

Abstract

Emissions from deforestation are estimated to be 0.8 and 2.2 Gt of carbon annually, despite the variation in measurements this represents a significant contribution towards climate change. Reduced emissions from deforestation and degradation (REDD) been touted as an easy and relatively cheap way of reducing emissions from this sector. International disagreement and technical difficulties have thus far stopped REDD from being included in CDM, however alarm at the growing emissions from non annex one countries has led to a renewed interest in REDD and large amount of research is currently under way. This study explore some of the technical issues with REDD and looks at the state of REDD today. It finds that although significant effort has been made to identify issues, there is still a lack of genuine solutions for the most intractable problems, such as leakage. Secondly the study looks at the opportunity costs associated with REDD projects given the very high food prices at the moment. It finds that although the profitability of farming is much higher now than it was 12 months ago, the break even carbon price for OC's associated with cattle pasture is still below US\$10t/C and the funding of REDD projects on the global carbon markets is a very real possibility. Finally the study finds no clear link between OC and deforestation trends, which limits the usefulness of OC's in policy making to very broad scale assessments. Further study is needed on micro level drivers of deforestation before the situation is fully understood, this would enable a better understanding of a REDD projects long term viability and allow additionality (essential for the CDM) to be demonstrated more easily.

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1.0 Introduction

This project has two major aims; the first is to calculate time series of the opportunity costs of REDD projects for two Municipios in the Mato Grosso state of Brazil, Alta Floresta and Querência, and to relate this to the potential success of REDD on the carbon markets; the second aim is to ascertain if there is any causal link between opportunity costs and deforestation, therefore getting a basic assessment of the usefulness of high level cost studies to REDD policy makers.

1.1.0 Why?

Emissions from deforestation range from 0.8-2.2Gt of carbon per year (Houghton *et al* 2000, Achard *et al* 2004 and Ramankutty *et al* 2006), corresponding to between one third and one eighth of all anthropogenic GHG emission (Fearnside and Laurence 2004). Hence Projects to reduce emissions from deforestation and degradation (REDD) are currently one of the most hotly debated topics in climate policy. REDD has been a central issue for much of the recent climate negotiations in Bali and Bonn, where it missed out on inclusion into the CDM on technical grounds. Subsequently there has been an explosion in REDD related research from many international bodies. It is potentially a cheap and effective way to reduced emissions and bring in funds for sustainable development to some of the poorest areas of the world. More importantly it could be achieved through the carbon markets, without the need for large amounts of international aid. If implemented properly REDD has the potential to commercialise vast amounts of forest carbon and reverse current economic trends where forests are worth more felled than standing.

Opportunity costs associated with REDD projects are the revenues forgone by not deforesting. There are currently 2 major studies estimating opportunity costs of REDD in the Brazilian Amazon (Nepstad *et al* 2007)(Grieg-Gran 2006 based on Vera Diaz and Schwartzman 2003) and several more that look at the economics of cattle ranching in the Amazon but do not deal with REDD directly (Arima 2006 *et al*, Barros 2002, Margulis 2003). All of these studies are based on agricultural returns

calculated in 2006 or earlier, consequently they do not take into account the currently high profitability of farming because of very high global commodity prices. By using a basic empirical model this study aims to assess the impact of these price rises on the costs associated with REDD projects in the Amazon.

The inability to put a monetary value on benefits derived from intact forests has led to a felled forest being worth more economically than standing ones. Since the seminal paper by Costanza *et al* (1997) where he valued the world's ecosystem services at US\$33 trillion per year, there has been much research in the field of commercialising these services. REDD aims to commercialise one such service, that of carbon storage and sequestration and as such economic evaluation of REDD (such as OCs) has been important to policy making decisions. This is ably demonstrated by the use of work by Greig-Gran (2006) in the Stern report (2006) and work by Nepstad *et al* (2007) as a policy document for the Bali conference. Such reports do give a good idea of the long term economic viability of project. However the extent to which they can be used to infer deforestation drivers and hence potential long term success (regardless of economics) of REDD is largely untested. By comparing a time series of deforestation and OC's the study aims to establish if there is a link between the two and conduct a basic assessment of how useful these studies are more generally in the policy making arena.

2.0 Literature Review

2.1.0 Drivers of deforestation in the Amazon

Brazil has the highest absolute rates of deforestation of any country in the world (Achard *et al* 2002) however the forces which drive this are complex and overlapping making them very hard to identify. A detailed description of the drivers of deforestation is well beyond the scope of this project, hence only a brief one is given below.

There seem to be close links between farm land expansion and deforestation for both cattle ranching (Mertens *et al* 2002, Pattanayak 2005, Ferraz *et al* 2005), soy bean cultivation (Laurance 2007, Vera Diaz and Schwartzman 2005) with roughly 70% of deforested land being used for cattle pasture (Vera Diaz and Schwartzman 2005). The simple explanation is that in order to increase agricultural production the amount of land under cultivation is increasing and this primarily comes from the conversion of forested lands. This, although partly true, is only a fraction of the real picture with local interactions between loggers and farmers (Margulis 2003), fiscal incentives from the government (Arima and Uhl 1997, Camargo *et al* 2002), rich organisations (Chomitz *et al* 2006) expansion of transport links (Alves 2002, Fearnside 2005) and even the level of economic development within the country (Ewers 2006) all contributing to deforestation. The myriad of overlapping factors and drivers make it very difficult to make broad generalisations about what is driving deforestation and ascertain what is a cause and what is an effect. Do roads cause deforestation or does deforestation and subsequent economic development cause roads, for example? There is also potentially high heterogeneity of deforestation drivers between areas meaning local level studies of factors driving household decisions are needed to understand deforestation in any given area.

2.2.0 Food Prices

Much like the drivers of deforestation the reason for the current high prices in food are complex and well beyond the scope of this project to explore fully so only a brief explanation will be given here. Between January 2007 and March 2008 the price of wheat had risen US\$196 per tonne to US\$440 per tonne (USDA 2008) a rise of 224% in 15 months. The increase was driven by both supply side and demand side factors, on the supply side the recent rise in the price of oil had two effects. The first was an increase in the cost of production as fertilizers and fuel, higher fuel prices also increased the cost of transport both of the farmer to market and from the market to the consumer (Wiggins & Levy 2008). Second, the rise in oil prices increased the demand for biofuels, which are produced from grains such as corn, hence there was a corresponding increase in demand and subsequently price, the effect was compounded by ill judged biofuel policies in the EU and the USA (Wiggins & Levy 2008). Finally the failure of crops in several countries, most importantly Australia after several years of drought, reduced overall production and led to further price increases.

On the demand side prices have been driven up by growing economies in India and China and the associated increase in demand for high value foods such as fish, meat and dairy. The increase in livestock production corresponds to an increase in demand for feed grains such as soy and wheat (Wiggins & Levy 2008) and hence an increase in price. The current prices are regarded as a short term spike. Price predictions (up to 2020) estimate agricultural commodities will decrease from current levels but will remain around 30% higher than 2005 levels (Wiggins & Levy 2008). However on a cautionary note, most food price predictions are based around the price of oil and hence the predictions are subject to any number of socio-economic and political factors (Wiggins & Levy 2008)

2.3.0 Kyoto Protocol and CDM

Wednesday February 16th 2005 was for most people much like any other day, but on that Wednesday the first commitment period of the Kyoto protocol, signed some 7 years previous, began and with it came the start of a somewhat belated global effort to curb green house gas emissions. Under the conditions of the protocol ratifying developed nations were committed to binding emission reduction targets, which for the second commitment period (2008-2012) was 5% below 1990 levels, the principle of 'common yet differentiated responsibility' meant ratifying developing nations did not have to make commitments (UNFCCC 1998).

The protocol also included a flexible mechanism whereby developed nation could invest in projects to reduce emissions in developing countries and these reductions would count towards the developed nation's targets, this was called the clean development mechanism (CDM)

(UNFCCC 2005). Central to every CDM project is the concept of additionality, there is some argument as to what constitutes additionality, but simply put a project with additionality achieves emissions reductions that would not otherwise have occurred without the incentive of the CDM. The CDM can then be thought of as providing incentives that are additional to the business as usual situation, hence the term 'additionality'. It is under the auspices of the CDM that the current

Cap-and-trade carbon system

A company may buy carbon credits off a country or government body within a country etc, as long as the emissions are certified to have additionality under CDM conditions. Under this system companies are given emission reduction targets by a central agency (usually a government body), companies who are not going to meet their target must be in possession of sufficient credits equal in value to their excess emission, these credits can be purchased from other companies who have reduced emission to below target levels and hence can sell their excess emissions. This transfer of emission takes place by the buying and selling of credits in the open market.

cap-and-trade carbon market in existence today was created (UNFCCC 2005). A brief description of the cap-and-trade market is given in box 1, although the term

company is used in reality it involves any entity which has to meet a reduction target or has carbon to sell. For example a company may buy carbon credits off a country or government body within a country etc, as long as the emissions are certified to have additionality under CDM conditions.

2.4.0 Forestry and Kyoto

Emissions from deforestation are estimated to be between 0.8-2.2Gt of carbon per year (Houghton et al 2000, Archard et al 2002, Hirsch *et al* 2004 and Ramankutty et al 2006), which is between one third and one eighth of all anthropogenic GHG emission (Fearnside and Laurance 2004). The debate stems from the different methods used to measure land cover change and the assumptions in the calculations involved (Fearnside and Laurance 2004, Ramankutty 2006), but despite disagreement over the details there is a broad consensus that emissions from deforestation make a substantial contribution towards climate change (Fearnside 2000).

Ostensibly the use of the CDM to reduce deforestation seems to very sensible, through the carbon markets it would be possible to make it economically more attractive to keep forest than to fell them. Instead during initial negotiations for the CDM reduced emissions from deforestation came up against some very strong resistance from several parties (Fearnside 2001). The resistance stemmed from two main issues, the first was one of leakage (discussed later), the second was the idea it represented an easy way out (Fearnside 2001), potentially the number of credits earned from REDD would make their price very low allowing developed nations to cheaply buy their reduction targets (Coomes *et al* 2008). Hence under the Kyoto protocol only afforestation and reforestation were able to earn credits through the CDM and avoided deforestation (REDD) was excluded.

In 2005 however the proposal found favour again after being proposed by the coalition of rainforest nations (COMIFAC) (UNFCCC 2005). Alarm at the rapidly increasing emissions from non Kyoto committed nations (1990-2004: USA 15.8%, China 47%, India 55% (EIA 2004)) was probably partly responsible for the renewed support enjoyed by REDD particularly from European based agencies (Laurence 2007). Since then REDD has been gaining support, but many of the technical issues still remain (discussed later) hence it missed out on inclusion at the most recent COP of the UNFCCC in Bali 2007. On the surface this snub could be seen a major setback and in some ways it is, however Bali put REDD firmly on the climate politics agenda and paved the way for much more research and negotiation before the next COP in Poland this year and the negotiations around post 2012 commitment period in Copenhagen 2009 (Ott *et al* 2008).

2.5.0 REDD Funding Mechanisms

The funding for REDD projects is a complicated and divisive issue. The mechanisms fall into one of 2 broad categories, market based and non market based. The UNFCCC SBSTA define at least 5 of the former and 6 of the latter (see box 1). Before exploring the issues that surround individual mechanisms it is important to first look at the two main categories in a wider political context.

Whether market or non-market based financial instruments are better is a major political sticking point, the majority of rainforest nations are in favour of some kind of market based funding. Submissions to the UNFCCC SBSTA talk of “the development of market based mechanisms” (Bolivia, Nicaragua, Costa Rica and PNG) (UNFCCC 2006) and that “new positive incentives should be based first on an ambitious cap and trade system and market mechanisms” (COMIFAC)(UNFCCC 2006). Furthermore all rainforest nations support non market based funding, such as overseas development aid and fund based mechanisms (Potvin *et al.* 2008, UNFCCC 2006), the sticking point comes when looking at the position taken by Brazil. Brazil

is strongly opposed to any market based funding of REDD projects, their reasons simple:

“The Government of Brazil does not envisage any mechanism related to reducing emissions from deforestation in developing countries that could be used by Annex I countries to meet their quantified greenhouse gas emission limitation and reduction commitments”
(UNFCCC 2006)

Box 1: REDD Funding mechanisms taken from the UNFCCC SBSTA

74. Market-based mechanisms could include the following:

- (a) Trading of carbon credits;
- (b) Project-based, programmatic and/or sectoral CDM;
- (c) Barter transaction (similar to existing market approaches but credits could be paid by using currency other than money, e.g. debt cancellation, trading opportunities, employment, etc.);
- (d) Payment for ecosystem services;
- (e) Levies on emission reductions units issued or assigned amounts units first traded on the carbon market. The complexity of discussing and agreeing upon such levies was highlighted.

75. Non-market-based financial resources could include the following:

- (a) Overseas development assistance;
- (b) Voluntary contributions from governments and NGOs;
- (c) Private sector sponsorship/donations;
- (d) Potential new and additional financial resources under the Convention;
- (e) Funds created under the Convention and its Kyoto Protocol (e.g. the Special Climate Change Fund, the Adaptation Fund) and the Trust Fund of the Global Environment Facility (GEF);
- (f) Taxes on carbon-intensive commodities and services. The complexity of discussing and agreeing upon such taxes was highlighted.

(UNFCCC SBSTA 2007)

The Brazilians are also opposed to binding targets, they believe all commitment to reducing deforestation by rainforest nations should be voluntary and are unwilling to submit to binding targets (deforestation or emissions) (UNFCCC 2006). This is indicative of Brazil’s firm belief in the principle of common but differentiated responsibility. These two stem from the wider issue of forest sovereignty. Brazil fear by allowing other countries and private organisations to invest in maintaining areas of forest through financial mechanisms such as carbon credits they will effectively lose control of their own forest (Laurence 2007).

2.5.1 Issues- Market based mechanisms

Box 1 outlines the market based funding options as identified by the UNFCCC, one of the main problems with market based finance options is that REDD projects were specifically excluded from the first commitment period of the CDM (up to the end of 2012)(the reasons for this are explored elsewhere). This means currently REDD projects are unable to earn carbon credits that can be traded in anything other than the voluntary market. However current ongoing negotiations aim to change this, the result of which won't be until after the Copenhagen conference in 2009.

