A Risk Based Methodology for Quantifying Natural Capital Credits Issued to Projects Operating under the Natural Forest Standard, with application in Amazonia

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Introduction

Despite international efforts to reduce emissions from deforestation and degradation (REDD) tropical forests remain under threat. Resources provided centrally to governments to control land use change are often misdirected or inefficiently applied (Davenport et al. 2010)[1].

Improved understanding of carbon stocks at risk and emissions likely to occur in the absence of conservation interventions, is important information in deciding how to target interventions and how to evaluate the impact of conservation measures in terms of avoided emissions.

The following risk-based method has been devised to apply to large scale projects and programmes in areas such as the Brazilian Amazon where broadly similar processes, legal and institutional constraints, play out across the forest ecosystems.

The output of the method is an estimate of emissions avoided by protecting large areas against deforestation over periods in the order of a few decades. It does not involve prediction of land use changes at specific locations and specific dates. Indeed, we argue below that precise spatial prediction of land use change is not possible, and given that climate change will occur over decades to centuries, precise temporal prediction is not necessary.

The method addresses emissions associated with deforestation but does not include potential emissions from degradation (in the case of Amazonia, degradation occurs mainly in the form of illegal selective logging). The reasons for not including degradation in this method are as follows:

- Carbon emissions associated with selective logging are not accurately known, and likely to be highly variable as the proportion of logged wood within any given area will vary depending on the attractiveness of the species.
- Areas subject to selective logging may either gradually recover their carbon stocks or may be subject to increased disturbance leading to conversion to agriculture / ranching. In the case of

[1] Davenport, D., Bulkan, J., Hajjar, R., and Hardcastle, P. (2010) *Forests and Sustainability.* Chapter 5 of "Meeting the Challenges of International Forest Governance" IUFRO World Series Report No. 28., Edited by Rayner, Buck and Katila. International Union of forest research organizations.

recovery the emissions are not permanent, and in the second case, conversion will be considered within the deforestation baseline.

- There may be mid-cases where the nature of disturbance produces a permanently reduced carbon stock (while still maintaining forest cover), however, there is little information as to the extent of such disturbance.

The methodology, approved by the NFS can be used to quantify the number of Natural Capital Credits (NCC) issued to a project. The methodology applies a risk approach to baseline quantification and could be described as an application of a risk adjusted performance benchmark. According to the VCS (Seager and Lehman, 2011)[2] performance benchmarks are *a promising alternative to determining baselines and assessing additionality on a project-by-project basis.* A performance benchmark provides advantages for a programmatic approach to reducing emissions where projects within a given region can use a consistent set of baseline data and accounting methods. Performance benchmarks may aid programmatic evaluation, reducing costs for individual projects. Benchmarks may be adjusted over time according to evidence.

This approach requires application at scale and over relatively long time periods to produce valid results (we propose a minimum area of 20,000 ha per project and a minimum timescale of 20 years). Similar risk based assessment methods are applied in the public health sector, where the effects of a public health campaign may be assessed at a population level but not at an individual level (Munro, 2005)[3].

The credits issued as a result of a programmatic risk based analysis, such as described here, are not identical to project based "offset instruments" insofar as they do not claim to precisely and permanently cancel out an emission of CO_2 at a given point in time (we have doubts as to whether other instruments actually achieve this goal). However, they do provide a consistent and practical environmental performance metric that reflects the on-going conservation of carbon at risk within natural forests. As the crediting programme progresses it should be possible, through comparison between crediting schemes, to establish acceptable ratios of NCCs to other tradable carbon instruments.

[2] Seager, J., Lehmann, M. 2011. Standardized Approaches to Baselines and Additionality, Public Consultation. [presentation] Available at:http://v-c-s.org/sites/v-c-s.org/files/VCS%20Presentation,%20Standardized%20Approaches,%20Webinar,%2013%20SEP%202011.pdf [Accessed: 09.01.13]

[3] Munro, B.H., (2005) Statistical Methods for Healthcare Research. Publ. Lippincote, Williams and Wilkins.

Calculation of Natural Capital Credits to be Issued

The calculation of credits to be issued (Qi) in a given year is as follows:

$$Qi = Qp - \{Edef + Eleak\}\ (tCO2)$$

Where:

$Qp = potential\ credits\ (tCO2)$

$Edef = Emissions\ from\ deforestation\ (tCO2)$

$Eleak = Emissions\ from\ leakage\ (tCO2)$

Now within any eligible area:

$$\mathrm{Qp} = \sum \mathrm{Area} \cdot \mathrm{R} \cdot \mathrm{Vc} \cdot \frac{44}{12} \cdot 0.05$$

(potential annual credits for a given area = sum of pixel areas multiplied by the vulnerable carbon at risk multiplied by CO2 conversion divided by 20 years)

Where:

$R = Risk\ Index\ (for\ each\ pixel\ derived\ from\ approved\ Risk\ Map, a\ value\ from\ 0\ to\ 0.8)$

