LAND COVER ANALYSIS AND AFFORESTATION OPTIONS FOR MITIGATION OF CLIMATE CHANGE IN THE BOLIVIAN LOWLANDS

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ABSTRACT

Land use in South and Central America is still very dynamic. While in many regions deforestation is ongoing, in others the abandonment of pasture land is prevailing. Conversion of these lands into forests may have a series of beneficial effects, for the natural resources (such as water, soil, biodiversity), but also from a socio-economic point of view. Potential income from carbon sequestration may serve as an additional stimulus for land owners to systematically convert those lands into forest.

The present study focuses on an evaluation of the overall potential of afforestation projects for carbon sequestration, in the Region of Buena Vista in Bolivia.

Satellite image analysis was carried out in order to locate best sites for carbon sequestration. Land use analysis revealed that the area suitable for conversion of pastures into plantations was about 9.800 ha. Plantations of Serebo (Schizolobium amazonicum) were considered and biomass estimations taken in 10 plantations of different ages.

With that information, a cost benefit analysis was performed to identify the conditions under which landowners may change their pasture lands into plantations, benefiting from future payment for carbon sequestration. In order to calculate opportunity costs, the net present values of two land uses were compared (cattle ranching and forest plantations).

The study shows that, in the absence payment for carbon sequestration, plantations of Serebo are not competitive compared to cattle ranching. Assuming a forest stand that produces both timber and carbon, the net income of a plantation of Serebo is higher than the net income from cattle ranching in the region.

KEYWORDS

Biomass, Bolivia, carbon sequestration, clean development mechanism, cost-benefit analysis, grazing, land cover analysis, plantations, *Schizolobium amazonicum*.

INTRODUCTION

The phenomenon and effects on natural resources through deterioration of soil and water quality is intensified by the spontaneous migrations of low-income populations in Amazon Lowlands of Bolivia, where agricultural activities and cattle grazing are proceeding by unsustainable practices which contribute to the soil, flora and fauna degradation.

Anthropogenic actions such as massive exploitation of soil, flora and fauna affect the ecosystems. Agricultural practices in the Amazon are limited by very low soil fertility, and this is particularly true in cattle grazing systems where ecological conditions are constantly challenged. The increasing poverty of tropical soil drives peasants to work in new crops and low income generation. Tiessen *et* *al.* (1992) reported that land under shifting cultivation in the semi arid-NE Brazil usually sustains about 5 years of cropping, during which yields decline until farming is uneconomical and the land is abandoned to regrowth of secondary vegetation. During this bush fallow, fertility levels are improved and the land may become available for further cultivation cycles (Tiessen *et al.* 1992). Increasing land scarcity results in reduced fallow periods. Fertilization is commonly neither economical nor available to subsistence farmers in semi-arid environments where crop production is severely limited by moisture availability.

Cleared areas occupy enormous areas in Bolivia. However, their extension has not been precisely determined. In many of these cleared areas the dominant land use represents low productivity cattle pasture (compared with other regions in the country), over half of which is thought to be in some state of degradation (Ruiz, 2001). On the other hand, there is an enormous potential for land use and forestry (LUCF) activities to mitigate carbon emissions in most tropical areas of Bolivia (Brown, 1997).

In recent years there is a growing interest in the role of tree plantations in the development of sustainable land use systems in Bolivia. This interest is stimulated by the potential role that tree plantations can play in the sequestration of carbon. Nevertheless, there is a lack of information concerning plantation's potential to provide timber and carbon benefits, and therefore hesitation to invest in forestry projects. There are some experiences worldwide where instruments given by the Kyoto Protocol have generated additional income in the period between planting and harvesting. These instruments make tree plantations an interesting object to improve income generation in developing countries facing extreme poverty such Bolivia.

Additional income from carbon sequestration may stimulate landowners to convert part of their non-forest land to forest and to improve their socio-economic situation. Plantation with native species and agroforestry systems are well suited to improve land productivity and conserve natural resources in the Amazon (De Koning, *et. al.,* 2002). Ecosystem services and forest productivity may stimulate land users to convert to forests, but the benefits and sustainability of conversion into forest is still not well documented and understood by land use decision makers.

The aim of this research is to explore afforestation potential for mitigation of climate change by providing timber and carbon sequestration benefits in Lowland Bolivia (*Buena Vista*- Santa Cruz).

The study presents a land cover analysis and biomass modelling which were carried out in order to locate best sites for carbon sequestration options in the region of *Buena Vista* - Bolivia. With that information, a cost benefit analysis was performed to identify the conditions under which landowners may change their pasture lands into plantations, benefiting from future payment for carbon sequestration. In order to calculate opportunity costs, the net present values of two land uses were compared (cattle ranching and forest plantations).

These estimates are determined for fast growing Serebo (*Schizolobium amazonicum*) plantations which might produces both timber and carbon benefits. Finally, implications are given concerning the findings of this research as well as issues where future research is needed.

