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Authors: Karen Lawrence and Sarah Hutchison, WWF-UK

ABSTRACT

In 2009, UK broadcasting and entertainment company Sky and WWF partnered on an initiative called Sky Rainforest Rescue, to help safeguard one billion trees in the Amazon. The flagship project of Sky Rainforest Rescue is based in the state of Acre in the north-west of Brazil, and is implemented in partnership with the Acre state government. The project aims to develop ways to help tackle deforestation in areas of small-scale subsistence farming that could help inform efforts around forest-based economies, payments for environmental services and REDD+[1] in different parts of the Amazon. The paving of a major highway, the BR 364, which cuts through the area, was set to transform the land use dynamic. The project deploys a number of approaches to slowing deforestation along the colonisation fronts – especially the road – to form a type of buffer for the intact forest that lies beyond these colonised areas. This paper presents the methodology employed and the findings to date around three areas: estimating how the project is helping safeguard one billion trees; how it is helping reduce deforestation; and its associated carbon dioxide emissions.

Two different methods are employed, one that seeks to understand the project contribution to avoided deforestation and the other that uses a counterfactual approach to estimate the project's attributable contribution to avoided deforestation. An annex includes further analyses that were explored. From the first method, we estimate that 22.6 thousand hectares of deforestation will have been avoided, along with an associated 10 million tonnes CO2 equivalent of emissions, by 2016 if deforestation trends are on track in the project area to meet the Government's target of 80% reduction by 2020, compared with the historical baselines. While the project's impact will have helped contribute to this amount, this methodology does not necessarily tell us the scale of its contribution. From the second methodology, which provides a possible "without project" scenario, we estimate that the avoided deforestation attributable to the project by 2016 will be 8.3 thousand hectares and 3.76 million tonnes CO2 equivalent of avoided emissions. Over one billion trees continue to thrive in the project area.

[1] As defined by the UN-REDD Programme, Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

INTRODUCTION

In 2009, UK broadcasting and entertainment company Sky and WWF joined forces on an initiative called Sky Rainforest Rescue, to help safeguard one billion trees in the Amazon. The flagship project of Sky Rainforest Rescue is based in the state of Acre in the north-west of Brazil, and is implemented in partnership with the Acre state government. Through public donations matched by Sky, the initiative has raised in excess of £9 million for the implementation of the project in Acre, until June 2016, and for tackling the drivers of deforestation in other parts of the Amazon, in Brazil, Colombia and Bolivia. In addition, Sky Rainforest Rescue has included outreach and engagement with Sky customers, staff and the public in the UK and Ireland on the importance of the Amazon, the threats it faces and what actions people in the UK can take in their daily lives to help Amazonian conservation.

This paper centres on the Sky Rainforest Rescue flagship project in Acre, which was established with the aim of developing ways to help tackle deforestation outside of protected areas – in areas of small-scale subsistence farming – that could help inform efforts around forest-based economies, payments for environmental services and REDD+ in different parts of the Amazon.

Acre's frameworks for reducing deforestation

In 2010, it was estimated that over 96% of Acre's carbon dioxide emissions are due to land use change (Falberni de Souza Costa et al. 2012). The Acre government has established a target of reducing deforestation by 80% by 2020. The government of Acre is also a signatory to the New York Declaration, which seeks to eliminate all loss of natural forest by 2030. It is one of the very few subnational jurisdictions that have operational forest reference emissions levels and that receive payments for performance against these levels from Germany's REDD Early Movers Programme. The state is recognised as a leader in sub-national REDD+, due to a suit of policies that include its jurisdictional policy on valuing ecosystem services (known as SISA) – which includes a state-wide REDD+ approach called ISA-Carbono (WWF-Brazil 2013). Further programmes under the SISA law that focus on other ecosystem services such as water and hydrological systems and biodiversity are under development.

The Sky Rainforest Rescue project is one of a number of complementary efforts, led by the Acre government, to improve livelihoods at the same time as tackle deforestation in a particularly vulnerable part of the state. There has been a coordinated effort between the use of Sky Rainforest Rescue funds with funds from the Acre Government, Brazil's Amazon Fund,[2] and more recently from part of the funds from the REDD Early Movers Programme, to help meet the project's ambitious aims. More than one donor source can be supporting each project component (see below). Therefore, when referring to "the project" we include all the coordinated efforts by this group of donors that occur in the project area.

Working in a vulnerable area

In 2009, together with the Acre State Government, WWF and Sky selected an area in which to focus project implementation. The area chosen was very isolated and with low historical deforestation. However, the paving of a major highway – the BR 364 – that cuts through the area was set to transform the land use dynamic.

Many researchers have documented a relationship between forest destruction and degradation in the Amazon and road developments. For example, in the Eastern Amazon, where work on the Belém-Brasília highway began in 1958, Laurance et al. (2009) describe the highway's impacts as 'a 400-km-wide swath of forest destruction and secondary roads across the eastern Brazilian Amazon'. The concern is that a similar outcome should not occur in the western Amazon, where integration through infrastructure development is promoted by both national and international institutions alike (van Dijck 2013).

The dynamics of land use change following road developments are highly dependent on the particular actors, both state and non-state, involved and may take years or even decades to fully materialise

[2] Brazil's Amazon Fund (http://www.amazonfund.gov.br/FundoAmazonia/fam/site_en) has provided non-returnable funds to both the Acre Government and WWF-Brazil. These grants include work relating to the project's objectives in the project area.

(Ahmed et al. 2013). They also depend on a complex set of factors, such as the type of road and how isolated or connected it is, whether it is paved or unpaved, the tenure and land-use potential in the area, market accessibility, settlement policies along the road and the general governance scenario. This makes predictions of precise deforestation trajectories difficult. In the project area in Acre, most deforestation is carried out to make way for subsistence slash and burn agriculture by a few thousand families. Many of these families have limited or no recognised land rights. Geist and Lambin (2001) describe various patterns of deforestation, including the well-known fishbone pattern associated with planned settlements. The conditions in Acre suggest land use change would more likely conform to their corridor deforestation pattern, which is 'associated with roadside colonization by spontaneous migrants'. However, Caldas et al. (2010) provide a good example of how site specific the trajectories can be. They describe broadly similar spontaneous settlements (i.e. by colonists with little capital and no prior land rights) along the Transamazon highway in Pará. They show that even between communities in the same area, differing socio-economic histories were associated with differing levels of deforestation. Nonetheless, despite the complexities of interactions between road developments and land use change, for the Amazon at least, there is a consistent association between road developments and deforestation (Pfaff et al. 2009). Controlling and reducing the deforestation and other environmental impacts associated with road developments is therefore a considerable challenge (see, for example, Laurance et al. 2015).

Deforestation in the Sky Rainforest Rescue project area could be a mix of both legal and illegal deforestation according to each property's level of compliance with Brazil's Forest Code. The project's challenge was to reduce deforestation to below what otherwise might be expected without any of the project's interventions.

Distinct to other parts of the Amazon, where medium- to large-scale ranching is a major driver of forest loss, in the project area most current forest clearance is due to the activities of a few thousand subsistence farmers, who use slash and burn practices to typically clear 1–2 hectares of forest every one to two years. Most of these farmers are located along the BR 364 road and the main navigable rivers. The main staples produced are cassava, corn, beans and rice. Many of the more remote families, especially those living along the rivers, are rubber tappers. Other forest products are also harvested, such as acai berries, but Brazil nuts, which are an important source of income in other parts of Acre, do not occur in the project area. Few farmers have recognised land rights, with the exception of federal government settlement projects in the more urban areas that border the project area, although government efforts are gradually helping improve the recognition of land rights.

Project strategy

The project is deploying a number of approaches to slowing deforestation along the colonisation fronts – especially the road – to form a type of buffer for the intact forest that lies beyond these colonised areas. The four approaches are as follows.

1. Incentives and support to producers to move away from slash and burn agriculture, by improving soils and production on already cleared lands. The main mechanism for delivery is Acre's voluntary land certification scheme. This involves a package of support, based on a property management plan, including technical assistance, seeds, seedlings, tools and a cash bonus. Sky Rainforest Rescue funds have been used alongside government funds and money from the Amazon Fund to support each of these components.

2. Improving the value of locally important forest product chains, especially wild rubber, acai berries and the giant arapaima fish. To date, this work has been mostly funded by Sky Rainforest Rescue, with the recent additional support from the Amazon Fund's grant to WWF-Brazil for fisheries work in the project area. WWF facilitates multi-stakeholder dialogue for each of these market chains, which in turn has been serving to help coordinate government support to these activities and to secure new funding sources, such as federal government funding for acai research. Part of Germany's REDD Early Movers Programme funding is employed to pay the subsidies available on wild rubber.