$Vc = Vulnerable\ Carbon\ (for\ each\ pixel\ derived\ from\ approved\ Carbon\ Map\ or\ from\ plots)$

And within any given area the vulnerable stock of carbon was estimated on a conservative basis as follows:

$Vc = \{[AvgC - (2.StdDevC)].Vf\} + VSoilC$ if regional carbon maps and available literature are used

or

$Vc = \{[AvgC - (1.StdDevC)].Vf\} + VSoilC$ if plot based measurements according to the "RAINFOR" field manual methods are used (Philips et al. 2009)[4]

Where:

[4] http://www.rainfor.org/upload/ManualsEnglish/RAINFOR_field_manual_version_June_2009_ENG.pdf

$AvgC$ = mean value of above and below-ground carbon in woody biomass within the area ($tCha^{-1}$)

$StdDevC$ = the Standard Deviation of carbon in woody biomass from the mean

Vf = the vulnerable fraction of woody biomass (%)

$VSoilC$= the vulnerable soil carbon within ($tCha^{-1}$)

The methods used to quantify R in the Brazilian Amazon are described in Annex 1. The source of carbon factors for this area - AvgC, Vf, and VSoilC, are described in Annex 2 and the proposed methods for quantifying Edef and Eleak are described in the Annex 3.

Annex 1: A Method for Mapping Risk of Deforestation in the Brazilian Amazon

This Annex describes the method used to produce a risk of deforestation map in the Amazon region of Brazil.

The methodology does not provide a prediction of future forest loss but assigns relative risk values, based on the ACEU criteria (i.e. land that is Accessible, Cultivable or has Extractive value and is Unprotected is likely to be deforested unless conserved; Grace et al., 2010). It is assumed that within Amazonia the majority of land has either cultivable or extractive value since few areas are unsuitable for timber extraction or extensive cattle grazing (the main drivers of land use change). Risk was therefore assessed using indicators of accessibility and the protection status of areas.

The resulting risk map is intended to aid project developers and conservation organisations wishing to target efforts to areas where they are most needed.

The output is also intended to be used as an input to the calculation of Natural Capital Credits under the Natural Forest Standard.

Risk Factors

Accessibility: Risk of deforestation associated with access by road and rail:
Proximity to roads and railways access was considered to be the most important factor in accessibility. A map displaying accessibility via road and rail was created by: sourcing an official road map of Brazil (PNLT, 2008), and creating a continuous map displaying 'distance from road' going up to a maximum distance of 100 km (based on local expertise on the distance up to which roads/railways pose a threat to forests; Fig. 1). The 100 km buffer was then divided into 32 risk classes/values (each class was 3.125 km wide and 32 classes best represented the continuous field of risk from roads and rail), with areas closest to the road/railway given highest risk (=32) and areas furthest away given lowest risk (=1).

