD), fees of consultants for determining baseline, additionality, permanence, leakage, measurements, field surveys etc.
Negotiation Costs	Costs for coming to an agreement (e.g. time, visits and drafting of contract)
Approval Costs	Costs that arise when the trade must be approved by a government agency (e.g. modifications)
Monitoring Costs	Costs to observe the transaction and to verify adherence to the terms of contract (e.g. hiring a verification service)

Enforcement Costs	Costs to insist on compliance once divergence from contract is detected (e.g. suing the defaulter in court)
Insurance Costs	Costs for insurance policy (e.g. for compensation in the event of loss of the good)

Source[24]

4.4 Conceptualising a Carbon Market for India

As discussed in the preceding sections, a domestic carbon market for India has been conceptualized with two broad objectives, one, to reduce greenhouse gas emissions from India towards its contribution as a responsible nation in addressing the grave global problem of climate change; secondly, to harness the opportunities arising out of the efforts to mitigate the problem of climate change in addressing the country's domestic challenges like soil impoverishment, falling productivity of agriculture fields, low income of farmers etc.

Making use of the principles of economics in dealing with the externality, as discussed in the preceding sections 4.2 and 4.3, a domestic carbon market has been conceptualized. A schematic diagram depicting broad outline of the carbon market for the country is presented in the Fig 4.6 below.

[24] Dudek D.J., Wiener J.B., (1996), Joint Implementation, Transaction Costs, And Climate Change

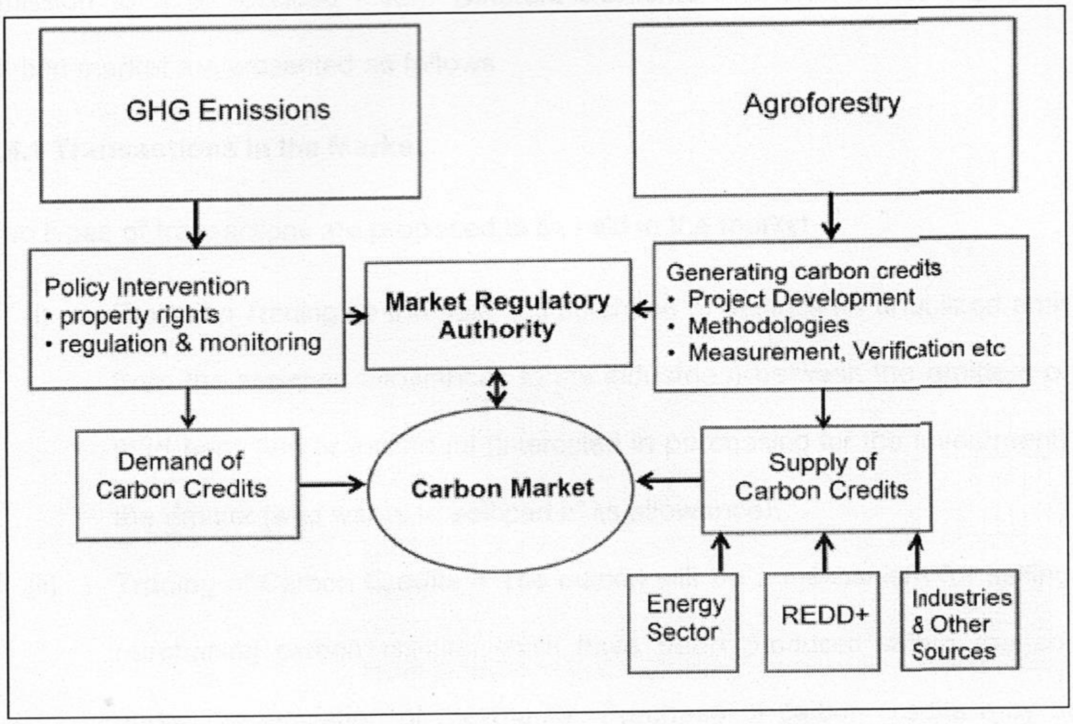

Fig 4.6 Schematic diagram showing concept of domestic carbon market

REDD+[25]

The proposed carbon market for India is based on a mix of two approaches of internalizing an externality viz Command & Control and the Coase Theorem. Command & Control is in the form of rules and regulations governing different actors and processes in the market, whereas, the application of Coase theorem is limited in assigning property rights (in the form of emission allowances) to the industries causing emissions. Trade of emission allowance which the carbon market proposes to allow is a

[25] **Reducing emissions from deforestation and forest degradation** (**REDD**) is a mechanism that has been under negotiation by the United Nations Framework Convention on Climate Change(UNFCCC) since 2005, with the twin objectives of mitigating climate change through reducing emissions of greenhouse gases and removing greenhouse gases through enhanced forest management in developing countries. '+" denotes addition of three more components to REDD viz conservation, sustainable management of forests and enhancement of forest carbon.

form of bargaining the property right for solution to the externality (by limiting the emission to a pre-decided level). Different elements and features of the proposed carbon market are presented as follows

4.4.1 Transactions in the Market

Two types of transactions are proposed to be held in the market

(i) Emission Trading i.e the sale and purchase of balance (or unutilized emission from the assigned allowances to the industries) between the emitters or any third party firm or individual (interested in purchasing for the investment) and the emitter (who wants to sell part of its allowance).

