Generating Credits in REDD – Does the Forest Transition Hypothesis provide options for the establishment of country specific baselines? - Preliminary results of a Regression Analysis

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Abstract

The integration of REDD as a potential element in a future climate agreement needs a baseline against which actual emissions from deforestation and degradation can be set in contrast. These baselines are to be defined in a manner that considers country specific circumstances. One option for this is seen in applying the Forest Transition Hypothesis (FTH) for projections of country specific anticipated deforestation rates. According to this hypothesis, a country's forest cover is first declining during the course of time, and after reaching a turning point at a specific forest cover, increasing again.

This study tested in the first step the Forest Transition Hypothesis to its validity on the global level. A global pattern of deforestation was found by a regression analysis of national cross sectional data, showing a core relation between forest cover (as % of potential forest area) and population density per forest area. The influence of further variables was tested as well.

The estimated deforestation curve can be used for REDD baseline design by predicting future national deforestation rates. But several uncertainties related to compensation rules and possibilities of misleading exist and need to be discussed further when aiming at giving incentives to participate in a future REDD regime. The position of a country's forest cover related to the global average can be assessed by applying the curve, but also the direction and rate of deforestation need to be considered, when baselines are set.

As the curve is not related to time but to population density mainly, the performance in time is more complicated to assess. Likewise it needs to be considered, that the model primarily provides information about forest area but not on carbon content, although carbon content information can be integrated in an additional step.

1 Introduction

The course is set for an integration of REDD (Reducing Emissions from Deforestation and degradation in Developing Countries) in a post-Kyoto climate agreement (see Clemencon 2008; UNFCCC 2008; UNFCCC 2009). This could make a reduction of such emissions in a given period to be rewarded. Thus, an assessment of the magnitude of emission reduction is required, which is disposable for rewarding. For this purpose actual emissions will be contrasted against an agreed reference, the so called baseline or reference emission level.

Baselines for REDD

Several methodologies are possible for establishing such a reference: It could either be constructed by continuing historic deforestation trends, or by modelling deforestation according to its causes and drivers, or else by generally leaving it to the international negotiations in the scope of climate agreements (Pirard and Karsenty 2009). Probably an agreement will finally end up in a mixture of these three approaches. Using a strict historic continuation of trends could offer potential windfall gains for some of the countries (see Leischner and Elsasser 2010). Likewise, some countries could be disadvantaged if they have had low deforestation rates in the past, because this would automatically imply debits in case they show any additional deforestation in the future (see Griscom, Shoch et al. 2009). Thus, reflecting national circumstances in an as prominent manner as possible could be highly important for a future REDD scheme, a concern which is also reflected in the current international negotiations (UNFCCC 2009).

Several studies have already assessed potential drivers and causes for deforestation (see for example Angelsen 1999; Angelsen and Kaimowitz 1999; Geist and Lambin 2001; Lambin, Turner et al. 2001; Vanclay 2005) or potential correlations of macroeconomic indicators with deforestation (Vanclay 2005; Wang, DesRoches et al. 2007). Indicators could become even more variable in more regional assessments of the causes for deforestation (see for example Casse, Milhoj et al. 2004).

Analyses of the causes for deforestation could explain past or present deforestation. In the scope of REDD, the identification of causes and their interactions is important for identifying adequate incentives and instruments for benefit transfer. From a methodological point of view, information about deforestation drivers is needed for modelling which amount of deforestation in a country can be expected in the future, if such an “anticipated deforestation rate” (referred to by Karsenty 2008) will be used as a reference for the individual countries’ commitments.

Forest Transition Hypothesis

The *Forest Transition Hypothesis* (FTH) might contribute valuable information about potential future deforestation rates and thus be suitable for establishing baselines which allow for reflecting national circumstances (e.g. in Angelsen 2007; Angelsen, Brockhaus et al. 2009; Wertz-Kanounnikoff and Kongphan-apirak 2009). This hypothesis is based on a relationship originally formulated by (Mather 1992) and Mather and Needle (1998), which describes the development of forest cover throughout time. According to this hypothesis an initial forest cover runs through a phase of deforestation which is mainly driven by a growing population’s need for agricultural area, and which has varying intensity. At some point in time, the bottom of deforestation is reached, and is followed by a phase of reforestation and stabilisation of the forest cover. A schematic illustration of this development is shown in Figure 1.

