Regional Extrapolation of Tropical Ecosystem Structural Properties

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Abstract & Introduction

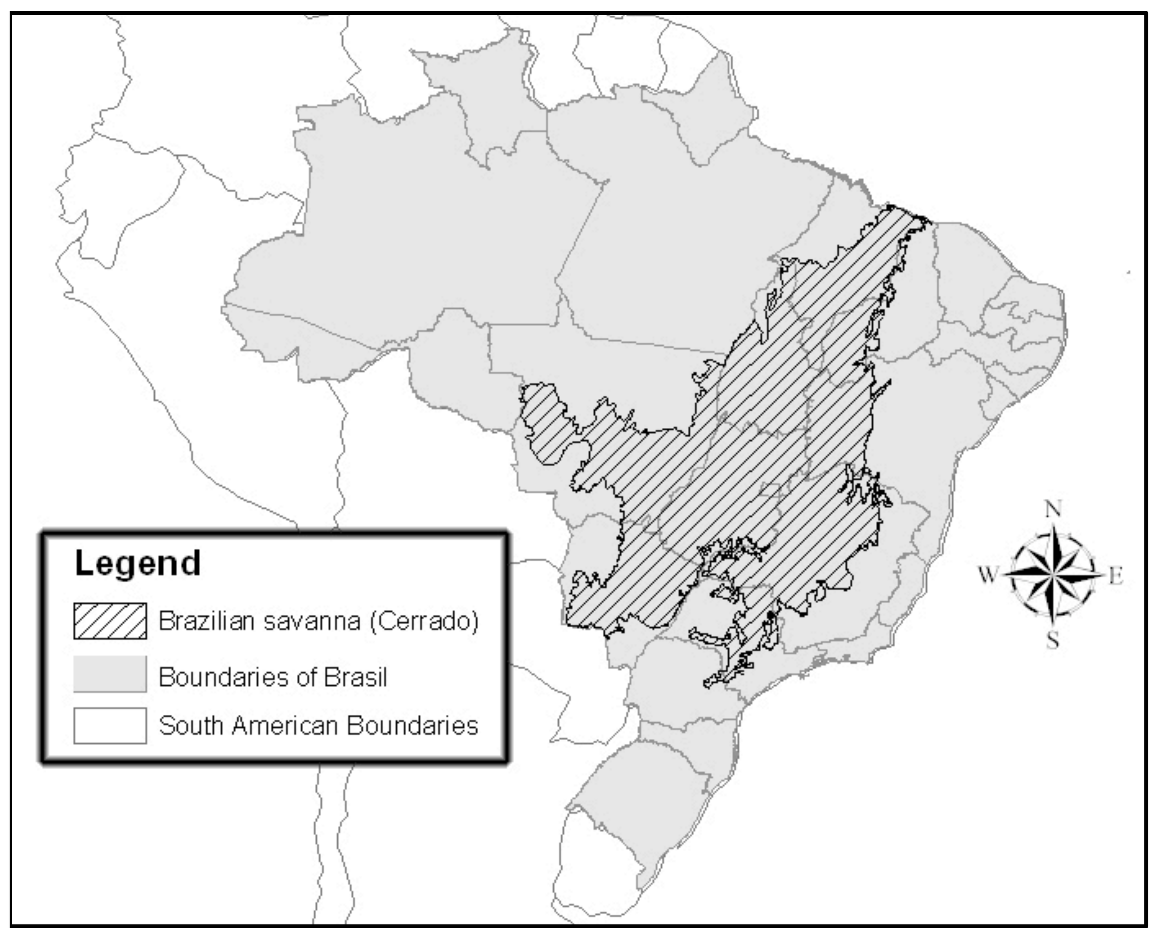

Figure 1. The Cerrado (hatched) is shown against the area of Brazil (grey) with state and national boundaries for Brazil and South America

Abstract

We plan to use multiscale optical remote sensing and field observations to quantify changes in vegetation cover and net changes in vegetation C-stocks in the Brazilian Cerrado region, from 1964 to 2008. For the years 2000 to 2008, we will also produce annual estimates of vegetation cover and C-stocks in vegetation. Our analysis will depend upon a range of remote sensing data including moderate resolution and very high resolution satellite-borne optical sensors and historical aerial photography. These data will be calibrated with ground based biometric plot data from a Brazilian network of ground based Cerrado observations. High resolution image processing using an automated crown detection algorithm will be key to linking field observations with synoptic reflectance imagery.

