IJRDMS • Volume 15 • Number 1 • June 2023

LAND USE CHANGE AND CARBON SEQUESTRATION SUPPLY FUNCTION BY DEVELOPING COUNTRIES

Mohammad Nur Nobi*

Abstract: *This study estimates the carbon sequestration supply function of developing countries through the land use change characteristics using OLS estimates of the log-log model. The coefficient of the log-log model defines the elasticity which has the practical implication. The elastic values of land use characteristics reveal that the developing countries have high potentiality in carbon sequestration through changing land use in favor of forestation. The land use activities used in carbon sequestration are reduction of deforestation, sustainable agricultural practice, afforestation /reforestation and forest areas. In addition of these, CDM project is also used for sequestration. In contrast, the inelastic value of supply the function with respect to price refers that the carbon price is not a good incentive for enhancing carbon sequestration in developing countries. That is, price is not a good indicator of profitability yet and thus to promote developing countries in carbon sequestration the carbon price must be sufficiently higher.*

Keywords: *Land use, Carbon sequestration, supply function, Developing countries.*

1. INTRODUCTION

Carbon sequestration is an alternative solution of emission reduction through land use and land use changes. It is considered as the cost effective way of emission reduction than others. The carbon sequestration refers to, *"The process of removing carbon from atmosphere and depositing it in a reservoir"* (Carbon Finance, 2011 P. 39). To combat negative climate change affects 39 developed countries (countries listed in Annex B in Kyoto Protocol) are committed through the Kyoto Protocol(1997) to reduce their greenhouse gas emission on average of 5.2% of 1990 level (Smith and Scherr,2002). To achieve that goal Annex I parties (countries are listed in Annex I under UNFCC) have agreed to limit their greenhouse gases (GHG's)e mission between 2008-2012 whether they can consider afforestation, reforestation, reduction of deforestation and other agreed land use, land use change and forestry activities to meet the commitment (Kyoto Protocol 1997, Article 3.1). On the other hand, developing countries have opportunities to increase the carbon sequestration through land use change and using terrestrial forests. In this consideration, these countries can use their tropical forest as a carbon sink and change in land uses in favor of forest land so that terrestrial carbon sequestration increases. By this sequestration process, the developing countries can achieve two fold benefits, such as contributing in adaptation of climate change effects and earning foreign remittance. Thus, the aim of this study is to estimate the potential supply function of carbon sequestration of developing countries to change in land uses.

* Assistant Professor, Department of Economics, University of Chittagong, Bangladesh

2. OBJECTIVE OF THE STUDY

The objective of this study is to estimate the carbon sequestration supply function by developing countries through the land use change to combat climate change affect. More specifically the aims of the study are,

(i) to estimate the carbon sequestration (supply) function on land use change by the developing countries;

(ii) to focus the importance of carbon sequestration to the economy of the supplier countries.

3. LITERATURE REVIEW

Land use, land use change and forestry are the important sources of carbon sequestration which is cost effective and has an income flow from developed countries to developing through carbon trading. Analyzing eight existing estimates of different regions of Africa, Asia and tropical America on land use and land use change offset potentials, Bloomfield and Pearson (2000) have concluded that GHG emission could be reduced by increasing carbon storage. Mentioning the importance of land use characteristics in carbon storage they have considered reforestation, plantation, agro-forestry, improved management of cultivable land and production of energy crops. Whereas for carbon pool they have considered above and below ground biomass and soil, soil and fossil fuel offsets. The offset potential for reforestation they found varies from 5.7 to 12-29 billion ton of carbon per year, for slowing deforestation it ranges from 4.5 billion ton to 11-21 billion ton, plantation ranges from min 2-5 billion ton to maximum 16.4 billion ton and improved management of cultivated land and energy crops 0.2-0.7 billion ton of carbon per year. In contrast, for carbon benefit they have stated that it would be either increasing carbon storages or use of wood as bio fuels. That is carbon storages will be enhanced if the earnings from carbon exceeds the earnings from wood uses.

McDowell (2002) argued that the plan announced by the World Bank that time will create an opportunity for the rural communities in the world's poorest nations to earn income by using their forests and agricultural land to sequester carbon dioxide. He also added that by that announcement bio-carbon fund will allow companies and public sector organizations in the developed world to offset some of their carbon emission in the projects in developing world, such as tree planting schemes, which absorb carbon from the atmosphere.

Niles *et al.* (2002) analyzed that 48 tropical and sub tropical developing countries that have the potential to reduce carbon burden about 2.3 billion tons of carbon in the next 10 years. For carbon sequestration they have considered afforestation, deforestation halted, and sustainable agricultural practice as land use characteristics. With a given price USD 10 per ton of carbon and 3% discount rate they have calculated that this sequestered carbon will generate USD 16.8 billion as foreign earnings collectively for those countries. Karberg *et al.* (2008) reported that conversion from non-till land to till land increases 0.07 to 0.48

metric tons of carbon per hectare per year in the USA. In contrast, agricultural land converted to forest land increases soil carbon between 0.20 to 0.66 metric tons per year. The accumulated rate for above ground biomass from trees and forestlands ranges from 1 to more than 10 metric ton per hectare per year. The following table shows the carbon accumulation rate for different forest types.