Although there are a number of market based options the most likely way REDD projects can generate funds in this manner is through access to the global carbon market. REDD mechanisms have the potential to earn large sums of money for forest conservation through the carbon market, estimated at US\$ 2.2-13.5 billion (Ebeling & Yasué 2008) which is well in excess of current forestry spending, around US\$1.1 billion annually (Laurance 2007). There have been 2 system developed to achieve this (Achard et al. 2005 and Santilli et al. 2005), both of these mechanism involve national baselines. These baselines are intended to sidestep the problem of national leakage (Mayer *et al* 2005, Murray *et al* 2004)(discussed elsewhere) and a country would then be awarded credits for reducing emission from deforestation from this baseline, this is known as compensated reduction (CR). There are many issues CR systems (discussed later), but from a funding perspective governance is a major issue. For REDD to be effective revenue earned must be paid to the people on the forest frontier who incur the costs, by earning incentives at a national scale it is possible a sizable proportion of the benefits could be lost to corruption before it reaches the stakeholders. If this were the case it is possible the revenue received is less than the costs incurred and hence the emissions are no longer avoided.

The inclusion of REDD projects in the CDM credit system will only work if it does not undermine the current system, this is rightly a concern of many countries

(UNFCCC 2006). Coomes et al. (2008) suggest that REDD credits would be cheap in a fully fungible market, due to relatively low cost of starting and running a REDD project when compared to afforestation/reforestation (AR) projects (currently included in the CDM). It is essential there is a sufficient level of demand in the Carbon Market to include REDD without undermining the existing AR credit system. This demand would be created by more stringent binding target for annex 1 nations. If the USA were to ratify the Kyoto protocol and submit to binding emissions target, it is likely this would create sufficient demand in the carbon market to support awarding credits to REDD projects (Laurence 2007).

Aside from the issue of sovereignty market based mechanisms are potentially risky. In a new developing market price fluctuations are common due to buy and seller uncertainty about supply and demand. Furthermore when the market is developed there is still no guarantee the carbon price will remain above a level at which the project costs are recovered. Given the proportionally large likely starting cost of REDD projects (Wunder & Albán 2008, Nepstad *et al.* 2007 and Rodriguez 2005) some developing nations may be reluctant to invest in REDD given the uncertain nature of returns from the carbon market (Potvin *et al.* 2008). Importantly however using a market based system of finance will allow many more actors (especially private sources of investment) to access the REDD system, the majority of whom would be excluded by an entirely fund and aid based system.

2.5.2 Non-Market finance mechanism

There have been 2 fund based mechanisms to finance REDD have been put forward to the UNFCCC, one by COMIFAC and the other by Brazil (UNFCCC 2006). The COMIFAC proposal is interesting as it does not attempt to link deforestation to emissions, instead it looks to reward countries which engage in sustainable forestry management and gives a “climate regulation grant” which is measure of forest area weighted by deforestation rate (UNFCCC 2006). Under this scheme funds would

flow into the countries which made efforts to reduce deforestation without the need for complicated measures of emissions reduction and more importantly binding targets for the countries involved.

The second fund based mechanism was proposed by Brazil (UNFCCC 2006) this mechanism uses agreed national baseline and then employs a credit/debit system to reward countries who reduce deforestation below the national baseline. The baseline is set using a historical annual average and is update periodically. Countries in the fund would be rewarded with a proportional share of the credits earned by the fund over time. The main issue with Brazil's proposal is contribution to the fund is voluntary and not linked emission reduction targets in annex 1 countries. This in effect means there is no guarantee about the size of the fund and hence participating countries have no idea if enough funds can be raised to cover the cost of REDD schemes (Potvin et al 2008). Furthermore the voluntary nature of this system could generate a perverse incentive to not attempt to reduce deforestation, the reason being countries in the scheme would incur significant REDD start up cost. Without a guarantee of sufficient returns to cover these costs, it would be economically favourable to not enter the scheme at all (Potvin et al 2008). Also having a scheme which has less than total participation in a geographical area leads the REDD project open to high levels of transnational leakage (Gan & McCarl 2007).

The problem with non-market fund based mechanisms is one of funding, none of the major proponents of such mechanisms has made any real concerted effort to identify a consistent source of funding. The amount of money needed to fund REDD schemes that are economically viable is large, for example Panama would require an estimated US\$3.6 million a year (Potvin et al 2008) to cover the cost of avoiding deforestation for just 5 km² of land. When you consider for the Municipio of Juara in Mato Grosso state Brazil there was 110.1 km² of deforestation in 2007 alone (PRODES 2008), the sums of money needed are vast. A further problem is that REDD funds must provide a constant revenue source for projects. A

potential source of this kind of funding would be from overseas development aid (ODA). The UN Earth Summit Agenda 21 document (1992) estimates the cost sustainable development at around US\$600 billion per year, US\$125 billion of that to come from ODA from annex 1 nations (UN 2005). Using a significant chunk of this figure in REDD projects is the only way non market fund based methods could be successful. In reality the level of ODA globally is much lower, in 2000 it was only US\$53.1 billion (Martens 2001), to include REDD funding in to the ODA mechanism would require a much stricter adherence to the targets set out in agenda 21, otherwise using these funds for REDD would have serious knock on effects on other projects.

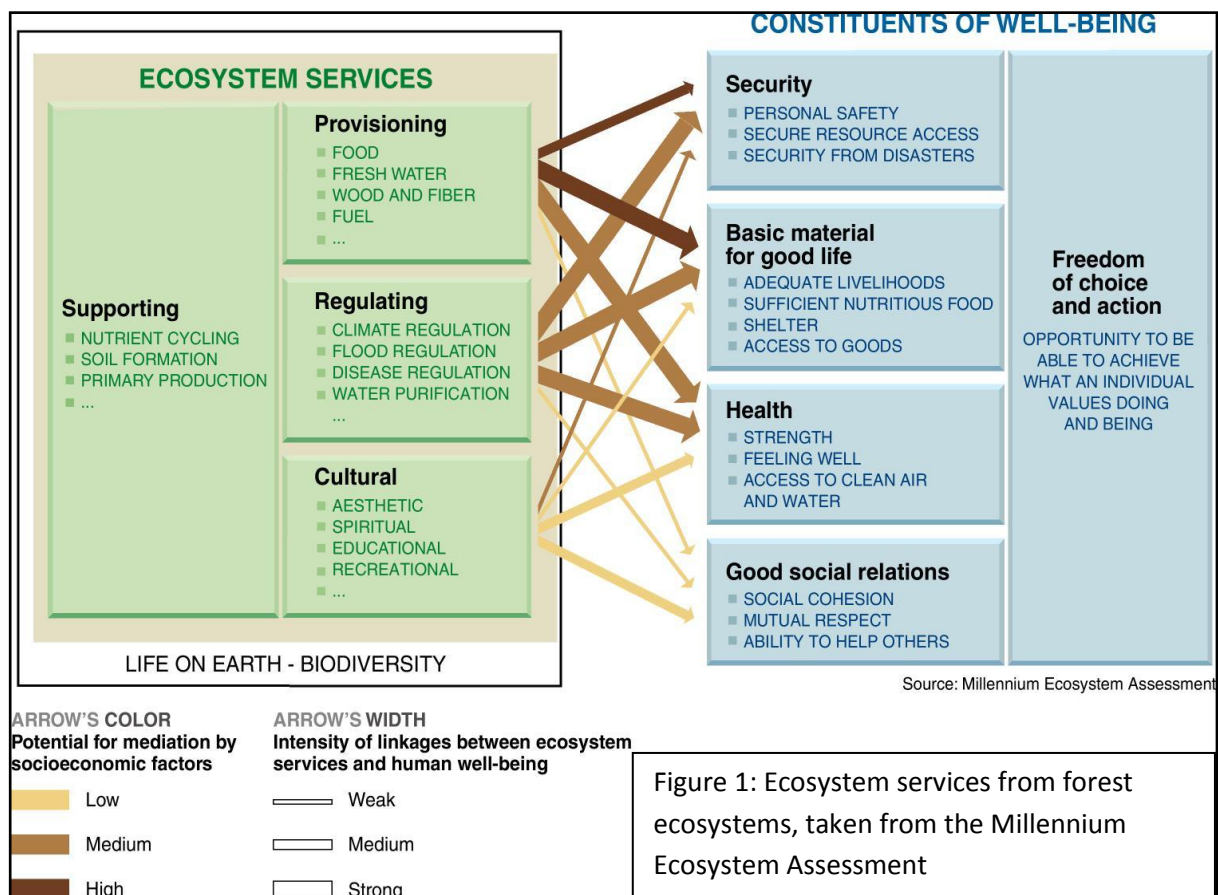
2.5.3 Combined Funding

With the exception of Brazil, most countries accept that a variety of both market and non-market based funding mechanisms are required to run effective REDD mechanisms. The high start up costs of REDD (discussed elsewhere) mean there is a need for significant amounts of *a priori* funding. Under an entirely market based system of funding this could seriously reduce the attractiveness of REDD to the potential investor, as large sums of money would be needed up front with no guaranteed rate of return. To overcome this problem it has been suggested that discounted credits could be bought by investing nations at the outset of the project, these would then be redeemable in 2012 (the first possible date of REDD's inclusion in the CDM) (Santilli et al 2005). Although it is possible this mechanism could provide funds for REDD start up, in my opinion it is unlikely to be the primary source simply because it still represents serious risk to the investor, the inclusion of REDD into the CDM is not certain and in the event of it not being included the credits could be worth less, as they would only be redeemable on the voluntary carbon market where the price is considerably lower. Furthermore the investor is still exposed to market risk with no guarantee of price when they come to sell in 2012.

Non-market based mechanisms are likely to be an important source of *a priori* funding, in the REDD mechanism. Funds available under the Kyoto protocol such as the Trust Fund of the Global Environment Facility (GEF) and the Special Climate Change fund, combined with already established funds, the World Banks Forest Carbon Partnership and more donor led funds such as the recently established Brazilian fund for the Amazon (BBC 2008) will provide countries with a valuable start up funds. It is unlikely that one single method of funding will be sufficient to set up and run REDD projects, but instead non-market aid driven fund based approach's will proved resources during REDD establishment, when the perceived risk to the investor is too great. Then market based carbon credit led financial mechanisms will likely provide a consistent revenue stream to maintain the projects.

2.6.0 Payments for ecosystem services

Using the value of the ecosystem services provided by rainforests other than carbon



sequestration is an interesting and potentially lucrative source of funding for REDD. In 1997 Costanza *et al* estimated the value of ecosystem services to the global economy at US\$33 trillion per annum just under double the global gross national product of the time, US\$18 trillion. This figure although staggering in itself is now regarded as “a serious underestimate of infinity” (Toman 1998). Rainforests themselves provide a range of ecosystem services, water shed, rainfall, food, and the intrinsic value of biodiversity itself, many of which are essential to human wellbeing (See figure 1).

The extent to which these services can be used to generate finance is another matter. Water shed services are the easiest and the most commonly marketed ecosystem service, there are example of success schemes from the US (Appleton 2002), France (Perrot-Maître 2006), Costa Rica (Pagiola 2008), Ecudaor (Wunder and Albán 2007) and Honduras (Cisneros *et al* 2007). At present the majority of users of watersheds do not pay for the services they use, there is the potential to charge all sorts of users from domestic (Appleton 2002, Wunder and Albán 2007), to a range of commercial users, such as hydro electric (Guo *et al* 2007, Pagiola 2008) agriculture (Pagiola 2008) and mineral water (Perrot-Maître 2006). Furthermore all users should be liable and willing to pay for a service. If a REDD project is in a suitable area, the marketing of watershed services allows more local level actors to access a market they would otherwise be excluded from.

Brazil has around 60 million hectares of land under cultivation, produces 80% of the worlds orange juice and is the world’s leading exporter of soy and sugar (Brazil government 2008). It is therefore the perfect place to market forest ecosystem services to agriculture other than watershed services. Although some forest ecosystem services are essential but not marketable (food and fuel provision), some are potentially very lucrative to the receivers and eminently marketable, for example Priess *et al* 2007 suggest that areas of intact forest provide pollination services worth up to US\$68 per hectare in coffee agroforestry systems. There is also much

suggesting rainforest provide essential climate regulation services affecting the levels of rainfall and temperature, with large scale conversion of land from forest to pasture leading to a warmer and dryer climate (Snyder et al 2004, Lean and Rowntree 1997, McGuffie et al 1995). It can be argued that all farmers in Brazil benefit from intact areas of forest regardless of whether the forest is on their land or not and only the farmer whose land contains forest bears the costs. It is not impossible to envisage a mechanism where such services are used to generate finance for REDD projects.

The financial potential of PES schemes for REDD projects is vast. Forests, provide many services, unfortunately many of them, such as biodiversity, aesthetic value, recreational and spiritual, only have intrinsic value that is very difficult to market financially. Although techniques (contingent valuation, willingness to pay and multi criteria analysis) have been developed to try and quantify these values to inform policy it is difficult to see how these can be used to generate resources for REDD projects. However the recent news that private equity firm Canopy Capital have purchased the rights to the ecosystem services from 371,000 hectares for rainforest in Iwokrama Guyana (Butler 2008) suggests the people do believe in the future of marketing ecosystem services from rainforests.

2.7.0 Administration and transaction costs

For an area of forest to accrue carbon, credits efficient administration and monitoring systems must be in place, but these come at a cost. Efficiency of administration is vital to ensure a high proportion of the potential benefits is not swallowed up by spiralling costs. Using current payments for environmental services schemes (PES) as a guide it is clear the level of administrative costs corresponds directly to the scale on which the scheme is working (Greig-Gran 2006). Economies of scale lead to smaller projects having correspondingly higher costs per hectare, however the use of PES schemes is itself problematic. Details of how REDD

schemes will work at a national level is required for a better assessment of transaction costs (Chomitz 2006). Since these do not exist yet all cost estimates are speculative and based around projects that are perceived to be similar.

In Costa Rica, which has one of the most well established PES schemes, the administration is on a national level and to control costs FONAFIFO is legally required to spend no more than 7% of its total budget on administration. Using data from Rodriguez (2005) and the GEF (2005) Greig-Gran puts the cost of this scheme at US\$3 per hectare over the entire 250,000 ha under contract. Smaller scale PES projects can incur much higher transaction costs. A study of 2 small scale projects in Ecuador (Pimampiro and PROFAFOR) by Albán and Wunder (2008) has shown these costs to be associated with a much higher fixed cost of starting the project. In the case of the PROFAFOR (running since 1993) the average running costs are US\$6/ha/year, but this cost rises to US\$17/ha when the initial start up costs are included. The Pimampiro case is even more striking, the running costs are US\$1.57/ha/year, but the start up transaction costs are US\$69/ha (Albán and Wunder 2008).

