

## Physical conservation surveying in Lavapes River basin, Botucatu, sp

C. Sérgio<sup>1</sup>, X.B. Zacarias<sup>1</sup>, G.C. Lincoln<sup>1</sup>,  
L.R. Fernanda <sup>1</sup> and A.A.J. Armino<sup>1</sup>

<sup>1</sup>Departamento de Engenharia Rural – FCA/UNESP – CP – 237 - CEP – 18603-970, Botucatu, SP.

### Abstract

The aim of this research was to elaborate the physical conservation survey of the basin of the Lavapés River, Botucatu, São Paulo, Brazil, for the rational soil occupation based on the «Ruggedness number». The following conclusions showed that the degree of the environmental physical deterioration for the basin was of 69.46%. The high values of the determination degree was probably due to the inappropriate use of the land which caused silting of the reservoirs and the creek sedimentation. The average Ruggedness number for the basin of Lavapés River allowed its classification for agricultural, cattle-raising and reforest, with the principal vocation for the cattle-raising use (Class B). The images of the Sensor TM LANDSAT 5 allowed a quickly mapping of soil use of the basin, and provided a database for future planning. The parameter and the ruggedness number allowed to classify the basin as 5, 8 and 9 with vocation for agriculture (Class A); basins 1, 6, 9 and 10 for cattle-raising (Class B); basins 2, 4 and 7 for cattle-raising and reforest (Class C) and basin 3 for forestry and reforest (Class D).

**Keywords:** ruggedness number, soil occupation, physical conservation surveying.

### Introduction

The planning of the use of the land is one of the most important research in the handling of water basins, once understood the existing areas of conflict as handling units (11).

The information of environmental deterioration, caused by the uncontrolled use of natural resources,

can be obtained through a survey of the ground's use, which according to Rocha (10) consists on a completed mapping of the edaphoclimatic conditions, quantitative evaluation of the vegetal covering and other existing elements on the studied region, which must be used with adequate symbols with the aim of

facilitating the identification.

The integrated handling of water basins is for Rocha (11) an educative and corrective proposal to recoup the damaged environment, suggesting the most viable alternatives for the protection and preservation of nature and to improve the quality of life of human beings and of the communities allowing thus, the use of more rational natural resources with a scientific foundation.

The mapping of a water basin or sub-basin of a district or city, allows

to do a planning research of rural and urban activities, with determination of the use of the ground, indicating as the most propitious areas the agricultural, cattle or forest exploration, forecast of harvest and urban planning (8).

This research was done with the aim of elaborating a physical conservation survey of Lavapés, river basin, Botucatu, SP, that would benefit the planning in the improvements of Botucatu (SP) city.

## Materials and methods

The Lavapés basin, located in Botucatu, São Paulo, Brazil, is of great importance for the city, the basin begins and leads into the city besides being in the urban area. It is located between the geographic coordinates: 22° 42' to 22° 56' of latitude S and 48° 20' 48" to 48° 22' of longitude W Gr., presenting a 10.670 area ha.

The predominant local weather classified according to Köppen system, is of the Cfa type – mild rainy climate with predominant winds guided to the Southeast (IF).

Soils in the area had been classified as: Ultisol, Oxisol, Inseptisol and Entisol, according to Oliveira *et al.* (9).

Units of Inseptisol soils, as Oliveira *et al.* (9) point out, are deep soils with a slight texture, which are very drainage, with a generally yellowish red color, with sequence of horizons B and C, originated from sand with low fertility, these soils are acid and are very liable to erosion.

The clay content is low, being lower of 15% and varying from 7.8 to 15% in A and B horizons, while the lime content in horizons B varies from 0.2 to 2.3%

The predominant relief is soft and rolling. When soils are tiny rolled hills present soft declivities and form open valleys in V and, when soils are rolled, hills or mountains are more declivous and valleys in V are closer

The altitude varies from 420 to 740 meters, being the highest parts from 600 to 740 meters and the lowest from 420 to 600 meters.

There is a closed-type vegetation, and the original material is sandstone.