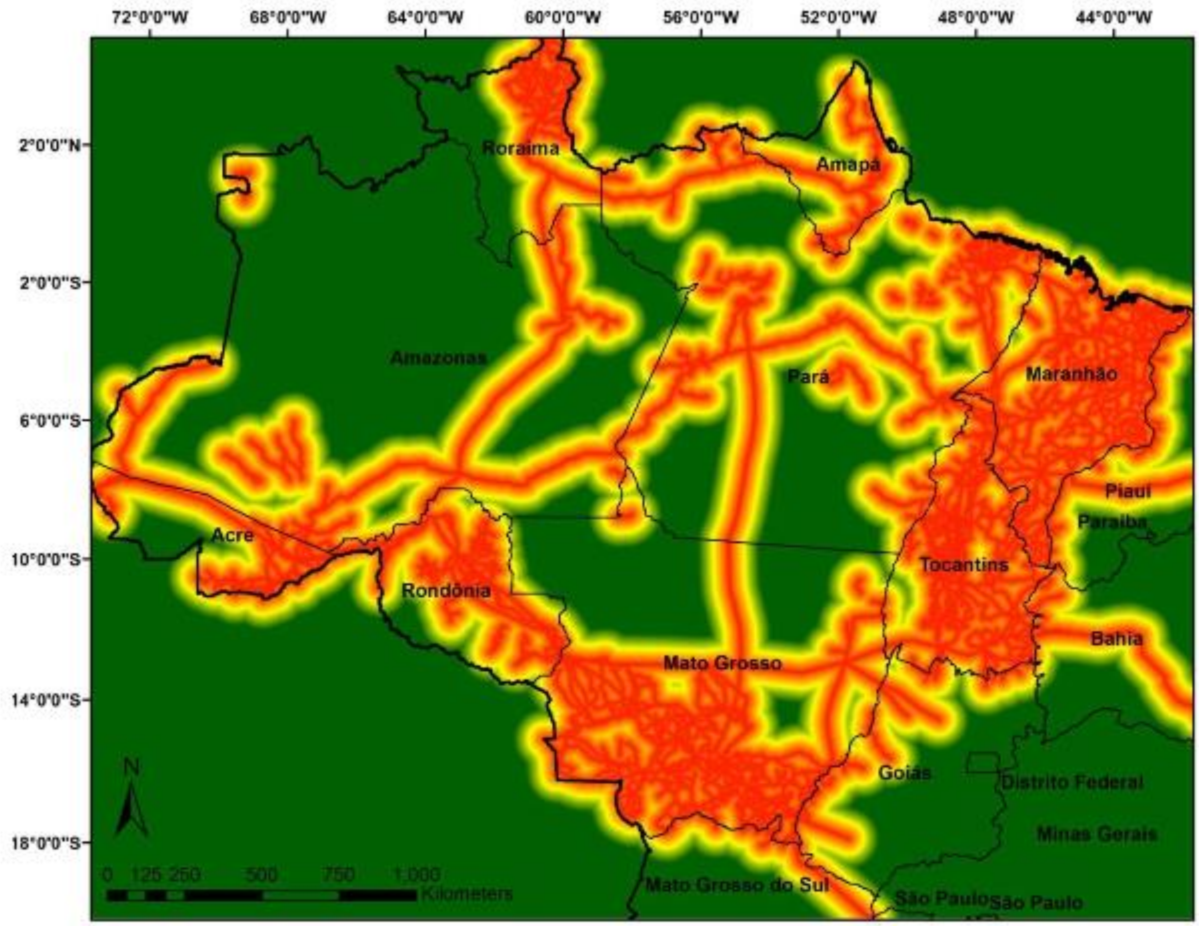

Figure 1: Risk of deforestation due to access by roads and railways to areas in the Brazilian Amazon. Red shows high risk (closer to roads or railways), while green shows low risk. Risk is calculated for up to 100 km from a road or railway.

<u>Risk of deforestation associated with access by rivers</u>:

Accessibility to forested areas by rivers (PNLT, 2008) also increases the risk of deforestation. However, river access was given a lower weighting than road access because of the logistical effort of transferring goods and livestock between boat and truck (communications with Amazon Livre). A continuous map of 'distance from navigable rivers' up to a maximum distance of 12.5 km was created on the distance up to which rivers pose a threat to forests; Fig. 2. As with the risk from roads and railways, the 12.5 km buffer was divided into four 3.125 km wide buffers, and given risk classes/values, with areas closest to the river given highest risk (=16), the second buffer given medium risk (=11) and the third and fourth buffers furthest away given lowest risk (=6).

