Risk based methodology for assessing avoided deforestation with application in ICF forest programmes in Brazilian Cerrado

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1 INTRODUCTION

The International Climate Fund (ICF) was set up by the UK government in 2011 with the aim of working in partnership with developing countries to reduce carbon emissions through promoting low carbon development, to help the world's poorest people adapt to climate change and reduce deforesation.

Forest activities funded under ICF should support developing country actions on Reducing Emissions from Deforestation and forest Degradation (REDD) and contribute to low carbon growth that reduces poverty. An improved understanding of forest areas at risk as well as historic and ongoing deforestation likely to occur in the absence of conservation interventions is important in deciding how to target interventions and how to evaluate the impact of conservation measures in terms of avoided deforestation.

The following risk-based method takes advantage of earth observation data and geospatial information products and has been devised to apply to large scale programmes in areas where broadly similar processes, legal and institutional constraints play out across forest ecosystems.

The output of the method is an estimate of avoided deforestation derived from the amount of expected forest loss within an area over a 20 year period versus observed annual forest loss. Expected loss is estimated by applying an ACEU - type[1] risk model which assumes that land areas are at greater risk of deforestation and degradation if they are easily Accessible, are suitable for Cultivation, have an Extractable value, and are Unprotected. The methodology does not provide a prediction of future forest loss but assigns relative risk values, based on the ACEU criteria.

Each of the four ACEU parameters are defined and assigned a level of risk based on assessments of region-specific drivers of forest loss and land use change. 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 method was assessed for feasibility in 3 ICF project areas with markedly different forest types and drivers of land use change in southern Ghana, Terai and Churia in Nepal and Brazilian cerrado. This document describes the methodology used to produce a risk of deforestation map in each of these areas.

An important part of this work was in defining forest extents in each region, identifying drivers of forest loss in consultation with local experts and assessing the quality and availability of data. It is suggested

[1] The ACEU risk model determines an overall level of risk as the product of the risks associated with each of the four ACEU parameters: A = Accessible – local actors able to reach the area (RA); C = has Cultivable value – land can be used for subsistence or commercial crops (RC); E = Extractable Value – forest biomass has economic value (RE), U = Un/Protection Status – land tenure regime does not prevent extraction or conversion (RU). Risk is calculated as: RISK FACTOR = (RU)+ (RC)+(RE)+ (RA)

that the risk maps may be updated in the future, to take account of new risks and changes to the understanding of drivers.

2 DESCRIPTION OF STUDY AREA

An area of 77 835 133 ha within the Cerrado biome in the states of Bahia, Tocantins and Goiás was chosen for the risk analysis because of the presence of ICF projects in Bahia, on the boundary to Tocantins & Goias.

3 DEFINING CERRADO FOREST EXTENTS

The first step for mapping risk of deforestation, is to identify the forest extent within the study area. To determine the extent of Cerrado forest and woodland within the study area, several forest cover datasets were investigated, including the 2010 JAXA forest/non-forest 25m product[2] and the MODIS VCF percentage tree cover dataset[3]. We chose to produce the final risk map using the forest extent as represented by the Global Tree Canopy Cover (Hansen et al, 2013) and PROBIO 2002 datasets (see below). The first was chosen because the ICF Avoided Forest Loss methodology is based on a comparison of estimated and observed forest loss, and the Hansen et al data gives both forest extent and observed forest loss. We included the PROBIO dataset because it was locally produced specifically for Cerrado vegetation.

A. Global tree canopy cover for the year 2000, produced by Hansen et al (2013)[4] was used to determine Cerrado forest vegetation areas according to Brazil's minimum canopy cover of 30% and minimum area requirement of 1 ha for forests. To extract areas defined as forest according to the official Brazilian definition, the percentage canopy cover pixels were resampled to 1 ha by averaging the original 30 m pixel values within a 1 ha area. All pixels with more than or equal to 30% canopy cover were defined as Cerrado forest areas. This represented forest extent for 2000; to adjust the forest cover extent to 2013, the *Hansen et al (2013) Global forest cover loss (2000-2012)*[5] data was subtracted from it. Figure 1 shows the resulting forest extent map, of which Cerrado forest extent totals 22 309 120 ha.

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[2] Masanobu Shimada, Takuya Itoh, Takeshi Motooka, Manabu Watanabe, Shiraishi Tomohiro, Rajesh Thapa, and Richard Lucas, "New Global Forest/Non-forest Maps from ALOS PALSAR Data (2007-2010)," Remote Sensing of Environment, accepted April 4, 2014 DOI=10.1016/j.rse.2014.04.014. http://www.eorc.jaxa.jp/ALOS/en/guide/forestmap_oct2010.htm

[3] DiMiceli, C.M., M.L. Carroll, R.A. Sohlberg, C. Huang, M.C. Hansen, and J.R.G. Townshend (2011), Annual Global Automated MODIS Vegetation Continuous Fields (MOD44B) at 250 m Spatial Resolution for Data Years Beginning Day 65, 2000 - 2010, Collection 5 Percent Tree Cover, University of Maryland, College Park, MD, USA. http://glcf.umd.edu/data/vcf/

[4] 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, & J. R. G. Townshend (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53 http://earthenginepartners.appspot.com/science-2013-global-forest.

[5] An area of 7 358 163 ha was recorded as forest loss for the study area between 2001 and 2012 (Hansen et al, 2013).