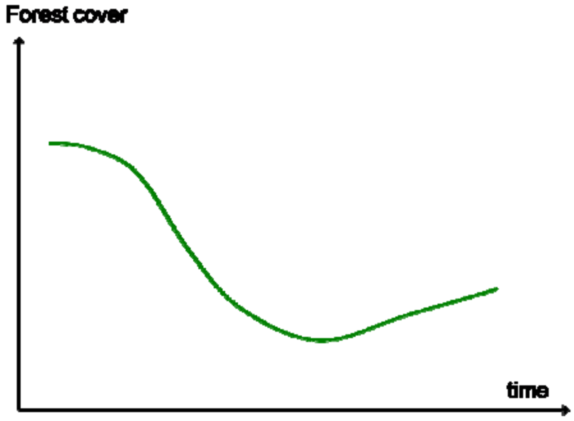

Figure 1: Development of a country's forest cover over time according to the Forest Transition Hypothesis

The FTH has regained momentum in the scope of the REDD discussions. If a country's location along the transition curve can be identified, an "anticipated deforestation rate" could gain more trustability. By integrating the FTH into the establishment of REDD baselines, a baseline could be set in a manner which firstly is based on national historic deforestation and secondly takes into account national circumstances, both requirements for baselines identified and stated in UNFCCC negotiations (UNFCCC 2009).

The initial model has strict limitations, e.g. by neglecting the drivers for the choice of agricultural parcels (Mather and Needle 1998). The hypothesis was developed further, and various explanations for the shape of the curve have been offered (e.g. Rudel, Coomes et al. 2005; Perz 2007; Satake and Rudel 2007; Barbier, Burgess et al. 2010). Empirically, Griscom et al. (2009) have found evidence for the existence of a forest transition curve by comparing deforestation rates of several tropical countries. Various authors have investigated forest transitions in individual developed countries (e.g. Denmark (Mather, Needle et al. 1998), France (Mather, Fairbairn et al. 1999), Switzerland (Mather and Fairbairn 2000), the USA (Houghton and Hackler 2000), Scotland (Mather 2004) and Austria (Krausmann 2006), but also in some developing countries (Puerto Rico: (Rudel, Perez-Lugo et al. 2000; Grau, Aide et al. 2003); Dominican Republic: (Aide and Grau 2004); El Salvador: (Hecht, Kandel et al. 2006); Vietnam: (Mather 2007; Meyfroidt and Lambin 2007); China and India: (Mather 2007)). However, cross-national studies which might empirically support the generalisability of the FTH do scarcely exist.

2 Methods

2.1 Hypotheses

This paper asks, first, whether the Forest Transition Hypothesis is valid on global level, so that it would allow deducing future deforestation rates and predicting future forest area in a country. In a further step, potentials and implications of an integration of the FTH in future REDD-baselines are discussed, which is the main focus of the present article (for methodological details and a further explanation of theoretical backgrounds, we refer the reader to another paper of the same authors (in preparation)).

According to the FTH, the main cause for forest clearing is the demand for agricultural area (cropland or pasture). Developed countries have started early in history with this clearing and might have already run through the transition, or are at least in a later stage of the curve. A similar development is expected in the future for the less developed countries. Since the FTH supposes that the underlying dynamics is equal for all countries, it can be expected that modelling a globally uniform regression curve of forest cover development is possible, the shape of which is similar for all countries (whereas the positions of individual countries on this curve might differ).

2.2 Methodological Approach

Since it seems barely possible to model a curve like depicted in Figure 1 by one single functional approach, the curve was split into two parts for deforestation and later reforestation, respectively. The analysis in this article is limited to the deforestation part of the curve. Assuming that deforestation follows an (inverted) sigmoidal growth function, a logistic transformation was applied to the dependent variable (formula 1), thus making it possible to apply linear regression techniques. The assumption of a logistic deforestation curve implies that forest cover asymptotically approaches 100% at the beginning of the curve (this is a country's maximum potential forest cover in our model), and asymptotically approaches 0% at its end (which means that all former forest area has been changed into another land use).