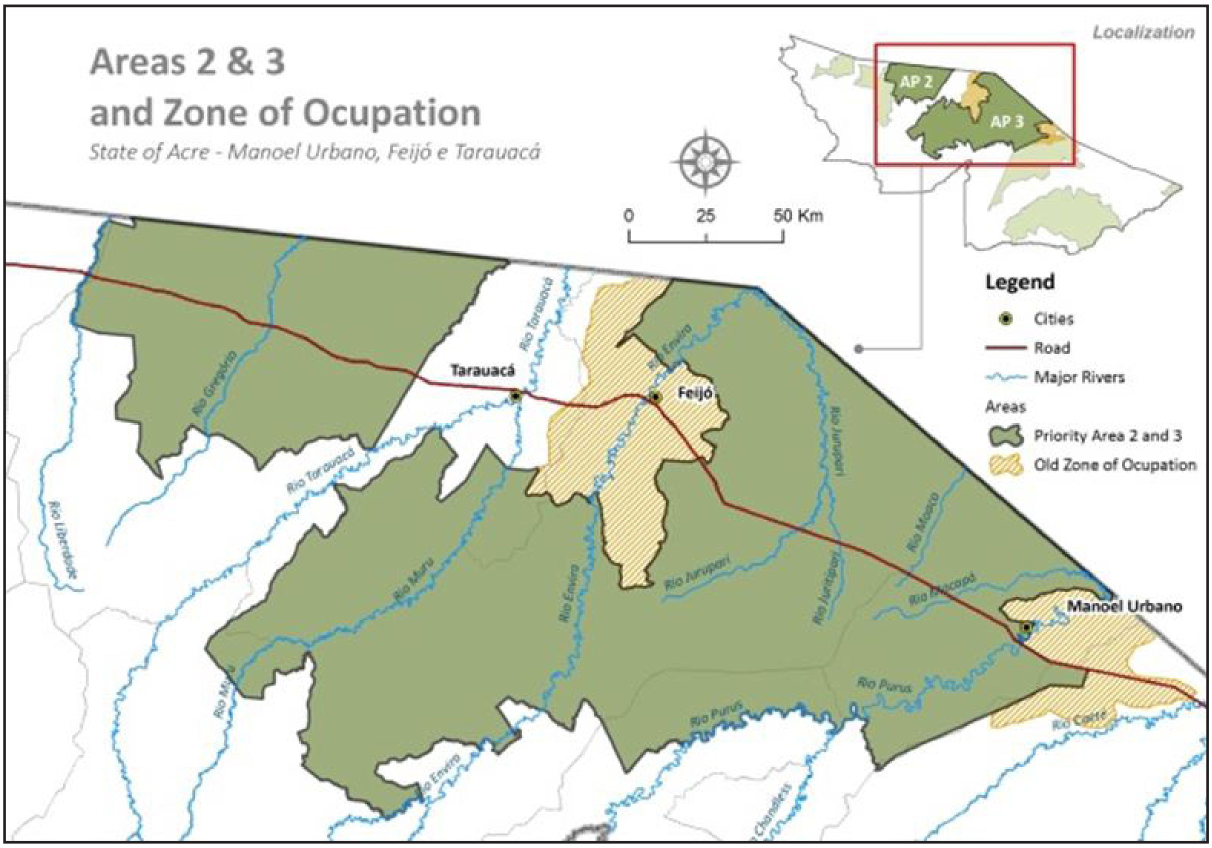
3. Influencing and strengthening policy frameworks that support forest economies, the valuing of ecosystem services, and incentives for forest conservation. This refers to Sky Rainforest Rescue funded work that looks to strengthen the Acre Government's policy frameworks, in addition to sharing lessons from Acre to other parts of the Amazon.

4. Innovative monitoring to inform government action and forest governance. This is a coordinated effort between the Acre Government's own monitoring unit and Sky Rainforest Rescue funded work conducted by WWF-Brazil. Other collaborators in this field are Cifor, as part of its global comparative REDD+ study, and the European Space Agency's G-ECO-MON project.

Location of the project area

The project area comprises two of Acre state's priority areas for tackling deforestation, see the green areas in Map 1. These are areas 2 and 3 of the state's seven priority areas identified in its 2008 policy on valuing forest assets. Early on, we detected from satellite images that a large amount of the deforestation was happening on either side of the project area, around the towns of Feijó and Manoel Urbano, where there are federal government settlement projects. Such settlements have greater permitted levels of legal deforestation. We therefore consider these areas as part of the project's extended coverage, as key pressure zones. The project area (in green) covers 3.14 million hectares. Ninety-five per cent of this area retained its native forest cover in 2013. The extended project area, including the settlement zones (in brown), covers 3.59 million hectares.

Map 1. The project area



This paper presents the methodology employed and the findings to date around three areas: estimating how the project is helping safeguard one billion trees, and how it is helping reduce deforestation and the associated carbon dioxide emissions. As the implementation of the Sky Rainforest Rescue project will last until June 2016, an updated paper will be produced when this phase of the project concludes.

METHODOLOGY

The project's monitoring system for deforestation and fires operates at four levels, and uses a variety of Earth Observation data sets:

1. Federal Government level: annual monitoring of deforestation in Brazil's Legal Amazon[3] is conducted by Brazil's National Institute for Space Research (INPE) through its PRODES project.[4] Since 1988, the PRODES project has monitored deforestation on a yearly basis. Landsat images are used. The analysis reports clear-felled areas of 6.25 ha and above. Preliminary figures for the year are announced in November and finalised by May the following year, at which time the data are made available for public download. The Brazilian government uses PRODES data as its official deforestation dataset, and it is used by the federal government and by Acre state for their calculations of emissions from deforestation, as per Brazil's submission on reference levels for the Amazon to the UNFCCC.

2. Acre state and project area: The Acre Government has its own geo-processing unit – UCEGEO – to help monitor deforestation and fire occurrence and inform command and control measures. In contrast to INPE/PRODES, the UCEGEO methodology has registered deforested areas of half a hectare and above. As part of the partnership agreements, UCEGEO has provided yearly data to WWF on the project area. Currently, the UCEGEO methodology is under revision in collaboration with INPE, to potentially use rapid eye data sets.

3. Project landscape: Using the same datasets as in point two above, annual deforestation is monitored in a subset of the project area in the principal colonisation fronts. This involves monitoring deforestation 5 km either side of the BR 364 road and 3 km either side of the large rivers.

4. Sample of properties in project area: WWF-Brazil combines remote sensing using high resolution satellite images and socio-economic questionnaire data in sample properties between two periods (2009/10 to 2012/13 and 2012/13 to 2015) to be able to assess the project's impacts on land-use and livelihoods at the property level.

Estimating tree numbers

To be able to communicate the scale and ambition of the project to Sky supporters and the general public in the UK and Ireland, we chose to use tree numbers as an explanatory metric. We estimated the number of trees standing in the project area in 2009 and, taking into account historical rates of forest loss, we established the target of ensuring that a billion trees were safeguarded by the project.

To estimate the number of trees standing in the project area, we used Acre government (UCEGEO) remote sensing data to calculate the hectares of standing forest (as opposed to areas that have already been cleared for agriculture and other land uses). This area can then be multiplied by an estimate for the number of trees per hectare.

Salimon et al. (2011) estimated the average tree density in Acre's forests to be 337 trees per hectare, based on 44 research plots across the state. In this case, a tree is defined as having a trunk of 10 cm or more diameter at breast height. This could be considered a conservative estimate, as a published analysis of permanent forest research plots across the Amazon found a median density of 565 trees per hectare (ter Steege et al. 2013). Tree density in Acre tends to be less than that of some other parts of the Amazon, as there is a high predominance of palms and bamboo on Acre's sandy soils, many that have trunks less than 10 cm diameter at breast height. Three plots in Acre that are part of the RAINFOR[5] long-term Amazon forest monitoring programme were recorded as having 632, 498 and 488 trees per hectare (Malhi et al. 2002).

Within the project area there are no plot-based estimates of tree density from within the project area, so we based our calculations on the average found by Salimon et al. (2011), thereby assuming that a density of 337 trees per hectare is representative of the forests within the project area.

[3] A politically defined region that covers 520 million hectares and includes the states of Acre, Amapa, Amazonas, Para and Roraima, and portions of Rondonia, Matto Grosso, Maranhao and Tocantins.
[4] http://www.obt.inpe.br/prodes/index.php
[5] http://www.rainfor.org/en

Estimating the contribution of the project to tackling deforestation

In this paper we use two different methodologies to estimate the contribution that the project is having on tackling deforestation. The first of these seeks to understand the project contribution to avoided deforestation based on a historical baseline and Acre State's target for reducing deforestation, and the second uses a counterfactual approach to estimate the project's attributable contribution to avoided deforestation.

Method 1. Historical baseline and state target

In this methodology, deforestation in the extended project area[6] is calculated using INPE/PRODES data, as described above[7] for the years 2006 to 2013 (see Table 1). The projection of annual deforestation rates from 2014–2020 is based on the reduction in deforestation required for the state to reach its 2020 target of reducing deforestation by 80% compared with its first historical reference level of 1996–2005[8] (Table 2). This target is stated in Acre's State Plan for the Prevention and Control of Deforestation (PPCD/AC 2010). Acre's target to reduce deforestation by 80% mirrors Brazil's national target for the Amazon.

To reach this target in the extended project area, deforestation in 2020 would need to reduce to 2,038 hectares/year from the historical reference level of 10,192 hectares/year (see Table 2). To calculate what this means on an annual basis, we have taken the difference in the deforestation values for 2013 and 2020 and divided it by the seven intervening years (5,532 – 2,038 = 3,493 hectares, divided by 7 is 499 hectares/year). This value of 499 hectares/year is therefore the target yearly area of deforestation in the project area from 2014–2020 to be able to reach the 2020 goal.

To estimate avoided deforestation in the extended project area, these annual deforestation rates are compared against a ten-year historical average baseline that is recalculated every 5 years (Tables 2 and 3). This method, known as a rolling average method, is the methodology used for Brazil's Amazon Fund.[9] This is a slightly different method to that submitted to UNFCCC[10] by Brazil, and in Brazil´s climate change decree 7390/2010. Under the Amazon Fund method, the first historical deforestation average reference level is from 1996–2005, the second historical average deforestation level is from 2001–2010 and the third is from 2006–2015. As the Sky Rainforest Rescue project began in 2009 and will run until 2016, we have adapted the method to this timeframe as follows:

- Avoided deforestation per year from 2009 to 2010 = 1st historical reference level minus annual recorded deforestation
- Avoided deforestation per year from 2011 to 2013 = 2nd historical reference level minus annual recorded deforestation
- Estimation of avoided deforestation per year from 2014 to 2016: in this methodology, we assume that between 2014 and 2020, the target rate of deforestation is achieved. A third baseline reference level (2006–2015) is not yet possible to calculate, so we use the second reference level. Therefore, the calculation is the 2nd Historical reference level of deforestation minus annual projected deforestation.