Introduction

Tropical savanna ecosystems cover 22.5 x 10^6 km², an area nearly 30% larger than the area of tropical forests. Although the average carbon (C) content of savanna vegetation is only about 25% as great as forest vegetation (29 vs. 120 Mg C ha^{-1}) (Watson et al. 2000), land use changes in savannas are more rapid. Consensus values for the net effects of land use changes on the global C-budget were approximately 1.7 ± 0.8 Pg C y^{-1} for the decades of the 1980's and 1990's (Watson et al. 2000, Houghton 1999, Houghton et al. 1999, 2000). However, recent studies of the net effects of tropical deforestation using satellite remote sensing data account for about 0.6 ± 0.2 (Achard et al. 2002) from humid forests and 0.9 ± 0.4 Pg C y^{-1} (DeFries et al. 2002) from forests and woodlands the 1980's and 1990's. If the net tropical C-sources are smaller than supposed, then terrestrial C-sinks outside of the tropics must be smaller than previously proposed. Alternatively, tropical C-sources are indeed large but sources of C from tropical savannas have been underestimated.

Background

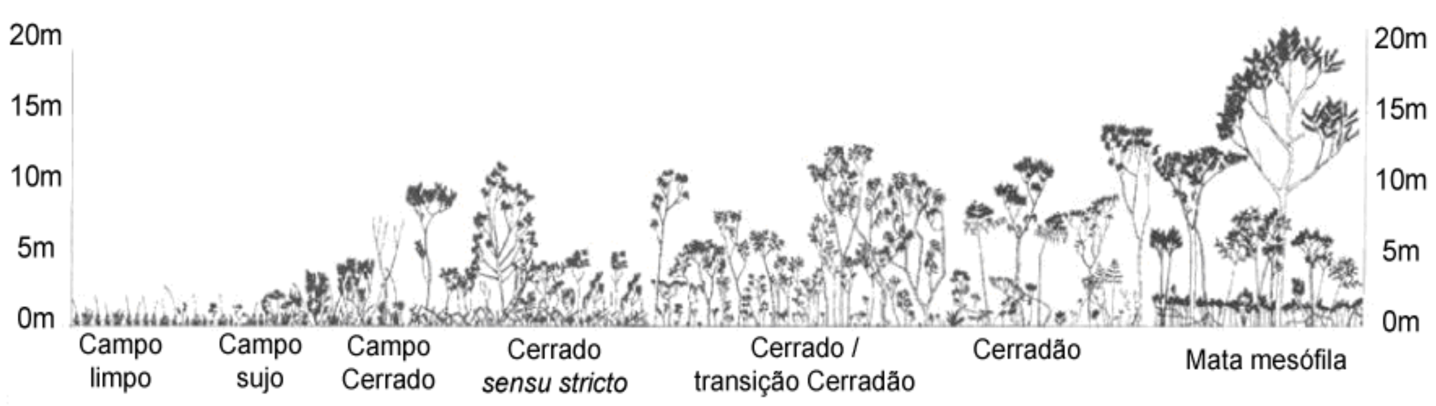

Figure 2. A schematic view of Cerrado physiognomies showing vegetation heights. The Portuguese names for the different vegetation types are: campo limpo= grassland; campo sujo = grass savanna; campo cerrado = open savanna; cerrado sensu stricto = savanna woodland; cerradão = woodland; mata mesófila = mesophytic forest. Gallery forests (matas ciliares) are present along water courses. Cerrado physiognomies are described in detail by Oliveira-Filho and Ratter (2002)

For estimation of C-budgets, tropical savanna conversion has been treated as a secondary question compared to the clearance of tropical forests. Achard et al. (2004) expanded on their 2003 forest estimates using FAO remote sensing surveys of "woodlands and forests of the dry tropics" resulting in an additional flux of 0.08 and 0.21 Pg C y^{-1}. These values are based on assumptions such as the use of a single value (0.2) for the ratio of below-ground to above-ground biomass. In fact, this ratio is almost always greater than 1 for tropical savannas (Grace et al. 2006) and varies widely by vegetation types reaching values as high as 7.7 (Castro and Kauffman 1998). Assuming that the average ratio of below-ground biomass to above-ground biomass is 1 for the dry tropics, then estimates for C-flux from deforestation in the dry tropics by Achard et al. (2004) would be 67% greater (0.13 to 0.35 Pg C y^{-1}). Therefore the lack of consistent information for biomass and land cover changes from large regions of tropical savannas is a significant source of uncertainty in global C-budgets.