(ii) Trading of Carbon Credits – The market will be a mechanism for selling and purchasing carbon credits which have been produced within the country under the regulation of the market. Purchase of carbon credits may be for offsetting the emission targets in compliance to the emission quota (for example if an industry which has been assigned an emission limit is not able to reduce the emission by itself then for the balance amount of emission the industry can offset by purchasing carbon credits). They can also be bought for any other voluntary purpose such as investment, corporate social responsibility, green branding etc.

4.4.2 Demand Side

(a) Assigning emission allowances – Major industries causing emission would be assigned the emission allowance i.e they will be allowed to emit up to a limit which may be certain percentage (fraction) of their current level of emission. For the emission reduction, they will be allowed certain period, normally five years. The balance they will have to prevent in the given period.

It is proposed in this study that

(i) in the first phase following three sectors may be selected for assigning emission allowances

Table 4.2 Top three Industrial Sectors in GHG Emission

Sector/Industry	Current Emission Level (in million tonnes/yr)
Coal and gas based thermal power plants	719.30
Cement Industries	117.32
Iron & Steel Industries	129.92
Total	**966.54**

(ii) the above emission reduction would be distributed among the industries of the above sectors. Industries would be assigned emission allowance of 80% in the next five years, implying that these industries will reduce emission by 20% in the five years period

(iii) the above emission allowance will create an annual demand of upto 190.31 million carbon credits (maximum).

(iv) though whole of the above reduction will not result into the demand of carbon credits, as industries will also physically cut their emission by improving efficiency, substitution etc. Some emission cut will take place by emission trading also.

4.4.1.1 Forest Carbon

The study also proposes to create a specific demand of Forest Carbon Credits. The term 'Forest Carbon Credit' here (for the purpose of this study) implies the carbon credits which have been created by practice of agroforestry or other forestry activities. Considering the multiple co-benefits of agroforestry (which has been described in section 4.5), the study proposes that 25% of the emission reduction (by offset) by each industry be done by Forest Carbon Credits only. This can be done through regulation by market regulator. This will create a demand of 47.6 million carbon credits of agroforestry origin.

Earmarking of carbon credits to the agroforestry based carbon credits (termed forest carbon credit in the study) will amount to payment of ecosystem services (PES) i.e a farmer practicing agroforestry will be paid for carbon sequestration by trees which he/she has planted in his/her field. This will also result in capital flow from industries causing emissions directly to the farmers under overall supervision of market regulator, this has been depicted in the following Fig 4.7.

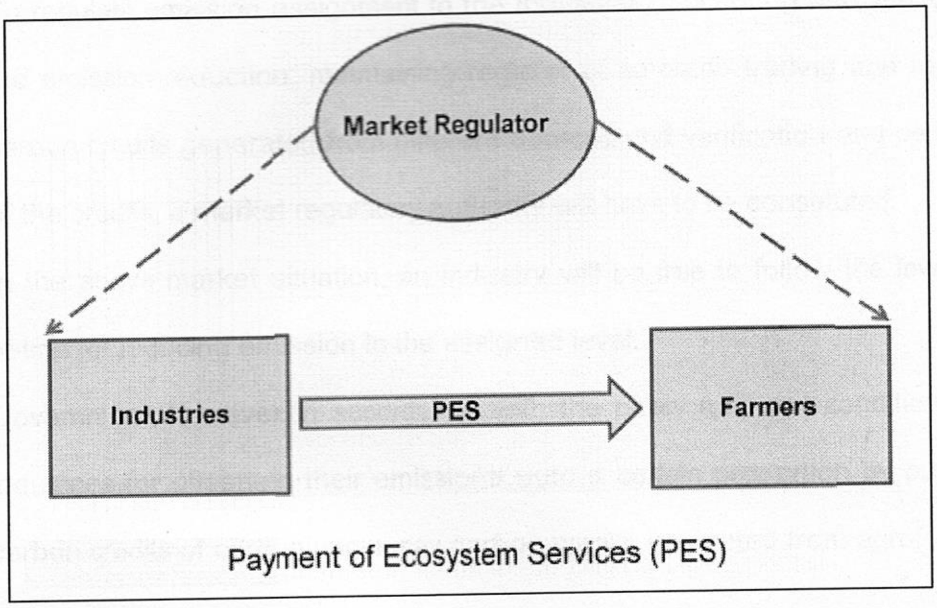

Fig 4.7 Concept of Payment of Ecosystem Services

(b) Options for the industries to reduce GHG emissions – The industries will have following three options to meet their assigned limits

(i) By investing in energy efficiency measures, switching over to less polluting fuels, improving industrial processes etc and thus cut emission

(ii) By purchasing unutilized emission quota from other industries i.e emission trading

(iii) By purchasing emission offsets (Carbon credits) i.e certified emission reductions from the carbon market which have been generated from the approved carbon mitigation projects like agroforestry, renewable source of electricity generation etc. Offset of emission will be allowed only from the mitigation activities approved under the market regulation.