Table 1. Recorded and target deforestation for the extended project area, for Acre to meet its target of an 80% reduction in deforestation by 2020 compared with the historical reference level

Year/extended project area	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Recorded deforestation; INPE/PRODES (ha)	5339	5834	5256	3547	5058	4526	6677	5532							
Projected deforestation based on Acre state's target (ha)									5033	4534	4035	3536	3037	2537	2038

[6] The extended project area includes the settlement zones.
[7] The data for the project area were downloaded from INPE's PRODES from http://www.obt.inpe.br/prodes/ on 15 December 2014.
[8] The PPCD/Acre (2010) mentions an ambition of exceeding the 80% to reach 83% by 2020, but we have used 80% for these calculations.
[9] http://www.amazonfund.gov.br/FundoAmazonia/export/sites/default/site_en/Galerias/Arquivos/Boletins/Amazon_Fund_-_Project_Document_Vs_18-11-2008.pdf
[10] http://unfccc.int/files/land_use_and_climate_change/redd/application/pdf/redd_brazil_frel_final_19nov.pdf. The method submitted to the UNFCCC by the Brazilian government as part of its forest reference emission level (FREL) for REDD+ readiness is based on an updating average. Brazil was the first country to submit a REDD+ forest reference emission level to the UNFCCC based on this simple method (UN-REDD 2014). This compares deforestation against three historical averages (1st: 1996–2005; 2nd: 1996–2010; 3rd: 1996–2015). Applied to this dataset, this gives about a 50% higher value for avoided deforestation than the Amazon Fund method. For prudence, and because the Amazon Fund is contributing to the project, its method was chosen to calculate avoided deforestation and therefore avoided carbon emissions.

Table 2. First historical reference level for deforestation for the extended project area (1996–2005)

Year/extended project area	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	1st reference level (10 year average)
Recorded deforestation for extended project area; INPE/ PRODES (ha)	9955	9955	12783	12783	12783	5783	9772	17915	3465	6729	10192

Table 3. Second historical reference level for deforestation for the extended project area (2001–2010)

Year/extended project area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2nd reference level (10 year average)
Recorded deforestation for extended project area; INPE/ PRODES (ha)	5783	9772	17915	3465	6729	5338	5834	5255	3545	5058	6869

This methodology of continuing forward historic rates of deforestation ignores any deforestation acceleration following road paving, or any slowing that might take place after the initial road-induced rush. It also ignores the changing Amazon-wide deforestation context over the period, driven by climate variability and changes in the social, economic and political context.

It should be noted that the early years of the project (2009–2012) are expected to show a less significant impact on tackling deforestation than the projections in Table 1 indicate, as it takes time to engage large number of small-scale farmers and forest product harvesters and begin implementation. The number of project beneficiaries receiving support for their agricultural activities has grown year on year, as part of a nine-year scheme to help them shift their practices onto a more sustainable basis.

In addition, as the historical deforestation rates were low in the project area, we would expect to see some increase in deforestation, especially in the early years following the paving of the road. However, we would expect deforestation to be less severe than it would have been without the project's interventions. Hence the use of the second methodology, which tries to assess what might have happened without the project.

Method 2. "Without project" scenario

The second methodology explores a scenario of what might have happened in the project area without the project's interventions.

Creating "without intervention" scenarios is often also referred to as "business as usual" or counterfactual scenarios. Such scenarios are a description of what did not happen, but what might, could or would happen under different conditions, and are inevitably based on a series of assumptions and predictions.

The basic methodology we have employed compares the amount of forest in the project area measured using the Acre government's remote sensing data (UCEGEO data) with the amount of forest that could have been left under scenarios that we have estimated based on a pre-existing, publicly available study (Reymondin et al. 2013). There are two critical elements to this approach; defining the period of time for the scenario and choosing which scenario to compare with the actual situation.

Defining the period of comparison

The BR 364 is the only road that connects Acre to Sao Paulo and the rest of Brazil. The period of works along the BR 364 has several dates that are key, according to government information. The road connects two of the largest towns in Acre – Cruzeiro do Sul at the western end of the state and the capital Rio Branco to the east – both of which were formed long before the road. Along this road are a number of towns, such as Tarauacá, which is over 100 years old, and Feijó and Manoel Urbano, which are younger but still well established. Works to pave the road started in earnest in 2000. The connection between Tarauacá and Feijó was paved in 2003 and Cruzeiro do Sul and Tarauacá was completed a year later. The road from Manoel Urbano to Rio Branco was started in 2007 and several bridges along the route were completed in 2008. The two main bridges (Rio Tarauacá and Rio Jurapuri) were completed in 2011, and the section between Feijó and Manuel Urbano (area 3 of the SRR project area) started soon after but was finally completed in 2013. Given the range of possible dates, 2008 was taken as the period from which to run the scenarios because this marked the start of when the project area began to experience much better road connection to the capital and other parts of Brazil; it marked the end of significant works not only from Manoel Urbano (on the eastern edge of the project area) to Rio Branco, but also the paving of the road from Rio Branco to Porto Velho, a key trade hub. This was also the date that the interoceanic highway was completed, that connected Brazil with Peru.

Choosing suitable scenarios

The principal options for a “without-project” scenario include (a) commissioning the construction of a sophisticated mathematical model to predict annual forest loss; (b) drawing on evidence from areas with similar characteristics that have undergone similar events; or (c) considering the trends from the larger surrounding area that is subject to similar pressures and drivers. All these approaches have their advantages, limitations and different cost implications. Consideration of cost, and expected performance at the project scale led us to reject option (a). The pre-existing literature provided us with some useful options for (b) and (c). We considered several scenarios, based on available data, to compare and contrast results and understand the envelope of possible scenarios, from the more extreme to the more conservative in their projections. We present here the scenario we consider to be most realistic, but for reference three other scenarios that we explored can be found in the accompanying annex.

The Interamerican Development Bank’s technical paper on the impact of roads in five Latin American case studies includes the case of the BR 364 in Acre and Rondonia (Reymondin et al. 2013). The remote sensing methodology used is called Terra-I, which is a near-real time monitoring system that employs satellite based rainfall and vegetation data. It detects disturbances that may be attributed to human activity by identifying changes in the greenness of landscapes that deviate from baseline values. In Brazil, habitat status was monitored every 16 days from January 2004 to June 2011. The methodology is described in detail in the annex of the Reymondin et al. paper.

The two sections of the road analysed were (i) a 623 km corridor from Cruzeiro do Sul in the west of Acre state to the state’s capital Rio Branco. This section of the road transverses the Sky Rainforest Rescue project area. Note, however, that the paving of the road in the project area between the towns of Feijó and Manoel Urbano only happened after the timeframe of this study. The other sections were paved between 2002 and 2010. (ii) A 515 km corridor from Rio Branco in Acre to Porto Velho in Rondonia state. There was also a technical paper to complement this analysis, which described in detail the findings for the BR 364 (CIAT and others, 2012).

To use this study as the basis of a “without-project” scenario we have compared recorded and expected deforestation in the project area with the rate of change that the Reymondin et al. study shows – expressed as a percentage of the area, as described below.

This study was considered to be apt, as it documents change along the same BR 364 road, and therefore presents very similar conditions of road connectivity, governance regimes, and socio-economic conditions. Some sections of the road traverse settlement areas and areas of subsistence farming. Outside of the project area, the road also crosses some indigenous territories, which may present certain differences to the project area where there are no indigenous lands. The conditions along Acre's other main road, the BR 317, are considerably different, with many more large scale ranches and greater historical deforestation. Hence, the changes documented along the BR 364 by Reymondin et al. can be considered to be representative of the possible changes post-paving in the project area.

Calculating recorded and expected forest loss during the project duration

Annual deforestation data from 1988 to 2013 was calculated from UCEGEO data for the project area (areas 2 and 3 covering 3.14 million ha) as seen in Table 4. To calculate actual forest cover per year in this area, we subtracted the deforested area in one year from the total forest cover in the previous year. For example, remaining forest in 2008 = 3.038 million ha (forest cover in 2007) – 4,312 = 3.033 million ha.

For the remaining duration of the project 2014–2016, we have estimated the likely area deforested each year and calculated how much forest would remain under these deforestation estimates. To do this, we have assumed a continuation of the mean average area of deforestation between 2009 and 2013. This is based on the assumption that the mean area of deforestation will remain relatively stable in the timeframe of the project. Although we would still expect to see variation year on year, we would expect less extreme peaks and troughs and for the general trend to become more stable and downward, as the project activities reach maturity. The mean average area deforested from 2009 to 2013 is 8,107.4 hectares/year. See Table 5 for the predicted remaining forest. The expected remaining forest in the project area at the end of 2016 is 2.97 million hectares.

Calculating forest loss under the "without project" scenario

The paper by Reymondin et at. (2013) found that, for the section of the BR 364 studied in Acre, the average area deforested each year was 18,700 ha/year before the road was paved, and after the road was paved the mean average jumped to 32,400 ha/year, resulting in a 72% increase (Table 6). Therefore it would be reasonable to expect a similar increase of 72% in the deforestation dynamics in the project area, if the same road, the BR 364, were paved in this area and no project activities were being implemented, which was the case in 2008. While this would be a counter-trend to Acre's target of 80% reduction by 2020, this target is state-wide. The short-term impacts of road paving in this particular area of very low historical deforestation rates could be reasonably expected to buck any state-wide downward trend from 2008 to 2016.

The projected "without project" scenario is therefore calculated in the following way for the project area: the pre-paving annual area deforested is calculated using the average rate from the period 1988–2007 (see data in Table 4) which is 5,007 ha/year. This value is then increased by 72%, giving 8,612 ha/year. This rate is applied in a linear fashion from 2008–2016. To estimate the amount of forest that could have been lost if the project and associated actions by government had not been implemented the difference is calculated between the expected remaining forest cover in 2016, and the amount of forest under this scenario.

