The Change of Health and Level of Protection of the Atlantic Rainforests Biome in Brazil from 2002 to 2018. Reveal the Most Valuable Woodlands and Mapping of the High Conservation Value Forests (HCVFs)

Report on the development of the project on 2nd year

Natalia Novoselova

Campinas, July 2018

Contents

GLOSSARY

Definition of the introduced terms

TFH (Tropical Forest Health). The relative parameter of rainforest intactness introduced in the study. It shows the native rainforest ecosystem health, "ecological quality" or the level of tropical forest degradation. Currently I did not elaborate exact values of this parameter. TFH may vary from "0" (the best health, or absolutely intact rainforest) to 10 (the worse health, very degraded forest). Or in contrary, 10 – the best health, 0 – the worse health.

Level of Fragmentation (LF). The widely used term for any numerical assessment of the degree of forest fragmentation (i.e. the division of a continuous large forest area into isolated fragments).

Radius **–** The radius of the largest circle inscribed in a forest fragment.
The new method of Level of Fragmentation Analysis basing on a *radius of a largest circle inscribed in a forest fragment* was elaborated and applied for Paper#1. This method has ecological sense which gives to it an advantage in comparing with fragmentation analysis basing on the area of a fragment. Find more in 3.2 Elaboration of the methodology of TFH assessment.

Area – The area of a forest fragment.

Indirect remote indicators of TFH – The parameters of remote sensing products indicating of TFH indirectly. In this study I am going to use the following parameters: NDVI, EVI, LAI, FPAR, GPP, Day surface temperature, Night surface temperature, which are produced by MODIS, Landsat-8 and Sentinel (Table 3).

Direct remote indicators – The parameters of remote sensing products indicating of TFH directly. In this study I am going to use the following parameters: Landsat Tree Cover, Level of Fragmentation (Table 3);

Direct field indicators – The forest characteristics measured in field investigations which can indicate the TFH directly (Table 4);

Standard forest ecosystem – The forest territory which was determined in our project as the healthiest, the most intact forest within ecological region of the Atlantic forest.

UCPI - Unidades de Conservação de Proteção Integral (Conservation Units of Integral Protection).
UCUS - Unidades de Conservação de Uso Sustentável (Conservation Units of Sustainable Use)
standard forest ecosystem

1. Introduction

1.1 The principle of the project development

The initial objectives in the original proposal of Doctoral project were formulated (with small modifications) as the following:
1.To elaborate the methodological approaches of complex estimation of tropical forest health (i.e. level of degradation) basing on combination of remote sensing data, GIS and field measurements.
2. To implement the elaborated methods directly for a complex assessment of tropical forest health and their long-term changes.
I considered both purposes related with each other, because the methodology of estimation of tropical forest health can be elaborated only in a process of study the quality of real territory with essential task of this study.

The first part of the project (and the first paper) is devoted to the analysis of the tropical forest health in the entire Atlantic forest biome of Brazil located in 16 States of the country.
Using MODIS data of small spatial resolution, I got new results about Atlantic forest condition and dynamic of its change which would be important to publish. Those results are new and quite interesting for the reason that previously it was only one study that explored completely all remnant Atlantic forests in Brazil: "How much is left, and how is the remaining forest distributed" (Ribeiro et al 2009).

I did not repeat all studies that were made for this paper. But by MODIS data I conducted observations which had never been implemented in those scale and tasks. Due to this, I got the important results which will be the first assessment of this kind across the entire Atlantic forests biome. Also, the obtained parameters together with the paper Ribeiro et al 2009, allow to compare the condition of the Atlantic forests in 2002 and in 2016, that is, to identify the dynamics of changes of TFH over 14 years.

By this example I saw that it is crucially important to formulate tasks to the methodology that have scientific newness, actuality and practical significance. In this case, the methodology will give the results that can be successfully publish and use in environmental practice. Also, it will attract other researchers who will be able to enter this direction and continue the development of such a technique. I considered this strategy from the beginning of the project.

The report is devoted to short description of the obtained results and the proposed five papers, which are considered in form of proposal.

I prefer not to write the general text of the dissertation, consisting from chapters or draft of papers. The last experience (the defence of the Master of Science thesis) has shown that this method slows down significantly the publication of the papers, since the double work has to be done. Also, basing on the same experience, I want to divide the material into small papers. Basing on this strategy, the number of papers was determined.

I think that I should work on papers almost simultaneously (and not one after another). The results of one paper may be important for other papers. Also, for 3 papers I need to do field investigations which are long and difficult to organize.
I suppose that the rest 2 years of my position with CAPES funding – will be enough to implement of those plans. But if I will not have enough time, I will finish (preparation for the defense) without CAPES funding, as I did during my Master of Science project. For the project's goals and my future work (I want to continue the development of this line in Brazil and South America), the most important thing to finish and publish these papers in the detected format (or with small changes), that finish in the deadline of the CAPES scholarship. But I think that 2 years is enough time.

1.2 Correction of the focus research

The obtained results and immersion into the problem (review of literature, communication with experts) allowed to focus the project on the important issues and to narrow its scope. As a result, the original title of the project was changed (Table 1).

Despite the modification of the project title, almost all initial ideas are planned to be implemented and distributed according to the proposed papers. Now I am exploring only Atlantic forests (Cerrado biome and Amazon forests were excluded from plans). The "Environmental Corridors" were also removed from the title of the project, but this notion is reflected in the focus of all papers in the concepts of *Intact Forest landscapes* (IFL), *High Conservation Value Forest* (HCVF) and *Ecological Networks* ("ECONETS)" (or the concept of connectivity of protected natural areas). I excluded this term for the reason that in Brazil there is no valid protected environmental category "*Environmental or Biodiversity Corridors*". I found that the category entitled as the "*Corredores de Biodiversidade*" is rather geographical zoning, because it includes of huge urban territories (like the metropolis of Sao Paulo and Rio de Janeiro). Also, they don't have any special protection by legislation of Brazil. Instead of them, the important environmental working concepts which were mention above (HCVF, IFL, ECONETS) were introduced into the project, around them the study is being built.

2. The proposed papers: objectives, research questions, methods, practical importance, expected results

The proposed papers (Table 2) have both methodological and practical goals. The methodological goals are being solved to achieve the stated practical objectives. Implementation of the practical goals will give of contribution in the methodology of tropical health assessment.

The proposed papers are divided in two parts by the scale of the remote sensing products applied for investigation. The basis of all papers is open access (free of charge) satellite images and products from them. The idea of application of the remote sensing data of very high resolution and other special characteristics (hyperspectral, UAV imagery) is considered as additional study for Paper#4.

PART I. Investigation basing on the satellite images of small and middle resolution (30, 100, 250, 500 and 1000 meters in 1 pixel of image)

Paper#1

Change of the Atlantic rainforest health in Brazil from 2002 to 2016 inside and outside of the conservation natural areas. Compare of two protection regimes by their efficiency

Introduction

The paper is devoted to the assessment of changes of Tropical Forest Health (TFH) and Level of Fragmentation (LF) in the Atlantic rainforests biome in Brazil from 2002 to 2016 (between 2002 and 2013, between 2014 and 2016). Those years were selected basing on the available data of georeferenced fragments of the remnant Atlantic rainforests produced by SOS Mata Atlântica, as well as the years of the launch of MODIS, Landsat Tree Cover, Global Forest Change data production (Table 3). The TFH and LF parameters will be compared between 2002, 2013 and 2016 (2018 for TFH) and the tendency of their changes will be estimated.
Study of TFH and LF changes will be divided on 3 parts:

(i) The entire Atlantic rainforest biome in Brazil (will be considered situation in total, for entire area occupied by Atlantic forests).

(ii) By state (will be considered situation separately in 16 Brazilian states maintaining of the Atlantic rainforest).

(iii) By two groups of Conservation Units of Brazil, that is, by two regime of protection: Conservation Units of Integral Protection (Unidades de Conservação de Proteção Integral, UCPI) and Conservation Units of Sustainable Use (Unidades de Conservação de Uso Sustentável, UCUS).

Significance

Those objectives allow to get valuable information about condition of Atlantic forests which will be important for both scientific and practical conservation point of view. Separate assessment by states and comparison of two regimes of management of the protected natural areas in Brazil will be important for conservation purposes.

Background information for Introduction of the paper

Protected natural areas in Brazil are divided in two groups[1]:

(i) The Conservation Units of Integral Protection (Unidades de Conservação de Proteção Integral, **UCPI**). The principal objective of this group to protect of wild nature from any human activity and destruction. Thus, all types of human activity, all form of use natural resources - are prohibited there. This group includes 5 categories: Reserva Biológica, Parque Nacional, Monumento Natural, Refúgio de Vida Silvestre, Estação Ecológica.

(ii) The Conservation Units of Sustainable Use (Unidades de Conservação de Uso Sustentável, **UCUS**). The principal objective of this group - to organize a sustainable application of natural resources and, at the same time, to conserve of natural ecosystems. Thus, many forms of human activity are allowed, but in limited character. This group includes 7 categories: Área de Proteção Ambiental (APA), Área de Relevante Interesse Ecológico, Floresta Nacional, Reserva Extrativista, Reserva de Fauna, Reserva de Desenvolvimento Sustentável, Reserva Particular do Patrimônio Natural.

Those categories include both public and private Conservation Units; Conservation Units which are managed by municipality, by state and by federal government[2].
The main difference between two groups or two regime of nature protection is the **ability to use of natural resources**. In UCPI is impossible to use any natural resources, people can't live on the territory for a long time. In UCUS – the natural resources can be used in limited form, as well as the people can habitat on the area.

Objectives

Practical objectives for Paper#1

Objective#1

Answer the question: Tropical Forest Health (TFH) of the Atlantic rainforest biome became better, became worse or did not change from 2002 to 2016? (i.e. between 2002 and 2013, between 2014 and 2016). Estimation will be conducted for the entire Atlantic rainforest biome and for each Brazilian state contained Atlantic rainforests. **The condition of the entire Atlantic rainforest biome will be studied in consideration of ecological regions on which the biome is divided**[3].

Objective#2

[1] Categorias de Unidades de Conservação do Brasil: https://uc.socioambiental.org/o-snuc/categorias-de-ucs
[2] As unidades de conservação da esfera federal do governo são administradas pelo Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). Nas esferas estadual e municipal, por meio dos Sistemas Estaduais e Municipais de Unidades de Conservação.
[3] Find details below in the section "Consideration of ecological types of Atlantic forests in analyses. Additional plans for Paper#1".

Answer the question: Level of fragmentation (LF) of the entire Atlantic rainforest and by state became better, became worse or did not change from 2002 to 2016 (i.e. between 2002 and 2013, between 2014 and 2016).? Estimation will be conducted for the entire Atlantic rainforest biome and for each Brazilian state contained Atlantic rainforests.