(c) To regulate emission assignment to the industries, monitoring and verification of the emission reduction, maintaining register of emission trading and registry of carbon credits generated from different sources and verification and certification of the credits, a market regulatory authority will have to be constituted.

(d) In the above market situation, an industry will be free to follow the lowest cost option for reducing emission to the assigned level.

(e) Government, however in accordance with the policy may put conditions to the industries for offsetting their emissions upto a certain proportion by purchasing carbon credits of certain origin, say carbon credits generated from agroforestry.

4.4.2 Supply Side

(a) Suppliers in the market will be the firms or persons who have generated the carbon credits by some emission abatement action which is approved in the market rules.

(b) Those industries that have been allotted emission allowance but their actual emission is less than their limit may also sell the surplus allowance in the carbon market. However, there would be a limit to which they can sell their allowances

(c) For a buyer in the market two products for reducing emissions will be available

(i) saving of emission quota by the other industry which has been assigned certain limits

(ii) certified emission reduction (CERs) or carbon credits generated by the approved mitigation action. Here also there would be a limit upto which an industry can reduce its emission by offset (by purchasing carbon credits from the market)

(d) the buyer in the market could be any of the following

- industry looking for emission reduction in compliance to the assigned limit
- an individual or firm with any of the following motivation
  - Corporate responsibility/environmental ethics.
  - Image and public relations.
  - The sale of "carbon neutral" products ".
  - Anticipation of future regulations (pre-compliance).
  - Business model influenced by climate change di business.
  - Pure investment.

4.4.3 Market Regulator

Institution of Market Regulatory Authority is central to the conceptualized model of carbon market for India. The authority would not only ensure smooth functioning of the market but will also be responsible for regulations and verification. Market regulator would ensure the command & control actions built in the market as well as see that negotiations of the property rights (of emission allowance) take place in true market environment. Functions and responsibilities of the Market Regulatory Authority have been further discussed in execution framework section of the next Chapter.

4.5 Agroforestry for Carbon Sequestration and Other Co-benefits

The study proposes to carve out an earmarked quota for supply of carbon credits of agroforestry origin in the carbon market, justification for this has been discussed in this section. Agroforestry is drawing growing attention as a potential land use practice for carbon sequestration, as it offers additional socio-economic, ecological, soil enhancing benefits. Agroforestry systems are very important given the area currently under agriculture, the number of people who depend on land for their livelihoods, and the need for integrating food production with environmental services. Agroforestry is defined as "a land-use that involves deliberate retention, introduction, or mixture of trees or other woody perennials in crop/animal production field to benefit from the resultant ecological and economical interactions"

In agroforestry systems there are both ecological and socio-economic interactions between different components. This implies that

- Agroforestry normally involves two or more species of plants (or plants and animals), at least one of which is a woody perennial;
- An agroforestry system always has two or more outputs.[26]

Among the multiple benefits of Agroforestry, the ones most relevant in the current Indian situation are its role in providing ecological support to the agriculture, income generating opportunities to the farmers and its role in soil enrichment. Degradation of land and erosion of productive soil is a serious concern for the country as this is leading to marginalization of agriculture productivity. To maintain agriculture production, farmers are increasingly using fertilizers, pesticides and other inputs, which on one hand have led to the diminishing returns from the agriculture and on the other are causing soil and ecological degradation. Extent of degradation of land in the country has been estimated by various scientists and institutions, following table shows estimates from three sources including Ministry of Agriculture and Cooperation, Government of India.

[26] Agro-forestry , Dr. Salil K. Tewari (2008)

Table 4. 3 Estimates of Extent of Land Degradation in India

(in million ha)

Type	Ministry of Agri. & Co-operation		Sehgal and Abrol		NBSS &LUP
	1980	1985	1994	1997	2005
Soil erosion	150.0	141.2	162.4	167.0	119.2
Saline and Alkaline soil	8.0	9.4	10.1	11.0	5.9
Water logging	6.0	8.5	11.6	13.0	14.3
Shifting cultivation	4.4		4.9	9.0	7.4
Total degradation	168.4	159.1	189.0	200.0	146.8

It is estimated that about 5334 million tonnes of soil is lost annually, which works out to 16.35 tonnes/ha (Dhruva Narayana and Ram Babu,1983) of which 29% is lost permanently in the sea[27]. Loss of soil is loss of productivity and this is an irreversible loss. Among the possible ways to deal with the problem, agroforestry with multiple benefits is one major solution which can be implemented if suitable policies are put in place, enabling environment is created and agroforestry is made financially more attractive in terms of returns vis-à-vis competing land uses.