In addition to the official monetary costs it is possible and indeed likely some transaction costs associated with any PES or REDD scheme will be absorbed by the landowners themselves. In Costa Rica intermediaries can charge landowners between 12 and 18 per cent of the initial income to help them access the PES scheme, even though the CNFL does not charge (Miranda *et al* 2003). A poor knowledge base among local landowners of how the scheme works is responsible (Miranda *et al* 2003). Including these costs in the calculation would effectively double the transaction costs of the scheme (Greig-Gran 2006).

The wide range of transaction and running costs in currently operational PES schemes make it very difficult to accurately predict the costs associated with REDD projects. Greig-Gran suggests using a lower cost band of US\$4/ha and an upper of

band of US\$15/ha, this equates to transaction costs bands for a REDD project covering all the deforestation in the legal Amazon in 2007 of US\$4,488,000 and US\$16,830,000 per year (PRODES 3.7.08). This figure can be expected to increase as other areas of land are added annually.

Instead of using PES schemes as a guide Nepstad *et al* (2007) estimated the costs of encompassing the whole of the legal Amazon into a REDD project. They took the transaction cost figures from a study looking at the cost from the Amazon region protected areas programme (ARPA), these were estimated at US\$20 per km² for existing public forests and US\$50 per km² for additional land. These figures much lower than in Greig-Gran's (2006) analysis, however unlike this analysis Nepstad *et al* (2007) include the costs of bringing existing protected areas into the REDD scheme rather than simply focusing on the area potential deforestation. Hence a much greater area of land is protected and the transaction costs are correspondingly larger, estimated at US\$25 million per year for public forests (increasing by US\$8 million annually for expansion) and US\$16 million to encompass private land in the REDD project. Although the scale of the project proposed by Nepstad *et al* (2007) is much larger than any of the current REDD projects, experience from other large scale PES schemes (Costa Rica) suggest the cost estimates may be a little ambitious.

If included in the CDM REDD projects are likely to take place on a large scale as countries look to maximise their revenue from REDD projects. This means that transaction costs are likely to be reduced by economies of scale and will be similar to those observed in the national level PES schemes, such as found in Costa Rica. However considerable investment will be required in the early stages of the project to establish the regulatory and monitoring mechanisms. It is essential that transaction costs do not significantly impact on payments to people on the ground and hence a system where transaction costs are legally capped (such as seen in Costa Rica) will likely be required.

2.8.0 Monitoring of deforestation

The success of any REDD project is determined in a large part by the efficacy and cost effectiveness of its monitoring systems. To further explore REDD monitoring option we must first look at the state of national forest monitoring systems now. Between 1972 and 1992 there were at least 10 international instruments referring specifically to forests (Ruis 2001), in 1992 the United Nations Conference on the Environment and Development (UNCED) failed to agree on an international forest convention and in the international dialogue of the proceeding 14 years an agreement is still no closer (Persson, 2005). This repeated international failure to reach agreement on how best to monitor forests is due in a large part to sovereignty issues, most countries wish to retain control of their forest resources and are unwilling to have binding management targets set by an international convention (Holmgren & Marklund 2007). Consequently forest monitoring is piecemeal and generally done on a national basis. Importantly the majority of Koyoto protocol non-annex 1 countries do not have any systematic forest inventories (86% for forest area and 92% for carbon stocks), but instead they rely on expert opinion and independent review (Holmgren & Marklund 2007).

Any system of national monitoring for REDD projects must be transparent, systematic and regularly repeatable (Holmgren & Marklund 2007) simply because the system will have to applied across many different countries and be repeated several times a year. Regardless of what methods are applied the system must be able to accurately detect deforestation and degradation within and outside project areas, it must be able to provide accurate and precise measurements of national emissions from deforestation and degradation and furthermore it must be able to provide accurate measures of Carbon stocks (UNFCCC 2007). In essence the demands placed on the national forest monitoring system by REDD are large, but also show a high degree of overlap with other forestry policy objects (Holmgren &

Marklund 2007). Therefore it is unlikely a single method of monitoring will provide all the data required and several techniques will need to be applied.

2.8.1 Remote sensing

There are several different types of remote sensing from satellites; optical, microwave or radar and LiDAR (light detection and ranging) (Gibbs *et al* 2007). While these are generally regarded as being cost effective and robust ways of monitoring forest cover and changes therein (UNFCCC 2007), none of them are able to measure forest carbon stocks directly and hence require ground truthing (Drake *et al* 2003). More research is needed before remote sensing techniques can be used to make the regular assessments REDD requires (Baccini *et al* 2004). Furthermore Asner *et al* (2005) has showed current methodology to be very ineffective at detecting forest degradation. Techniques in Brazil underestimated size of logged forests by up to 123% and hence missed a sizable portion of emissions (Asner *et al* 2005). Although remote sensing is cost effective and accurate for some parameters it does not provide the complete monitoring solution for REDD at the moment.

2.8.2 Monitoring at the moment

The parties of the UNFCCC (2008) agree, remote sensing is not the complete solution, a good illustration of the current state of REDD monitoring is in a recent report by the UNFCCC SBSTA (2008), paragraph 64 states:

“While remote sensing is viewed as an important and verifiable method for monitoring forest are and forest cover and their changes, some participants highlighted the fact that remote sensing cannot provide carbon stock data and pointed out the need to couple this method with ground-truthing and reliable carbon stock inventories. In particular for ground-truthing, the high costs of sampling were noted.”

A system that uses the relatively cheap large scale remote option and then uses the expensive ground techniques is the preferred option. The secondary ground surveys

can be used to check the accuracy of the remote systems and allow methodologies that can be used to infer parameters not directly measured to be developed.

In context the majority of countries do not systematically monitor forests with a sufficient degree of accuracy and precision to allow the distribution of fund through a REDD mechanism (Holmgren & Marklund 2007), one of the reasons REDD was excluded from the CDM. However the future of forest monitoring is bright with more than 30 countries currently working with the FAO to improve national monitoring systems (FAO 2008). Currently very few countries have the monitoring systems to successfully run REDD projects, however over time the techniques will become cheaper and easier and with the growth of the sector the financial incentives greater. Consequently there will be a rapid growth in the number of countries willing to invest in robust and efficient monitoring systems.

2.9.0 Project Leakage

Leakage is defined by the IPCC special report on land use, land use change and forestry (LULUCF) (2000) as:

“changes in emissions and removals of greenhouse gases outside the accounting system that result from activities that cause changes within the boundary of the accounting system.”

In plain English forest conservation in one area can and does cause deforestation in another (Sohngen *et al* 1999). There are 4 different types of leakage (IPCC 2000): firstly there is activity displacement, this is when activities, such as farming expansion or timber harvesting, are prohibited inside the REDD project area and simply take place in other suitable areas; secondly there is demand displacement, when demand for forest products such as timber is no longer supplied within the project area it can simply be transferred to other areas outside the project; thirdly supply displacement, when the areas ceases to supply forest products other areas increase production; fourth there is investment crowding, large scale

investment in forestry (such as in a REDD project) increases the price (due to increased demand) and hence other investors in the sector are less likely to invest in other projects (generally smaller scale investors).

Leakage is potentially a huge issue for REDD projects. The funding of REDD is based entirely on reducing emissions, if however a reduction in one area simply displaces the emissions to another the project, from an emissions perspective, gains nothing. Although the project will still derive many additional benefits, such as watershed services (Guo *et al* 2007, Pattanayak 2004) and the conservation of biodiversity, its primary reason for existence and the source of much of its funding comes under threat.

Leakage occurs both nationally and transnationally, and both can potentially undermine any gains made by a project (Gan & McCarl 2007, Mayer *et al* 2005, Murray *et al* 2004). Rates of leakage are difficult to quantify, partly because although the projects are specific to one sector the leakage effects occur over many sectors (Murray *et al* 2004). Results of studies looking at the effects of leakage of emissions reductions from policies aimed at reducing emissions from the energy sector are variable, Barker (2008) rates leakage effects as insubstantial where as Felder and Rutherford (1993) estimate leakage rates of around 25% of the total emissions reduction.

Murray *et al* (2004) used a combined analytic, econometric and sector level optimisation model to calculate leakage rates from forest carbon projects within the USA. Leakage rates for avoided deforestation programmes were estimated at between 8.9% and 92.2% depending on project location. Chomitz (2002) examined the reasons for leakage from forest carbon projects, he suggests the way in which the project is integrated into the broader economic and physical environment determines the likely level of leakage.

Leakage also occurs trans-nationally. Forest conservation in China and Finland (in the case of China 100 billion yuan (US \$12 billion) is being spent over a period of 10 years (Wang *et al* 2004)), is reducing the domestic wood supply.

Demand remains constant hence both countries reliance on timber imports from Russia is increasing (Mayer 2005), leading to increased forest degradation in Russia (Mayer 2005). Interestingly these leakage effects can 'boomerang' back to the country of origin, in this case Finnish forests interact directly with Russian forests through species migration and dispersal (Lindén *et al* 2000). So the increased degradation of the Russian forests could directly undermine Finnish conservation efforts.

Gan and McCarl (2007) use the Global Trade Analysis Project (GTAP) model (Hertel 1997) to estimate transnational leakage from forest conservation, their results show 42%-95% of reduced forestry production in country will be taken up outside the country. They go on to suggest that this sort of leakage can be reduced by greater international cooperation.

The studies above indicate that with respect to REDD projects leakage is a very big issue and more importantly very hard to deal with. In order to combat national leakage, one solution is to use a set national baseline of emissions from deforestation and degradation and to reward any reduction from this baseline (Santilli *et al* 2005). This neatly side steps the problem of leakage from specific projects and takes into account Chomitz's (2002) suggestion of considering the project on a larger scale. The national baseline scenario does have some major issues, for example simply deciding on where the baseline should be set is very difficult. The biggest problem however is that national baselines will clearly reward the countries with the worst record on deforestation, for example Indonesia and Brazil would stand to gain a lot, whereas India and Costa Rica, countries where successful policy has significantly reduced deforestation (Sanchez-Azofeifa 2007, Mather 2007), stand to gain little. CR mechanisms could also give perverse incentives, where a nation will deliberately encourage deforestation in the years leading up to a commitment period to get a high national baseline set to increase the potential gain.. National baselines also completely ignore the problem of transnational leakage.

On a national level it is vital that a REDD projects fits with the broader economic and physical situation of a region or country is given a high priority during the design phase (Chonitz 2002). This would allow an assessment of the potential for national leakage and hence the success of the project. It may show opportunities for investment in the surrounding area which could reduce leakage, such as improved farming yields through investment in infrastructure and technology. In order to combat leakage, dealing with the supply and demand for timber products is essential. 21%-75% of reduced timber harvest in developed countries is offset by harvest in developing countries (Gan and McCarl 2007), so investment in timber production in developed countries may reduce the pressure on tropical forest. Most importantly it is essential leakage is taken into account during the evaluation of REDD projects and payments are weighted accordingly. National leakage rates could be defined by periodic studies (5 years) performed by an independent body, payments to REDD projects could then be adjusted appropriately. This mechanism would have to be used with some kind of insurance system, otherwise carbon price and leakage rates could combine to undermine a nation REDD systems in a particularly bad year. This kind of system would only be possible with a robust and effective nation level monitoring programme which could detect leakage.

3.0 Materials and methods

The aim of the project as defined in the introduction was ascertain the opportunity costs of REDD projects to farmers, to do this the net present value of the land was calculated. Since around 70% of deforested area in the Amazon ends up as cattle pasture (Vera Diaz and Schwartzman 2005) and the cultivation of soy beans in forest areas is becoming increasingly common, increasing from 212km² to 414 km² (2003-2007) in the north region of Brazil (IBGE 2008), two different agricultural systems were considered. One in which the forest was converted directly into pasture and used for cattle ranching and the second was a system for the cultivation of soy beans. In this system forest is rarely converted directly into fields, instead it is used as pasture for a period of approximately five years (Vera Diaz and Schwartzman 2005), hence the returns from soy farming were calculated using an initial period of 5 years of pasture.

First the revenue generated per hectare per month by the two systems of farming was calculated, the revenue(R) was a function of price per tonne (p), costs per Ha(c) and productivity per ton/Ha(Y). In the case of cattle ranching production was measured in arrobas (@) per hectare. An @ is 15kg of beef and is the unit in which beef is traded in South America:

$$R = (p * Y) - c$$

Local price per tonne of Soya was obtained from Professor Lucilio Rogerio Aparecido Alves at the University of São Paulo Centro de Estudos Avançados em Economia Aplicada (CEPEA). The price of beef in the state of Sao Paulo was obtained from the CEPEA as used as a proxy for beef prices in Mato Grosso as it has been shown to correlate well (Arima et al 2006) and it was the only available data. Productivity figures for soy were obtained from the IBGE and beef productivity figures were taken from Arima et al (2006) and the CEPEA. Production cost indices for beef were obtained from Embrapa and for Soy from FGV DADOS

In order to calculate the net present value of the revenue streams the returns per hectare are discounted over 30 years using the negative exponential format. The whole 30 year stream is summed and that is the net present value of the revenue stream. In the case of soy farming the five year discounted revenue stream from cattle farming is added to a 25 year discounted revenue stream from soy farming, in keeping with the methodology of Vera Diaz and Schwartzman (2005). A discount rate of 10% was used, however there is much evidence that discount rates on the developing world are higher than this (GEF 2005, Chomitz *et al* 2006) and a small change in discount rates wildly effects the net present value (Ninan and Sathyapalan 2005). Discount rates are also affected by the timescale of the analysis, so the opportunity costs were calculated at 5%, 10%, 15% and 20%, with only the 10% costs being subjected to further analysis.

The returns from timber harvesting are calculated by multiplying the average stumpage value (the cost of buying rights to cut a tree) by the timber potential of the land. A timber potential of 37.5m²/ha (Barreto et al. 1998) was used in this study, this was because lands with high timber potential represent areas of high additionality and given is an essential component of CDM project. The stumpage price used is US\$13.22 and is an average price paid weighted by the proportion of wood harvested, taken from Gutierrez-Valez and MacDicken (2008).

Finally the costs of pasture establishment are the subtracted, these are assumed to be US\$100 dollars a hectare, this figure is taken from Arima and Uhl (1997) and Greig-Gran (2006).