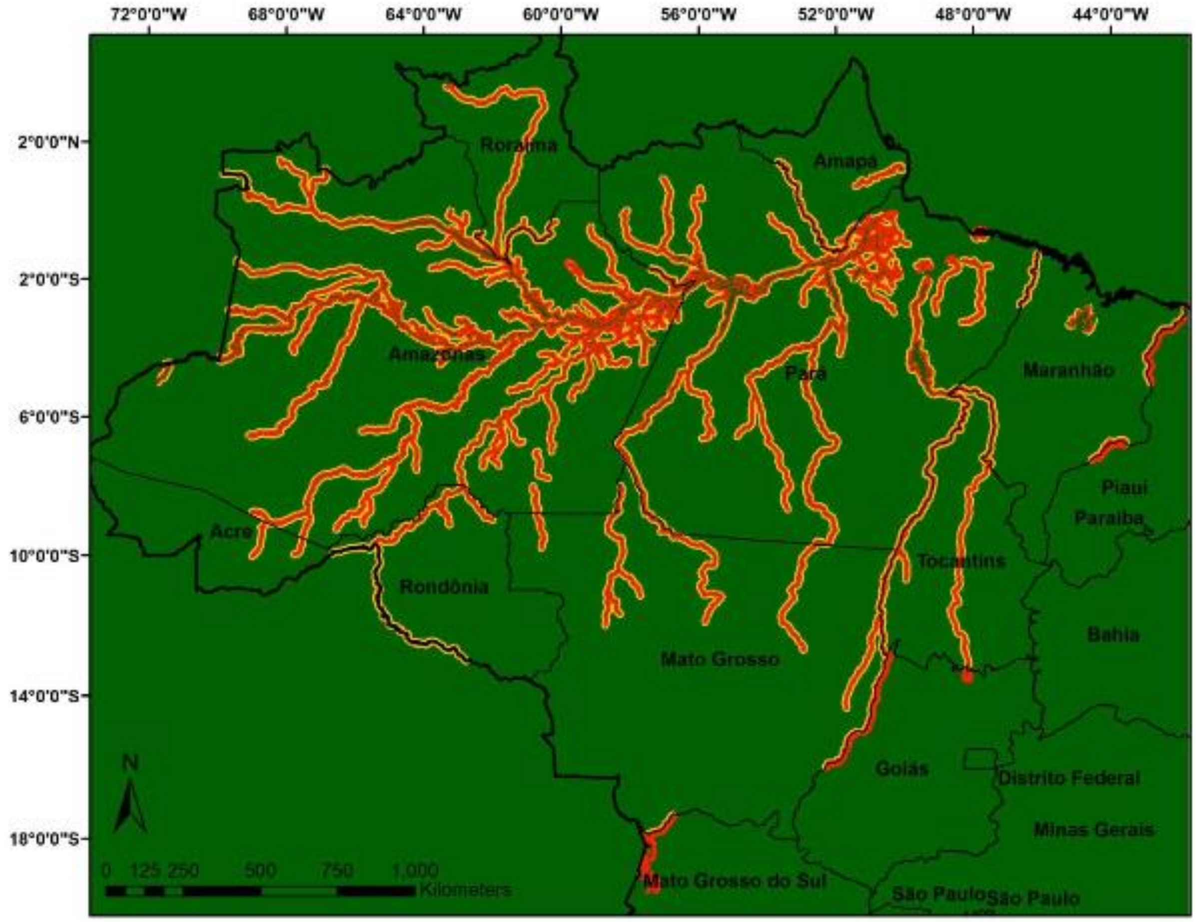

Figure 2: Risk of deforestation due to access by rivers to areas in the Brazilian Amazon. Red shows high risk (closer to rivers), while green shows low risk. Risk is calculated for up to 12.5 km from a river.

Risk due to proximity to previous sites of deforestation:

Areas where deforestation has occurred in the past indicate higher risk of future deforestation, since these areas have been accessed previously and any controlling agencies have not prevented land use change, previous deforestation indicates accessibility, lack of protection and some degree of economic attraction. A density map of deforestation events that occurred between 2005 and 2011 (Soares-Filho et al., 2006) was created (Fig.3). The map was then divided into 32 classes based on the density values – i.e. group of highest density values were given highest risk value (=32) and the group of lowest density values were given lowest risk value (=1).