Generating carbon credits from agroforestry practice could be one way to make it even more attractive as income generating activity. Agroforestry has importance as a carbon sequestration strategy because of carbon storage potential in its multiple plant species and soil as well as its applicability in agricultural lands. For smallholder agroforestry

[27] Dhruva V., Narayana V., Babu R., (1983), *Estimation of Soil Erosion in India*, J. Irrig. Drain Eng. 111(4)

systems in the tropics, potential C sequestration rates range from 1.5 to 3.5 $tCO_2e\ ha^{-1}\ yr^{-1}$. Agroforestry can also have an indirect effect on C sequestration when it helps decrease pressure on natural forests, which are the largest sink of terrestrial C. Another indirect avenue of C sequestration is through the use of agroforestry technologies for soil conservation, which could enhance C storage in trees and soils. Agroforestry systems with perennial crops may be important carbon sinks, while intensively managed agroforestry systems with annual crops are more similar to conventional agriculture[28].

Finding low-cost methods to sequester carbon is emerging as a major international policy goal in the context of increasing concerns about global climate change. Agroforestry provides a unique opportunity in not only a cost effective way of carbon sequestration but also to combine the twin objectives of climate change adaptation and mitigation.

Agroforestry, the practice of introducing trees in farming has played a significant role in enhancing land productivity and improving livelihoods in both developed and developing countries. Although carbon sequestration through afforestation and reforestation of degraded natural forests has long been considered useful in climate change mitigation, agroforestry offers some distinct advantages. The planting of trees along with crops improves soil fertility, controls and prevents soil erosion, controls water logging, checks acidification and eutrophication of streams and rivers, increases local biodiversity, decreases pressure on natural forests for fuel and provides fodder for livestock. It also

[28] Carbon sequestration: An underexploited environmental benefit of agroforestry systems F. Montagnini and P. K. R. Nair, *Agroforestry Systems* 61: 281–295, 2004

has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change.[29]

4.6 Benefits of agroforestry systems

Agroforestry has the potential to provide both economic and environmental benefits. For every region, there are suitable agroforestry models which are in practice for many years. Pictures of few such models are shown in Fig 4.8, Fig 4.9, Fig 4.10 and 4.11. Some of the major benefits of agroforestry systems are mentioned below.

4.6.1 Improved soil fertility: Enhancing and maintaining soil fertility is vital for food security, reducing poverty, preserving environment and for sustainability. Agroforestry land use systems like agro-horticulture, agro-pastoral system, agri-silvipastoral system, etc., are efficient ways of restoring soil organic matter[30]. The leaf litter from agroforestry practices, forms humus after decomposition and improves various soil properties. Agroforestry can control runoff and soil erosion, thereby reducing losses of water, soil material, organic matter and nutrients. It can check development of soil toxicities, both soil acidification and salinization and trees can be employed in the reclamation of polluted soils.

4.6.2 Increased income: The diverse component of agroforestry provides multiple harvests at different times of the year. It increases food production, improves supply of fodder for fish and livestock, increases supply of fuelwood, improves soil fertility and water supply, habitats, etc. Thus it reduces the risk of crop failure and ensures alternate income for the farmers.

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[29] Murthy IK, Gupta M, Tomar S, Munsi M, Tiwari R, et al. (2013) Carbon Sequestration Potential of Agroforestry Systems in India. J Earth Sci Climate Change 4: 131. doi:10.4172/2157-7617.1000131

[30] Pandey DN (2007), Multifunctional agroforestry systems in India. Current Science 92: 455-463.

4.6.3 Increased carbon stock: Agroforestry has a huge potential as mitigation strategy to the changing climate because of its potential to sequester carbon in its multiple plant species and soil[31]. The average carbon sequestered by these practices has been estimated to be 9, 21, 50, and 63 t Cha^{-1} in semiarid, sub-humid, humid, and temperate regions respectively. In tropics, for small agroforestry systems, it has been found to be ranging from 1.5 to 3.5 $tCO_2e\ ha^{-1}yr^{-1}$ and thus can be a viable strategy for carbon storage[32]. In degraded soils of the subhumid tropics, agroforestry practices have been found to increase top soil carbon stocks up to 1.6tCha-1yr^{-1}.

4.6.4 Reduced vulnerability: Agroforestry increases the resilience of farming systems by buffering against various risks, both biophysically (hydraulic lift, soil fertility) and financially (diversification, income risk). Other advantages include reducing seasonal labor peaks, earn income throughout the year and ensure benefits over the short, medium and long term[33].

4.6.5 Increased productivity: Studies have shown that the productivity of agriculture crops is enhanced when they are intercropped with the trees. Agriculture crops in Taungya plantations in the Terai region of UP, and intercropping of wheat and paddy along with trees in Punjab show that forest influenced soils give higher yields than ordinary soils. Loss in production of agriculture crops because of shade is compensated to a great extent because of enhancement in productivity due to soil improvement in agroforestry systems

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[31] Montagnini F, Nair PKR (2004), Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agroforestry Systems 61: 281-295.
[32] Roshetko JM, Lasco RD, Angeles MSD (2007) Small holder agroforestry systems for carbon storage. Mitigation and Adaptation Strategies for Global Change 12: 219-242.
[33] FAO (Food and Agriculture Organization) (2005) Realizing the economic benefits of agroforestry: experiences, lessons and challenges. In: State of the World's Forests 2005.