Table 1
Above Ground Carbon Accumulation Rates for Converted Crop Land to Forest

Forest type	*Rotation years*	*Uptake(Mg C/ha/yr)*	*End use*
Hybrid poplar	12	4-10	Pulp, biomass
Allegheny hardwoods	80	2-3	Saw timber
Northern hardwoods	80	1-3	Saw timber
Misc. decidious	?	3.7	?
Subalpine	?	0.8	?
Average of conversion to forest	5.9		

Source: Karberg *et al.* (NIACS ,2008 [quoted from Chimner (2002), Netzer *et el.* (2002), Hoover (2004), Giardina (2004), Johnson (2005)]

Pfaff and Kerr (1999) and Pfaff *et al.* (2000) assessed the carbon sequestration and its cost function. They defined a carbon sequestration supply function in Costa Rica as a relationship between a monetary carbon reward and carbon sequestration supplied by the landowners using the existing Global Information System (GIS) data on land use and land cover and other factors affecting the land use choices. They used three types of modeling such as advance process-based modeling which is known as CENTURY Model for simulation of Carbon (C) and Nitrogen (N) dynamics which reflects carbon to nitrogen activity in soil sample, advance empirically-based modeling for carbon storage where they used advance adaptation of life zone type modeling for predicting carbon storage and finally advance observationally-based economic modeling of land cover (GIS projection). In economic modeling, they considered the landowners to solve a dynamic optimization problem where the landowners seek to earn the greatest returns from the land uses. The return also depends on land use characteristics, present and past land use, price and yields of different crops, cost of production and access to market, cost of changing land use, and expected future values of these factors. Depending on their theoretical model they derived empirical/econometric models which focused the effects of key observable factors in the estimation process. In estimation they used both the traditional approach and more dynamic approach.

Rokityanskiy *et al.* (2007) have estimated the carbon sequestration supply function depending on land use change using the DIMA model. DIMA model is used to make interaction and feedback between ecosystem and human land-use. Their study has focused on carbon sequestration and biomass production and with a pre-set price they have calculated the carbon sequestration potentials. They found a significant change in land use and carbon sequestration with introduction even a low carbon price.

Masera *et al.* (1995) studied the economic response options to avoid carbon emission and increase carbon sequestration in the forests in Mexico. They examined the carbon sequestration and its cost in three policy scenario in the years 2000, 2010 and 2030. For these policy scenarios, they used benefit-cost analysis. They have estimated that yearly carbon sequestration is 115 million ton based on the available primary information on benefit, cost and other carbon related parameters. Calculating the benefit-cost analysis with 10% discount rate they found that option results in low net benefit equated USD 58 per hectare. In conclusion, they suggested that Mexican forest has potentials to carbon sequestration as it is profitable.

Tomich *et al.* (1997) have analyzed the profitability of conversion of imperata (a small genus of grass) grass land to tree plantation and estimated various tropical vegetation carbon in Indonesia. The rough estimates of carbon sequestration they found for dipterocarp (one type of tropical tree) forest is 365 ton, rubber agro-forest is 215 ton, a mangium (a quick growing softwood) plantation is 200 ton, imperata grassland is 90 ton and annual food crops is 63 ton per hectare per year. In Asia they reported that the organic stock from typical mature forest is 365 ton per hectare per year.

So, it is clear from the above literature studied that the developing countries have the potentials to sequester carbon in their forest lands through change in land use. The estimated accumulated afforestation area in 2100 would be about 700 M hectare for bio-energy and carbon supply or 500 M hectare in a different scenario and for deforestation it would be 200 M hectare or 489 M hectare (Rokityanskiy et al., 2007). As carbon sequestration brings foreign earnings for the developing countries and thus those countries can contribute mitigating the climate change affects through carbon trading. Carbon trading reduces the emission where it is least costly but fair burden sharing between the trading partners is also more important than achieving the cost efficiency only (Leimbach, 2002).

The literatures reviewed above have provided focus on carbon sequestration potentials, accumulation rate in different options and benefit of carbon sequestration in different developing countries. Those literatures have focused potentials of carbon sequestration either only one country or some regions of a country. So, there is a gap observed for aggregate supply function for carbon sequestration. This study has focused in estimating carbon sequestration supply function in global perspective.

4. THEORETICAL BACKGROUND

Carbon sequestration is expected to be financially beneficial through policies from afforestation and reducing deforestation. The carbon sequestration supply function depends on land use changes across the countries. Land use changes basically for two reasons such as, (i) avoiding deforestation which is enhanced by carbon price; and (ii) additional afforestation by joint carbon and biomass projects (Rokityanskiy *et al.*, 2007). The supply of carbon sequestration in the carbon market depends on many determinants like any other usual supply function. Primarily the supply of the carbon sequestration is a function of carbon price, land prices (rent), primary forest area, afforestation/reforestation rate, maintenance cost of afforestation /reforestation and reduction of deforestation rate (deforestation halted rate) and many more biological factors. But, mostly the carbon sequestration depends on land use patterns of the countries. So, the supply function stands for,

$$S_{CS} = f(P_C, A/R, RD, SAP, CDM, FA)$$

Here, S_{CS} stands for supply of carbon sequestration, P_C refers the price of carbon, *A*/*R* means afforestation/reforestation, *RD* means reduction of deforestation, *SAP* sustainable agricultural practice, *CDM* for Clean Development Mechanism and *FA* refers forest area. According to the theory of supply, the carbon sequestration supply function will be proportional to its price if other thing remains constant. Thus the carbon sequestration supply curve is expected to be as follows because of the land use decision of the land owners in favor of sequestration.