Objective #3

Answer the questions:

1. What percentage of the entire Atlantic rainforest biome is covered by Conservation Units of Integral Protection (UCPI) and by Conservation Units of Sustainable Use (UCUS)?
2. What percentage of the most valuable (i.e. largest and intact) fragments of the Atlantic rainforest biome is covered by UCPI and UCUS?
3. How TFH parameter was changed between 2002 to 2016 within UCPI and UCUS?
4. What difference in efficiency of UCPI and UCUS? Which type of conservation unit is better conserves and restores the rainforest ecosystems?

Expected results
I expect to get the results that UCUS conserve and restore rainforests much worse than UCPI. Thus, I will conclude that UCUS regime of protection is not sufficient to protect the most valuable (i.e. large and undisturbed) fragments of the remnant Atlantic forests. However, currently the high percentage of area of those fragments are covered by UCUS. The significant area is not protected at all.

I will give the numerical parameters of the evaluation. I suppose to make a recommendation that the most valuable fragments of the remnant Atlantic forests should be covered by UCPI. While around them it is necessary to make a wide buffer zone on which can be established UCUS.

Methodological objectives for Paper#1

Objective#4 [methodological]

Study what *indirect remote indicators* (ndvi, evi, lai, fpar, gpp, day-surftemp, night-surftemp) correlate stronger with *direct remote indicators* (Landsat Tree Cover, Level of Fragmentation); and with *direct field indicators* (Table 4)[4]
The research question should be answered: Which indirect remote indicators can be used for Tropical Forest Health (TFH) analyses?

Practical significance of objective #4

The *indirect remote indicators* which will be revealed as the most effective indicators of TFH (i.e. which show the highest dependence on direct indicators of TFH) will be applied for estimation of TFH on huge areas and for creation the maps of TFH. Also, those parameters will be recommended in the paper for the same purposes to other researchers.

Obhective#5 [methodological]

Answer the question: which method (Radius of the largest circle inscribed in the fragment; Area of fragment) [5] is the best for fragmentation analysis? Consider the biological sense of the "Radius" method as significant advantage.

---

[4] The relationship between indirect remote indicators and direct field indicator will be explored in Paper#4. I consider it here as **verification** of Paper#1.

Methods

1.Several biophysical parameters reflected health, biomass and biological productivity of vegetation cover produced from MODIS satellite images (Terra and Aqua satellites) of small resolution (250 and 500 m in a pixel) will be applied for estimation of tropical forest health. There are: EVI (Enhanced Vegetation Index), NDVI (Normalized Difference Vegetation Index), LAI (Leaf Area Index), FPAR (Fractional Photosynthetically Active Radiation) and GPP (Gross Primary Productivity). Also, the Day surface temperature and Night surface temperature, obtained from MODIS thermal bands (1000 m in a pixel) will be applied with the same purpose. All these parameters will be considered as indirect remote indicators of TFH (Table 3). The GFC (Global Forest Change), consider as direct remote indicators of TFH will be used to detect forest areas which were not cut since 2001 to 2016 and areas which lost forests between 2001 and 2016 (Table 3).

2. Methods for Objective#1, steps for implementation:

Step-1. Compare the values of indirect remote indicators (NDVI, EVI, LAI, FPAR, GPP, Day surface temperature and Night surface temperature**)** for all fragments with area > 10 sq km between 2002 and 2014; 2014 and 2016 (or only between 2002 and 2016).

Step-2. Compare the values of Landsat Tree Cover parameter between 2000 and 2015.

Step-3. Make map by Delta: **$Delta = Value_{(2002)} – Value_{(2016)}$** for parameters which show be most clear indicator of TFH.

Step-4. The Delta analysis will give answer about the change of TFH of Atlantic rainforests:

Delta>0, the health decreased,
Delta<0, the health increased,
Delta=0 the health has not changed.

Step-5. Calculate Delta "in total" (i.e. for the entire Atlantic rainforest biome) and for each Brazilian state, containing Atlantic forests.

3. Methods for Objective#2, steps for implementation:

Step 1. Conduct the Level of fragmentation analysis by "Radius" and "Area" method[6] using the georeferenced fragments of Atlantic forests produced by SOS Mata Atlântica for 2015-2016 and for 2013-2014[7] (Table 3).

The results of the analysis will be the table and histogram showing the distribution of fragments by Radius and by Area for the entire Atlantic rainforests and for each Brazilian state. The following question will be answered:

- What difference in distribution of fragments by **Area** had been occurred between 2002 (by Ribeiro et al 2009) and 2014 in the entire Atlantic forest?
- What difference in distribution of fragments by Area and by Radius had been occurred between 2014 and 2016 in the entire Atlantic forest and by each state?

---

[5] Analysis of the level of fragmentation by the ***Radius of a largest circle inscribe in a fragment*** – is one of the methodological results of the project. It will be considered and applied for fragmentation analysis in the Paper#1. I'd like to compare the effectiveness of fragmentation analysis by Radius and by Areas of a fragment.

[6] Look in Glossary

[7] Initially I prepared the Level of Fragmentation Analysis only for 2013-2014, since there were no other data. But in January 2018 the SOS Mata Atlantica uploaded the data for 2015-2016. Thus, we can now compare these years. I suppose use both series of data.

Step 2. Estimate the tendency of the Level of Fragmentation by comparing its change between 2002 (by Ribeiro et al 2009); 2014 (by data of SOS Mata Atlântica 2013-2014); and 2016 (SOS Atlântica 2015-2016) for the entire Atlantic rainforests and for each state. The following research questions will be answered:

- How the area of the largest fragment was changed? (Will be compared the area of the largest fragment in 2002, 2014 and 2016).
- How the number of fragments was changed? (Will be compared the number of fragments in 2002, 2014 and 2016).
- How the total area of all fragments (i.e. the area of pure Atlantic rainforests) was changed? (Will be compared the area of all fragments in 2002, 2014 and 2016).

4. Consideration of ecological types of Atlantic forests in analyses. Additional plans for Paper#1.

I. The Atlantic Rainforest Biome is divided on 8 ecological regions:
Floresta Ombrófila Densa
Floresta Ombrófila Aberta
Floresta Ombrófila Mista
Floresta Estacional Semidecidual
Floresta Estacional Decidual
Manguezais,
Restinga,
Brejos de Altitude.

The maps of Vegetation and Biomes of Brazil can be download from IBGE website as PDF and GeoJSON files[8].

It is obviously that natural conditions of the intact Atlantic forest in ecological regions (i.e. the maximum value of TFH) will differ from each other. Thus, it would be incorrect to study the direct and indirect indicators of TFH of the Atlantic Rainforests considering those regions as unique type. According to this, for Paper#1 I will conduct the analyses of indirect and direct indicators of TFH separately for each ecological region.

For this I am going to select the *standard ecosystem* (i.e. the largest fragment with the best values of indicators of TFH) in each ecological region and estimate the TFH of each ecological region separately, using the values of indicators of TFH of those standard ecosystems as a measure of the best TFH value. Thus, for each ecological region, I will compare the TFH of each point with TFH of *standard ecosystem.*

For each ecological region the *standard ecosystem* will be detected by the following way. Firstly, the largest fragments will be selected. Secondly, a region within those fragments with best values of indicators of TFH will be detected.

II. Within each ecological region the natural condition of healthy Atlantic forest should be differ according to the following geographical parameters:

1. Remoteness from the Equator, i.e. the Latitude.
2. Continentality or the remoteness from the Atlantic Ocean, i.e. the Longitude.
3. Height among the sea level (forest on mountains), i.e. the Altitude
4. The amount of annual precipitation

I suppose that it will be impossible to consider those parameters in Paper#1, because of the small scale of its study. However, the ecological regions, which will be consider in Paper#1, depend from those geographical parameters. Their consideration will be enough for investigation of small scale.

[8] Look in the REFERENCE (Mapa de Vegetação do Brasil, Mapa de Biomas for Brasil)

I can consider those geographical parameters in Paper#4 and Paper#5 by selection of appropriate territories for filed measurements.

Paper#2

The first mapping of the high conservation value forests (HCVFs) of the remnant Atlantic forest in Brazil. The level of protection of the most valuable woodlands.

Introduction

The paper is devoted to continue the assessment of tropical forest health (TFH) in the Atlantic rainforests biome. I am going to emphasis the **forest quality criterion** as a key factor causing a **conservation value of tropical forests**. I will tell about the importance of use this criterion in various conservation practices: monitoring of forest areas (especially within Protected Natural Areas), development of natural corridors to link the forest fragments, creation of new protected areas and rainforest restoration.

Another purpose of the paper is mapping of **high conservation value forests** (HCVFs) basing on TFH assessment, i.e. to implement the first and pilot mapping of HCVFs in Brazil in national scale. This purpose of the paper is closely related with the first one, because HCVFs mapping can be considered as a form of forest mapping by its quality, health and conservation value parameter. The cartographic categories of HCVFs will be imposed on TFH map, which will be constructed previously.

In the Introduction section of the paper the following topics will be considered:

1. Three widely known conservation concepts[9]:
    - High Conservation Value Forest (HCVF)
    - Intact Forest Landscapes (IFL)
    - Ecological Network (ECONETS)

2. Tropical Forest Health (TFH) parameter as a measure of forest quality and conservation value of tropical forest. [link on Paper#1 or just use this term]

3. Three most valuable clusters of the remnant Atlantic rainforest biome (basing on the result of Paper#1 and literature):
    - Serra do mar Mountain Belt (states: Parana, Santa-Catharina São-Paulo, Rio de Janeiro),
    - Parque Nacional do Iguaçu (belongs to Intact Forest Landscape by international classification)
    - Large fragment of the Atlantic forest in Piauí state.

Objectives

Objective #1

To estimate of ecological quality of the remnant Atlantic rainforests by mapping and analysis of TFH remote (indirect and direct) indicators.

Objective #2

2.1 To develop the principles of High Conservation Value Forests (HCVFs) detection and mapping appropriate for Atlantic rainforests in Brazil.

2.2 To construct a map of HCVFs for the entire Atlantic forests. The both mapping (TFH and HCVF) should be linked with each other.

[9] The definitions of the concepts are considered in the section 3.4 The conservation concepts applied in the project.

Methods

The principle of HCVFs detection and mapping appropriate for Atlantic rainforests will be elaborated basing on the international principles of HCVF concept applied in various countries (Jennings et al 2003, HCV Resource Network (website)) as well as on experience of elaboration of the special HCVF categories sharpened to the specifics of natural zone and country (WWF International 2007, Maesano et al 2016, Yaroshenko et al 2001, Aksenov et al, 2006, Andersson et al 2009, Kobyakov et al 2011). In this paper, the HCVF categories will be revealed and mapped in a small scale, cover 16 Brazilian states consisting remnant Atlantic forests. Thus, the criteria of HCVF mapping should be very simple. They will be the following:

1. Size of a forest fragment (i.e. the Radius of the largest circle inscribe in this fragment; its Area)
2. Tropical Forest Health (TFH) parameter, determined by the most effective indirect remote indicators (considered in Paper #1).
3. Distance to the nearest "large forest fragment" (i.e. fragment with area > 30-50 sq km).

Then, each criterion will be defined by intervals. All territory occupied by Atlantic forests biome will be divided mechanically into HCVF types based on the affiliation to the value of intervals.