Table 4. Annual deforestation rate and remaining forest area from 1988–2013 in the project area

Year/Areas 2 & 3	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Deforestation per year for project area (ha)	23236	2838	1684	2764	2248	3204	2744	1429	5229	3681	2775	6224	5233
Area of forest remaining (ha)	3,114,470	3,111,632	3,109,948	3,107,184	3,104,936	3,101,733	3,098,989	3,097,559	3,092,330	3,088,649	3,085,874	3,079,650	3,074,417

Year/Areas 2 & 3	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Deforestation per year for project area (ha)	4192	5048	6709	2959	884	10416	6640	4312	7911	10533	4241	7761	10092
Area of forest remaining (ha)	3,070,225	3,065,177	3,058,467	3,055,509	3,054,625	3,044,209	3,037,569	3,033,256	3,025,346	3,014,813	3,010,572	3,002,811	2,992,719

Table 5. Estimated rates of deforestation and remaining forest for 2014–2016 in the project area, based on a 5-year mean average

Year/Areas 2 & 3	2009	2010	2011	2012	2013	Total 5 year deforestation	5 year mean average rate	2014	2015	2016
Deforestation per year for project area (ha)	7911	10533	4241	7761	10092	40,537	8,107	8107	8107	8107
Area of forest remaining (ha)	3,025,346	3,014,813	3,010,572	3,002,811	2,992,719			2,984,612	2,976,505	2,968,397

Table 6. Results for the BR 364 from the Reymondin et al. (2013) paper

	Acre	Rondonia
Road construction period	2002–2010	2002–2010
Pre-road deforestation rate (ha/year)	18,700	79,000
Post-road deforestation rate (ha/year)	32,400 (+72%)	113,000 (+43%)
Peak deforestation	2008	2006
Road footprint	20–30 km	20–30 km

Calculating avoided carbon dioxide emissions

REDD+ projects that look to register and sell carbon credits on the voluntary market would be expected to undertake more detailed assessment of expected emission reductions. This is often done using Verified Carbon Standard (VCS) methodology, or methodologies used by other certifying agencies. These can be lengthy and expensive processes. Given that the Sky Rainforest Rescue was established to help tackle deforestation – and its associated emissions – without any trading of carbon credits, we have estimated emission reductions based on the above two methodologies.

For both methods employed above, the area of avoided deforestation is converted into carbon dioxide equivalents by first multiplying it by the estimated average biomass for Acre's forests and then multiplying by a standard carbon conversion factor that accounts for the weight difference between solid carbon and gaseous carbon. Average biomass in tonnes of carbon per hectare is 123 according to Acre state's Plan for the Prevention and Control of Deforestation (PPCD/Acre 2010). This in line with the findings of Salimon et al. (2011) for the state. This value refers only to above-ground biomass. If below-ground biomass were factored in, the estimation of avoided emissions would be higher. The national Climate Policy (Decree 7390 - 2010) states an average biomass of 132.3 tonnesC/ha for above- and below-ground biomass.

This same national policy provides the conversion factor from 1 tonne of stored carbon to tonnes of CO2 emission equivalents as 3.67 (or 44/12) – this is a standard figure based on the relative masses of carbon and CO2 molecules.

RESULTS

Tree numbers safeguarded

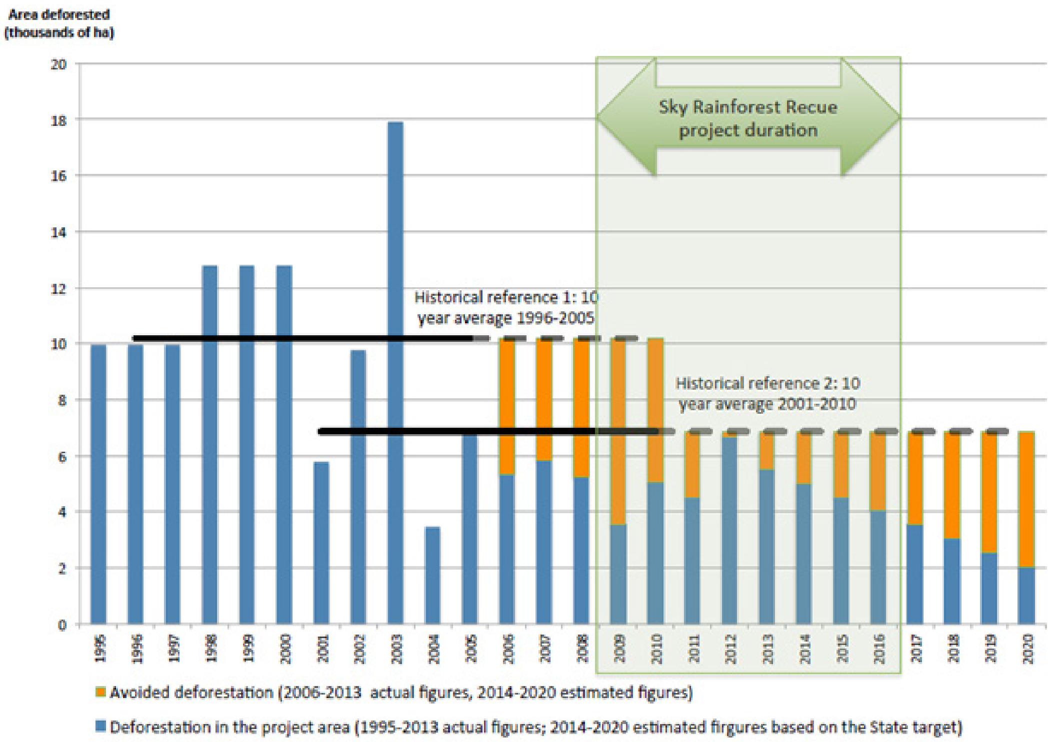
The project area is 3,137,706 hectares, of which 2,992,719 hectares were standing forest in 2013 (2014 data have not been analysed at the time of writing). The current (2013) estimate of trees in the project area is therefore 1,008,546,208 (one billion and eight million). If the extended project area is considered, this figures increases to 1,050,500,427 (one billion and 50 million).[11]

Avoided deforestation and emissions based on the historical baseline and state target method

Using the recorded deforestation data, up to 2013, it has been calculated that 15,654 ha of deforestation has been avoided. The estimated accumulated avoided deforestation from 2009 to 2016 is 22,661 ha. Therefore, the estimated avoided carbon emissions that the Sky Rainforest Rescue project may have contributed to is estimated as 10 million tonnes CO_2 equivalent.[12] Looking further ahead, the accumulated avoided deforestation from 2006 to 2020 is expected to be 53,140 ha (Table 7). Graph 1 shows these calculations more visually.

Table 7. Estimated avoided deforestation in the extended project area (the figures in italics denote estimated rather than recorded data)

Year/extended project area	2009	2010	2011	2012	2013	2014	2015	2016
Avoided deforestation using 1st ref level (ha)	6646	5134						
Avoided deforestation using 2nd ref level (ha)			2343	193	1338			
Estimated avoided deforestation using 2nd ref level (ha)						1837	2336	2835
Accumulated Avoided Deforestation (ha)	6646	11,780	14,123	14,316	15,654	17,490	9,826	22,661



Graph 1. Avoided deforestation based on the historical baseline and state target method, using INPE/PRODES data.

[11] This includes 361,674 additional hectares of forest in the settlement zones. To estimate tree numbers in this area we used a lower estimate of tree number of 116 trees per hectare, to reflect the higher human use and disturbance that these areas may be subject to. This figure is based on the lowest estimate in Salimon et al. (2011) for open canopy forest with bamboo, densely growing.
[12] Calculation: the estimated amount of avoided deforestation during the project's lifetime (22,661 ha (Table 4)) x 123 (carbon in biomass) x 3.67 (CO_2 e) = 10,229 tonnes CO_2 equivalent.

Avoided deforestation and emission based on “without project” scenario

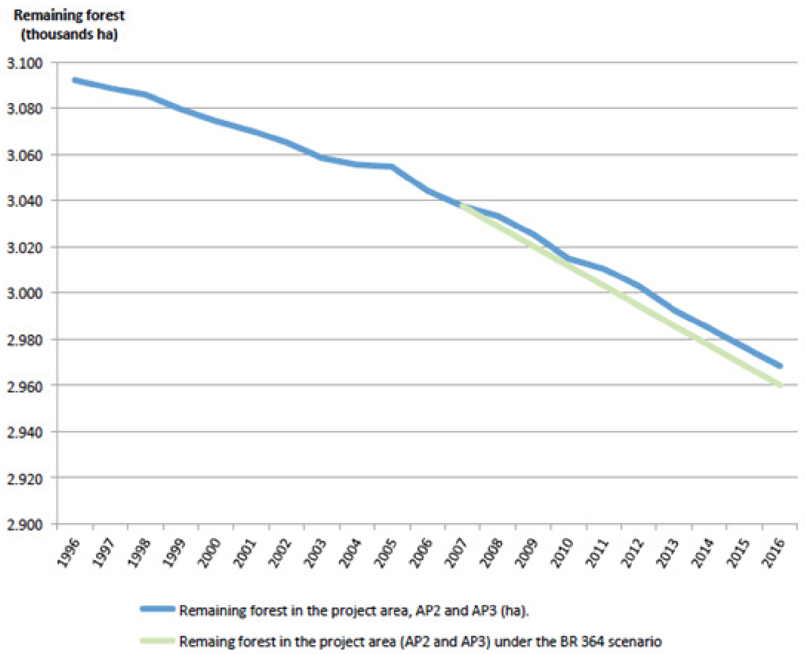
The remaining forest in the project area by the end of 2016 under this scenario would be: 2.96 million hectares (Table 8). Under this scenario the project has helped avoid 8,335 hectares of deforestation (see Table 9).[13] The estimated amount of avoided emissions is 3.76 million tonnes CO_2 equivalent. Graph 2 shows the results of the remaining forest under this scenario compared with the recorded remaining forest until 2013 and the expected amount of remaining forest in 2016.