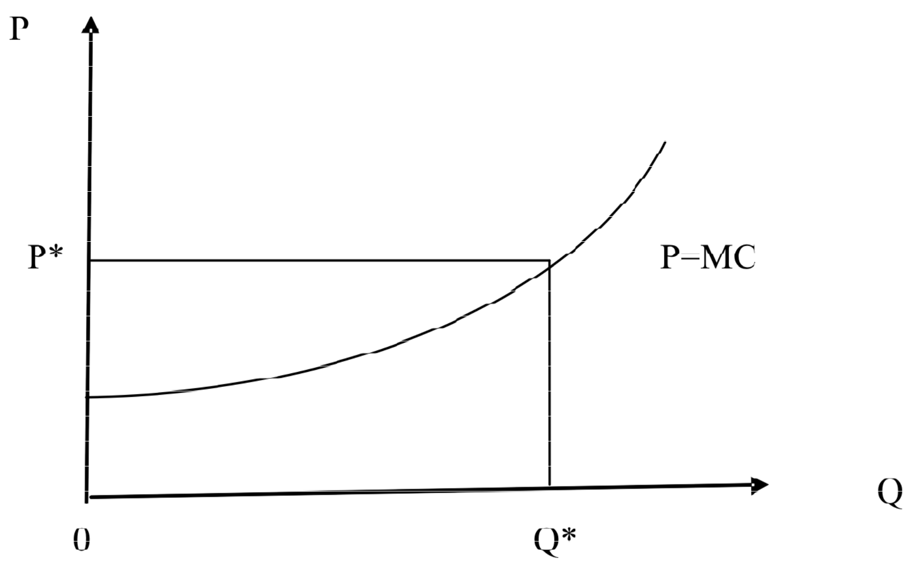


Figure 1: Theoretical Supply Function of Carbon Sequestration

Though the price of carbon is an important determinant but there might have few more factors which play role on the carbon sequestration supply function. Thus the important determinants of carbon sequestration are discussed as follows,

4.1. Carbon Price

Carbon sequestration supply function is expected to increase if the price of carbon increases. The land owners or entrepreneurs will shift some of their agricultural lands to afforestation/ reforestation for carbon sequestration if the carbon price increases. Thus, for enhancing carbon sequestration the price of carbon needs to be higher or at least equal to the yield of agriculture or any other use of land (Dushku *et al.*, 2007). For estimating the price of carbon the opportunity cost approach is used in various studies. Dushku *et al.*, (2007) has suggested that the price should be equal to the marginal return to the farmer whether the marginal return is the difference between estimated revenue and input costs for agricultural enterprises. For simplicity they used only variable costs of agriculture.

According to Point Carbon (Carbon, 2008) 73% of EU ETS survey respondents agree that the carbon price is relevant to their investment decision though 6% do not think the price as an important factor for investment decision in carbon sequestration. The survey shows the expectation of price of the supplier and it is reported that it will be USD 24 and USD 35 per ton in the year 2010 and 2020 respectively. In 2007 average global price was USD 14.8 per ton of carbon while the price of carbon credit in CDM market was USD 12.67 per ton.

4.2. Reforestation/Afforestation Rate

Reforestation rate is one of the important determinants of the carbon sequestration supply in the global carbon market. Especially the tropical countries are feasible for afforestation (Rokityanskiy *et al.*, 2007). Afforestation and reforestation is better than the mature forest regarding carbon sequestration as plantation has higher rate of carbon sequestration (Bloomfield and Pearson, 2000). If the reforestation rate increases or if it is higher the size of the carbon sinks increases and creates more supply in the market. After the enforcement of Kyoto Protocol (1997) many projects were introduced in several developing countries with higher reforestation rate. Sedjo *et al.* (2001) have stated that 33-44% of the reduction (carbon reduction) could be met cost effectively through forest-based sequestration. They have also compared the sequestration cost with previous research works and summarized that the supply of carbon sequestration is function of available land, forest carbon accumulation rate, land and planting cost, government subsidy and price of carbon.

4.3. Maintenance Costs/ Unit Costs

Maintenance cost is one of the key determinants of carbon sequestration. If the cost is low the carbon sequestration projects will be enhanced in the developing countries. Maintenance cost of reforestation/afforestation involves fertilizer cost and monitoring costs. Cacho et al. (1993) discussed that the monitoring costs depend on number of trees, diversity of trees in a project and diversity of environment. They also considered the transporting costs of worker to the projects in the monitoring costs. If the monitoring cost is lower, higher number of projects comes into the operation of carbon sequestration. Cacho *et al.* (2007) proposed three types carbon monitoring costs, such as initial establishment costs; annual fixed costs which are independent of the number of sampled plots and annual variable costs (in monitoring plots). These costs affect the profitability of projects in different ways which involved land rent and investment expenditure in the sequestration projects. In CDM and

REDD (Reducing Emission from Deforestation and Degradation) projects investments are financed by developed countries but for profitability farmers need to be concerned about the monitoring costs.

4.4. Reduction of Deforestation

After fossil fuel deforestation has the highest emission which is 12% of global emission (Werf *et al.*, 2009). Thus avoiding deforestation can reduce emission with other indirect benefits such as bio-diversity, water and air quality and maintenance of local climate (Bloomfield and Pearson, 2000). EIA found it as cost effective measure than other sources of emission reduction. In many developing countries REDD projects are in operation by NGO's. It is market based and fund based incentive payments for reduction of deforestation in the developing countries (Ecomagazine, 2012/04/11). A comparative research study showed that share of global deforestation reduces exponentially with the carbon price from 5% to 75% of predicted deforestation (Rokityanskiy *et al.*, 2007). So, reducing deforestation is a key determinant of carbon sequestration through changing land use.