The Brazilian savanna, known as Cerrado, covers about 2 x 10^6 km² (Figure 1). The Cerrado is the largest savanna in South America (Goodland 1971) and has an area comparable to the Miombo savanna of Southern Africa. The Cerrado has been the focus of intensive land use change since 1970 onward. According to recent estimates between 40% and 55% of the region (Klink & Machado, 2005) has been converted to pasture and other agricultural uses with peak rates in the early 1970's (Ferreira et al. submitted). Assuming that land use conversion took place over 40 years and that average net biomass change was 29 Mg C ha^{-1}, this implies an average loss of C from the Cerrado of nearly 0.1 Pg C y^{-1}.

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Overview

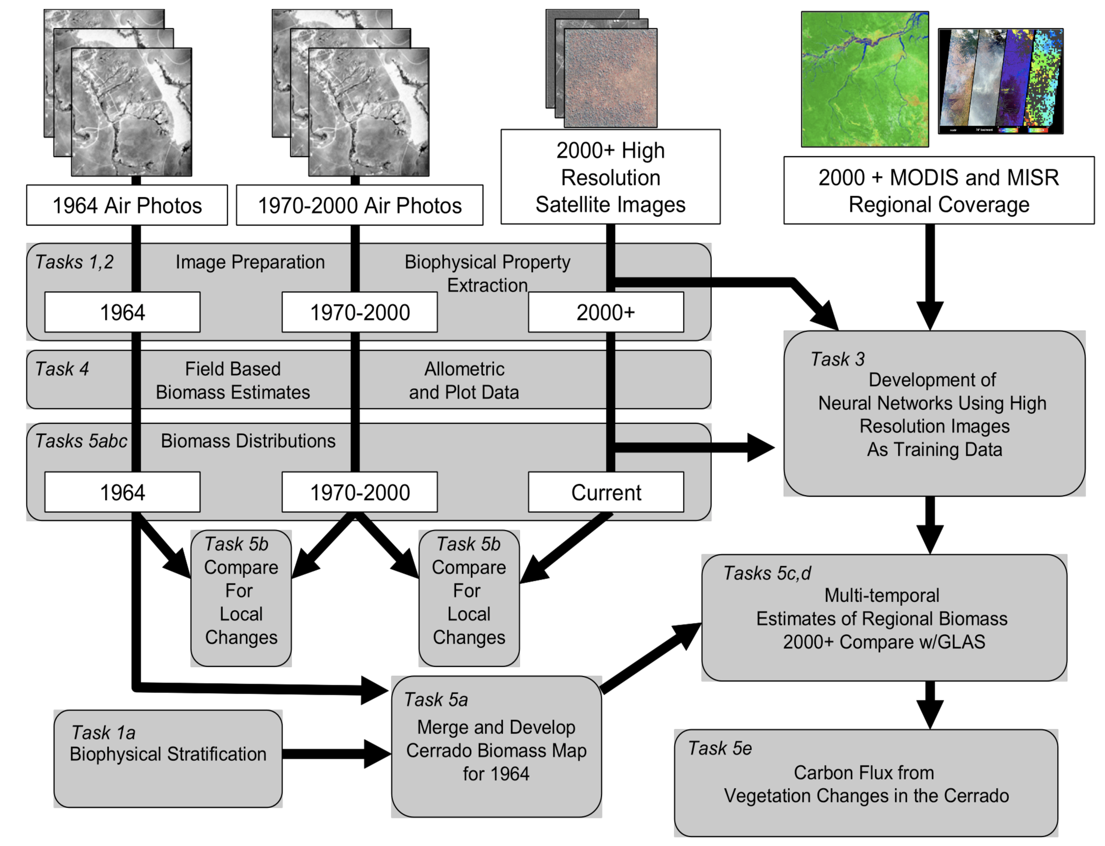

Figure 3. A schematic diagram of the strategy for the study of Cerrado biomass change. Field data collected as part of this study will be used to calibrate textural metrics and biophysical variables derived from contemporary high resolution satellite images and aerial photography. The variables will include stem density for woody plants and distributions of crown diameters based on our crown delineation algorithm (Palace et al. in press) and other textural analysis methods. The variables extracted from high resolution images will be used to train artificial neural network models for classification of land cover and quantification of biomass using combined MODIS and MISR data.

Questions

1. What was the spatial extent and pattern of Cerrado vegetation and biomass C prior to large scale development in the region (pre-1970)?