The sum of the discounted revenue streams is then added to the potential returns from timber harvesting to give the opportunity costs per hectare of a REDD project to both cattle ranchers and soy farmers. For the purposes of evaluation a moving 3 month average of this figure was used, a three month average was chosen after testing various options (2,3,4 and 5 months). By taking a moving average the

level of 'white noise' in the data is reduced, allowing trends to be detected more easily and it relates the data better to real life where decisions will be based on more than a single snapshot of costs. Using a three month average removes some of the most extreme short term variations while leaving in enough to see some shorter term trends that are lost when using larger averages.

Because of the difficulties associated with measuring above ground biomass (Saatchi et al 2007) and the widely varying estimations of forest carbon content 66-340 (Hirsch et al 2004, Houghton 2003, Houghton et al 2000), it was decided to calculate the breakeven carbon price at a range of carbon content values.

All of these values were calculated on a monthly basis for the period of January 2001 to March 2008. Although some of the data sets continued up until July 08, many of them did not and March 2008 was the latest date that all dataset were available and hence the last date opportunity costs could be calculated.

3.1 Statistics

All statistical tests were calculated using R version 2.7.0 (R core development team 2008) except for the summary statistics which were calculated in Microsoft Excel.

First the data sets for OC's were regressed against the data sets for deforestation in the municipios of Alta Floresta, Querência and the state of Mato Grosso. This was done to establish if there was any direct causal relationship between revenues from deforestation and the rate of deforestation. Several multiple regression models were created, initially looking at the relationship between both OC datasets and deforestation at minicipios and state levels. To test the relative effectiveness of OC's at inferring deforestation trends a measure of average monthly rainfall was then added to the models and the comparative effectiveness of the models were tested using an anova. The models contained the interactions between rainfall and soy and rainfall and beef, but not between soy and beef, this is because

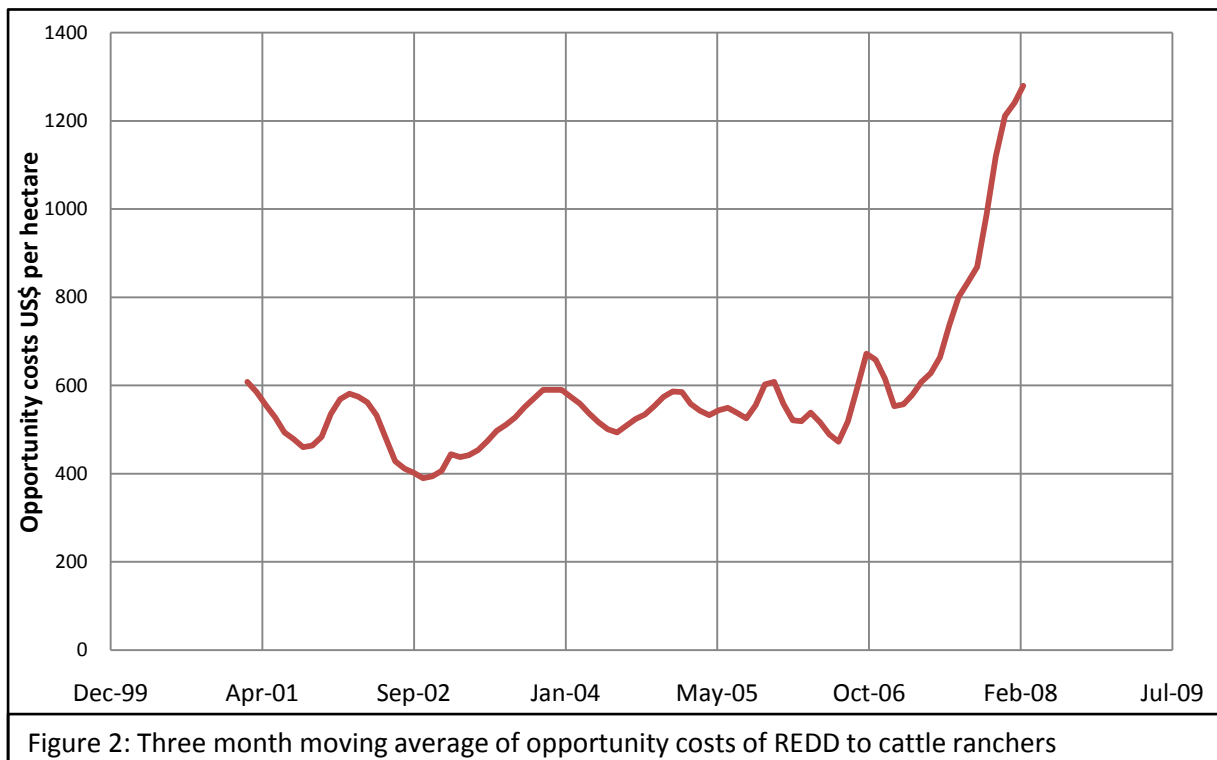
while rainfall is likely to have an effect on soy and cattle prices, the soy prices are unlikely to affect cattle prices (and vica-versa). The monthly rainfall data was taken from Global Historical Climatology Network database as hosted on www.ncdc.noaa.gov.

Next the data were analysed as time series, before this could be done the data had to be de-trended, this is because all time series analysis techniques assume the data to be untrended. To de-trend the data each series was regressed against time to gain a predicted value for each point, the predicted values were then subtracted from the actual values to return an untrended data set. These data sets were then analysed using autocorrelation and then in some cases partial autocorrelation. Autocorrelation describes how data from one week is related to data from the next week at a given lag, if significant interaction were found partial autocorrelation is used discover at what lag these interactions occur. These tests analyse the individual data sets for periodicity. After this the datasets for the OC's were then autocorrelated with the datasets for deforestation in both municipios and the state, as before any significant autocorrelations were then tested for partial autocorrelation. Any significant partial autocorrelations were plotted at the significant lags.

4.0 Results

4.1.0 Opportunity costs

Figures 2 and 3 show a three month moving average of the opportunity costs of REDD to farmers under the two different agricultural schemes as discussed in the method. Both graphs show a marked increase in opportunity costs in the last year for both soy farmers and cattle ranchers. In the case of soy farmers between March 2007 and 2008 the OC increased from US\$1419 per ha to US\$6294 per ha a 443% increase. For cattle ranchers in the same period the OC increased from US\$567 per ha to US\$1279 a 214% increase. The main reason for this increase in costs is the sudden and rapid increase in both the beef and soy prices over the last 18 months. Although production costs have been steadily increasing they have not kept pace with price increases.



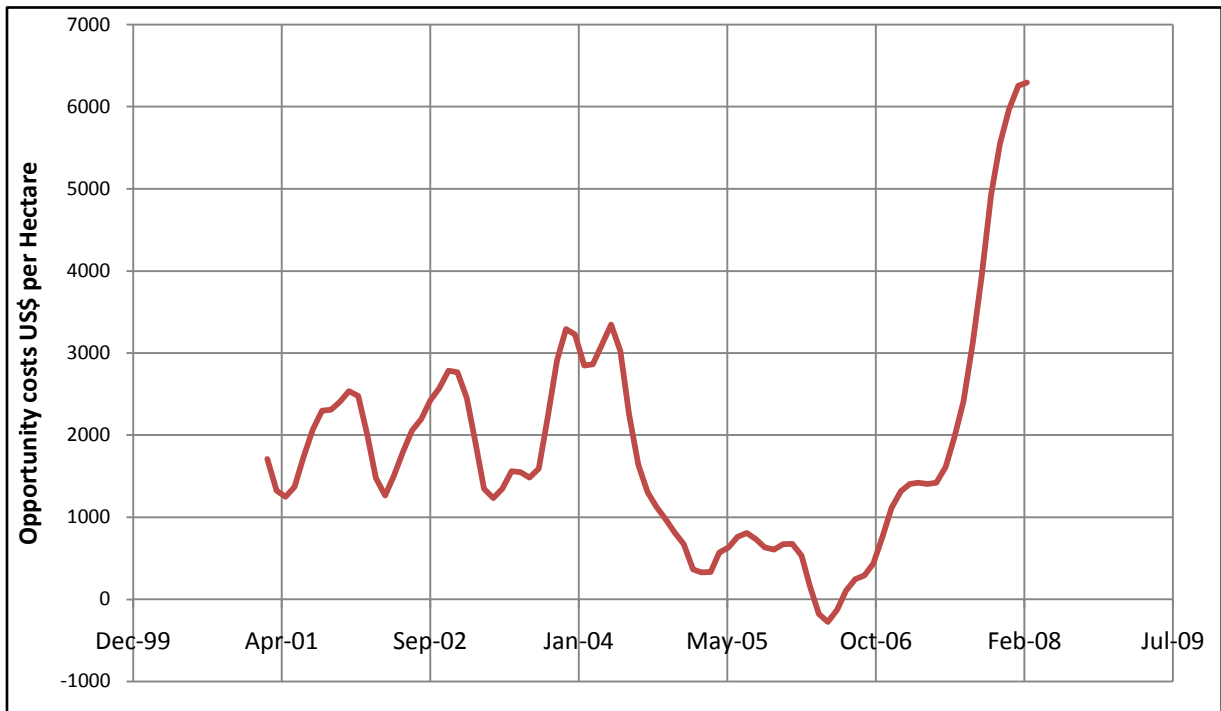


Figure 3: Three month moving average of opportunity costs of REDD to soy farmers

Figure 3 shows graphically the comparative instability of returns from soy farming when compared to cattle ranching in figure 2. This instability is reflected in the much higher standard deviation of soy OCs, 1375.9, than cattle ranching OCs,

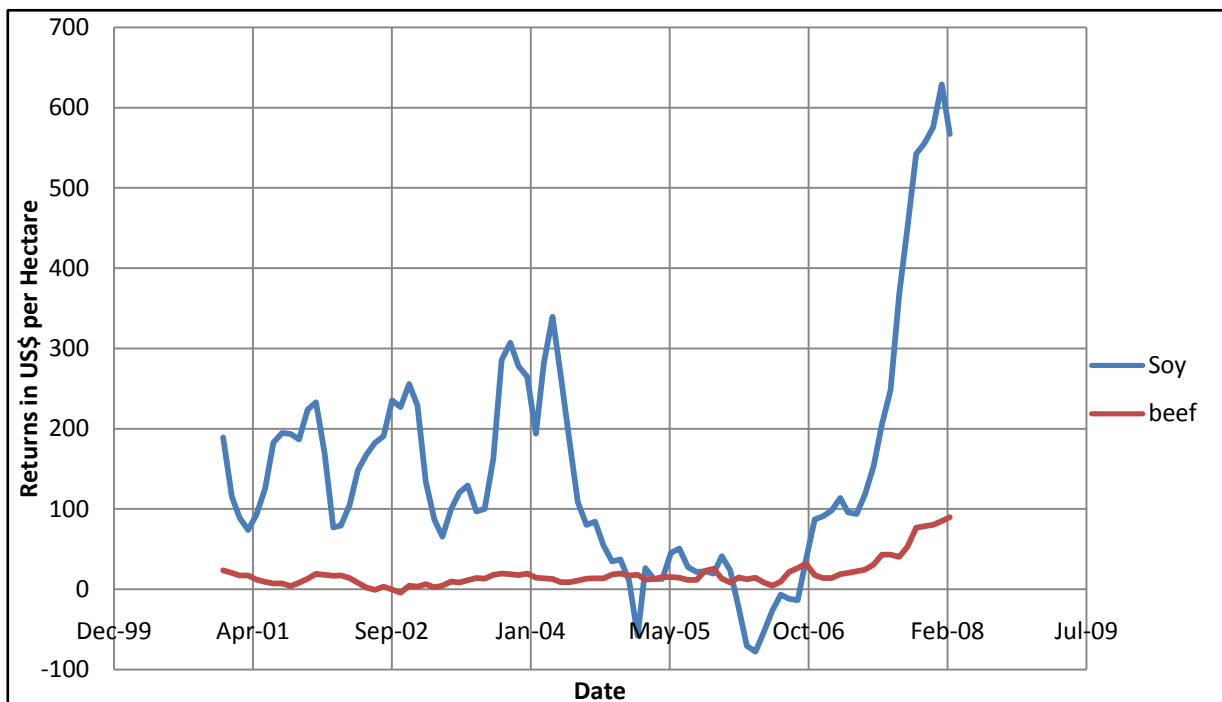
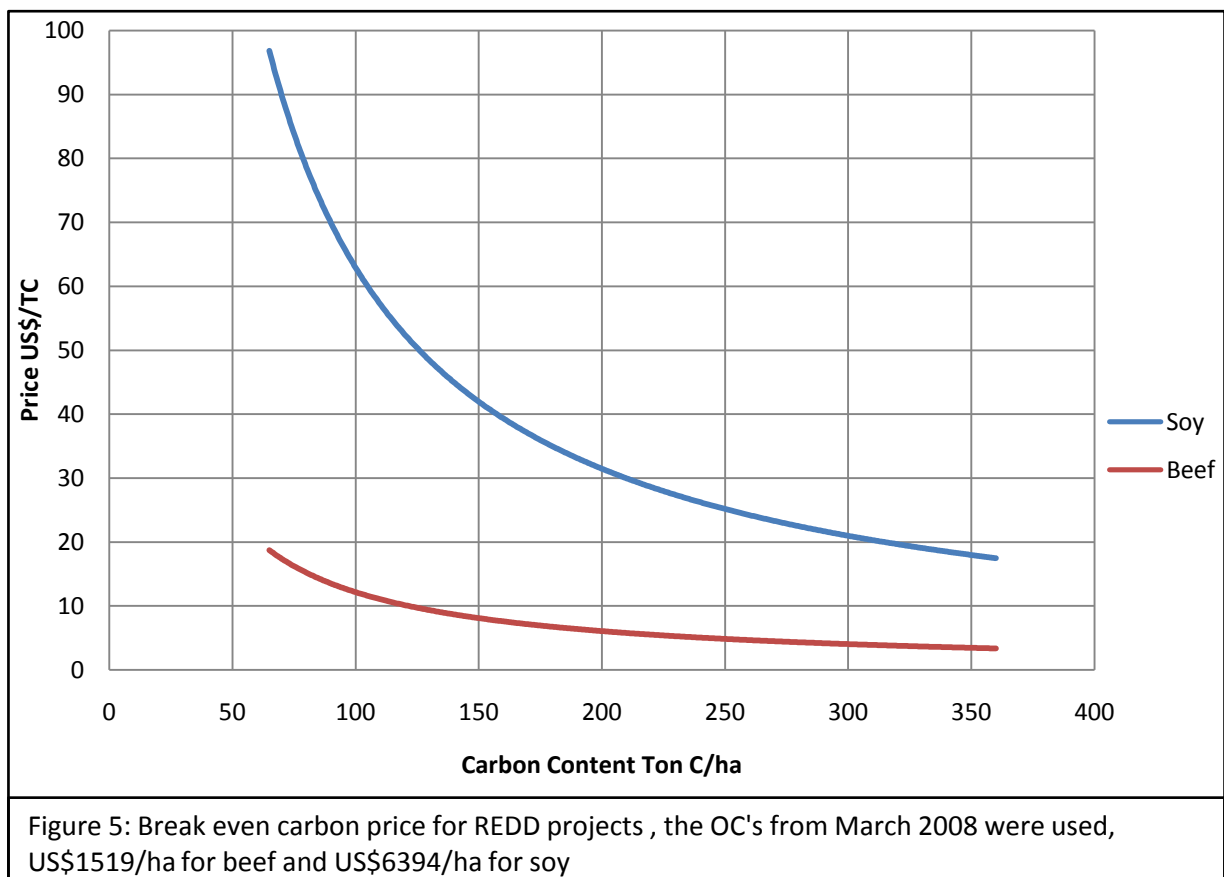


Figure 4: Net profit per hectare of cattle ranching and soy farming

159.6. Figure 4 show soy farming to be generally much more profitable than cattle ranching with recent profits being in excess of US\$600 per hectare compared to cattle ranching which has only recently reached over US\$80 per ha. This is also reflected in the summary statistics where for the period 2001-march 2008 the mean profitability of soy farming was US\$146.7 per ha and only US\$17.7 per ha for cattle ranching.