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$$FC_t^* = \ln\left(\frac{FA_{pot}}{FA_t} - 1\right) \quad (1)$$

with FC^*= transformed forest cover at year t; FA_{pot} = potential forest area; FA_t = remaining forest area at year t (indices to distinguish individual countries are omitted for simplicity).

Afterwards, linear regression was run on FC^*_t:

$$FC_t^* = \beta_0 + \beta_i X_i + \varepsilon \quad (2),$$

where X is a vector of explanatory variables, with coefficients β.

Predicted values of remaining forest cover can then be calculated after some rearrangement according to:

$$FC_t = \frac{FC_{pot}}{1 + e^{\beta_0 + \beta_i X_i}} \quad (3)$$

The further procedure was split in two steps. In a first step, several functional forms and combinations of dependent and independent variables were tested for linearity, using the time series data of MPI (Pongratz, Reick et al. 2007). This data base contains global estimates of today's potential natural vegetation as well as population numbers (based on data review and completion of several other studies) and a reconstruction of global agricultural area, remaining forest cover for every year between AD 800 and 1992 in a 0.5° resolution grid map which was broken down to country level information in five year steps. From this data base we selected the developed countries only, here defined as those countries which are listed in Annex I to the Kyoto Protocol (because most of these countries already have begun early with deforestation according to the above mentioned hypotheses, and are supposed to have run through major parts of their deforestation history, and thus cover a larger part of the curve). In order to exclude observations after the turning point of the FT curve, which do not belong to the deforestation part of the curve according to the FT hypothesis and thus would have biased results, we used only data up to the turning point. Since the MPI time series is basically a simulation which relies on several assumptions, specifically about the relation between population and land use change due to farmland demand, we used these data primarily for finding a suitable functional form, but not for estimating regression coefficients.

The latter was done in a second step which utilised global forest data from FAO's most recent available Global Forest Resource Assessment ("FRA 2005", (FAO 2006)) for a cross section regression analysis. This procedure is based on the abovementioned assumption of the FTH that a globally uniform regression curve of forest cover development exists on which only the positions of the respective countries differ. If this assumption holds (and if there are no additional data problems), then time series data and cross section data of global forest cover development will lead to similar results. However, again the problem had to be circumvented that many Annex I countries today have already passed the transition phase of their forest cover development. In order to account for this aspect, we replaced FAO observations for these Annex I countries by those data simulated by MPI for the year 1820 (i.e. a point in time before forest transitions occurred). Hence the data origin of the cross section analysis is mixed, consisting of recent observations for the Non-Annex I countries (FRA data for 2005) and historic data for the Annex I countries (MPI data for 1820).

Further explanatory variables originate from several sources. Population data originated from McEvedy and Jones (1978), Maddison (2009) and UN (2009) and in case historic data was available for selected years only, data was linearly interpolated. Population projections for future years are those of UN (medium projection, 2009).

3 Results

An estimate of the global deforestation curve

Since the focus of the present article is on the usability of an empirically estimated reference curve based on the FTH for REDD purposes rather than on technical details of data handling and estimation, we restrict the following presentation to selected results of one estimation model only (for further details we refer to the abovementioned more technical paper of the authors).

As a first result, analysis of the MPI time series data revealed that a globally uniform and linear regression curve can be constructed by regressing forest cover on population density (here defined as number of persons per forest area), but not on years (i.e. $FC^*_t = f(P_t/FA_t)$).

The cross sectional regression analysis was started from this core relation with MPI and FAO data (named observed data in the following), and resulted in a determination coefficient of 71%. In a next step further explanatory variables have been included in the regression model and various models have been estimated to explain the variations of the observed data (e.g. potential forest area, surface area of the country and Gross Domestic Product per capita). In this paper we focus on the regression of the core relation; the resulting estimated forest cover curve is displayed in Figure 2 in comparison to observed forest cover data.

For population densities of less than 10 persons per km² forest area a forest cover of at least 80% is estimated. A phase of faster deforestation occurs between population densities of 10 to 1.000 persons per km², when forest cover declines to about 20%. In population densities of more than 1.000 persons per km^2 forest area deforestation slows down and approximates zero.