4.5. Sustainable Agricultural Practice

Sustainable agricultural practice refers a managed and well planned agriculture that could help in sequestering carbon. Small farm size and use of pump in water irrigation in agriculture is responsible for emission (Sugden, 2010). Thus managed agriculture and efficient use of energy can reduce cost of farmers and be a source of carbon sequestration. Schulte and Lanigan (2011) reported that Ireland agriculture is responsible for 29.1 % of total national GHG emission and in the Climate Change Response Bill emphasizes 30% emission reduction in agricultural sector to make it sustainable. It is observed that agriculture in developing countries is unplanned and unmanaged. Thus, making it a sustainable one can increases income and food supply with equity which can prevent reduction of forest land conversion into cultivable land followed by reduction of greenhouse gas emission (Bloomfield and Pearson, 2000).

4.6. CDM Projects

Clean Development Mechanism (CDM) is a flexible mechanism under the Kyoto Protocol (1997) which allows the Annex I countries funding in carbon sequestration projects in the developing countries. As a result, CDM projects in developing countries are working as on commercial basis for supplying carbon credit to the developed countries. Right now 2665 CDM projects are funded out of 7912 in different countries by top 20 buyer companies (UNEP Riso Centre, 2012). As a result, presence of a CDM project in a country refers supply of more carbon sequestration.

4.7. Forest Area

Forest area is another important determinant of carbon sequestration. If the size of a forest increases it will increase carbon sequestration. Sedjo and Solomon (1998) emphasized expanding forest areas to offset world's carbon sequestration (cited from Richards and Stokes, 2004). As forest is considered as the sink of carbon sequestration thus it is expected that the area of forest is proportionately related to the carbon sequestration. That is the more the sink increases the more the sequestration increases.

5. DATA DIAGNOSIS

This study is based on carbon sequestration information of 58 developing countries (Annex A). The data for different variables are collected from different sources like FAO, UN data, CDM Pipeline, World Bank and some published journals. The estimation is based on collecting different cross section data. Since the data on carbon price for different countries are not available thus average unit cost of carbon is used as a proxy of carbon price considering it as shut-down price. In a competitive market average variable cost is considered as shut-down price where firms hardly manage the costs only to remain the production. Thus for simplicity we considered that in the carbon trading market every individual supplier country is in equilibrium on shut-down point equating average unit cost is to price. As a result, average unit cost (Deveny *et al.*, 2009) is used as a proxy for carbon price though these prices not necessarily assure the profitability. The different sources of data are cited in the following table.

Table 2
Variables and Data Sources

Name of Variable	*Data Source*	*Variable Type*
Carbon Sequestration (million ton)	Niles *et al.*, (2002)	Dependent
Price ($/tC02)	Deveny *et al.*, (Forest Carbon Index 2009)	Independent
Afforestation/ Reforestation Rate (1000 ha)	Niles *et al.*, (2002) & FAO Forest Data	Independent
Reduction of Deforestation (1000 ha)	Niles *et al.*, (2002)	Independent
Sustainable Agriculture Practice (1000 ha)	Niles *et al.*, (2002)	Independent
Forest Area (1000 ha)	UN data (2007)	Independent
CDM (1=yes, 0= otherwise)	CDM Pipeline, UNEP Riso Centre	Independent

Note: Compilation from the above mentioned sources

After collecting the data, mathematical and graphical diagnosis were conducted to check the normality condition as in a normally distributed observation data lies equally in both sides of the median value. A normally distributed data is bell-shaped where mean, median and mode all are equal.

In a normal distribution 68% observation lies between -1σ to $+1\sigma$, 95% observation lies between -2σ to $+2\sigma$ and 99.7% observation lies between -3σ to $+3\sigma$. Thus to have the trend of the data set using Eviews 7 shows that none of them are normally distributed (Appendix B1).

As a result remedial measure is necessary to have the normal data. For transformation Box-Cox transformation method is used where a variable transferred from Y to Y" a

Figure 2: Standard Normal Distribution Curve (ð=0, ó=1)

parameter λ is used while $T(Y) = \frac{T^{\lambda} - 1}{\lambda}$ where λ can take any value between –5 to +5. But a standard region is -1 to +1. In contrast λ = 0 is simply the natural logarithmic transformation and λ = 1 is linear transformation. In this study natural logarithmic transformation is used or all variables except the binary variable Clean Development Mechanisms (CDM). In addition, variables taking 0 (zero) values were considered a minimum positive value (0.0001) to avoid mathematical errors in logarithmic transformation. After transformation, the data look like normally distributed though they are not exactly normal (Appendix B2). The mean and median are very closer to each other and the skewness is close to zero meaning that the transformed data follows the normally distributed variable (not exact normal). It is also seen that variables *LnSAP* (log of sustainable agricultural practice) and *LnFA* (log of forest area) are not that much close to normally distributed variable. It could be the reason of small sample size. On the contrary, the data on price seems similar before and after the logarithmic transformation which could be seen in the var diagram (Appendix B3).

In addition to have an unbiased estimator, a correlation matrix (Appendix B4) was calculated to identify the multicollinearity among the explanatory variables. The correlation matrix shows that none of the variables are highly correlated to each other. That is, there is no worry for multicollinearity problem. The correlation matrix shows that ln of forest area has collinearity with other land use variables but the coefficient of correlation among the variables range between 0.33 to 0.47 which not necessarily show an exact multicollinearity. Thus, considering it a sample problem no concern was given for multicollinearity.