Inseptisol, according to Oliveira *et al.* (9), are few developed soils with thickness around of 35 cm, constituted by the A horizon and D layer.

These soils have a clay content of around 46.7% granulometrically, being the lime amount very low, around 2.1%.

These soils have two types of altitudes, distributed in small spots, being the ones of wavy strong relief of rounded off, flowing convex tops and valleys in V with declivity around 40% and an altitude around 700 meters.

The predominant weather is of the Cfa type and the original material is of basalt rocks and volcanic origin (basic erosions).

The predominant native vegetation in these soils is the tropical deciduous forest.

The mapped areas by Oliveira *et al.* (9) as part of the Ultisol soil, are characterized by being deep ground of slight texture, well drained, with yellow and red coloration formed from sandstone, these soils are acids with low fertility and with small variations in the characteristics, causing that certain sub-horizons look like if were divided with transition varying from gradual to diffused.

The grain sized composition of this type of soil presents a clay content between 15 to 30%, in A and B horizons, generally being the clay content lower in horizon C than in B.

These soils are located in regions of high plain, where these form continuous spots interrupted by soils of other units. These soils generally run into the surfaces of the ridges, which can be narrow or very wide, presenting a softly rolled topography with slopes of hundreds of meters, or completely plain and very rare rolled with long slopes.

The altitude varies from 500 to 1000 meters, being in the best part between 600 to 900 meters.

The vegetal covering is

changeable, presenting in the high part clean fields, savannah vegetation and open pastures, in the low parts is finer and with crooked shrubs, there is more predomination of savannahs and in the transitions it presents vegetation of savannah however shrubs of the open pasture are more straight and vigorous.

The predominant weather for this soil's unit is the Cfa, with a rainy index varying from 1100 to 1700 mm.

The origin material of these soils is constituted by sandstone of Botucatu and Furnas and maybe by sediments of the tertiary.

The characteristics of the three main units of soil are presented in table 1.

The panchromatic aerial photographs proceeding from the photogrammetry coverings of São Paulo city, were used in 1962 in an average scale of 1:25000, with a longitudinal covering of approximately 60% and 30% in the lateral, and the satellite image, gotten from the «*Thematic Mapper*» sensor of LANDSAT - 5, in scale 1:50000, orbit 220, point 76, A quadrant, ticket of 15 of April of 1989 in bands 3, 4 and 5, correspondent to the regions of the visible ranging, the infra-red ray and the average infra-red ray were considered for the elaboration of the map of land use of the 1989, having as a cartographic reference the Letter of Brazil, edited for the IBGE in 1969, referring the Botucatu town. The mapping and identification of the soil's unit were gotten from the soil's map of São Paulo, in 1:500000 scale, edited by Oliveira *et al.*(9).

**Table 1. Characteristics of the three main soil's units in the ten micro-basin of the Lavapés river, Botucatu, SP, according to Oliveira *et al.* (1999).**

Characteristics	LVA	RL	RQ
Location	Botucatu parish	Botucatu parish	Botucatu parish
Rock	Bauru group		Pirambóia formation
Texture	Sandy	Sandy	Sandy
Weather	Cfa	Cfa	Cfa
Relief	Slightly rolled	Very rolled	A little rolled
Depth	Very deep	Low depth	Very deep
Internal drainage	Very drainage	Moderate drainage	Very drainage
Texture horizon A	Medium	Mud	Sandy
Texture horizon B	Medium	-	Sandy
Structure horizon B	Massif porous	-	Massif
Water retention	Medium to low	Low	Low to medium
Erodability	Low	Very sensitive	Low
Fertility	Low to very low	High	Very low to low

Vegetal coverings were visually obtained in satellite image, scale 1:50000, orbit 220, point 76, quadrant A, a ticket of April 15, 1989, in bands 3, 4 and 5, correspondent to regions with visible ranging, afterward the infra-red ray and the average infra-red ray were visually identified, as well as the limits of the areas covered with forests, reforestations, pastures, agriculture practices, constructed areas and urban and dams, barrages among others, after that, these elements of interest were transferred to a sheet of polyester paper Terkron D - 50 microns.