Table 8. Estimated “without project” deforestation rates for the project area 2008–2016

Year/AP2 & AP3 Areas	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Deforestation per year for project area (ha)	6640	8612	8612	8612	8612	8612	8612	8612	8612	8612
“Without project” area of forest remaining (ha)	3,037,569	3,028,957	3.020.345	3.011.733	3.003.121	2.994.510	2.985.898	2.977.286	2.968.674	2.960.062

Table 9. Comparison of “with” and “without project” scenarios in the project area to estimate avoided deforestation

Project area	“With project scenario” forest loss from recorded monitoring data (UCEGEO) and expected loss in 2014–2016 (ha).	“without project” scenario (ha)	Difference: estimated avoided deforestation (ha)
Estimated forest cover in 2016 under the two scenarios	2,968,397	2,960,062	8,335



Graph 2. Remaining forest for the project area for the “with” and “without” project scenarios.

[13] 8,335 ha of avoided deforestation would equate to 2.8 million trees.

DISCUSSION

Comparing the methods

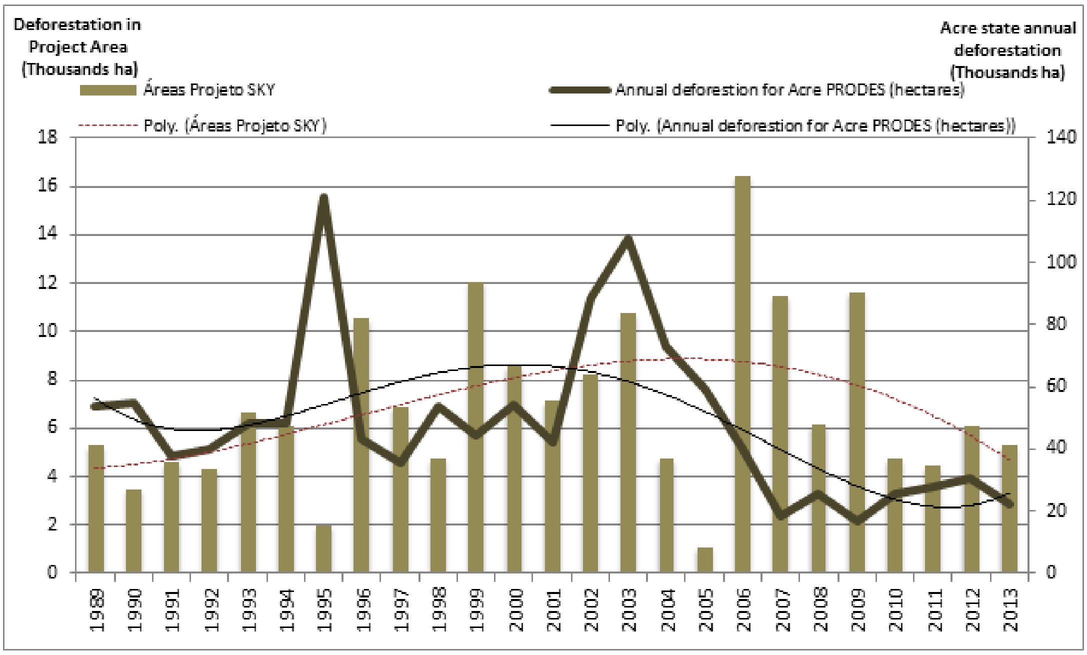
The two approaches described above differ significantly in their methodology. They also draw on different remote sensing data sources. For the first approach we have looked at the extended project area, and for the second approach we have focused on the main project area. The timeframe used for the first approach is 2009–2016, while for the second approach it is 2008–2016. In both cases we have made assumptions about the likely rate of deforestation that will occur until 2016, which is the end of the funding period for the Sky Rainforest Rescue partnership.

Under the first approach, we can assess the overall estimated amount of avoided deforestation towards which the project contributes. This is 226.6 km^2 or 22,660 hectares. It is not possible, within this overall amount, to assess the comparative scale of the project's influence. The project is one of a complex set of factors operating in that landscape during that period of time. As the project is conducted in partnership with the state government, we count a large portion of government action as part of the initiative as it is part of a coordinated effort between various government departments and donors towards the same set of goals. However, there are other government-led actions that are operating in the area that are outside of the scope of the partnership, such as work funded by the Inter-American Development Bank (IDB) on the sustainable development programme of the Acre government.

The second approach helps us get closer to assessing the amount of avoided deforestation that is attributable to the project's actions. Here, we can see the dynamic that has resulted from the paving of other sections of the same road, within the same state, and within broadly the same political and socio-economic conditions. We have used only the findings of Reymondin et al. (2013) for the BR 364 in Acre state, to avoid exaggerating the scenario by including the more severe deforestation dynamic seen in Rondonia state, given that they suggest that Acre has more favourable and effective conservation policies being implemented. Under this scenario, the avoided deforestation is 8,335 hectares.

For the scenario, we applied a linear rate of change in deforestation. In reality, we know that there is annual variation in rates, with peaks and troughs that can be caused by a number of factors, such as cloud cover on the earth observation images, which mask changes in one year that are then detected in a future year, climatic influences where deforestation may increase in dry years, and annual variations in the rate of clearance due to social, economic and political causes. As it is impossible to predict these yearly variations, we assume the linear rate reflects the general trend over multiple years.

To illustrate the annual variation observed, Graph 3 shows the historical dynamics of deforestation in the project area and that of the state from 1989 to 2013 (INPE-PRODES data). The graph shows that there was initially a similarity in the trend lines between the state and the project area, followed by an increase in the project area compared with the state between 2006 and 2009, followed by a downward trend from 2007. It should be noted that the jump seen in 2006 in the project area data set may be in part due to deforestation from 2005 only being captured in 2006. 2005 was a severe drought year, with many fires causing cloud cover, which could mean that deforestation was not recorded in that year but was registered in the following year's figures. We suggest that the period of 2005–2007 is the period when the project area started to become more sensitive to the various road section improvements made to the BR 364 from Cruzeiro do Sul to Rio Branco that occurred at different times from this period until the present.



Graph 3. Deforestation dynamics in Acre state and the project area from 1989 to 2013, using INPE-PRODES data (poly = poly coordinate trend line, i.e. a trend line that moves at 4 points to show a curved trend line)

Reymondin et al.'s original research was done using terra-I and these data are then used to inform a trend that is applied to UCEGEO data from the project area. These two different data sets use different remote sensing techniques and also define deforestation in different ways. Inevitably this produces different results in terms of the amount of deforestation detected in any one place and in any one year, although they may show similar trends. We have tried to remove the uncertainties of these different data sets by taking the percentage rate of change and applying this consistently to our data. We assume that the trends detected in the source data could hold true in our "with-project" dataset.

Given the challenges of predicting what might have happened without the project's existence, we examined three other possible scenarios that are laid out in the annex. One of these scenarios[14] generates what was considered to be an exaggerated amount of avoided deforestation, so – excluding this case – the amount of avoided deforestation and emissions range from 8,335 to 21,977 hectares and 3.76 to 9.92 million tonnes CO2 equivalent, respectively. The scenario presented in the body of this paper is considered to be the most robust, and is also the most conservative in its results. Under all the "without project" scenarios, the estimated number of trees would have fallen below one billion.

WWF will continue to monitor deforestation trends in the project area. This longer-term monitoring is crucial to understand trends, as year-on-year variation can be high and the data can be compromised by cloud cover in any one year.

Supporting jurisdictional REDD+

It is important to note that the Sky Rainforest Rescue project is not a carbon offset project. It was established to help implement and inform Acre State's jurisdictional policy on valuing ecosystem services (SISA). WWF supports jurisdictional REDD+ initiatives over isolated project-based initiatives. Jurisdictional/subnational REDD+ works on sizable, subnational landscapes, at a number of intersecting and mutually reinforcing scales of intervention, with a focus on building capacities, safeguards and engagement for REDD+ from the bottom up. With this approach, REDD+ can be implemented and tested on a scale that is biologically meaningful, because it can contain intact ecosystems, and socially and politically meaningful, because it aligns with recognised jurisdictions, such as government-designated provinces, departments or districts. At this scale, REDD+ can be effectively managed by or with existing national and subnational administrations to conserve some of the world's most important landscapes (WWF-International 2013). WWF therefore views it as important that organisations working on the ground add their support to this state-wide approach.

[14] The "deforestation front" scenario.

Going beyond a billion trees

It should be noted that the overall impact of Sky Rainforest Rescue is expected to be much larger and broader than that reported in this paper. The project is currently assisting the Acre state government to develop its other programmes under SISA that look to go beyond carbon to include ecosystem services relating to freshwater and biodiversity. An example of how these programmes may help to strengthen a sustainable forest economy is the subsidy paid to rubber tappers in recognition of their role as stewards of the rainforest, in which role they help safeguard the ecosystem services that the forest provides as they go about their daily round of tapping wild rubber. Further analysis is ongoing on the social and environmental impacts of the project, and land-use changes at the property level. A full report on the achievements of the Sky Rainforest Rescue partnership will be available in 2016.

About a quarter of the funds raised through the Sky Rainforest Rescue campaign are being used to support work in other parts of the Amazon, for example to address drivers of deforestation such as road development in Colombia and Bolivia and to improve cattle ranching practices in Amazonas state, Brazil. We do not have a monitoring system that allows us to say what the combined effect of these geographically distinct initiatives is on tree numbers safeguarded and deforestation avoided, but the initiative will certainly contribute to a larger overall impact than that estimated for the Acre project area alone.

The project is also helping inform and influence policies in Brazil that impact on the Amazon. For example, it has funded WWF's convening role in bringing together key stakeholders to generate recommendations for Brazil's national payments for environmental services law. Lessons from Acre have been important for this national process. From these discussions, a series of recommendations has been published to help strengthen this important proposed national policy (WWF-Brazil 2014).

The work begun in Acre in 2009 through the partnership will not come to an end in 2016. WWF plans to continue supporting key areas of work in the project area and to influence state policy, to ensure the long-term sustainability of the processes initiated. We therefore expect the benefits and impacts of the project to endure and expand in the future.

CONCLUSION

This paper aims to provide transparency around the estimated results that WWF and Sky communicate in relation to the Sky Rainforest Rescue flagship project area in Brazil's Acre state. This centres on the estimated number of trees being safeguarded, the estimated amount of deforestation avoided and the project's contribution to avoiding carbon dioxide emissions. To do this, we have employed two simple but conservative approaches.

