

# *Numerical Models to Forecast the Sugarcane Production in Regional Scale Based on Time Series of NDVI/AVHRR Images*



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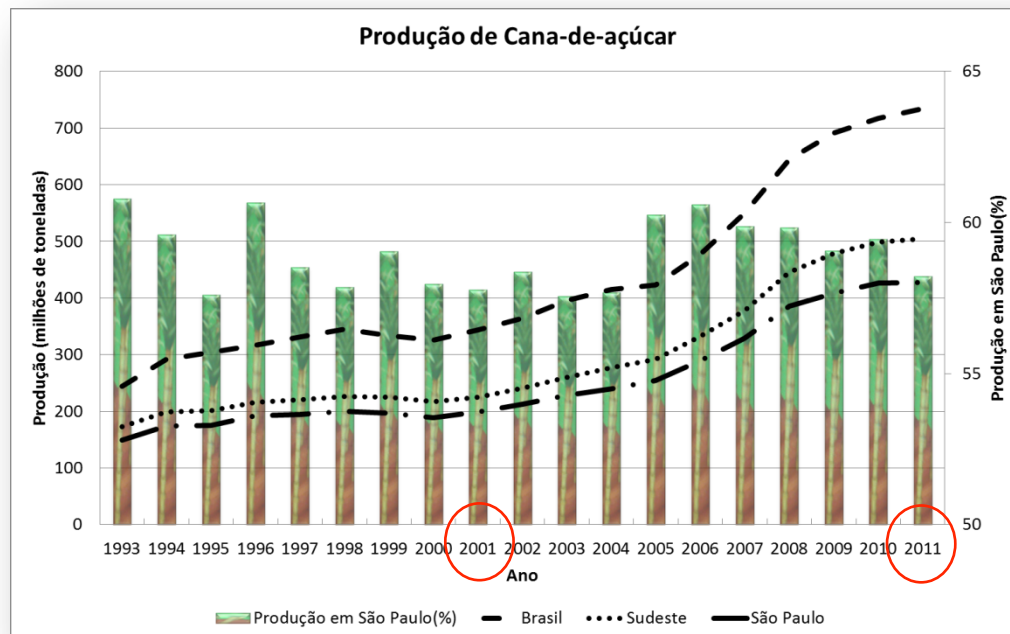
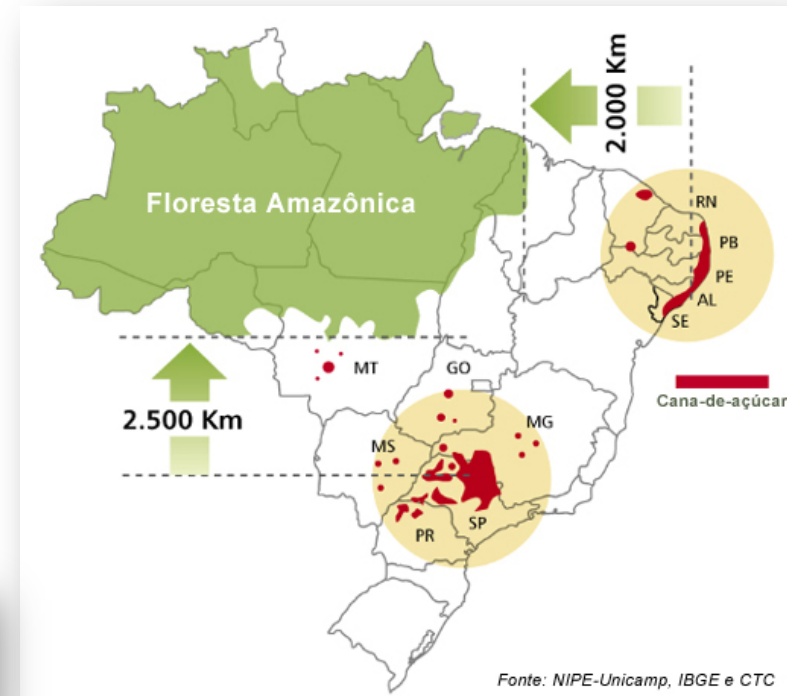
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**MULTITEMP 2015**



# Brazilian Sugarcane Production - Economic Importance

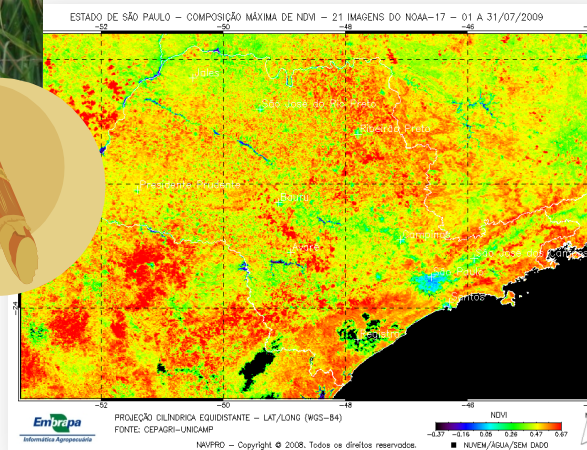
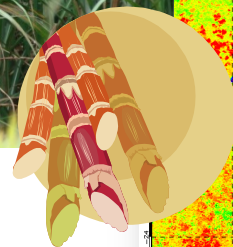
- 8.5 million hectares
- about 2.5% of the entire farmland
- 35% of World production
- Largest producer and exporter of sugar in the World
- Second largest producer of ethanol in the World



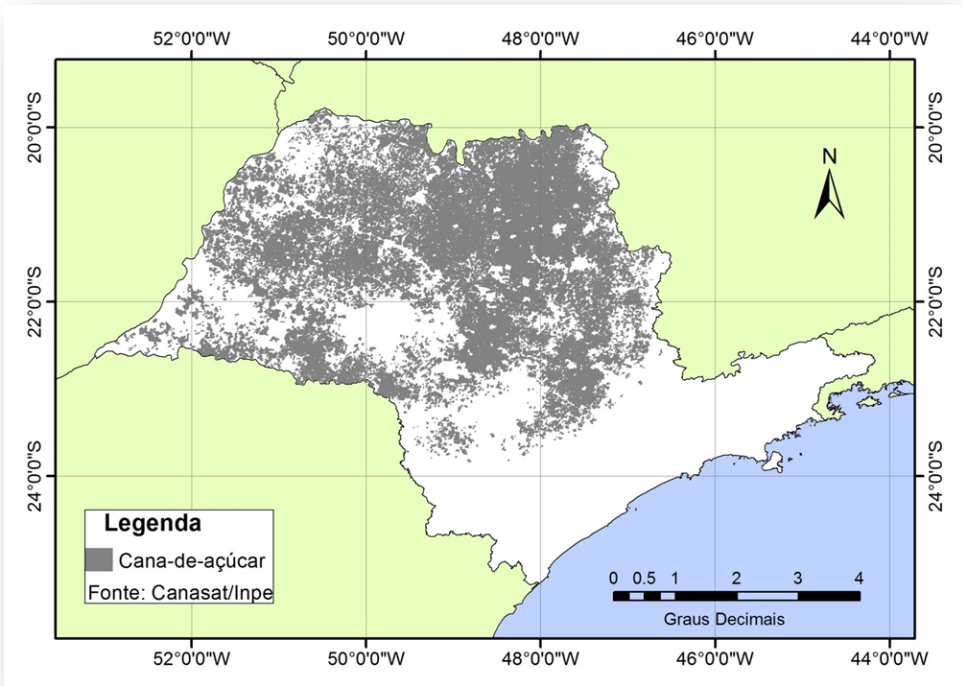
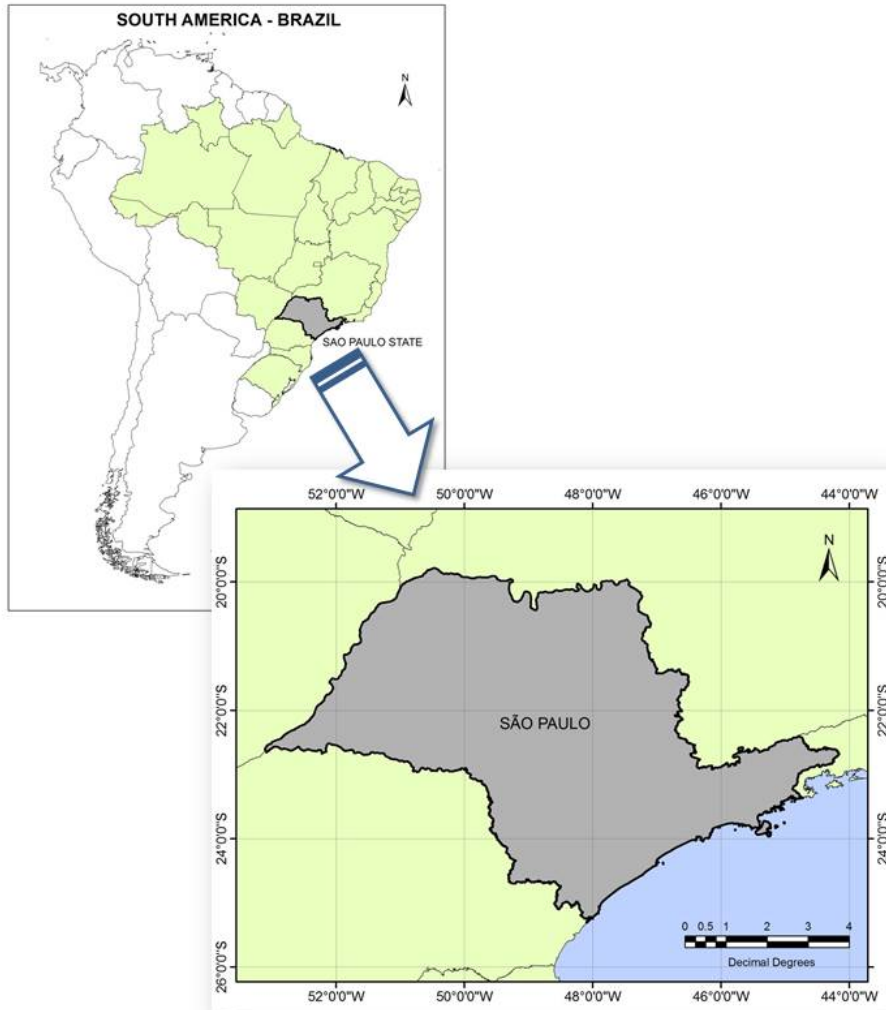
- 2012/2013 = ~532 million ton
- 2013/2014 = ~587 million ton