MATERIALS AND METHODS

Satellite image analysis was carried out in order to locate best sites for carbon sequestration. Topographic maps and terrestrial observations supported the analysis, 120 training areas collected in fieldwork were used for supervised classification of satellite image.

The activities carried out during this research included:

1) field sampling for supervised classification and validation of land cover mapping results,
2) satellite image interpretation for land cover mapping,
3) and qualitative description of land covers classes.

The software packages ERDAS IMAGINE 8.4 and ArcView 3.1 were used to analyze the remote sensing data. Global Positioning System (GPS) was used in sample gathering in the study area.

On the analysis, 7 different land cover classes were considered: arable lands and permanent crops, permanent pastures, open forest, closed forest, riverbed, urban (concrete and asphalt), inland water bodies.

Secondary and primary data were used focuses on the evaluation of the overall potential of afforestation projects for carbon sequestration in *Buena Vista*-Bolivia. The carbon sequestration potential in plantations of Serebo (Schizolobium amazonicum) was estimated using biomass estimations taken in 10 plantations of different ages.

Following the application of biomass regression equations to stand tables a biomass equation developed for broadleaf forests and described by Dauber *et. al.* (1999) for all productive forest in Bolivia was tested in order to estimate above ground biomass.

Additional four biomass equations were tested and compared with the Dauber equation. These four equations were developed for broadleaf forests and described by Brown (1997). All equations were calculated from a data base into two climatic zones which fit on the climatic condition of the study area.

Equations Y1 and Y2 were developed from data where rainfall is considerably less 1500 mm and a dry season of several months occurs, equation Y3 and Y4 for moist or where rainfall approximately balances potential evapotranspiration (e.g. 1500-4000 mm rain/year and a short dry season to no dry season) and equation Y5 proposed by Dauber *et. al.* (1999) considers all productive forest in Bolivia with annual rainfall ranging from 1200 – 4000 mm/year.

Biomass regression equations used for estimating biomass of tropical trees were:

$$Y = e^{(-1.996+2.32*\ln(D))} \qquad (Y1)$$

$$Y = 10^{(-0.535+\log(BA))} \qquad (Y2)$$

$$Y = 42.69-12.800(D)+1.242(D^2) \qquad (Y3)$$

$$Y = e^{(-2.134+2.530*\ln(D))} \qquad (Y4)$$

$$Y = e^{(-2.4090+0.9522*\ln(D\hat{}2 \; * H * d)} \qquad (Y5)$$

Where:

Y= Biomass per tree (kg),
D = DBH (cm),
BA = Basal Area (cm^2),
H= Total Height (m),
d = Wood density (ton/m^3)

In order to obtain a DBH increment to the rotation age, taken into account that available data have a maximal stand age of 8.7 years, following Hunt (1982), functional DBH analysis was used to estimate relative DBH and total height rates. Relative DBH rates were estimated from a set of data which were used to describe the relationship between DBH and age. Total 440 trees were fit to the Chapman-Richard's function:

$$D' = \beta 0 \, (1- e^{(-\beta 1 \, (A))})^{\beta 2} \qquad (Y6)$$

Where:

D' is the estimated DBH in centimeters
A is the age in years
$\beta 0$, $\beta 1$, and $\beta 2$ are parameters

The unknown coefficients were estimated via the simplex and quasi-Newton as implemented in StatSoft Inc. (1995).

A lineal equation was adjusted to estimate total height (m) to DBH (cm).

$$Ht' = \beta 0 + \beta 1 \, D \qquad (Y7)$$

Where:

$\beta 0$ and $\beta 1$ are parameters
Ht' is the estimated total height in meters
And D is the DBH in centimeter

With that information, a cost benefit analysis was performed to identify the conditions under which landowners may change their pasture lands into plantations, benefiting from future payment for carbon sequestration. In order to calculate opportunity costs, the net present values of two land uses were compared (cattle grazing and forest plantations) (see Figure 1).