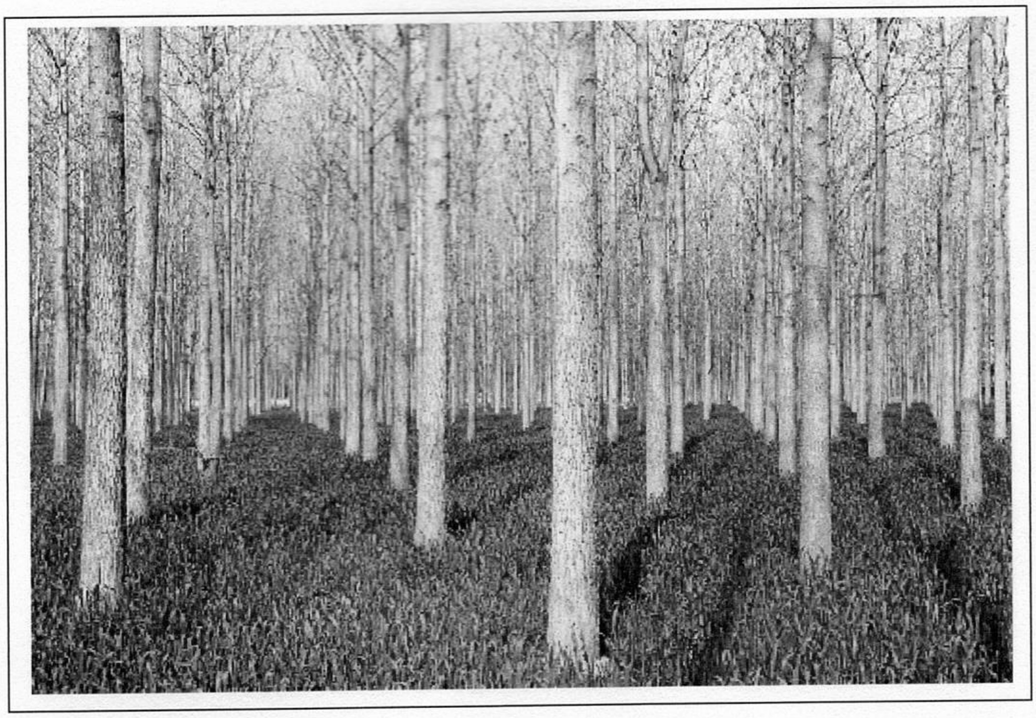

Fig 4.8 Poplar with Wheat

Fig 4.9 Poplar with Turmeric

Fig 4.10 Khejri with Millet

Fig 4.11 Poplar with Sunflower

4.6.6 Aesthetic Value: Agroforestry practices may use only 5% of the farming land area, yet account for over 50% of the biodiversity, improving wildlife habitat and harboring birds and beneficial insects which feed on crop pests. Tree biodiversity adds variety to the landscape and improves aesthetics.

Other advantages include—utilization of solar energy more efficiently than mono-cultural systems, reduced insect pests and associated diseases, increased nitrogen inputs because of nitrogen fixing trees and shrubs and it can also moderate microclimates. Shelter given by trees improves yields of nearby crops and livestock.

4.7 Estimation of Carbon Sequestration Potential from Agroforestry in India

This dissertation seeks to delineate policy and execution framework for forest carbon market in which supply of forest carbon credits is envisaged largely from agroforestry. One of the basic information in determining feasibility of the market is the potential supply of the carbon credits from agroforestry. An effort has been made to estimate the carbon sequestration potential or the potential number of carbon credits which can be generated by the practice of agroforestry from the whole country under a set of assumptions.

4.7.1 Methodology

(i) Extent of 'net area sown' and 'culturable waste land' for each State and Union Territory (UT) was collected from the 'Land Use Statistics, Ministry of Agriculture, Government of India, 2008-09.

(ii) The estimate is based on the assumption that 25% of the 'net area sown[34]' (the total area under agriculture) will be brought under agroforestry. Low intensity tree planting with 150 to 300 trees per ha in the agriculture fields has been presumed with the consideration that agriculture yield is not sacrificed much.

(iii) Since carbon sequestration per unit area from agroforestry will vary with number of factors like moisture status at the place, soil, choice of species, density of tree plants etc. The dominant among the factors are the moisture regime and soil; choice of species will be according to these factors only. Keeping this in view, the States and UTs have been categorized into 4 classes viz very dry (arid), dry, sub humid and humid.

(iv) Carbon sequestration rates from agroforestry plantations from the above four broad regions have been compiled from the published literature. Data collected from the Central Soil & Water Conservation Research & Training Institute have also been used. The average values of sequestration from agroforestry per unit area for the four regions were computed. The values are presented in the Table4.4. This is important to mention here that while computing the average carbon sequestration values for agroforestry in different regions, only above ground woody biomass in stems and branches of the trees has been taken in to account, carbon in other pools like foliage, below ground biomass, deadwood and litter etc have been purposely left from

[34] MoEF, (2012), *India State of Forest Report 2011*

the considerations of allowance for permanence and also to keep the methodology of assessment simplified for the farmers.