6. ECONOMETRIC MODEL AND RESULTS

In estimating the supply function bottom-up engineering cost analyses or optimization models are widely used where marginal costs are constructed by the use of information revenues and costs of production of alternative land uses on representative types or locations of land, and sorting these in ascending order of cost (Lubowski *et al.*, 2007). Here we will use the econometric model to estimate the supply function. The carbon sequestration function is thus stands for,

$$CSS = f(Pc, AF / RF, DH, FA, CDM, SAP)$$

As the variables transformed into natural logarithm, thus the econometric model for carbon sequestration is thus stands for log-log model. One important features of the log-log model is that the slope coefficients express the elasticity of dependent variable with respect to independent variables (Gujrati, 2004). So the econometric model to be estimated is as follows,

$$ln\ CSS = \mu_1 + \mu_2 P + \mu_3 lnRD + \mu_4 lnRF + \mu_5 lnSAP + \mu_6 CDM + \mu_7 lnFA + \varepsilon\text{–}3$$

Here *LnCSS* refers natural log of carbon sequestration, *LnP* for natural log of price, *LnRD* stands for natural log of reduction of deforestation, *LnAF / RF* is used for natural log of afforestation/reforestation, *LnSAP* is used for natural log of sustainable agricultural practice, CDM for clean development mechanism (1 = there exists at least one project in the country and 0 = others) and *LnFA* for natural log of forest area. The μ's are parameters to be estimated in the model and ε is error term. Thus using the Ordinary Least Square (OLS) regression, the estimation of the log-log or log-linear models of carbon sequestration supply function on land use change factors are as follows,

Table 3
Estimated Results

Variables	*Model 1*	*Model 2*	*Model 3*
Constant	-4.56	-4.141	-3.495
	2.237	2.167	2.071
	-2.041*	-1.910*	1.688**
LnP	0.959	0.935	0.796
	0.750	0.747	0.734
	1.279	1.251	1.084
LnRD	0.170	0.162	0.156
	0.061	0.061	0.061
	2.743*	2.66*	2.567*
LnAF / RD	-0.042		
	0.051		
	-0.81		
CDM	1.217	1.171	1.182
	0.359	0.353	0.353
	3.388*	3.312*	3.344*
LnSAP	0.1374	0.1193	
	0.12	0.118	
	1.14	1.009	
LnFA	0.324	0.291	0.335
	0.12	0.111	0.103
	2.72*	2.604*	3.255*
R^2	0.449	0.442	0.431
$ADj\ R^2$	0.384	0.388	0.388
F	6.93	8.2375	10.039
$P>F_{value}$	0.000	0.000	0.000

Note: The parenthesizes are standard errors and t values respectively. The t-values marked * are significant below to the 5% and ** are significant below to the 10% level of significance.

The above Table 3 shows the estimated results from three successive regressions. In model 1, Ln of reduction of deforestation, Ln of forest area and CDM are found significant below to the 5% level of significance and no other variables are found significant below to the 10% level of significance. The R^2 value is 0.45 that the model can explain 45% variation in dependent variable. The moderate R^2 and few insignificant t statistics not necessarily mean the presence of high multicollinearity. The correlation matrix (Appendix B4) also satisfies the absence of high multicollinearity. In model 2, to avoid insignificant t statistics regression was made excluding LnAF/RF and again the t statics for the coefficient of LnP and LnSAP are not significant. In model 3, another regression was conducted excluding LnSAP and still the t value for LnP is insignificant. Except the constant coefficient other variables are significant below to the 5% level of significance.

7. DISCUSSION AND ANALYSIS

From the above results (Table 3), we can see that the result in estimated model 3 is quite better. In model 3; the coefficient of determination R^2 and Adj R^2 are almost similar to the other two models respectively. Moreover, it has only one variable; LnP is statistically insignificant. Comparing with other two models model 3 is good as it gives almost same R^2 and Adj R^2 with lower number of estimated parameters. One reason for the insignificant t ratio for variable LnP might be the non-normality of the data. It could be seen in the var diagram (Appendix B3) and in descriptive statistics (Appendix B1 and B2) that the variable P and transformed variable LnP have the same magnitude. That is variable LnP does not satisfy the normality assumption like variable P. Thus this could be a reason for the t ratio of estimated coefficient of LnP to be insignificant.

The coefficient of LnP in model 3 is, 0.796 which is the price elasticity of carbon sequestration supply function. This result shows that carbon sequestration increases 0.796% with respect to 1% change in price. This result assures that the carbon sequestration supply function is inelastic or less than unity to its price. The scatter grams (Appendix C) show the attitude of elasticity of different variables. The coefficients for other variables show an elastic situation (more than unitary) of carbon sequestration with respect to land use change characteristics; such as CDM, LnRD and LnFA. Thus the partial elasticity of carbon sequestration supply function with respect to price is 0.796, reduction of deforestation is 2.567, CDM is 3.344 and forest area is 3.255 respectively.

8. MAJOR FINDINGS

This study found that the responsiveness of carbon sequestration supply function with respect to its price is not statistically significant. The reason of insignificant coefficient of price might be for its lower value. In our data section we had considered the average unit cost as a proxy of carbon price which was equivalent to break-even price. Thus, to induce the carbon sequestration the price needs to be a markup of average unit cost such as, $Price = \text{Cost}(1 + \mu)$. Where μ, the markup could be determined by the gain sharing of the developed countries. On the other hand, the supply elasticity of land use variables are greater than unitary which show that the developing countries have potentiality in sequestering carbon to their terrestrial forests. Thus it needs to allocate more land use in the developing countries in favor of carbon sequestration to fight against the climate change affects. At the same time the carbon price needs to be regulated so that carbon sequestration benefits the developing countries.