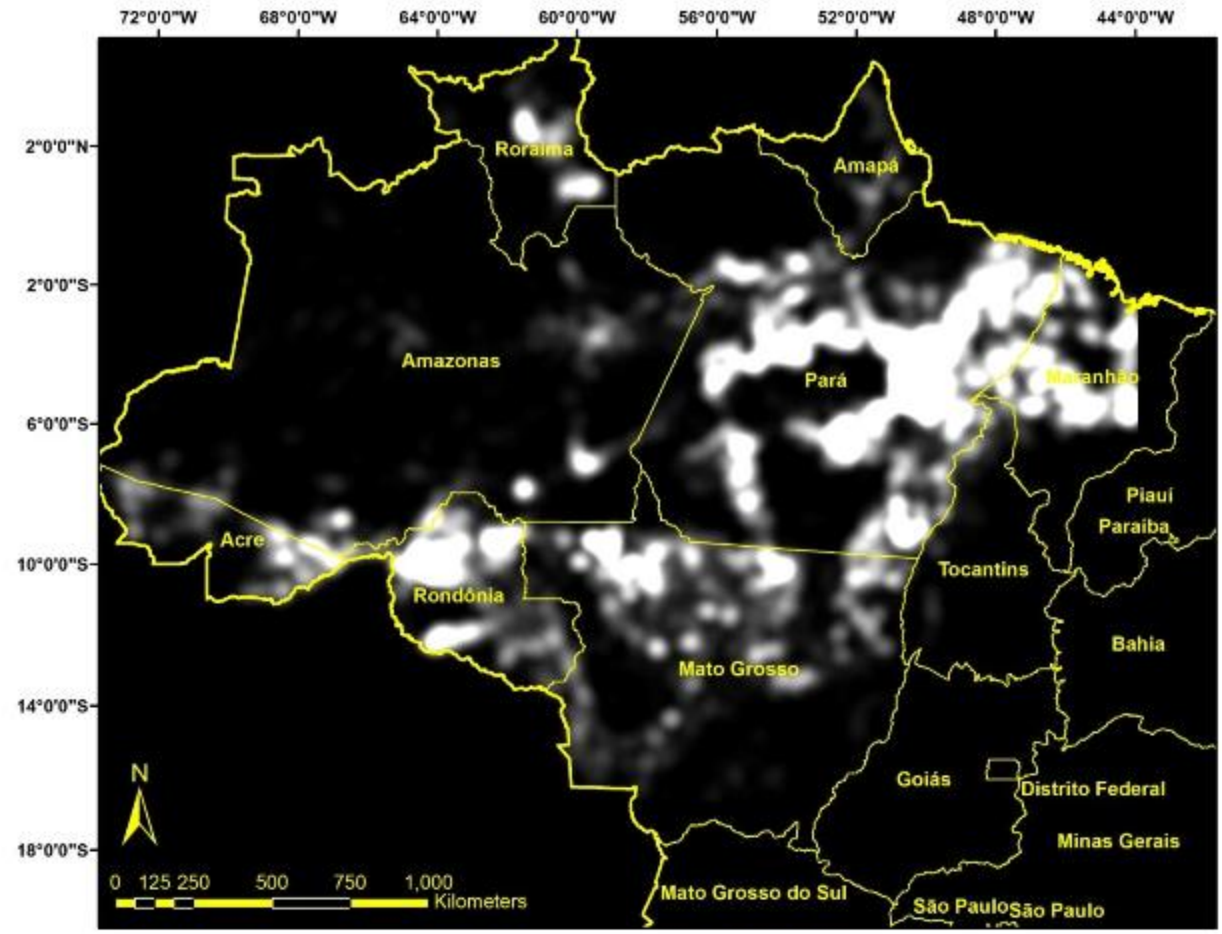

Figure 3: Density map of past deforestation in the Brazilian Amazon. White shows areas of high number of deforestation events, while black shows low density of deforestation events.

Protected indigenous areas:

The legal protection of areas in the Brazilian Amazon is a method of enforcing conservation of forest resources and biodiversity (Verissimo, 2011). Approximately 1.6 million km2 of indigenous lands and protected areas (under federal protection and state protection) can be identified in the region of interest (PNLT, 2008; Fig.4). In the calculation of risk, areas that are designated with “indigenous protection” are considered to be at low risk of deforestation as it is assumed that these areas have some protection status.

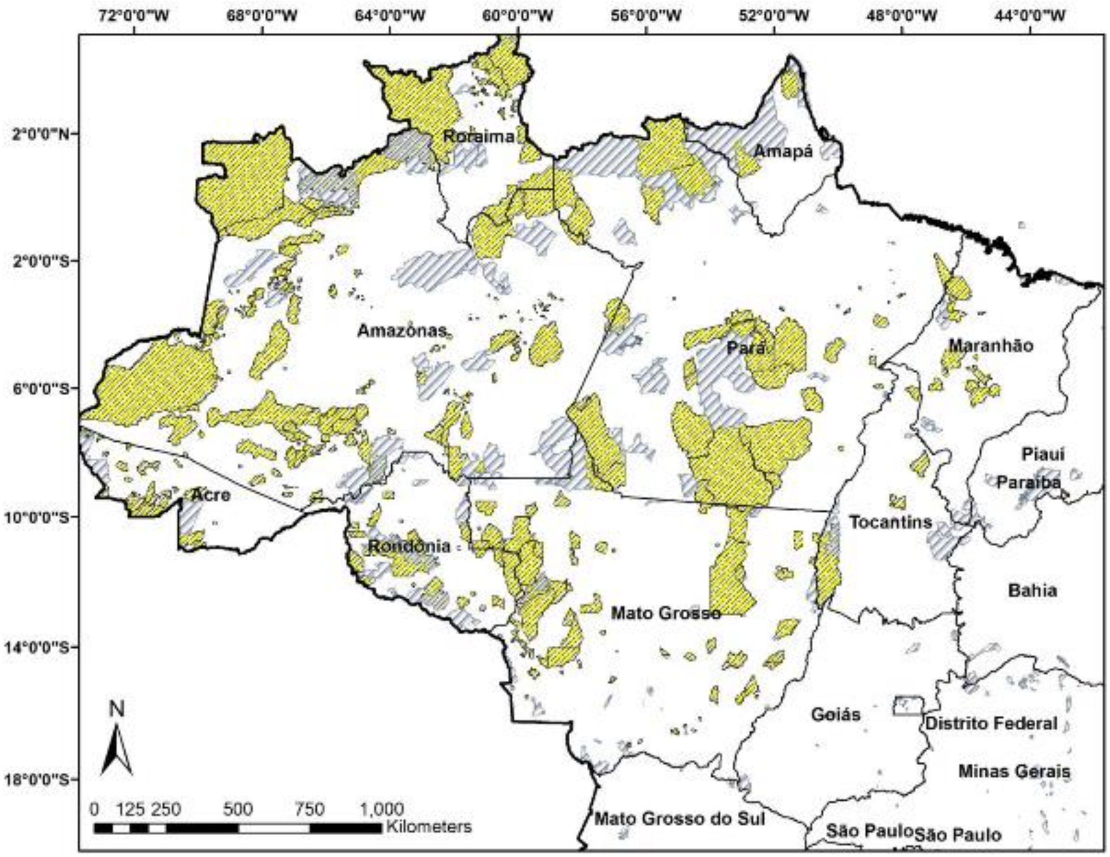

Figure 4: Map of Federal and State Protected Areas and Indigenous lands in the Brazilian Amazon.

Risk of Deforestation – Methods and Calculations

The total threat of deforestation in forests of the Amazon was derived using the four input maps described above (Fig.1-4).