The stereoscope observation of both aerial vertical photographs was done with the help of the mirrow Wild stereoscope, ST-4 model, and the transferred of the copied elements of the photos for the map-base was done using the Aerosketchmaster Carl Zeiss, Yena.

First, a compilation of all the aerial vertical photographs of 1962, correspondent to an area of the basin of the Lavapés river was done in order to be visualized, afterward, flight lines were traced and the area was delimitedated, according to Coelho (1972). With the help of a stereoscopy a part of the drain of the basin of the Lavapés river and the limits of 10 water basins of third order of ramification were taken using polyester film Terkron D – 50 microns.

The draining density (Dd) as Christofoletti (6) and Rocha (11) said, is given by the expression:  $Dd = \frac{\sum l(R, C, T)}{A}$ , where:  $Dd$  = draining density in km/ha;  $\sum l(R, C, T)$  = total of the lengths of the gullies (R), canals (c) and tributaries (t) in km and = basin areas in ha.

In the analysis of land's use of the areas being studied, the environmental parameters used in the study of water basins, the drainage density (Dd), mean declivity (H) and ruggedness coefficient (CR), are important indicators of the aptitude in the use of the land.

The letter of Brazil, edited by IBGE (1969), in 1:50000 scale, for the Botucatu city, was used extracting the level curves of 10 basins which are being studied, being the mean declivity (H) of water basins of third order calculated by the proposed expression by Horton (1914):  $H = 100 \cdot D \cdot L/A$ , where H= means declivity of the basin in %, D= vertical equidistance of level curves in Km, L= total length of the level curves of the basin in Km, and A= total area of the basin in km<sup>2</sup>.

The ruggedness coefficient (CR) by being a parameter that controls the potential use of land, and the agricultural, cattle and forestry activities, with reforestation or for permanent preservation, was used with the aim of defining four types of the land's use of water basins of third order, of the Lavapés river, Botucatu, SP, these are: A (lower value of CR) – appropriate land for agriculture; B – adequate land for cattle raising; C – adequate lands for cattle raising and reforestation and D (higher value of CR) – appropriate land for the forest and reforestation. According to Rocha (11), the ruggedness coefficient (CR) is defined by the expression:  $CR = Dd \cdot H$ , where: Dd = drainage density and H = mean declivity.

The interest areas were evaluated using the SPLAN software – Digital planning system (12).

## Results and discussion

Table 2 shows that these 10 basins are constituted with 95.55% of soil LVA (46.56%), RQ (19.86%) and LV (29.13%), being the rest 4.45% for GX (0.55%) and RL (3.90%) respectively. Basins 1, 2, 3, 4 and 5 were composed by almost 93.13% of LVA soil units. These soils (LVA, RQ and LV) have a rolled topography, light texture, are well drained, and deep, and are sensitive to erosion, fertility is from low to very low.

Basins 6, 7, 8, 9 and 10 (table 2) have a mean value of 33.23% of soils with low fertility (RQ) and 57.87% of soils with high fertility (LV). According to Oliveira *et al.* (9) RQ soil's unit is a deep soil, with a very slight texture and market drainage, low fertility, acid, and very sensitive to erosion, with a softly rolled relief, contrary to LR soil's unit which have an average texture, moderate drainage, mean depth, a little resistance to erosion, high fertility

and soft relief.

The average declivity (20.89%) and the ruggedness coefficient of ten micro-basins of the Lavapés river basin, Botucatu, SP (table 3), indicate that these are appropriate areas for the use of cattle rising, being the relief classified as rolled. The average declivities for micro-basins 5 (17.38%), 8 (17.86%) and 9 (16.70%) allows to classify them with the ruggedness coefficient (type A) to be used for agriculture and urban area.

Values of average declivity for the micro-basins 1 (22.09%), 6 (23.21%) and 10 (18.77%) and the ruggedness coefficient (type A) indicate the use of the soil for cattle rising and forest purpose. While, values of average declivity for micro-basins 2 (27.39%), 4 (20.99%) and 7 (18.63%) and the ruggedness coefficient (type C), allow to classify these soils for the cattle and forest exploitation.

**Table 2. Average percentage of soil's unit in the ten micro-basin of the Lavapés river, Botucatu, SP.**

Bassin	LVA	RQ	LV	GX	RL
1	92.54	7.46			
2	75.06	24.94			
3	100.00				
4	100.00				
5	98.03		1.97		
6		17.49	76.97	5.54	
7		69.81	30.19		
8		15.38	45.67		38.95
9		63.47	36.53		
10			100.00		
Mean value	46.56	19.86	29.13	0.55	3.90

**Table 3. Area, drainage density, mean declivity, ruggedness coefficient and classification for the use of land in the basins of the Lavapés river, Botucatu, SP.**

Micro-Bassin	Área (A) in ha	Drainage density (D) in km/ha	Mean declivity (H) in %	Ruggedness coefficient (CR)	Type
1	242.700	0.02101	22.09	0.46411	B
2	576.701	0.02119	27.39	0.58039	C
3	544.482	0.02819	25.83	0.72815	D
4	468.807	0.02368	20.99	0.49704	C
5	443.752	0.01487	17.38	0.25844	A
6	304.895	0.01706	23.21	0.39596	B
7	194.895	0.02591	18.63	0.48270	C
8	1023.451	0.01544	17.86	0.27576	A
9	262.818	0.01275	16.70	0.21293	A
10	139.601	0.02149	18.77	0.40337	B
Mean value	420.210	0.02017	20.89	0.43011	B

Micro-basin 3, is the only one classified by the ruggedness coefficient as type D, and by its mean declivity (25.83%) it must be exclusively explored with reforestation.

The urban area, referring the Botucatu city, was of 31.55% (table 4). The forest and vegetation of savannah, mainly of micro-basins 2 and 6 were considerable once these showed 10.09% and 13.47% respectively. Micro-basins 6 (35.32%), 7 (37.18%), 8 (74.37%) and 9 (45.25%) of agriculture practice were more significant.

Busy BusyB areas with dams, barrages and others, were considered in micro-basin 7 (12.69%). The volume of water in micro-basin 7 was fluent, with construction of land barrages to consider the necessities of cattle milkmaid. These areas were considered only at a time that in an

either panchromatic or colorful satellite image, the visual interpretation turns difficult to differentiate some vegetal covers, due to the small scale of orbital image, to its space and photograph processing.

The occurrence of conflicts can be observed by the current use of the land, contrary to the defined tendency of the ruggedness coefficient in the ten water micro-basins of third order of ramification, studied in the water micro-basin of the Lavapés river, Botucatu; on the other hand, it shows the obtained results by the area to be forested, attending the legal exigencies of the Forest Code, law nº 4.771 of 15/09/65, and 7.803 of 18/07/89 and 7.895 of 13/11/89, and the technical recommendations in function to the average slope of each basin, with the aim of protecting them against erosion (11).

**Table 4. Relative percentage of the land's use of ten micro-basins of the Lavapés river, Botucatu, SP.**

Micro-basin	Location of the soil					
	Forest and vegetation of savannah	Reforestation	Natural marsh	Agriculture practices	Constructed and urban areas	Dam, barrage, among others
1	1.85	-	64.15	2.45	31.55	-
2	10.09	10.91	77.88	1.12	-	-
3	8.29	-	63.56	6.64	20.12	1.39
4	9.28	3.05	76.14	-	11.53	-
5	1.32	4.76	81.07	8.45	4.40	-
6	13.47	-	51.21	35.32	-	-
7	5.24	-	44.89	37.18	-	12.69
8	3.75	1.52	19.71	74.37	-	0.65
9	0.31	-	46.03	45.25	3.11	5.30
10	2.09	-	85.52	8.43	-	3.96
Mean value	5.57	2.02	61.02	21.92	7.07	2.40

In the region, cattle raising is practiced in an extensive way with pastures of low quality, besides, producers are not used to do correction in pH (lime-coated) neither in fertilization in order to improve the quality of food. Since the conservation of soil is an uncommon agricultural practice by cattleman, soils which are already poor, are abandoned causing the sedimentation of the Lavapés river, and the reduction of the vegetation capacity for the cattle, thus, the fall of milk production. The average environmental deterioration of the basin of Lavapés river, was of 69.46% (table 5) considering that the cattle area as conflict, is a direct indicator of the high degree of deterioration, degree that is above of the acceptable limits which is of 10% according to the recommended by FAO. The environmental degree evidences the reduction on the quality of the environment by human beings. The inadequate use of lands has caused permanent damage to the soil and vegetation, that might contribute to the low socioeconomic level of the rural owner of the Botucatu region.

The inadequate use of the land, the market average slopes in the micro-basin and the uncontrolled deforestation, among others practices that were submitted in those areas, suggest that all basins need to be forested from 39.9% to 50% with reforestation, because the amount of remaining bushes, which is already small, will continue reducing in the period of two years (2).

Deforestation attacks the soil, leaving it uncovered and under the action of certain rain appearing, in

consequence, the erosion and leaching of the essential nutritive elements for the survival of the plant. In this matter, the use of the soil must be done in a rational way, adequate to prevent the damage in the environment.

The high mean slope present in ten micro-basins, and the deforestation to which was submitted the area of the micro-basin, which can be seen through two values observed in table 3, mainly for micro-basin 1, 3, 5, 7 and 9 that did not have vegetal cover, makes possible to conclude that these basins need a forest complementation with vegetation. In this matter, Coelho (4) affirms that as the natural fall of plants is not hindered and its recovery is slow, the eucalyptus planting will cover the economical necessities, as well as it will constitute a protection against erosion in the southwest of São Paulo.

Table 4 shows that all micro-basin need to be forested, with an average of 46.89% to 44.43% in order to reach a technical recommendation of 50% of forest cover, as a goal to preserve in a rational and adequate way the handling of the basin, in order to protect it against erosion, therefore, improving the environmental conditions.

Analyzing the corresponding results of the environmental control parameter of the ruggedness coefficient, it was verified that basins 5, 8 and 9 have had the potential use of land classified as Type A, it means, adequate soils for agriculture and urban use, on the other hand, basins 1, 6 and 10 were classified as type B, that is, appropriate soil for cattle raising, while basins 2, 4 and 7 were

**Table 5. Relative percentage of the land's use, conflicts, forest complement, forest complement, and damage of the ten micro-basins of the Lavapés river, Botucatu, SP.**

Micro-basin	Conflicts	Forest	To be forested	Excess (+) or availability (-) in agriculture	Area to be worked in the correct handle of the basin	Damaged area by the basin
1	2.46	1.85	48.15	2.45	50.61	50.61
2	1.13	10.09	39.91	1.12	41.03	41.03
3	70.21	8.29	41.71	6.64	48.35	100.00
4	0.00	9.28	40.72	0.00	40.72	40.72
5	8.44	1.32	48.68	37.16	94.28	57.12
6	35.32	13.37	36.53	35.32	71.85	71.85
7	37.18	5.24	44.76	37.18	81.94	81.94
8	74.37	3.75	46.25	-25.02	95.60	100.00
9	45.25	0.31	49.69	-3.66	91.28	94.94
10	8.43	2.09	47.91	8.43	56.34	56.34
Mean value	28.28	5.57	44.43	15.70	67.20	69.46

classified as type C, it means, for cattle raising or reforestation use, only micro-basin 3 was classified as type D, it means, favorable soils for forestation use.

The average ruggedness coefficient for ten water micro-basins of third order of ramification allowed to classify the basin of the Lavapés river as type B, that is, favorable land for the use of pastures, which agrees to the regional information, but is not advantaged, instead, it is used for the production of cattle milk.

The average declivity of the micro-basin (20.89%) allowed to classify it as an accidental relief according to the criteria of Chiarini & Donzeli (3); however 62.95% of the total area of the basin have an advisable topography for the agricultural usage with annual crops, on the other hand these are areas of favorable mechanization, being the relief classified by Chiarini & Donzeli (3) as rolled. The rest area, 27% have a pretty market topography, prevailing a steep declivity, indicating that the agricultural activity must be considered a practice with risks, therefore, if there are not adequate conservationist practices basins might suffer huge lost caused by erosion.

Micro-basins 3 and 9 with 100% of deterioration presented damaged areas of 70.27% and 74.37%, it means, areas used inadequately, without planning, causing low productivity and impoverishment of soils.

Basin 5, classified according to the ruggedness coefficient as propitious for the agriculture use,

have an area to be used for the correct handling of 94.28%, including the rest of the areas in agriculture, which are the damaged and the reforested ones.

Micro-basins 8 and 9, classified according to the ruggedness coefficient as type A, that is appropriate lands for agriculture, presented 25.02% and 3.66% respectively, as available areas for agriculture, which might be used in the correct handling of these basins. Since the available areas in the basin are of 95.60% and 91.28% beyond the available areas for agriculture, these can be used for the conflicting and forested areas.

Micro-basins 1, 6 and 10 classified according to the ruggedness coefficient as type B, presented conflicting and exceeding areas at the same time respectively, to the order of 2.46%, 35.32% and 8.43%, because are micro-basins guided for cattle purpose, it means to the pasturing of the cattle, the areas used for the correct handling of the basin are of 50.61%, 71.85 and 56.34% respectively. The mentioned areas are also used for the correct handling of the areas to be forested which corresponds to 48.15%, 36.53% and 47.91% respectively.

According to the ruggedness coefficient values of micro-basins 2, 4 and 7, these basins were classified as type C, it means, appropriate lands for cattle and vegetation, micro-basins 2 and 7 presented 1.13% and 37.18% of conflicting areas, and micro-basin 4 did not present conflicting areas. For the correct use of these three micro-basins the area to be worked is in the order of

41.03%, 40.72% and 81.94% including in this case the exceeding areas in agriculture, 1.12% in micro-basin 2 and 37.18% in micro-basin 7, considering that micro-basin 4 did not have exceeding areas in agriculture, and the areas to be forested were of 39.91% in micro-basin 2, 40.72% in micro-basin 4 and 44.76% in micro-basin 7.

The only micro-basin classified as type D, that is, favorable lands for vegetation, was micro-basin 3 which presented 48.35% as an area to be worked for a correct handling, being the correspondent conflicting area of 70.21%, including the one of incorrect handling, the areas to be forested with 41.71%, and an excedent in agriculture of 6.64%.

The 10 water micro-basins of third order of ramification of Lavapés river, Botucatu, SP, had low index of forested cover, from 0.31% to 13.37%, with a mean value between those two of 5.57%, below the pre-established index of FAO, which is of 25%.

Micro-basins 1 (1.85%), 5 (1.32%), 8 (3.75%), 9 (0.31%) and 10 (2.09%), have a mean value of 1.86% of area cover with forest, instead of micro-basin 2 (10.09%), 3 (8,29%), 4 (9.28%), 6 (13.37%) and 7 (5.24%) which have a mean content of 9.25% of vegetal cover, therefore, the micro-basins used in the research have a mean value less of 2% of covered area with forest, while the other mean values are a little higher of 9%.

The deterioration degree used in the environmental control for micro-

basin 10 was relatively high (69.46%), that is, varied from 40.72% to 100%, very high compare to the acceptable limit of 10, according to the recommendations of FAO. The damaged value of 69.46% occurs due to the incorrect use of the land, mainly because of the cattle activity of the region, and by the uncontrolled deforestation, specially in soils with good fertility, and of more adapted ecological conditions for the economic exploration, so far being the poorest soils used in function of the population increment and of the agronomical and technical advance. The forest, besides slowly diminishing in the region, in São Paulo city, Brazil, and in the World, is being damaged qualitatively, being a problem when it is thought about conservation and improvement of renewable natural resources.

Forests, according to INCRA were in 1985 around 13.9% in São Paulo; nowadays, this value is lesser, due to deforestations continues happening, in this matter, Campos *et al.* (1) evidence the presence of only 3.2% of vegetal cover by forest in the micro-basin of the Lavapés river, Botucatu.

The forestation activity can be improved in some micro-basin, because, according to some researcher, this vegetal cover attends the necessities controlling the erosion, that is, if cattleman would not use these lands for the cattle purpose.

## Conclusions

According to the used methodology and with the obtained results in the research, it was possible to conclude saying: the images of the TM sensor of LANDSAT 5, allowed the mapping of the land's use of the basin in a faster way, besides supplying an excellent data for future planning in the area; the physical conservation surveying also allowed to show the environmental physical deterioration degree of the basin of the Lavapés river, Botucatu, SP, of

69.46% very above of the acceptable limit, which is 10%, according to the recommended by FAO; the environmental parameter «ruggedness coefficient», for the basin of the Lavapés river, Botucatu, SP, allowed to indicate that the main purpose of this basin is for cattle use (type B), and the 10 micro-basin of third order of ramification are mainly composed by the LVA and RQ soil's unit, which are soils of low to very low fertility.

## Literature cited

1. Campos, S. 1993. Fotointerpretação da ocupação do solo e suas influências sobre a rede de drenagem da bacia do Rio Capivara – Botucatu, SP, no período de 1962 a 1977. Tese de Doutorado. Faculdade de Ciências Agrônomicas. Brasil. 164p.
2. Campos, S., J.A. Tebet, L.G. Cardoso and Z.X. Barros de. 1993. Modificação da paisagem na bacia do Rio Lavapés – Botucatu, SP, de 1977 a 1989. Congresso Brasileiro de Engenharia Agrícola. Brasil. (23) .319-328.
3. Chiarini, J.J. and P.L. Donzelli. 1973. Levantamento por fotointerpretação das classes de capacidade de uso das terras do Estado de São Paulo. Boletim Técnico do Instituto Agrônomico. Campinas. (3):1-29.
4. Coelho, A.G. de. 1968. Fotointerpretação da eucaliptocultura e estudo do planejamento agrícola. Boletim do Instituto Agrônomico, Campinas, (187): 1-60.
5. Coelho, A.G. de. 1972. Obtenção de dados quantitativos de fotografias aéreas verticais. Rev. Aerofotogrametria. São Paulo. 8(1): 1-23.
6. Christofoletti, A. 1980. Geomorfologia. São Paulo, Ed. Edgard: Blucher Limitada. 2º edição. 188p.
7. Horton, R.E. 1914. Derivation of runoff from rainfall data. Discussion. Trans.A.S.C.E., 77: 369-75.
8. Mello Filho, J.A. and J.S.M. Rocha, da. 1992. Diagnóstico físico-conservacionista das sub-bacias hidrográficas dos rios Alambari e Sesmária, em Rezende, em RJ. Congresso Brasileiro de Engenharia Agrícola. Santa Maria. Brasil. 2178-2191.
9. Oliveira, J.B. de Camargo, M.N., Rossi, M., Calderan Filho. 1999. Mapa pedológico do Estado de São Paulo. Campinas. Empresa Brasileira de Pesquisa Agropecuária. 64p.
10. Rocha, J.S.M. da. 1978. Fotografias aéreas aplicadas ao planejamento físico rural. Dissertação de Mestrado. Universidade Federal de Santa Maria, Brasil. 51p.
11. Rocha, J.S.M. da. 1991. Manual de manejo integrado de bacias hidrográficas. Santa Maria. Brasil. 2º edição. 181p.
12. Silva, C.M., Cataneo, A., Cardoso, L.G. 1993. Sistema de Planimetria Digitalizada. Jornada Científica da Associação dos Docentes. Universidade Estadual Paulista. Brasil. p.109.