2. What is the current spatial distribution of Cerrado vegetation and biomass C?

3. How has Cerrado vegetation and biomass C changed between 1964 and the present? What portion of this change can be attributed to direct land use conversion and what portion can be attributed to changes in density of woody cover?

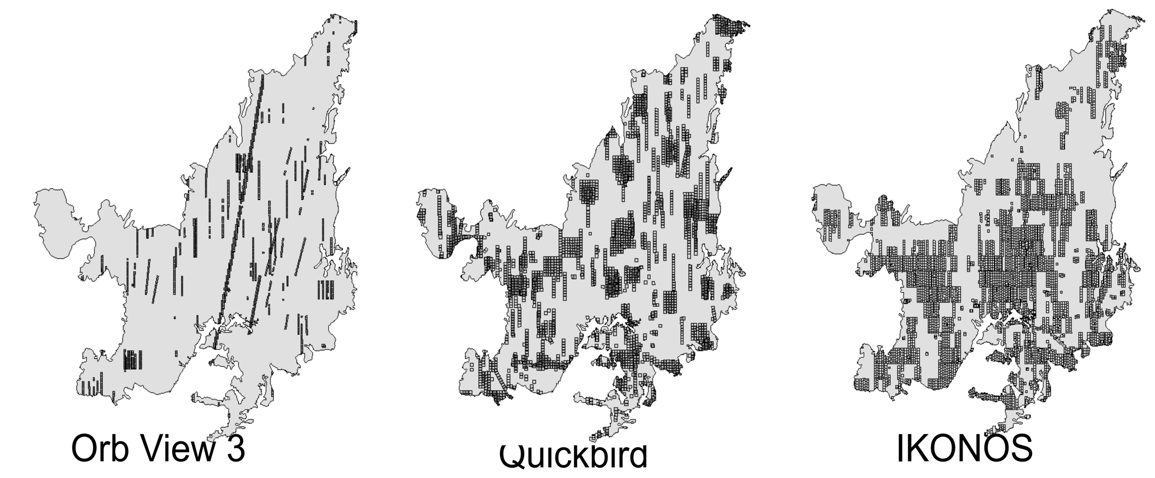

Figure 4. Archival images (<20% cloud cover) available from three high resolution satellite sensors for the Cerrado for 2000-2007. (Data provided by GeoEye and DigitalGlobe). The number of images with <20% cloud cover during this period is 7494 for IKONOS, 2168 for Orb View 3, and 4465 for Quickbird, for a total coverage of about 50% of the region.

Methods & Expected Results

Methods

1. Aerial Photography Selection, Acquisition, and Preparation
1a. Selection and preparation of the 1964 aerial photograph series
1b. Selection and preparation of the post-1964 aerial photographs
2. High resolution imagery approaches.
2a. High resolution satellite image selection and preparation
2b. Application of texture methods for land cover classification
2c. Application of a crown delineation algorithm
3. Literature, database, and field studies of allometry and biomass
3a. Survey and synthesis of allometric data
3b. Survey existing Cerrado biomass data
3c. Cerrado biomass field sampling and analysis
4. Moderate resolution imagery (MODIS + MISR) approaches
4a. Pre-process the training data
4b. Pre-process the MODIS and MISR data
4c. Generate maps of land cover at moderate resolution
4d. Generate maps of Cerrado biophysical characteristics at moderate resolution
5. Synthesis and uncertainty estimation
5a. Production of vegetation and biomass maps of the Cerrado for 1964
5b. Cerrado land cover and biomass trajectory case studies
5c. Vegetation change in the last decade from moderate resolution image analysis
5d. Independent estimate of vegetation biomass using GLAS data
5e. Synthesis of vegetation and biomass change from 1964 through the present