- First, risks from roads/railways and rivers were added, resulting in a map where risk values ranged from 2 to 48.
- On this map, risk values in areas that were protected (indigenous lands, and those under federal and state protection) were re-assigned to lowest risk (i.e. risk value 2).
- Risk due to past deforestation (derived from the density map, Fig.3) was then added, resulting in a map with risk values ranging from 3 to 62 (Fig.5). Past deforestation was considered as a risk to both protected and non-protected areas, since recent deforestation is an indicator of the limited effectiveness of protection.
- Finally, risk on all water bodies (rivers, lakes) in the region, which obtain untrue risk values due to the buffering and density method described above were re-assigned to “no risk areas”.

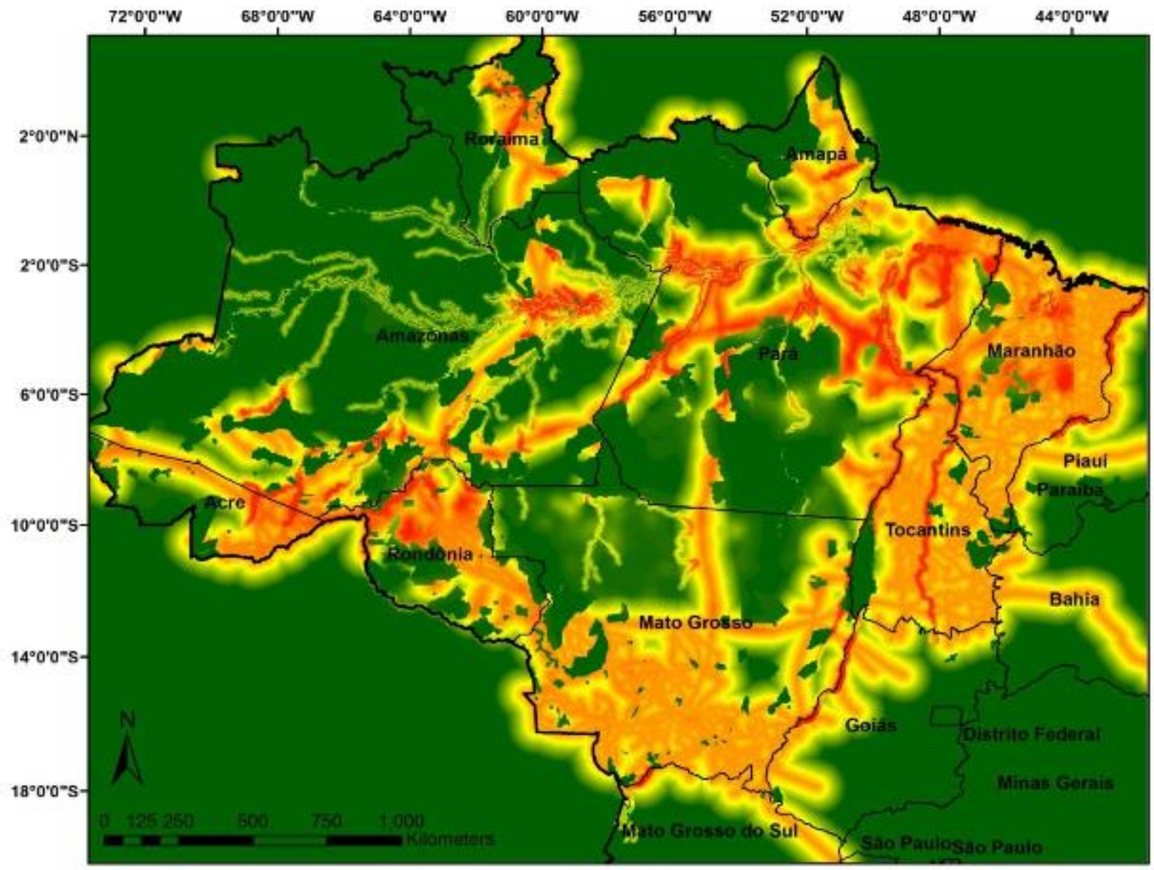

Figure 5: Risk of deforestation map for the Brazilian Amazon, based on protection status of lands and threat of access to forests by road, rail and rivers. High risk areas are represented in red, while low risk areas are in green.

Outputs and Classification

The output above (Fig.5) shows a continuous field of risk of deforestation. Risk values are further classified into 5 risk categories. The classification is done by dividing the dataset into quintiles, i.e. equal-areas data subsets, with the group of highest values being assigned 'Very High Risk' and the group of lowest risk values being assigned 'Very Low Risk'. Note that water bodies (e.g. rivers) are still classified as "No Risk". Since a large number of areas had an original risk value of 3 (see method above), these are the only areas that make the "Very Low Risk" category.

Risk Indices

Risk Indices were then assigned to the risk categories, assuming that not all carbon in the categories are lost equally (see section 'Calculation of Natural Capital Credits to be Issued', which uses the risk indices in the calculation of potential credits).