From the first method, we estimate that 22.6 thousand hectares of deforestation will have been avoided, along with an associated 10 million tonnes CO_2 equivalent of emissions by 2016, if deforestation trends are on track in the project area to meet the Government's target of 80% reduction by 2020, compared with the historical baselines. While the project's impact will have helped contribute to this amount, this methodology does not necessarily tell us the scale of its contribution. From the second methodology, which provides a possible "without project" scenario, we estimate that the avoided deforestation attributable to the project by 2016 will be 8.3 thousand hectares and 3.76 million tonnes CO_2 equivalent of avoided emissions.

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ANNEX: OTHER SCENARIOS EXPLORED

In addition to the paper by Reymondin et al. (2013), which we refer to in this annex as the BR 364 scenario, we looked at three other sources that could help indicate a "without-project" scenario. The first of these is the much cited 2006 modelling paper by Soares-Filho et al., which has an additional case study on the area of influence of the interoceanic highway. The second is a recent publication from WWF's Living Amazon Initiative on deforestation fronts in the Amazon. The third is INPE/ PRODES data giving the state average deforestation rate for Acre.

Modelling scenario

In 2006 Soares-Filho et al. (2006a) published a much cited paper on modelling conservation in the Amazon basin. Supplementary to this paper is a case study[15] (Soares-Filho et al., 2006b) using the model SimAmazonia 1 to project deforestation trends following the paving of the interoceanic highway that connects Acre to Peru and the BR 364 in Acre. The model uses data from prior to 2006 to project to 2030 and 2050.

The technical paper (Soares-Filho et al., 2006b) that supports this landmark study, ran the SimAmazonia 1 model for three particular areas to give more detailed analysis for 2030 and 2050. The model was run under four possible scenarios of varying levels of governance. The case study for the area of direct influence of the paving of the interoceanic highway and BR 364 is shown in Map A1, and the results for the different scenarios can be seen in the map as well as in Table A1. This area includes all of the state of Acre and neighbouring parts of the Amazon.

For our scenario, we used the paper's own BAU scenario for 2030, as both the interoceanic highway and the BR 364 have been paved. Although the BAU case in the paper includes the section of the BR 364 that passes through the project area, the case study does not assume that the part of the BR 364 in the project area is paved, but rather looks at the influence of two other roads on the region's deforestation dynamics.

For our scenario, the difference was calculated in the model's deforested area for the period 2003–2030 (7,932,500 ha), and divided by the intervening number of years (23) to get the average area lost each year over this period of time (293,800 ha/year). To convert this into a percentage of the area, the annual average was divided by the area covered by the analysis (the sum of deforested, forest and non-forest in the table is 91,022,900 ha). This gives a percentage of 0.32% decrease in forest cover per year. If we apply this figure to the project area, it represents 10,128 ha/year of deforestation. This is then projected in a linear fashion to the years 2008–2016, as shown in Table A2. Therefore, the projected remaining forest in the project area by the end of 2016 under this scenario (modelling) would be 2.95 million hectares.

[15] The model is described in detail in the supplementary notes that are available with the paper: http://www.nature.com/nature/journal/v440/n7083/suppinfo/nature04389.html#close

Table A1 . Results for the interoceanic highway case study from Soares-Filho (2006b) expressed in hectares

	Landscape, 91,022,900 ha total area			Average deforestation per year from 2003 to 2030 (27 years) and 2050 (47 years) has.		Annual deforestation as a percentage of total area	
	2003	2030	2050	2030	2050	2030	2050
	BAU, Interoceanic Highway paved in 2008						
Deforested	3,304,400	11,236,900	21,240,000	11,236,900-3,304,400 = 7,932,500/27 = 293,800	500,200	0.32%	0.55%
Forest	81,729,900	73,826,300	63,823,200	7,903,600	10,003,100	8.68%	10.99%
Non-forest	5,988,600	5,959,700	5,959,700				
	Historical trend, no further road paving						
Deforested	3,304,400	9,477,300	17,985,600	228,600	425,400	0.25%	0.47%
Forest	81,729,900	75,585,900	67,077,600	6,144,000	8,508,300	6.75%	9.35%
Non-forest	5,988,600	5,959,700	5,959,700				
	Governance plus extensive road paving						
Deforested	3,304,400	8,853,500	11,767,300	205,500	145,700	0.23%	0.16%
Forest	81,729,900	76,209,700	73,295,900	5,520,200	2,913,800	6.06%	3.20%
Non-forest	5,988,600	5,959,700	5,959,700				
	Governance no further road paving						
Deforested	3,304,400	7,870,600	10,658,700	169,100	139,400	0.19%	0.15%
Forest	81,729,900	7,7192,600	74,404,500	4,537,300	2,788,100	0.00%	0.00%
Non-forest	5,988,600	5,959,700	5,959,700				

Map A1. Area and results for the Interoceanic highway case study from Soares-Filho (2006b)

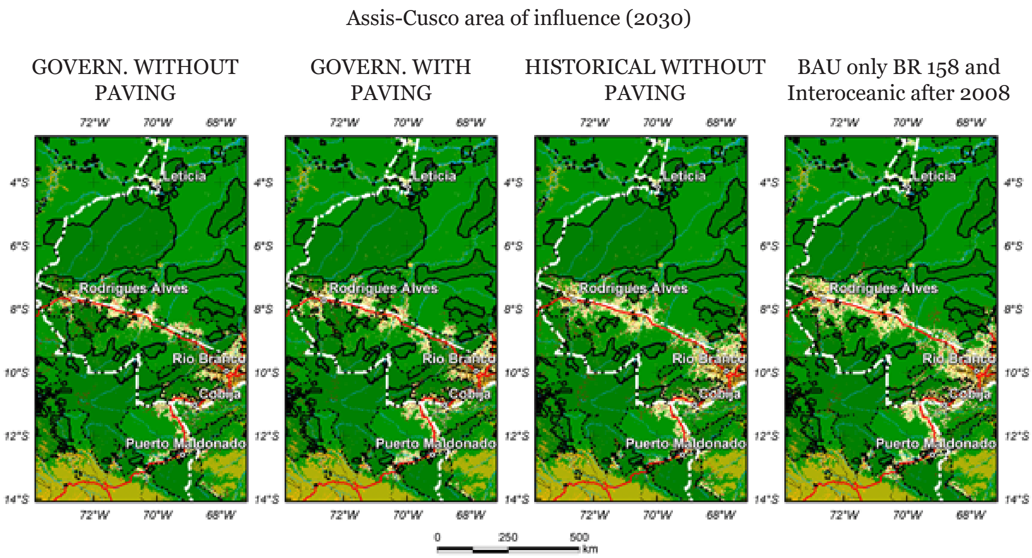


Table A2. Annual deforestation rate and remaining area of forest under the modelling scenario

Year/Areas 2 & 3	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Deforestation per year for project area (ha)	6640	10,128	10,128	10,128	10,128	10,128	10,128	10,128	10,128	10,128
Area of forest remaining (ha) Modelling scenario	3,037,569	3,027,441	3,017,313	3,007,186	2,997,058	2,986,930	2,976,803	2,966,675	2,956,548	2,946,420

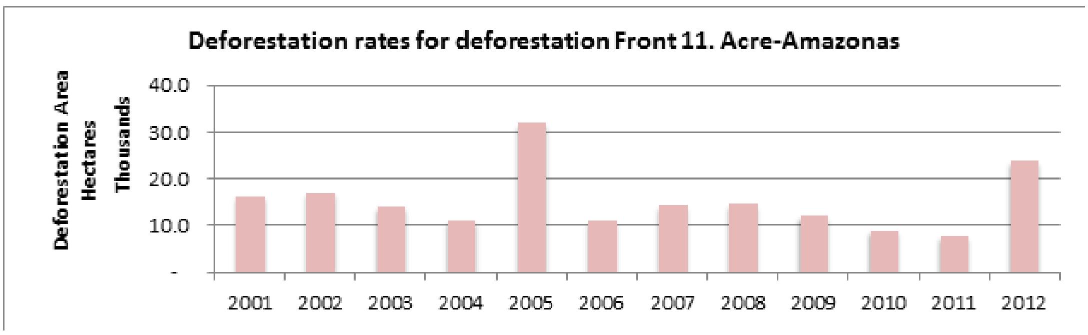
Deforestation front scenario

In December 2014, WWF's Living Amazon Initiative published a preliminary summary on deforestation fronts in the Amazon region. This identified 25 active fronts across the Amazon biome that act as pressure points for expanding deforestation in the Amazon. One of these fronts is in Acre, along the two main highways, and overlap in part with the Sky Rainforest Rescue project area. Front 11 is situated along the BR 364 where major navigable rivers meet with the road in the area of Tarauacá. It covers an area of 3,114,500 ha. The deforestation rate for this front was calculated using Global Forest change open source data supported by Maryland University, for the period 2001 to 2012.

There were two notable peaks in the data; 2005 and 2012. Looking at the history of the BR 364 these are one year after two key road improvements; paving and connection of Tarauacá with Cruzeiro do Sul in 2004 and the finalisation of two bridges along at Rio Tarauacá and Rio Jurapuri in 2011. These peaks show a jump of approximately 200% with respect to the previous year. This indicates non-linearity in the deforestation dynamics along the BR 364 that could be, in part, associated with road improvements, which we have not considered in our scenarios where we use a linear projection. However, there were also severe droughts in the state in 2005 and 2010 and it is not sure how they also impact on the area of the front, if at all.

The study found that the average mean annual deforestation rate for the area was 15,400 ha/year (Living Amazon Initiative 2014), which as a percentage of the total area of front 11 (31,14500 ha) is 0.49%. If this percentage is applied to the project area this would give an equivalent deforestation rate of; 0.49% of 3,137,706 ha = 15,515 ha/year.

