

English Version

Abstract

The expansion of the citrus crops in the State of São Paulo and particularly in Botucatu, associated to the progress of the techniques of environmental monitoring, as the remote sensing, were the decisive factors for the development of the present researches. The objective of this work was to evaluate the space-temporary alterations of the citrus crops in Botucatu-SP, in the period from 1962 to 2005, using geotechnology, such as: panchromatic aerial photographs of 1962, 1972 and 1977 and colored of 2000 and 2005, associated to the techniques of Remote Sensing and Geographic Information System - GIS. The obtained results allowed to conclude that the expansion of the citrus crops of Botucatu-SP had an increment of 3,41% and an expansion of 65,27% in the period of five years (2000 to 2005); that means an increase of 12722,56 ha. The aerial photography associated to SIG was efficient in the determination of the expansion citrus crops in Botucatu-SP.

Keywords: geographic information systems; remote sensing; geoprocessing

Expansion of citrus crops in Botucatu - SP, obtained by aerial photography¹

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Introduction

Citriculture has become an important activity in the national Agribusiness, mainly in the state of São Paulo. The municipality of Botucatu already presents great participation in this sector since their lands are still free from the major diseases which occur in this culture.

Brazil, since the decade of 1980, has become the largest world producer of oranges, having in the state of São Paulo, its largest production with approximately 70% of the boxes of oranges produced and 98% of the production of juice (HASSE, 1987). It is the second activity in terms of agro-economic importance of the state of São Paulo, moving 5 billion reais per year. Besides generating 400 thousand direct employments, moves the economy of 316 municipalities of São Paulo and approximately 15 municipalities of Minas Gerais, being for them the base of the local economy.

SILVA (2000) shows that according to data of the Secretaria da Agricultura e Abastecimento do Estado de São Paulo (Secretary of Agriculture and Food Supply for the State of São Paulo), orange occupied in that period an area of 737 thousand hectares, inferior only to sugarcane and pasture. It was 207 million threes, 15% in phase of formation,

indicating that the increase on the population should remain in the next years. It is estimated that the sector should generate more than 1 billion dollars of exportation and a collection for the state of São Paulo of US\$ 350 millions per year of Imposto sobre Circulação de Mercadorias e Serviços – ICMS (Taxes on Consumption of Goods and Services).

According to SPREEN et al. (2007), São Paulo and Flórida, together, are responsible for more than 80% of the world production of orange juice and than other productive regions, as Spain, Italy, Cuba, Argentina, Mexico and California, which do not have individually more than 5% of the world production.

Comparing to other cultures it can also be verified the economical importance of orange in the state. According to TSUNECHIRO et al. (2005), in the crop 03/04 orange for industry occupied the 3rd place in the value of production among the main products of the agriculture of São Paulo, being exceeded by sugarcane (1st), and by beef meat (2nd), being in front of poultry meat (4th), corn (5th), soybean (6th) and orange (7th) on the totality of the income with agriculture of São Paulo.

São Paulo in 1957 was already the larger producer of orange of the country, being its dynamism explained not only by favorable conditions of climate and soil, but, mostly, by the business attitude

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adopted by the citrus growers from São Paulo in the management of their business (ARANTES FILHO, 1989).

Climate and soil are aspects of the fundamental importance in the choice or a local of a region to implant a commercial production of citric fruit. According to MONTENEGRO (1991), the climate factors are more important than soil, since they can be easily corrected or less limiting than the climate problems, among which temperature would be the preponderant factor, in which we may observe that latitudes superior to 40° North or South and temperatures below -5 °C are generally limiting to planting. The main citrus growing region are placed between the parallels 20° and 40°, mainly due to the favorable effects of the temperature over the plant yield and over the fruit quality. The same author reports that citrus have extraordinary possibilities of adaptation to the different types of soil. He cites, though, that it is more preferable soils with predominance of clay and silica sufficiently provided with humus, fertile, well drained and deep.

The use of aerial photography has been of great importance, mainly due to the reduction of the time of field work and costs. For SILVA et al. (2007), the photointerpretation achieved the intended results, in the geotechnical mapping of the study area, from the evaluation of the simplest and most evident properties. The main function of the photointerpretation is not to substitute the field survey, but to provide subsidies to identify factors which facilitate the process of mapping. The photointerpretation of the field landscape indicate the elements linked to topography and soil, which may be evaluated under the watershed trough its morphometric characteristics.

For TEIXEIRA et al. (1992), geographic information is the data set whose meaning contain associations or relations of spatial nature. These data may be presented in a graphic (point, lines and polygons), numerical (number catalogs) or alphanumeric (combination of letters and numbers). A Geographic Information System (GIS) uses a computerized data base which contains spatial information (the aspects of the natural mean as relief, soil, climate, vegetation, Hydrography, etc and the social, economical and political aspects, which allow

a theme division in subsystems which integrate a GIS, being these compounds the attributes), over which a series of spatial operators act (set of algebraic, Boolean and geometric operations, used in the data cross-checking by GIS). It is based in a technology of storage, analysis and treatment of spatial, non-spatial and temporal data and in the generation of correlated information.

Each specialist deals with specific concepts of his discipline (social exclusion, fragments, mineral distribution). To use a GIS it is necessary that each one of them transform the concepts of their discipline in computer representation. After these translation, it becomes viable to share study data with other specialists (eventually of different disciplines). In other words, when one says space is a common language in the use of GIS, he is referring to the space computationally represented and not to the abstract concepts of geographic space (CÂMARA et al., 2004).

Thus, the objective of this work was to evaluate the space-temporal changes of the Citriculture in the municipality of Botucatu – SP, in the period from 1962 to 2005, using geotechnologies as: panchromatic aerial photography from 1962, 1972 and 1977 and colorful from 200 and 2005; together with techniques of Remote Sensing and Geographic Information System.

Material and methods

The municipality of Botucatu (Figure 1) presents an area of 148300 ha, being located geographically between the coordinates: latitude 22° 35' to 23° 06' S and longitude 48° 12' to 48° 52' WGr. The soils of the region prescribed by OLIVEIRA et al. (1990) were: LVA (Latosolos Vermelho – Amarelos), NV (Nitossolos Vermelhos), PVA (Argissolos Vermelho-Amarelos)¹.

The predominant climate in the municipality of Botucatu is according to the Köpen system Cfa – temperate rainy climate and the predominant Wind direction is Southeast (SE). The average annual temperature, in the region, is 20.2 °C, considering that the average temperature of the hottest months

¹ Brazilian soil classification

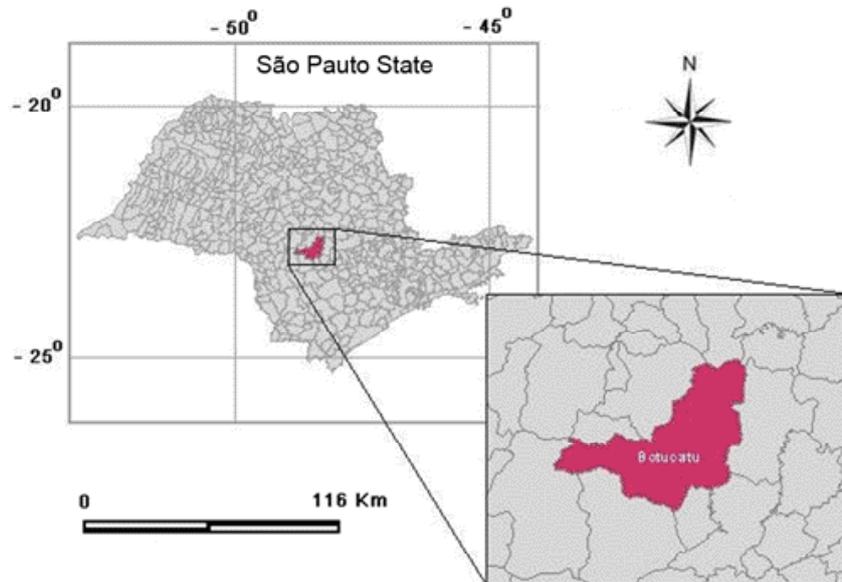


Figure 1. Localization of the municipality of Botucatu – SP.

is 23.2 °C and 16.9 °C in the coldest (MARTINS, 1989). The annual rainfall is approximately 1447 mm, with an average of 223.4 mm in the rainiest month and 37.8 mm in the driest.

In the development of the work it was used a notebook HP with processor AMD Turion™ X2 Ultra Dual Core; 3.0 GB of RAM memory; winchester of 250 GB; with operational system Windows Vista.

To the entrance of the information, referent to the limit and the citrus growth area of the municipality of Botucatu it was used the scanner of the printer HP Photosmart C4480.

The Geographic Information System Idrisi 15.0 Andes was used in the processing of the georeferenced information and in the conversion of the vector data in raster, while the applicative CartaLinx 1.2 was used in the vectorization of the limit of the municipality obtained trough the Planialtimetric Maps and of the citric growth areas obtained from panchromatic and colorful aerial photography. The limit of the area of the municipality of Botucatu (SP) was obtained from the Planialtimetric Maps from IBGE, being later vectorized in the CartaLinx and exported to SIG-Idrisi Andes 15.0.

It was used as cartographic base, the Brazilian

Maps: Pratânia, SF-22-Z-B-V-4; Rio Palmital, SF-22-Z-B-V-3; Botucatu, SF-22-R-IV-3; Itatinga, SF-22-Z-D-II-2; Barra Bonita, SF-22-Z-B-VI-1; Santa Maria da Serra, SF-22-Z-B-VI-2; Pardinho, SF-22-X-II-I; Anhembi, SF-22-R-IV-4; São Manuel, SF-22-Z-B-V-2, in scale 1:50000, edited in 1969 1970, 1973 and 1974 by IBGE with equidistance of 20 meters as cartographic support, covering the municipality of Botucatu.

In order to obtain the map of the citrus growth areas of the municipality of Botucatu it was used panchromatic vertical aerial photography coming from the aerophotogrametric coverage of the state of São Paulo, performed in 1962 and 1972 with approximate nominal scale of 1:25000 and 1977 with scale 1:45000, as well as colorful aerial photography, performed in 2000 and 2005, with approximated nominal scale 1:30000, with longitudinal coverage of approximately 60% and 30% in the lateral.

The stereoscopic observation of the pairs of vertical aerial photography was performed with aid of a mirror stereoscope brand WILD, model ST-4 and the transference of the elements of interest was modeled with help of Aerosketchmaster CARL ZEISS, YENA.

The maps of land occupation of the watershed of the river Lavapés were obtained, having as

cartographic support the Carta do Brasil (1969), in scale 1:50000, edited by IBGE - Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics). The mapping and the identification of the soil units were obtained by the Carta de Solos do Estado de São Paulo (Soil Map of the State of São Paulo), in the scale 1:500000, edited by Comissão de Solos (1960).

In order to obtain the map of the citrus growth areas in 1962, 1972, 1977, 2000 e 2005, initially, it was made a montage with all the set of vertical aerial photography corresponding to the area of the Municipality of Botucatu in order to have a general view of it, being later traced the flight line and the delimitation of the effective area, according to COELHO (1972). After that, with aid of the stereoscopy, it was traced in a polyester film Terkron D -50 microns, the areas of the vegetal covers, object of study.

In the identification of the vegetal covers, it was followed the general and agricultural criterions of photointerpretation described by RICCI and Petri (1965), MARCHETTI and GARCIA (1977) and PIEDADE (1983).

The map of the citrus growth area obtained in a polyester film Terkron D-50 microns was scanned to be georeferenced in the SIG-Idrisi. Later, the georeferenced file was vectorized in CartaLinx and

exported to SIG-Idrisi to conversion of the vector file to raster.

Result and discussion

The citric growth occupation in the municipality of Botucatu in the years of 1962, 1972 and 1977, analyzed trough aerial photography presented an area of 78.55 ha, periods in which this kind of culture was not cultivated to commercial purpose but to the internal consumption. These areas were distributed in several parts of the municipality of Botucatu, which may be seen in the aerial photography from 2000 and 2005, in which they were substituted for pasture.

It can be emphasized that in this period the regional citriculture expansion was already beginning, but not in Botucatu; it was beginning in Fazenda Morrinhos, municipality of Itatinga, one of the pioneers in the region, being this citric growth activity initiated approximately in the decade of 70.

The municipality of Botucatu in 2000 (Figure 2) presented a citric growth area of 7745.48 ha, area which increased, as it can be verified in the aerial photography of 2005. It can be observed that there was more concentration of the citric growth areas in the Northeast region of the municipality, next to the dam Barra Bonita and other fragmented Southwest areas (Figure 2). It should be emphasized that in this year the citricultural areas of the Fazenda

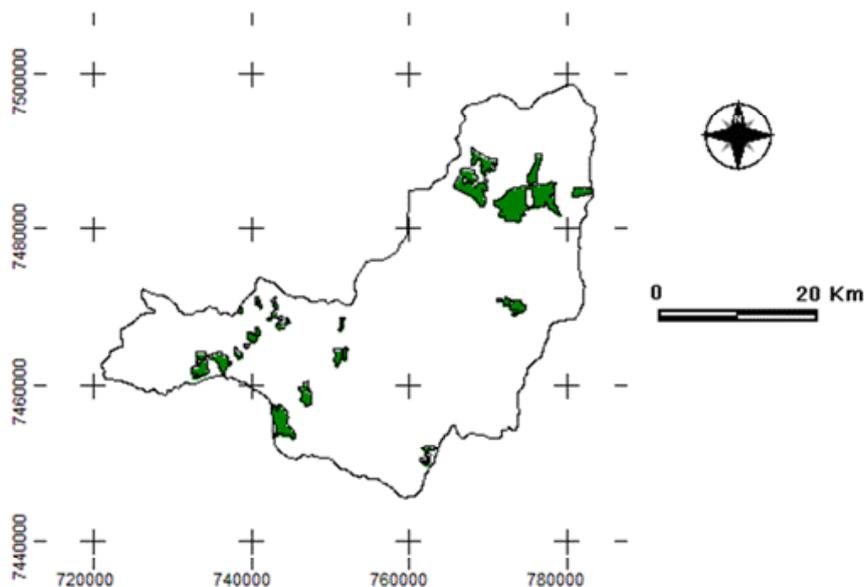


Figure 2. Citrus area of the municipality of Botucatu – SP, in 2000.

Morrinhos had already expanded to the municipality of Botucatu.

The municipality of Botucatu, in 2005 (Figure 3), presented a citrus area of 12801.01 ha, considering that these areas which expanded were occupied in the year 2000 by pasture in a predominant way, campo sujo¹, soils prepared to agriculture and eucalyptus, according to which was verified in the aerial photography of the referred year.

This expansion may be verified in area and production, thanks to the organization of the productive chain of the fruit, domain of the technology and production and, mainly, by the condition of being an agricultural alternative in substitution to the pasture areas.

It can be noted that the citrus expansion still prevailed in the Northeast area of the municipality, with great expansion in the region close to Barra

Bonita and also in the Southeast (Figure 3).

The area occupied by citrus in the municipality of Botucatu in 2000 represented 5.22%, and it occupied 8.63% in 2005, representing an increase of 3.41% in the total studied area and an expansion of 65.27% if the citrus growth area in the period (Table 1). This increase results from the citrus expansion in the state of São Paulo, since the municipality of Botucatu is an area where citriculture presents great adaptation, in function of the climate unfavorable to the development of citrus diseases as Citrus Variegated Chlorosis - CVC, which are adapted to hot and dry weather. CVC is a disease caused by the bacteria *Xylella fastidiosa* which, after installed in the plant, multiplies and obstructs the vases of ksilema, responsible for taking water and nutrients from root to shoot. The obstruction causes typical symptoms, among them the reduction of the size of the fruit, and may make it inappropriate for consumption (MELO and ANDRADE, 2006).

¹ Type of cerrado

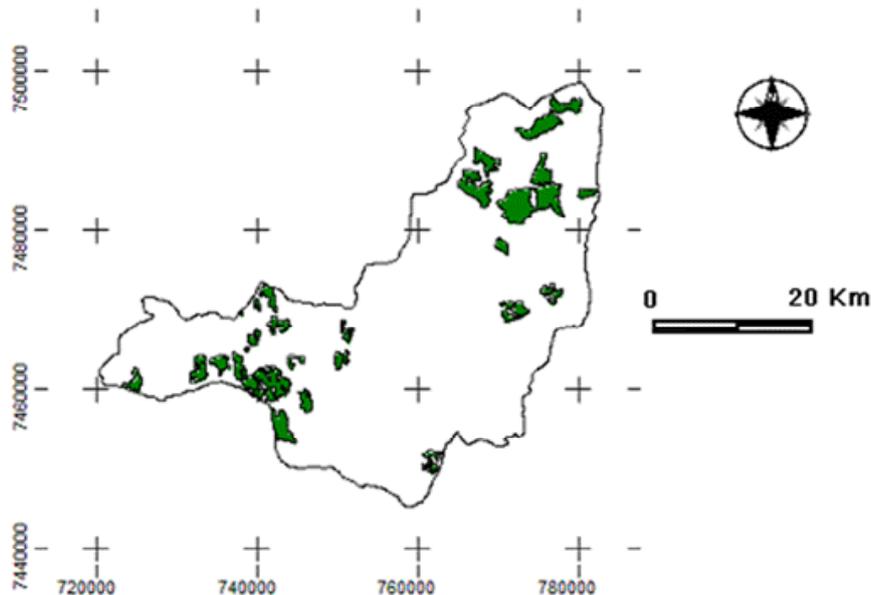


Figure 3. Citrus area of the municipality of Botucatu – SP, in 2005.

Table 1. Citric expansion in the municipality of Botucatu – SP, in the period of 5 years.

Area occupied by citrus in the municipality (%)		Increase (%)	
2000	2005	Municipality	Citrus area
5.22	8.63	3.41	65.27

The municipality of Botucatu has not been occupied in a predominant way by citrus, since the soil occupation in the region is performed by several cultures as sugarcane, eucalyptus, pasture, native vegetation, campos sujos, exposed soil and soil prepared to agricultural activities (Figures 4 and 5).

and an expansion of 65.27% of the citrus area in the period of five years (2000 to 2005) and an increase of 12722.56 ha from 1962 to 2005.

The aerial photograph associated to GIS was an indispensable tool in the determination of the citrus expansion in the municipality of Botucatu – SP.

Conclusion

Citriculture in the municipality of Botucatu – SP suffered an increase of 3.41% in the total studied area

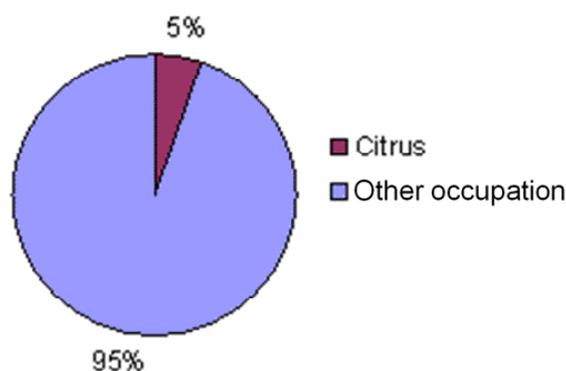


Figure 4. Citrus area of the municipality of Botucatu – SP, in 2000.

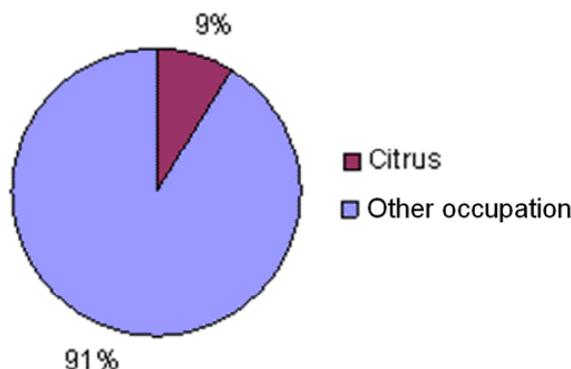


Figure 5. Citrus area of the municipality of Botucatu – SP, in 2005.

References

- ARANTES FILHO, A.G. Perspectiva de exportação de suco cítrico. **Revista Laranja**, Cordeirópolis, p. 45-70, 1989.
- BASE AEROFOTOGRAMETRIA E PROJETOS S/A. **Fotografias Aéreas Verticais Pancromáticas**. São Paulo, 1962. 1. Fotografia, 23,5 cm x 23,5 cm. Escala 1:25000.
- BASE AEROFOTOGRAMETRIA E PROJETOS S/A. **Fotografias Aéreas Verticais Pancromáticas**.

- São Paulo,1972. 1.Fotografia, 23,5 cm x 23,5 cm.Escala 1:25000.
- BASE AEROFOTOGRAMETRIA E PROJETOS S/A. **Fotografias Aéreas Verticais Pancromáticas.** São Paulo,1977. 1.Fotografia, 23,5 cm x 23,5 cm.Escala 1:45000.
- BASE AEROFOTOGRAMETRIA E PROJETOS S/A. **Fotografias Aéreas Verticais Coloridas.** São Paulo,2000. 1.Fotografia, 23,5 cm x 23,5 cm.Escala 1:30000.
- BASE AEROFOTOGRAMETRIA E PROJETOS S/A. **Fotografias Aéreas Verticais Coloridas.** São Paulo,2005. 1.Fotografia, 23,5 cm x 23,5 cm.Escala 1:30000.
- CÂMARA, G. et al. **Análise espacial de dados geográficos.** Brasília: EMBRAPA, 2004. 209 p.
- COELHO, A. G. de. Obtenção de dados quantitativos de fotografias aéreas verticais. **Rev. Aerofotogrametria,** São Paulo, v. 8, n. 1, p. 1-23, 1972.
- COMISSÃO DE SOLOS (CNEPA). Levantamento de reconhecimento dos solos do estado de São Paulo. **Bol. Cent. Nac. Ens. Pesq. Agron.** Rio de Janeiro, v. 22, p. 634, 1960.
- EASTMAN, J. R. Idrisi Andes: guide to GIS and image processing. Worcester: Clark University, 2008. 328p. Manual Version 15.0.
- HASSE, G. A. **Laranja no Brasil 1500 - 1987.** São Paulo: Duprat & Iobe Propaganda, 1987, 296 p.
- HAGAN, J.E.; EASTMAN, J. R.; AUBLE, J. **Cartalinx:** the spatial data builder. Worcester: Clark University, 1998. 197p. Manual Version 5.0.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Carta do Brasil:** quadrícula de Botucatu. Folha: Botucatu, SF-22-Z-B-V-4. Rio de Janeiro, 1969.1 mapa. Escala 1:50000.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Carta do Brasil:** quadrícula Rio Palmital. Folha: Rio Palmital, SF-22-Z-B-V-3. Rio de Janeiro, 1968.1 mapa. Escala 1:50000.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Carta do Brasil:** quadrícula de Itatinga. Folha: Itatinga, SF-22-Z-D-II-2. Rio de Janeiro, 1970.1 mapa. Escala 1:50000.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Carta do Brasil:** quadrícula de Barra Bonita. Folha: Barra Bonita, SF-22-Z-B-VI-I. Rio de Janeiro, 1970.1 mapa. Escala 1:50000.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Carta do Brasil:** quadrícula de Santa Maria da Serra. Folha: Santa Maria da Serra, SF-22-Z-B-VI-2. Rio de Janeiro, 1973.1 mapa. Escala 1:50000.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Carta do Brasil:** quadrícula de Pardinho. Folha: Pardinho, SF-22-X-II-I. Rio de Janeiro, 1973.1 mapa. Escala 1:50000.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Carta do Brasil:** quadrícula de Anhembi. Folha: Anhembi, SF-22-R-IV-4. Rio de Janeiro, 1974.1 mapa. Escala 1:50000.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Carta do Brasil:** quadrícula de São Manuel. Folha: São Manuel, SF-22-Z-B-V-2. Rio de Janeiro, 1974.1 mapa. Escala 1:50000.
- MARCHETTI, D. A.B., GARCIA, G.J. **Princípios de fotogrametria e fotointerpretação.** São Paulo: Nobel, 1977. 257p.
- MARTINS, D. Clima da região de Botucatu. In: ENCONTRO DE ESTUDOS SOBRE A AGROPECUÁRIA NA REGIÃO DE BOTUCATU, 1., 1989, Botucatu. **Anais...** Botucatu: UNESP, 1989. p. 8-19.
- MELO, M. B.; ANDRADE, L. N. T. Principais doenças da citricultura em Sergipe e seu controle. In: MELO, M. B.; SILVA, L. M. S. **Aspectos técnicos dos citros em Sergipe.** Aracaju: EMBRAPA Tabuleiros

Costeiros; Deagro, 2006. p. 71-84.

MONTENEGRO, H. W. S. Clima e Solo. In : RODRIGUEZ, O.; VIÉGAS, F.; POMPEU Jr., J.; AMARO, A. A. (Orgs). **Citricultura brasileira**. Campinas: Fundação Cargill, 1991. p. 227-239.

OLIVEIRA, J. B de. **Solos do Estado de São Paulo**: descrição das classes registradas no mapa pedológico. Campinas: IAC, 1999. 108 p. (Boletim científico, n. 45).

PIEIDADE, G.C.R. **Noções de fotogrametria e fotointerpretação**. Botucatu: Faculdade de Ciências Agrônômicas, 1983. 44p. (Apostila)

RICCI, M., PETRI, S. **Princípios de aerofotogrametria e interpretação geológica**. São Paulo: Cia Editora Nacional, 1965. 226p.

SILVA, C. P. L.; SILVA, C. A.; SILVA, J. P.; SOUZA, N. M.; ARCAYA, S. G. C. emprego de fotografias aéreas e modelo digital de terreno no mapeamento geotécnico da área de proteção ambiental do Rio São Bartolomeu - DF. In: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 13., 2007, Florianópolis. **Anais...** São Paulo: INPE, SELPER, 2007. p. 1353 - 1360.

SILVA, J. G. et al. A reestruturação do complexo citrícola: de oligopólio competitivo ao oligopólio concentrado. **A crise do complexo citrícola paulista**: uma proposta não excludente. São Paulo: Secretaria Agrária do PT. 2000.

SPREEN, T. H.; BROWN, M. G.; MURARO, R. P. The project impact of citrus greening in São Paulo and Florida on processed orange production and price. **Proceedings of The Florida State Horticultural Society**, Florida, v. 120, p. 132-135, 2007.

TEIXEIRA, A. L. A.; MORETTI, E.; CHRISTOFOLETTI, A. **Introdução aos sistemas de informação geográfica**. Rio Claro: O autor, 1992. 79 p.

TSUNECHIRO, A. et al. Valor da produção agropecuária do estado de São Paulo em 2004. **Informações Econômicas**, São Paulo, v. 35, n. 4, p. 61-71, 2005. Série Apta.