Very High Risk (Risk Index = 0.8)
High Risk (Risk Index = 0.6)
Medium Risk (Risk Index = 0.4)
Low Risk (Risk Index = 0.2)

Very Low Risk (Risk Index = 0)

Comparison with Other Analysis

The output of this risk map produces results that are of similar overall pattern to the output from SIMAMAZONIA (Soares-Filho et al 2006)[5] which is the most comprehensive predictive model of future land use change in Amazonia. This is not surprising given the linkage to roads and other forms of access. However, looking at a time-frame of 20 years from 2012 the risk map produced here appears more conservative than the SIMAMAZONIA business as usual output - with an output that approximates the forest loss by 2020 (8 years away), rather than 2032.

Note on further potential work

Risk assessment is an inexact science as the drivers of land use change can vary according to economic trends, new policy developments and environmental changes (droughts, floods, etc).

Our methods of risk classification could incorporate fine scale detail as this becomes available for the area as a whole. However, there is a danger of trying to make fine scale risk calls in situations that are inherently unpredictable.

It is suggested that the risk map may be updated in the future, to take account of deforestation occurring in the intervening period and newly available information and data. Consideration of flooded forest areas (poorly accessible), the effects of population centres and road intersections could also be examined further.

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Annex 2: Carbon Values for the Brazilian Amazon

This Annex describes the sources and methods used to obtain the carbon values used in the NFS quantification in the Brazilian Amazon.

Carbon Stocks in Biomass (AvgC)

Carbon stocks are obtained directly from the NASA JPL 2012 pan-tropical carbon map (Saatchi et al., 2011). The NASA JPL data was derived from a combination of in situ inventory plots, LIDAR, optical and microwave satellite imagery, acquired during the 2000's at a resolution of ~1km.

Correction of the base year carbon map to account for deforestation that may have occurred prior to project commencement

In order to account for any deforestation occurring before the commencement of a project, PRODES deforestation data from the Brazilian space agency for the years 2000 up to approximately the time that the project started is used to adjust the NASA carbon map values.

Deforested areas are given an assumed above-ground and below-ground carbon value of 0. This is a conservative approach, which gives a worst-case assumption. Adjustment of the crediting calculation, to avoid issuing credits for conservation of soil carbon in areas deforested before the project start is also taken into account – this is discussed below.

Due to the difference in resolutions of the PRODES deforestation and JPL NASA and carbon datasets, the adjusted carbon map is produced based on the percentage of deforestation occurring in a pixel within the JPL NASA carbon map. For example, where 50% of a pixel has been deforested the resulting pixel gets a value of 50% of carbon in the original carbon map.

The Standard Deviation of Carbon Stocks

The standard deviation of the distribution of carbon calculated using the formula for standard deviation of a sample -

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - x_m)^2}$$

where,

N is the number of values, and x_m is the mean of the values (tC).

Vulnerable Fraction of Carbon in Biomass (Vf)

The vulnerable fraction of carbon in above and below ground biomass lost on deforestation is estimated at 0.9 based on a review of relevant literature, summarised below.

A number of studies have estimated the “vulnerable fraction” of carbon in above and below ground biomass in forest that is lost upon conversion to cropland or pasture.

Common approaches to calculate the vulnerable fraction include the use of IPCC summary figures which provide approximate biomass stocks for different vegetation types. Fearnside (1997) made estimates of “equilibrium levels” of biomass in different land use types for areas within the Amapa, Amazonas, Maranhao, Mata Grosso, Para, Roraima, Tocantins/Goias - obtaining an area weighted mean of 464 t biomass/ha for undisturbed forests. This is approximately equivalent to 232 tC as the carbon content of biomass is approximately 50%. From this, a percentage loss in carbon can be estimated from the change in biomass when land is converted to farmland (with 0.7 metric tons of biomass per hectare), productive pasture (with 10.7 metric tons of biomass per hectare) or degraded pasture (with 8.0 metric tons per hectare). These equilibrium figures, suggest a vulnerable fraction of between 97% to 99% depending on the subsequent land use. See Table 1 for details.

Total carbon (tC/h) ha in pre-logged forest (including AGB + BGB)	VC Forest to Farmland	VC Forest to Productive pasture	VC Forest to Degraded pasture
232 tC	99.83%	97.67%	98.28%

Table 1: The percentage of vulnerable carbon (VC) in above and below ground biomass when transitioning between different land use types. Figures of C in forest (232), farmland (0.7), productive (10.7) and degraded pasture (8.0) are adapted from Fearnside (1997)

Vulnerable Soil Carbon (VSoilC)

The vulnerable soil carbon relevant to deforestation occurring in the Brazilian Amazon is estimated at 8 $tCha^{-1}$ based on a review of the most relevant literature.

Carbon pools in soil are difficult to estimate because of limited knowledge about specific properties of soil types, high spatial variability of soil C within one soil map unit, and the different effects of the factors controlling the soil organic carbon cycle [Bernoux et al 2002, and Cerri et al 2007].