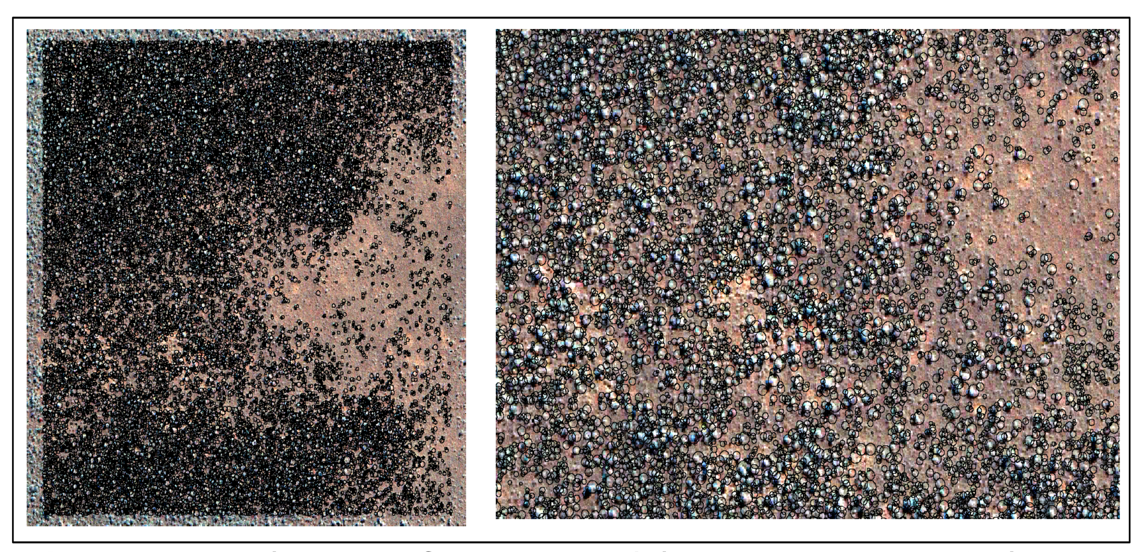

Figure 5. Application of our crown delineation program (Palace et al. 2008) on a 500 by 280 m section of an IKONOS image from a Cerrado area in Aguas Emendadas Park. The original panchromatic image (left) compares well to the delineated crowns (white circles) overlaid on the right image showing crown widths and locations.

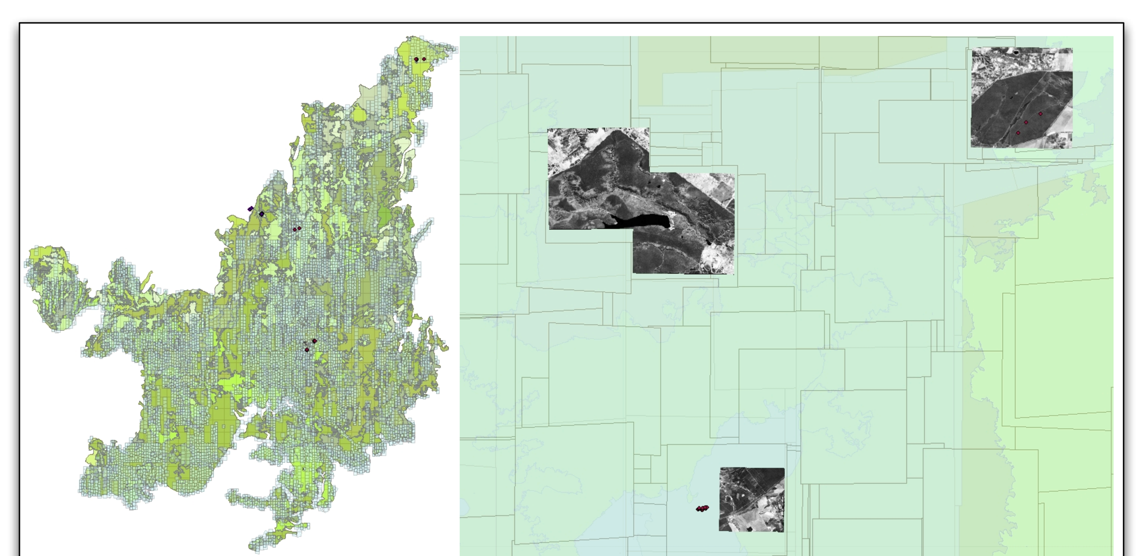

Figure 6. Organization of data and development of a stratified sampling scheme is underway. Using the Probio vegetation class (reduced to 15 classes) overlaid with archival areas of IKONOS and Quickbird, we are determining which images to acquire. In addition our focus will include field sites where biometric data has been collected.