CONCLUSION

This study has set up that the percentage change of carbon sequestration with respect to the percentage change in price is less than unitary. That is the price elasticity of carbon sequestration is 0.796. The inelastic supply functions of carbon sequestration refers that the supply function is less responsive to its price. One reason for the less responsiveness of carbon sequestration might be the case for lower market price. In the present market the price is very low and it is comparatively lower than the abatement costs for Annex I countries. In contrast, the responsiveness of carbon sequestration supply function with respect to land use variables is greater than unitary.

This is study has some shortcomings of unavailability of data, use of proxy variables and different data sources. In contrast, the data regarding the carbon sequestration is not that much available comparing its importance. In spite of these limitations, the estimation of carbon sequestration supply function using change in land uses may be helpful for further research and policy matters. This study has able to seek the carbon sequestration supply function for developing countries which may be helpful for global policymakers in combating negative climate change affects.

References

Bloomfield, J., and Pearson, H. L. (2000), "Land Use, Land-use Change, Forestry, and Agricultural Activities in the Clean Development Mechanism: Estimates of Greenhouse Gas Offset Potential", *Mitigation and Adaptation Strategies for Global Change,* 5(1), pp. 9–24.

Carbon Finance Annual Report (2011), Carbon Finance for Sustainable Development, World Bank also available at *http:// siteresources.worldbank.org /INTCARBONFINANCE /Resources/ 2012_Carbon_Finance_2011_AR_WEB_OPT.pdf* [Date accessed June 20, 2012].

CDM pipeline [Date accessed April 12, 2012] also available at *http://www.cdmpipeline.org/*

Deveny, A., Nackoney, A., Purvis, N., Gusti, M., Kopp, R. J., Madeira, E. M., Stevenson A. R.., Kindermann, G., Macauley, M. K. and Obersteine, M. (2009), "*The Geography of Forest in Climate Solutions" Resources for the Future, Report* 2009.

Ecosmagazine (Date accessed11/04/2012) also available at *http://www.ecosmagazine.com /paper/ EC10048.htm*

Global Forest Watch (Date accessed 2012/04/11) available on *http://www. Global forestwatch.org /english/ indonesia/forests.htm*

Gujarati, D. N., (2004), "Basic Econometrics 4th edition" The McGraw-Hill Companies.

Health Guidance: Blumentha, F. "Sustainable Agriculture in Developing Countries-Challenges and U.S. Role" [Date accessed on 15/04/2012] also available at *http://www. healthguidance.org/entry/6226/ 1/Sustainable-Agriculture-in-Developing-Countries-Challenges-and-US-Role.html*

IPCC [Date accessed on April 5, 2012] also available at *http://www.grida.no /publications/ other/ipccsr/ ?src=/climate/ipcc/emission/050.htm*

Kossoy, A and Ambrosi, P. (2010), "State and Trends of the Carbon Market 2010" World Bank.

Leimbach, M. (2002), "Equity and Carbon Emission Trading: A Model Analysis" Energy special issue, Chaina.

Lubowski, R. N., Plantinga, A. J. and Stavins R.N. (2006), "Land-use Change and Carbon Sinks: Econometric Estimation of the Carbon Sequestration Supply Function." *Journal of Environmental Economics and Management*, 51(2), pp. 135–152.

Masera, O. R., Bellon, M. R. and Segura, G. (1995), "Forest Management Options for Sequestering Carbon in Mexico", *Biomass and Bioenergy,* 8(5), pp. 357–367.

McDowel, N. (2002), "Developing Countries to Gain from Carbon-trading fund" Nature 420(4).

McDowel, N. (2002), "Developing Countries to Gain from Carbon-trading Fund" Nature 420(4) also available at *http://www.nature.com/nature/journal/v420/n6911/full/420004a.html*

Mongaby[Date accessed June 15, 2012] also available at *www.rainforests.mongabay.com /deforestation/*

Niles, J. O., Brown, S., Pretty J., Ball, A. S. and Fay, J. (2002), "Potential Carbon Mitigation and Income in Developing Countries from Changes in Use and Management of Agricultural and Forest Lands." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* 360(1797), pp. 1621–1639.

Pfaff, A. and Kerr, S. (1999), "*A Carbon Sequestration Supply Function and Development of Feasible Clean Development Mechanism Rules for Tropical Forest Carbon Sinks"* Working Paper No.9899-08, Department of Economics, Colombia University, USA.

Pfaff. A. S. P., Kerr S., Hughes, R., Lie S., Sanchez-Azofeifa G., Schimel D., Tosi J. and Watson V. (2000), "The Kyoto Protocol and Payments for Tropical Forest: An Interdisciplinary Method for Estimating Carbon-offset Supply and Increasing the Feasibility of Carbon Market under the CDM" *Ecological Economics,* 35(2), pp. 203-221.

Richards, K. R., and Stokes, C. (2004), "A Review of Forest Carbon Sequestration Cost Studies: a Dozen Years of Research." *Climatic Change,* 63(1), pp. 1–48.

Rokityanskiy D., Benítez P. C., Kraxner F., McCallum I., Obersteiner M, Rametsteiner E., and Yamagata Y. (2007), "Geographically Explicit Global Modeling of Land-use Change, Carbon Sequestration, and Biomass Supply." *Technological Forecasting and Social Change,* 74(7), pp. 1057–1082.

Schulte, RPO. and Lanigan, G. (2011), "Irish Agriculture, Greenhouse Gas Emissions and Climate Change: Opportunities, Obstacles and Proposed Solutions" Teagasc (The Irish Agriculture and Food development Authority) Oak Park, Carlow.

Sedjo, R., Sohngen, B. and Mendelsohn, R. (2001), "Estimating Carbon Supply Curves for Global Forests and Other Land Uses" Discussion Paper 01–19, Resources for the Future.