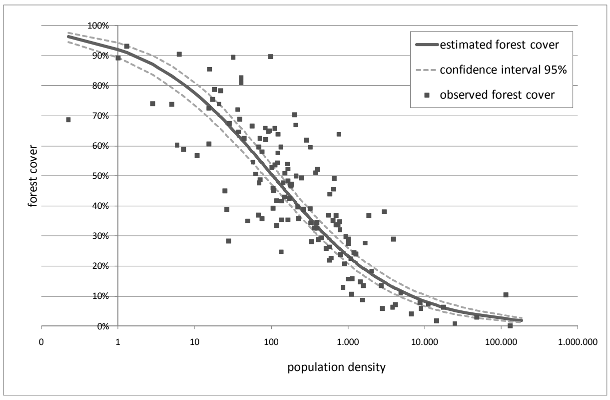

Figure 2: Estimated deforestation curve with observed forest cover of the countries

The regression model shows the global average development of the forest cover in relation to the development of population density. Today's position of each country relative to the deforestation curve is influenced by two factors. The first is its stage on the curve, i.e. the question of whether the country takes an "early" position at the left hand side of the curve, or a "late" position at its right side. In this regard, the countries may be grouped according to their progress along the deforestation curve up to now. The second factor is the deviance of the individual country from the curve, i.e. whether it is located above or below the curve. With regard to movements along the curve, note that the speed of deforestation on a time axis might be different even between countries which move exactly along the curve, because the underlying population growth can be different between countries.

Figure 3 shows modelled forest cover of selected Non-Annex I countries for the period 1990 to 2005. Only the top 20 Non-Annex I countries with most extended forest area in 2000 are displayed[1] in order not to overload the presentation.

[1] These 20 countries possess together about 79% of the total forest area of the countries included in the analysis.

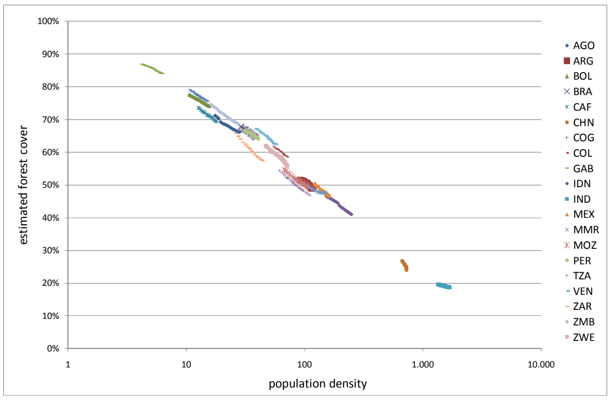

Figure 3: Estimated forest cover development of selected countries (time frame: 1990-2005)

According to Figure 3 most of the selected countries show a forest cover between 90% and about 40%. The gradient of decline in forest cover is not exactly the same in all countries. Likewise, some of the countries have moved further along the curve than other countries within the time frame 1990 to 2005, i.e. their development has been faster than in other countries.[2]

4 Alternative options for applying the deforestation curve in a REDD baseline

The deforestation curve may be used for REDD baselines in different ways, e.g. to categorize countries related to their deforestation development stage, to compare the countries' performance relative to the global average or to predict future deforestation rates. As establishing a REDD baseline is a normative issue, an empirical estimate of the deforestation curve can help in establishing such a baseline, but it cannot prescribe in which way it should be applied – rather, this is a matter of negotiation between the participating countries.[3] Basically, three different options exist for integrating the deforestation curve and the baseline determination (which might be combined in some way or the other, but are presented here in a stepwise fashion):

[2] Note that figure 3 is displayed in logarithmic scale, as a logarithmic relation to population density was identified. The growth of high population densities might be underestimated.

[3] A further comment is due to the question of whether a REDD baseline derived from the FTH should resort to the deforestation part of the forest transition curve only (as it is implicitly discussed here) or whether it should also account for the later increase in forest cover which is predicted by the FTH. Basically, this is again a matter of negotiation, since this question may have significant distributive implications. If the reforestation phase was included in the baseline, then especially the more developed countries (or those with rather high population rates, respectively) would have to produce higher forest cover values than otherwise (i.e. if the baseline relied on the deforestation curve only). Keeping in mind that deforestation often affects biodiversity-rich primeval forests, whereas reforestation may include monocultures and other more simply structured forests, there are at least some arguments in favor of focusing at the deforestation part of the forest transition curve, rather than at the whole curve.