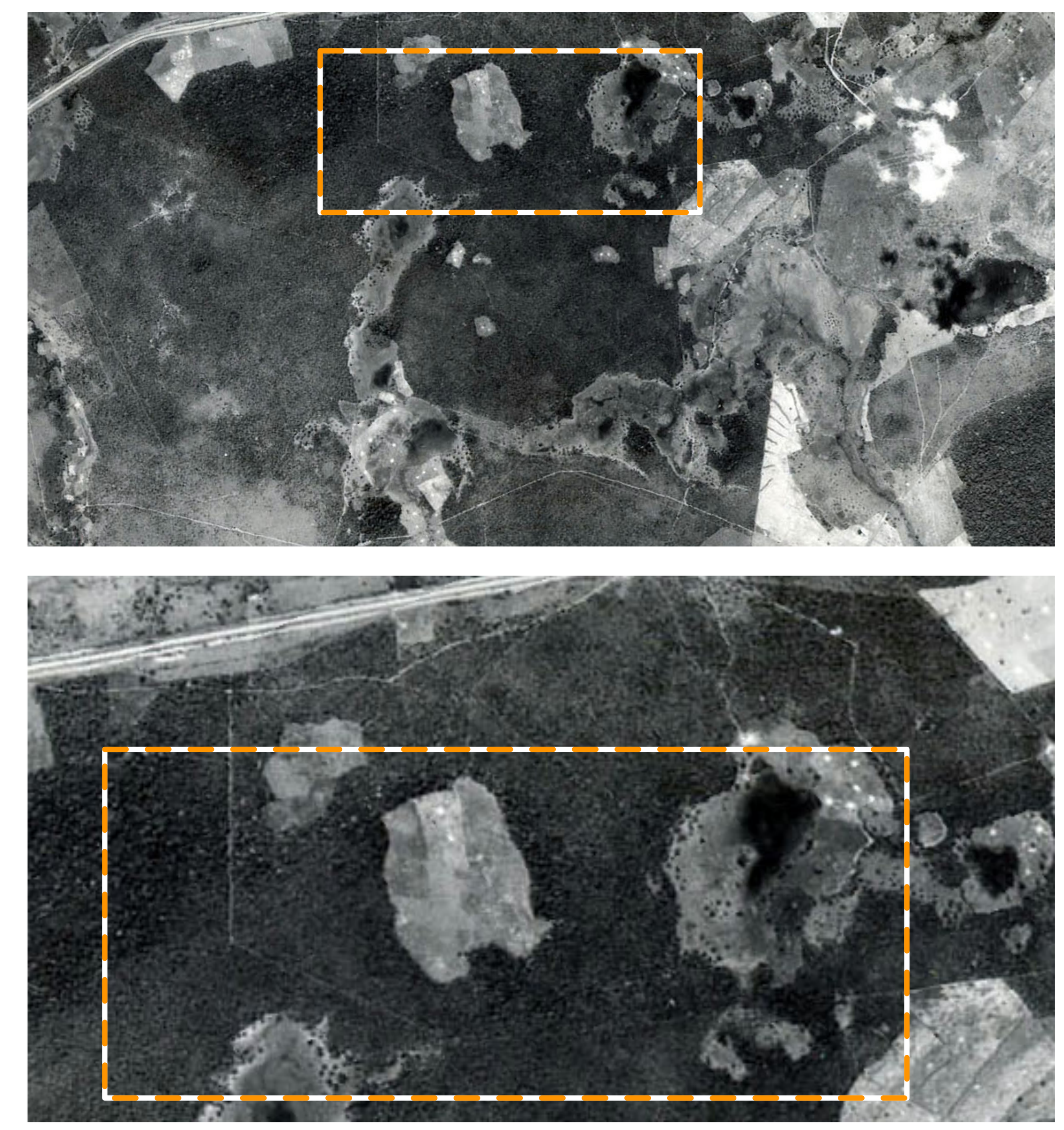

Figure 7. Sample image, and a close-up, from the collection of aerial photographs discussed above. In addition to large area coverage, these images contain both textural information (associated with community dynamics), and information about coarse land cover patterns from natural and human disturbance.

Expected Results

- Revised allometric relations for Cerrado woody vegetation using tree diameter, height, and wood density as independent variables.
- Vegetation cover and biomass C maps (with uncertainties) of the Cerrado region in 1964.
- Selected case studies of the trajectories of land use and biomass C change from 1964 through the present to enrich our understanding of the pace and mechanisms of C-flux between the Cerrado and the atmosphere during the period.
- Maps of annual changes in vegetation cover and C-stock changes (with explicit uncertainties) from vegetation change from 2000 through 2008 based on moderate resolution remotely sensed data and an artificial neural network model of vegetation cover/biomass-C trained using high resolution remote sensing data that is in turn calibrated with field studies.
- An independent estimate of current Cerrado biomass C based on GLAS lidar data.
- A synthesis of the changes in vegetation cover and C-stock changes (with explicit uncertainties) in the Cerrado from 1964 through 2008.

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