The remaining forest for the project area is then calculated the same way as in the previous scenario, giving us the following results for 2008 to 2016. Therefore, the remaining forest in the project area by the end of 2016 under this scenario (deforestation front) is 2.90 million hectares.



Graph A1. Deforestation rates (2001–2012) for Front 11 from WWF Living Amazon Initiative (2014)

Table A3. Annual deforestation rate and remaining area of forest under the deforestation front scenario

Year/Areas 2 & 3	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Deforestation per year for project area (ha)	6640	8612	8612	8612	8612	8612	8612	8612	8612	8612
Area of forest remaining (ha) deforestation front scenario	3,037,569	3,022,169	3,006,769	2,991,369	2,975,969	2,960,569	2,945,169	2,929,769	2,914,369	2,898,969

INPE/PRODES Acre state average 2001–2010

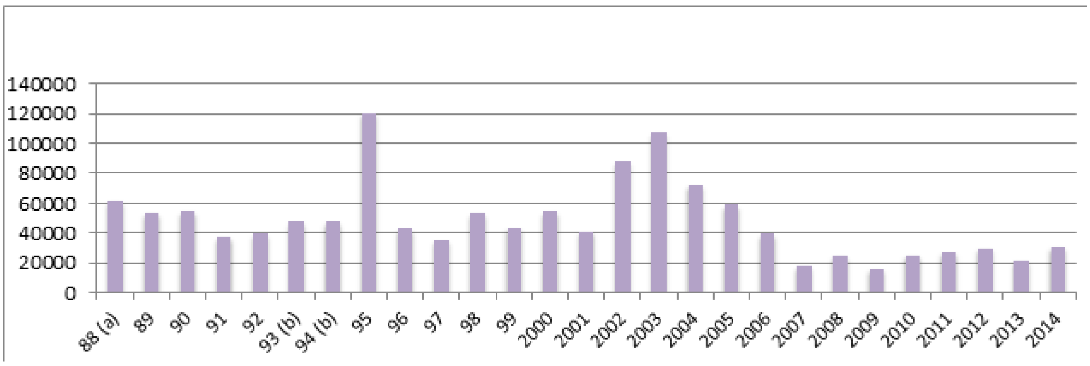
For this scenario we use Brazil's official state-wide average deforestation rates for Acre (INPE/PRODES data) which are publicly available from 1988 to 2014 (where 2014 is still a provisional estimate). See the results below for Acre.

We take a 10-year average deforestation rate from 2001 to 2010 – as a percentage of Acre's size – and apply it to the project area to give an overall sense of what would happen under "average" state deforestation. Table A4 gives the annual state deforestation rate for the calculation of the 10 year average. The total area of Acre state is 16,420,000 ha (Acre state statistics 2013) so as a percentage of the total state the mean 10 year average deforestation rate is 0.3%. If this percentage rate is applied to the project area we get an annual deforestation rate of:

0.3 x 3,137,706 ha = 9,482 ha/year

The remaining forest for the project area is then calculated the same way as in the previous scenarios giving us the following results for 2008 to 2016 (Table A5).

Therefore, under this scenario (Acre state average) the remaining forest in the project area by the end of 2016 would be 2.95 million hectares.



Graph A2. INPE/PRODES annual deforestation rate for Acre state 1988-2014 (ha)

Table A4. INPE/PRODES 2001–2010 annual deforestation rate for Acre state and 10 year average

Year/Acre state	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	10 year total	10 year average
Deforestation per year for Acre state	419	883	1078	728	592	398	184	254	167	259	4962	4962/10 = 496

Table A5. Annual deforestation rate and remaining area of forest under the Acre state average scenario

Year/Areas 2 & 3	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Deforestation per year for project area (ha)	6640	9482	9482	9482	9482	9482	9482	9482	9482	9482
Area of forest remaining (ha) Acre average scenario	3,037,569	3,028,087	3,018,605	3,009,123	2,999,641	2,990,159	2,980,677	2,971,195	2,961,713	2,952,231

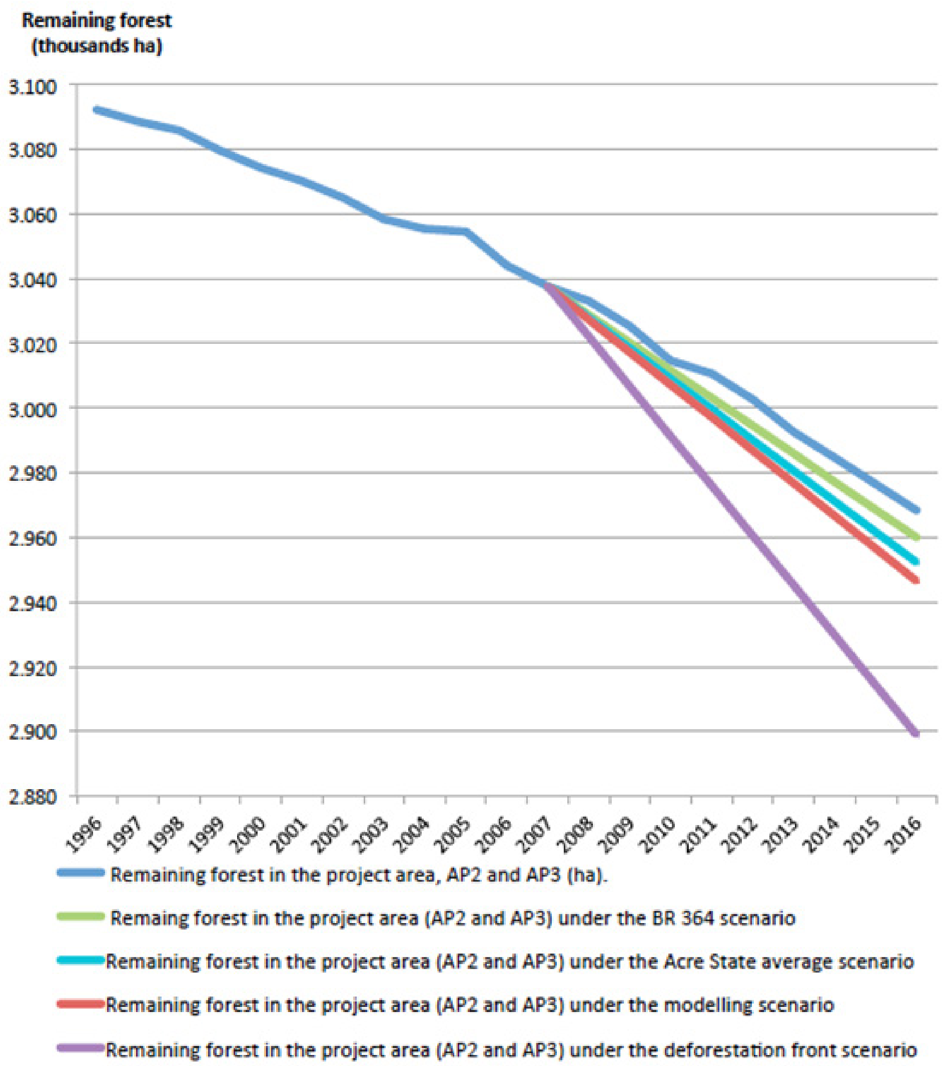
Summary of the results for the four scenarios

Graph A3 shows the results of the remaining forest under the scenario presented in the main paper and the three scenarios in this annex compared with the recorded deforestation until 2013, and the projection for the remaining forest until 2016.

The scenarios vary in their results but form an envelope of possible "without project" scenarios that enable comparisons with the actual observed trends. The remaining amount of forest, estimated number of trees, estimated avoided deforestation and carbon dioxide emissions for each case is given in Table A6.

Table A6. Comparison of the results of each scenario with recorded and expected data

Project area	"With project" scenario forest loss from recorded monitoring data (UCEGEO) and expected loss in 2014-16	"Without project scenarios"			
		BR 364 scenario	Modelling scenario	Deforestation front scenario	Acre state average scenario
Estimated forested area in 2016 (ha)	2,968,397	2,960,062	2,946,420	2,898,969	2,952,231
Estimated Avoided deforestation (ha)		8,335	21,977	69,429	16,166
Estimated tCO2 emissions from avoided deforestation		3,762,471	9,920,844	31,340,846	7,297,480



Graph A3. Remaining forest in the project area for the “with” and four “without project” scenarios.

Main assumptions, strengths and limitations

Table A7 provides a summary of the main characteristics, assumptions, strengths and limitations for each of these four scenarios. Table A8 compares the different remote sensing methods these scenarios and data sets are based on.

There are some assumptions that apply to all of these. As described in the main paper, we have applied a linear rate of deforestation to capture multi-year trends.

Different data sources are used for each of the original data sources: modelling, terra-I, Global Forest Change and PRODES. PRODES, UCEGEO and terra-I use different remote sensing techniques and also define deforestation in different ways that can produce different results in terms of the amount of deforestation detected in any one place and in any one year, although they may show similar trends. To reduce the possible influence of these differences, the percentage deforestation per area for each case was calculated for the estimates and applied to the project area, giving a new average area deforested per year, which was then applied to UCEGEO annual deforestation data from 2008. It is assumed that by using percentage rates, the variations between these four methods would have been reduced to the minimum.

It was assumed that significant deforestation dynamics due to each of the case conditions were expected to occur from 2008 in all cases. There are a variety of key dates relating to road infrastructure development that may affect each of the scenarios. The year 2008 was chosen for consistency and because some significant road improvements and connections correspond to this date, which are all assumed to affect all four scenarios in the same way.

A matching sample approach is recommended in order to compare “without project” scenarios with the measured and expected deforestation dynamics (Margoluis et al. 2009). The socio-political conditions as well as the ecological conditions are equally as important to match in this type of approach; however, in some ways the former are more difficult to mirror, especially within the Amazon biome, due to different governance and socio-economic contexts at municipal, state and country levels. It was assumed that by taking cases looking at deforestation rates from within Acre state that contained the BR 364 within their area, the socio-economic and political conditions of the project area would be as similar as possible. However, the disadvantage with this approach is that some of the areas for comparison identified may also contain the project area itself in the deforestation rates presented by each. Therefore using the same area to define itself could introduce a type of double counting error. This type of error is present in each case but to different degrees. Given that the Acre policy context is known to be different compared with its neighbouring areas, it was felt that these errors were smaller and acceptable in comparison to using examples and cases from different states or countries with the same ecological conditions.