Option 1 (focussing only at a country's position relative to the deforestation curve at a specific point in time):

The estimated deforestation curve can be used as a baseline itself by defining the allowed deforestation rate at a specific development stage (according to the used variables in the regression analysis). Correspondingly each country will be either on the curve (average deforestation), above the curve (less deforestation than average) or below the curve (stronger deforestation than average). Accordingly, a country would generate credits for reduced deforestation if it has at a specific time a forest cover above the curve, and debits if below. This option would strongly focus at the countries' performances in the past.

Option 2 (focussing at the change in deforestation intensity over a given period):

For valuing the performance over certain time periods not only the position of a country relative to the average curve would have to be considered, but also whether it moves towards the curve or away from it. Since a movement along the deforestation curve (i.e. the baseline) is predicted to be the "normal" development, only movements leading towards the curve (or away from it, respectively) would generate credits (debits). This option would give less weight to a country's inherited forest cover and thus could imply stronger incentives for an active forest protection policy.

Option 3 (accounting for different speed of deforestation)

Because the modelled deforestation curve relates deforestation to the population growth rate of a country rather than to time, reduced deforestation which is caused by a decrease in population growth would not be considered under options 1 and 2, however influential it may be for the forest area development of a country. It therefore might seem sensible to allow additionally for different population growth rates, or respectively, for the different time that countries may need for moving along the deforestation curve. Allowing for the influence of active population policies could, at the one hand, be negotiated separately from the deforestation baseline (that is, an additional rewarding scheme might be negotiated for the positive effects of reduced population growth on forest development, but also on other carbon relevant issues like per capita energy consumption etc.). Alternatively, a direct integration of the effect of a slowed down population growth would require that the speed of any movement along the deforestation curve be additionally accounted for, e.g. by fixing a reference year for each country on the curve, and then measuring how far a country moves away from this starting point during a commitment period. This option would contain an additional incentive for countries to consider the influence which (changes in) population growth may have on deforestation.

Some implications of these different accounting options are discussed subsequently and illustrated by Figure 4.

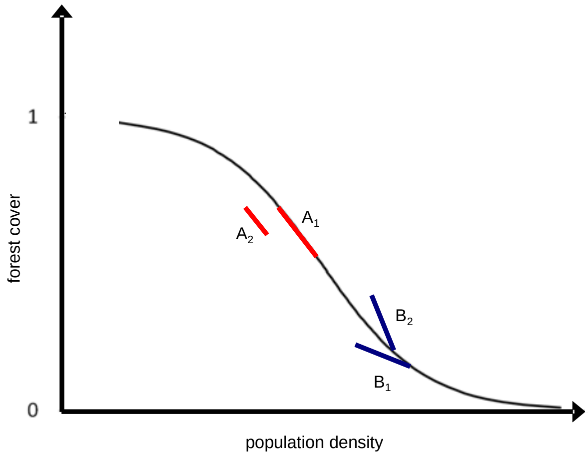

Figure 4: Implications of country specific baselines according to the estimated deforestation curve on compensation for REDD (schematic display of one period)

Basically, countries which show a development along the deforestation curve perform like predicted (e.g. Country A_1 in Figure 4). Under options 1 as well as 2, neither credits nor debits would be generated. A country with a similar deforestation rate, but location below the curve (which means forest cover lower than allowed at a given population density; e.g. country A_2) would create debits under option 1, but neither credits nor debits under option 2 if the slope of its individual deforestation rate was the same as in the average curve. On the other hand, country A_1 has reduced its forest cover more strongly than country A_2 within the same time. Therefore, under option 3 credits would be allocated to country A_2 rather than to country A_1.