(v) The above data was used in excel to compute, carbon sequestration potential from agroforestry for each State and UT and the total gave the potential for India. State and UT wise carbon sequestration potential figures are presented in the annexure I. Estimate for total carbon sequestration potential for India is presented in the Table 4.5.

Table 4.4 Average Carbon Sequestration Rate Agroforestry for different Regions (average values for above ground woody biomass only)

(in t ha^{-1} Yr^{-1})

Sl No	Moisture Status	Average CO_2 Sequestration Rate	Reference of the Papers/Studies (Sl no from the Bibliogarphy
1	Arid	1.08	(vii), (ix), (x), (xxiii), (xxiv)
2	Dry	1.66	
3	Sub humid	2.73	
4	Humid	3.21	

Table 4.5 Estimate of Potential of Generating Carbon Credits from Agroforestry in India

(in million units per year)

	25% of 'Net Area Sown' under Agroforestry	33% of 'Net Area Sown' under Agroforestry
Estimated Potential of Generating Carbon Credits from Agroforestry in India	60.36	80.48

(each carbon credit is equal to sequestration of 1 tonne of CO_2 from the atmosphere)

4.8 Economics of Agroforestry Plantations with and without carbon credits

Agroforestry systems on croplands bring significant economic benefits to the farmers due to improved and sustained productivity. Tiwari (2008) has presented economics of different agroforestry systems from various regions of the country; the study shows that in some agroforestry system like Populus deltoids (Poplar) with wheat and paddy in Punjab, Haryana and western UP under irrigated conditions, the IRR could be as high as 68%. Based on the data collected during the field visit to Yamuna Nagar, economics of a Poplar plantation with wheat and paddy intercropping has been calculated. I also got data for an agroforestry model from Rajasthan in which Khejri (Prospis cineraria) has been grown with millet crop in rainfed conditions. Economics of both the models has been worked out with and without carbon credit benefits to analyse the significance of incremental benefit of carbon sequestration to the farmers practicing agro forestry.

Table 4.3 Economics of two Agroforestry Models with and without Carbon Credit Benefits

(amount in Rs)

Agroforestry Model	Agriculture Crops Only			Agroforestry			Agroforestry with Carbon Credits		
	Cost	Benefit	B/C	Cost	Benefit	B/C	Cost	Benefit	B/C
Poplar (P. deltoids) with Wheat & Paddy in Haryana under irrigated conditions	56084	99705	1.78	170989	579793	3.39	170989	595421	3.48
Khejri (P.cineraria) with Millet In Rajasthan under rainfed condition	20433	40865	2.00	73294	257582	3.51	73294	271714	3.71

***assuming price of carbon credit @ Rs 1000 per unit and no transaction cost**

Table 4.4 Cost Benefit Ratio with different price of carbon credit

(amount in Rs)

Sl No	Price of Carbon Credit (in Rs)	Benefit – Cost Ratio & Net Profit (per ha) (assuming zero transaction cost)					
		Poplar- Wheat & Paddy in irrigated conditions in Haryana			Khejri with Millet in rainfed conditions in Rajasthan		
		Net Profit[1]	B/C	% gain over agroforestry	Net Profit[1]	B/C	% gain over agroforestry
1	600	418180	3.45	1.62	192767	3.63	3.29
2	1000	424431	3.48	2.70	198419	3.71	5.49
4	1500	432244	3.53	4.03	205486	3.80	8.23
5	2000	440059	3.57	5.39	212552	3.90	10.97
6	2500	447872	3.62	6.74	219619	4.00	13.72
7	3000	455686	3.67	8.09	226685	4.09	16.46
8	3500	463500	3.71	9.43	233751	4.19	19.20
9	4000	471314	3.76	10.78	240817	4.29	21.95

[1]NPV at 10% discount rate and plantation rotation age of 7 years for Poplar and 20 years for Khejri model.

The above cost benefit analysis for the two agroforestry models, one in irrigated conditions and the other one in rainfed and dry conditions - nearly the two extreme ends of the wide range of agroforestry models, shows that due to additional income from carbon credits, though BC ratio keeps improving with the increasing carbon credit price but at the lower end of the carbon credit price i.e. Rs 600/unit (which is nearly the prevailing international price in the voluntary market, USD 10), the gain in either of the two models is not significant. Only at a price above Rs 2000/unit, gain from carbon credits become significant; it becomes 5.39% higher over agroforestry gain for Poplar based agroforestry model and 10.97% for Khejri based model. The above analysis leads to following important points

a. For making agroforestry adequately attractive with carbon credit benefits, carbon credit price will have to be much higher than the prevailing international price of carbon credit, one way of doing this could be minimum support price (MSP) like for other agriculture commodities.
b. Though carbon credits of various origins may be serving the same purpose of abatement of one tonne of CO_2, but because of the economics of their generation (production) and the co-benefits which they offer, they are like different commodities. This is also one reason that a separate space for the carbon credits of agroforestry origin in the domestic carbon market has been proposed in this study.
c. It is evident from the above table that the prevailing price of carbon credit in the international market will not be able to induce enough motivation for wide acceptance of agroforestry for carbon credits. This is also an

argument in favour of domestic carbon market. If we have our own market, we will have flexibility to use innovation according to our domestic circumstances and priorities. For example, after having enough conviction about the immense benefits of agroforestry in rural India, the carbon market can adopt instruments like MSP for making it financially attractive for people to adopt it and the larger good in terms of emission reduction, environmental and soil benefits, income generation for the villagers etc is achieved. This kind of flexibility is not possible in the international market.

d. It can also be inferred from the above table that benefit from carbon credits become more significant in case of agroforestry on marginal lands with low productivity or rainfed farmlands.