4.2.0 Break even Carbon price

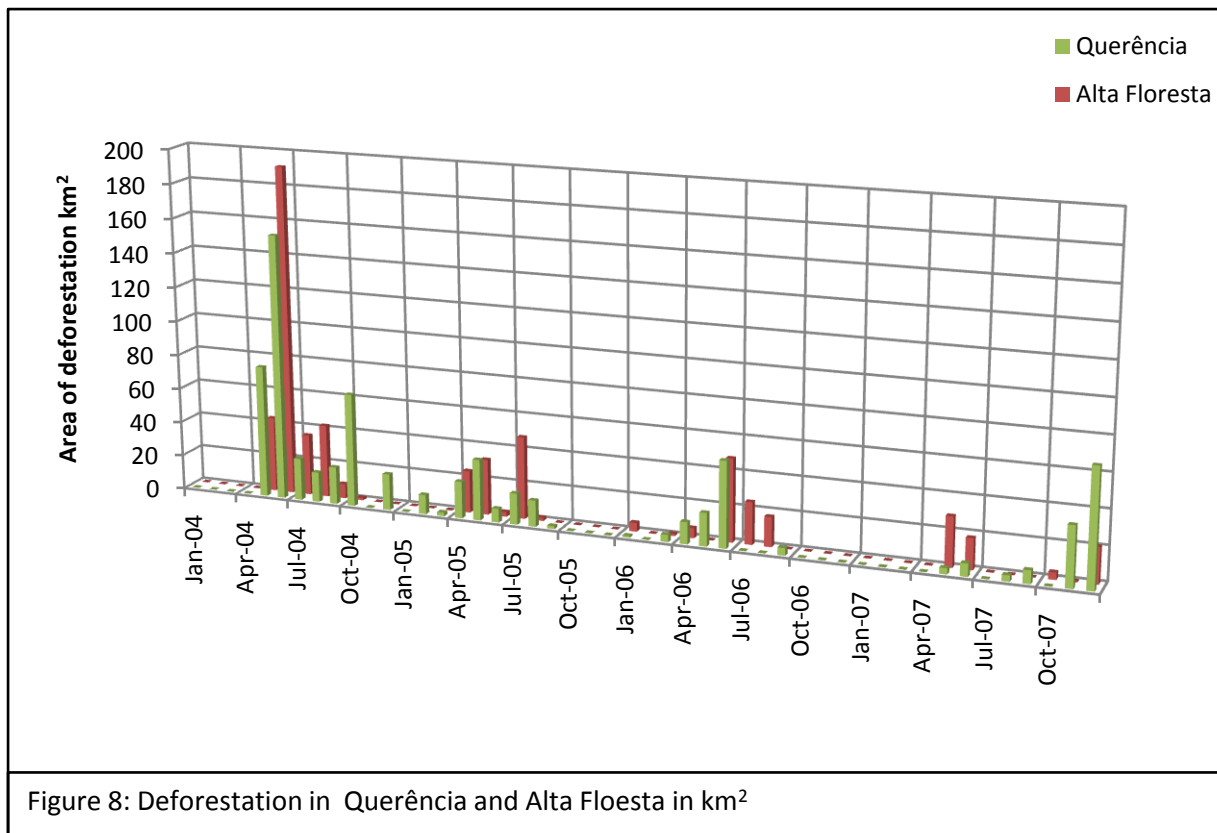
Figure 5 shows the break even carbon price for REDD projects over a range of possible forest carbon contents, 65-360tC/ha. At low carbon contents the difference between the break even carbon prices for the two methods of farming is much larger than it is at medium to high carbon prices, as is to be expected given the exponential nature of the curve. At very low carbon contents the breakeven price for soy farmers

is well in excess of US\$90 per ton where as it never reaches above US\$20 with regards to cattle ranching.

4.3.0 Deforestation and Opportunity cost

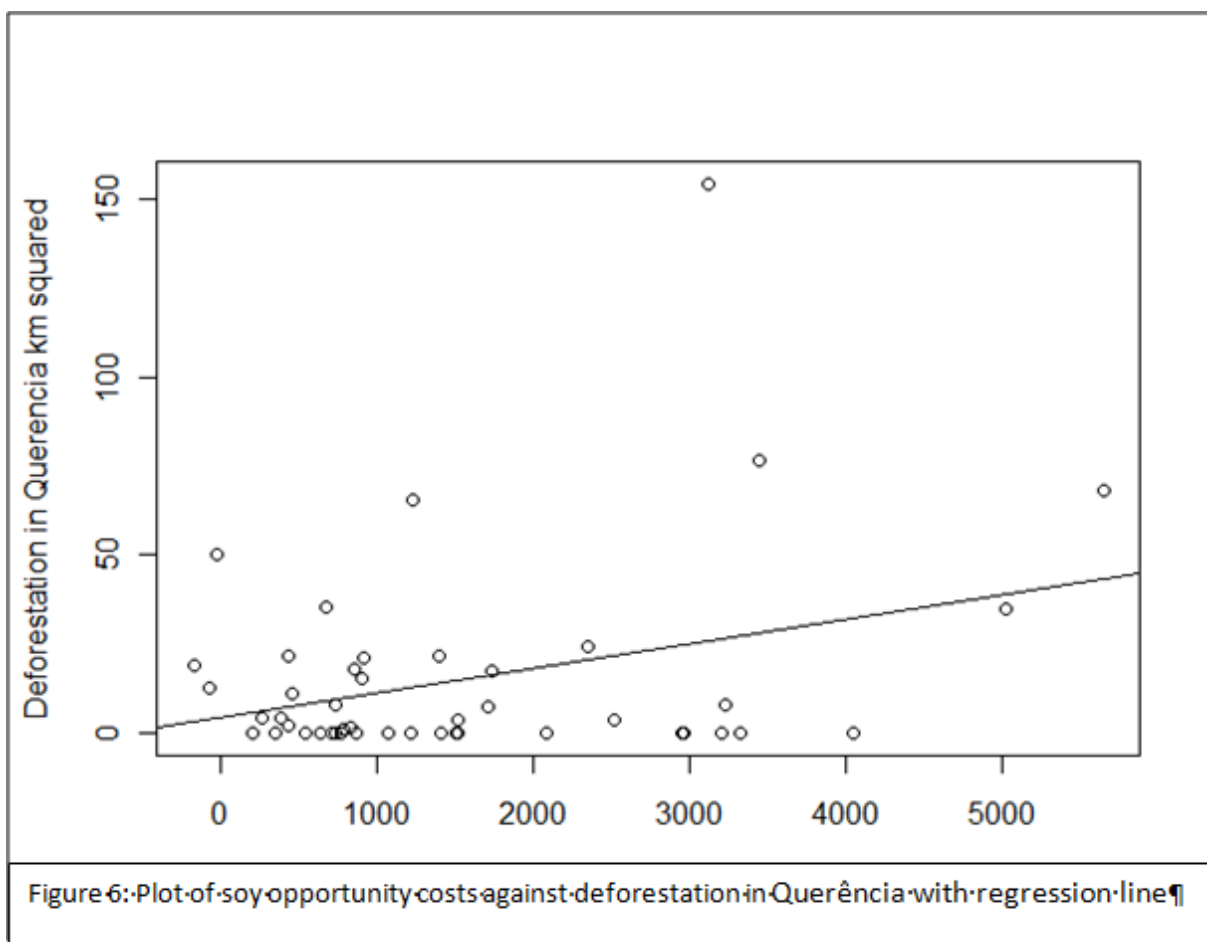
4.3.1 Regressions

The deforestation data for the two study areas is displayed below in figure 8, there are two features of the data that are worth noting. Firstly, the rate of deforestation was much higher in 2004 for both areas than it was in any of the following years, and secondly almost all the deforestation takes place between the months of March and August. In total there was more deforestation in Querência than in Alta Floresta during this period, 72.1km² compared to 125.2km², combined these 2 municipios represent 6% of the total deforestation in the state of Mato Grosso during this period.



In order to try and establish if there was a relationship between returns to farmers from deforestation (OC's of REDD) and deforestation, deforestation at a state and municipios level was regressed against the OC's of beef and soy, the results are summarised on table 1.

Table 1: P values from regression of deforestation against opportunity cost			
	State	Alta Floresta	Querência
Beef	0.2395	0.2066	0.8404
Soy	0.3955	0.2755	0.02284



All but one of the regressions returned a p value that was insignificant, the one weakly significant result came from the regression of soy OC's and deforestation in Querência, the R^2 was 0.0882. In this case there was a weak but statistically significant positive correlation between the revenues from deforestation for soy

farmers and the level of deforestation. This result suggests as the OC of REDD to soy farmers increase so does the deforestation rate.

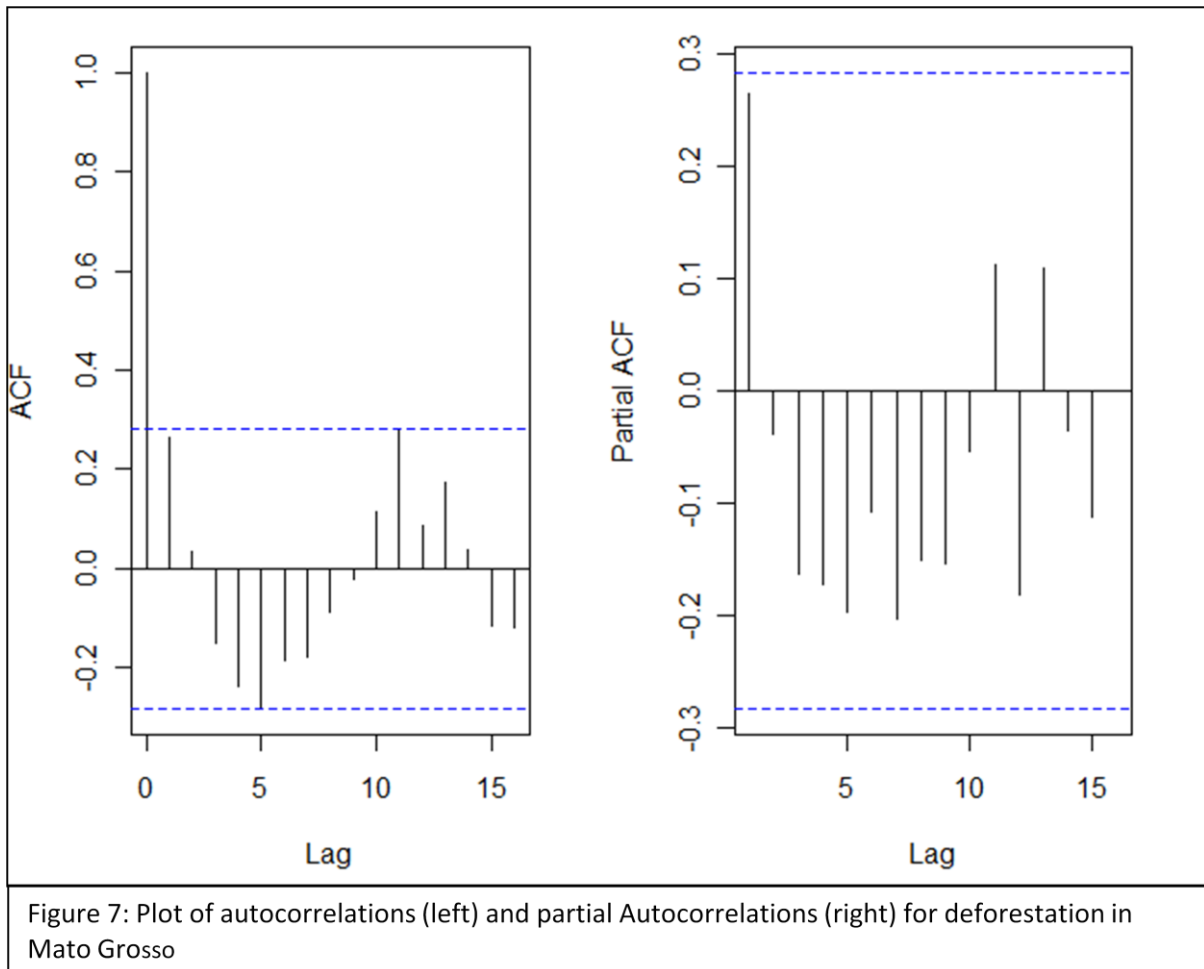
The results from the multiple regressions are summarised in table 2:

Table 2: Summary of results from multiple regression models					
	Soy/Beef		Soy/beef and rain		Anova
	Adj. R ²	P value	Adj R ²	P value	P value
State	0.103	0.033	0.337	>0.001	0.001
Alta Floresta	0.153	0.009	0.368	>0.001	0.002
Querência	0.141	0.012	0.364	>0.001	0.001

In every single instance the addition of a monthly rainfall term significantly increases the effectiveness of the model (p values of the anova's). In all cases the rainfall term more than doubles the adjusted R² values for the models, this suggests rainfall (and it's interactions with price) has roughly the same effect on deforestation as both the OC's for soy and beef combined. Hence opportunity costs associated with soy farming and cattle ranching can not be used to infer deforestation trends effectively.