Smith, J. and Scherr, S. J. (2002), "Forest Carbon and Local Livelihoods: Assessment of opportunities and Policy Recommendations" Centre for International Forestry Research, paper no. 37

Sugden, C. (2010), "Carbon Footprint of Agricultural Development: the Potential Impact of Uptake of Small Electric and Diesel Pump in Five Countries in Sub Saharan Africa" Stockholm Environmental Institute, Working Paper-2010.

TEEIC [Date accessed May 09, 2012] also available at *http://teeic.anl.gov/er/carbon /carboninfo/reduce/ index.cfm*

The Dictionary of Sustainable Management [Date accessed on September 20, 2012] also available at *www.sustainabilitydictionary.com/the-kaya-identity/*

UNEP Riso Centre [Date accessed on May 16, 2012] also available at *http://www. uneprisoe.org/ Default.aspx*

UNFCCC [Date accessed on April 16, 2012] also available on *www.cdm.unfcc.intOfficial*

UNSTATS [Date accessed on July 12, 2012] also available at *http://unstats. un.org /unsd /methods/icp/ ipc7_htm.htm*

Werf, G. R., Randerson, J. T., Giglio, L., Collatz, G. J., Kasibhatla, M. Mu, P. S., Morton, D. C. , DeFries, R. S., Jin,Y. and Leeuwen, T. T. (2010), "Global Fire Emissions and the Contribution of Deforestation, Savanna, Forest, Agricultural, and Peat Fires (1997-2009)" *Atmospheric Chemistry and Physics*, 10(6), pp. 16153–16230

Appendices

Appendix A: List of Countries in the Sample

Afghanistan, Argentina, Angola, Bangladesh, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cambodia, Cameron, Central African Rep, Chile, Chad, China, Colombia, Costa Richa, Cote dÍvoire, Dem. Rep.Congo, Dominucan Rep, Ecuador, Ethopia, Guatemala, Guyana, Honduras , India, Indonesia, Kenya, Laos, Madagascar, Malaysia, Mali, Mexico, Mozambique, Morocco, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguaya, Peru, Philipines, Senegal, South Africa Sudan, Srilanka, Tanzania, Thailand, Uganda, Venezuela, Vietnam, Zambia and Zimbabwe.

Appendix B1
Descriptive Statistics of Data

Name of Variables	*Mean*	*Median*	*St. Deviation*	*Skewness*	*Kurtosis*	*Jarqe-Bera*	*Probability*
CSS (MtCO2)	47.50	18.01	102.67	5.72	39.23	3488.83	0.00
P($/tC02)	13.25	13.39	2.47	-0.625	3.96	5.911	0.05
CDM (1=yes, 0= Otherwise)	0.74	1.00	0.44	-1.10	2.22	13.24	0.00
Per Capita GDP (Int. dollar)	3726.33	2153.03	3520.42	1.17	3.06	13.24	0.00
Afforestation/ Reforestation (1000ha)	65.77	20.00	128.86	3.65	17.38	628.00	0.00
Deforestation Halted (1000 ha)	29.84	10.15	62.68	4.18	21.81	1023.98	0.00
Sustainable Agriculture (1000ha)	903.55	450.00	1713.94	4.41	25.27	1386.97	0.00
Forest Area (1000 ha)	31338.00	12067.00	68302.00	5.07	31.65	2232.00	0.00

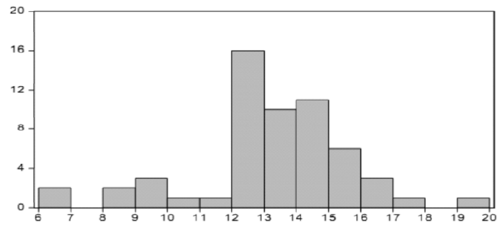
Note: The data statistics were calculated with the help of Eviews 7

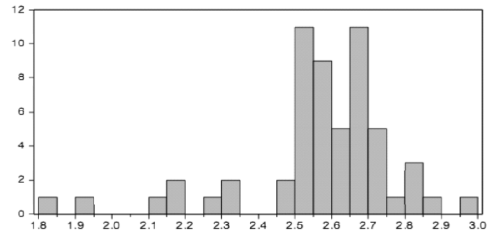
Appendix B2
Descriptive Statistics after Data Transformation

Name of Variables	*Mean*	*Median*	*St. Deviation*	*Skewness*	*Kurtosis*	*Jarqe-Bera*	*Probability*
LnCSS	2.83	2.89	1.49	0.01	2.39	0.90	0.64
LnP	2.56	2.59	0.21	-1.42	5.58	34.95	0.00
CDM	0.74	1.00	0.44	-1.10	2.22	13.24	0.00
LnAF / RF	2.89	2.99	1.77	-0.15	2.43	0.98	0.61
LnDH	2.16	2.31	1.73	-0.44	3.44	2.38	0.30
LnSAP	5.88	6.10	1.49	-0.84	5.87	26.83	0.00
LnFA	9.28	9.40	1.59	-0.63	4.46	8.98	0.01

Note: *LnCSS* = Natural log of Carbon Sequestration, CDM = Clean Development Mechanism (1 = There exists at least one project in the country and 0 = others), *LnP* = Natural log of price, *LnAF* / *RF* = Natural log of afforestation/reforestation, *LnRD* = Natural log of reduction of deforestation, *LnSAP* = Natural log of sustainable agricultural practice and *LnFA* = Natural log of forest area.