Fearnside and Barbosa’s (1997) review of studies of soil carbon impacts of land use change from forest to cattle pasture in the Amazon found conflicting evidence. Some of the varied results that have been reported can be explained by effects of soil compaction, clay content and seasonal changes. Most studies reviewed compared roughly simultaneous samples taken at nearby sites with different use histories (i.e., 'chronosequences'). Whether pasture soils are a net sink or a net source of carbon depends on their management, but an approximation of the fraction of pastures under `typical' and `ideal' management practices indicates that pasture soils in Brazilian Amazonia are a net carbon source, with the upper 8 m releasing an average of 12.0 tC/ha in land maintained as pasture in the equilibrium landscape that is established in the decades following deforestation. Considering the equilibrium landscape as a whole, which is dominated by pasture and secondary forest derived from pasture, the average net release of soil carbon is 8.5 tC/ha.

Adjustment to avoid issuing credits for conservation of soil carbon in areas deforested prior to project commencement

The following adjustment is made to avoid issuing credits for the conservation of soil in areas that were deforested in the period between the date of acquisition of data of the base map and the commencement of the project.

Potential credits associated with conservation of Vulnerable Soil Carbon due to deforestation before project start date are calculated using the following equation:

Soilcredits = VSoilC x Area x 3.667 / 20

where,

VSoilC = 8 tC/ha

Area = area deforested before the project start date (ha)

3.667 = 44/12; Conversion of Carbon to CO2

20 years = period of crediting

Potential credits associated with Vulnerable Soil Carbon are deducted from the total potential credits calculated per area in a given year.

Adjustment of the potential credits to account for seasonally flooded forest areas

Seasonally flooded areas are excluded from generating credits given their reduced accessibility and attractiveness for agriculture.

Potential credits are calculated for areas categorised as regularly or permanently flooded according to the ESA Globcover V2.3 land cover map for 2009:

- 160: Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily) - Fresh or brackish water
- 170: Closed (>40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water
- 180: Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water

Credits associated with seasonally flooded areas are deducted from the total potential credits calculated per area in a given year.

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Annex 3. Methods Used for Monitoring Emissions from within NFS Project and Leakage Areas in the Brazilian Amazon

This Annex describes the methods for monitoring emissions from NFS projects within the Brazilian Amazon.

Monitoring is carried out using a combination of remote sensing and ground based data collection methods in both project areas and leakage areas. Monitoring is combined with forest protection measures to actively respond and close down unauthorised deforestation activities as part of project measures.

Project Area Monitoring

Project area monitoring combines measurements from a number of sources, including the following:

- ***Ground based monitoring from road and boat***
  Ground based monitoring by protection officers is carried out along all access routes on a schedule to be determined by local intelligence as most likely to intercept potential deforestation agents at early stages. Where deforestation activity is detected the team will report a hotspot for medium to high resolution remote sensing analysis to assess the extent of the area affected.
- ***Annual monitoring by PRODES***
  The PRODES programme implemented by the Brazilian Space Agency provides reasonably accurate annual assessments of deforestation.
- ***Medium and high resolution mapping of identified hotspots***
  Hotspots identified by the protection team and selected areas around road intersections will be subject to high resolution mapping on an intra-annual basis to detect quantify and intervene as early as possible.
- ***Near-real time alerts***
  Monitoring may be supplemented by near real time alerts from MODIS as processes for accurately detecting deforestation on a monthly basis become available.

The areas identified and confirmed as deforestation are mapped and compiled within an annual report, using a project's geospatial platform.

Leakage Area Monitoring

A leakage zone of 10 km from the boundaries of the project area is monitored.

Leakage area monitoring comprises remote sensing from PRODES deforestation data as well as MODIS near real time alerts, when this becomes available.

Any emissions from deforestation occurring in the leakage area of a project will be counted as project emissions unless the project can demonstrate they are shown to be caused by external pressures, as opposed to activities translocated from the project area.

All deforestation areas =>20 ha should be investigated to determine whether they are attributed to actors from within the project area translocating activities.

The areas identified and confirmed as deforestation are mapped and compiled within an annual report, using a project's geospatial platform.

Calculation of emissions from deforestation after the project start date

PRODES deforestation data from the Brazilian space agency (INPE) is used to quantify deforestation within a project area in a given year. The yearly PRODES deforestation data covers the period from August of the previous year to July and is generated from the interpretation of Landsat and CBERS images, with a spatial resolution of approximately 30m.

When deforestation is detected and confirmed, emissions for any area are quantified as follows.

Emissions = Area x { [*AvgC x Vf*] + V*soilC* } *x* 3.667 *x Ud (tCO2)*

Where:
AvgC = carbon stocks in biomass (tC)
Vf = vulnerable fraction (tC)
VsoilC = vulnerable soil carbon (tC)
Ud = factor to account for deforestation undetected by PRODES monitoring

Calculation of Ud:

Ud is currently estimated at 1.09 per year based on the conservative interpretation of a study carried out using high resolution RapidEye satellite data to check the accuracy of PRODES outputs in an area near the Trocano NFS project which found that 9% deforestation was missed by PRODES (Viergever and Morel, 2013).

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