4.8.1 Influence of Transaction Cost on Benefit Cost Ratio

The above figures of benefit cost at net present value have been calculated with assumption of zero transaction cost. However, in practice transaction cost is never zero. To analyse, how transaction cost impacts profitability in the agroforestry systems, calculations with different transaction costs were done and B-C ratio in each case was observed. The following table shows BC ratio at different transaction costs, transaction cost was fed in the formula as initial transaction cost in incremental manner, starting with Rs 1000/ha (transaction cost in the subsequent years of the project, which is mainly towards periodic measurement and verification has been assumed as certain percentage of the initial cost only). In the table below, transaction cost has been shown as percentage of the benefit accrued from the carbon credits.

Table 4.5 Impact of Transaction Cost on BC Ratio

(a) Poplar with Wheat and Paddy

Sl No	Transaction Cost[1] in terms of % of the total benefit from carbon credits[2] (in %)	BC Ratio
1	0	3.48
2	7.762	3.46
3	11.34	3.45
4	15.13	3.44
5	18.91	3.43
6	22.69	3.42
7	26.47	3.41
8	30.25	3.39
9	34.03	3.38

[1]Price of carbon credit has been assumed Rs 1000 per unit in the above calculation

[2]NPV has been calculated at 10% discount rate

(b) Khejri with Millet

Sl No	Transaction Cost[1] in terms of % of the total benefit from carbon credits[2] (in %)	BC Ratio
1	0	3.70
2	13.23	3.64
3	15.88	3.62
4	19.84	3.61
5	26.46	3.58
6	33.07	3.55
7	39.69	3.51
8	46.30	3.49

[1]Price of carbon credit has been assumed Rs 1000 per unit in the above calculation

[2]NPV has been calculated at 10% discount rate

In both of the above cases it may be seen that as expected, BC ratio falls with increase in transaction cost. At one stage, transaction cost nullifies the gain accrued from the carbon credits completely (let this be called 'threshold transaction cost' for this discussion). At threshold transaction cost, the BC ratio from the agroforestry with carbon benefits becomes equal to the agroforestry (without carbon benefits). As seen in the tables above, the threshold transaction cost in case of Poplar model and Khejri model is 30.25% and 39.69% of the benefits from carbon credits respectively. At these threshold transaction costs the entire gain from the carbon credits is nutralised and the activity yields the returns of pure agroforestry activity only i.e. 3.39% and 3.51% respectively (please refer to the table 4.3), above the threshold transaction cost the returns would become negative compared to the agroforestry activity (without carbon benefits). For making agroforestry attractive enough, the transaction cost will have to be kept much lesser than the threshold level and as low as possible.

Attractiveness and profitability from the agroforestry (with carbon benefits) is a function of price of carbon credit and transaction cost. With increase in price of carbon credit the profitability rises whereas, at a given carbon credit price, with increase in transaction cost it diminishes. The combined effect of these two factors can be seen in the following table and an idea about the feasible combination of the two can be inferred.

Table 4.7 Additional Gain from Carbon Credits over Agroforestry for different Carbon Prices and Transaction Cost combinations

Agroforestry Models	Price of Carbon Credit (in Rs/unit)							
	2000		2500		3000		3500	
	Transaction Cost as % of carbon benefit	% gain over agroforestry	Transaction Cost as % of carbon benefit	% gain over agroforestry	Transaction Cost as % of carbon benefit	% gain over agroforestry	Transaction Cost as % of carbon benefit	% gain over agroforestry
Poplar Model	3.78	4.72	3.03	6.06	2.52	7.40	2.16	8.74
	5.67	4.39	4.54	5.72	3.78	7.06	3.24	8.39
	7.56	4.05	6.05	5.39	5.04	6.72	4.32	8.05
Khejri Model	6.62	8.99	5.29	11.68	4.41	14.38	3.78	17.07
	9.92	8.02	7.94	10.69	6.62	13.36	5.67	16.03
	13.23	7.07	10.58	9.72	8.82	12.26	7.56	15.01

It is logical that additional gain from carbon credits would play important role in making agroforestry more attractive and acceptable to large number of farmers, but it would require a wider study to analyse constraints, other than the financial considerations, in extension of agroforestry and motivations to the farmers to practice it. The study will have to be done for different regions as the analysis would in general vary from region to region. It is reasonable to assume that additional income from carbon credits in the range of at least 7% to 10% over agroforestry would be reasonable motivation to the farmers. Price of a commodity in a market is determined by its demand and supply. However, considering the larger social good, government also fixes minimum support price of some commodities. For a new commodity like carbon credit being created from agroforestry in the domestic market and considering the wider and long term social and environmental benefits of the activity, it is justifiable to fix a minimum support price for carbon credits of agroforestry origin, at least in the initial phase of the market.