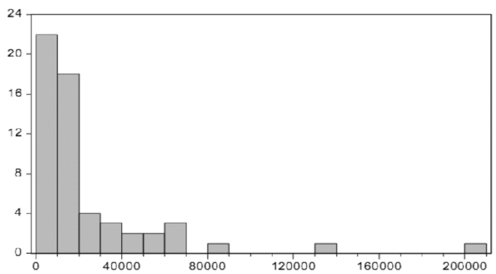
Appendix B3
The var Diagram of Different Variables before and after Box-Cox Transformation

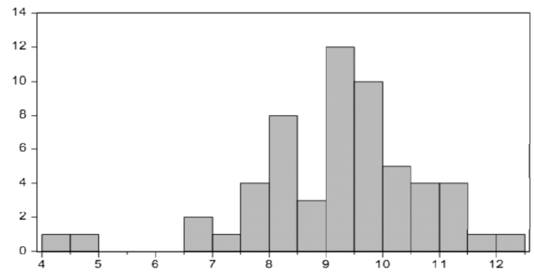




P

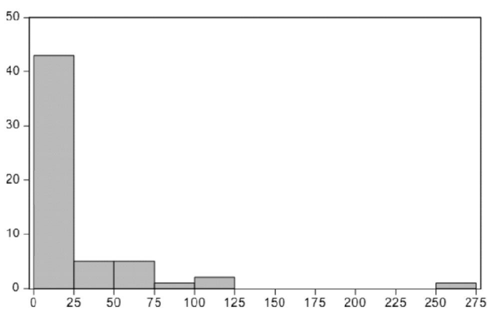
LnP

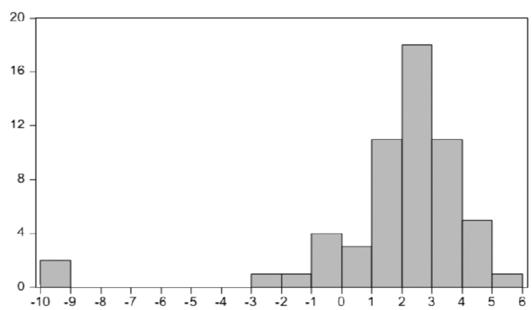




FA

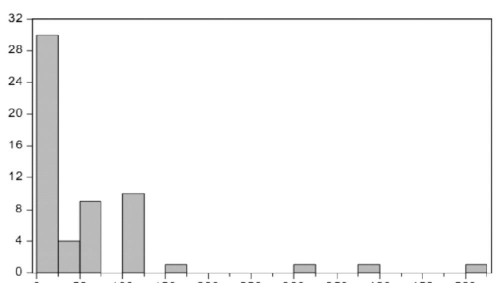
LnFA

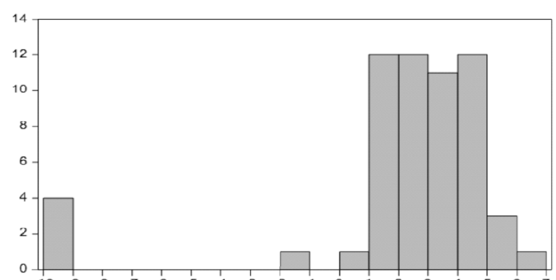




RD

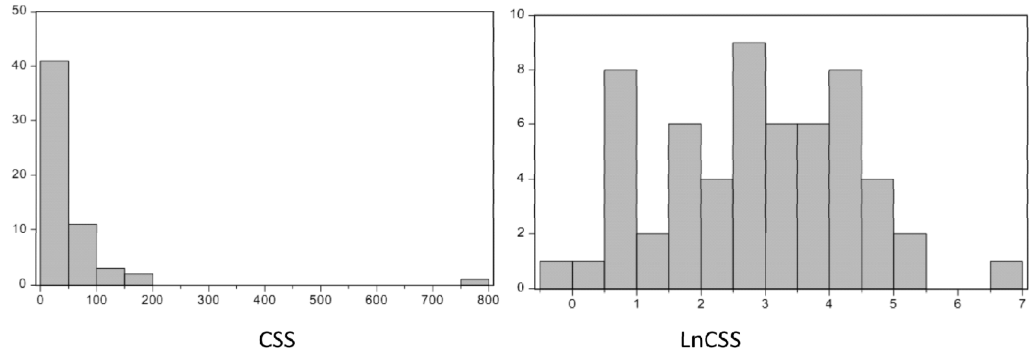
LnRD





AF/RF

LnAF/RF



Note: The raw data series (left graphs) show that the data is not normally distributed rather they are skewed. But after Box-Cox transformation into natural log the data series come close to normal distributed though they are not exactly normal.

Appendix B4
Correlation Matrix

	CDM	*LNCSS*	*LNFA*	*LNP*	*LNRD*	*LNRF*	*LNSAP*
CDM	1	0.373	0.051	0.139	-0.044	0.160	0.029
LNCSS	0.373	1	0.475	0.171	0.389	0.248	0.229
LNFA	0.051	0.475	1	0.024	0.337	0.474	0.371
LNP0.139	0.171	0.024	1	0.002	0.035	-0.158	
LNRD	-0.044	0.389	0.337	0.002	1	0.255	0.031
LNRF	0.160	0.248	0.474	0.035	0.255	1	0.311
LNSAP	0.029	0.229	0.371	-0.158	0.031	0.311	1

Note: Calculated from the data. The green marked values show collinearity with dependent variable and others explanatory variables. But the red marked values show collinearity among the explanatory variables and it shows Lnrf and Lnfa has high collinearity(0.474) thus in final regression (model 3) process Lnrf was deducted.

Appendix C
Scatter Gram between Dependent Variable and other Independent Variables