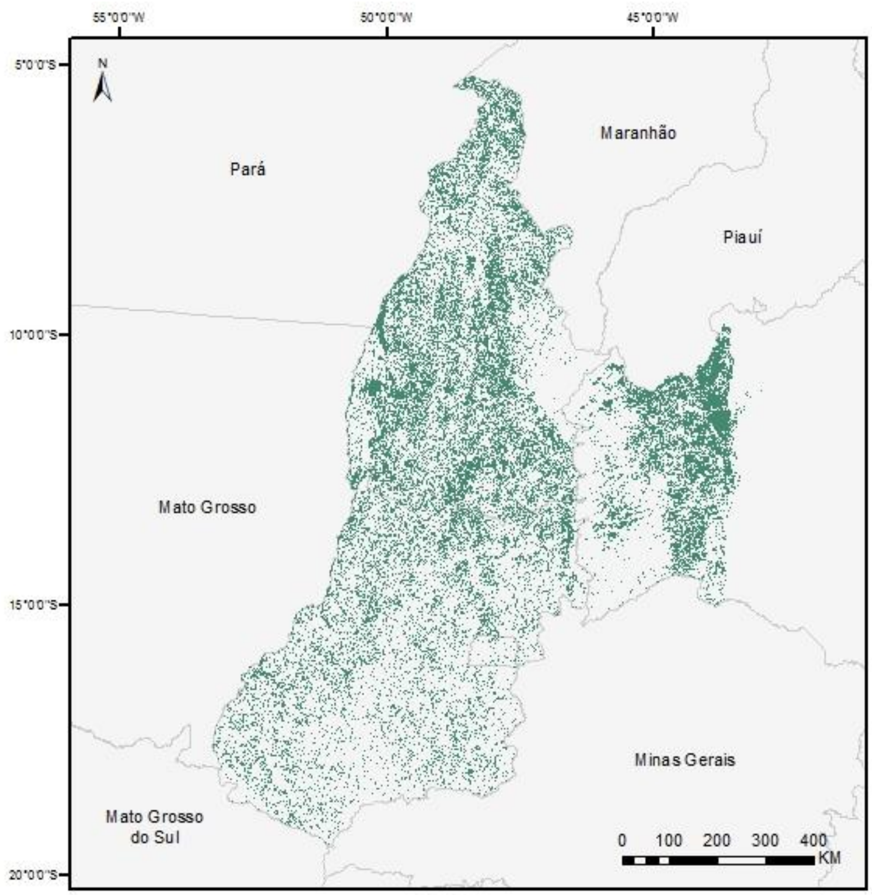

Figure 1: Cerrado forest extent derived from Hansen et al (2013) Tree Canopy Cover for 2000 and Global Forest Cover Loss 2000-2012. Areas over 1 hectare and with equal to or more than 30% canopy cover were classed as Cerrado forest.

B. The PROBIO Cerrado and Caatinga Biome-scale land cover mapping data[6] *for the year 2002* was used to define Cerrado forest extent by extracting the following classes: Dense and Open Alluvial Rain Forest, Dense and Open Submontane Rain Forest, Mixed Montane Rain Forest, Seasonal and Semi-seasonal Deciduous Forest, Forested Savanna, Wooded Savanna, and Grassy/Woody Savanna with gallery forest. Figure 2 shows the resulting forest extent map, in which Cerrado forest extent totals 31 716 486 ha. The reason for the PROBIO dataset showing a much larger extent of forest is probably due to the fact that it includes several savanna classes that are specific to the Cerrado biome, which may not be have sufficient canopy cover or minimum area to be classed as 'forested' within the Hansen et al dataset.

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[6] Mapeamento de Cobertura Vegetal do Bioma Cerrado (MMA), Edital Probio 02/2004 Projeto Executivo B.02.02.109. 2007. Available at http://mapas.mma.gov.br/geodados/brasil/vegetacao/vegetacao2002/cerrado/documentos/relatorio_final.pdf

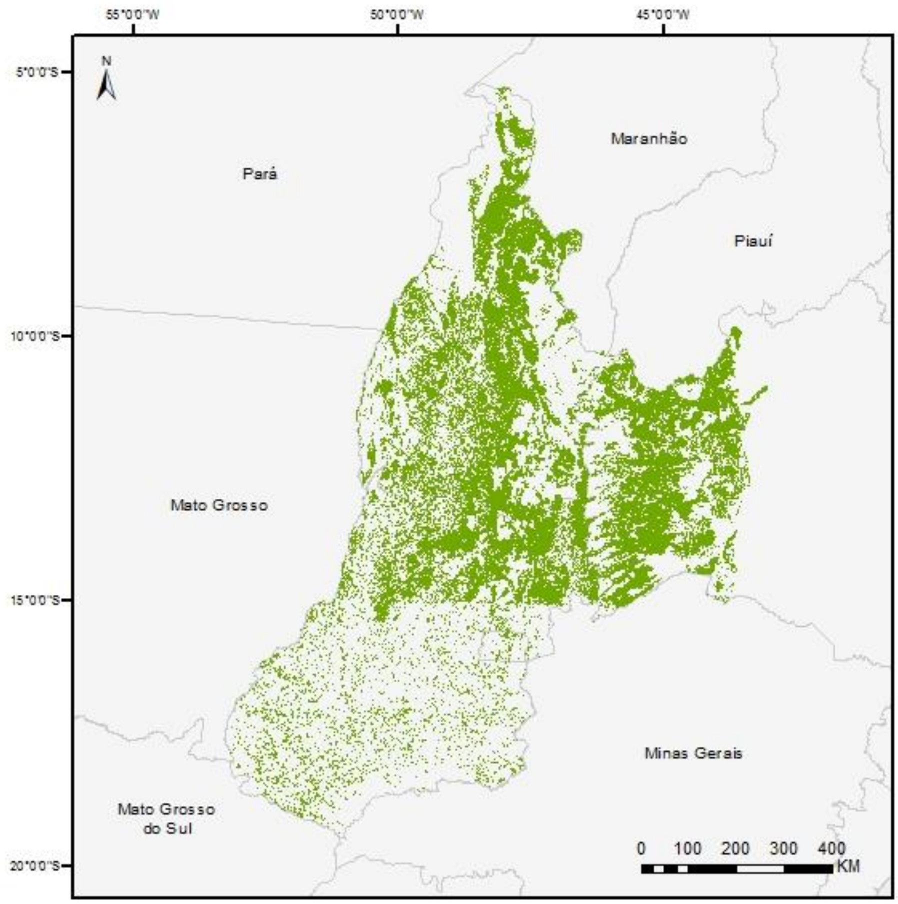

Figure 2: Cerrado extent derived from the PROBIO 2002 land cover classes that contain both forest and savanna woodland.

4 RISK FACTORS

This study applies the qualitative ACEU risk model, which is based on the hypothesis that forest areas are at greater risk of deforestation if they are accessible (A), located in areas suitable for cultivation of staple crops (C), contain timber resources that have an extractable value (E) and are unprotected (U). The sections below explain how each of these four parameters are defined and assigned a level of risk. Local knowledge was used as much as possible to assign values to the risk factors, but gaps were filled by literature study. It is important to note that these risk maps are early version first drafts and can be improved over time as newer data and information becomes available.

Although small-scale extraction for firewood or construction does occur, the extractive value of cerrado was assumed to be secondary to its cultivable value as burning is often used to renew pastures or clear land for conversion[7]. Risk was therefore assessed using indicators of accessibility, cultivability and the protection status of areas.

4.1 ACCESSIBILITY: RISK OF DEFORESTATION ASSOCIATED WITH ACCESS BY ROAD

Proximity to roads and populated areas was considered to be the most important factor in determining accessibility.