With the exception of the deforestation front scenario, the other three are based on significantly larger areas than the Sky Rainforest Rescue project area. Each one will include a range of conditions and deforestation dynamics.

Having compared and contrasted these four possible scenarios, we considered that the scenario based on the study by Reymondin et al. (2013) was the most adequate to use for our “without project” calculations of avoided deforestation. It also happens to be the most conservative of the four scenarios. The most extreme scenario was the deforestation fronts one, which while being similar in size to the project area, we discarded due to it not being very comparable to the project area in terms of population density. The modelling scenario can be considered less robust due to the wide area covered by the case study and the fact that it was generated at a time of peak deforestation across the Brazilian Amazon. The Acre state average scenario provides a useful comparison, but is considered to be less robust that the BR 364 scenario as it includes a large diversity of conditions that can be found across the state.

Table A7. Main characteristics, assumptions, strengths and weaknesses for each scenario

Scenario and source	Main characteristics of the source information	Main assumptions for use as a "without project" scenario for the Sky Rainforest Rescue project
BR 364 Scenario (Reymondin et. al. 2013)	Analysis of road development impacts associated with IDB loans, including sections of the BR 364 in Acre. The Terra-I remote sensing methodology used is a near-real-time monitoring system that employs satellite-based rainfall and vegetation data. It detects disturbances that may be attributed to human activity by identifying changes in the greenness of landscapes that deviate from baseline values. Timeframe: 2004 to 2011	The trend of a 72% increase in deforestation rate following road paving is representative of what could have happened along the BR 364 in the project area from 2008 onwards.
Modelling scenario (Soares-Filho et al. 2006b)	A model of the Amazon (SimAmazonia 1), which models different scenarios including low governance and the potential impact of road paving on the Amazon basin forest cover. PRODES is used as the input source for Brazil Legal Amazon. Area covered: 91 million hectares Timeframe: 2003 start data for 2030 and 2050 projection case study for the Interoceanic highway.	The model adequately predicts deforestation associated with road improvements and the "BAU" characteristics defined in the interoceanic highway case study would hold true to a "without project" scenario in the project area from 2008 onwards.
Deforestation front scenario (WWF Living Amazon Imitative 2014)	Analysis of deforestation fronts in the Amazon biome uses Global Forest Change data supported by Maryland University. 25 deforestation fronts were identified, one of which includes two towns in Acre and a river that traverses the project area and the state border with Amazonas state. This area is referred to as Deforestation Front 11. The study calculates the mean average deforestation per front. Area covered: 3.1 million hectares Timeframe: 2001 to 2012	The trend in deforestation seen in this deforestation front is representative of what could happen in the project area from 2008 onwards. This assumption is unlikely to hold true, given the density of population in front 11, which is representative of some – but not all – of the project area.
Acre state average scenario (www.inpe.br)	PRODES data from Acre state downloaded and analysed. The 10 year mean average deforestation rate was calculated for Acre state. Area covered: 16.4 million hectares Timeframe of the complete data set: 1988 to 2014, 10 year average calculated from 2001 to 2010	Acre state average deforestation (which includes a wide range of contexts, from roads, colonised and uncolonised rivers, protected areas and indigenous lands, etc) presents a realistic business as usual view of what deforestation trends in the project area could be, from 2008 onwards.

Strengths	Limitations
A recent study of the actual impacts of road paving along sections of the same road that traverses the project area. Identifies the mean average deforestation rate before the road is paved and after it is paved.	Although the area of the BR 364 that passes through area 3 was not fully paved by the end of this study, it is included in the study and in its calculation of mean average deforestation rate. Therefore “double counting” could have occurred and thereby may reduce the validity of this approach.
The source information is a case study that covers Acre and includes the BR 364. Well cited paper; Soares-Filho et al. (2006a) considers BAU case with clearly defined parameters associated with the two roads (excluding the effect of any improvements on the BR 364 for the case study). Uses PRODES data.	Case study area covers a large area (including all of Acre state) so will encompass a wide range of contexts that are different to the project area. It was designed to look at trends at scale across the Amazon and therefore may not be that good at predicting changes at finer scales. The model was developed during a period of peaking national deforestation rates and does not take account of recent policy initiatives to curb deforestation in the Brazilian Legal Amazon.
A recent study that considers a deforestation front that is located between areas 2 and 3 and contains the BR 364. Two peaks in the deforestation data for this front show a degree of sensitivity that seems to correlate to road improvements in the area.	The Maryland open data includes Amazon data sets that are known to over-estimate deforestation rates when compared with PRODES. The area considered for deforestation front 11 also includes part of the project area; therefore, the mean average deforestation rate could be considered as double counting. The deforestation front includes a large proportion of settlements that are known to have more intense deforestation dynamics than Areas 2 and 3.
PRODES is Brazil’s official data set for the legal Amazon. The state average incudes a range of contexts – as does the project area contain a range of contexts.	The project area is included in the annual state deforestation rates, therefore it double counts the deforestation effect along the BR 364.

Table A8 . Comparison of the different methodologies used by the sources discussed above[16]

Date Source	Data used in Deforestation Front Analysis	
	Global Forest Change supported by University of Maryland -Google tree cover loss	Global Forest Change supported by University of Maryland - Forma Alerts
Function	Identifies areas of tree cover loss	Detects areas where tree cover loss is likely to have recently occurred
Resolution/ scale	30 x 30 m	500 x 500 m
Geographic coverage	Global land area	Humid tropical forest biome
Source Data	Landsat 7 ETM+	MODIS
Frequency of updates	Annual	Displayed on the Global Forest Watch site as monthly alerts, but available for download in 16-day increments
Date of content	2001–2012	2006–present
Tree Cover Density	Varies according to selection	For the purpose of Global Forest Change study, “tree cover” was defined as areas with greater than 25% canopy cover (as determined by the Vegetation Continuous Fields data set), and change was measured without regard to forest land use. Tree cover assemblages that meet the 25% threshold include intact forests, plantations, and forest regrowth.

[16] Information on the first three types of data sources in this table was obtained from Global Forest Watch website, 27 March. Please see the following link for more details on these: http://www.globalforestwatch.org/sources/forest_change?t=umd_tree_loss_gain

Terra-I Alerts	PRODES	UCEGEO
Detects areas in Latin America where tree cover loss is likely to have recently occurred	New areas of 100% deforestation greater than 6.25 ha	100% deforestation for areas greater than 0.54 ha
250 x 250 m	20 to 30 m	20 to 30 m
Latin America	Brazil legal Amazon	Acre state
Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices and water body presence data; Tropical Rainfall Measuring Mission (TRMM) precipitation data	Landsat-TM 5, were frequently used historically, more recently images CCD of CBERS-2 and of CBERS-2B. Images LISS-3, India's satellite and Resourcesat-1, and UK-DMC2	Landsat 5TM Same images used by PRODES
Monthly	Annual rates An estimated rate is provided in December of the same year and final values are presented in the first three months of the following year.	Annual rates (unpublished)
2004–present	2002–present	1998–present

Caution	For the purpose of Global Forest Change study, "tree cover" was defined as all vegetation taller than 5 m in height. "Tree cover" is the biophysical presence of trees and may take the form of natural forests or plantations existing over a range of canopy densities. "Loss" indicates the removal or mortality of tree canopy cover and can be due to a variety of factors, including mechanical harvesting, fire, disease, or storm damage. As such, "loss" does not equate to deforestation.	The algorithm behind the FORMA alerts is constantly evolving to fix bugs and improve accuracy. As a result, what appears on the site and the results of analyses conducted on the site may change over time. It is important to always include the access date when citing FORMA. FORMA is designed for quick identification of new areas of tree cover loss. The system analyses data gathered daily by the MODIS sensor, which operates on NASA's Terra and Aqua satellites. The FORMA alerts system then detects pronounced changes in vegetation cover over time, as measured by the Normalized Difference Vegetation Index (NDVI), a measure of vegetation greenness. These pronounced changes in vegetation cover are likely to indicate forest being cleared, burned, or defoliated.
References and weblinks	Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. (2013). "Hansen/UMD/Google/USGS/ NASA Tree Cover Loss and Gain Area." University of Maryland, Google, USGS, and NASA. Accessed through Global Forest Watch. www.globalforestwatch.org.	Hammer, Dan, Robin Kraft, and David Wheeler. (2013). "FORMA Alerts." World Resources Institute and Center for Global Development. Accessed through Global Forest Watch. www.globalforestwatch.org.

Given the lack of ground-based data, the methodology was validated using data from other forest monitoring systems such as PRODES (http://www.obt.inpe.br/prodes/index.php) which have been validated separately. The Terra-i algorithm for change detection does not automatically identify events that occurred because of wild fires or within secondary forests or oil palm plantations. Furthermore, the moderate resolution of the MODIS sensor does not detect small scale events (<5 ha). Terra-i is intended to be used to quickly identify deforestation hotspots which should then be more thoroughly investigated with higher resolution imagery or field validation.	6.25 ha mappable areas 1998 to 2002 used a different methodology	0.54 ha mappable areas 2005 analysis was estimated
Reymondin, Louis, Andrew Jarvis, Andres Perez-Uribe, Jerry Touval, Karolina Argote, Julien Rebetez, Edward Guevara, and Mark Mulligan. (2012). "Terra-i alerts." CIAT-Terra-i. Accessed through Global Forest Watch. www.globalforestwatch.org.	http://www.obt.inpe.br/prodes/index.php	National institute of space research (INPE). Monitoring the Amazon forest cover by satellite 2008. Available at http://urlib.net/sid.inpe.br/mtc-m18@80/2009/04.28.13.43 > Accessed 25 September 2014.

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