The above table gives an idea about the price of carbon credit which can yield a reasonable gain. Transaction cost cannot be avoided, but transaction cost impacts profitability. Thus there is a tradeoff between the gain, transaction cost and price of carbon credit. The above table is a kind of three dimensional matrix of these three parameters in respect of two near extreme ends of the spectrum of models of agroforestry. Without indulging in optimization mathematically, it can be inferred from the above table that the gain of 7% to 13% from carbon credits over agroforestry (without carbon benefits) with wide range of agroforestry models is possible if the price of carbon credit is in the range of 2500 to 3000 and transaction cost is within 5% to 8% of the total benefits from the carbon credits. This analysis helps in developing an idea about the contours of carbon credit price, gain and transaction cost in respect of carbon credit of agroforestry origin.

4.9 Summarising Policy Inputs from the Economic Analysis of Carbon Credits of Agroforestry Origin

(i) Considering diverse environmental, economic and social benefits from Agroforestry, a fixed quota to the carbon credits of agroforestry origin in the emission offset by the industries would not only sustain demand of the carbon credits of agroforestry origin in the proposed carbon market but will also ensure capital flow from the industries to the farmers a form of payment of ecosystem service (PES).

(ii) Transaction cost is a critical factor in determining economic feasibility and wide participation in the carbon market. Creation of carbon credits from agroforestry would be economically viable only if transaction cost is kept low i.e. in the range of 5% to 10%.

(iii) Gain from the carbon credits created from agroforestry would be significant and attractive enough for people to adopt the practice, only if the price of carbon credit is at least around Rs 2500 per unit. Carbon credits generated from other mitigation activities may be viable at a lesser price; therefore to sustain carbon credits of agroforestry minimum support price for it would be necessary.

(iv) Carbon credits resulting from different mitigation or abatement activities are different in the economics of producing these carbon credits (cost—benefit analysis) and also in terms of co benefits which are associated with the activities. Rather, abatement or mitigation of one tonne of CO_2 is the only common attribute of them. Carbon credits arising from agroforestry or other forest related activities are believed to offer maximum ecological and social benefits and also serve as adaptation measures. Because of this feature, carbon credits of forestry origin stand out and deserve special place in the carbon market.

4.10 Agroforestry along with Biomass based Power Generation: Additional Carbon Credits

Wood based electricity generation can be done in decentralized manner in the villages. Technology for such micro power plants of the size 1 to 5 MW has matured over a period of time and there are quite a few such plants successfully running in India in the last few years[35]. If wood from agroforestry plantations is used for electricity generation in the villages then the activity becomes even more beneficial in several ways[36]

- The farmer producing wood gets additional carbon credits for avoidance of fossil fuel for electricity generation—farmer gets carbon credit equivalent to the quantity of coal or gas (averted), which could have generated the same number of units of electricity produced in such power plants using the wood supplied by the farmer; the credits are generated in terms of equivalent CO_2 emission.
- There could be several models of running the micro power plant by self help groups (SHG), cooperatives or Gramsabhas which would generate employment to the local villagers.
- The power generated from the power plant can be distributed and sold in the same or cluster of villages nearby or it can also be sold to the national grid.
- The activity may be a good source of revenue to the bodies operating it and thus would add to the income and quality of life of villagers.
- Would lead to better availability of electricity in the villages
- If many such plants come up in the villages, there would be larger benefits of lesser transmission losses, better energy efficiency in electricity generation and considerable environmental benefits.

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[35] Biomass Energy In India:Transition From Traditional To Modern, Biomass Energy In India: by P. R Shukla, Published in The Social Engineer, Vol. 6, No. 2

[36] Compendium of Gasifier based, Power Plant Operation Data, Biomass Energy for Rural India (BERI, 2013)

The following data taken from a successfully operating wood based power plant under BERI Project[37] at Kabbigere in Karnataka and the paper by Mittal (2011)[38] give the average idea about the possibilities with such projects.

- Average specific fuel consumption (SFC) in producing 1 kilowatt-hour (kwh) of electricity is 1.36 kg/kwh
- Average consumption of coal in producing 1 kilowatt-hour (kwh) of electricity is 0.75 kg/kwh
- Average all India CO_2 emission per unit of electricity is 0.94 kg/kwh
- Thus on an average 1450 kg of wood utilized for power generation would generate one additional carbon credit (in addition to the carbon credit earned for sequestering CO2 while)
- The above figures translate to generation of additional 1.5 to 3 units of carbon credits from 1 ha of agroforestry plantation per year. Economics of carbon credit benefits from agroforestry in case of coupling with biomass based power plant will be much more attractive than without it.

[37] Compendium of Gasifier based, Power Plant Operation Data, Biomass Energy for Rural India (BERI, 2013)
[38] Estimates of Emissions from Coal Fired Thermal Power Plants in India, Moti L. Mittal (2011)