Radius = [R1..R2] (size)

Area = [S1…S2] (size)

Distance = [D1….D2]

TFH = [TFH1…..TFH2]

The each HCVF category will be described by the following parameters:

- Value of each interval of criterion (Radius and\or Area, Distance, TFH).
- Social significance
- Ecological quality or conservation value

The 1st parameter will determine the 2nd and 3rd ones.
TFH will be analyzed separately in each ecological type of the Atlantic forest, because the maximum value of remote and field indicators of TFH should differ among ecological types.

The most valuable categories of HCVF will be revealed in the best clusters of the remnant Atlantic forest of Brazil (Serra do mar Mountain Belt, Parque Nacional do Iguaçu, Fragment in Piauí state). Their identification also will be based on the same principle and criteria:

(i) **Intact Forest Landscape (IFL)**. The international HCVF category (Potapov et al 2017, Yaroshenko et al 2001, Table 3). It includes all fragments of native forests which areas more than 500 sq km and Width more than 10 km, which don't have any destructive human activity, like roadways, agriculture, buildings, forest cutting).

(i) **Quasi IFL**. Since the entire Atlantic rainforest biome has only 4 fragments which were detected as IFL by international system (Potapov et al 2017), it is possible to introduce the additional HCVF criteria for fragments which have close characteristics to IFL. We can base on the same methods which were implemented in revealing of the HCVF in Russia (Andersson et al 2009, Kobyakov et al 2011)

(ii) **Fragments with small distance between each other, fragments with ragged boundaries** (Ecological Network (ECONET) can be created from those fragments more easily)

(iii) **Small fragments in the vicinity of very large fragment** (Ecological corridor can be created more easily between them).

I am going to discuss those criteria with experts in HCVFs detection and mapping.

Paper#3

The dependence of activity of several frugivorous species on tropical forest health in a small fragment of Atlantic forest (case study: Mata Santa Genebra, SP, Brazil)

Collaboration with Eduardo Rigacci (Master of Science student, of Unicamp University, Institute of Biology)

Research question#1

Does the activity of frugivorous species in a small fragment of Atlantic forest depends on tropical forest health?

Objective question#1

Study how the distribution of frugivorous species in a small fragment of Atlantic forest (Mata Santa Genebra, SP, Brazil) depends on tropical forest health.

Methods

The observation will be conducted in a small fragment of the Atlantic forest located in the west of São-Paulo state, Brazil (Mata Santa Genebra, 252 ha, latitude -22.823598, longitude -47.113989).
Three groups of factors will be analyzed in 31 observation points located along the border of forest fragment:

1. The number of visits of several frugivorous species collected during a year by dint of camera trap.
2. The Normalized Difference Vegetation Index (NDVI) and Day surface temperature parameters, collected by a satellite image Landsat-8 produced in daylight hours of May 2018. The both remote sensing parameters will be considered as indirect remote indicators of TFH. Maybe some other indices of satellite images will be applied.
3. The field measurements listed in Table 4, which will be considered as direct field indicators of TFH.

The main objective of the paper to test the hypothesis that TFH influences strongly on the density of frugivorous species and on diversity of those species within forest area. For this, we will consider the observed activity of several frugivorous species as parameter dependent on TFH, while remote sensing indices and field measurements will be considered as indicators of TFH. By dint of statistical tests (Principle component analysis, Multiple regression analysis) we will study, which parameter of both categories influences stronger on number of visits of frugivorous species in a viewpoint. Also, we will analyze the relationship between indirect and direct indicators of TFH by dint of Pearson correlation test. We consider this test as a form of verification.

The other idea of the paper – to estimate the relationship between 3 categories of parameters indicating TFH (the activity of several frugivorous species, indirect remote indicators and as direct field indicators).

Paper#4

Assessment of the Atlantic rainforest health by remote sensing data of high resolution and field indicators

Proposal to Fundação Florestal for work in Protected Areas: June 2018.
Expected work: October – December 2018 or March – May 2019

Introduction

This study will continue the purposes of the previous papers in evaluation of TFH, detection and mapping of HCVFs in a regional scale, that is, with more detailed and precise results.

The technical objectives of the study: (i) to develop a method for using direct field indicators (Table 4) as independent TFH indicators; (ii) to study the possibility of combining direct field indicators and indirect remote indicators of high resolution. The practical objectives of the study to reveal and map of HCVFs for three best clusters of the remnant Atlantic rainforests in Brazil.

Objectives

Objective#1 [methodological]

To elaborate of the methodology of Tropical Forest Health (TFH) evaluation and High Conservation Value Forests (HCVF) detection and mapping, appropriate for a regional scale by two approaches:
1. indirect remote indicators (remote sensing data of middle resolution; if it will be possible - remote sensing data of high resolution, hyperspectral images, UAV imagery).
2. direct field indicators (the field parameters considered in Table 4)

Objective#2 [practical]

To reveal and map of High Conservation Value Forests (HCVF) in 3 most valuable clusters of Atlantic forest[10], i.e. **Serra do mar Mountain Belt, Parque Nacional do Iguaçu, Fragment in Piauí state**, basing on the elaborated methods. To conduct verification of the revealed HCVFs by field studies.

Methods

Preparing for field studies

The field studies will be implemented in areas located in three most valuable clusters of the Atlantic forest, i.e. **Serra do mar Mountain Belt, Parque Nacional do Iguaçu, Fragment in Piauí state.**
The areas chosen for study for Paper#4 will be also the *standard ecosystem* of the appropriate ecological region, selected for Paper#1[11].
Most probably that appropriate areas will be located in the Protected Natural Areas. It will be necessary to obtain a special permission for investigation in Fundação Florestal. The study area should be located in the most intact forest, i.e. in a large fragment, far from its boundaries, roadways and any towns and villages. [Question#1]

Question#1. I need to select of protected natural areas appropriate for field investigation. They should be located in 3 best clusters of the remnant Atlantic forest (Serra do mar Mountain Belt, Parque Nacional do Iguaçu, Fragment in Piauí state), in the largest forest fragments, far from roadways and towns. Could you recommend of protected natural areas which I can study?

I am going to apply of proposal about a permission of investigation in chosen Protected natural areas and expect to implement those works between October and December 2018, and\or between March and May 2019. At the same months I am going to develop other papers as well (so I expect to work in fields by short-term periods).

[10] The most valuable clusters of Atlantic forest were identified previously by the Level of Fragmentation analysis as concentration of the largest fragments of the remnant Atlantic forest and by indirect remote indicators (NDVI, Day Surface temperature). Those conclusions will be considered in Paper#1 after completion of analysis.

[11] For Paper#1 I am going to select the *standard ecosystem* (i.e. the largest fragment with the best values of indicators of TFH) for all ecological regions of Atlantic forests. Thus, the largest fragments detected as IFL by international system will be selected as *standard ecosystem* of the appropriate ecological region.

The scheme of the field investigations in each chosen protected area will be the following:

1. At first, the possible **zoning of Atlantic forest types** within the chosen Protected area will be conducted. The zones can be selected by parameters of altitude above sea level, distance to Atlantic Ocean (longitude) and distance to equator (latitude). Also, the published zoning map will be applied if it will be found.
2. Then, 1-3 **typical areas** (TA) within each type of the Atlantic forests will be selected for field and remote sensing investigations.
3. Next, the field studies according to Table 4, and the analyses of the satellite images (Landsat-8 and\or Sentinel) according to Table 3 will be conducted.

By this manner we will obtain both – indirect remote indicators and direct field indicators of TFH of each typical area.

We can consider the values of those indicators, as parameters of "standard forest ecosystem" of each type of Atlantic forest (as they were obtained on undisturbed forest areas with highest level of TFH). I titled those values of indicators as "standard values of indirect remote indicators" and "standard values of direct field indicators".

The standard values of indirect and direct indicators can be applied for the following:

(i) **Revealing of HCVF of each type of Atlantic forest**
The reveal and mapping of HCVFs will be conducted by dint of standard values of indirect remote indicators. The **buffer zone**s of standard values will be selected and automatic classification will be implemented in ArcGIS or ENVI software. The idea is the following – we will include in HCVFs of each type of Atlantic forest all areas with **ideal values of TFH** (i.e. the **standard values of** indirect remote indicators) and all territories with values fallen within the buffer (i.e. those territories are not so healthy *as standard forest ecosystem*, but still enough health and appropriate to be included in HCVF).

(ii) Verification of the revealed HCVF by field studies
Verification of the revealed HCVF will be implemented by direct field indicators (by field measurements), which will be conducted in plots selected randomly, or plots of equally spaced grid.

(iii) Monitoring of HCVFs

Monitoring of the detected HCVFs should be carried out annually during many years. This measure will be appropriate for Protected natural areas (thus, we can recommend to do it in studied protected areas in our papers).

I am going to implement the Objective#2 of Paper#4 by implementation of (i) and (ii) steps of the considered scheme. While (iii) step I will considered in recommendation or conclusion of the paper.

Finally, I expect to obtain the maps of TFH and HCVFs of the studied protected natural areas and (probably) the same map for the entire three best clusters of the Atlantic Forests (I consider the protected areas as a model for study).

Field investigation

To explore the **standard values of direct field indicators** of TFH, the field investigation in each **typical area** will be conducted. For this, a series of plots (10 x 10 m, 3-5 plots in a series with a distance of 25 m between adjacent plots) will be conducted and field parameters considered in Table 4 will be measured. However, the field methodology in still open question (Question#2):

Question#2. What do you think about the methodology of measurement of the filed parameters (Table#4) and size of plot where those measurements will be implemented?

I am thinking about two variants of plot – square plots 10x10 m (I worked with them previously) and plot as transect (4 m in width and 30-40 m in length). According to the literature review, there are no single standard in size of a plot using to study the plant species diversity and other ecosystem parameters. However, a lot of projects were implemented using 1 ha plots. Thus, 1 ha (100m x100m) should be considered as the most common and appropriate size of plot for exact analysis. However, I am working on a fast method of TFH estimation and 1 ha plot – is too large for this purpose, since it is unreal for one or two people to implement the necessary measurements (Table 4) in a 1 ha plot.

To verify the HCVFs mapping, the same field investigations in series of 3-5 plots will be conducted in the tested areas, which will be chosen randomly or as equally spaced grid within verified territory.

Remote sensing studies of middle resolution (free of charge)

Several biophysical parameters reflected health, biomass and biological productivity of vegetation cover produced from **Landsat-8**, **Sentinel** of middle resolution (30 m in a pixel) will be applied for estimation of tropical forest health. There are: EVI (Enhanced Vegetation Index), NDVI (Normalized Difference Vegetation Index), LAI (Leaf Area Index), FPAR (Fractional Photosynthetically Active Radiation) and GPP (Gross Primary Productivity). Also, the Day surface temperature and Night surface temperature, obtained from Landsat-8 and Sentinel thermal bands (100 m in a pixel) will be applied with the same purpose. All these parameters will be considered as indirect remote indicators of TFH (Table 3).
The GFC (Global Forest Change), consider as direct remote indicators of TFH will be used to detect forest areas which were not cut since 2001 to 2016 and areas which lost forests between 2001 and 2016 (Table 3).

Remote sensing studies of very high resolution (probable, if I found money or imageries)

Remote sensing data of very high resolution can be used to reveal of more accurate indicators of TFH. However, initially I did not base the project on those instruments as the principle methods, because of their high cost. The high cost narrows possibility of methods spreading. Also the project's goal to make of TFH assessment methodology available for everybody, thus the methods should be developed basing on free data and software.
I suppose that UAV (unmanned aerial vehicle) among all remote sensing data of very high resolution, has the greatest prospects for this study. This is the cheapest and the most flexible technology, because the photographing is conducted only over the necessary areas and controlled by operator. The hyperspectral imagery conducted by special hyperspectral camera of UAV can be especially important for the project's goals. LiDAR data also can give interesting possibilities.

Therefore, the plans of investigations with those instruments will be elaborated only in case I found the opportunities to work with them. Each instrument has its own spectrum of possibilities, which should be considered in plan elaboration (Question#3).

Question#3 What about possibilities of remote sensing data of very high resolution: satellite images, LiDAR data, UAV with cameras, which I can use for this study?

Paper#5

Soil as indicator of Atlantic rainforest disturbance

Collaboration with geochemical laboratory of the Institute of Applied Economic Geology of the University of Concepción, Chile.

Objectives

The purpose of the study is to find parameters in soil, which can serve an indicator of the history of logging in the forest area, that is can show whether a logging was carried out on the studied area or the forest is undisturbed. Also this indicator should detect the approximate period of the last logging for the secondary forest and for deforested areas.

The key objective of the study is to find a clear soil indicator of undisturbed rainforest, i.e. to prove that no logging has been carried out in this area (or in the last 200 to 300 years).

The soil indicator of intactness of tropical forest can serve for detection, mapping and monitoring of High Conservation Value Forests.

Methods

This study is proposed as combined project with the geochemical laboratory of the Institute of Applied Economic Geology of the University of Concepción, Chile.

We are going to study the soil profiles in three typical environments. First, we will sample the soil section formed under intact cover of Mata Atlantica. Then, we wish to research the soil horizons deposited under pastures substituting the deforested Mata Atlantica for many decades. Finally, we will visit the secondary vegetation restored on the site of the cut down Atlantic forest [Mata Santa Genebra?]. The study sites should be chosen in order to minimize the impact of none-anthropogenic factors to soil characteristics; i.e. parent rock chemistry and lithology, local climate, altitude should be the same. At the initial stage we will study the full sequence of soil and regolith horizons from A to C levels. The objective of this first stage will be to design a universal model of soil forming processes and to outline a possible impact of deforestation to the soils. Then, after those characteristics will be determined, we will sample the impacted soil levels only to collect the extended dataset for statistical analyses.

Soil cuts with expected depth of 1-2 m will be sampled every 0.1 m. All samples will be studied in the geochemical laboratory of the Institute of Applied Economic Geology of the University of Concepción, Chile.

The grain size analyses are cheap and robust means to distinguish the samples of distinct genesis. The impact of deforestation can be reflected by a drop in the P80 of the soil particles as finer eolian sediments can be effectively transported to the upper horizons. The laser diffraction granulometry (Hosokawa Micron Powder Systems LS I3 320) is a fast and easy option to complement a basic chemical database generated by XRF data. Additionally, the determination of specific surface areas and porosity by the dint of the BET method (Quantachrome NOVA 2200e) should be carried out on the undisturbed soil-chips. The BET surface area may be another important distinguishing feature for eolian impact to the soil lithology. The particles with higher ratio of BET areas versus their weights are preferentially transported by wind.

Chemical analysis of whole samples is another promising approach for the soils characterization. Depending on time-frame, elements of interest, limits of detection, and efforts to be invested in sample preparation, X-ray fluorescence spectrometry (XRF - Rigaku ZSX Primus II), and ICP-OES (Perkin-Elmer Optima 5300 DV) prevail as measurement options. For our study cases, wavelength dispersive XRF will be used in a non-standardized mode for compacted powder disks. Given the ease of sample handling, this type of analysis will be applied to all samples from whole profiles and samples from horizons of interest. This will generate an initial site database which together with particle size distribution will permit statistical identification of sample families and thus will reduce the number of samples for further, more time consuming chemical and mineralogical characterizations.

At the next stage we will process the tabulated data with principal component, multiple regression and hierarchical cluster analyses in the IBM SPSS Statistics 20 (SPSS, Chicago, IL, USA) software. Those techniques are often applied in geochemistry to classify rocks by their chemical composition (e.g. Vasilenko et al., 1997). In order to mitigate the impact of abundant rock-forming elements, we will normalize the variation of concentrations among samples to 1. Also we will exclude from consideration all incomplete and uncertain data. To implement the hierarchical clustering, the number of samples has to exceed two times the number of variables (Argyrous, 2005). The method bases on the computation of vector distances (D^{ab}) between samples:

$$D^{ab} = \|\boldsymbol{x^a} - \boldsymbol{x^b}\| = \sqrt{\sum_i^n \left(x_i^a - x_i^b\right)^2} \qquad \text{(Eq. 1)}$$

where $\boldsymbol{x}\{x_{1,}x_{1,} \dots, x_n\}$ are numerical characteristics (elemental contents, P80, fraction less than 2 µm, ect) of samples *a* and *b* normalized to maximum value among all samples. The software generates a matrix of distances, looks for a couple of samples with the least distance, redefines this couple as a new sample with averaged characteristics and repeat the loop till all the samples are classified. The result of calculations is presenting as a dendrogram with relative distances between clusters of samples. The most typical sample of each cluster will be determined by minimal vector distance ($Affinity$) to the median composition ($\boldsymbol{\bar{x}}\{\bar{x}_{1,}\bar{x}_{1,} \dots, \bar{x}_n\}$):

$$Affinity = \|\boldsymbol{x} - \boldsymbol{\bar{x}}\| \qquad \text{(Eq. 2)}$$

Further microscopic analysis (Bruker SEM coupled with EDS) will reveal the mineralogy in those most typical samples. By means of this approach we wish to explain the shown heterogeneity in eolian input and secondary mineralization related with deforestation and subsequent restoration of Mata Atlantica.

3. Preliminary results (short summary)

3.1 Data collection

In the past period of the project the all necessary data for Paper#1 and Paper#2 were collected, the technique of their application was studied by special manuals and papers.
Those data are:
1.1 MODIS products for September 2003, September 2014 and September 2017: EVI (Enhanced Vegetation Index), NDVI (Normalized Difference Vegetation Index), LAI (Leaf Area Index), FPAR (Fractional Photosynthetically Active Radiation) and GPP (Gross Primary Productivity); the Day surface temperature and Night surface temperature (Table 3).
1.2 The georeferenced data (polygonal shape file) of all fragments of the remnant Atlantic rainforests, Restinga and Mangrove forest in Brazil, produced by SOS Mata Atlântica for years 2013-2014 and 2015-2016 (Table 3).
1.3 Landsat Tree Cover for 2000 and 2015 (Table 3)
1.4 Global Forest Change for 2016 (Table 3)
1.5 Other georeferenced data which will be applied in analysis and map construction - Protected Natural Areas, Rivers, Roadways, Tree plantations, Urbanized zones (Table 3).

3.2 Elaboration of the methodology of TFH assessment

In the past period of the project there was a progress in the development of the methodology of TFH assessment by satellite images of small resolution and existent georeferenced data of forest fragments.

1. The novel method of **Level of Fragmentation Analysis** was elaborated and applied for the project purposes. The method is based on *Radius of a largest circle inscribed in a fragment* (Radius). This method has a clear **ecological sense**, which gives it an advantage in comparing with fragmentation analysis based on *Area of the fragment* (Area). However, one of the aims of the project - to compare the effectiveness of both methods.

The ecological sense of the "Radius" method of fragmentation analysis is the following:

a. The *Radius of a largest circle inscribed in a fragment* denotes the **largest distance** which any wild animal can move away from the boundaries of a fragment into its depth. This parameter, which I called "**the maximum distance of possible ingress in a forest**" (distance maximum), is a **limiting ecological factor** for any native animal species. It determines the possibility of using this fragment for habitat and for migration (for habitat its value should be greater than for migration). In general, it can be supposed that the larger the animal, the greater the distance maximum it needs. The Area of a fragment does not define this parameter, because the fragment can be narrow and long (i.e. a fragment may have small distance maximum , but large area).

b. The *Radius of a largest circle inscribed in a fragment* denotes the **depth of a fragment**, which in its turn determines the **degree of conservation of undisturbed forests** in this fragment. According to my hypothesis (which I also want to test in the project), any fragment has a **buffer zone** in which the forest quality (TFH) decreases rapidly. Outside this buffer zone the forest ecosystem is stable and does not change its quality. In general, the larger the radius, the more valuable the forests within this fragment can be.

2. I proposed a **buffer zone hypothesis**: Each fragment should have a **buffer zone** with width **constant** in equal natural conditions (i.e. latitude, longitude and altitude) where the forest quality (TFH) is rapidly reduced. Within the fragment (outside this buffer zone) the forest ecosystem should be stable and does not change its quality during years. The preliminary results (profiles of NDVI and Day surface temperature parameters constructed for a large forest fragment) can be interpreted as a confirmation of this hypothesis (Fig. 1, Fig. 2). However, it is necessary to conduct more analysis of fragments (while the facts are not enough to prove it).

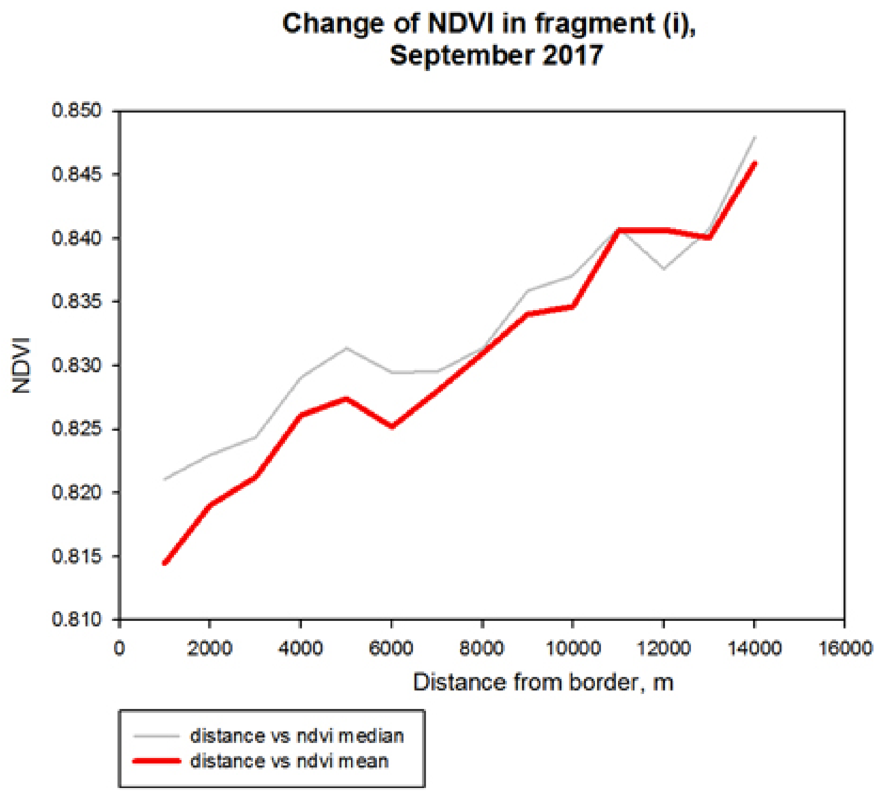

Fig. 1 Change of NDVI in a fragment of the remnant Atlantic forests (Serra do mar, September 2017, MODIS product).

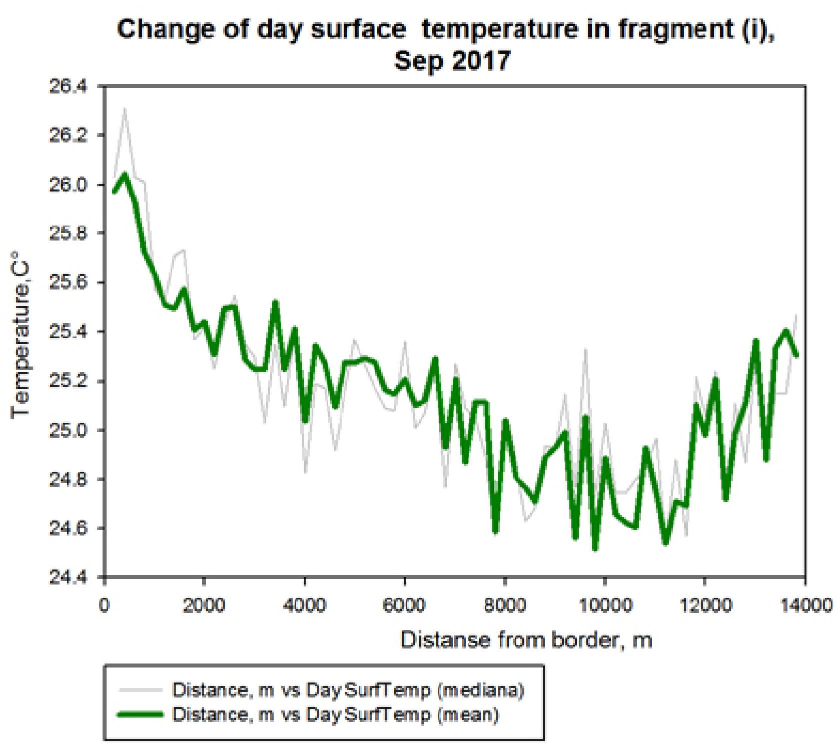

Fig. 2 Change of day surface temperature in a fragment of the remnant Atlantic forests (Serra do mar, September 2017, MODIS product).

If the hypothesis will be confirmed, it can be used to classify the forest fragments by their conservation value. If the Radius is less than the Width of the buffer zone, the entire fragment will be in the zone of rapid degradation. The bigger the Radius of the fragment the Width of the buffer zone, the greater the area inside the fragment occupied by sustainable forest ecosystems, the areas valuable for conservation. In particular, this could be used to select the best pathways for natural corridors linking the forest fragments.

The objectives of the project (Paper#1) include:

1. Test the hypothesis
2. Find the width of buffer zone for different types of Atlantic forest.

3. To study the effectiveness of the biophysical and temperature parameters obtained from MODIS (NDVI, EVI, LAI, FPAR, GPP, Day surface temperature and Night surface temperature) as indicators of Tropical Forest Health (TFH), the Principal component analysis (PCA) and the Pearson Correlation Test (PCT) were conducted with two parameters of fragment size - Area and Radius. Here I considered the both parameters of fragment size as **direct indicators of TFH** (I supposed that the greater the Area and Radius, the bigger TFH should be). Also (according to literature and results of my studies) I considered that the high values of biophysical parameters and low value of temperature parameters will indicate the high TFH.

I applied for statistical tests all fragments of Atlantic forest georeferenced by SOS Mata Atlântica for 2013-2014 (Table 3) with area larger than 10 square kilometres. By dint of several technical steps implemented in QGIS, I obtained the mean value of each MODIS parameter within each fragment. In PCA all parameters were considered as independent variables. In PCT the parameters were compared by pairs (biophysical parameter & Area or Radius).

PCA showed a high direct correlation between all biophysical parameters (NDVI, EVI, LAI, FPAR, GPP) and high inverse correlation with Day surface temperature (Fig.3, Fig.4).
This result allows to conclude that if one of those parameters is **a real indicator of TFH**, all other parameters – are also indicators of TFH.
There are a lot of confirmations in literature, that NDVI is clear indicator of vegetation health, including tropical forests (Genesis et al. 2014). In general, the higher is NDVI the better THF should be. Day surface temperature – should be also a clear indicator of TFH, since this temperature depends on shadows of forest canopy (the smaller is the day surface temperature the higher TFH should be). Also, in my previous not published studies in Forest of Jundiaí, Forest of Serra do mar belt near Casa de Farinha (June 2014) I got high invers correlation between day of surface temperature and TFH and high direct correlation between NDVI and **TFH**.

Therefore, the PCA result can be interpreted as a clear proof, that all those parameters (NDVI, EVI, LAI, FPAR, GPP and Day surface temperature) can be applied as indicator of TFH.

At the same time, PCA showed the absence of relation between those parameters and fragment size, i.e. Area and Radius parameters (Fig.3, Fig.4).

The PCA result allow to conclude that in case of use of all fragments of Atlantic forest georeferenced by SOS Mata Atlântica, the **size of a forest fragment is not a direct indicator of forest quality**. This means that inside the fragments selected by SOS MA as Atlantic forests, there are many those fragments, which, having a large size, contain very degraded forests (with low values of biophysical parameters and high value of day surface temperature).

Both conclusions are new and important facts, which are interested from the methodological and the actual point of vew. They will be elaborated more and included in the paper

Rotated Component Matrix[a]

	Component	
	1	2
FPAR_mean	,937	-,011
LAI_mean	,919	,002
GPP_mean	,889	,006
ndvi_mean	,891	,041
EVI_mean	,868	,023
Daysurftemp_mean	-,693	,116
Radius	-,011	,995

Fig. 3

Rotated Component Matrix[a]

	Component		
	1	2	3
FPAR_mean	,883	-,302	,085
LAI_mean	,868	-,274	,112
GPP_mean	,796	-,360	,147
ndvi_mean	,912	-,116	,091
EVI_mean	,903	-,093	,052
Daysurftemp_mean	-,365	,877	-,294
NightSurfTemp_mean	-,207	,839	,296
Delta_T	-,302	,368	-,727
Area	,006	,186	,686

Fig. 4

The Pearson Correlation Test conducted between each biophysical parameter and fragment size parameter (Area and Radius), showed that distribution of all biophysical parameters is divided in two clouds of points (upper and lower, Fig. 5). Within each cloud there is a high correlation, but there is no total correlation. The results of PCT showed that for such analysis it is impossible to use all the fragments included in Atlantic forests Biome by SOS Mata Atlantica (Table 3). It is necessary to make a sample of fragments in which there will be no fragments containing large areas of degraded forest.
I will continue these studies and include the results in Paper#1.

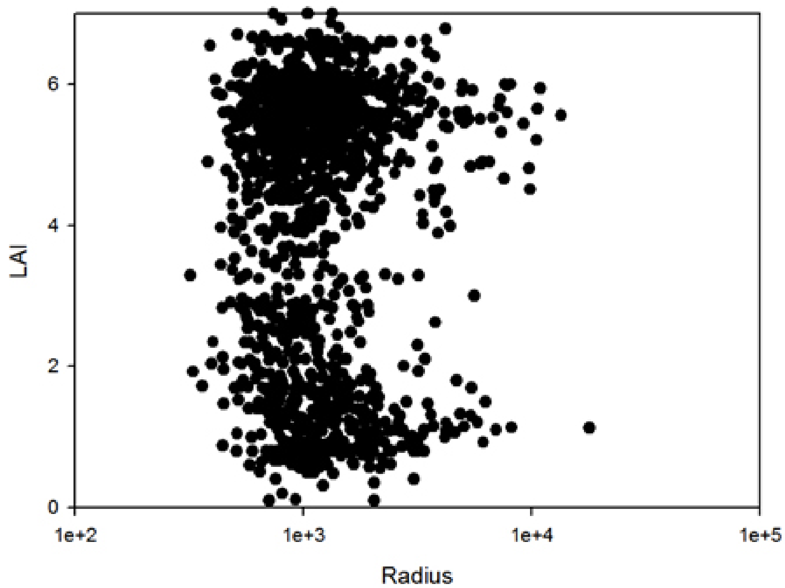

Fig. 5

4.3 Preliminary results of the Atlantic forest health assessment

(i)Analysis of the TFH of the Atlantic rainforest by NDVI

Preliminary, I used only NDVI to analyze the TFH of the entire Atlantic forests, since this index of vegetation was confirmed as indicator of health of vegetation cover, including tropical forests (Genesis et al. 2014, my studies)

For a healthy (undisturbed) rainforest, the NDVI value should be 0.8-0.9, for secondary and degraded tropical forest NDVI can be 0.5-0.6. Preliminary results shown that high percent of Atlantic forest fragments has NDVI <**0.3-0.5**, which is not typical at all for forests, especially for tropical forest. In general, the range of NDVI varies from 0.2 to 0.9, but only small percent of fragments have the best values of NDVI (0.8-0.9).

This allow to suggest, that significant percent of area, determined by SOS Mata Atlântica as Atlantic forest biome (Table 3), has a strongly degraded vegetation cover, which TFH is far from the values of healthy original ecosystems of the Atlantic forests.

I will finish these studies and then present results in clear form (tables, histograms of distributions, maps, statistical tests result).

(ii) Level of fragmentation analysis

The analysis of fragmentation of the entire Atlantic forest biome for 2013-2014 (Table 3) was conducted and compared with situation considered in Ribeiro et al, 2009 for 2000-2005. I used the same territory as in Ribeiro et al, 2009, i.e. 139,584,893 ha (94% of the original Brazilian Atlantic Forest region). The definition of this area was based on the extent defined in Brazilian legislation (Federal Decree No. 750/93 and Atlantic Forest law No. 11 428, of December 22, 2006), and slightly expanded according to the delimitation of BSRs by Silva and Casteleti (2003). (Ribeiro et al, 2009).

Also, as in Ribeiro et al, 2009, I joined Atlantic, Restinga and Mangrove forest in a single type and analyzed the level fragmentation for it.

The inclusion of data on Mangrove and Restinga forests does not significantly distort the assessment of pure Atlantic forests, due to their small **percentage in** area and location mainly on the Atlantic coast. In 2014 the Mangrove forest occupied 239870.74 ha or 0.17% of the total mapped area; Restinga forest covered 649186.15 ha or 0.47% of the total mapped area. In total both types of forest covered 889056.88 ha or 0.64% of the total mapped area. In 2005 (Ribeiro et al, 2009) the total area of Remaining Restinga and Mangrove forests was 658135 ha or 0.47% of the same mapped area. In 2014, the portion of Mangrove forests and Restinga forests relative to the area of all three biomes (i.e. 18786778.58 ha) was 4.7%. In 2005 the portion of Mangrove forests and Restinga relative to the area of all three biomes (i.e. 16,377,472 ha) was 4.1%.

The number and area distribution of fragments

The results showed that the number of fragments increased from **245,173 at 2005 to 271,096 in 2014.**
In the distribution of fragments by area there was a slight decrease in the proportion of small fragments (up to 1000 m) and an increase in the proportion of fragments larger than 1000.
The most important difference in the data of 2005 and of 2014 is a **significantly decrease the areas of the largest fragments of the Atlantic forest biome**. In 2005 the largest fragment occupied an area of **1,109,546 ha**, covering the coastal mountainous areas of the São Paulo and Rio de Janeiro states. Following him, also in the mountain system Serra do Mar, there were fragments with areas 508,571 ha (coastal zone of Paraná state) and 382,422 ha (coastal zone of Santa Catarina state).
However in 2014, the largest fragment was found in the state of Piaui and covers an area of **328,124.81 ha**, and in the mountain system of Serra do Mar, the largest fragments have an area near only 90000 hectares (Table 6, Fig.3 – 5). Thus, there was a reduction in the area of the largest fragment from **1,109,546 ha to 328,124 ha.**

Since the largest fragments have **the greatest environmental value**, the revealed fact (a significant reduction of the area of the largest fragments) is a very serious negative factor in changing the condition of the entire Atlantic forests Biome. This is a strong fact for publication.

But it is important to identify and specify in the paper the reason for such sharp decrease the area of the largest fragments. The reason may be real (during 10 years the new roads were built, which cut large fragments into several smaller ones). Also, the reason may be methodological. I considered any automobile road (that was included in the Road of Brazil georeferenced layer of IBGE (Table 3) **as the object that divides the forest area into fragments**. Therefore, the original layer of Atlantic forests (SOS Mata Atlântica, 2013-2014) I cut by these roads. I did this on the basis of a common understanding that any automobile road creates fragmentation, as well as basing on international criteria applied in Intact Forest Landscapes (IFL) and close types of HCVF identification (Potapov et al. 2017, Yaroshenko et al 2001). It is possible that in the processing of data of Atlantic Forests in 2005 (Ribeiro et al, 2009) the roads was not taken into account. This question may be able to answer by prof. Milton Ribeiro as principal author of this paper (Question#4):

Question#4. Question about the data processing for the paper "How much is left, and how is the remaining forest distributed", (Milton C. Ribeiro et al, 2009): Were the automobile roads considered as objects dividing of a solid forest area on fragments in the processing of the georeferenced data of the Atlantic Forests (SOS Mata Atlântica, 2008)?

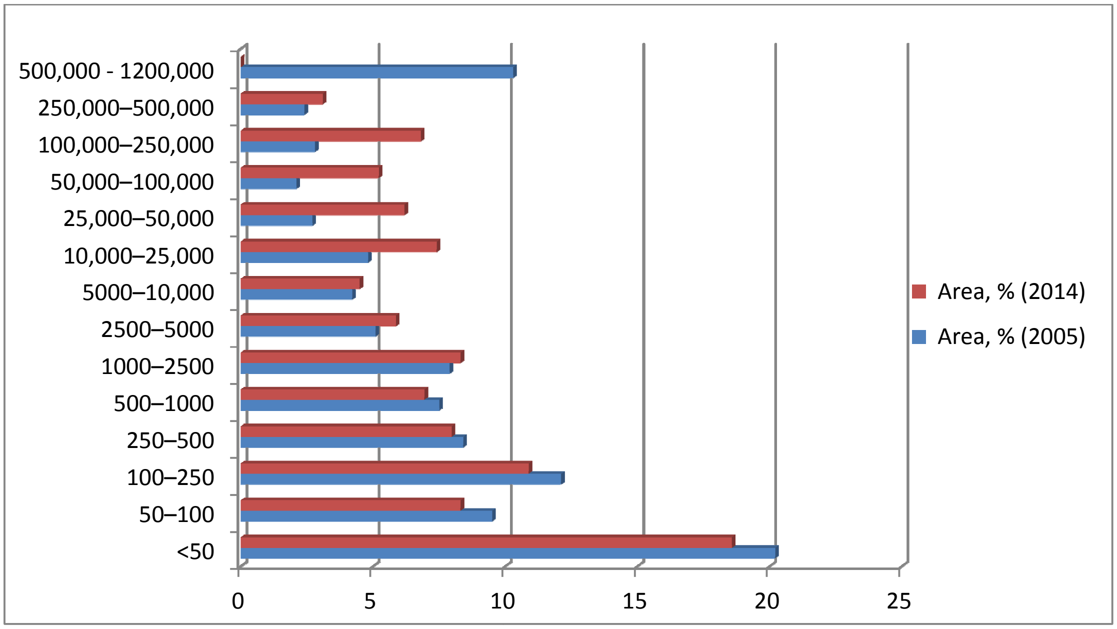

Fig. 6. Sum of Area, % (2005, 2014)

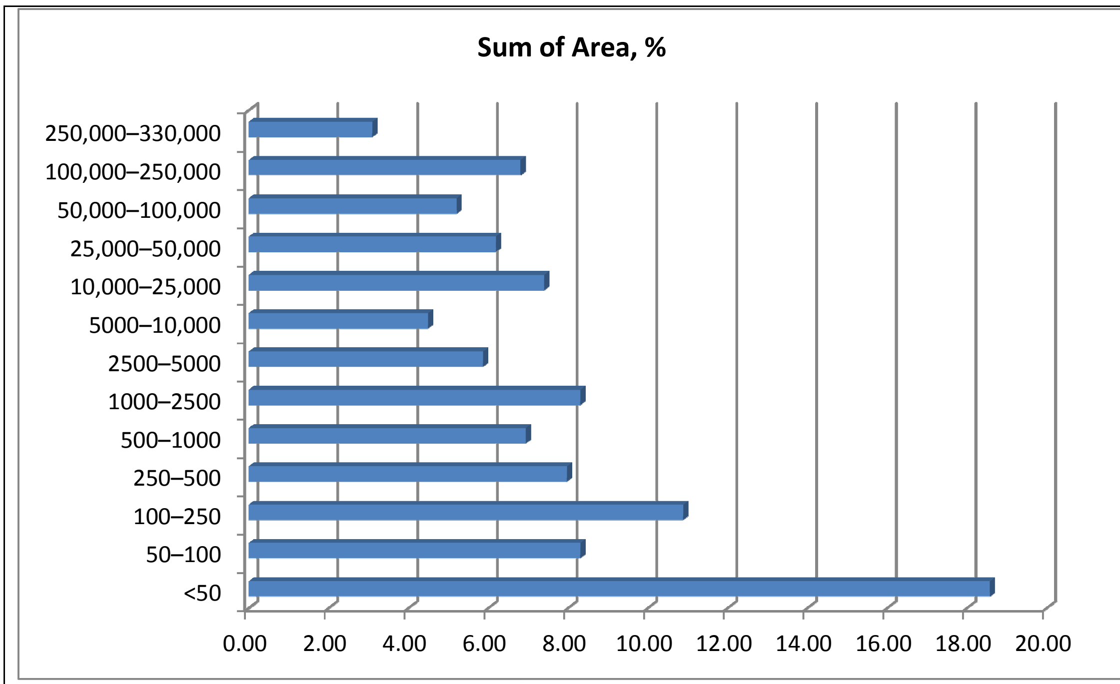

Fig 7. Sum of Area, % (2014)

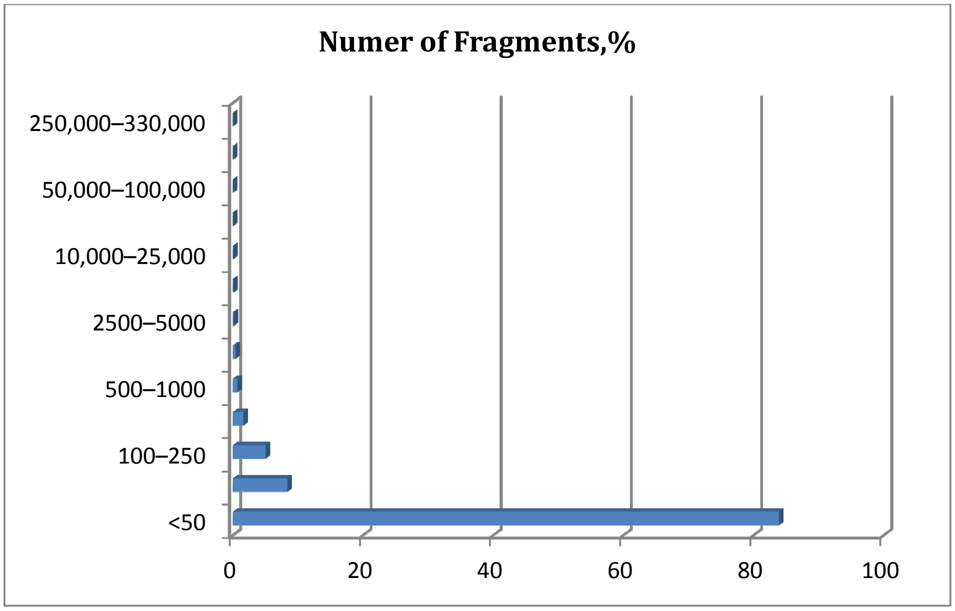

Fig. 8 Number of Fragments, % (2014)

3.4 The conservation concepts applied in the project

The literature review and conversation with specialists in GIS, Remote sensing, Nature Conservation, HCVF detecting and Voluntary forest certification FSC (Forest Stewardship Council) allowed to advance in the conservation "strategy" of the whole project, that is, to develop its environmental ideas, its actuality and ways of its implementation in the practical conservation process in Brazil.

I have increased my knowledge in principles of work of important environmental concepts which widely applied in the world in conservation practice. There are the following:

1. High Conservation Value Forests (HCVFs)
2. Intact Forest Landscapes (IFL)
3. Ecological Network (ECONETs)

Those concepts directly related with the initial principal objectives of the project. I believe that these concepts should be included in the project as the key concepts in relation with which the studies will be implemented. This will increase the practical significance and actuality of project, the potential of its use for tropical forests conservation and, in this regard, the publication of papers in strong international journals.

The definitions of those concepts and the literature through which they can be found are considered below.

High Conservation Value Forest (HCVF) is the area of forest required to maintain or enhance a **High Conservation Value** (Table 7).

The **High Conservation Value Forest (HCVFs) concept** was introduced in 1996 by the purpose of forest voluntary certification. The FSC[12] started considering the term of high conservation values in 1996 and

[12] Forest Stewardship Council (FSC) - the international non-profit, multi-stakeholder organization established in 1993 to promote responsible management of the world's forests. It provides the voluntary forest certification, which became the

included the term high conservation value forests in the FSC Principles and Criteria of Forest Stewardship in January 1999.

FSC uses the concept of HCVFs among its others criteria to create a sustainable forest industry and to protect of valuable forests. The essence of the concept of HCVFs is considered in the book "*The High Conservation Value Forest Toolkit*" (Jennings et al. 2003), which was translated in many languages and applied for publication the national manuals about methodology of HCVFs identification. It was also published in Portuguese (Guia geral..2013).

The **Intact Forest Landscapes (IFL) concept** was introduced in 2001 by a large team of environmental organizations. The initiators of the development of this concept was the Forest Department of Greenpeace of Russia (namely Alexey Yaroshenko, the head of this department). Greenpeace involved in this work many of Russian experts of the remote sensing and nature conservation (Transparent World, Biodiversity Conservation Center, WWF of Russia), colleagues from Germany (Greenpeace of Germany) and United States (Maryland University, Global Forest Watch). In 2014 on the initiative of Greenpeace of Russia (exactly Alexey Yaroshenko), the IFL concept was included in the FSC standards as the form of "Motion-65»: http://ga2014.fsc.org/download.motion-65.120.pdf

Actually, the IFL concepts is a part of the HCVF concept, since the definition of Intact Forest Landscapes corresponds to HCV1, HCV1 and HCV3 categories of High Conservation Value Forest (Table 7).

However, the IFL (or intact forests) has acquired its own criteria of definition. The IFL includes those native forest, which has not been cut down for several hundred years, the area of which is not less than 500 square kilometers and the width of which is not less than 10 km. (Potapov et al. 2017, Yaroshenko et al 2001). The authors of the IFL concept evaluated the intact forests around the world. The results of the last (and second) evaluation of the remnant intact forests are given in the paper Potapov et al. 2017 and the related interactive map on Global Forest Watch (section LAND COVER): https://www.globalforestwatch.org/map

Since the year of foundations, both concepts have been applied to protect of valuable ecologically and socially forests outside the FSC voluntary certification system and within it. A lot of projects dedicated to forest evaluation and HCVFs mapping were conducted among the world (WWF International 2007, Maesano et al 2016). Many of those projects were implemented in various natural areas of Russia principally by leadership of WWF and Greenpeace. The results of those project were published as valuable methodological manuals describing the methods of identification and mapping of HCVF. (Yaroshenko et al 2001, Aksenov et al, 2006, Andersson et al 2009, Kobyakov et al 2011). The considered methods in those publications with small national modifications can be used for other regions.

FSC works in Brazil. However, the HCVFs concept (identification and mapping of valuable forests, consider this data in the forest industry and nature conservation) has not been developed.

It seems that in 2007 it was an attempt to introduce the HCVFs concept in Brazil for development of the FSC forest certification system and for general environmental objectives. But this attempt was not succeed. However, the FSC has a great interest in the development of HCVFs concept in the country. This follows from the website of HCVFs international:

https://www.hcvnetwork.org/resources/countrycontainer.2006-09-27.2436295488/country.2006-09-27.1197150034)

---

most popular and the most effective voluntary forest certification in the world. Many countries have national FSC offices which certify the forest company if their activities are consistent with the FSC criteria (codex of rules)

HCVF development in Brazil

There is now considerable interest in developing a framework for HCVF in Brazil. The conversion of natural forest to pasture or soybean agriculture remains controversial throughout the country, not just in the Amazonian frontier, and both agricultural and forestry sectors have recognised the need for a way to ensure High Conservation Values are protected in areas where land use change is taking place.

The FSC National initiative is about to undertake a review of the national certification standards for Natural Forest and Plantations (due early 2007) and the incorporation of additional guidance on implementation of Principle 9 would be timely.

Notes

I believe that a pilot mapping of High Conservation Value Forests (HCVFs) of entire area of Atlantic rainforest (or at least the most valuable clusters) would be good input to the Doctoral project and papers. This step may allow to launch the application in Brazil of HCVF concept, which is an important international environmental concept and practice allowing better conservation of valuable forest. It has already been widely developed in many countries of the world, but Brazil still does not work with it.

In my project I am elaborating the methods which allow to identify and map the health, ecological quality and conservation value of rainforests. Therefore, I can present those methods as methods of identification, mapping and monitoring of High Conservation Value Forests. Also, the HCVFs identification is exactly needs the estimation of the health and ecological quality of the forest.

By this step the project and papers may give an important contribution to the scientific sphere (by assessment the change of Atlantic rainforest quality since 2001, elaboration of the methodology of this assessment) and to the practical conservation sphere. The conservation significance of the project may include:

(i) Assessment of tropical forest quality, which is important to use in several areas (multiyear monitoring of forests in protected areas, development of natural corridors linking the forest fragments, creation of new protected areas and rainforest restoration projects)
(ii) Mapping of **high conservation value forest** (HCVF)

The launch of HCVFs concept in Brazil, i.e. creating and initial "pilot" map of HCVF of entire Atlantic forest may give the following practical conservation value:

1. If the HCVFs and IFL map will be made, the society (first of all, the government, scientific and environmental organizations, the press) will know that some forest fragments have an extremely high ecological value. Classification of Atlantic forest fragments according to their TFH (ecological value) will allow to motivate the work on the creation of a protected regime for those natural areas which do not have it or where the protected regime is not sufficient.

2. If the HCVFs and IFL map will be made, it can stimulate the development of FSC forest certification in Brazil, which implements a powerful positive environmental impact on society, leads to development of sustainable forest industry, helps to protect of valuable forests. Since 2014 the independent objective of FSC in the whole world - to protect of Intact Forest Landscapes (which is among the most important objectives in the whole world).

In my project I'd like to make a classification of forests ecological value within the HCVFs and IFL concepts. Also I want to use their categories and to elaborate on their basis the similar categories that will fit the

conditions of Atlantic forests. This objective is related with the principal purposes of my project, since this is a form of practical application of the elaborated methods.
For this part of the project I am going to search collaboration with HCVF specialists in other countries or international ones. I hope to interest them in the goals of the project. I am already communicating in the professional environment community of Russia with Russian specialists in HCVF (Greenpeace, WWF, FSC) which may help.

The practical actuality and novelty will increase the chance of publication the papers. Also, it may help to find valuable **collaboration** in project implementation, as well as to continue the development of this direction (assessment of tropical ecosystem quality, HCVF and IFL reveal and conservation) in Brazil in future. By dint of these papers I may find a position in the close sphere, obtain a financial support on those project, etc.

4. Questions

1. I need to select of protected natural areas appropriate for field investigation. They should be located in 3 best clusters of the remnant Atlantic forest (Serra do mar Mountain Belt, Parque Nacional do Iguaçu, Fragment in Piauí state), in the largest forest fragments, far from roadways and towns. Could you recommend of protected natural areas which I can choose?

2. **What do you think about the methodology of measurement of the filed parameters (Table#4) and size of plot where those measurements will be implemented?**

   I am thinking about two variants of plot – square plots 10x10 m (I worked with them previously) and plot as transect (4 m in width and 30-40 m in length). According to the literature review, there are no single standard in size of a plot using to study the plant species diversity and other ecosystem parameters. However, a lot of projects were implemented using 1 ha plots. Thus, 1 ha (100m x100m) should be considered as the most common and appropriate size of plot for exact analysis. However, I am working on a fast method of TFH estimation and 1 ha plot – is too large for this purpose, since it is unreal for one or two people to implement the necessary measurements (Table 4) in a 1 ha plot.

3. What about possibilities of remote sensing data of very high resolution: satellite images, LiDAR data, UAV with cameras, which I can use for this study?

4. **Question about the data processing for the paper "How much is left, and how is the remaining forest distributed", (Milton C. Ribeiro et al, 2009):** Were the automobile roads considered as objects dividing of a solid forest area on fragments in the processing of the georeferenced data of the Atlantic Forests (SOS Mata Atlântica, 2008)?

APPENDIX

Table 1. The change of title and the research focus of the Doctoral project

Initial title and focus of the research	Restoration and Conservation of Rainforest and Cerrado Biomes within Environmental Corridors: Spatial and Temporal Analyses Applying the Hyperspectral and Multispectral Remote Sensing Technologies	August 2016
Current title and focus	The change of Health and Level of Protection of the Atlantic Rainforests Biome in Brazil from 2002 to 2018. Reveal the Most Valuable Woodlands and Mapping of the High Conservation Value Forests (HCVFs).	July 2017 - Present

Table 2. The proposed papers

Paper	Title	Start	Expected finish for submission
Paper#1	Change of the Atlantic rainforest health in Brazil from 2002 to 2016 inside and outside of the conservation natural areas. Compare of two protection regimes by their efficiency.	Aug 2017	Oct– Dec 2018
Paper#2	The first mapping of the high conservation value forests (HCVFs) of the remnant Atlantic forest in Brazil. The level of protection of the most valuable woodlands.	June 2018	Nov - Dec 2018
Paper#3	The dependence of activity of several frugivorous species on tropical forest health in a small fragment of Atlantic forest (case study: Mata Santa Genebra, SP, Brazil)	June 2018	Sep 2018
Paper#4	Assessment of the Atlantic rainforest health by remote sensing data of high resolution and field indicators	Oct 2018	May 2019
Paper#5	Soil as indicator of Atlantic rainforest disturbance	May 2019	

Table 3. The georeferenced remote sensing products which can be used as indicators of Tropical Forests Health

Parameter	Producer	Type	Temporal resolution	**Spatial resolution** metres per 1 pixel	Application as indicator of TFH	Indicator of TFH	Link
i. The remote sensing parameters reflected the Tropical Forest Health (TFH)							
Small resolution products: 250-1000 (MODIS)							
NDVI (Normalized Difference Vegetation Index)	MODIS	raster	2002-present	250	NDVI = [0, 1] The greater is the value of index, the higher is the biomass >> the higher is the TFH. For the health (intact) tropical forest NDVI= 0.8-0.9. The lower the NDVI value, the less TFH	indirect remote	link
EVI (Enhanced Vegetation Index)	MODIS	raster	2002-present	250	the same	indirect remote	link
LAI (Leaf Area Index)	MODIS	raster	2002-present	500	the same	indirect remote	link
FPAR (Fractional Photosynthetically Active Radiation)	MODIS	raster	2002-present	500	the same	indirect remote	link
GPP (Gross Primary Productivity)	MODIS	raster	2002-present	500	the same	indirect remote	link
Day surface temperature **Night surface temperature** Temperature within the forest canopy, on open areas - temperature of surface	MODIS	raster	2002-present	1000	The smaller is the Day surface temperature >> the higher is TFH	indirect remote	link
Soil moisture	SMOS	raster	2010-present	35,000 – 50,000	The higher is the soil moisture >> the higher is the health of tropical forest	indirect remote	
Middle resolution products: 30-100 m (Landsat, ASTER, Sentinel)							
NDVI (Normalized Difference Vegetation Index)	Landsat-5, Landsat-8	raster	1984-present	30	NDVI = [0, 1] The greater is the value of index, the higher is the biomass >> the higher is the TFH. For the health (intact) tropical forest NDVI= 0.8-0.9. The lower the NDVI value, the less TFH	indirect remote	

Landsat Tree Cover	Global Land Cover Facility	raster	2000; 2005; 2010; 2015	30	The greater is the value, the higher is the percentage of forests cover on area. Thus, **Delta = LTC(2015) – LTC(2000)** indicates what happened with forest cover during 2000-2015. Delta > 0 - forest cover increased; Delta < 0 forest cover decreased, Delta = 0 forest cover did not changed.	direct remote	link
Global Forest Change between 2001 and 2016	Maryland university	raster	2001-2016	30 (1 arc-sec) on Equator	Lossyear = 0 indicate that forest was not cut from 2001 to 2016; 1-16 - indicates the year of loss event. But we can't sure that this forest was not cut early and later that this interval.	direct remote	link
Intact Forest Landscapes	Maryland university, Greenpeace of Russia	raster	2000, 2013	30	The Scale is notes as 1:1.000.000, however, the map was made by Landsat analysis >> the accuracy 30 m per pixel		-
Day surface temperature Temperature within the forest canopy, on open areas - temperature of surface	Landsat-8, ASTER (AST_08)	raster	2013 - Present 2000 - Present	100 and 90	The smaller is the Day surface temperature >> the higher is TFH	indirect remote	
ii.Georeferenced data							
Atlantic forests fragments	SOS Mata Atlântica	shape polygonal	2013-2014		The georeferenced data of all fragments of the remnant Atlantic rainforests, Restinga and Mangrove forest in Brazil for **2013-2014**	direct remote	
Atlantic forests fragments	SOS Mata Atlântica	shape polygonal	2015-2016		The georeferenced data of all fragments of the remnant Atlantic rainforests, Restinga and Mangrove forest in Brazil for **2015-2016**	direct remote	
Burned areas	MODIS	raster	2002-present			direct remote	
The land application of Brazil		shape polygonal				direct remote	
Urbanized zones	SOS Mata Atlântica	shape polygo				direct remote	

		nal					
Tree plantations	WRI	shape polygonal				direct remote	
Roadways in Brazil	IBGE	shape linear					
Mining	GFW	shape polygonal					
Rivers, lakes	Divagis	shape linear, polygonal					
Conservation Units or Protected Natural Areas	WPDA	shape polygonal					
air temperature, precipitation, wind speed, relative humidity	Global Surface Summary of the Day (GSOD)	shape point, tables			The weather data of meteorological stations		
Administrative boundaries of Brazil	Divagis						

Table 4. The direct field indicators of TFH (the forest characteristics which will be measured in the field investigation)

№	Field measurements	Details	Instrument
1	Number of morphological types of all plant species	In total and separately – for all tree species, for other herbaceous species	visually
2	Perimeter of all trees in a plot measured at a height of 130 cm above the ground (PAP).	From PAP the following indicators of TFH will be calculated: (i).Basal area (in percentage from the area of a parcel); (ii).Distribution of various diameters of trees within a plot. Or only percentage of trees with diameter measured at a height of 130 cm above the ground bigger than 20 cm.	flexible tape measure
3	Height of the tallest trees in a plot		Laser range finder, altimeter, inclinometer (Nikon Forestry Pro)
4	Day surface temperature	At a height of 0 cm and 130 cm above the ground	electronic or mercury thermometer
5	Soil	(for Paper#5)	
6	Existence of the following native plant species (or detected species, number of individual plants)	1) Lianas 2) Bromeliads (and other epiphytes) 3) Mushrooms 4) Lichens 5) Invasive species (both trees and herbaceous)	visually
7	Existence of invasive species (or detected species, number of individual plants)		visually

Table 5. The MODIS products applied as indirect remote indicators of TFH

Parameter	Product	**Spatial resolution** metres in 1 pixel of image	Years of product work	Web site
Day surface temperature, Night surface temperature	MOD11A2 8 day composite	1000 m	March 2000 - Present	MOD11A2: MODIS/Terra Land Surface Temperature and Emissivity 8-Day L3 Global 1 km Grid SIN V006
EVI (Enhanced Vegetation Index), **NDVI** (Normalized Difference Vegetation Index)	MOD13Q1 16 days composite	250 m	February 2000 - Present	MOD13Q1: MODIS/Terra Vegetation Indices 16-Day L3 Global 250 m SIN Grid V006
LAI (Leaf Area Index), **FPAR** (Fractional Photosynthetically Active Radiation)	MCD15A2H 8 day composite	500 m	July 2002 - Present	MCD15A2H: MODIS/Terra+Aqua Leaf Area Index/FPAR 8-Day L4 Global 500 m SIN Grid V006
GPP (Gross Primary Productivity)	MOD17A2H 8 day composite	500 m	February 2000 - Present	MOD17A2H: MODIS/TERRA Gross Primary Productivity 8-Day L4 Global 500 m SIN Grid V006

Source: MODIS Product Table LP DAAC NASA
https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table

Table 6. Sum of Area of forests, % (2005, 2014)

Interval of fragment area	Area, % (2005)	Area, % (2014)
<50	20.2	18.57
50–100	9.5	8.30
100–250	12.1	10.88
250–500	8.4	7.96
500–1000	7.5	6.94
1000–2500	7.9	8.30
2500–5000	5.1	5.87
5000–10,000	4.2	4.49
10,000–25,000	4.8	7.40
25,000–50,000	2.7	6.19
50,000–100,000	2.1	5.21
100,000–250,000	2.8	6.81
250,000–500,000	2.4	3.09
500,000 - 1200,000	10.3	0.00

Table 7. The High Conservation Values (HCV – Jennings et al. 2003)

Category	Description
HCV 1	Forest areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia). HCV1.1 Protected Areas HCV1.2 Threatened and endangered species HCV1.3 Endemic species HCV1.4 Critical temporal use
HCV2	Forest areas containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance.
HCV3	Forest areas that are in or contain rare, threatened or endangered ecosystems
HCV4	Forest areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control). HCV4.1 Forests critical to water catchments HCV4.2 Forests critical to erosion control HCV4.3 Forests providing barriers to destructive fire
HCV5	Forest areas fundamental to meeting basic needs of local communities (e.g. subsistence, health).
HCV6	Forest areas critical to local communities' traditional cultural identity (areas of cultural, ecological economic or religious significance identified in cooperation with such local communities

REFERENCE

Argyrous, G., 2005. Statistics for research: With a guide to SPSS (2nd ed.). Sage Publications, London.

Aksenov D. E., Dubinin M. Y, Karpachevsky M. L, Lysakova N. S., Skvortsov E. V., Smirnov D. Y., Yanitskaya T. O. 2006. Detection of the High Conservation Value Forest in Primorsky Krai of Russia. Categories important for conservation of vegetation. Moscow, publishing house of ISEU, 2006. 186 p.

Andersson, L., Alexeeva N. M., Koltsov, D. B., Kuksina N. V., Kutepov D. J., Mariev A. N., Neshataev V. Y. Identification and survey of biologically valuable forests in North-West European part of Russia. Vol. 1. Methods of detection and mapping. - Manual - St. Petersburg, 2009. - 238 p.

Dudley, N. (Editor) (2008). Guidelines for Applying Protected Area Management Categories. Gland, Switzerland: IUCN. x + 86pp. WITH Stolton, S., P. Shadie and N. Dudley (2013). IUCN WCPA Best Practice Guidance on Recognising Protected Areas and Assigning Management Categories and Governance Types, Best Practice Protected Area Guidelines Series No. 21, Gland, Switzerland: IUCN. xxpp

Genesis T. Yengoh, David Dent, Lennart Olsson, Anna E. Tengberg and Compton J. Tucker. 2014. The use of the Normalized Difference Vegetation Index (NDVI) to assess land degradation at multiple scales: a review of the current status, future trends, and practical considerations. Lund University Center for Sustainability Studies (LUCSUS), and The Scientific and Technical Advisory Panel of the Global Environment Facility (STAP/GEF).

Guia geral para identificação de altos valores de conservação (AVC). Guia de boas práticas para identificar AVCs em diferentes ecossistemas de produção. Outubro de 2013. - 63 p.

High Conservation Value Forests: The concept in theory and practice. - WWF International, 2007. - 25 p.

WWF International. High Conservation Value Forests: The concept in theory and practice, 2007. - 25 p.

Jennings S, Nussbaum R, Judd N. and Evans T.- The High Conservation Value Forest Toolkit, Edition 1, 2003. – 27 p.

Kobyakov K. N. (editor) Mapping High Conservation Value Areas in the Russian North-West Gap-analysis of the Protected Areas Network in Murmansk, Leningrad, Arkhangelsk, Vologda regions, Republic of Karelia, and the city of Saint-Petersburg// Collective of authors. - Saint-Petersburg, 2011. - 258 p.

Maesano M., Lasserre B., Masiero M., Tonti D. and M. Marchetti. First mapping of the main high conservation value forests (HCVFs) at national scale: The case of Italy, Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology, 2016.

Potapov P., Hansen M. C, Laestadius L, Turubanova S, Yaroshenko A, Thies C., Smith W, Zhuravleva I, Komarova A, Minnemeyer S, Esipova E., 2017. The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. Science Advances Vol. 3, no. 1.

The interactive map and the ability to download Intact Forest Landscapes as shapefile are presented on the Global Forest Watch resource section LAND COVER: https://www.globalforestwatch.org/map

Vasilenko, V.B., Zinchuk, N.N., Kuznetsova, L.G., 1997. Petrochemical models of diamond deposits of Yakutia. Nauka, Novosibirsk.

Yaroshenko A. Y., Potapov P. V., Turubanova S. A. The Last Intact Forest Landscapes of Northern European Russia. - Moscow: Greenpeace Russia, 2001. - 75 p

Links

Categorias de Unidades de Conservação do Brasil

https://uc.socioambiental.org/o-snuc/categorias-de-ucs

Unidades de Conservação (WWF Brasil): https://www.wwf.org.br/natureza_brasileira/questoes_ambientais/unid/

HCV Resource Network

https://www.hcvnetwork.org

Mapa de Vegetação do Brasil, Mapa de Biomas for Brasil (IBGE, PDF)

ftp://ftp.ibge.gov.br/Cartas_e_Mapas/Mapas_Murais/

Mapa de Vegetação do Brasil, IBGE, GeoJSON (can be transferred in SHP files): https://geo.socioambiental.org/arcgis/rest/services/monitoramento/tematicos/MapServer/5

The interactive map and the ability to download Intact Forest Landscapes as shapefile are presented on the Global Forest Watch resource section LAND COVER: https://www.globalforestwatch.org/map