Countries B_1 and B_2 represent further possible cases which might be affected differently by the mentioned options. Both countries move towards the average deforestation curve during the considered period, and finally end up at the curve. Therefore under option 1 both countries would neither generate credits nor debits, even though deforestation has been more intensive in country B_2 than in B_1. However, country B_1 is initially located below the curve, approaching the curve in the given period, whereas country B_2 shows a higher forest cover than predicted at the beginning coupled with a fast deforestation afterwards. Under option 2, B_1 would thus be rewarded, and B_2 would be penalised. Under option 3, it would have to be considered that in country B_1 population growth per forest area has been more pronounced than in country B_2 (i.e. it has moved further along the x-axis than B_2). Hence a rewarding scheme which additionally takes into account the effects of population growth would have to allocate additional incentives to country B_2 rather than B_1.

A further possible modification: accounting for carbon content of forests rather than forest area

Our regression analysis, as well as the original FTH, focuses at forest area, but not at the carbon stored in the respective forests. However, the natural carbon contents of forests in different world regions vary widely. Moreover, forest degradation can reduce the carbon contained in a given forest area significantly, and it seems important that this would be recognised by a REDD rewarding scheme. Basically, different natural carbon contents can be integrated into the approach by weighting forest area with the average carbon content of a country's forests, whereas accounting for degradation would probably require a monitoring specifically devoted to this problem, since an average carbon content would need to be assessed in any period to track changes caused by degradation or forest enhancement.

5 Discussion

A major issue for the empirical estimation of a global forest transition curve (or only the deforestation part of it) is that of data availability and quality. In order to cover at least a sufficiently long part of the curve, very long historical time series would have to be used. However, empirical observations do not exist for such long time spans at global scale. Although historical reconstructions like the MPI database utilised here offer a way out of this dilemma, it has to be kept in mind that such reconstructions are basically simulations of a possible past, which contain a multitude of simplifying assumptions. Some of these assumptions are integrated in our model and completed by further variables. Furthermore, data about historical forest cover is more reliable when related to regional scale, and is connected to uncertainties when broken down to current country borders.

Estimating the transition curve basically by cross sectional analysis of recent data rather than by time series analysis (as has been done here) circumvents many of the associated problems, but not all. First, even our cross sectional analysis had to resort partly (i.e. for the Annex I countries) to data which originate from historical reconstruction instead of observation, because using observations from countries which have already passed their forest transition phase (i.e. which show increasing forest cover with increasing population density) would have biased the deforestation curve upwards. Inevitably this requires mixing data from different sources, which have different reliability. Second, even though the recent FRA data (used here for the Non-Annex I countries) is currently the most comprehensive source of global forest cover data, its reliability is not above suspicion. Even though these data share FAO's common reporting framework, data collection takes place under national sovereignty, with different data acquisition methods and for different reference years; this can reduce the comparability of data across countries and over time (for some exaples, see Matthews 2001; Grainger 2008). Moreover, the definition of "forest" in the FRA is rather broad,[4] comprising closed as well as open forests (which may contain very different amounts of carbon).

With regard to the regression results utilised here, three items should be kept in mind. First, as already mentioned this article presents a simplified "core" version of the regression model for ease of presentation; more sophisticated models including additional explanatory variables will allow more detailed analyses, inter alia with respect to individual countries' position along the deforestation curve. Second, the regression still only covers the deforestation part of the global forest transition curve, but not its later reforestation phase. Although there are arguments in favour of orienting a REDD baseline at a deforestation curve rather than at a complete forest transition curve, such a decision would imply distributive effects for individual countries. Hence

[4] I.e., land spanning more than 0.5 hectares with trees that can grow higher than 5 meters and develop a canopy cover of more than 10 %, including palms and bamboo.

this issue is a matter of negotiation between the concerned countries. Third, the curve presented here focuses at the development of forest area rather than carbon content in forests. Integrating carbon storage development into the curve is generally possible on the basis of the estimated forest area, and indeed this is an important issue when it comes to avoiding not only deforestation, but also forest degradation. However, this might require additional monitoring and control efforts.

Finally, estimating a global deforestation curve empirically may help establishing a REDD baseline, but it cannot prescribe the way of application. Several options exist for integrating the empirical knowledge about global deforestation into REDD baselines which have shortly been discussed above. The decision between these options (or a combination or completion of them) is a normative issue which has to be left to negotiation between the participating countries.

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