4.3.2 Time series analysis

Next the results for the OC's and deforestation in Querência, Alta Floresta



and Mato Grosso state analysed for periodicity. Opportunity costs associated with soy and cattle ranching showed no significant periodicity (for autocorrelation plots see appendix). The time series for deforestation in Querência and Alta Floresta also showed no significant periodicity (see appendix), however the time series for state level deforestation initially shows some marginally significant periodicity (figure 7). There are significant correlations at 5 and 11 months, represented by the lines which touch the blue dashed line on left hand graph at lags 5 and 11, suggesting that deforestation cycles in periods of approximately 11 months. However the partial autocorrelation yield no significant interactions (figure 7) so the evidence for periodicity is weak.

Next the autocorrelations between the data sets were calculated, all of them were shown to be insignificant (see appendix) except for the correlations between deforestation in the state of Querência and the OC's associated with soy farming, which showed some lagged positive correlation, suggesting there may be some kind of interaction between the two, these were then analysed using partial autocorrelation. The partial autocorrelation shows some unexpected results, strong negative correlation were seen at lags 1,2,4,6,7,8,9,10 and 11, but on a different graph to the original significant results (appendix). The significant autocorrelations showed no significant partial auto correlations.

4.4.0 Discount rates

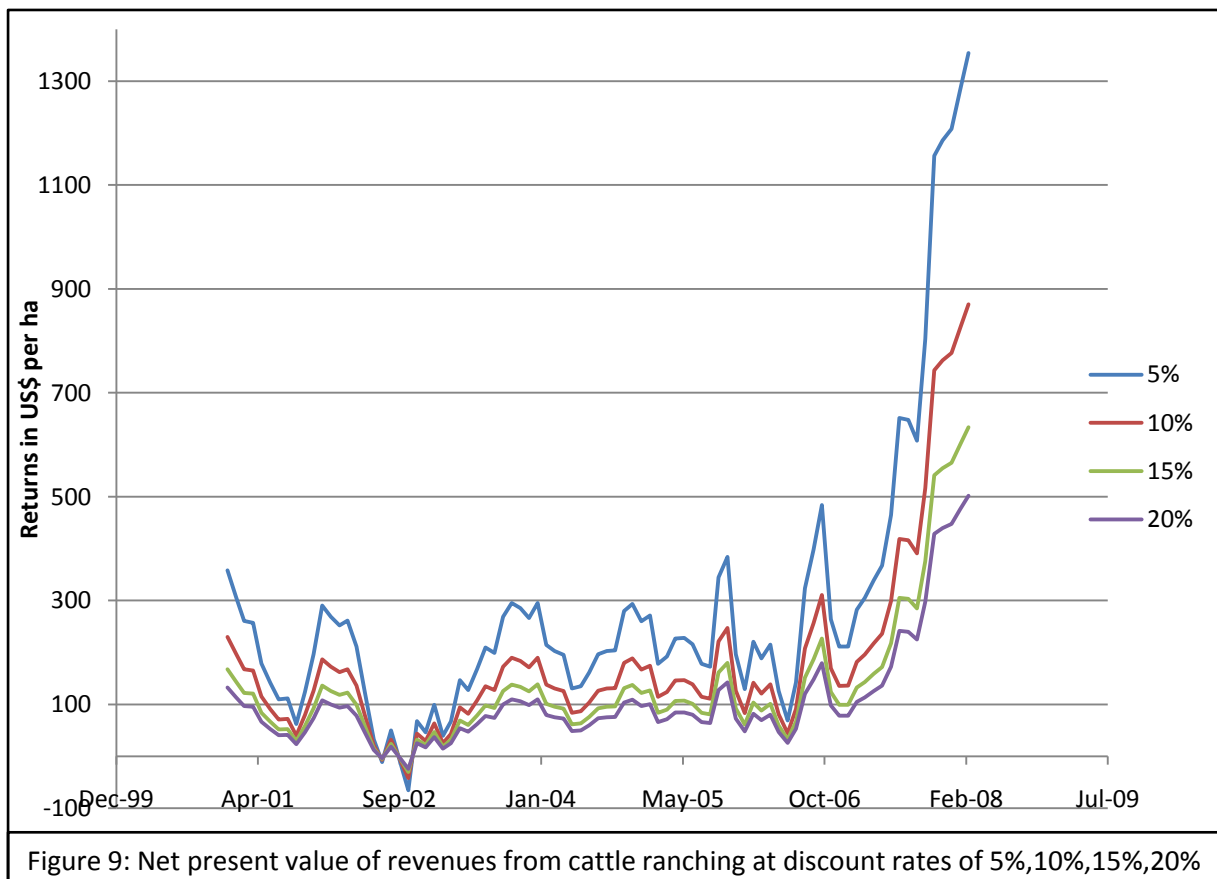


Figure 9: Net present value of revenues from cattle ranching at discount rates of 5%,10%,15%,20%

Figures 9 and 10 clearly demonstrate how discount rates impact the calculation of net present values, particularly at higher per annum returns. The net

present values for revenue streams from cattle ranching in March 2008 range from US\$501 per ha (with a 20% discount) to US\$1354 per ha (with a 5% discount rate) a difference of US\$853 per ha. Discount rate selection also has a large impact on revenues from soy farming with net present values ranging from US\$3368 per ha to US\$8395 per ha a difference of US\$5027 per hectare.

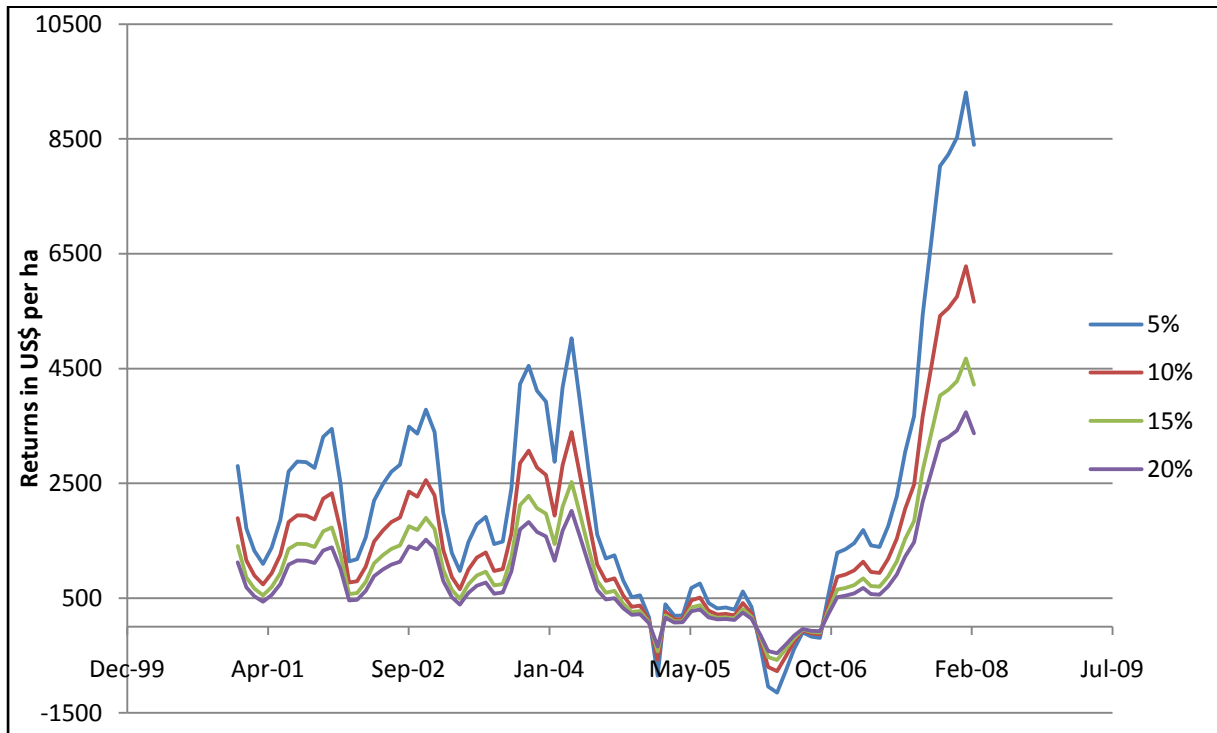


Figure 10: Net present value of revenues from soy farming at discount rates of 5%, 10%, 15%, 20%

5.0 Discussion

5.1.0 Methodology

There are several issues with the methodology used for the calculation of opportunity costs, the most important concerns the dataset's used. Significant difficulties were encountered when trying to gather local level price and cost data for the two system of agriculture, the most telling reflection of this is the use of beef price data from the state of Sao Paulo rather than the study area of Mato Grosso. While general production figures, such as soy yield and size of cattle heard, were readily available from the excellent Brazilian Institute of Geography and Statistics (IBGE) website all of the more technical production cost and price data were not. Fortunately this kind of data is published in annual volumes called the Agriannual (arable farming) and Anualpec (livestock) and the while the former was available in the British library the later was not. In the end production cost indices we procured from two different sources for the two different types of farming, the different methodologies involved in their calculation could have implications for the accuracy of cost estimations.

The second major data limitation of the study concerns the estimation of timber returns from deforestation. For the purposes of the study they were estimated as a fixed return (see methods), however this does not accurately represent the situation as the stumpage value and timber potential are very location specific. To increase the accuracy of the cost estimation a location specific measure of returns from timber returns which takes into account timber potential and transport costs (among other things) is needed. This would require the complexity of the model to increase dramatically and increase the data required, potentially reducing its usefulness and the ease with which can be applied to different areas.

The estimations of costs made here are the best possible using only freely available data. Given the increasingly big business nature of agriculture in Brazil (Margulis 2003), there are any number of agricultural statistics available at a price,

FGV dados, agribenchmark and Agra FNP being the 3 main suppliers. Access to these sources of data would have allowed the costs estimates to be more accurate and more complex. The cost estimates presented in this thesis are limited by the paucity of the available data, however I believe them to be accurate and they compare favourably with other estimates of this kind in the literature (Barros 2002, Nepstad 2007, Vera diaz 2005, Margulis 2003).

5.2.0 Discount Rates

The selection of appropriate discount rates is essential to the accurate calculation of net present value and consequently opportunity costs. There is much discussion in literature about what is an appropriate rate for the developing world is, but there is no clear consensus. Most studies relating to agricultural land in Brazil use a rate of 10% (Vera Diaz 2005) without any justification. Arima et al (2006) use the land prices and a returns per ha to derive discount rates for various areas of Brazil, these range from 2% in Sao Paulo to 11.6% in Alta Floresta, other studies estimating discount rates in Brazil are few and far between. Outside of Brazil several other studies have attempted to estimate discount rates in the developing world, one such study supports rates of 15-25% for Paraguay (Naidoo and Adamowicz 2005) and much higher rates of between 15 and 206% were estimated from a questionnaire study (GEF 2005).

The effect of discount rate on net present value is clearly shown in figures 8 and 9, the exponential nature of discount curve is demonstrated by the much higher differences between the lines at higher annual revenues. This difference is in excess of US\$3000 per ha for soy revenues between the highest and lowest discount rates considered, however even the smallest difference (between 15% and 20%) is still US\$849 per ha at March 2008 levels. The situation is similar when the costs associated with cattle ranchers are considered see figure 8

Discount rate selection has clear implications for decisions making at a policy level. If an inappropriate discount rate is used the attractiveness of an area can be drastically altered. If the rate used is too low associated opportunity costs become much higher than they actually are, reducing the attractiveness for use in a REDD project. Conversely if the rate is too high, the costs are low and the area in question's REDD potential increases, which could encourage implementation of REDD in unsuitable areas. For the opportunity costs of a REDD project to be effectively used in decision making more research needs to be done to understand the time preference of farmers on the Brazilian forest frontier. Although there is some evidence in the literature supporting a discount rate of around 10%, more research is needed in this area so the OC's associated with REDD can be fully understood and implemented effectively within a decision making framework.

5.3.0 Periodicity

The auto correlation of the state deforestation data shows some significant periodicity of 11 months. Figure 8 shows that deforestation in the two study areas takes place almost exclusively between March and August, a similar pattern is also clear in the data for the state deforestation, this corresponds relatively well with the dry season that can be identified in the rainfall data (see appendix). The reason for this is simple, during the dry season it is possible to burn areas of the forest. Since this is the cheapest way to clear forest it is unsurprising the preferred option, hence most deforestation takes place at this time and periodicity is observed. The lack of significant auto correlations shows that the periodicity is weak. This is likely to be because there are several other factors that mask the trend, such as increased enforcement over the time period. If a longer times series of deforestation was available then the evidence of periodicity would likely be stronger.

5.4.0 Opportunity costs

For the purposes these estimations 100% project additionality and 0 leakage is assumed. Given the complex nature of deforestation it is unlikely a REDD project will ever achieve 100% additionality, simply because patterns of deforestation are very hard to predict. In turn this means it will be almost impossible to say that 100% of a project area will have been deforested with under a business as usual scenario and hence there is 100% additionality. A zero leakage rate is also very unlikely and impossible to verify, as where and when leakage takes place is very hard to predict. Furthermore technical difficulties in what constitutes leakage and what is simply deforestation will hamper efforts to measure and assign leakage.