Official data produced by the Ministry of Transport for federal highways, state and local roads at a of scale 1: 1,000,000 for Brazil in 2008[8] was used to create continuous map showing zones at risk due to accessibility by road networks. Risk values were assigned to 5 buffer zones up to a distance of 22 km away from roads. Each zone was 4.5 km wide, with areas closest to the road given the highest risk value of 5 while areas furthest away were given the lowest risk (=1). A study undertaken in Mato Grosso do Sul in 2012 identified an area of approximately 9 km parallel to roads as most at risk of cerrado vegetation loss, while degradation and habitat loss has been recorded in caatinga vegetation areas further north in Brazil up to 12 to 15 km away from roads[9],[10]. Risk values were assigned using the results of these studies, however these assumptions may be adjusted in the future, based on local expertise regarding the distance up to which roads or railways pose a threat to cerrado forests. The dataset should also be updated when improved roads network data becomes available, or when new infrastructure is developed. It is suggested the roads data be separated into highways and primary roads, and minor road networks where possible as larger areas adjacent to highways are affected at greater distances.

While the Ministry of Transport PNLT 2008 data provided detailed and accurate highway and primary road network locations, data for smaller municipal roads and road networks for smaller populated areas were found to be less accurate when verified using visual comparison to high resolution optical imagery. Within the case study municipalities of Luis Eduardo Magalhães, Formosa do Rio Preto, São Desidério and Riachão das Neves only data for highways and primary roads were available, however several minor roads networks provide access to agricultural areas and potentially to Cerrado areas. In order to improve the accuracy of risk assessment due to road access, the PNLT road data can be combined with

[7] Jasinski E, et al. (2005) Physical landscape correlates of the expansion of mechanized agriculture in Mato Grosso, Brazil. Earth Interact 9(16):1e18.

[8] PNLT (2008). Plano Nacional de Logística e Transportes (2008). http://mapas.mma.gov.br/i3geo/datadownload.htm

[9] Santos, A. M. and Tabarelli, M. (2002) Distance from roads and cities as a predictor of habitat loss and fragmentation in the caatinga vegetation of Brazil. *Braz. J. Biol.* [online]. 2002, vol.62, n.4b, pp. 897-905. ISSN 1519-6984.

[10] Casella, J., Paranhos, A. (2013) The Influence of Highway BR62 on the Loss of Cerrado Vegetation Cover in South Western Brazil. Oecologia Australis, North America, Available at: http://www.oecologiaaustralis.org/ojs/index.php/oa/article/view/725/660

more recent OpenStreetMap transport network data which includes more detailed town roads. It should be noted that the OpenStreetMap data, like the PNLT data, is often geographically inaccurate or incomplete for rural roads further from populated places, and can be improved using high resolution optical EO data where available, although time and labour intensive.

Risk of deforestation due to access by rivers and railways were not included in this analysis due to the lower extractive value of cerrado and the burning practices used. While larger timber may be removed for fuel wood during the clearing of heavy cerrado forest, road access rather than rail or river was expected to be more relevant to risk of cerrado forest loss.

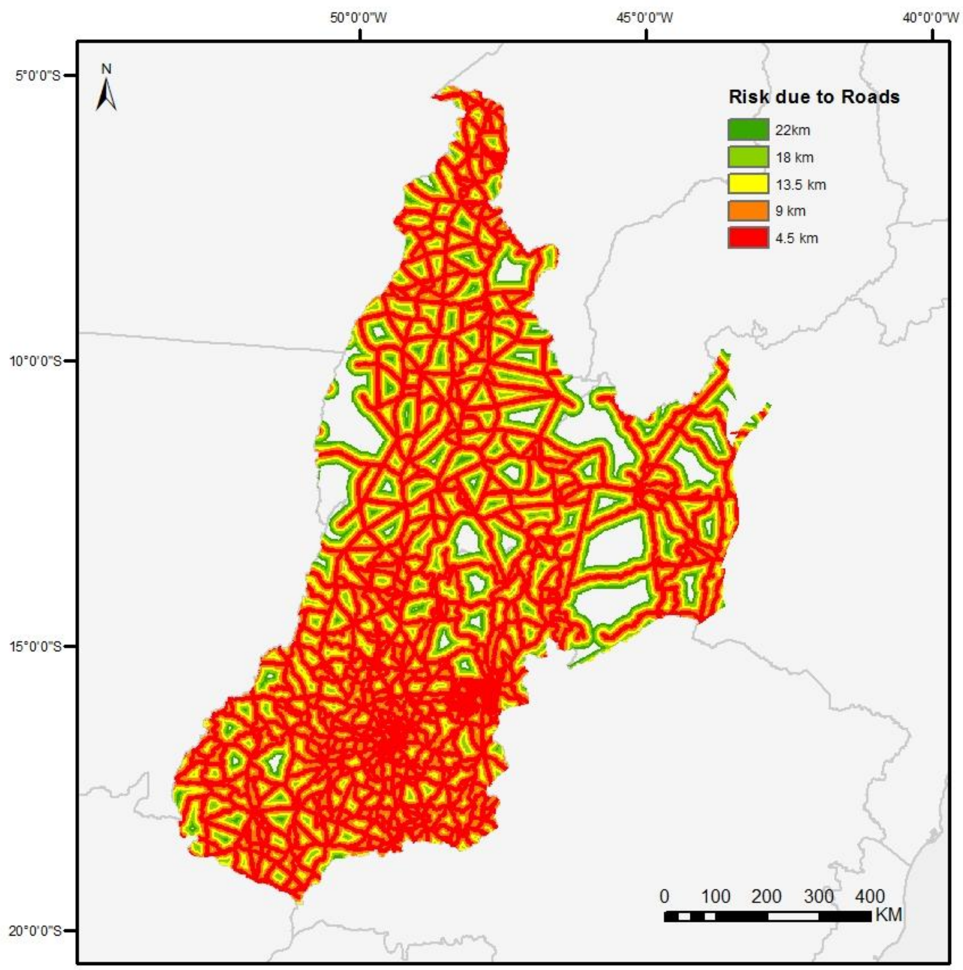

Figure 3: Risk of deforestation due to access by roads to cerrado areas in Bahia, Tocantins & Goias. Red shows high risk (closer to roads), while green shows low risk. Risk is calculated for a buffer area up to 22 km from a road.