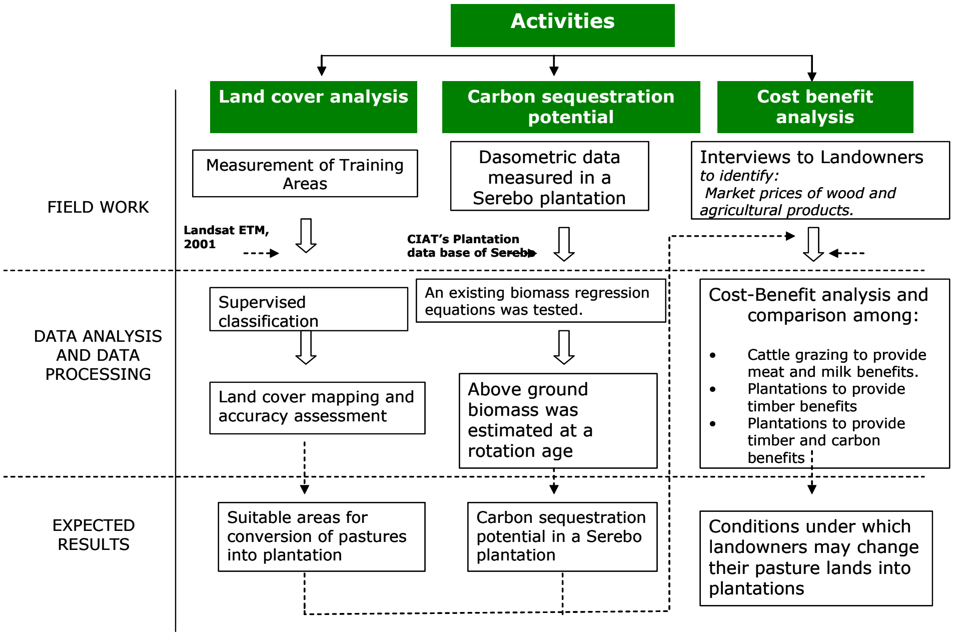


Figure 1. Methodological approach used on this research.

Interviews to landowners were needed to identify market prices of wood and agricultural products. With this information, a cost benefit analysis was performed for comparison between: cattle grazing (to provide meat and milk benefits), plantations which supplies timber and plantations which supplies timber and carbon benefits.

The carbon accounting method selected on this research is called “average storage method”. This method consists of averaging the amount of carbon stored in a site over the long-term according to the equation described by Moura Costa (2001).

RESULTS AND DISCUSSION

Land cover classes were estimated as follows: closed forest (21,794.31 ha), open forest (31,220.91 ha), pastures (9,810.54 ha), arable lands (14,382.81 ha), water bodies (2,998.35 ha), riverbed (967.86 ha) and urban (10,466.28 ha).

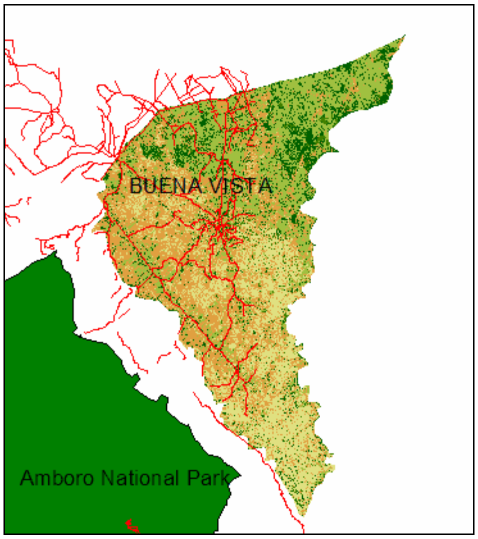


Figure 2. Location of the study area

Under the assumption that all the pasture land could be considered for conversion into plantations, land cover analysis revealed that suitable areas for plantations are at about 9.800 ha.

The Minimum Livelihood Classification (MLC) analysis on this study had an average overall accuracy of 84.0 %. The statistics results show that the accuracy of some individual classes are low due to several reasons, e.g. the lack of sufficient spectral discrimination between some categories of land cover (pastures vs. arable land) and the temporality within the image and the field visit.

To identify the afforestation potential, the relationship between DBH and stand age for the 440 trees were fit to the Chapman-Richard’s function:

$$D' = 35.6105\,(1 - e^{(-0.197756\,(A))})^{1.789227}$$

Where:

D' *is* the estimated DBH in centimeters
A is the age in years

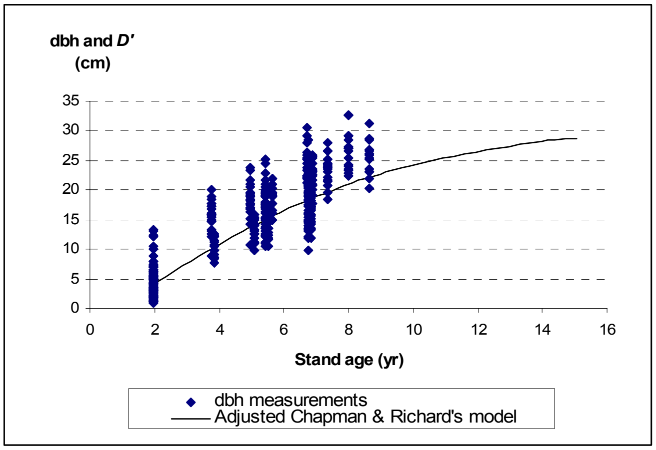
A significant logarithmic regression model was found with diameter at breast height as the independent variable.

$$Ht' = 5.65066 * Ln\,(\mathrm{DBH}) - 2.21159$$

Where:

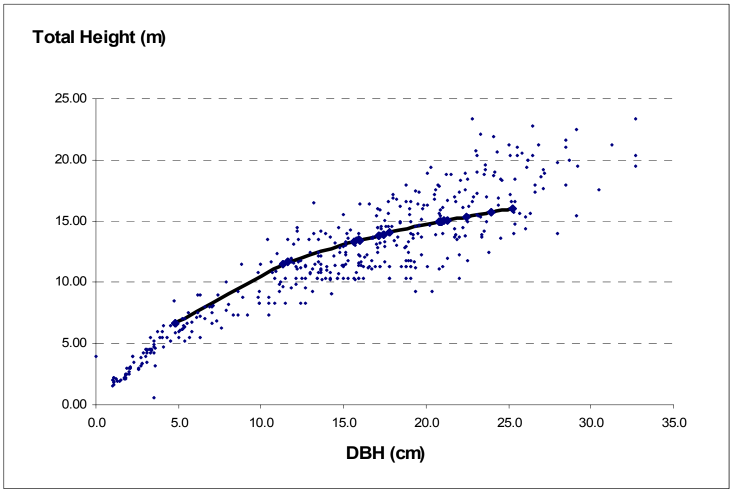
Ht' is the estimated total height in meters
DBH is the diameter at breast height in centimeter

The coefficient of determination of this regression model is 0.89. The DBH model to the age and the height model to the DBH are plotted in figures 13 and 14 respectively.



$D' = \beta0\ (1- e^{(-\beta1\ (A))})^{\beta2}$ (R =0.88236, Variance explained: 77.856%) where: *D'* is the estimated DBH in centimeters and A is the age in years. Iteration converged method: Simple and Newton. β0, β1 and β2 are constants.

Figure 3. Estimated DBH [*D*'] to the stand age [A] on Serebo (*Schizolobium amazonicum*) plantations, Bolivia.



$Ht' = \beta0 + \beta1\ Ln\ DBH$ *(with R = 0.89425926, R2=0.79969962, adjusted R2=0.79924231, P<0.000, F (1,438) =1749, standard error of estimates=2.2294)* where: *Ht'* is the estimated total height in meters and D' is the estimated DBH in centimeter. β0, β1 and β2 are constants.

Figure 4. Estimated total height [*Ht*'] to the DBH on Serebo (*Schizolobium amazonicum*) plantations, Bolivia.

The diameter range considered in developing models was 1 to 32 (cm). Most trees in Serebo plantations in the study area fall within a diameter range of 10-25 (cm).

Since the biomass yield of a tree stand is subject to great variability and dependent upon several factors (such as productive capacity of the site, stocking of the stand and silvicultural treatment given to the crop), it is important that these factors be taken into account in further research before developing local biomass yield prediction models.

Optimal rotation age was calculated. Productive capacity of the site affects both the volume of production per unit of area and the age of maximum mean annual increment (MAI). Poorer sites take a longer time to reach MAI culmination age as compared to a good site. In the case of *Schizolobium amazonicum* planted in *Buena Vista* it attains a MAI of 27.5 (m^3/ha) at 16.9 years of age. The determination of productive potential of a site by direct methods such as quantifying climates, soil properties and indicator plants, is not common practice in tropical countries. Instead, height/age relationship is used to determine site classification.

Estimates of volume of individual trees are based on regression functions derived from multiple diameter and height measurements of sample trees. Traditionally, volume equation was based on the Schumacher and Hall model transformed to a linear form.

$$V = \pi\left(\frac{D'^2}{40.000}\right) * H_t * Ff * N$$

Where:

V is the stumpage individual volume outside bark (m^3/ha),
D' is the estimated DBH (cm),
Ht is the estimated total height (m) and
Ff is the form factor = 0.65
N is the stand density and
π is the pi value (3.1416).

The following equation to the age was considered for predicting the total volume per ha at age A in an un-thinned plantation stands:

$$\boldsymbol{V = \beta 0\,(1 - e^{(-\beta 1\,(A))})^{\beta 2}} \qquad (Y9)$$

Where:

V is the expected stumpage individual volume outside bark (m^3/ha)
A is the age of the tree (year),
β0, β1 and *β2* are parameters (1.751891, 0.208673 and 0.217104 respectively)

The first derivative of equation Y9, is:

$$CAI = \frac{dv}{da} = \beta 0 * \beta 1 * \beta 2 (1 - e^{(-\beta 1 * A)})^{\beta 2 - 1} * e^{(-\beta 1 * A)} \qquad (Y10)$$

This is known as the instantaneous growth-rate function or the current annual-increment (CAI) function. The mean annual increment (MAI_t) at a time *t* in years is equal to:

$$\mathbf{MAI_{\mathit{t}} = V_t / A_t} \qquad (Y11)$$

And the age of MAI culmination occurs when the first derivative of MAI equals 0.