The opportunity costs of REDD has increased significantly over the past year reflecting the increasing food prices (discussed elsewhere). The rise has been dramatic (see figure 1 and 2) with OC's for both soy farming and cattle ranching nearly doubling the previous highs in little under a year. While production costs have also increased (FGVDADOS, CEPEA 2008), mineral salts for cattle ranching have increased 75% in the last 6 months (CEPEA 2008), these increases have not kept pace with price increases, meaning farming in the frontier regions of the Amazon has become significantly more profitable. There have been several studies done in this area, the two most notable ones being Nepstad et al (2007), Grieg-Gran (2006)(based on work by Vera Diaz and Schwartzman 2005), Margulis (2003)(based on work by Barros et al 2002) and Arima et al. (2006). The results of this study show higher net incomes from cattle farming and soy farming in the frontier regions of the Amazon than demonstrated in any of the other studies. All of the previous studies were based around prices for 2006 and before and so obviously do not account for the recent high food prices. Unfortunately the dearth of studies with new opportunity cost estimates makes a direct comparison very difficult, the figure estimated here are higher in all but one of the studies mentioned above. The only exception is the work done Vera Diaz and Schwartzman, their OC estimated for

cattle ranching are based on 2003 figures but are in fact slightly higher than my estimate, however their value is mainly derived from a very generous estimate of timber returns from deforestation and compounded by the lack of including pasture establishment costs.

In Alta Floresta where the farming system is entirely pasture based the total forgone revenues for avoiding all 72.1km² of deforestation is US\$9,221,590 (7210 x 1279) based on March 2008 cost figures, this has increased from \$4,085,904 for March 2007. For Querência the agricultural system is divided between cattle ranching and soy farming, the ratio is 54% cattle ranching and 46% soy farming. Bearing this in mind the OC's associated with a REDD project avoiding all 125.2km² of deforestation would be US\$44,706,648 per year ((6760.8 x 1279)+(5729.2 x 6294)). Assuming an average forest carbon content of 150 t/ha the break even carbon prices for the two areas are US\$8.5tC (Alta Floresta) and US\$24tC (Querência). As the carbon content drops, this value never gets above US\$20tC for Alta Floresta, but for Querência it peaks at over US\$90tC, thus projects which involve land suitable for soy farming have a much higher degree of risk and are less robust in the face of carbon price fluctuations.

This however does not fully represent the costs of a REDD project in these areas because it does not include transaction and monitoring costs of the project, which are likely to be substantial (discussed elsewhere). Using cost bands of US\$4 per ha to US\$15 per ha (Grieg-Gran 2005) the transaction costs for Alta Floresta would be between US\$28,840 and US\$108,150 per year, and for Querência US\$50,080-187,800. Although these figures are small in comparison to the opportunity costs, they still represent a considerable investment on the part of the host country. It is likely there will be a range of market and non market sources of funding available so lower prices may be sufficient. It is impossible to accurately predict the situation until an international agreement is reached. Furthermore this price assumes zero leakage, a situation which is unlikely to occur (discussed

elsewhere), given it is unlikely 100% of emissions will be avoided the breakeven carbon price would need to be higher still. Allowing the sustainable harvest of timber within a REDD project would reduce the associated OC's (Grieg-Gran 2005) and may reduce leakage rates.

Nevertheless the break even carbon price associated with protecting land that when cleared will be used for cattle ranching is still small despite the recent high food prices. This means it is entirely possible for REDD to be successfully funded through the carbon markets provided project areas are carefully selected, if the land is suitable for soy farming the OC's increase considerable and so does the chance of returns for the carbon markets being insufficient to cover costs.

5.4.1 Carbon Markets

The next question to address is whether the carbon markets are currently

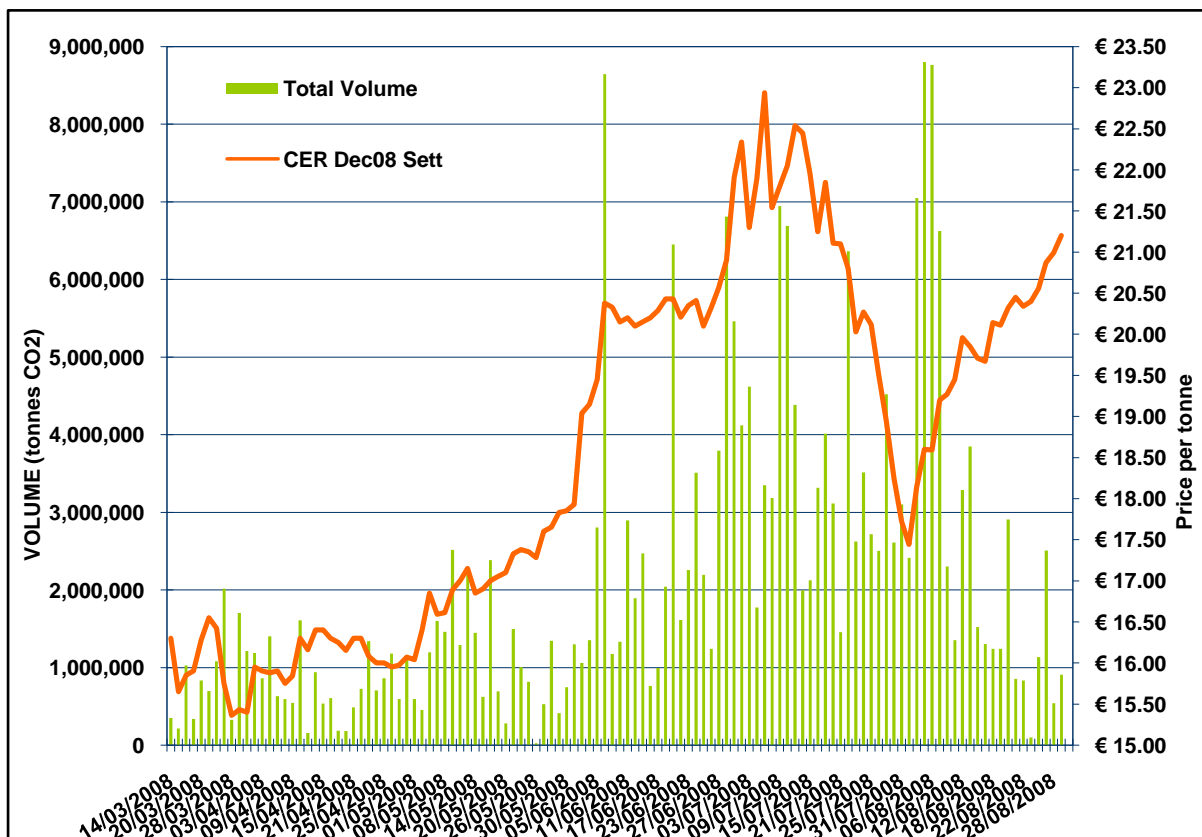


Figure 10: EXC CER futures, price and volume accurate up to 29/08/08

Source: www.europeanclimateexchange.com

large enough to support the inclusion of credits from REDD projects. The European trading scheme (ETS) currently represents approximately 70% by volume of all carbon traded globally, of this about 95% is traded on the derivatives market (futures, forwards and options). I shall be referring to carbon price and trade volumes for the EXC CER, which is an exchange for futures based on certified emissions reductions (CER) from CDM projects, this is market REDD credits are likely to be traded on if they are included in the next phase of the Kyoto protocol. There are voluntary carbon markets (most notably in Chicago) but as is demonstrated below they are unlikely to be a major source of REDD funding. Currently the price of carbon dioxide from CDM projects is US\$31.24 per ton on the European climate exchange (www.europeanclimateexchange.com) which equates to US\$114.34 per ton of carbon, ostensibly the carbon markets are at a level where they can fund even the most expensive project.

In reality the situation is very different, firstly the relatively low costs involved with REDD may lead to credits earned being worth less than other credits (Coomes *et al* 2008) how much less is difficult to judge, but it does suggest that current carbon prices are a poor guide to how much REDD carbon will be worth. The second potentially more important reason why current prices are misleading is related to the volume of carbon currently traded, in the year to date on the ECX CER futures exchange there have been 250,029,000 tons of CO₂ traded at mean of 2,118,890tCO₂/day and on the voluntary markets typically less than 75,000 t/day. Now let us consider the amount of carbon earned by ceasing the 2962km² of deforestation in 2007 in the state of Mato Grosso, this alone would avoid emitting 162,613,000tCO₂. This figure represent a fraction of the total amount of carbon that REDD could bring into the market place. Although there is little agreement on the actual level of emissions from deforestation it is estimated to be close to 6 billion metric tons of CO₂ (Ramankutty *et al* 2006), to put this into context there are around 2 billion tCO₂ in the whole system (Tollefson 2008). Allowing REDD credits to be

traded in the ETS system could potentially swamp the market with cheap carbon and undermine the whole system by allowing companies in the EU to reduce emissions by buying cheap carbon rather than addressing internal emissions issues, the same issue which prevented the inclusion of REDD in the CDM originally (Fearnside 2001).

As Tollefson (2008) points out carbon from forestry projects would gradually become available to the market over a long period of time and will probably not swamp the market as the ETS fear. It is likely inclusion REDD in emissions trading scheme would increase the amount of available carbon in the markets to beyond a level at which current demand can maintain the price (Potvin 2008, Coomes *et al* 2008). The lack of demand stems from the lack of binding emission reduction targets for some of the globes biggest emitters. Under the principle of common yet differentiated responsibility no developing countries have to commit to reducing emission this includes China and India. The USA is also yet to ratify the protocol and hence is still excluded from trading carbon in the official market place.

The inclusion of REDD into current trading scheme is likely to reduce the price of carbon, at least initially, as the market adapts to a sudden increase in supply. It is possible the price of carbon may fall below the level at which REDD requires to break even. This would have the double effect of both undermining both current emission reduction policies (Coomes *et al* 2008) and the REDD scheme's themselves. Consequently when the REDD schemes are unable to make enough money to fund themselves it is likely the emissions will not remain avoided, a situation which is compounded by the high price of food and correspondingly high costs associated with REDD at the moment. To counteract this either the amount of REDD carbon in the market place needs to strictly controlled or the level of demand needs to increase. The later is clearly more desirable and could be addressed by either having stricter targets for counties included in the scheme or by persuading more countries to commit to emission reduction targets.

There are at least two reasons why the future of REDD in carbon markets looks bright, first the recent investment by China in forest conservation (Wang *et al* 2008) may suggest a policy shift from one of the world's largest emitters. Second and more intriguingly the upcoming US election could lead to a change in environmental policy due to the inevitable regime change (regardless of result). Given the USA's position as the world's leading emitter of GHGs if they were to ratify the Kyoto protocol REDD carbon maybe essential to satisfy the massive increase in demand on the markets that would follow (Laurence et al 2007).

5.4.2 Opportunity Costs and deforestation drivers

One of the aims of this study was to see to what extent opportunity costs figures can be used to infer trends in deforestation. The result of the regressions indicated that cost measures on their own are very bad at predicting the rate of deforestation. Adding a rainfall term to the models doubled their accuracy illustrating the weak nature of the interactions between OC's and deforestation. Despite studies showing large areas of deforested land are used for agriculture (Morton et al 2006) there seems to be no clear link between the rate of deforestation and the returns generated by agriculture. This is undoubtedly because the drivers of deforestation are numerous and complex which makes deforestation very hard to predict (discussed elsewhere). Revenue from farming may still be an important driver of deforestation but recent policy shifts, technological improvements (DETER) and the enforcement programmes (Arc of Fire) have led to an overall reduction in deforestation in the last 3 years (PRODES). All these things could mask any potential link between OC's and deforestation in the last few years, a longer time series is needed to establish if there is any clear link between the two.

The simple regressions performed for the study would probably overestimate the extent of the correlation and much more complex statistical analysis is required. The reason being is that time series data may be serially dependent which invalidates the primary assumption of parametric statistics that all data points are

independent. For this reason the R^2 values and the p values associated with the multiple regression models must be viewed with scepticism.

In light of these results the usefulness of opportunity costs as an evaluation of an areas REDD potential is limited. They do provide a guide regarding the long term financial security and overall costs of a project. The OC's associated with an area are directly related to any potential projects ability to survive potential price fluctuations in the carbon market, which given its relative youth and political uncertainties are likely to be high. Furthermore it may be possible to use OC estimates as a measure of additionality, which is essential for any CDM project. However beyond this their usefulness is limited, as is the scale at which they can be usefully applied. Opportunity costs at a large regional scale are a good guide for identifying area where REDD is potentially financially viable and avoiding area of high costs.

For a true assessment of area for REDD potential much greater understanding of what is influencing decisions at a micro/household level is needed. A detailed knowledge of the micro influences of macro factors (such as commodity prices) and how these affect the patterns and rates of deforestation is required. While OC's can be used a policy guide at a very broad scale, they should not be used to judge potential long term success. OC's are a useful starting point within a integrated decision making framework which involves extensive stakeholder consultation. Only with micro level studies and a full understanding of an areas deforestation drivers can a REDD project demonstrate the required additionality for the CDM and hence be a success.

Conclusion

Before REDD can be fully integrated into the CDM there are still some significant technical difficulties which need to be overcome. First and foremost the lack of systematic national forest monitoring in most rainforest nations is a serious stumbling block (Holmgren & Marklund 2007). The successful development of such systems is essential for the implementation of REDD projects. Furthermore it is only with robust and effective monitoring systems that leakage (the second major technical difficulty) can be properly identified and accounted for. The detection and reduction of leakage is essential as without it, it would be impossible to accurately calculate the level of payments a REDD project could receive.

Despite these significant technical difficulties and increasing opportunity costs, it seems increasingly likely that REDD will be included in the CDM. With the ever growing public awareness of climate change politicians will be under increasing pressure to show real commitments to reducing emissions, REDD would be a very effective vehicle for this. Furthermore the changing political climate in the USA may lead to significant commitment on their part in the near future, dramatically increasing the global commitment to reducing emissions. It will be interesting to see how this policy sphere develops in the run up to Copenhagen 2009, but one thing is for certain, REDD is firmly back on the climate agenda and it is here to stay.