4.2 ACCESSIBILITY/CULTIVABILITY/EXTRACTABILITY: RISK DUE TO PROXIMITY TO PREVIOUS SITES OF DEFORESTATION

Historic patterns and rates of deforestation provide an indication of areas at higher risk of future deforestation as areas already deforested demonstrate accessibility, a degree of economic attraction and a lack of or ineffective protection under past or current management schemes[11]. A density map of deforestation events with a minimum area of 1 hectare that occurred between 2001 and 2013 was created based on the Hansen et al forest loss data (Hansen et al, 2013). The density map was then divided into 5 classes based on the density values, where the group of highest density values were given highest risk value (=5) and the group of lowest density values were given lowest risk value (=1).

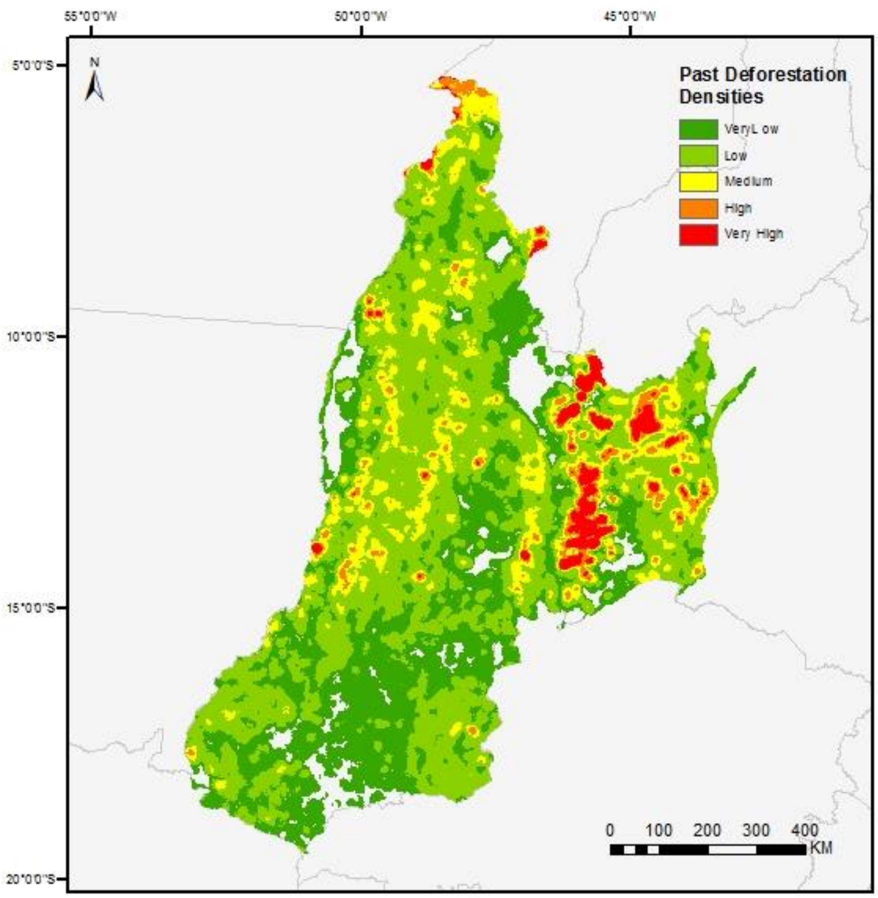

Figure 4: Density map of past deforestation in the cerrado region of Bahia, Tocantins and Goiás. The density values shown here were classed using a standard deviation classification, where areas in red show densities of deforestation above the mean, and green values show densities below the mean deforestation event densities across the study area.

[11] Soares-Filho BS, Rajão R, Macedo M, Carneiro A, Costa WLS, Coe M, Rodrigues HO, Alencar A (2014) Cracking Brazil's Forest Code. *Science* 344:363-364. http://www.sciencemag.org/content/344/6182/363

In a 2011 study, Oliveira Brandão Júnior et al investigated the distance at which deforestation events were most spatially autocorrelated or clustered together geographically in the Calha Norte region, in the south of Pará[12]. The peak of clustering of new deforestation was found to be concentrated at an average 10 kilometer radius with a Z-score of 112.33. Based on this study, a radius of 10 km around past deforestation events was used when creating the density map to identify areas at high risk of future deforestation.

4.3 CULTIVABILITY: PRECIPITATION

Through consultation with Embrapa, areas with annual precipitation lower than 1000 mm were confirmed as unsuitable for cultivation. With the exception of the areas with rainfall below this limit, it is assumed that within the cerrado region the majority of land has cultivable value for commercial crops or grazing pasture (the two main drivers of land use change[13]) since inputs can often be used to improve poorer, acidic soils.

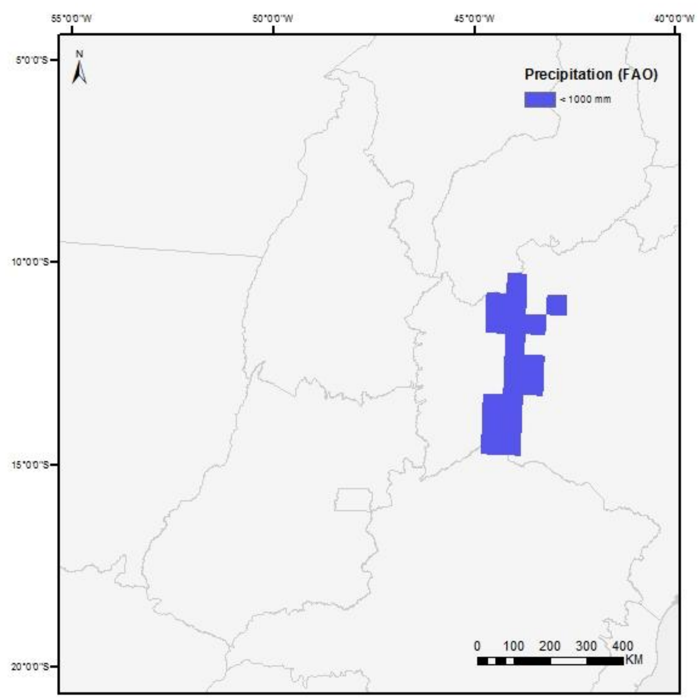

Figure 6: Areas with annual rainfall of less than 1,000 mm according to FAO precipitation data at 0.5 degrees resolution

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[12] Oliveira Brandão Júnior A de, Ogneva-Himmelberger Y, Moreira de Souza Júnior C (2011) Analyzing temporal and spatial dynamics of deforestation in the Amazon: a case study in the Calha Norte region, State of Pará, Brazil. Anais XV Simpósio Brasileiro de Sensoriamento Remoto. April 30.

[13] Bourscheit, A. (2010). Burning grows 350% in the Cerrado. Retrieved January 26, 2015, from http://www.wwf.org.br/informacoes/english/?26287/Burning-grows-350-in-the-Cerrado

Precipitation data was sourced from the FAO at a resolution of 0.5 degrees, shown in figure 6, as consultation with local experts in Brazil confirmed that cultivability can vary with rainfall - areas with less than 1,000 mm annual rainfall are considered less attractive for cultivation of crops.

Areas within Bahia with less than 1,000 mm annual rainfall were assigned one risk value lower than as previously assigned due to risk from proximity to roads and past deforestation to indicate their lower cultivable value, shown in figure 7.

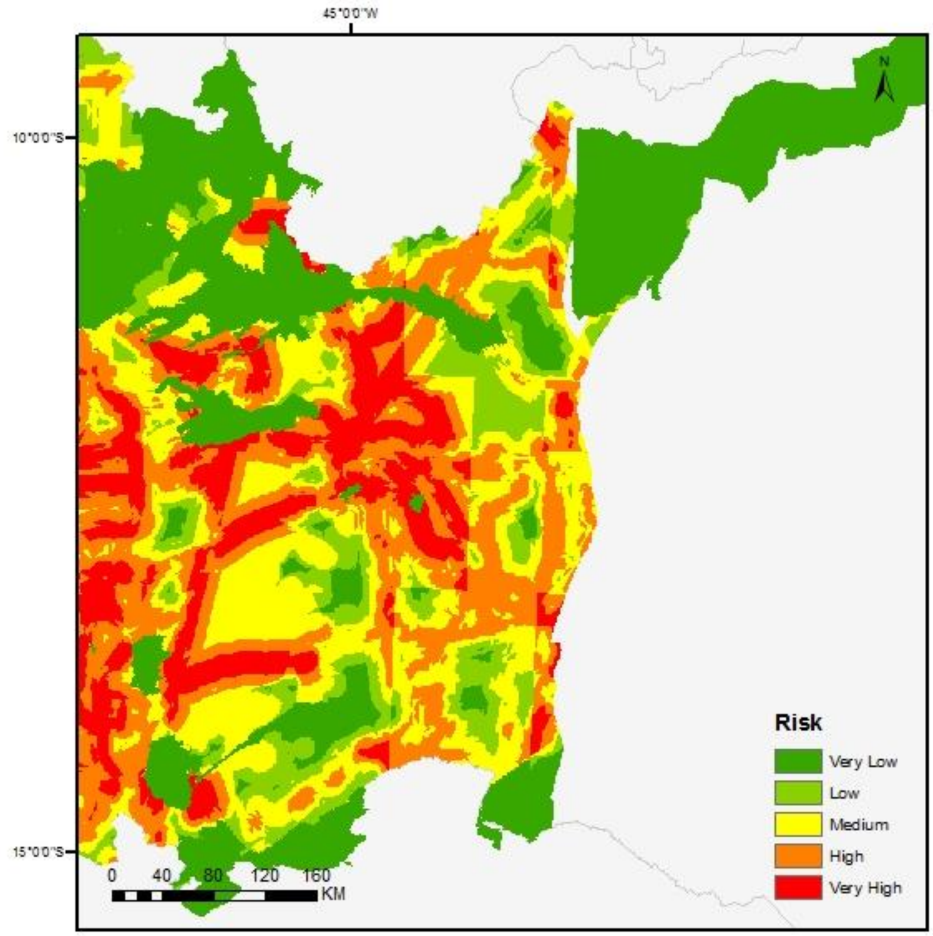

Figure 7: Zoomed in subset showing lowered risk due to low annual rainfall in areas of Bahia

4.4 PROTECTED AREAS

The effect of Protected areas was added as a final step, after all risk parameters discussed above were combined into 1 risk map. This is based on the assumption that federal and state protected areas, including legally protected areas, according to Brazil's new forest code approved in 2012, are at low risk of deforestation. Federal and state protected areas sourced from the Ministério do Meio Ambiente[14] within the study site[15] amount to a total area of 8,010,192 ha. Figure 5 shows the Federal and State Protected Areas within and adjacent to Bahia, Tocantins and Goiás. Our analysis shows that the Hansen Forest Loss data mapped a total area of 118,686.4 ha of forest loss within the cerrado region of Bahia, Tocantins and Goiás between 2001 and 2013, of which 92.4 % (109,679.6 ha) of deforestation occurred within non-protected areas. The remaining 7.6 % (9,006.8 ha) deforestation occurred within protected areas. We therefore deduct that protected status lowers the risk of deforestation in the study area, hence protected areas were assigned the lowest risk category of 1.

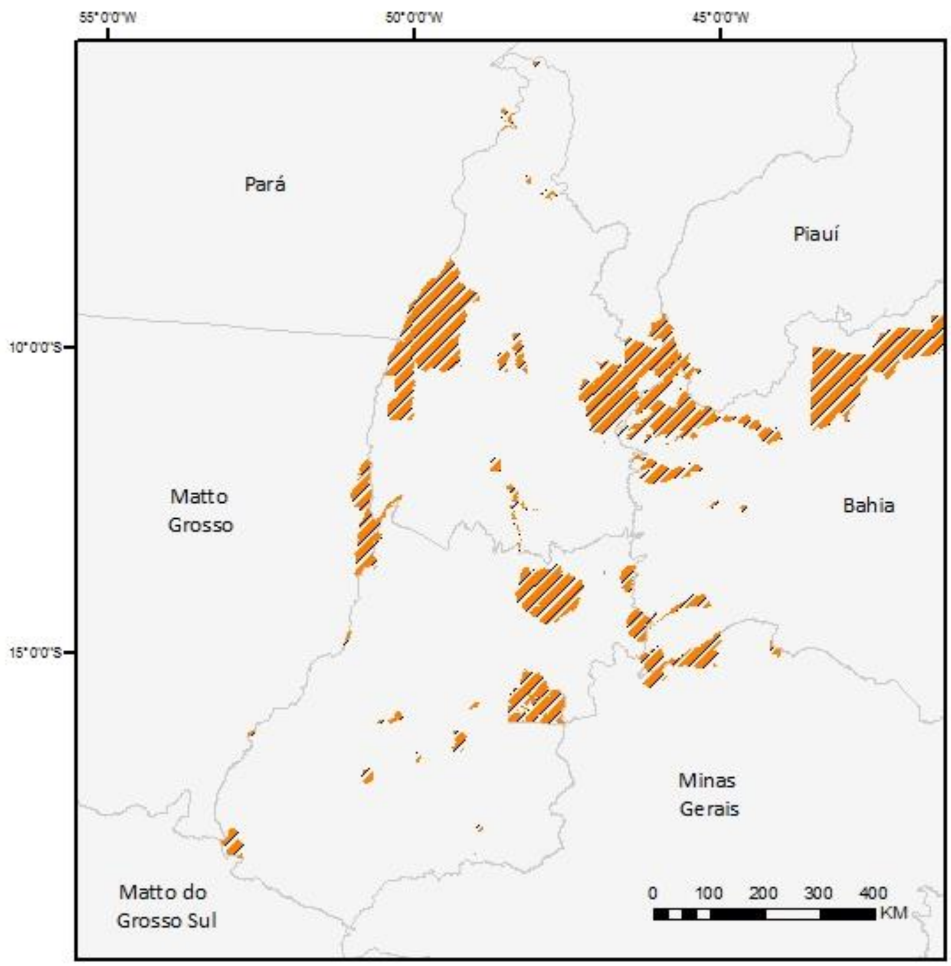

Figure 5: Map of Federal and State Protected Areas within and adjacent to Bahia, Tocantins and Goiás

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[14] MMA (Ministério do Meio Ambiente) - SNUC (Sistema Nacional de Unidades de Conservação). 2000. MMA, SNUC, Brasília.

[15] Protected areas overlapping the boundaries of Goiás, Tocantins and the cerrado regions of Bahia were clipped so that only areas falling within these boundaries were calculated.

Riparian buffer areas are classed as Permanent Protected Areas (PPAs), with the width of protected area dependent on the river width and the property size combined with the municipality they are located in (see Appendix A for details). Areas adjacent to natural or artificial lakes, lagoons or water reservoirs are also classed as Permanent Protected Areas, with the extent of the protection zone varying according to their size (see Appendix A for details).

Data for natural and artificial lakes and reservoirs was sourced from USDMA 2000 Vector Map[16] data at 1:1m scale, which included inland water bodies larger than 20 ha and larger rivers with widths greater than 50m. Based on the rules for PPA buffer zones sizes around rivers and inland water bodies (Appendix A) combined with the lack of detailed spatial data for property boundaries, ownership and smaller river and stream width, a conservative permanent protected area buffer zone of 100m was applied. Within these buffer zones around larger rivers, lakes and reservoirs, the risk category was assigned the lowest risk of 1.

In addition, the Brazilian Forest Code protects areas located at more than 1,800m above sea level or any steeply sloped area with an angle of at least 45° (Lasaponara et al, 2013). No such PPAs were identified within the study areas as the maximum elevation within the case study area was 1810m above sea level and slopes were more gentle.

5 RISK OF DEFORESTATION – METHODS AND CALCULATIONS

The total risk of deforestation for the cerrado vegetation within Bahia, Tocantins and Goiás was calculated using the risk parameters described above. First, risk values from 1 to 5 were assigned as follows:

- Risks due to proximity to roads were added first, resulting in a map where risk values ranged from 1 to 5.
- Risk due to past deforestation (derived from the density map, Fig.3) was then added, resulting in a map with risk values ranging from 2 to 10 (Fig.5).
- These values were reclassified equally into classes ranging from 1 to 5. Areas with less than 1,000 mm rainfall were then adjusted to one risk value lower.

This combined risk map was then adjusted to take into account the effect of protected areas:

- Risk values in areas under federal and state protection were re-assigned to lowest risk (i.e. risk value 1).
- Protected areas in PPA buffer zones around water bodies and large rivers were also assigned the lowest risk value of 1.

[16] United States Defense Mapping Agency (2000) *Vector Map Level 0* [computer file]. Highlands Ranch, CO: LAND INFO Worldwide Mapping, LLC

The classification of the final risk mapping outputs (Figures 8 and 9) was carried out by dividing the dataset into quantiles, 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'. As a last step, the final risk map was overlain by the two chosen forest extent maps to show the risk categories for forest areas (see Figs. 8 & 9), one based on the Hansen et al (2013) Global tree canopy cover adjusted for 2012 using the Hansen et al (2013) Global forest cover loss (2000-2012) dataset; and another based on the PROBIO Cerrado 2002 dataset.

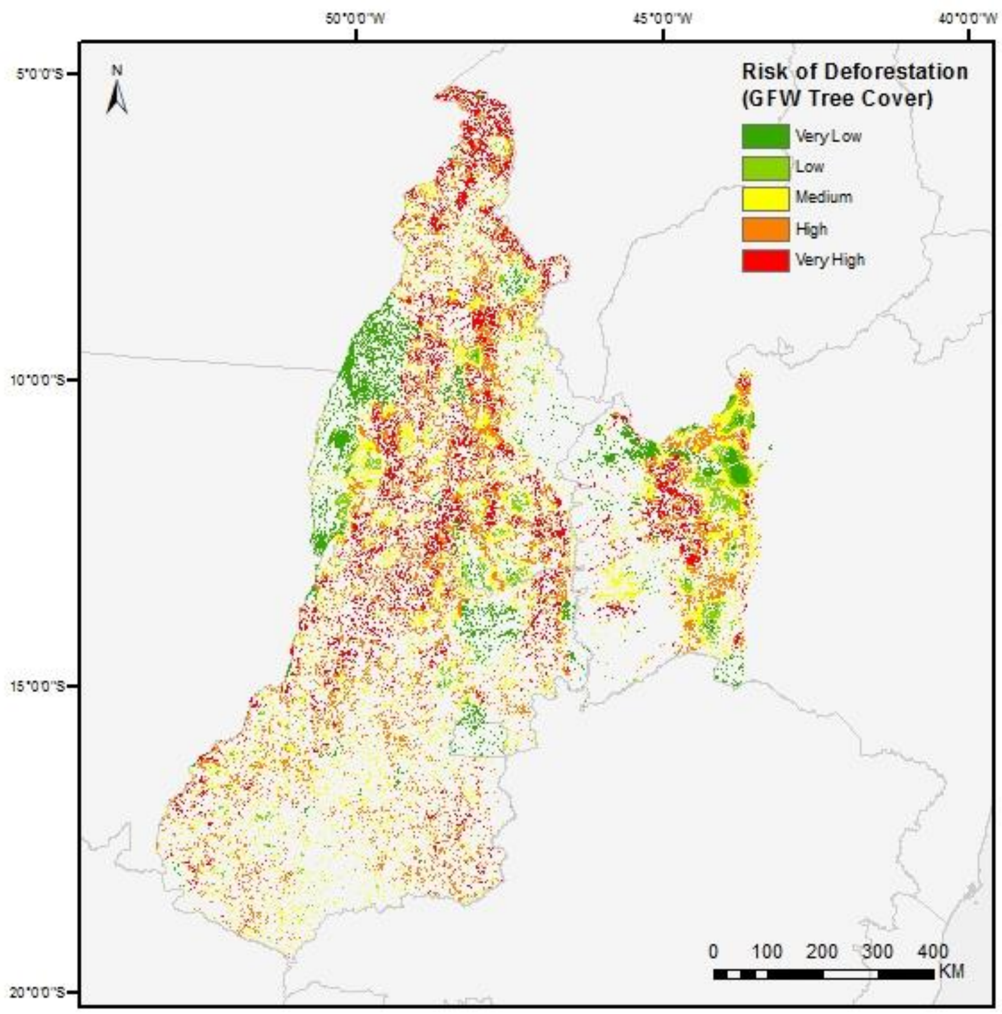

Figure 8a: Final risk of deforestation map for cerrado vegetation within Bahia, Tocantins and Goiás with the forest extent based on the Hansen et al (2013) global tree canopy cover dataset updated to 2012. High risk areas are represented in red, while low risk areas are in green. All protected areas were assigned the lowest risk value of 1.

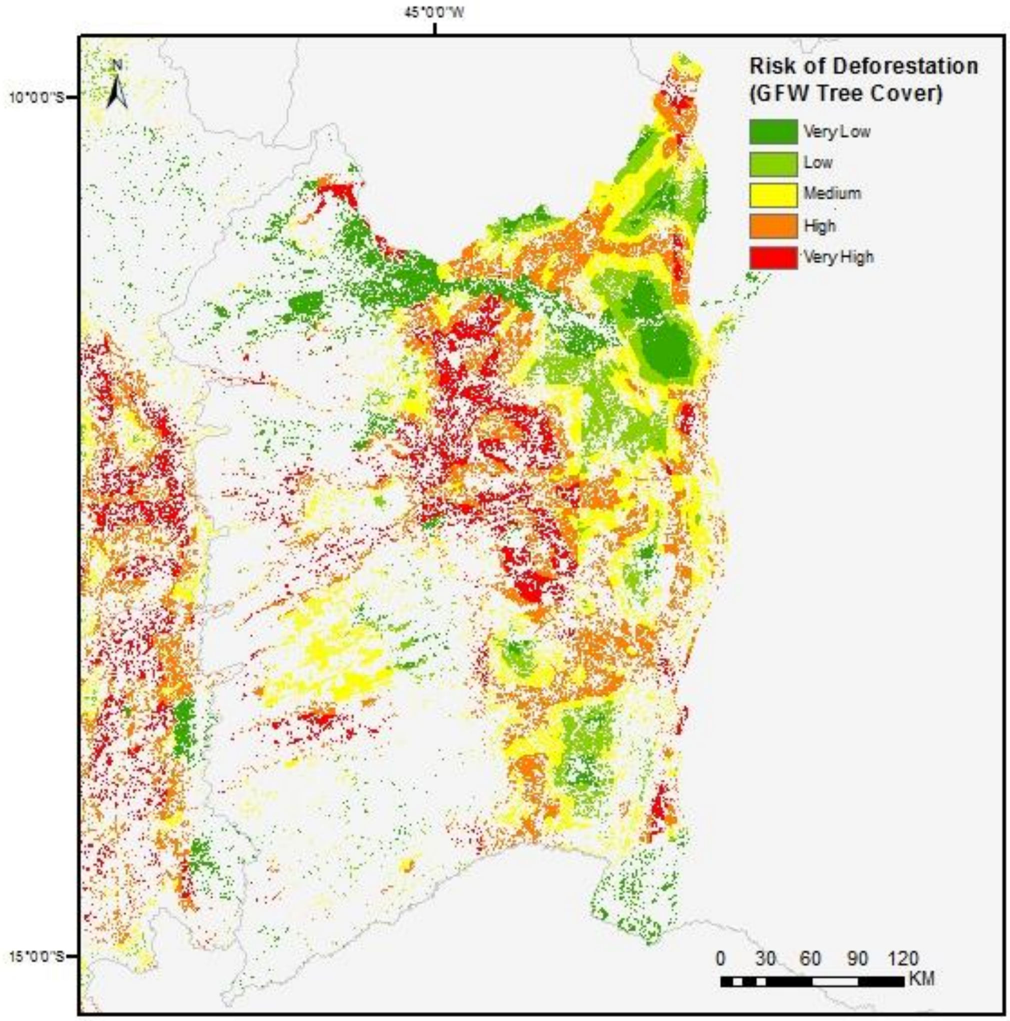

Figure 8b. Subset of risk of deforestation map for cerrado vegetation zoomed in to the study area, i.e. Luis Eduardo Magalhães, Formosa do Rio Preto, Sao Desidério and Riachão das Neves municipalities in Bahia.

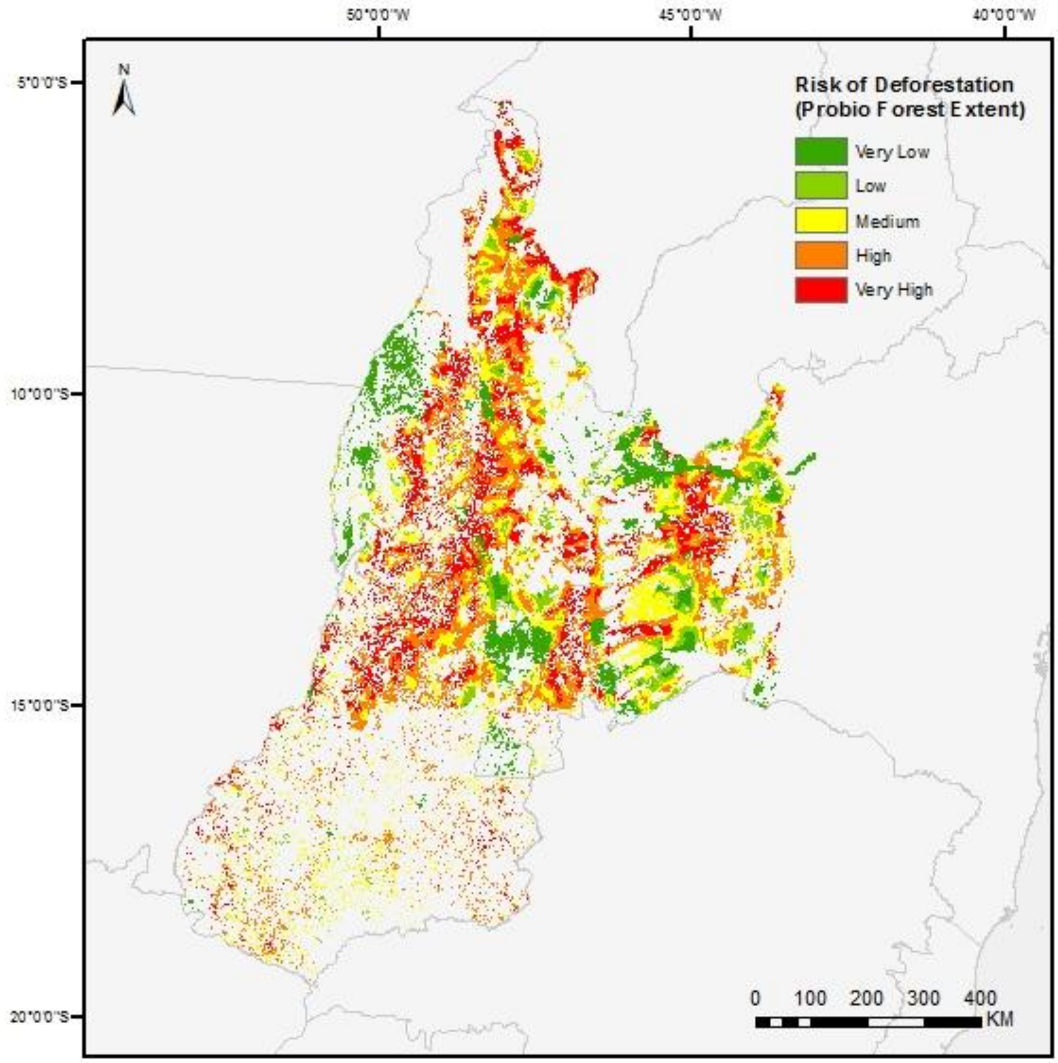

Figure 9: Risk of deforestation map for cerrado vegetation with the forest extent derived from the 2002 PROBIO cerrado dataset.

6 NOTE ON FURTHER 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).

The ACEU method of risk classification could incorporate finer scale data as this becomes available for the area as a whole, and further refined with local inputs and weightings for existing or additional deforestation drivers. However, there is a danger of attempting to create fine scale risk assessments in situations that are inherently unpredictable.

It is suggested that more accurate and finer detail roads data based on a combination of OpenStreetMap and high resolution imagery be included in subsequent maps. Detailed information on land ownership and property size as well as river widths would be required to more accurately include correct PPA buffer distances for protected areas adjacent to rivers and streams. The effects of population centres could also be examined further.

APPENDIX A: DETERMINATION OF THE PPA RIPARIAN BUFFER AREAS

The areas that must be protected adjacent to the rivers as set out by the Brazilian forest code are: between 5 and 15 meters for rivers up to 10 meters wide within rural establishments with an area of between 1 to 4 fiscal modules[17] and with consolidated areas[18]. For establishments with an area of greater than 4 fiscal modules, the area to be recovered depends on the river width: 30 meters for rivers up to 10 meters wide, 50m for rivers 10 to 50m wide, 100m for rivers 50m to 200m wide, 200m for rivers 200 to 600m wide, and 500m to rivers wider than 600m[19, 20].

For small farms of up to one fiscal module, with consolidated areas, an area of 5 meters from the river margin has to be recovered and protected. For properties of between 1 and 2 fiscal modules, with consolidated areas, an area of 8 meters from the river bank must be protected. Those with areas of 2 to 4 fiscal modules, 15 meters is required.

Areas adjacent to natural or artificial lakes, lagoons or water reservoirs are also classed as Permanent Protected Areas, with the extent of the protection zone varying according to their area: 50m around water bodies of up to 20ha and 100m for those larger than 20ha[21].

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[17] Rural establishments or small familial farms are measured in fiscal modules, which are multiples of a hectare between 5 and 110 hectares depending on the municipality they are located in and are representative of the quantity of land a worker and his family require to be able to support themselves17. A fiscal module in Amazonas has an average size of more than 90 ha, while in Goiás, a module is an average of 30 hectares. In Bahia, municipalities have fiscal modules of between 30 and 75 ha, with the exception of metropolitan areas, where the fiscal module is set at 15 ha. The case study municipalities of Luis Eduardo Magalhães, Formosa do Rio Preto, Sao Desidério and Riachão das Neves all have a fiscal module of 65 ha - Landau E.C., Da Cruz R.K., Hirsch A., Pimenta F.M., Guimarães D.P. (2012). Variação Geográfica do Tamanho dos Módulos Fiscais no Brasil. Documentos 146. Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Milho e Sorgo, Ministério da Agricultura, Pecuária e Abastecimento, Sete Lagoas, MG. (Documentos / Embrapa Milho e Sorgo, ISSN 15184277; 146).

[18] Rural consolidated areas are defined by law as as areas of rural property "with existing human occupation prior to July 22, 2008, that have buildings, improvements, or agricultural activities" - Soares, E. (2012) Brazil: 12 Articles of New Forestry Code Vetoed by the Government. Retrieved January 26, 2015, from http://www.loc.gov/lawweb/servlet/lloc_news?disp3_l205403176_text.

[19] Leonardi, Silvia S.; Namikawa Laércio M.; de F. Oliveira João R. and Rosim, Sergio (2014) Delimitation of permanent protected areas of rivers in Brazil, *Proc. SPIE* 9239, Remote Sensing for Agriculture, Ecosystems, and Hydrology XVI, 92391C; doi:10.1117/12.2066894; http://dx.doi.org/10.1117/12.2066894

[20] Ywata Carvalho, X., Mosnier, A., Kapos, V., Câmara, G., and Obersteiner, M. (2012). Policy considerations for landuse models in Brazil. REDD-PAC Project report.

[21] Lasaponara R., Masini N., Biscione M., Editors. EARSeL (2013) Brazilian forest code: an intriguing framework for designing worldwide protected areas. 33rd EARSeL Symposium 2013, Matera (Italy), 3 - 6 June 2013