# Objective

Propose numerical models  
to improve the operational monitoring of sugarcane production  
based on time series of NDVI/AVHRR and agrometeorological data

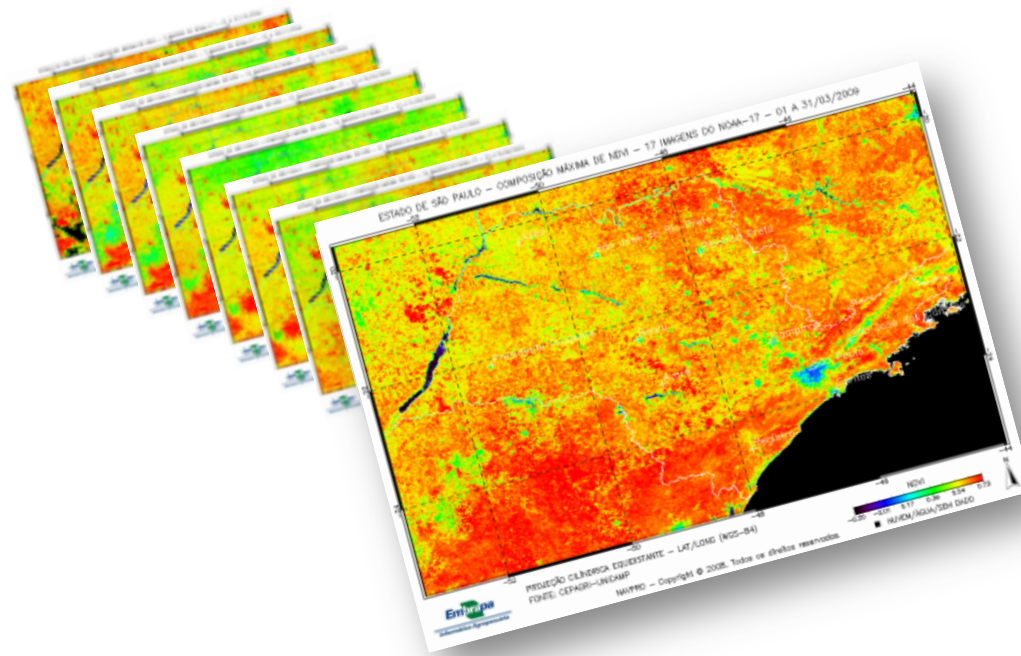


# Study Area



- SUGARCANE – São Paulo
- Source: CANASAT/INPE

# Material and Methods - NDVI data

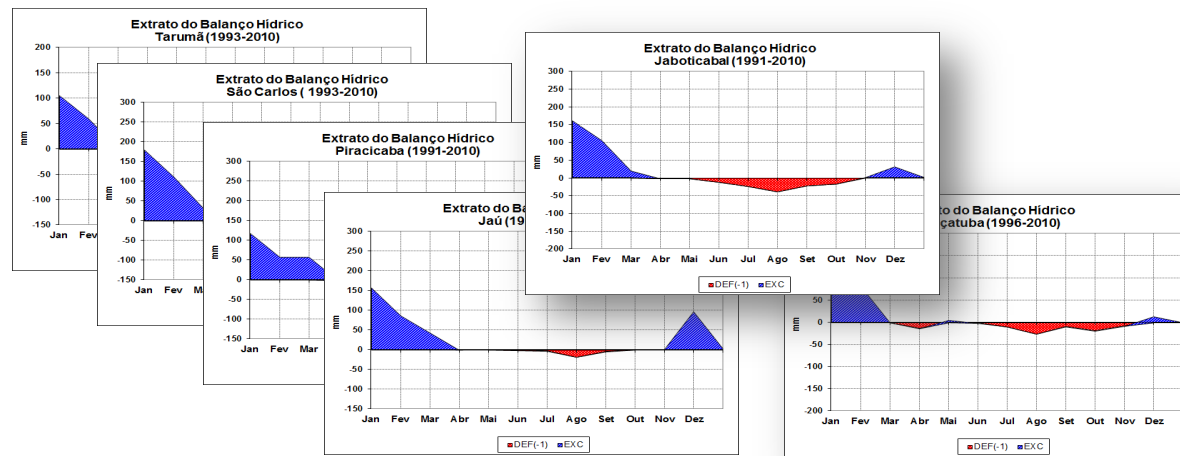


108 monthly NDVI/AVHRR images from April 2001 to March 2010  
(108 = 12 images/year \* 9 years)

Source: Database of Cepagri/Unicamp (daily raw data since April 1995)

Pre-processing: automatic radiometric and geometric corrections  
(Softwares SatImage and NavPro)

# Material and Methods - Agrometeorological Data

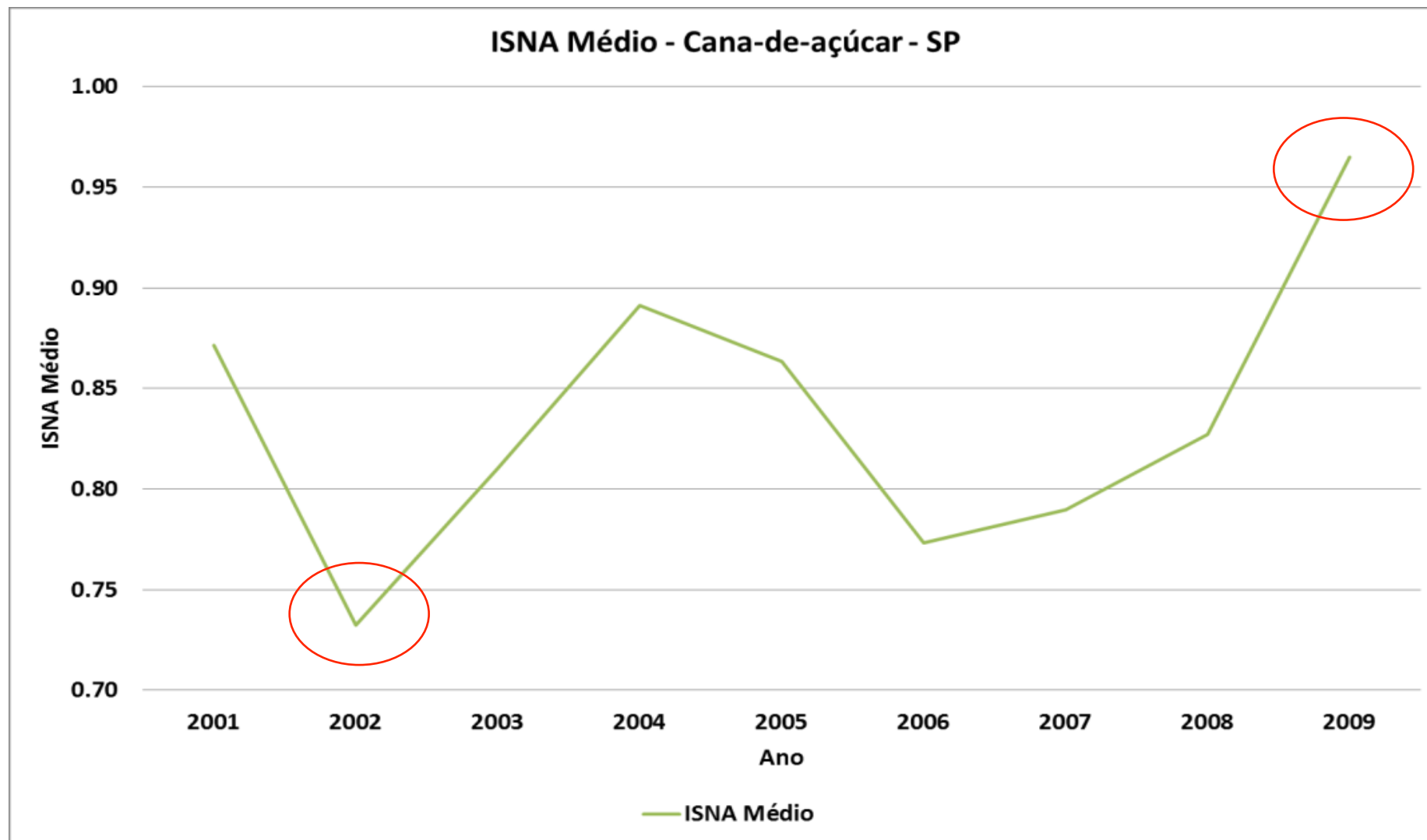


- Monthly Data of Temperature and Precipitation from April 2001 to March 2010

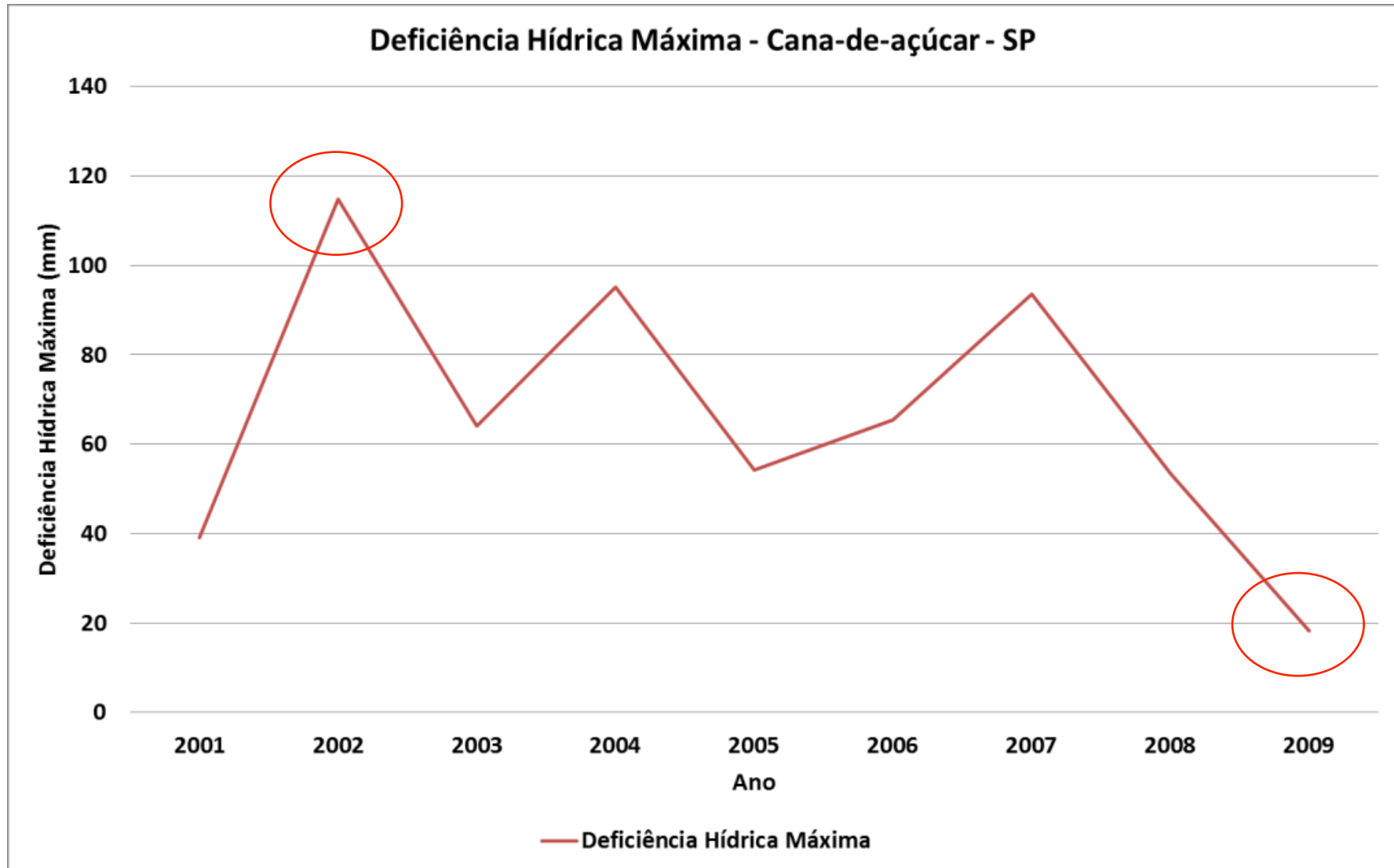
Source: TRMM (Tropical Rainfall Measuring Mission) 3B42 product from NASA (Goddard Earth Science - Distributed Active Archive and GES System)

-Water Balance Accounting - WRSI (Water Requirement Satisfaction Index =  $ET_{actual} / ET_{max}$ ), Moisture Deficit and Moisture Surplus (WRSI is an indicator of crop performance based on the availability of water during a growing season)

# Material and Methods - WRSI

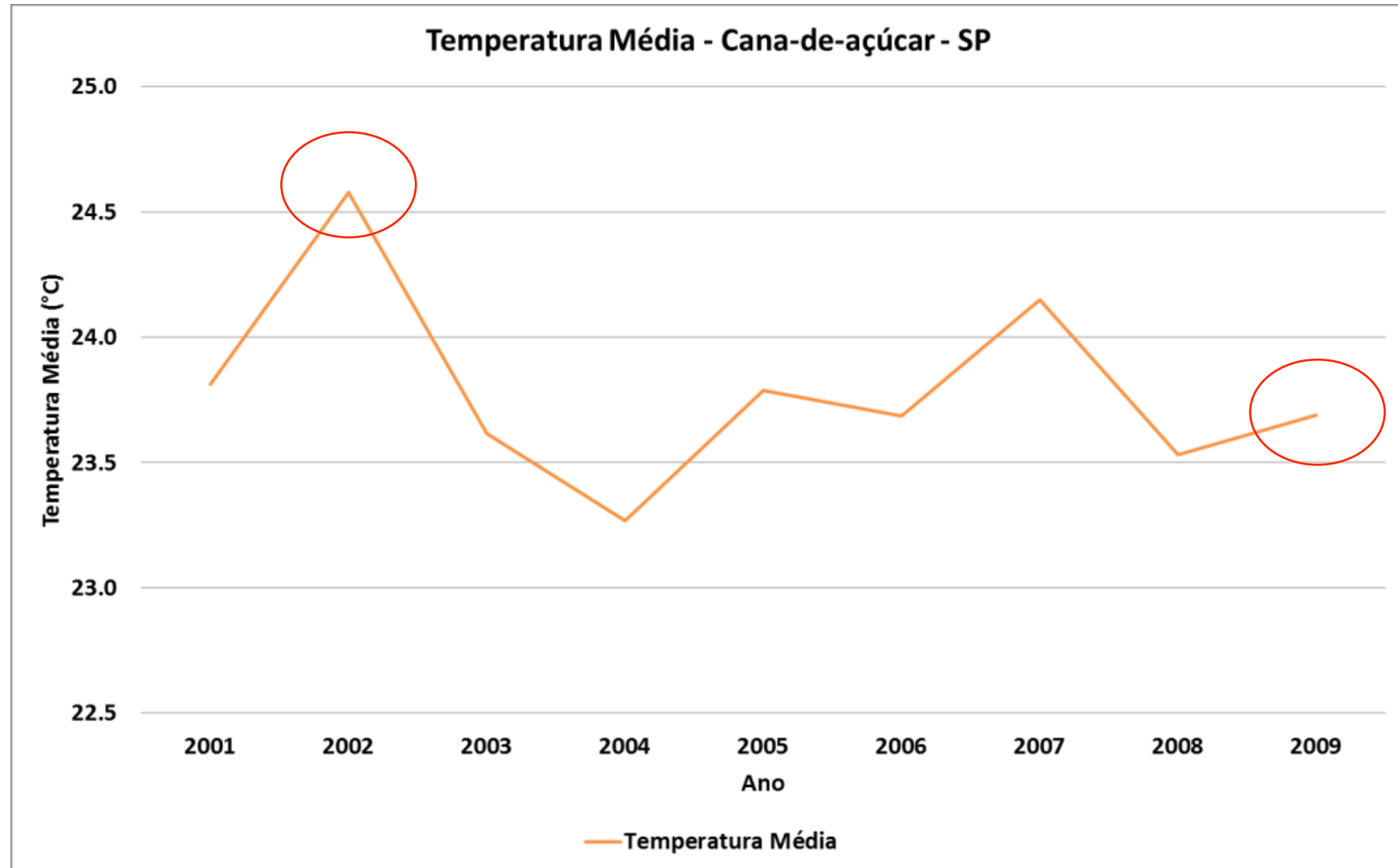


# Material and Methods - Moisture Deficit

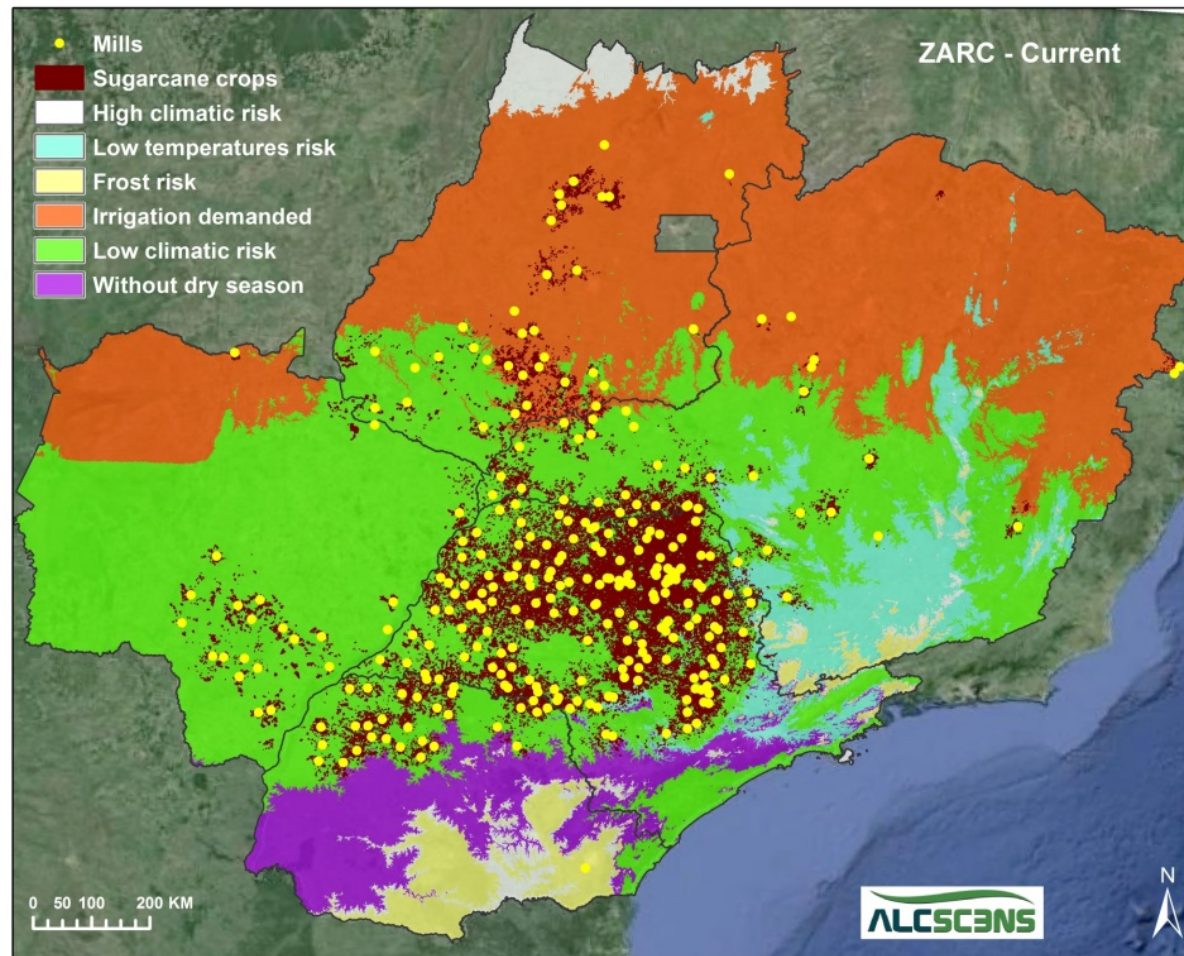




# Material and Methods - Average Temperature



# Material and Methods - Production Data



Area planted, Production and Yield of Sugarcane

Source: IBGE ([www.ibge.gov.br](http://www.ibge.gov.br)) – Brazilian Institute of Geography and Statistics

# Material and Methods

Original Data: NDVI, WRSI, Albedo, Moisture Surplus, Moisture Deficit, Precipitation, Surface and Air Temperature, Area Planted, Production and Yield of sugarcane

**Exploratory Data Analysis** – Selecting a reduced set of original variables

- Spearman Correlation - significance level of 0.95 (P-value <0.05) and
- Principal Component Analysis (PCA) – Analysis of interrelations among the original variables to explain them in terms of their common inherent dimensions.

Dependent variable (criterion): Sugarcane Production

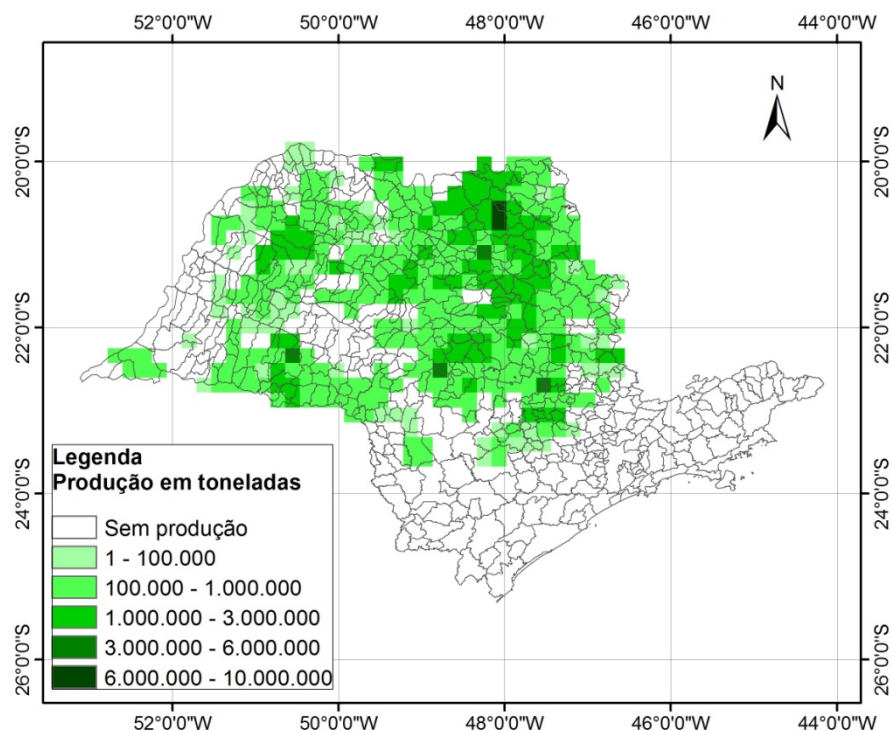
Independent variables (predictors): Area planted, NDVI and WRSI

Software: SiroSOM© software, Self-Organizing Maps, developed by CSIRO (Australian Commonwealth Scientific and Research Organization).

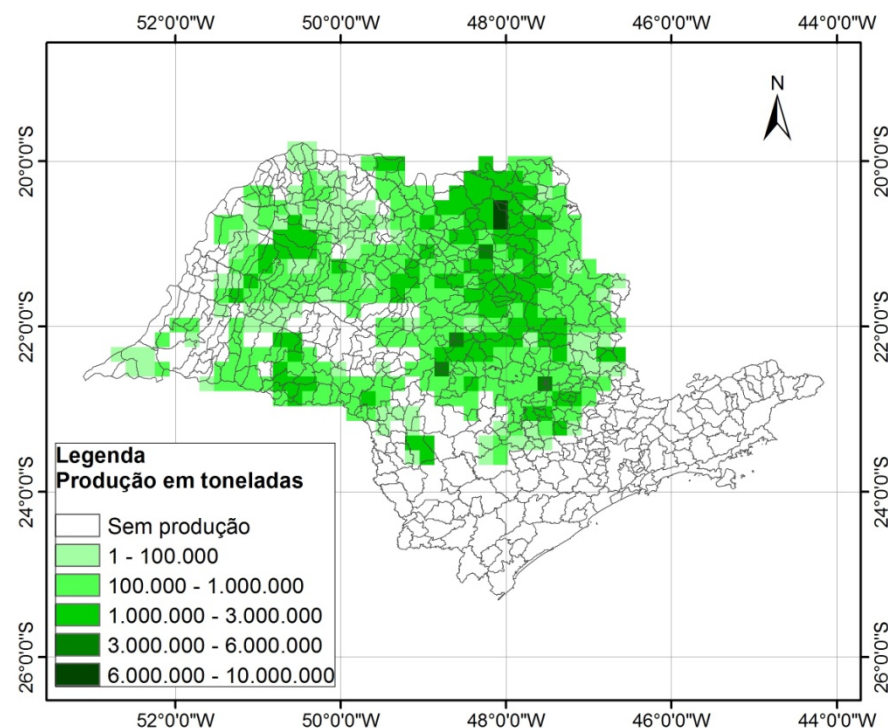
**Multiple Linear Regression**

# Results - Crop Season 2002/2001

Produção de cana-de-açúcar - Estimada - 2002



Produção de cana-de-açúcar - Observada - 2002

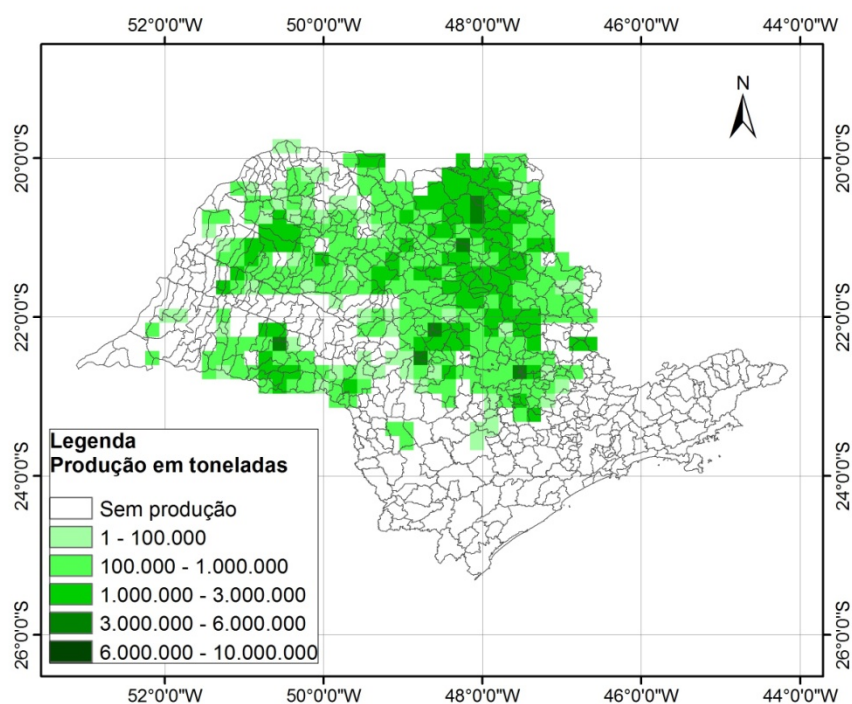


$$\text{Production}(2002) = 176,300 + 310,600 * \text{NDVI}(2001) + 78.32 * \text{Area}(2001) - 363,200 * \text{WRSI}(2001) \quad R^2 = 0.9602$$

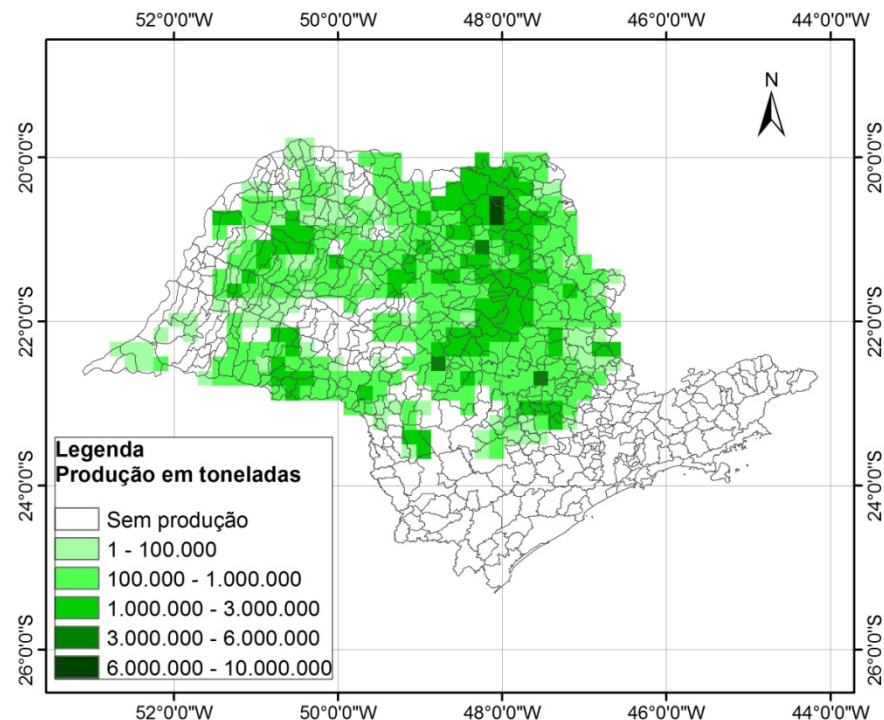
$R^2 = 0.9496$  – Estimated x Observed Values

# Results - Crop Season 2003/2002

Produção de cana-de-açúcar - Estimada - 2003



Produção de cana-de-açúcar - Observada - 2003



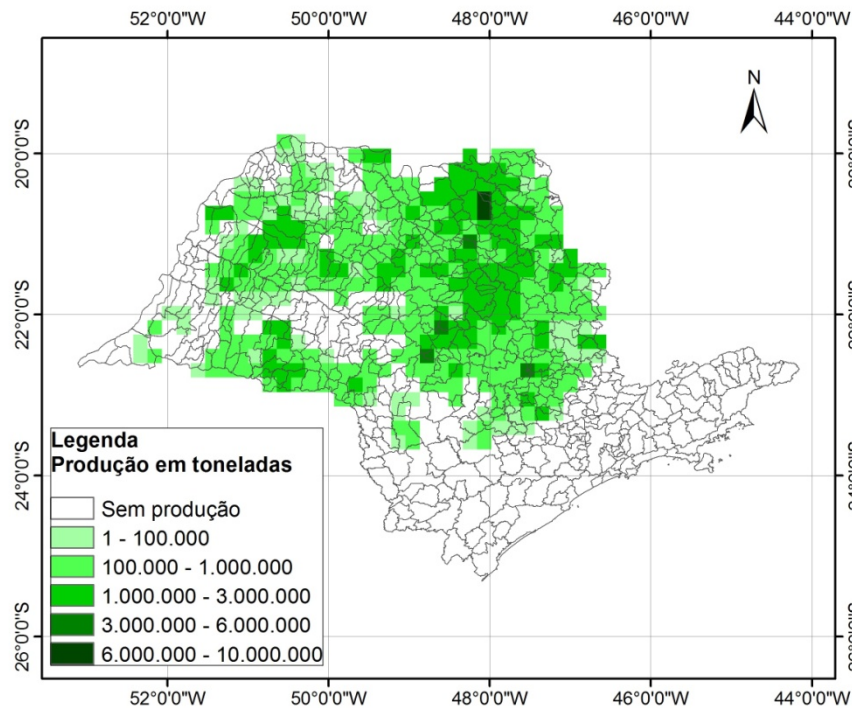
$$\text{Production}(2003) = -285,700 + 104,000 * \text{NDVI}(2002) + 90.40 * \text{Area}(2002) - 565,200 * \text{WRSI}(2002)$$

$$R^2 = 0.8682$$

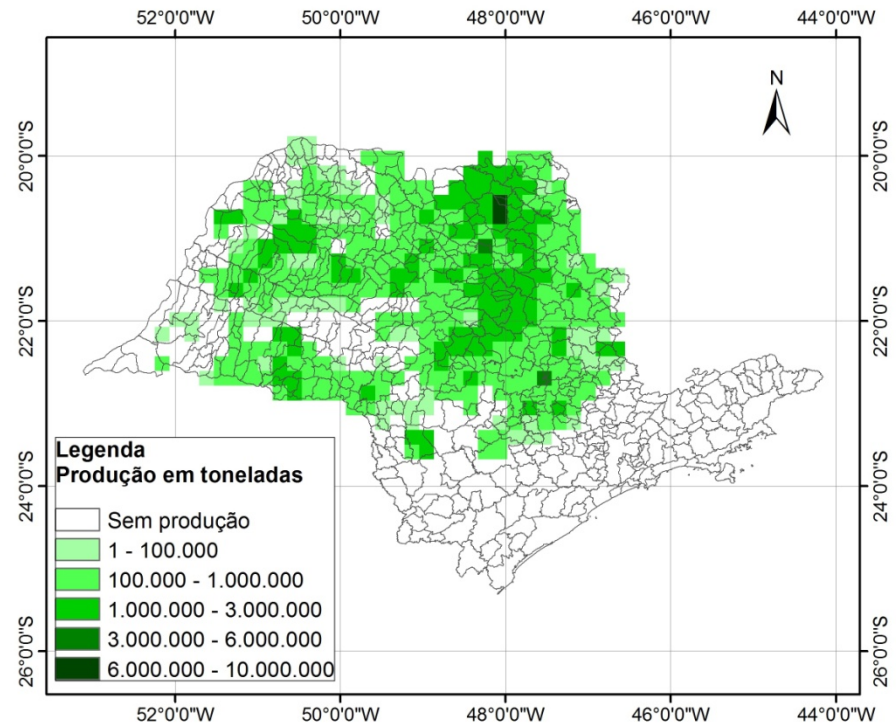
$$R^2 = 0.8706 - \text{Estimated x Observed Values}$$

# Results - Crop Season 2004/2003

Produção de cana-de-açúcar - Estimada - 2004



Produção de cana-de-açúcar - Observada - 2004

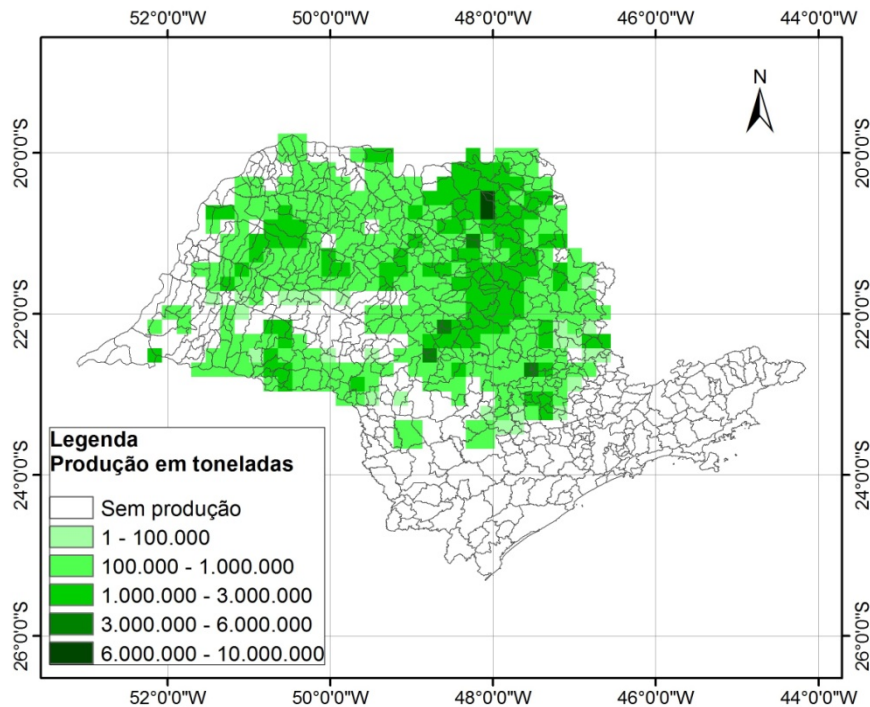


$$\text{Production}(2004) = -160,100 + 431,300 * \text{NDVI}(2003) + 83.36 * \text{Area}(2003) - 121,500 * \text{WRSI}(2003) \quad R^2 = 0.9770$$

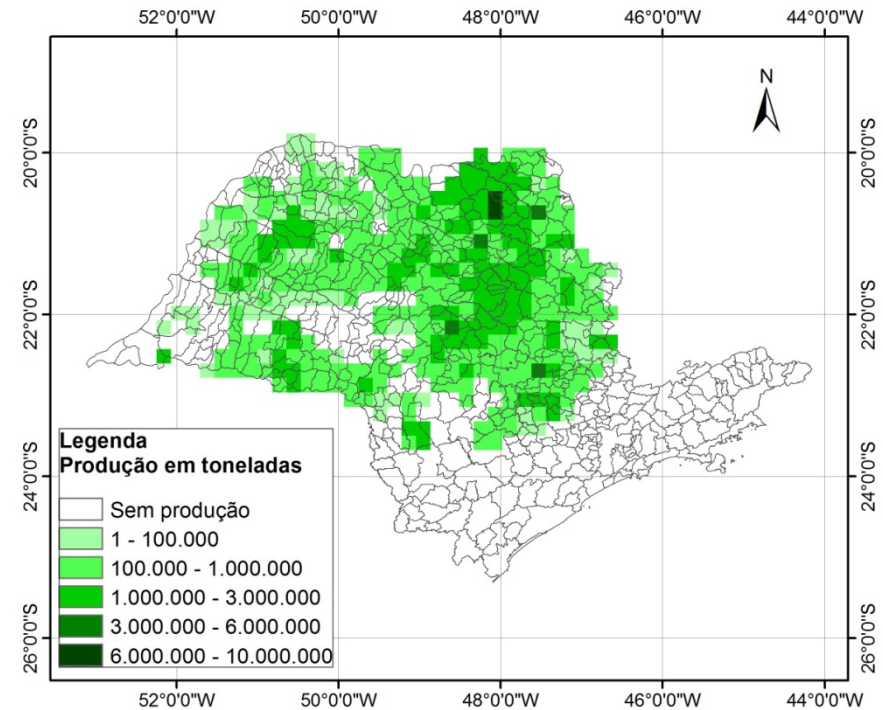
$R^2 = 0.9773$  – Estimated x Observed Values

# Results - Crop Season 2005/2004

Produção de cana-de-açúcar - Estimada - 2005



Produção de cana-de-açúcar - Observada - 2005



$$\text{Production}(2005) = 729,300 + 762,500 * \text{NDVI}(2004) + 83.57 * \text{Area}(2004) - 1,323,000 * \text{WRSI}(2004)$$

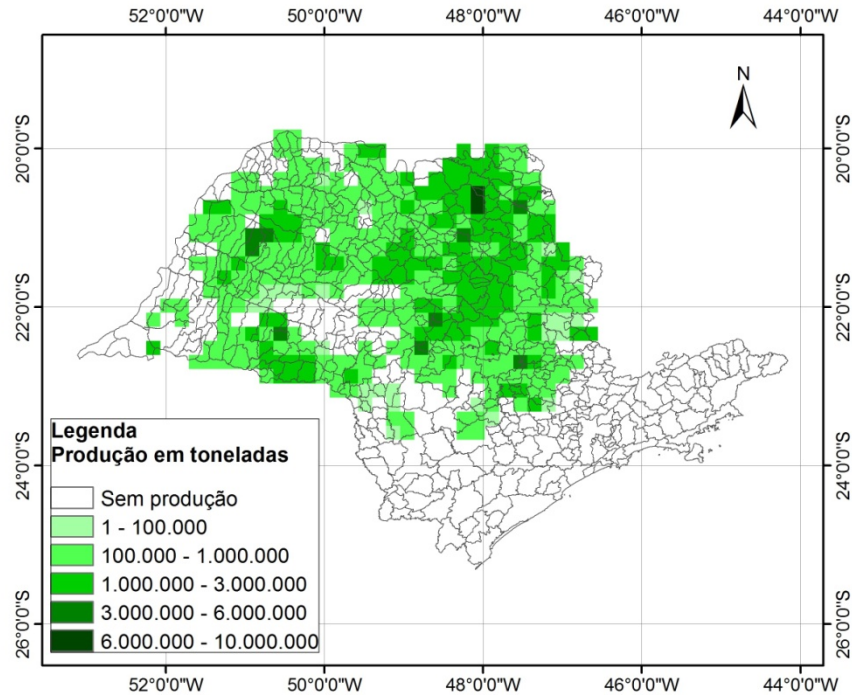
0.9643

$R^2 =$

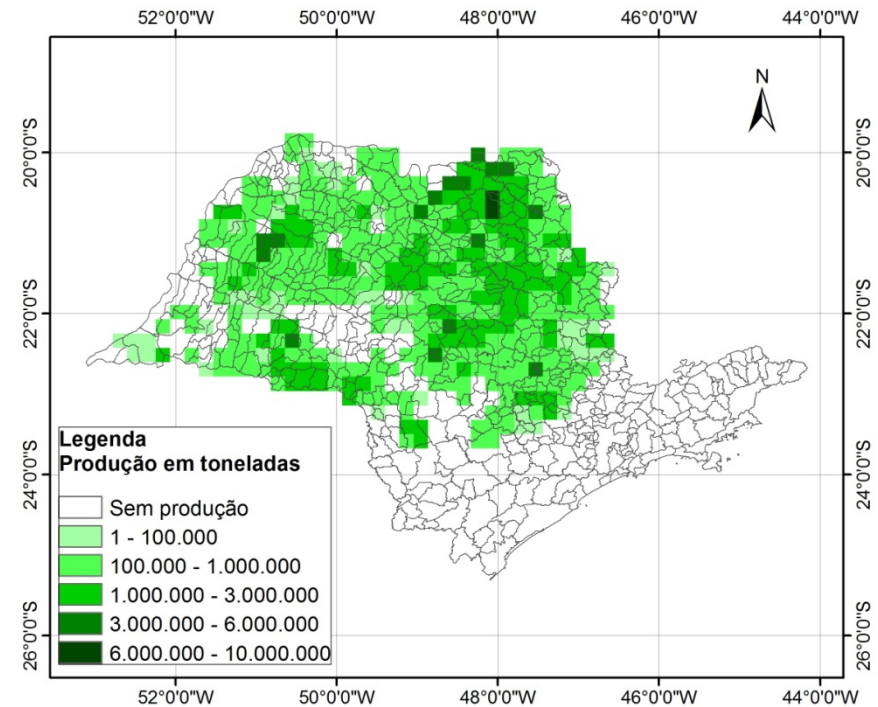
$R^2 = 0.9496$  – Estimated x Observed Values

# Results - Crop Season 2006/2005

Produção de cana-de-açúcar - Estimada - 2006



Produção de cana-de-açúcar - Observada - 2006



$$\text{Production}(2006) = 802,800 + 358,400 * \text{NDVI}(2005) + 86,36 * \text{Area}(2005) - 1,137,000 * \text{WRSI}(2005)$$

0.9412

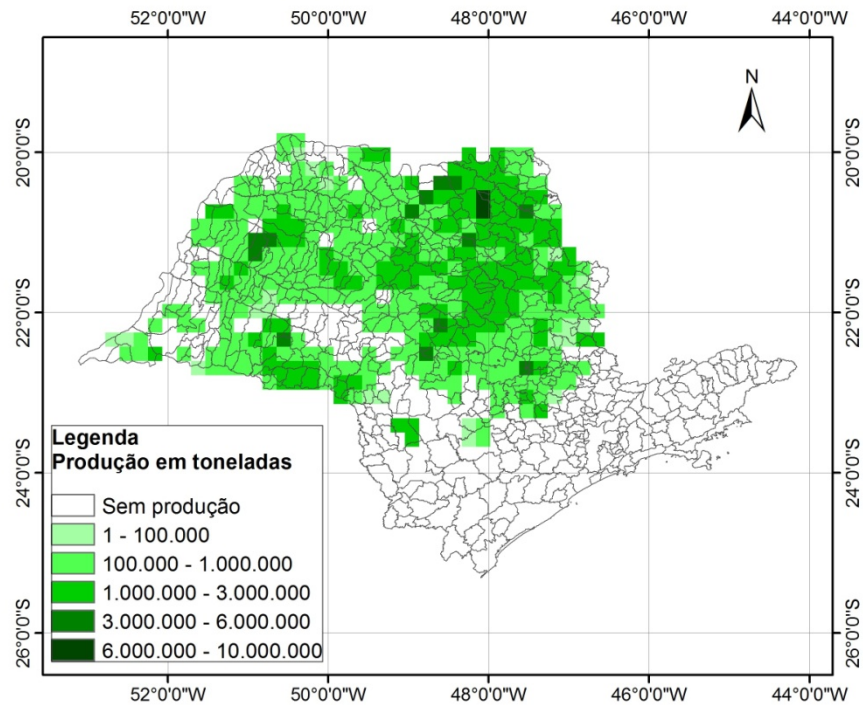
$R^2 =$

$R^2 = 0.9415$  – Estimated x Observed Values

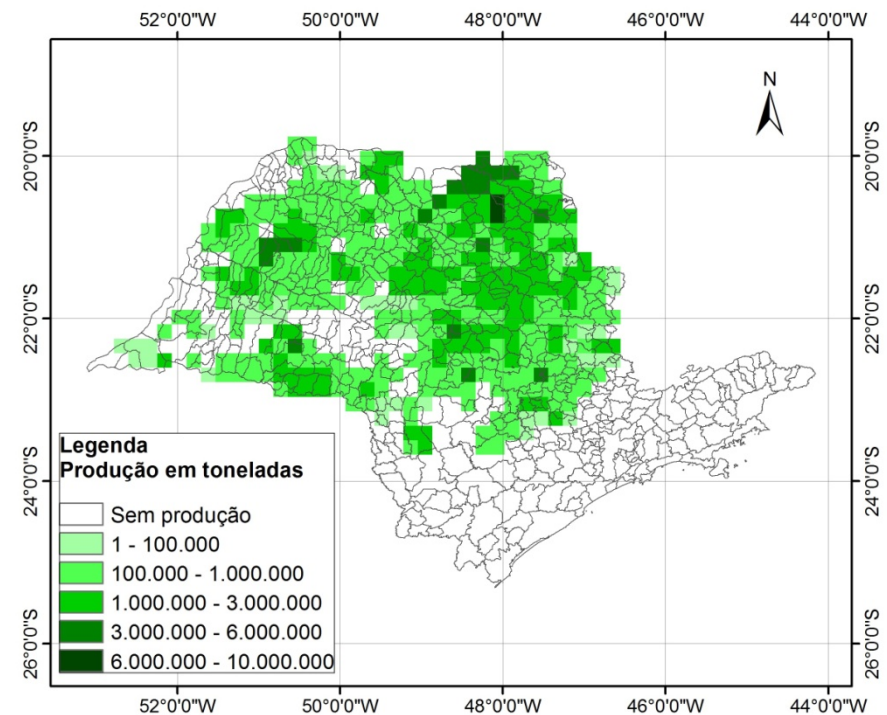


# Results - Crop Season 2007/2006

Produção de cana-de-açúcar - Estimada - 2007



Produção de cana-de-açúcar - Observada - 2007



$$\text{Production}(2007) = 1,045,000 + 347,200 * \text{NDVI}(2006) + 84.08 * \text{Area}(2006) - 1,516,000 * \text{WRSI}(2006)$$

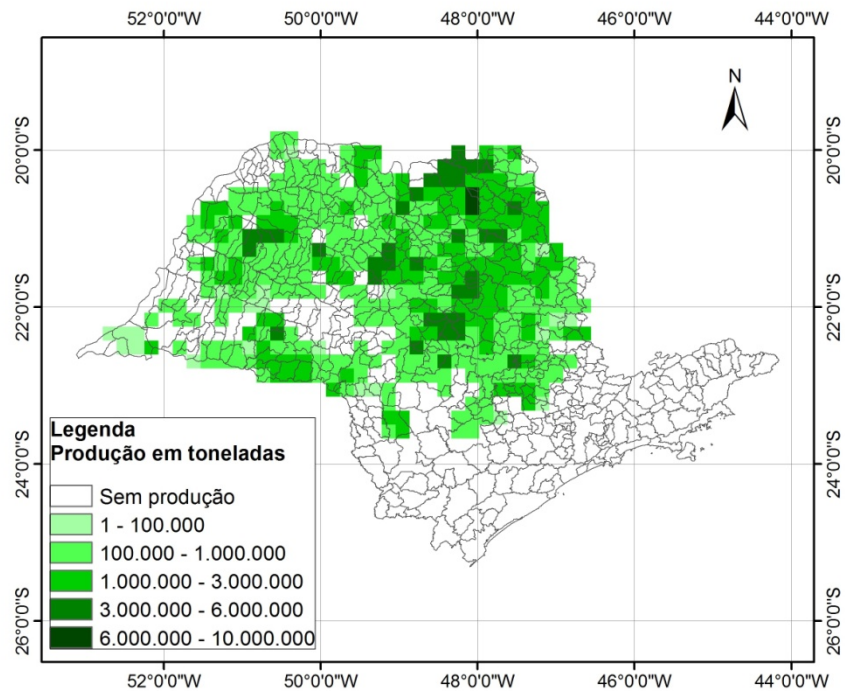
0.9024

$R^2 =$

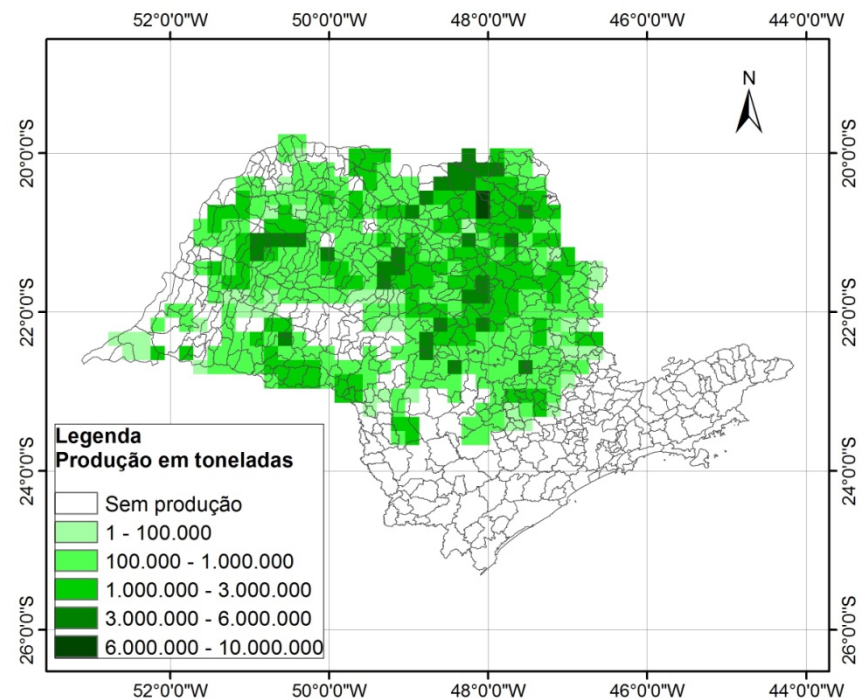
$R^2 = 0.9015$  – Estimated x Observed Values

# Results - Crop Season 2008/2007

Produção de cana-de-açúcar - Estimada - 2008



Produção de cana-de-açúcar - Observada - 2008

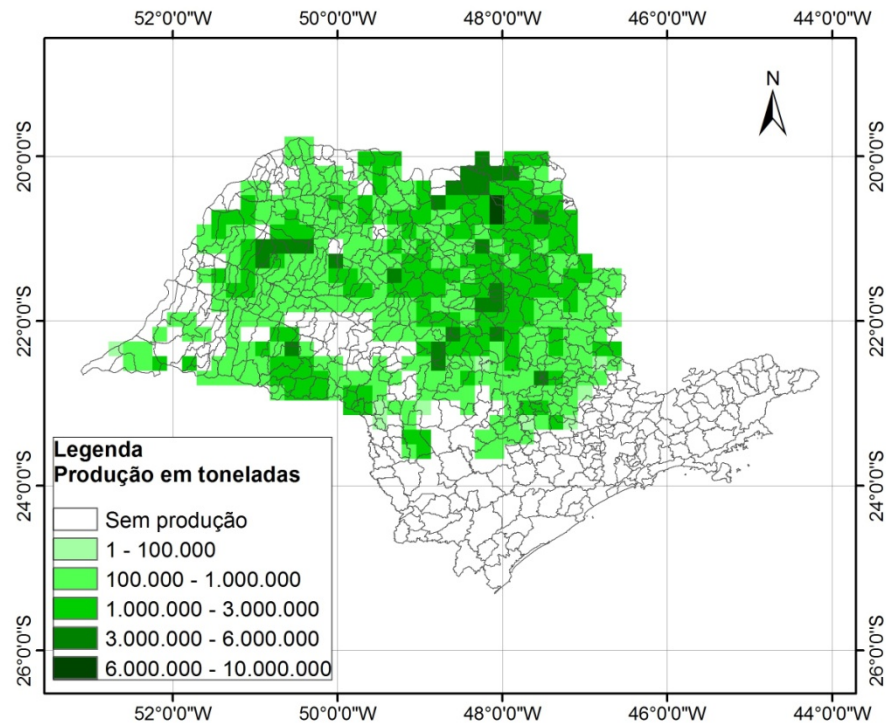


$$\text{Production}(2008) = 215,200 + 374,000 * \text{NDVI}(2007) + 94.99 * \text{Area}(2007) - 570,600 * \text{WRSI}(2007) \quad R^2 = 0.9237$$

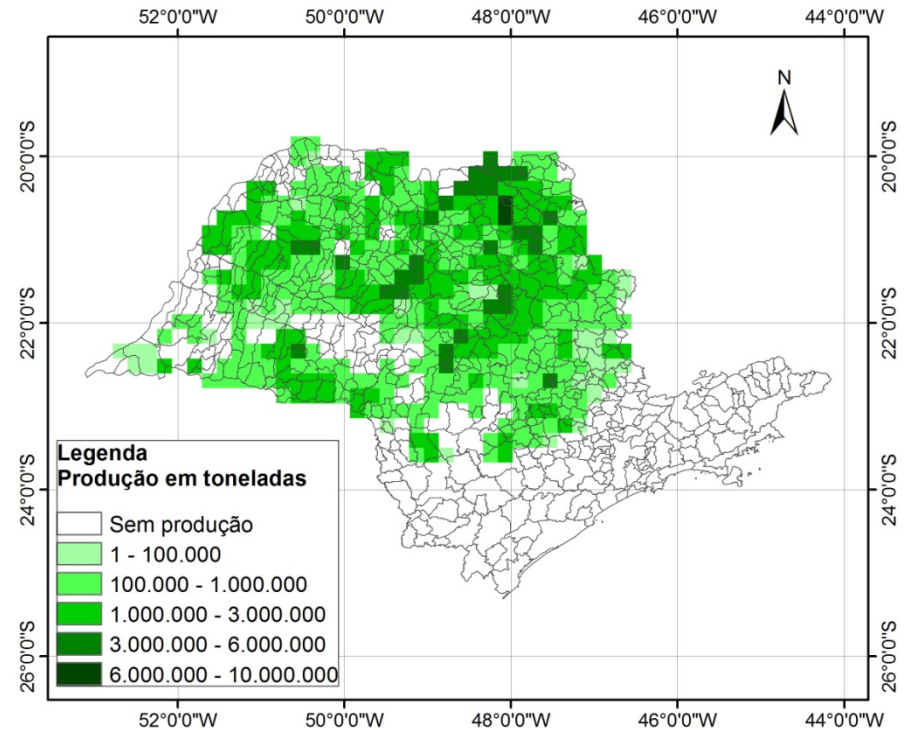
$R^2 = 0.9233$  – Estimated x Observed Values

# Results - Crop Season 2009/2008

Produção de cana-de-açúcar - Estimada - 2009



Produção de cana-de-açúcar - Observada - 2009



$$\text{Production}(2009) = 3,712 + 974,800 * \text{NDVI}(2008) + 77,05 * \text{Area}(2008) - 578,300 * \text{WRSI}(2008)$$

$$R^2 = 0,9027$$

$R^2 = 0.9028$  – Estimated x Observed Values

## Conclusions

It was possible to propose numeric models based on time series of NDVI, Area Planted and WRSI that can be applied to improve the operational monitoring of sugarcane production in São Paulo

Challenge: Adapt the models to GOES-R meteorological satellite

Other use: Impacts of climate change on the production of sugarcane

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