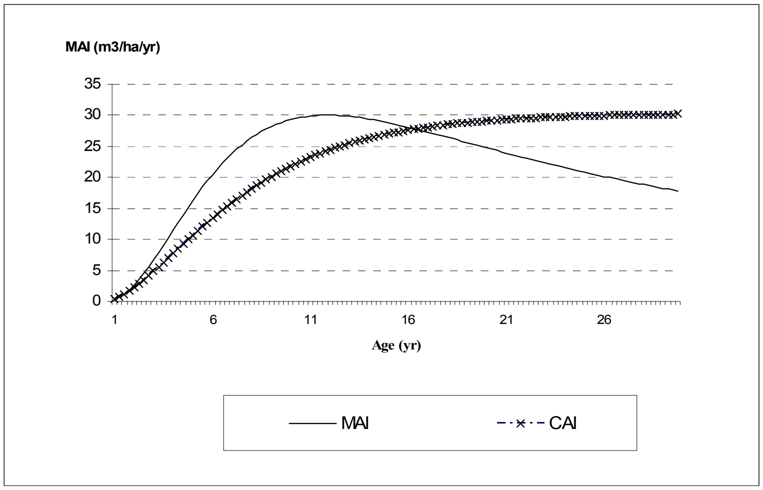


Figure 5. Mean Annual Increment MAI (m^3/ha/yr) and the Current Annual Increment CAI on Serebo (*Schizolobium amazonicum*) plantations, Bolivia.

Figure 5 shows the size of the sacrifice for different felling ages. Under the consideration that the objective of timber management is to produce a desired output during a specific time period the best rotation age is 16.8 years where MAI intersects CAI. This age represents optimal rotation age in terms of timber production but not in economic terms. For practical reasons, the rotation age assumed in this research for calculation on Serebo (*Schizolobium amazonicum*) plantations to provide timber benefits is at about 15 years.

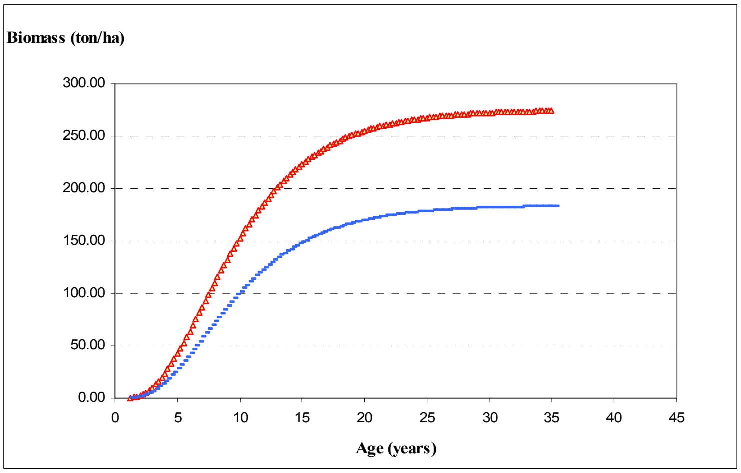
Stocking of the stand also affects the MAI culmination age on a given site. Utilization of site productivity is faster in high-density plantations as compared with low-density; hence rotation for a dense plantation would be shorter. Nevertheless, the same rotation age will be considered in this research for every stand density.

The dynamic of total above ground biomass sequestration potential for two different stand densities (300 and 450 trees/ha) ranged from 134 to 366 (ton/ha). An average total biomass of about 209 (ton/ha) is reached after 14 years.

As a sentisitivity analysis an average biomass expansion factor (BEF) of 1.3, suggested for tropical broadleaf plantations (Brown, 1997), was considered. The volume prediction outside bark of free bole was estimated at about of 434 (m3/ha) considering a stand density of 450 (trees/ha) and 15 years and a given wood density for Serebo of 0.45 (ton/m3).

The individual biomass density obtained was at about of 253 (ton/ha) which is relatively lower compared to the result obtained in the first method 223 (ton/ha). Based on the comparison, the biomass regression equation produced reasonable results for estimating above ground biomass.

Based on the biomass estimates, the cumulative carbon fixation per hectare is calculated for Serebo plantations, assuming that these plantations are established on pasture lands. It is also assumed that during 15 years and based on a simple management system it is possible to yield a volume of 16.93 (m^3/ha/yr) and 25.4 (m^3/ha/yr) for stand densities of 300 (trees/ha) and 450 (trees/ha) respectively as the previous section considered.



Data Adjusted to model Y5 = $e^{(-2.4090+0.9522*\mathrm{Ln}(D2\ *\ H\ *\ d)}$.Source*: Daubert et al*. (1999) using forest inventory data from all productive regions in Bolivia.

Figure 6. Above ground biomass growth curves (ton/ha) considering two different planting densities of 300 trees/ha and 450 trees/ha.

It is assumed that harvesting leads to an immediate release of all carbon stored, and that equilibrium of carbon pools is reached in the first rotation cycle. The curves illustrate carbon storage over time, and the straight horizontal lines show the average storage calculated for the two projects.

Because the biomass on products and roots are relatively low compared with the total biomass (6.90% and 8.46%) they were not considered in the final calculation of payment for carbon sequestration until additional data becomes available.

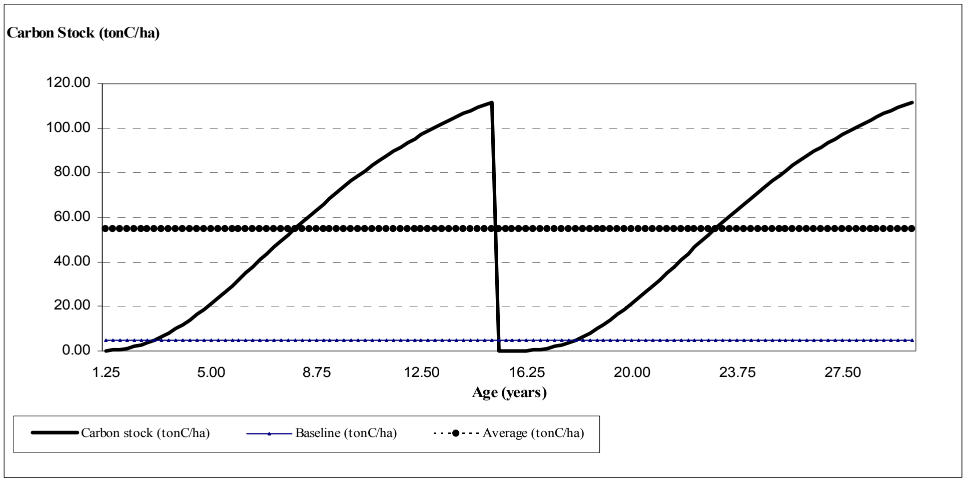


Figure 7. Carbon sequestration dynamics and the baseline in Serebo (*Schizolobium amazonicum*) plantations – two 15-year rotation projects, stand density of 450 trees/ha.

Taking the baseline into account the net average storage calculated for the duration of this project is: 38 (tonC/ha) and 53 (tonC/ha) for 300 (trees/ha) and 450 (trees/ha) respectively, that is reached before the end of the first rotation and remains the same irrespective of the duration of the project (if carbon in products and roots after first rotation are not considered).

Also, it was assumed that: a) the Carbon Emission Reduction credit (CER) price is constant and at about 15 ($/tonC) during the whole project b) there is a market for CER and c) payment is according to net increment of CO_2 storage until average net stored is reached and average payment per year is within the first eight years.

Comparative Equal Annual Equivalence in grazing and Serebo (*Schizolobium amazonicum*) plantations varies from 0 to 68 ($/ha/year). The final calculation of the overall utility value comes to the conclusion that cattle grazing in the case of big landowners with 68 ($/ha/year) is the most competitive project followed by the project which leads to an income generation at about 50 ($/ha/year) from timber and payments for carbon sequestration with higher stand density (see Figure 8). Thus, under the assumptions explained above, for medium and small landowners it is recommendable to convert from pasture into plantations considering timber and payment for carbon sequestration.

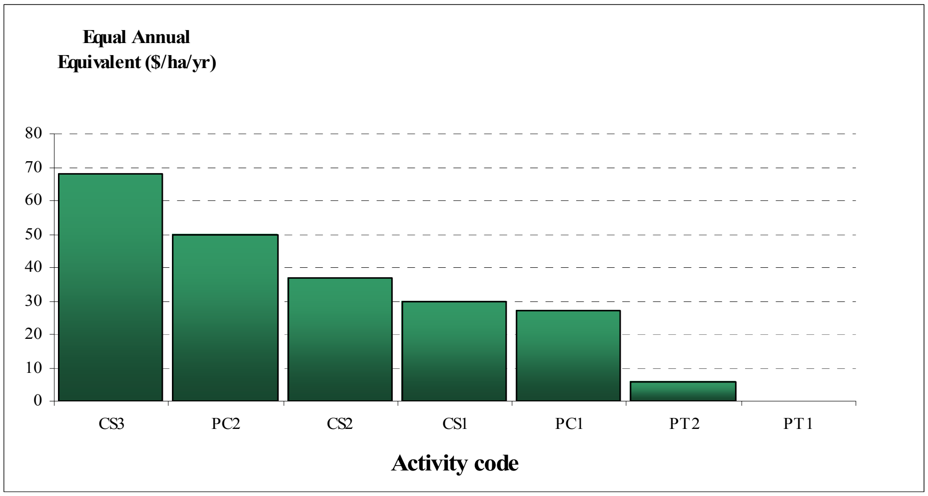
Opportunity cost for cattle was assumed to be at about of 200 ($/ha) which is considered to be available after adoption of a plantation project. This budget represents the revenues from sales of cattle.

Projects without considering income generation from payments for carbon sequestration are not competitive compared to cattle grazing projects.

The additional benefit of carbon storage in stand density of 450 (trees/ha) leads to conclusion that stand density and growth yield must be taken into consideration when considering projects with payment for carbon sequestration. The establishment of Serebo plantations might be stimulated even without payment for carbon sequestration in medium and small landowner cases if the timber price were to rise by 21%.

The feasibility of carbon sequestration projects depend on the international CER market and its price as well as the approach determining average net storage which may give different results compared to other carbon accounting approaches. Thus, it is recommended that in future best carbon accounting approaches, from the landowner and environmental point of view are evaluated, as well as sensitive analysis in CER price analysis that might give more accurate results.

Due to the fact that carbon sequestration projects under particular circumstances may be a suitable additional source of income generation, it would be of particular interest if such economic activities could also imply a reduction in rural poverty. The issue of poverty relief shall be essentially addressed in terms of the objective to raise the income level of rural activities, resulting in an improvement of the standards of living of the landowners.



DESCRIPTION		Code	Equal Annual Equivalent ($/ha/yr)
Cattle Grazing	*Small Landowner (25 ha)*	CS1	30
	Medium Landowner (25-100 ha)	CS2	37
	Big Landowner (larger than 100 ha)	CS3	68
Plantations to provide timber benefits.	*Stand Density (300 trees/ha)*	PT1	0
	Stand Density (450 trees/ha)	PT2	6
Plantations to provide timber and carbon benefits.	*Stand Density (300 trees/ha)*	PC1	27
	Stand Density (450 trees/ha)	PC2	50

Figure 8. Comparative Equal Annual Equivalence for grazing and Serebo plantations. Higher EAE corresponds to a plantation which considers timber and carbon benefits and a stand density of 450 (trees/ha).

With these results and taking into account the ownership pattern, the area economically feasible and suitable for conversion of pastures into plantations considering timber and carbon benefits is about 4,312 ha which corresponds to medium and small land ownership classes.

The economic results allows for the evaluation of the state of forestry projects in Bolivia in the context of Kyoto Protocol. These results show that within the considered ranges of CER price, timber prices, meat prices, and milk prices, afforestation projects without payments for CER are not competitive in comparison to cattle grazing in the region of *Buena Vista* – Bolivia. Thus, plantations are not attractive under current circumstances, as indicated by the payments for carbon sequestration needed to make plantation projects profitable.

CONCLUSIONS

1) Land cover analysis reveals that pasture lands cover about 9,800 ha. According to the accuracy analysis, the supervised classification was derived with a moderate accuracy (average accuracy of 79.0 %). Furthermore, allocation of pasture areas according to the three categories of landownership has been identified to be: 1,666 (ha), 2,646(ha) and 5,488 (ha) for small landowners (25 ha), medium landowners (25 -100 ha) and big land owners (larger than 100 ha) respectively.

2) The carbon sequestration potential of Serebo (Schizolobium amazonicum) plantations for implementation of mitigation forestry projects in the study area (considering only total above ground biomass for two different stand densities of 300 and 450 (trees/ha) ranged from 134 (ton/ha)

to 366 (ton/ha). Based on the biomass estimates, and taking the baseline into account the net average storage calculated for a rotation of 15 years ranged from 38 (tonC/ha) to 53 (tonC/ha) for stand densities of 300 (trees/ha) and 450 (trees/ha) respectively.

3) Cost benefit analysis revealed that in the absence of payment for carbon sequestration, plantations of Serebo are not competitive compared to cattle grazing. Cattle grazing in the case of big landowners was identify to be the most competitive project and produces 68 ($/ha/year). However, the second best choice leads to an income generation from timber and payment for carbon sequestration, with the higher stand density which produces at about 50 ($/ha/year). Assuming a forest stand that produces timber and carbon, the net income of a plantation of Serebo is higher than the net income from cattle ranching for medium (25-100 ha) and small (25 ha) landowners in the region.

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REFERENCES

Alavalapati, J.R.R., G.A. Stainback and D.R. Carter, 2002. Restoration of the longleaf pine ecosystem in the U.S. South: An ecological economic analysis. Ecological Economics. 40. March (2002):411-419.

Banko, G. (1998). A review of assessing the accuracy of classification of remotely sensed data and of methods including remote sensing data in forest inventory. International Institute for Applied Systems Analysis (IIASA). Interim report IR-98-081. Laxenburg-Austria.

Benitez, P., Olschewski, R., De Konig, F. and Lopez, M., 2001. Análisis costo- beneficio de usos del suelo en Ecuador Noroccidental y financiamiento de proyectos forestales mediante pagos por fijación de carbono. Proyecto Fijación de CO2, TOEB –GTZ, Universidad de Göttingen.

Brow, S., 1997. Estimation biomass and biomass change of tropical forest, a primary. FAO Forestry paper No 134. Fao, Rome, 55 p.

Brown, S. and Lugo, A.E., 1992. Aboveground biomass estimates for tropical moist forests of the Brazilian Amazon. Interciencia 17, 8–18.

Brown, S., Lugo, A.E. and Iverson, L.R., 1992. Processes and lands for sequestering carbon in the tropical forest landscape. Water Air Soil Pollut. 64, 139–155.

Brown, I.F., Nepstad, D.C., Pires, O., Luz, L.M. and Alechandre, A.S., 1992. Carbon storage and land-use in extractive reserves, Acre, Brazil. Environental Conservation 19, 307–315.

Brown, I.F., Martinelli, L.A., Thomas, W.W., Moreira, M.Z., Ferreira, C.A. & Victoria, R.A., 1995. Uncertainty in the biomass of Amazonian forests: an example from Rondonia, Brazil. Forest Ecology. Mgmt. 75, 175–189.

CIAT, 2000. Establecimiento y usos de sistemas silvopastoriles: Pasto Gatton (Panicum maximum) bajo árboles nativos para los valles cruceños. Centro de Insvestigación Agrícola Tropical

Dauber,E., Terán, J. and Guzman R. 2000. Estimaciones de biomasa y carbono en bosques naturales de Bolivia. Santa Cruz de la Sierra, Bolivia.

Davis, P., 2000. Carbon forestry projects in developing countries: Legal issues and tools. Forest Trends, Washington, D.C.

De Koning, F., Olschewski, R., Veldkamp, E., Benitez, P., Laclau, P, Lopez, M., De Urquiza, M. & Schlichter T., 2002. Evaluation of the CO_2 sequestration potential of afforestation projects and secondary forests in two different climate zones of south America. Internet source (08.2002):www.gwdg.de/~eveldka/toebecar.html

Justiniano, J., Pariona, W.,Fredericksen, T. and Nash D., 2001. Serebó o sombrerillo Schizolobium parahyba (Vell.) S.F. Blake Caesalpiniaceae. Ecología y silvicultura de las especies menos conocidas. Santa Cruz de la Sierra, Bolivia.

Moura Costa, P., 2001. Carbon accounting, trading and the temporary nature of carbon storage. EcoSecurities. 45 Raleigh Park Road, Oxford, UK Internet source (08.2002): www.ecosecurities.com

Olschewski, R., 2001. Economic assessment of forestry projects. International forest economics, Georg-August University of Goettingen.

Pacheco, P., 1998. Estilos de desarrollo, deforestación y degradación de los bosques en las tierras bajas de Bolivia. Serie Bosques y Sociedad No. 2. La Paz: CIFOR/CEDLA/TIERRA.

Pandey, D., 2000. A Unasylva technical note: Yield model of plantations in the tropics. College, Forest Research Institute and Colleges, Dehra Dun, India. Internet source (05.2003): www.fao.org/docrep/s4550E/s4550e0b.htm

Palaguna, H., 2001. Study of Landsat TM application to estimate tropical deforestation rate in Central Sulawesi. Thesis to obtain the Master of Science degree in Tropical Forestry at the Faculty of Forestry and Ecology, Georg-August University of Goettingen.

PLUS, 2002. Plan de uso del suelo – Municipio de Buena Vista. Ordenanza Municipal No 09/2002. Honorable Concejo Municipal de Buena Vista.

Ruiz, C., 2002. Tropical Deforestation and its effect on Global Climate: With especial emphasis in Amazonian Countries. Teaching assignment, Georg-August-Universität Göttingen. MSc.Forestry in the Tropics and Subtropics.

Ruiz, C., 2003. Certification Impacts in Bolivia: A community forestry perspective. International Frameworks in Forestry. International Forestry Student Association (IFSA). Freiburg, Germany.

Schlamadinger, B. and G. Marland, 2000. Land use and global climate change: forests, land management, and the Kyoto Protocol. Pew Center on Global Climate Change, Arlington, Virginia. Internet source (05.2003): www.cdigc.ornl.gov.pns/band.html

Shu, G., 2003. Detection and Analysis of Land cover Dynamics in Moist Tropical Rainforest of South Cameroon. Master of Science thesis in Geo-information Science and Earth

Observation, Rural Land Ecology. International Institute for Geo-information Science and Earth Observation, Netherlands.

Stainback, G.A. and Alavalapati. J., 2002. Economic analysis of slash pine forest carbon sequestration in the southern U.S. Journal of Forest Economics 8 (August-September 2002):105-117.

Tiessen, H., Feller, C. Sampaio E.V.S.B. and Garin P. 1998. Carbon sequestration and turnover in semi-arid savannas and dry forest. Climate Change, 40, 105-117.

Tiessen, H. Menezes, R.S.C., Salcedo I.H. and Wick B. 2003. Organic matter transformations and soil fertility in a treed–pasture semiarid NE Brazil. Plant and Soil 252:195-205.

Tiessen, H., Weisbach C. and Menezes, R.S.C. 1999. Estimating the Contribution of Trees to Available P. Agroforestry Foum, 9:1 – 4.

von Gadow, K. & Bredenkamp, B., 1992. Forest Management. A division of JL van Schaik (Pty) Ltd 1064 Arcadia Street, Hatfield, Pretoria.

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