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Appendix

Auto correlations of detrended time series

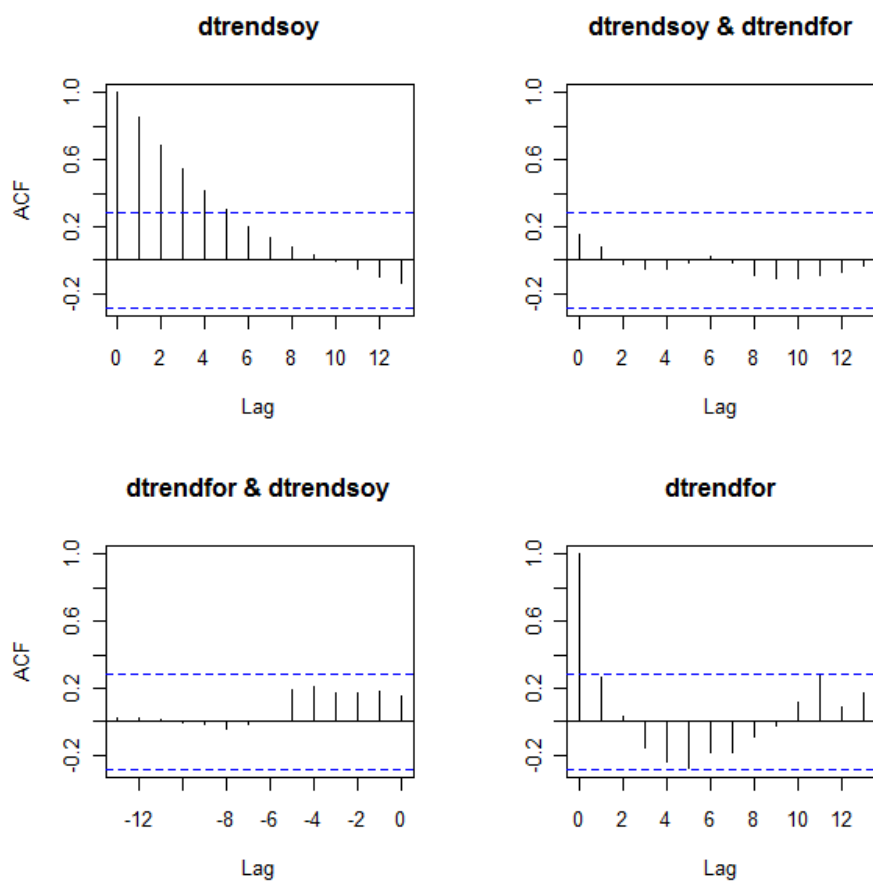
Detq: detrended deforestation for Querencia

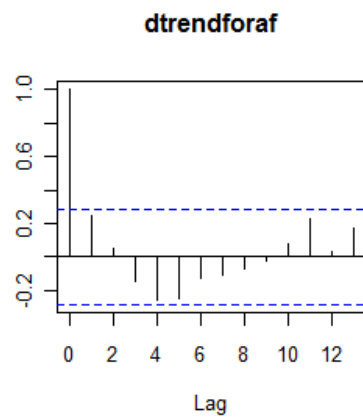
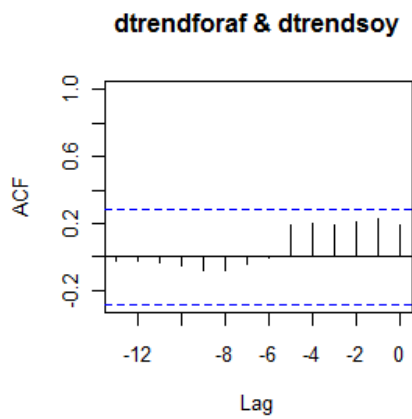
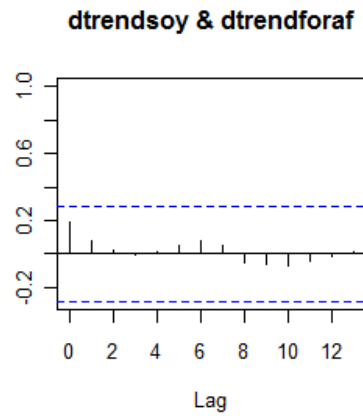
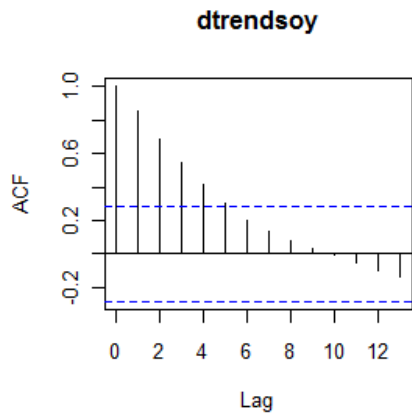
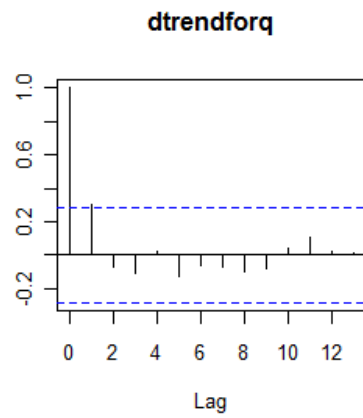
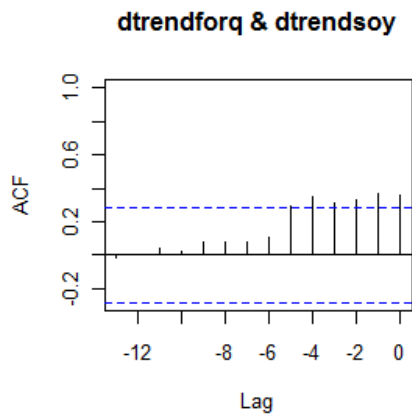
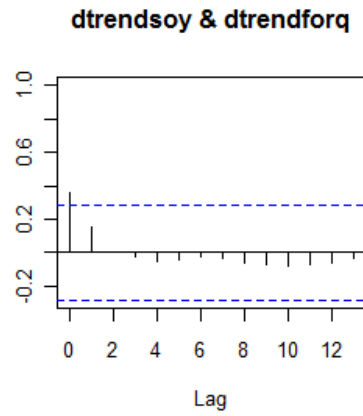
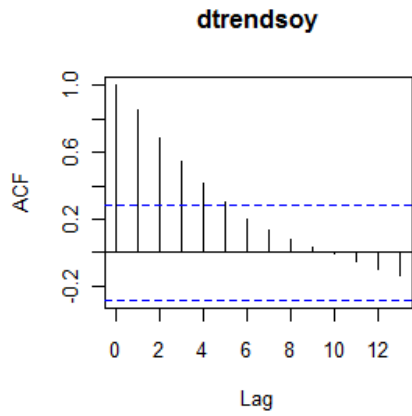
Dtaf: detrended deforestation for Alta Floresta

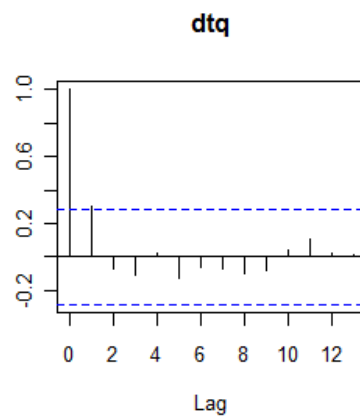
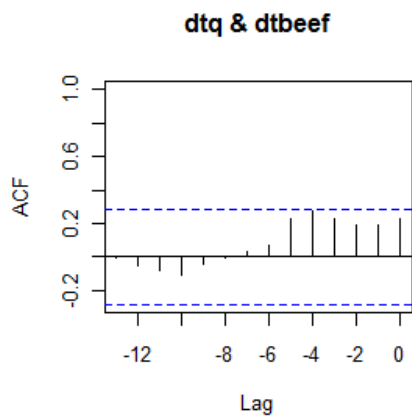
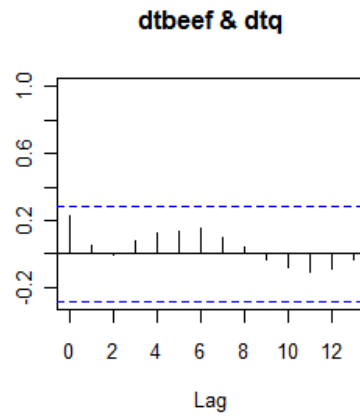
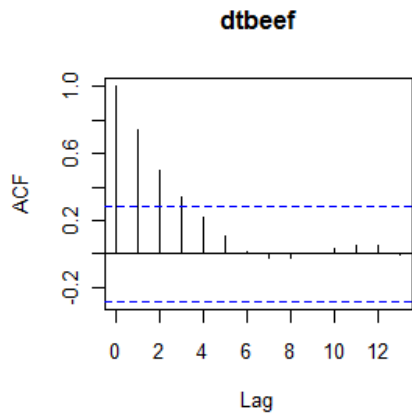
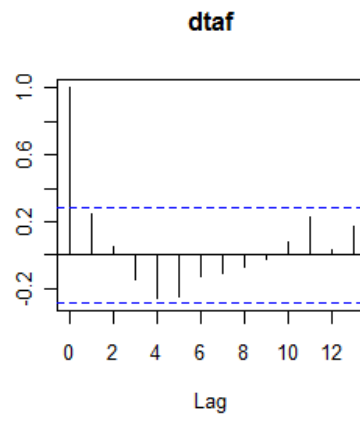
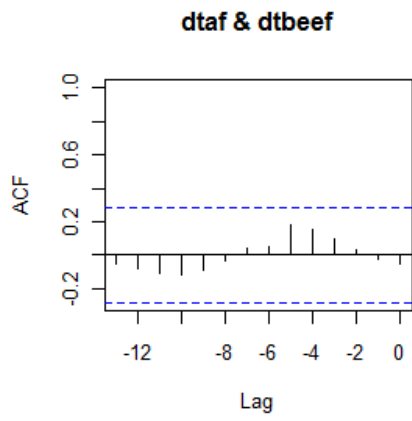
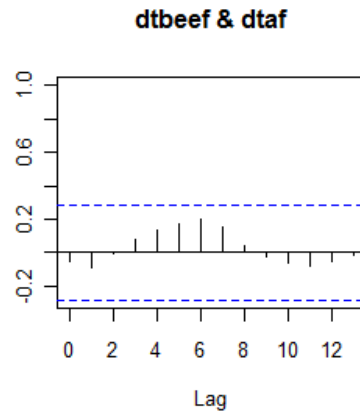
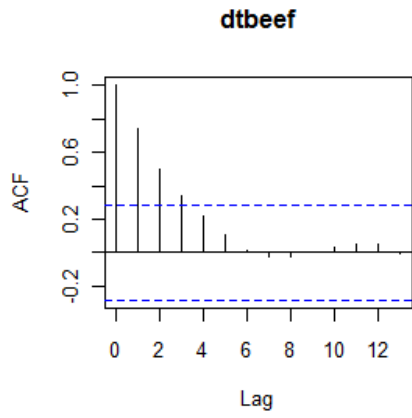
dtSoy: detrended OC for soy

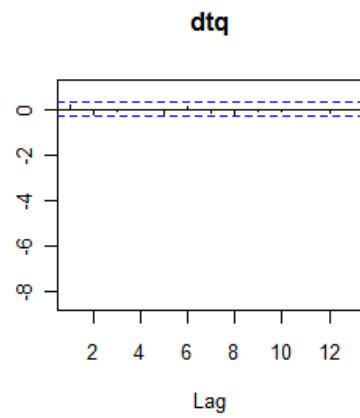
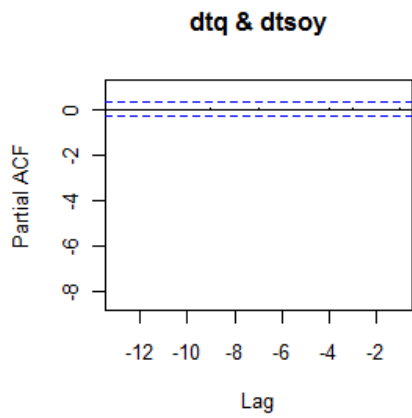
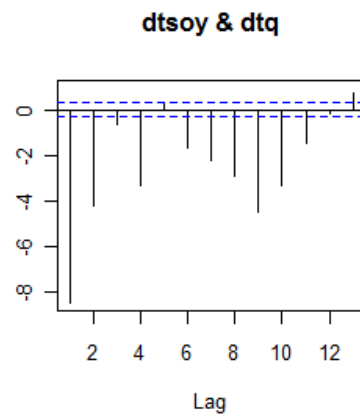
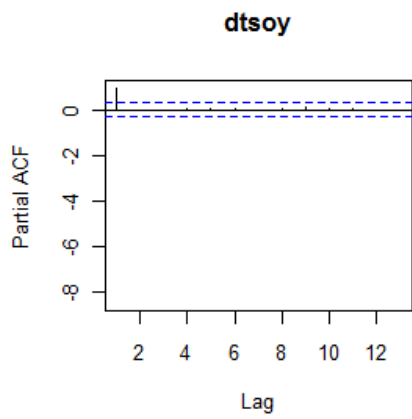
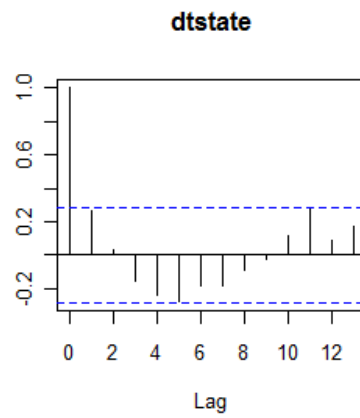
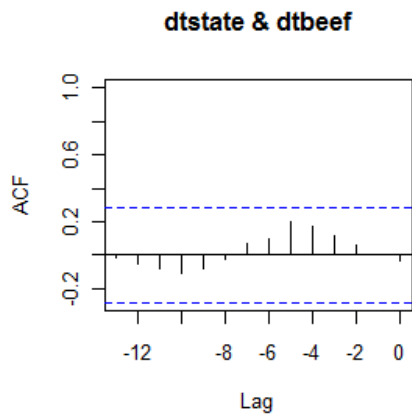
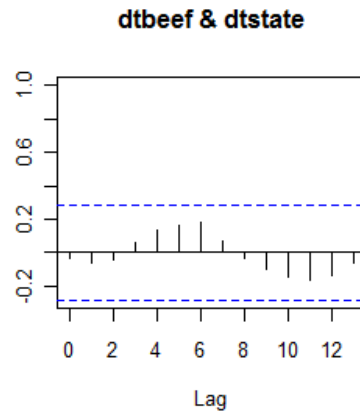
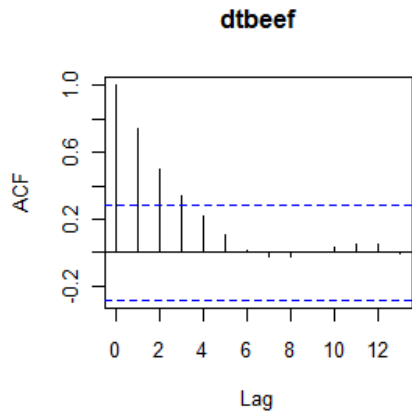
dtbeef detrended OC for beef

Top left and bottom right are autocorrelations for the individual data sets









Rainfall:

