Report on consulting activities in the project

Prevention, Control and Monitoring of Fires in the Cerrado (PN: 11.9035.4)

Supporting the implementation of integrated fire management in protected areas in the Cerrado through remote sensing

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Acknowledgements

This report is a product of efforts of RSS – Remote Sensing Solutions GmbH and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH resulting from continuous developments discussed during an expert workshop on fire severity in 2012, a working meeting with INPE and DLR in 2012, two workshops held in Palmas in April and November 2014 and various consultation meetings with partners. The authors wish to thank the team the project "Prevention, Control and Monitoring of fires in the Cerrado" in Brazil for facilitating and organizing all meetings with Brazilian partners. Special thanks go to James Possapp for accompanying the authors during meetings and particularly for translating which also contributed greatly to the successful setup of the workshops in Palmas.

We would like to thank the following people for taking the time to share their insights and experiences in Cerrado fires and conservation during consultations in October/November 2014: Luciana Machado, Isabel Schmidt, Thais Xavier, Kelly Maria Resende Borges, Livia Moura, Paulo Dias, Marco Borges, Robin Beatty, Clara Fonseca, Igor Proença, Pietro de Almeida Cândido, Gernot Ruecker and the fire brigades of the National Park Chapada das Mesas. Finally the author is very grateful to Philipp Buss and Anja Hoffmann from GIZ for the realization of the consultancy.

1. Introduction

The German-Brazilian project "Prevention, Control and Monitoring of Fires in the Cerrado" aims to preserve the Cerrado as a globally significant carbon sink and biodiversity hotspot. The project goals shall be achieved through effective fire prevention and control, improved management of protected areas and with new or improved tools for monitoring vegetation fires and deforestation in the Cerrado. Therefore, assessments of historical and current land cover, biomass and fire regimes as well as a modeling of greenhouse gas (GHG) emissions are foreseen in the second project phase planned from 2014 through 2016, with the aim of exploring the potential to reduce emissions through improved integrated fire management.

After initial talks with Brazilian partners and GIZ, a draft proposal outlining potential project activities for the assessment of land cover, land cover change, carbon stock, fire impacts and fire emissions by remote sensing as an element of an integrated monitoring, reporting, and management decision support system for the project area was submitted by ZEBRIS and RSS[1]. A report was drafted that details the results of a scoping mission that took place in March/April 2014[2].

Figure 1 shows the flow chart of the proposed monitoring concept that was used as a basis for discussion with partners. The present report is a summary of a follow-up consultation realized until November 2014 and can be seen as a complement to the report from the scoping mission[2]. The report describes the project activities from RSS between June and November 2014 and gives recommendations for the next year of MIF implementation.

[1] ZEBRIS/RSS (2013): Draft proposal: Prevention, Control and Monitoring of fires in the Cerrado: Assessing land cover, land cover change, carbon stock, fire impacts and fire emissions by remote sensing as an element of a monitoring, management, and decision support system

[2] RSS/ZEBRIS (2014): Report on consulting activities in the project "Prevention, Control and Monitoring of fires in the Cerrado" - Monitoring deforestation, biomass estimation, vegetation type mapping and estimation of GHG emissions to support Integrated Fire Management in the Cerrado

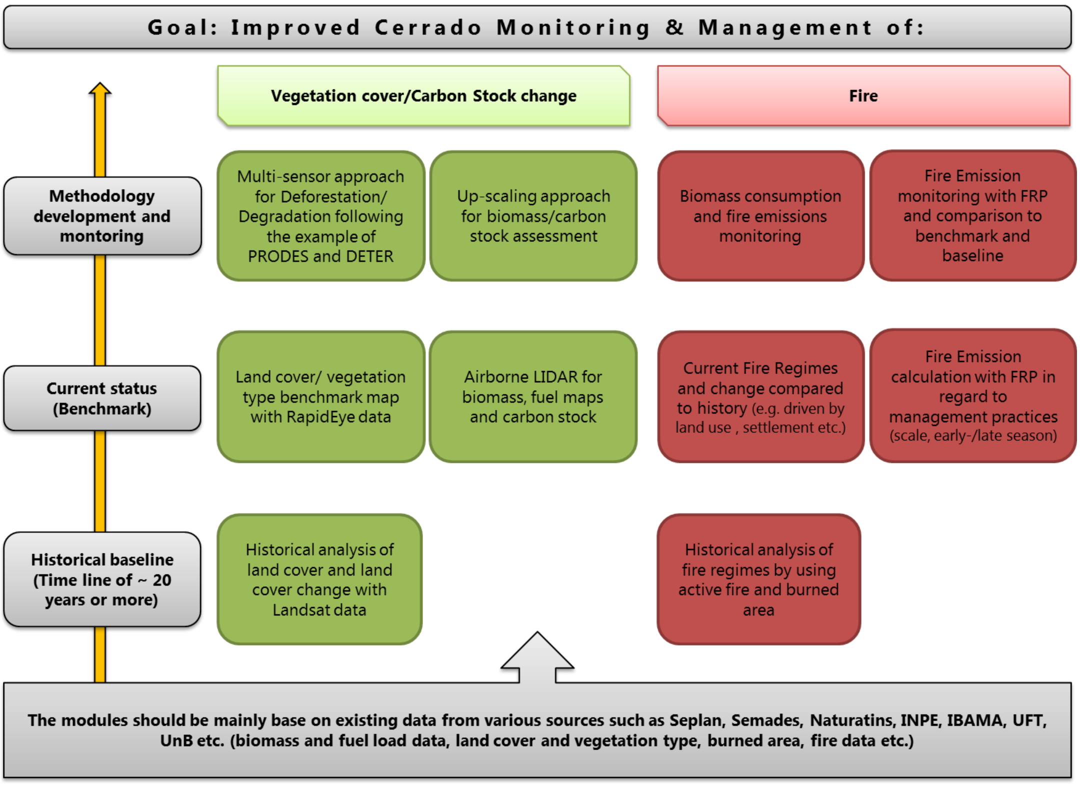


Figure 1: Concept of potential monitoring tasks in the project that was discussed with Brazilian partners during the first consultancy in Brazil (April 2014).

2. Objectives and methods

The main component of the consultancy was to provide technical support to the project team and project partners in the topics biomass estimation and vegetation type mapping for improved GHG emission calculations. The following activities were part of the consultancy:

1. Contributing to fire experiments in the National Park Chapada das Mesas through remote sensing information in close cooperation with University of Brasília, ICMBio, the international fire management specialist Robin Beatty and ZEBRIS.
2. Selection of suitable satellite images (Landsat, RapidEye, etc.) for monitoring the fire season, for mapping the fuel load (item 1) and for vegetation type mapping.
3. Mapping of the green and dry biomass based on remote sensing data for the three pilot areas in the Cerrado.
4. Identification and supervision of a candidate for a joint Brazilian/German master theses on high-resolution classification and stratification of vegetation types of the protected areas of the Cerrado based on RapidEye data (in cooperation with INPE, Ibama/CSR, Seplan and Semades).
5. Preparation of a LiDAR-survey for selected transects in the Cerrado (in cooperation with INPE).
6. Validation of provided maps through field visit in Chapada das Mesas.

During a workshop in Palmas (Tocantins) from 03.11.-04.11.2014, the individual tasks of the proposed approach were presented by RSS, in order to clarify the methodology behind the conducted analyses, to discuss the lessons learned from the remote sensing perspective during the first year of MIF implementation and to give recommendations for 2015.

3. Meeting schedule

The meetings and project activities during the October/November partner consultancy in Brazil are listed in Table 1.

Table 1: Meeting and travel schedule

Day	Meeting with	Location	Objective	Participants
27-10-2014	GIZ	Brasília	Preparation of meetings	Philipp Buss (GIZ)
	ICMBio	ICMBio-Brasília	Defining training needs for remote sensing analyses	Thais Xavier (ICMBio), Angela Garda (ICMBio), Philipp Buss (GIZ), Jonas Franke (RSS)
28-10-2014	GIZ	GIZ- Brasília	Discuss recent project activities	Philipp Buss (GIZ), Gernot Rücker (ZEBRIS), Jonas Franke (RSS)
	GIZ	GIZ- Brasília	Discussing deforestation and forest degradation monitoring using RapidEye data	Anselm Duchrow (GIZ), Taiguara Alencar (GIZ), Jonas Franke (RSS)
29-10-2014	Travel to Carolina	-	-	Gernot Rücker (ZEBRIS), Jonas Franke (RSS)
	Project team	Carolina	Planning of validation trip	Anja Hoffmann (GIZ), Robin Beatty (321Fire!), Luciana Machado (MMA), Marivaldo Santos Santana (Prevfogo), Igor Proença (Ibram), Pietro de Almeida Cândido (INPE), Miguel Bonilha (MB ICMBio), Paulo Dias (ICMBio), Livia C. Moura (LCM), Gernot Rücker (ZEBRIS), Jonas Franke (RSS)
30-10-2014	Project team	ICMBio-Carolina	Introduction to work of ICMBio in Parque National da Chapada das Mesas	See list above
	Project team	PNCM	Field validation in PNCM	See list above
31-10-2014	Workshop	Carolina	Meeting with the Fire Brigades of PNCM	See list above plus fire brigade
01-11-2014	Project team	PNCM	Field validation in PNCM	See list above
02-11-2014	Travel to Palmas	-	-	See list above
	Workshop moderators	Palmas	Discussion of workshop agenda and facilitation	Anja Hoffmann (GIZ), Robin Beatty (321Fire!), Pietro de Almeida Cândido (INPE), Paulo Dias (ICMBio), Livia C. Moura (LCM), Gernot Rücker (ZEBRIS), Jonas Franke (RSS)
03-11-2014	Workshop	Palmas	Evaluation of first year MIF implementation	See participants list
04-11-2014	Workshop	Palmas	Evaluation of first year MIF implementation	See participants list

4. Lessons learned from the first year of MIF implementation and achieved results

In the first year of MIF implementation, the external partners UnB, INPE, ZEBRIS and RSS collaborated in order to develop and calibrate remote sensing approaches in support of the MIF activities. Figure 2 shows the links between these partners with their respective main tasks in the project.

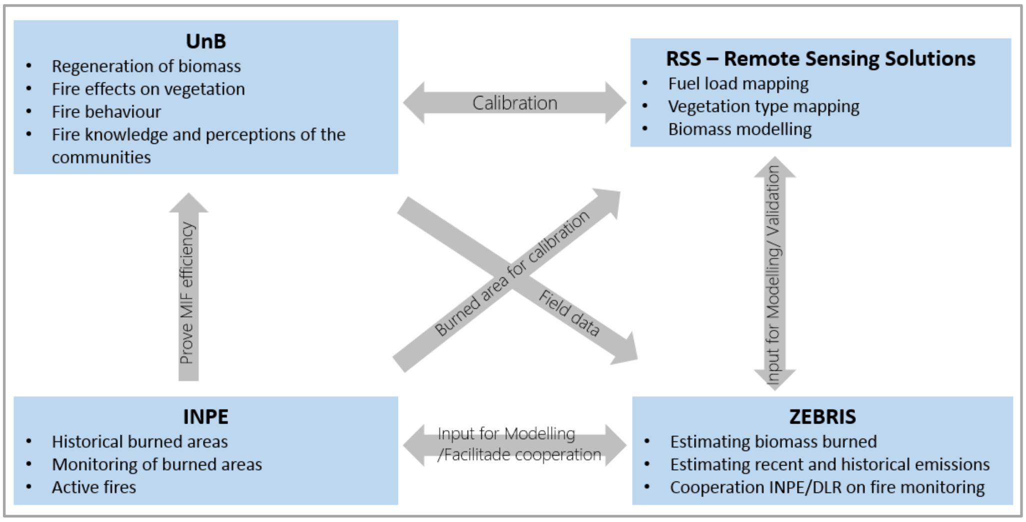
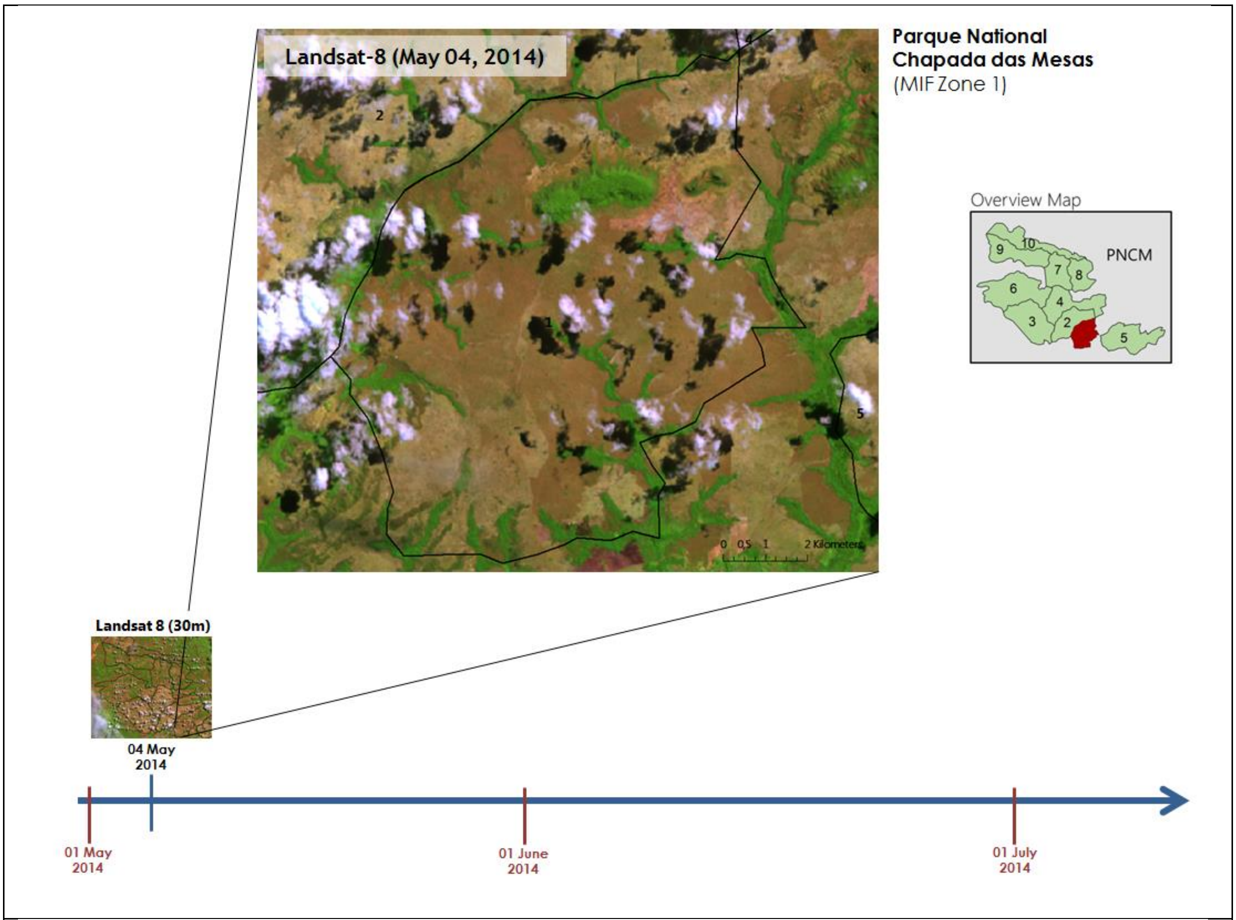


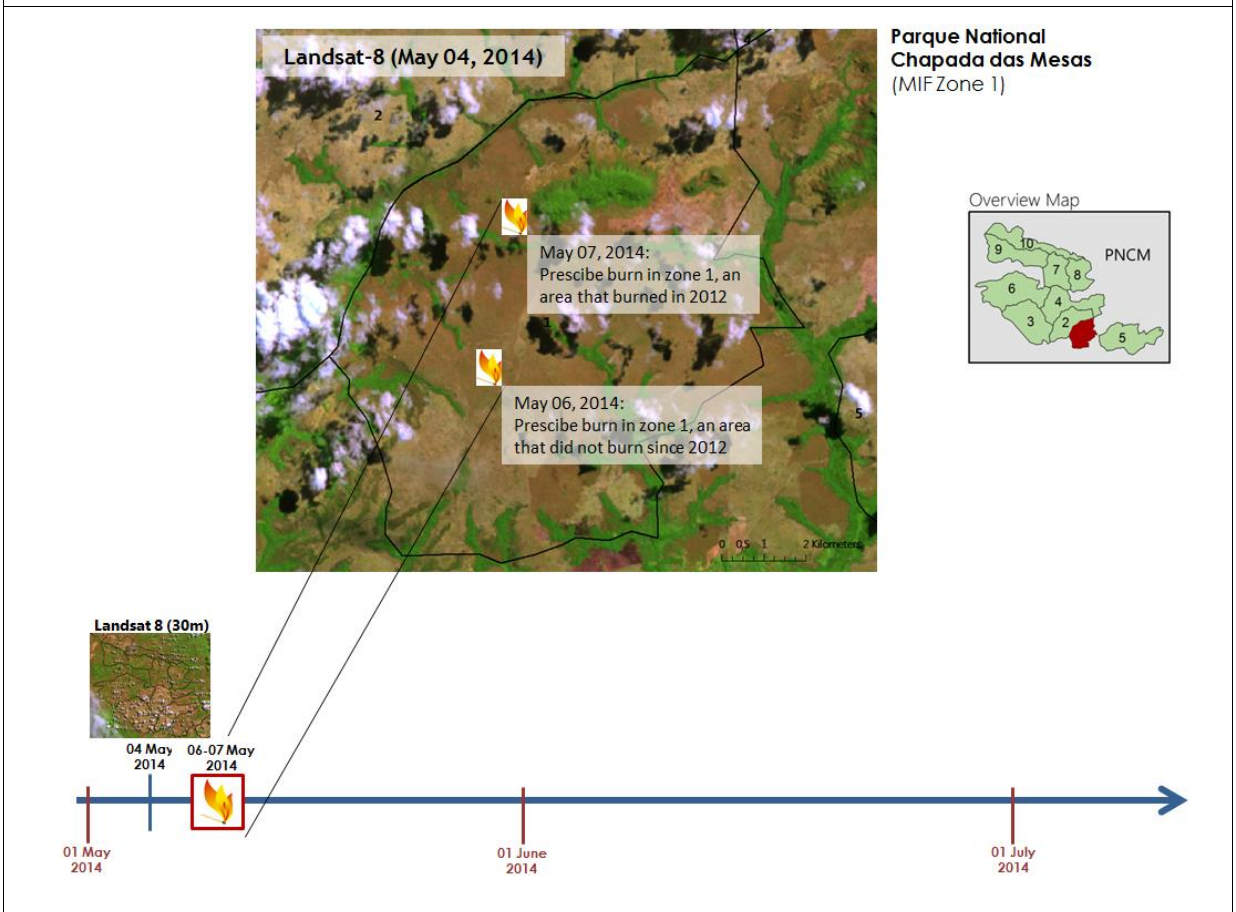
Figure 2: Links between the external partners in support of MIF

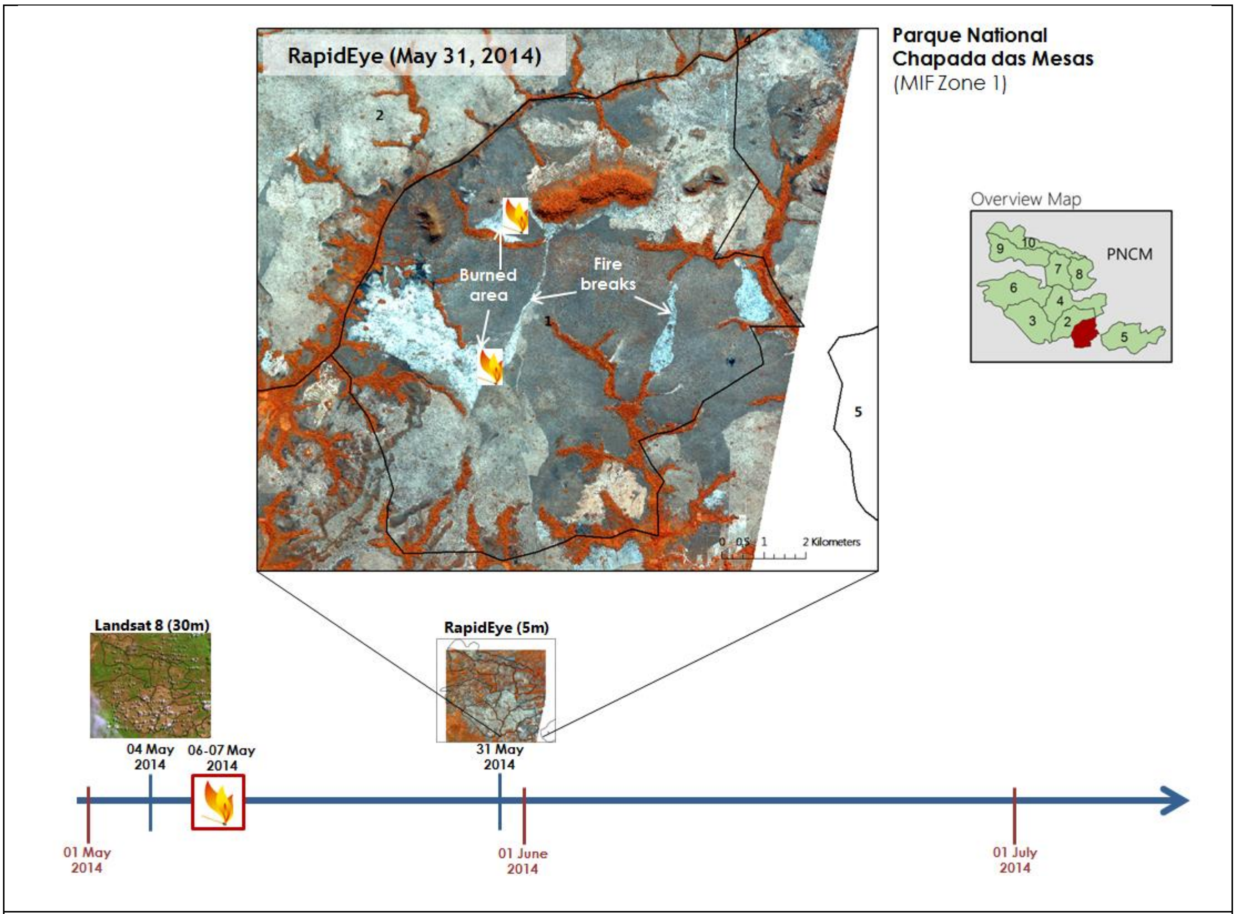
4.1 Fire experiments

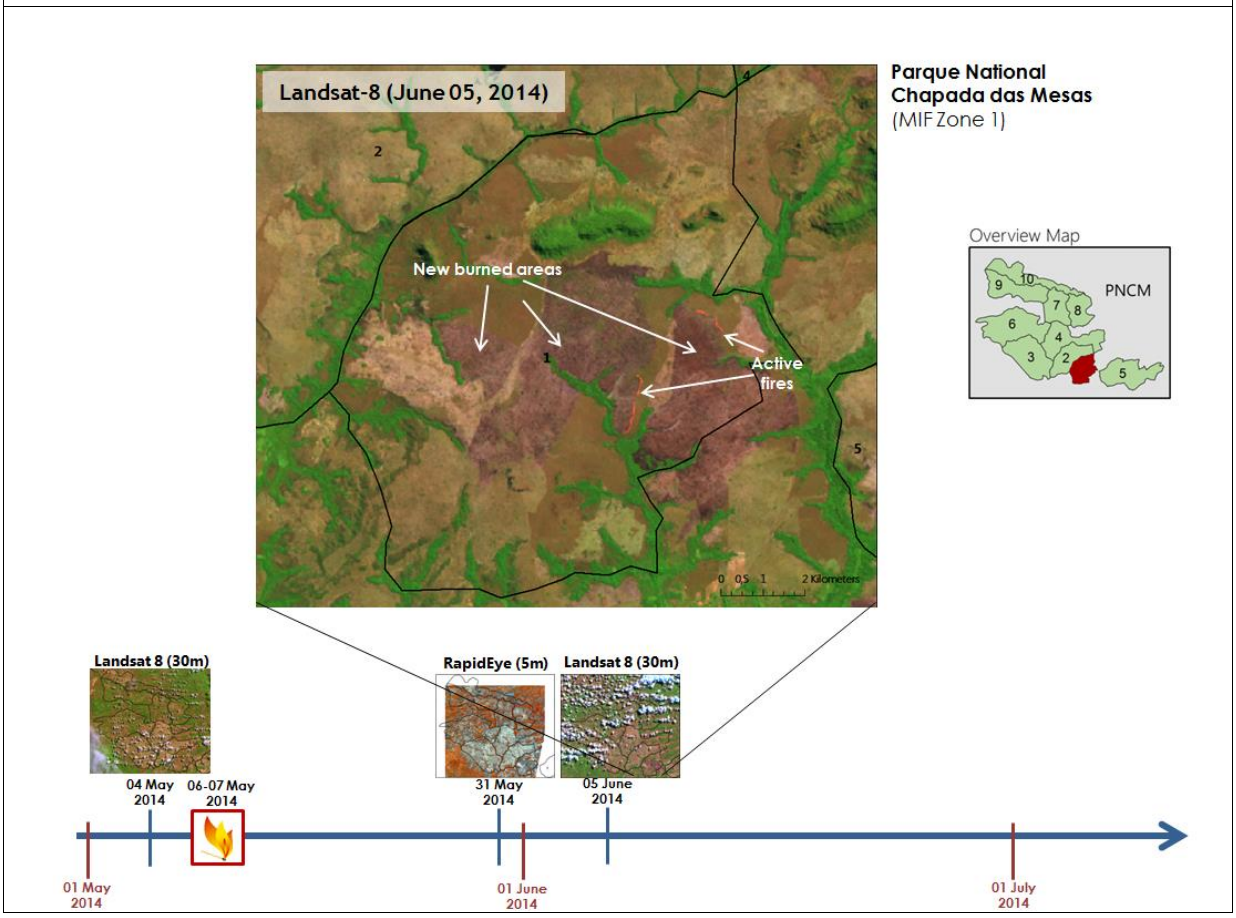
In May and June 2014, fire experiments have been realized in the National Park Chapada das Mesas, in Parque Estadual do Jalapão and ESEC Serra Geral do Tocantins in close cooperation between University of Brasília, ICMBio, Robin Beatty, ZEBRIS and RSS. The main objective was to coincide the controlled burning activities (ICMBio & Robin Beatty) with satellite overpasses of different sensors (ZEBRIS & RSS), accompanied by simultaneous biomass and fire measurements in the field (UnB). The aim was to analyze if the fires and their intensities can be detected with different satellites, to assess the biomass burned during the fire and to investigate the relationship between the fuel load mapped by remote sensing with the pre- and post- fire biomass measured in the field.

The controlled burning activities have been observed by Landsat-8 (30m spatial resolution) and RapidEye (5m spatial resolution) imagery in the National Park Capada das Mesas. Figure 3 shows the time series of Landsat and RapidEye images covering the period in which the fire experiments took place. The image from May 04 (Figure 3a) shows that until then no fire activity took place in MIF zone 1. On May 06 and May 07 (Figure 3b), controlled burning was carried out by the park management at the identified places. The resulting burned areas and fire breaks from these fires can be seen in the RapidEye image from May 31 (Figure 3c). In the Landsat image from June 05 (Figure 3d), new burned areas and even active fire fronts from the controlled fires of the mark management can be seen in zone 1, which led to larger burned area obvious in RapidEye imagery from June 12 (Figure 3e). In the Landsat image from July 07 (Figure 3f), a new fire was observed in the very northern part of zone 1.
It could be demonstrated that the use of moderate and high-resolution imagery is very suitable to regularly observe fire activities and resulting burned areas in the protected areas in a timely manner. This allows rapid first assessments of the fire affected area and the control of the effectiveness of controlled burning.


Landsat-8 (May 04, 2014)
Parque National
Chapada das Mesas
(MIF Zone 1)
Overview Map
PNCM
9
10
7
8
6
4
3
2
5
0 0.5 1 2 Kilometers
Landsat 8 (30m)
04 May
2014
01 May
2014
01 June
2014
01 July
2014


Landsat-8 (May 04, 2014)
Parque National
Chapada das Mesas
(MIF Zone 1)
Overview Map
PNCM
9
10
7
8
6
4
3
2
5
May 07, 2014:
Prescibe burn in zone 1, an
area that burned in 2012
May 06, 2014:
Prescibe burn in zone 1, an area
that did not burn since 2012
0 0.5 1 2 Kilometers
Landsat 8 (30m)
04 May
2014
06-07 May
2014
01 May
2014
01 June
2014
01 July
2014


RapidEye (May 31, 2014)
Parque National
Chapada das Mesas
(MIF Zone 1)
Burned area
Fire breaks
Overview Map
PNCM
0 0.5 1 2 Kilometers
Landsat 8 (30m)
RapidEye (5m)
04 May 2014
06-07 May 2014
31 May 2014
01 May 2014
01 June 2014
01 July 2014


Landsat-8 (June 05, 2014)
Parque National
Chapada das Mesas
(MIF Zone 1)
New burned areas
Active fires
Overview Map
PNCM
0 0.5 1 2 Kilometers
Landsat 8 (30m)
RapidEye (5m)
Landsat 8 (30m)
04 May 2014
06-07 May 2014
31 May 2014
05 June 2014
01 May 2014
01 June 2014
01 July 2014

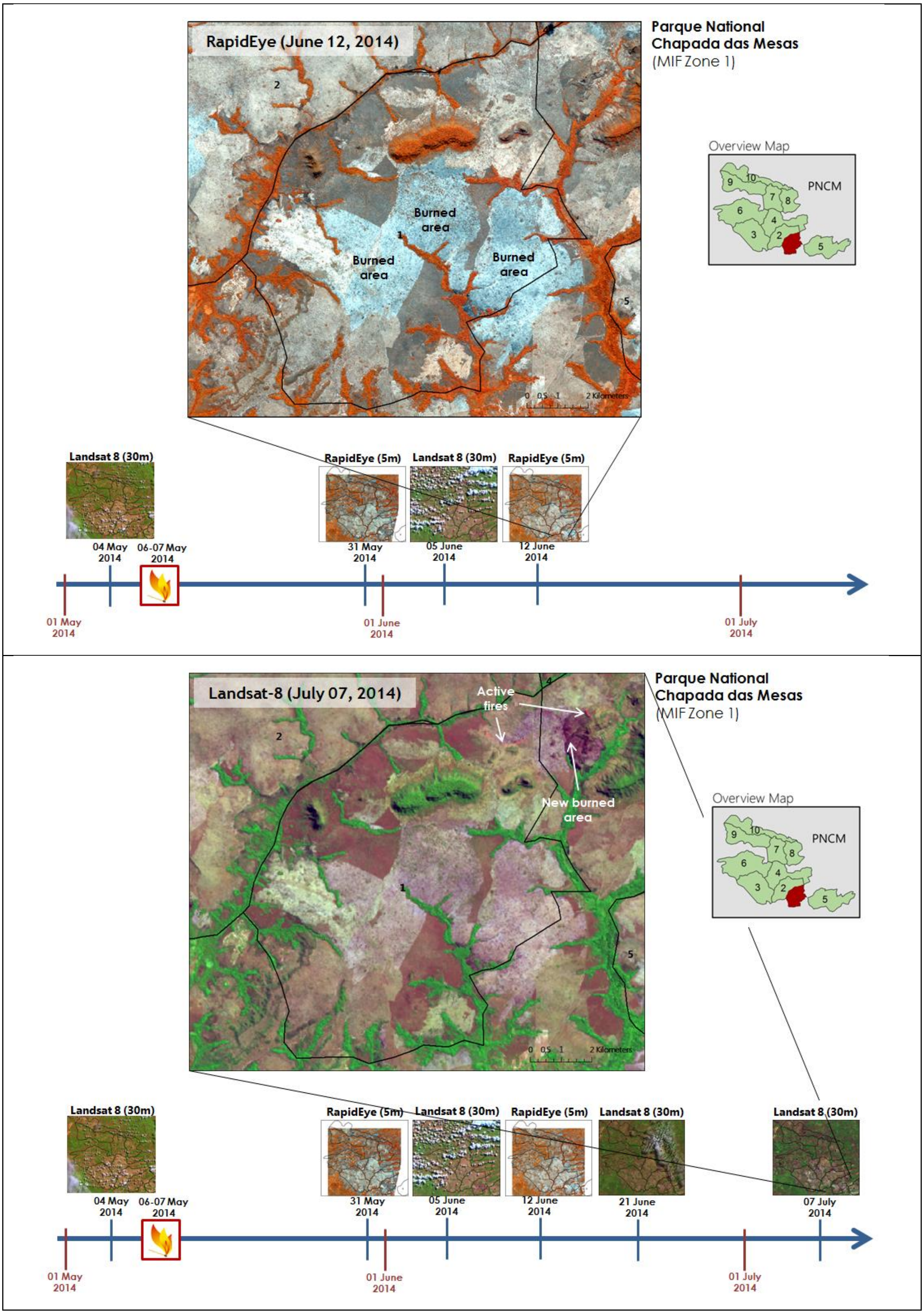


Figure 3: Time series of Landsat-8 and RapidEye imagery that shows the progress of controlled and uncontrolled burning in zone 1 of Chapada das Mesas from May to July.

In the context of linking the in-field measured biomass data from UnB with the different remote sensing data, it turned out that a new field protocol must be developed in order to collect data in a way which meets the requirements of fire ecology research and remote sensing. There are different requirements on field data collection particularly in spatial terms since the remote sensing data should be used to upscale the field data. Besides their use for the fire ecology research, the data collected in 2014 can only be used for qualitative remote sensing analyses (assigning biomass values to land cover types) and not quantitative analyses such as regression analyses for biomass estimations.

Recommendation 1: Develop a new field protocol for biomass assessments in close cooperation between UnB, ZEBRIS and RSS. This should be done by assessing existing literature on sampling strategies and by a common field visit to test and discuss sampling strategies. The final field protocol should then be applied and tested during fire experiments (cooperation between fire ecology research and remote sensing) in 2015.

4.2 Identification and pre-processing of remote sensing data for monitoring of the fire season, for mapping the fuel load and for vegetation type mapping

In order to support the first year of MIF implementation, remote sensing data was continuously acquired during the dry season for the monitoring of the controlled burning, the monitoring of wildfires and for the mapping of fuel loads. Mainly Landsat-8 data with 30m spatial resolution were acquired over the three pilot areas. In total 30 Landsat-8 scenes have been downloaded, 10 for each pilot area between May and October 2014. Table 2 lists all image dates that have been provided to the partners for the monitoring of fires and the respective burned areas. These satellite data, with a repetition cycle of 16 days, are free and are an excellent data source for the park managers for continuous large area observation of latest burned area distribution during the dry season.

Table 2: List of all Landsat-8 scenes that have been pre-processed and provided to the partners.

PNCM	PEJ	ESEC
04-05-2014	29-05-2014	29-05-2014
05-06-2014	14-06-2014	14-06-2014
21-06-2014	30-06-2014	30-06-2014
07-07-2014	16-07-2014	16-07-2014
23-07-2014	01-08-2014	01-08-2014
08-08-2014	17-08-2014	17-08-2014
24-08-2014	02-09-2014	02-09-2014
09-09-2014	18-09-2014	18-09-2014
11-10-2014	04-10-2014	04-10-2014
27-10-2014	20-10-2014	20-10-2014

These data were pre-processed for subsequent analyses through layer-stacking of the single spectral bands, an atmospheric correction and an object-based cloud masking. Figure 4 shows the flow chart of the applied pre-processing steps applied to the Landsat-8 data. The pre-processed and ready-to-use data have been provided to all partners via an ftp-server by RSS.

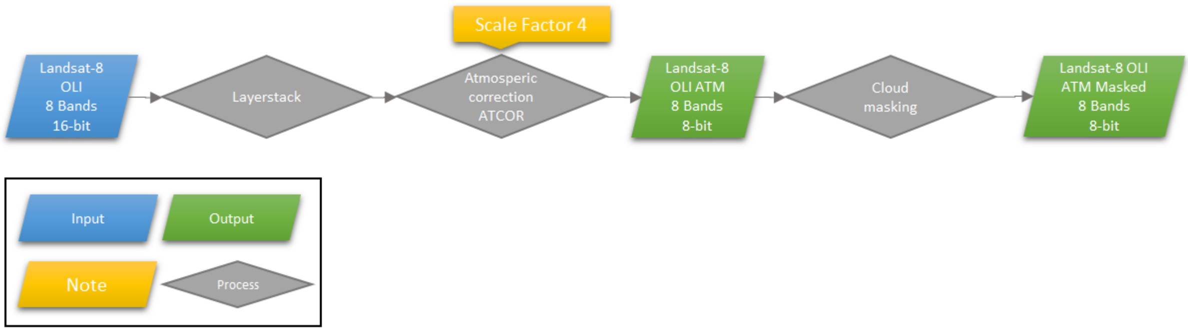


Figure 4: Work flow of the Landsat 8 preprocessing

In addition, BlackBridge, the data provider of RapidEye imagery, kindly provided two RapidEye coverages (5m spatial resolution) over PNCM during and after the fire experiments, which are also shown in Figure 3.

Figure 5 schematically shows the remote sensing activities done by RSS during the dry season 2014 in support of the fire experiments and the integrated fire management in the three pilot areas PEJ, ESEC and PNCM. First, fuel load maps have been provided for each pilot area using an "early dry season" Landsat-8 image (further described in the next chapter) in order to support planning of controlled early burning. Pre-processed Landsat-8 images were then used to monitor the spatio-temporal occurrence of wildfires over the dry season in the pilot areas (only almost cloud-free images with a 16 days repetition cycles). At the end of the dry season other fuel load maps were generated based on "late dry season" Landsat-8 images for the support of the 2015 MIF planning.

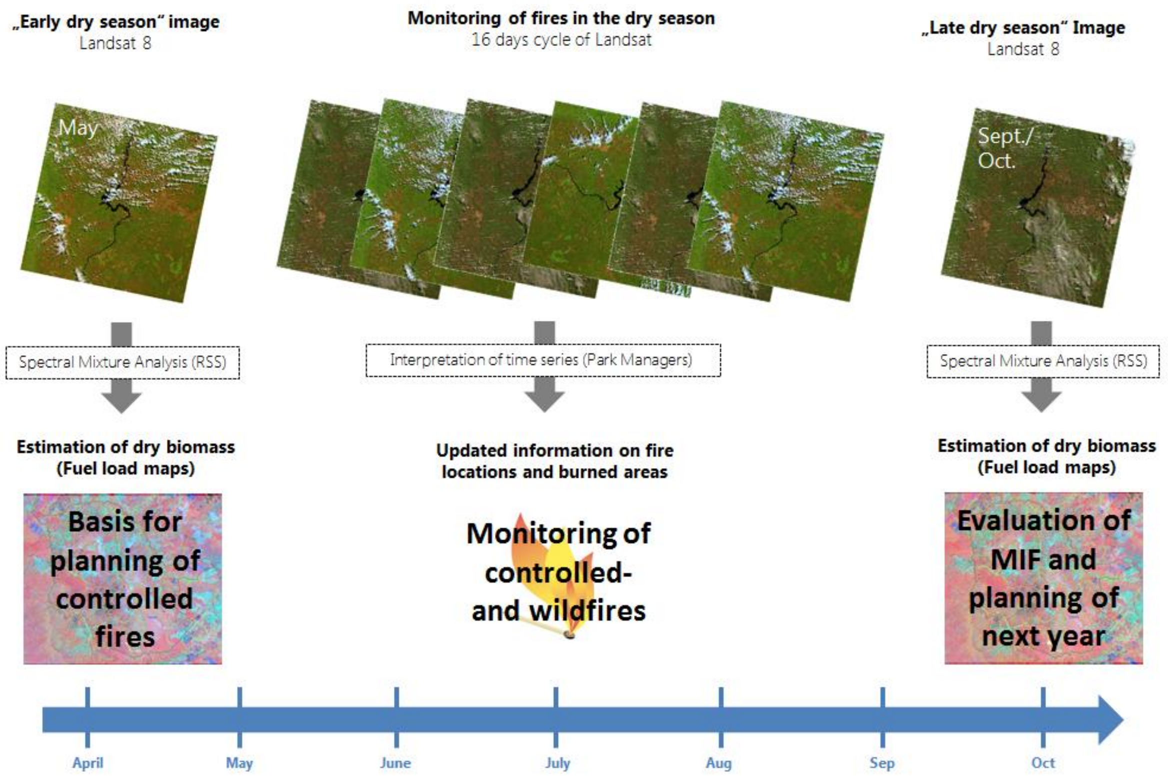


Figure 5: Schematic representation of the remote sensing-related activities done by RSS until July 2014 or which are in progress

<u>Recommendation 2:</u> Establish the use of freely accessible Landsat-8 and Sentinel-2 (from 2015 onwards) data for the large-area monitoring of wildfires during the dry season by the park managers. Only the use of satellite imagery allows the park managers to get an overview of the current distribution of burned areas over these large areas that cannot be observed by field visits alone.

4.3 Assessing the fuel load through remote sensing

The project aims at improving integrated fire management in the Brazilian savannah. One objective of integrated fire management is the implementation of controlled early burning in protected areas, to reduce the occurrence of large-scale late season fire by fragmentation of areas of different fuel load levels and thereby reducing fire severity. The planning and implementation of controlled early burning activities was supported by RSS with geo-information on fuel load conditions over large areas. The main purpose was to estimate dry biomass as an indicator for fuel load based on Landsat 8 data in support of the MIF zoning and of the planning of controlled early burning.

As shown in Figure 5, a Landsat 8 scene with 30m spatial resolution was acquired over PNCM on May 04, 2014 and two Landsat 8 scenes were acquired over PEJ and ESEC on May 29, 2014 for early season fuel load mapping. The image of PNCM has a cloud cover of approximately 30%, but can be used for most parts of the PNCM. The other images have a cloud cover of less than 5% in the areas of interest PEJ and ESEC. In addition, a late season fuel load mapping was conducted using Landsat 8 data from Sept 09, 2014 over PNCM and Sept 02, 2014 over PEJ and ESEC.

<u>Data processing:</u>
In order to characterize the vegetation in the area and to estimate the abundance of dry vegetation as an indicator for fire fuel load, a spectral mixture analysis (SMA) was applied to the data. The small spatial scale of different vegetation types and vegetation status in the Cerrado cause a mixed pixel problem due to the presence of photosynthetically active vegetation, non-photosynthetic vegetation and soil within the instantaneous field of view of the sensor (30m Landsat pixel). Mixed pixels are a function of the spatial resolution of the sensor and the spatial scale of the surface components. Figure 6 shows image examples of typical Cerrado vegetation with these three spectral components, whereby a Landsat pixel spectrum would have a mixed spectrum of these three components dependent on the fraction of each component.

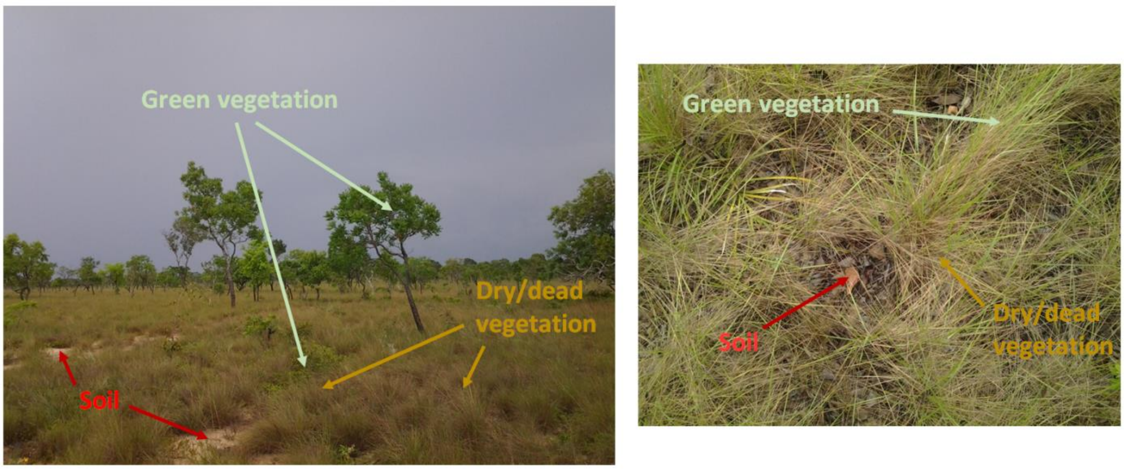


Figure 6: In the Cerrado, the main spectral components are green vegetation, dry/dead vegetation and soil. The left image shows a typical Cerrado landscape and the right image shows a nadir-taken image of the grassy vegetation layer with these three spectral components.

The advantage of SMA is that sub-pixel components can be detected, whereby continuous values of sub-pixel abundances of the components are derived. A linear SMA assumes that each pixel spectrum is a linear combination of a finite number of endmembers. Ideally, the endmember represents the signature of a pure component (pure spectral signatures of each component such as green vegetation, dry vegetation and soil). An SMA 'unmixes' the spectral signature of an image pixel spectrum and estimates the sub-pixel fraction of each component (Figure 7).

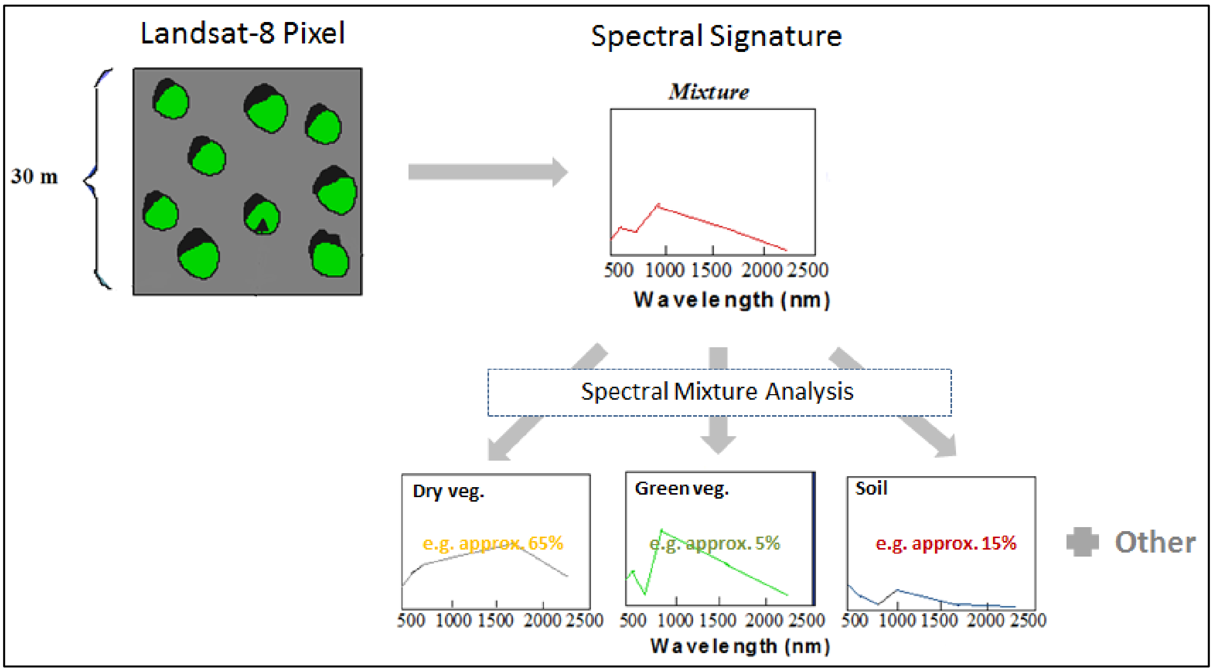


Figure 7: Schematic representation of the process of spectral mixture analysis of a 30m Landsat pixel spectrum.

A special type of SMA, the Mixture Tuned Matched Filtering (MTMF) was applied to the Landsat 8 data. As opposed to the classical SMA, the MTMF needs only one defined endmember spectrum in the spectral library (more endmembers can be considered if required). It is a partial unmixing, in which the known signature is matched by a matched filter calculation. The MTMF requires a minimum noise fraction transformed image (MNF) and a MNF-transformed endmember spectrum. A MNF transformation consists of two principle component analyses, whereby the first step estimates the noise in the data by decorrelating and rescaling the noise by variance. The second step creates a transformed data set of components (bands) that contain weighted information about the variance across all raw data bands as represented by eigenvalues. The work flow of the spectral mixture analysis is shown in Figure 8.

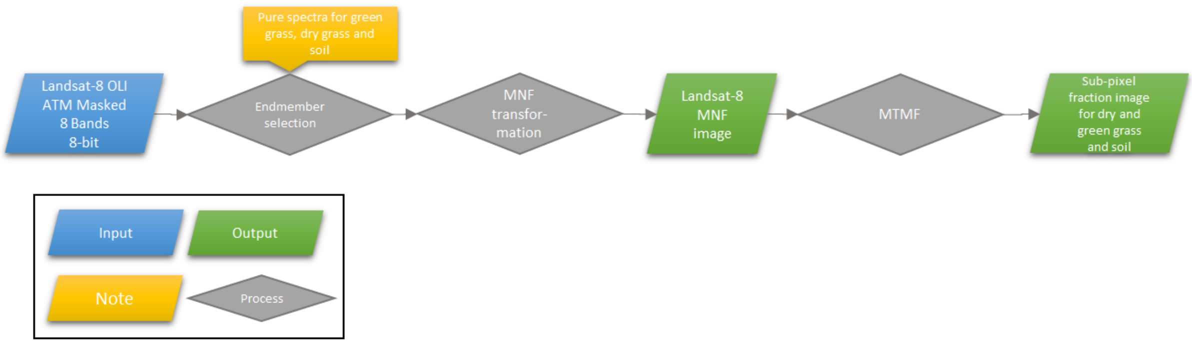


Figure 8: Work flow of the spectral mixture analysis

The result of the MTMF is a grey-scale matched filtering (MF) fraction image representing the estimated relative estimated relative degree to which each pixel matches the reference spectrum (

Figure 9). Matched Filtering can be described as the process of filtering the input data for good matches to the reference spectrum while suppressing background spectra. Endmembers for green grass, dry grass and soil were identified in the image. The matched fractions range between 0 and 1, where 1 indicated a perfect match of the pixel spectrum to the reference spectrum.

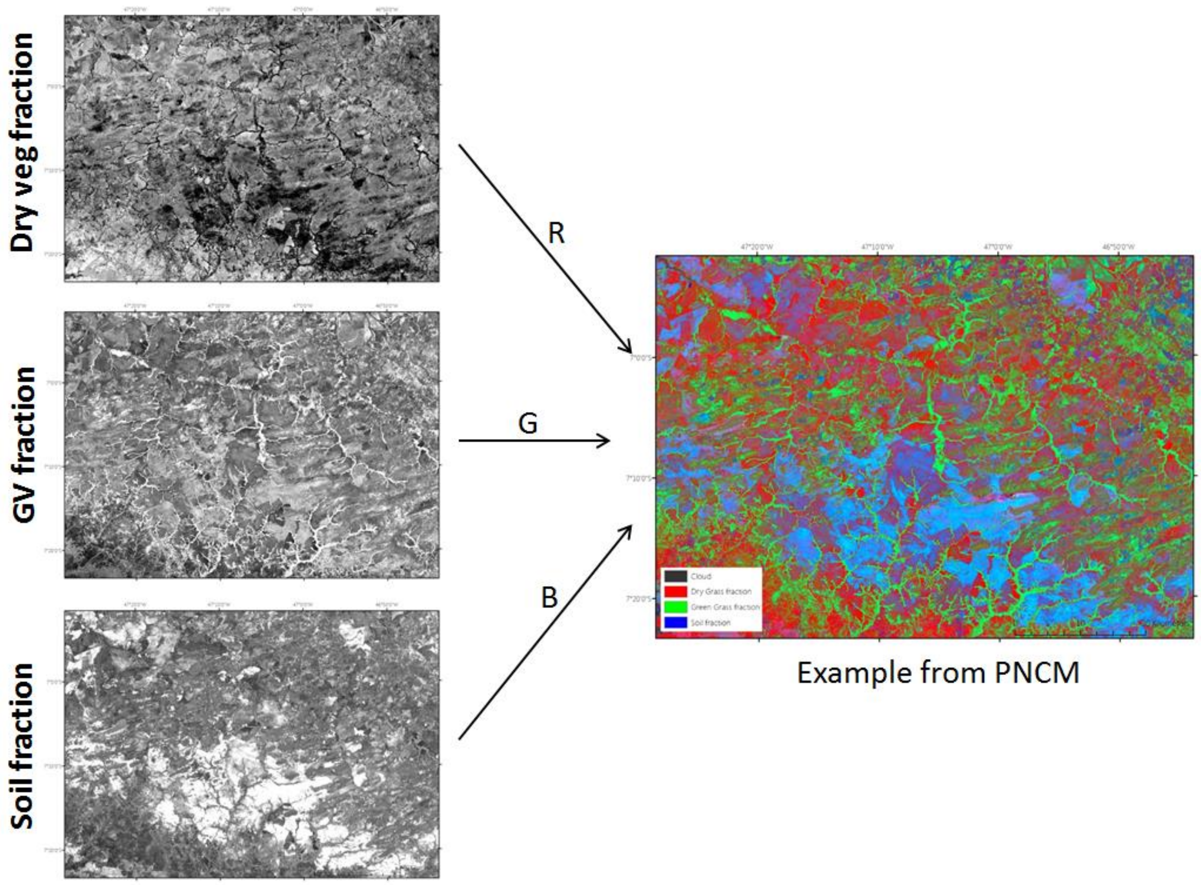


Figure 9: Example of a SMA result showing the fraction image of dry vegetation, green vegetation and soil for PNCM that can be shown as a false-color image.

<u>Results:</u>
The following maps (from Figure 10 to Figure 15) show the early and late season results of the spectral mixture analysis for ESEC, PEJ and PNCM, respectively. The fraction images of the spectral mixture analyses show the distribution of green vegetation, dry grass and soil with all mixtures between these components in detail. Red colors indicate a high abundance of dry grass and blue colors indicate a high soil fraction with a continuous mixture of both (purple colors). Green areas mainly represent gallery forests and green grass.

The early dry season fuel load maps were provided to park managers as a planning tool for controlled early burning. The updated fuel load maps (late dry season) have been created for the monitoring of fire effects and for planning of early burning measures in 2015. During the workshop in Palmas in November 2014, the wide-ranging benefits of the fuel load maps have been presented by the park managers.

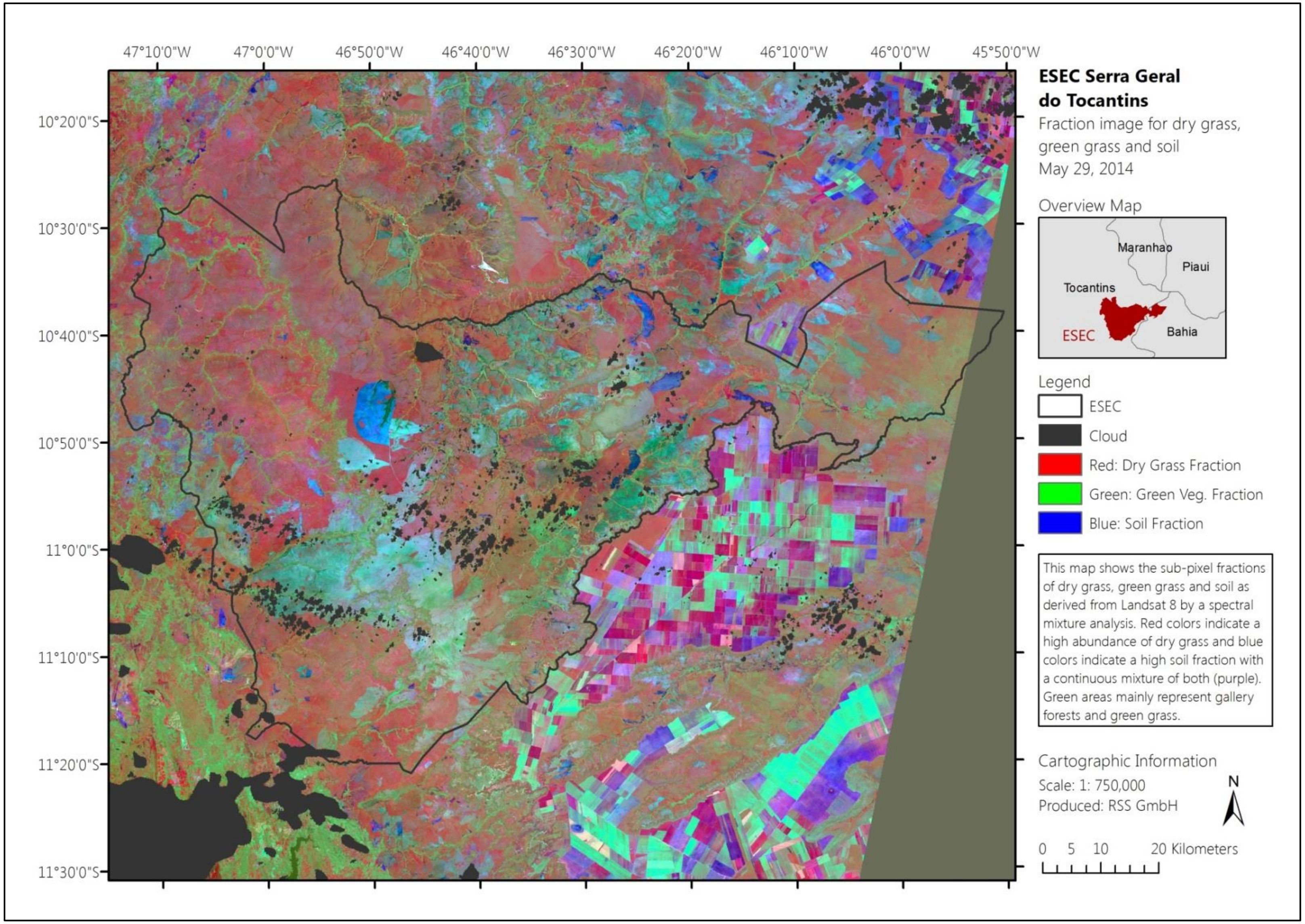


Figure 10: Early dry season fuel load map of ESEC

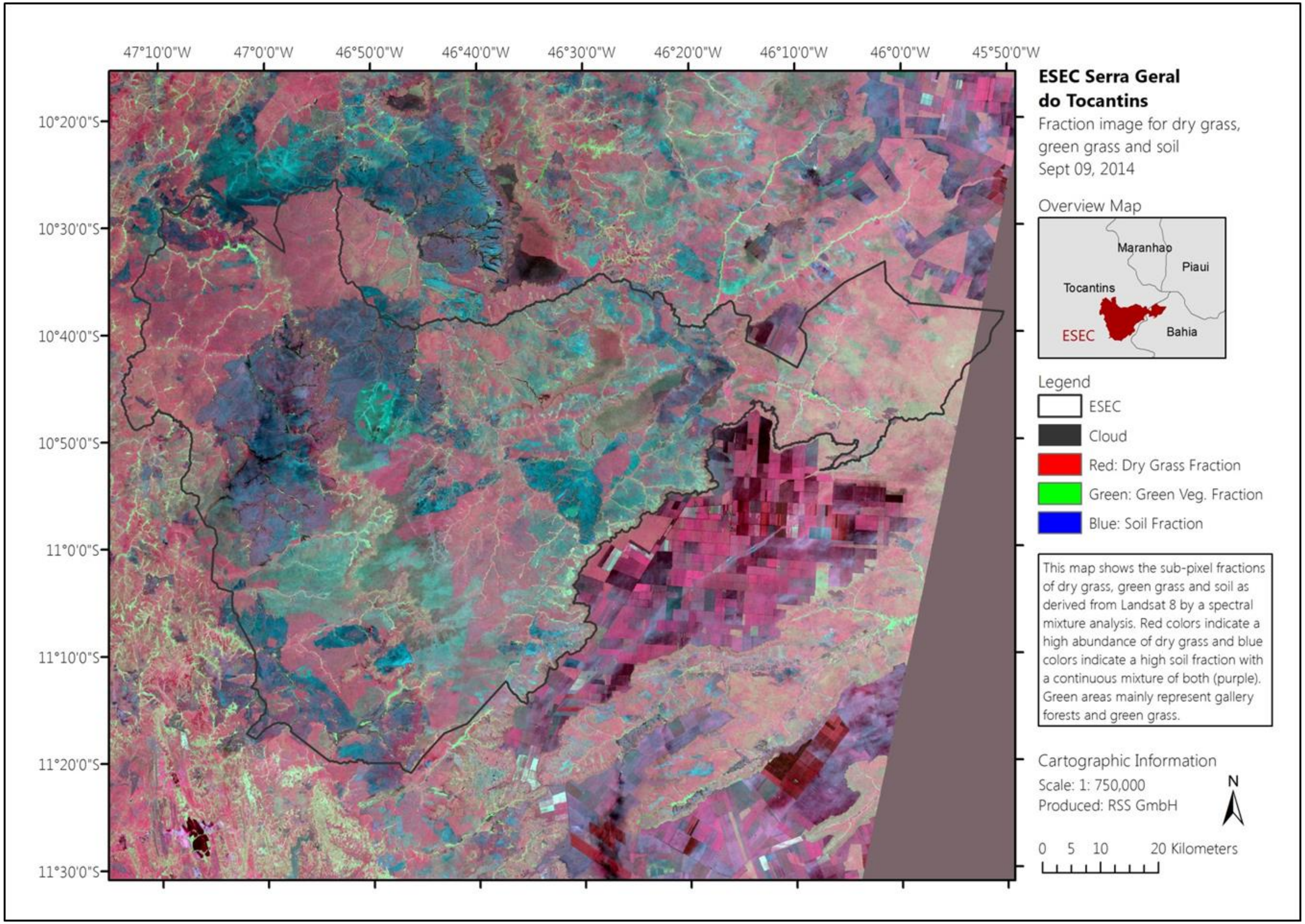


Figure 11: Late dry season fuel load map of ESEC

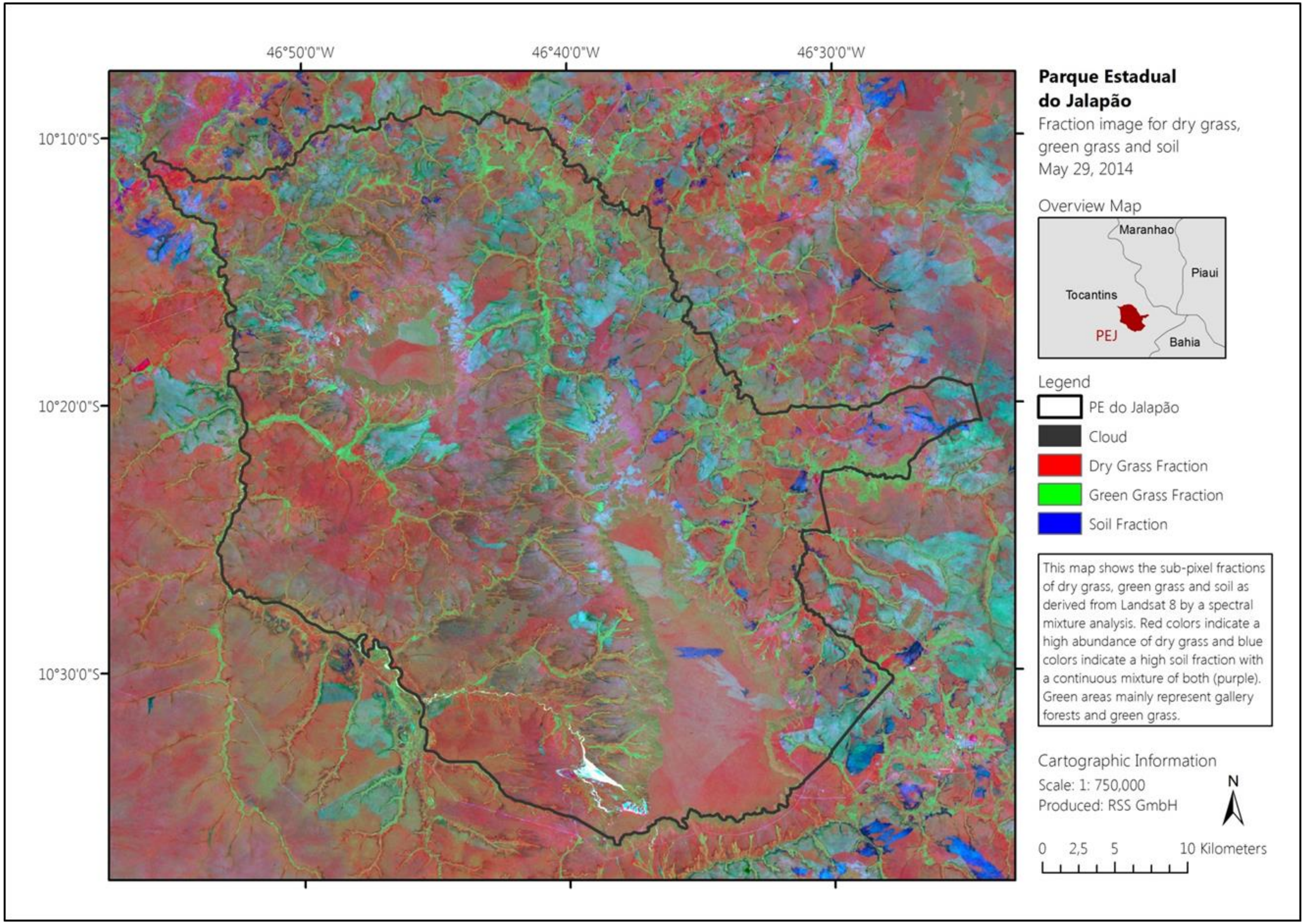


Figure 12: Early dry season fuel load map of PEJ

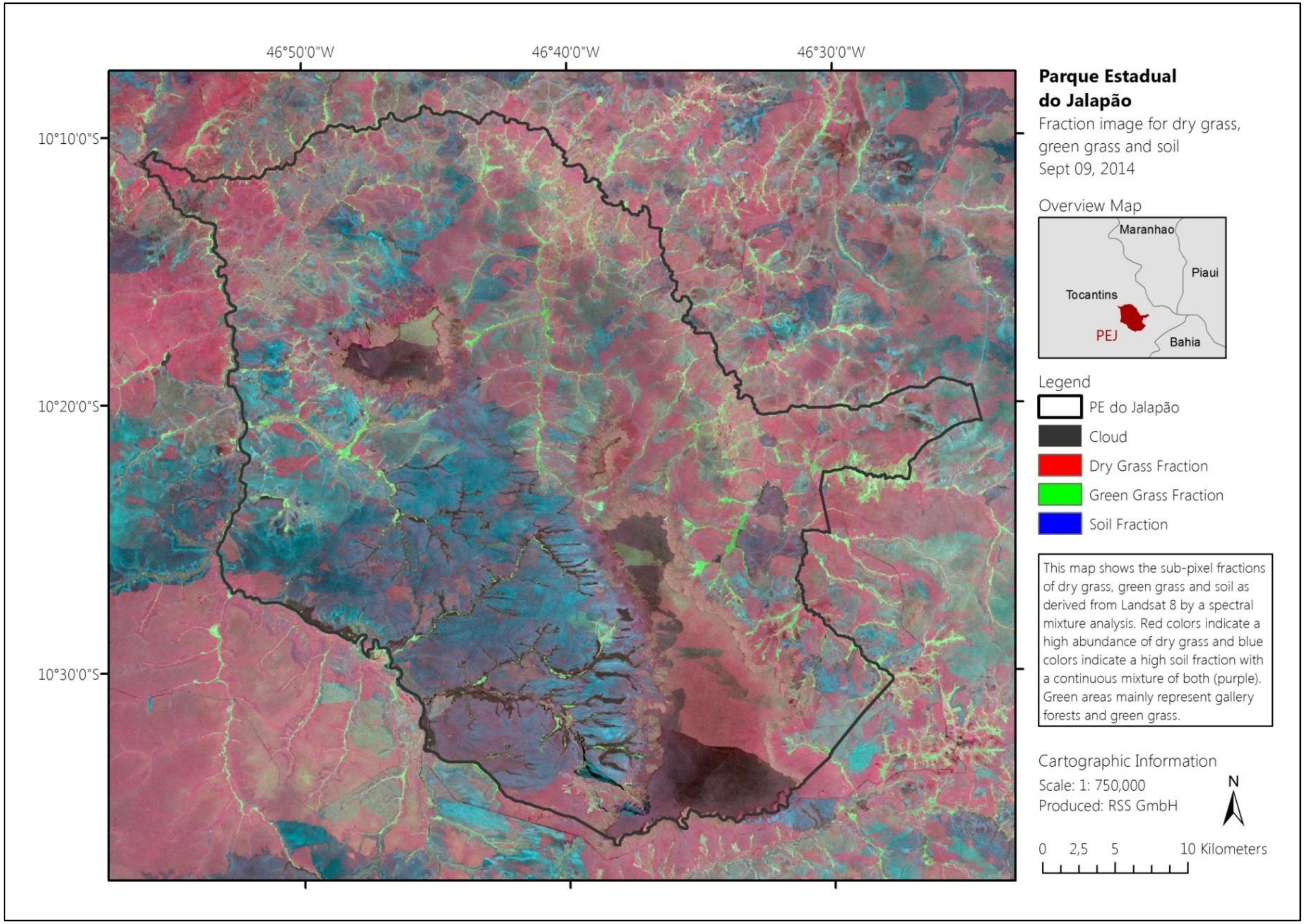


Figure 13: Late dry season fuel load map of PEJ

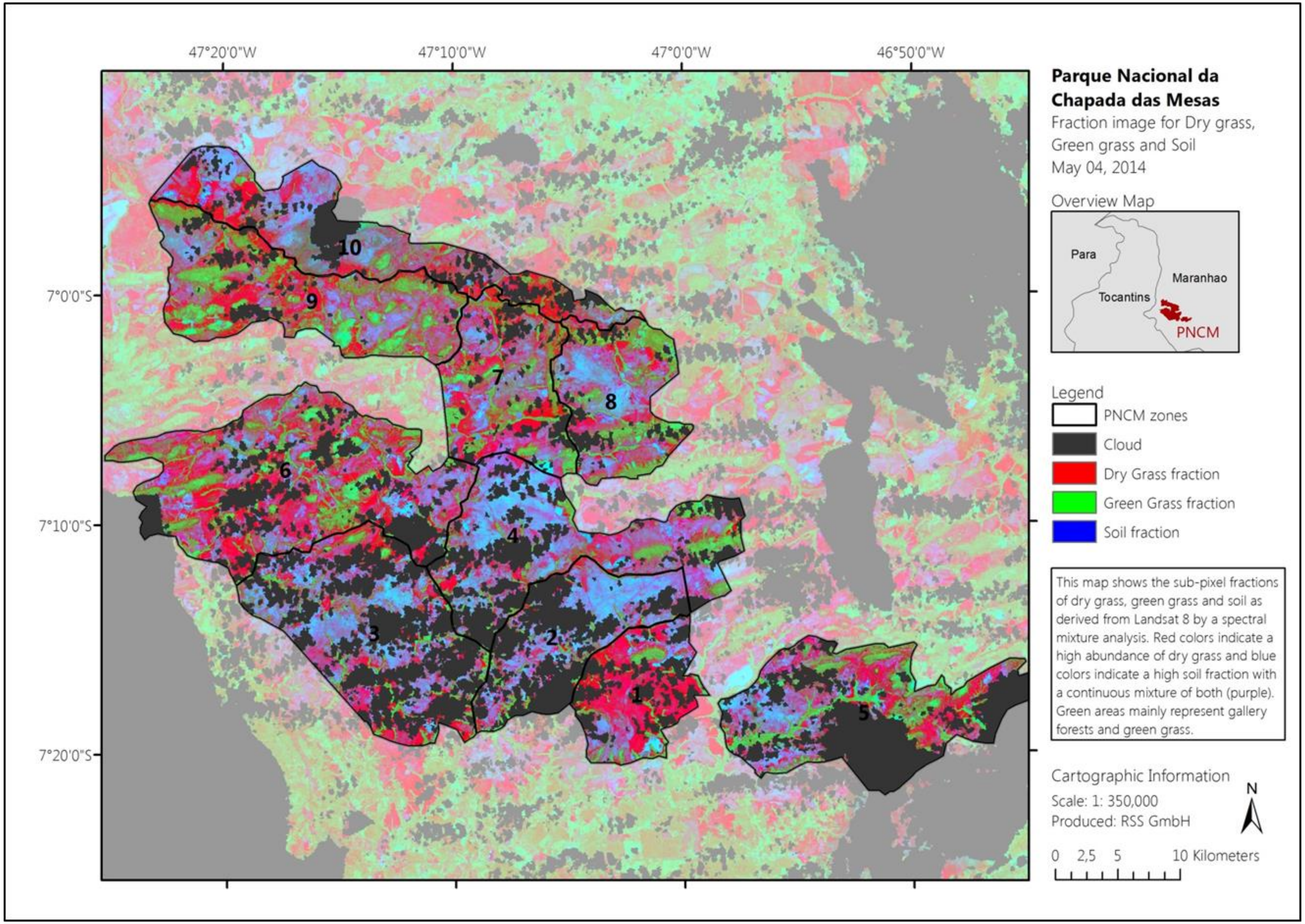


Figure 14: Early dry season fuel load map of PNCM

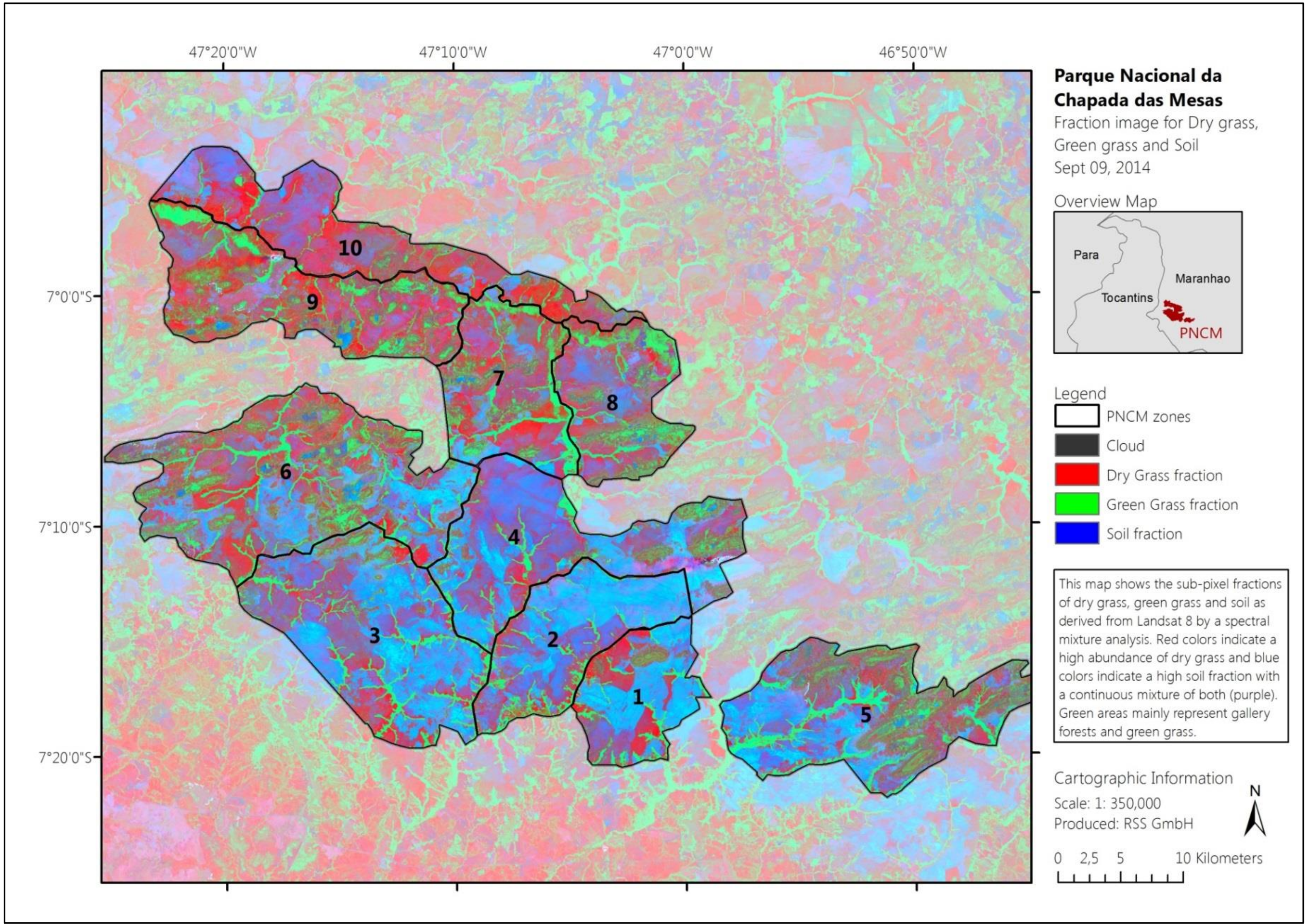


Figure 15: Late dry season fuel load map of PNCM

Validation:

The validation of the fuel load maps was two-folded: first, the mapped early season fuel loads were compared with the actual burned areas during the dry season and second, through field visits.

INPE mapped the burned areas in the three pilot areas in 2014 and these burned areas could be compared to the fuel load distribution. Figure 16 demonstrates that the burned areas in PEJ only occurred in places where high fuel loads were present. This not only proofs the validity of the fuel load maps, but also underlines the idea of MIF by fragmenting the fuel loads through early controlled burning. The fuel load maps are an important information source for the planning of fuel load management.

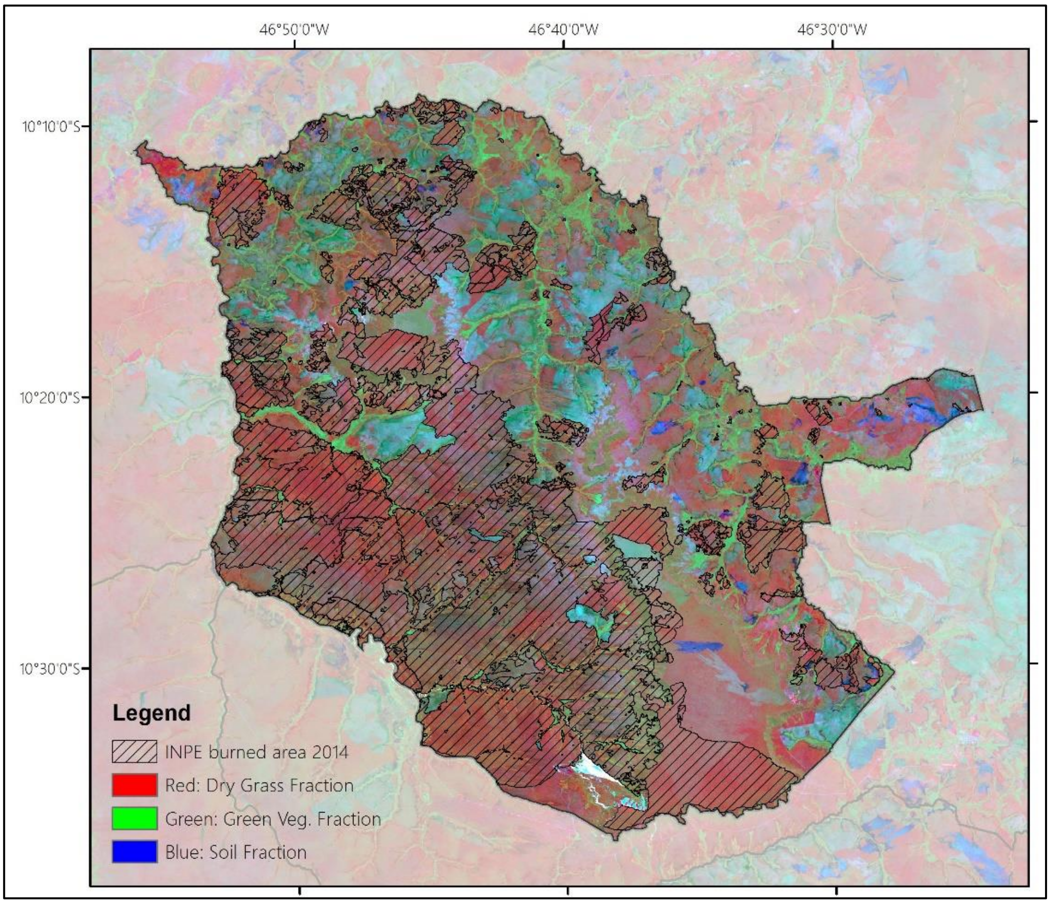


Figure 16: Early season fuel load map of PEJ with overlaid burned areas of 2014 as provided by INPE

Besides the continuous validation by the park managers and by Robin Beatty during the early season controlled burning (for which these maps were used in support of planning of the burning), an additional validation was done through a field visit in PNCM on 30.10.2014 and 02.11.2014 when 119 GPS-pictures were taken. During this field visit, the validity of the fuel load maps could be assessed in detail.

Figure 17 to Figure 19 show some image examples at different location with different fuel loads in order to demonstrate the accuracy.

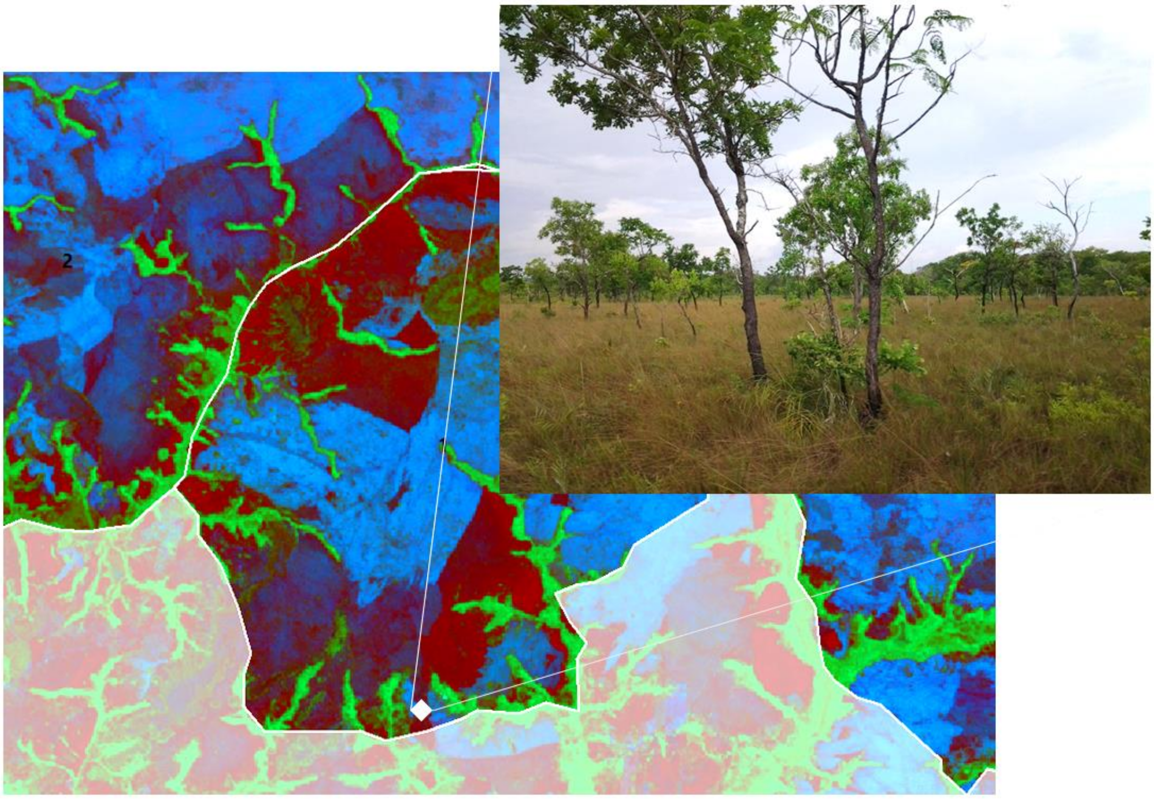


Figure 17: Example of an area with high fuel loads (indicated by red colors in the map and dense dry grass vegetation in the image)

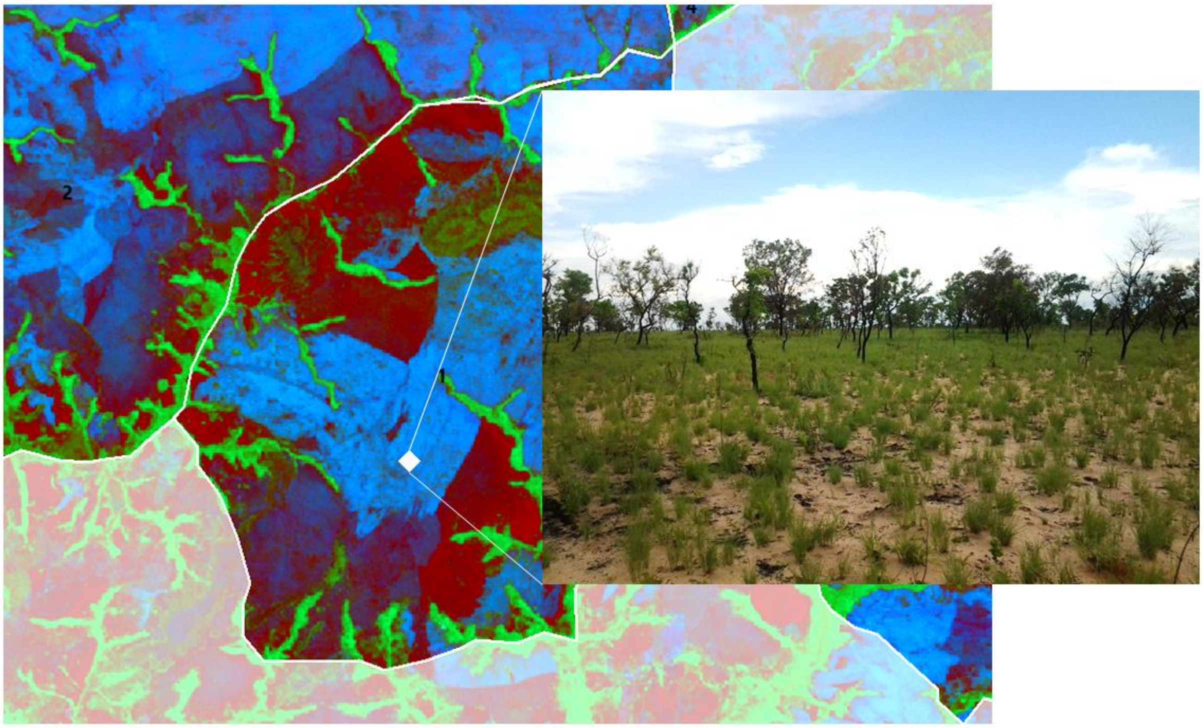


Figure 18: Example of an area with low fuel loads that burned in 2014 (indicated by blue colors in the map). The image shows that in this area a high soil fraction is present with only very sparse patches of recently regrown green grass).

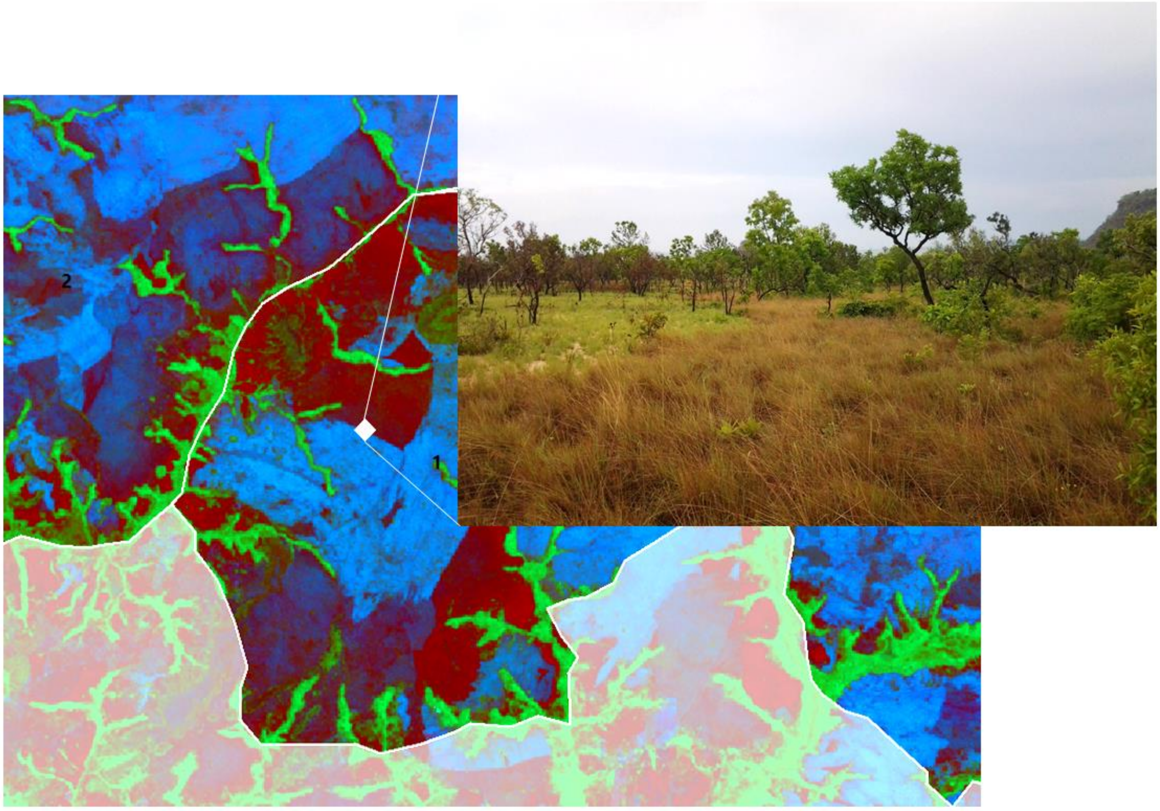


Figure 19: Example of an area where a fire stopped in 2014 (at the edge of a burned and non-burned area). The image shows the clear line between high fuel loads and a recently burned area.

<u>Recommendation 3:</u> First, provide training at ICMBio for various institutions on fuel load mapping for a future operational provision of maps to the protected areas. Second, establish a mechanism for constant exchange between ICMBio, INPE and the park managers on operational remote sensing services (requirements and feedback in order to improve the uptake of RS products for the daily work of the park managers).

4.4 High-resolution stratification of vegetation types of the protected areas of the Cerrado based on RapidEye data

In order to reliably characterize this diverse ecosystem and to identify different vegetation types and land uses by remote sensing, high spatial resolution data is required (Figure 20). The national coverage of RapidEye data of 2011, 2012 and soon 2013 acquired for the CAR-System can be used to characterize the pilot areas in high spatial detail, which has not been used so far outside the CAR-System (data available at MMA). Such detailed land cover benchmark map is required for future monitoring of land/forest cover changes and the impact of integrated fire management. In addition, such benchmark map can directly be used to support the planned integrated fire management in the pilot areas and to assess the biomass distribution via the stratify & assign methodology (by the use of existing vegetation type specific biomass inventory data from UFT and Seplan).

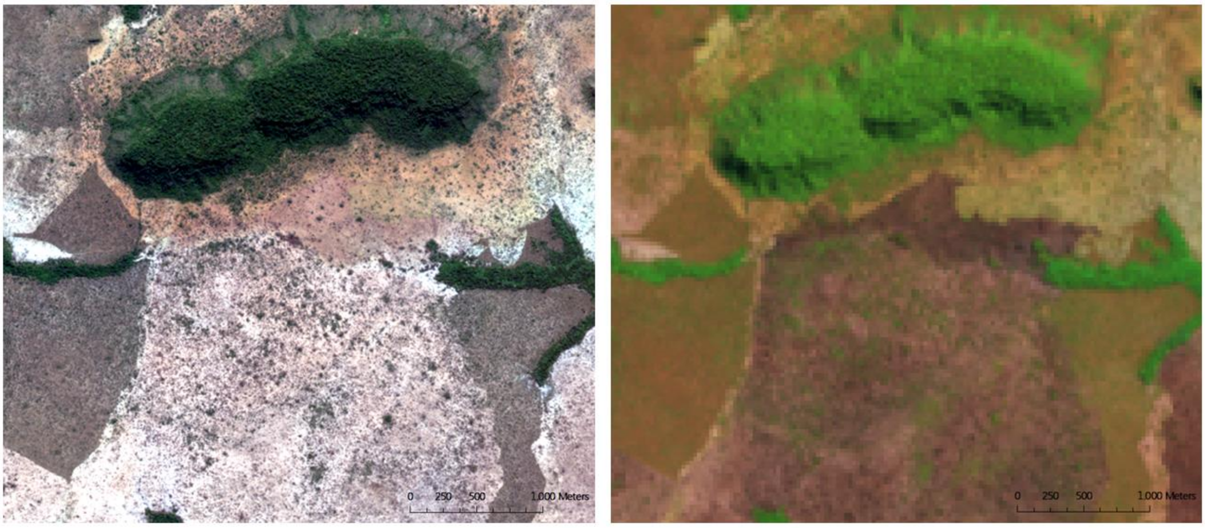


Figure 20: Comparison between high resolution RapidEye data (5m) left and moderate resolution Landsat-8 data (30m) right of an area in PNCM.

The vegetation type classes will follow the classification scheme used by INPE/IBAMA for the large-scale Cerrado mapping, the one suggested by Bruno Walter (Fitofisionomias do bioma Cerrado) and the classification scheme used by Seplan in the past. This will allow a comparison of the benchmark map with the existing historical land cover maps and will be in accordance with the INPE/IBAMA results. A class transformation table will be created as a basis for these maps.

Together with project partners, a master thesis was outlined in order to perform this work in the framework of a jointly supervised master thesis between Brazilian partners and RSS. From beginning of 2015, a student from UTF will start working on this vegetation mapping with the following main tasks and work packages in the rough schedule outlined below.

<u>Main tasks:</u>

- Clarify access to RapidEye data of 2011 with Semades
- Develop a classification scheme in close cooperation with INPE/IBAMA and Seplan and create a class transformation table
- Classify the RapidEye data by the use of other ancillary thematic data (such as the historical land cover maps from Seplan) by applying an object-based classification approach
- Create benchmark maps for each pilot area (Chapada das Mesas, Parque Estadual de Jalapão, and Estacão Ecologica de Serra Geral do Tocantins) according to the classification schemes of INPE/IBAMA and Semades
- Apply stratify & assign method using each benchmark map and biomass data from UFT and Seplan (indirect biomass map for the pilot areas)

<u>Work Packages (with likely place of execution):</u>

WP1 Requirements and Feasibility

- Consult stakeholders and clarify their requirements (land cover types, data format etc.) on final maps (*Brazil*)
- Feasibility analysis on which classes that are required by the project can be resolved by RapidEye (*Brazil*)
- Assess which soft- and hardware is required to perform the work on the long term (*Brazil*)

WP2 Data preparation

- Consult stakeholders and clarify data access to RapidEye data and existing land cover and other ancillary information (*Brazil*)
- Pre-process all other ancillary data to match the specification of the RapidEye input data (*Brazil*)
- Pre-process the RapidEye data (geometric and atmospheric correction) (*Germany*)
- Set-up a GIS-project that contains all data and ensure long-term access to project partners (*Germany or Brazil*)

WP3 Data classification

- Develop a classification scheme in close cooperation with INPE/IBAMA and Seplan and create a class transformation table (*Germany or Brazil*)
- Classify the RapidEye data by the use of other ancillary thematic data (such as the historical land cover maps from Seplan) by applying an object-based classification approach using eCognition (*Germany*)
- Create benchmark maps for each pilot area (Chapada das Mesas, Parque Estadual de Jalapão, and Estacão Ecologica de Serra Geral do Tocantins) according to the classification schemes of INPE/IBAMA and Semades (*Germany*)

WP4 Biomass mapping

- Clarify access to forest and field inventory data from different sources (Seplan, UFT etc.) (*Brazil*)
- Collect biomass data from literature (*Brazil or Germany*)
- Set-up a consolidated biomass data base for the project use (*Brazil or Germany*)
- Apply stratify & assign method using each benchmark map and biomass data base as an indirect biomass map for the pilot areas (*Brazil or Germany*)

WP5 Validation & Documentation

- Validate the final maps and data by the use of in-situ or other reference data (Brazil)
- Final documentation of applied methodologies, used data and final interpretation of results (*Brazil*)
- Create a map atlas that contains all vegetation type and biomass maps from the three pilot areas (*Brazil)*
- Provide a power point presentation that summarizes the work performed (*Brazil*)

<u>Rough time table for master thesis:</u>

WP	**Feb 2015**		**March 2015**		**April 2015**		**May 2015**		**June 2015**		**July 2015**	
1												
2												
3												
4												
5												

<u>Recommendation 4:</u> Create high-resolution vegetation benchmark maps until July 2015. Since the work has to be done partly in Brazil and partly in Germany, two supervisors are required. It is necessary that the supervisors are in a short communication cycles, in order to harmonize the next steps and to ensure that the project results match the expectations of the project.

4.5 Preparation of a LiDAR-survey for selected transects in the Cerrado

LiDAR-based (Light Detection and Ranging) biomass models allow for substantially more precise estimation of fuel loads and thus support upscaling of fuel load estimates from the ground scale to the satellite remote sensing scale and thus substantially improve the final GHG emission estimates through an improved biomass database.

The diverse ecosystem of the Cerrado is characterized by a wide variety of different vegetation types. Therefore, the biomass and carbon stock in the Cerrado shows a very high spatial variability which has not been assessed so far at larger scales. Remote sensing techniques, in particular Light Detection and Ranging (LiDAR) can deliver valuable information in these regards. LiDAR systems have advantageous characteristics such as high sampling intensity (between 2 and 12 points per square meter), direct measurements of canopy heights, precise geolocation and automatic processing. LiDAR allows the derivation of different elevation models such as digital elevation models (DEM), digital terrain models (DTM) and canopy height models (CHM). These properties make LiDAR systems highly useful for a direct assessment of vegetation characteristics and forest biomass at multiple scales from individual trees up to regional scales.

Furthermore, LiDAR data can accurately describe internal vegetation structure due to its ability to penetrate vegetation cover. The forest types differ significantly in the distribution of height, number of vegetation layers, and frequency of LiDAR returns in the different heights. In combination with field data on above ground biomass, this allows for an accurate description of forest structure and forms the basis for LiDAR-based spatial modeling of vegetation biomass and carbon stock. Field inventories could be conducted in different Cerrado vegetation types in order to collect reference data used for the calibration of the LiDAR based above ground biomass models.

Due to the costs of LiDAR data, we suggest an upscaling approach, in which field inventories are used to calibrate LiDAR transect based biomass models that can be further upscaled to the project area by the results of the vegetation benchmark map based on high resolution RapidEye data, in order produce accurate biomass and carbon stock maps for the project area.

The group of Prof. Marco Giongo of the University of Tocantins has collected one year of data (217 samples) for the quantification of surface fuel load, and are developing models for up-scaling this database using Landsat satellite images for non-parametric and parametric models. High resolution LiDAR data would be extremely useful for the further development of this fuels map product. The fuels map in turn could be used to further develop models of fire intensity, biomass combustion and fire emissions.

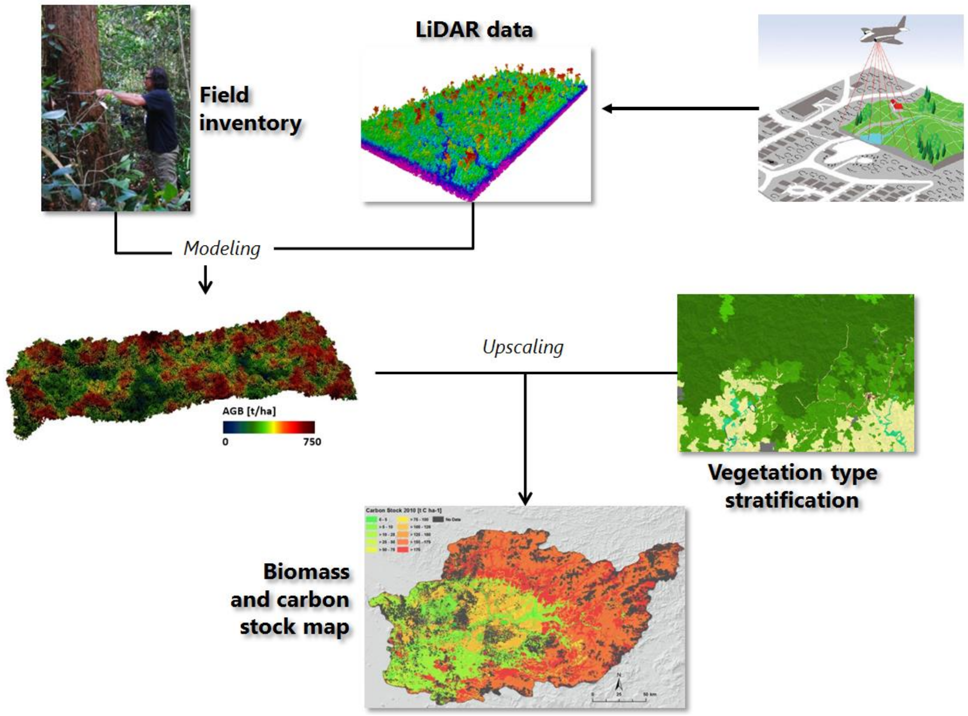


Figure 21: Approach of generating LiDAR-based biomass models for transects by the use of field inventory data and upscaling to large areas using satellite remote sensing data.

A LiDAR survey and data analysis shall be under the lead of INPE and RSS. For the preparation of such LiDAR survey, transects were proposed which are placed in a way that they cover a representative sample of vegetation types in PNCM and the Jalapão area (Figure 22). In total, 6 transects with a total length of 700km are proposed.

Figure 22: Location of transects for a LiDAR survey over PNCM and the Jalapão area.

In order to roughly estimate the costs of a LiDAR survey, a Brasilia-based company was contacted that realize LiDAR surveys (Topocart). RSS requested a cost estimate from Topocart based on the 6 transects as shown in Figure 22. The following assumptions were made:

- The total quantity of 6 flight lines totaling 700km
- Single tracks in one direction are flown
- Minimum of 2 points per square meter are required
- Transect width of 300m is required
- The LiDAR will be operated in Full Waveform mode (which allows assessments of canopy structure)
- The recorded data will be provided after pre-processing

Topocart estimated the total costs of such survey as 574,000.00 R$, of which 530,000.00 R$ are the costs of the LiDAR flight and 44,000.00 R$ are the costs for the pre-processing of the data.
Other companies could be contacted in order to get a more diverse comparison of prices.

<u>Recommendation 5:</u> Further elaborate on the realization of a LiDAR survey, since this would constitute a very valuable and unique data source for benefit of various project activities such as improved GHG emission estimates, impact assessment of controlled and uncontrolled fires, validation of mapping results and for fire ecology research.

5. Summary of recommendations

The following recommendations on project activities are made for the next phase of MIF implementation in 2015:

- Develop a new field protocol for biomass assessments in close cooperation between UnB, ZEBRIS and RSS. This should be done by assessing existing literature on sampling strategies and by a common field visit to test and discuss sampling strategies.
- Applied and test the final field protocol during fire experiments (cooperation between fire ecology research and remote sensing) in 2015.
- Establish the use of freely accessible Landsat-8 and Sentinel-2 (from 2015 onwards) data for the continuous large-area observation of burned areas during the dry season by the park managers. Only the use of satellite imagery allows the park managers to get an overview of the current distribution of burned areas over these large areas that cannot be observed by field visits alone.
- Provide training at ICMBio for various institutions on fuel load mapping for a future operational provision of maps to the protected areas.
- Provide training on the use of mobile mapping devices at different levels of difficulties (depending on the pre-qualification of persons), in order to assure that park managers, fire fighters, researchers etc. directly benefit from mapping products in the field.
- Establish a mechanism for constant exchange between ICMBio, INPE and the park managers on operational remote sensing services (requirements and feedback in order to improve the uptake of RS products for the daily work of the park managers).
- Support the park managers in MIF implementation through remote sensing information not only by fuel load maps for planning controlled fires, but also for managing uncontrolled fires (in the framework of fire experiments).
- Further assess the use and precision of the fuel load maps for fire behavior analysis (fuel load variation within patches) and for estimating GHG emission (correlate to FRP etc.)
- Further elaborate on the realization of a LiDAR survey, since this would constitute a very valuable and unique data source for benefit of various project activities such as improved GHG emission estimates, impact assessment of controlled and uncontrolled fires, validation of mapping results and for fire ecology research.