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EVALUATION OF THE ENVIRONMENTAL IMPACTS CAUSED BY DEFORESTATION IN THE HYDRIC REGIMEN OF THE METROPOLITAN REGION OF PETRÓPOLIS (RJ), BRAZIL

ABSTRACT

Vegetation has closer relationship with the hydrological cycle, changing them due to their conditions. Vegetation regulates the hydrological cycle making water faces all the stages adequately causing the process stability. Vegetation retains great parcel of the rainwater, freeing it for the water courses and surface and subterranean reservoirs, little by little. In this work, the impact of deforestation over the hydric regimen of the City of Petrópolis was analyzed. The results show that the reduction of vegetation coverage provoked annual outflows increases. The reduction of the vegetation coverage from 58% to 39% caused addictions in average outflow of 60%. This brought the increase of the draining index from 0.29 to 0.50. Changes are also verified concerning the annual average minimum and maximum outflows. In the first case, there was an increase of 86,3% and, in the second case, the annual average maximum outflow was increased in 49,9%.

KEYWORDS: Forests; Vegetation; Vegetation Cover; Environmental Impacts; Hydro Scheme.

AVALIAÇÃO DOS IMPACTOS AMBIENTAIS DO DESFLORESTAMENTO SOBRE O REGIME HÍDRICO DA REGIÃO METROPOLITANA DE PETRÓPOLIS (RJ)

RESUMO

A vegetação tem estreita relação com os processos do ciclo hidrológico, modificando-as em função das condições em que se encontre. A vegetação regula o ciclo hidrológico fazendo com que a água percorra as diversas fases do mesmo, de forma adequada a possibilitar a estabilidade do processo. A vegetação retém grande parcela da água precipitada, libertando-a, aos poucos, para os cursos d'água e reservatórios superficiais e subterrâneos. Neste trabalho, foi analisado o impacto do desflorestamento sobre o regime hídrico da Cidade de Petrópolis. Os resultados mostram que a redução da área de cobertura vegetal provocou aumentos das vazões anuais. A redução de 58% da cobertura vegetal para 39% provocou um acréscimo na vazão média de 60%. Isto implicou no aumento do índice de escoamento de 0.29 para 0.50. Mudanças são, igualmente, verificadas com relação às vazões mínimas e máximas médias anuais. No primeiro caso, teve-se um acréscimo de 86,3% e, no segundo caso, a vazão máxima média anual foi aumentada em 49,9%.

PALAVRAS-CHAVE: Florestas; Vegetação; Cobertura Vegetal; Impactos Ambientais; Regime Hídrico.

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INTRODUCTION

The hydrological processes in a hydric basin have tow outflow directions: vertical (represented by precipitation, evapotranspiration, infiltration and percolation); and horizontal (represented by the surface, below surface and subterranean draining). Vegetation has one fundamental role in all the hydrologic process of the hydric basin, mainly in the interception and evapotranspiration, acting, indirectly, over all cycle stages.

Forested soils present an increasing capacity of infiltration. However, it has been verified that an uncovered soil is more infiltrated than a forested soil, due to the parcel of rainwater which reaches the soil after being intercepted. The bigger the parcel, the less the size of vegetation. So, forested areas present low infiltration. On the other side, uncovered soils can present infiltration problems due to the soil proprieties alteration, caused by the rain drops impact.

The below surface draining, that one which runs lower, through the blanket of leaf debris and first soil layers, explains the fact of the rapid watercourses feeding, sooner after rain, without surface draining. On the other side, most part of the forests act to minimize the range of humidity variations and environment temperatures.

Evapotranspiration from lands and forests represent one considerable role when happens in great areas. In more restricted areas, the evaporated water is transported to other places by wind currents. Forest provides soil evaporation decreasing, since eases temperatures and diminishes the wind average speeds. Although evapotranspiration presents high values, this loss is compensated by the best economy of left water which follows the hydrologic cycle.

Dons (1986) shows that there are reductions of the rivers outflows in small hydrographic basins, provoked by the improvement of the evaporation of water intercepted by canopy during rains. According the same logic, trees lack would cause one increase in rivers outflows. Consequently, vegetation species of quick growth present reductions in outflows of hydrographic outflows. Scott and Lesch (1977), in one survey conducted in South Africa, it was found that in the six first years after the Eucaliptus. spp plantation there was 51% increase during rain seasons and 52% in dry seasons.

The forest reduces the flooding occurrence, as far as intercepts waters in one way that this cannot reach the soil rapidly; conserves and increases the infiltration capacity; holds and reduces erosion and the consequent debris deposit in fluvial canals; increases a capacity of retention of soil water by the porosity maintenance and growth and eases the elimination of the water kept in soil in the storms intervals periods. Therefore, vegetation has a closer relationship with the hydrologic cycle processes, changing them due to the current conditions. In this study the impact over the hydric regimen of the City of Petrópolis was analyzed.

MATERIAL AND METHODS

The area of study covers the region of Petrópolis is situated in one average height of 865 m., being surrounded by three uplands: the Couto Upland, the Araras Upland and Órgãos Upland, where this last one reached the higher height with the Sino Roxk with 2.232 high. Originally, the vegetal coverage was composed by “Dense Ombropylous Forest” and “Mixed Ombrophylous Forest”, this in smaller scale. The “dense ombrophylous forest” is one formation characterized by evergreen trees heights of 20 to 30 m. having foliar shoots without protection against drought. Its area of occurrence is formed by the steep slopes of the Serra do Mar forming deep and narrow valleys. The annual average precipitation ranges from 1300 to 1500 mm. The distribution of rainfall shows a well outlined sazonal variation, with longer periods of rain in the summer months and drier in the winter months, the characteristic behavior of tropical systems. The great concentration of rainfall in summer is mainly due to local orography which acts like barrier to mass penetrations of humid air which come from coast. The most part of the soils are cambisol and distrophic álico cambisol. Heights range from 200 to 1000 meters. The rivers of Petropolis have longitudinal profile with much accentuated slopes, with numerous jumps and rapids.

Radical changes over land use occurred in the last decades. Forest gave way mainly to cycling agricultural cultures, pastures and property occupation. The major part of the forests remnants is degraded. The major part of the lands is not enabled for agricultural use. Only one small percentage is regularly enabled for short or long term cycle cultures.

Concerning the vegetal coverage, the option was to work with the area of the hydrographical basin with arboreal vegetation, using relative and absolute data. The several types of arboreal vegetation, like *capoeira*, secondary forest and primary forest, were reunited in one unique group, despite their own particularities related to each relationship with the hydrological cycle. It was used the *Carta do* Brasil at scale of 1:50.000, and satellite images at scale of 1:250.000 (TM-LANDSAT). The areas evaluation was found through by planimetry. The precipitation and river outflow daily data were provided by the *Agência Nacional de Energia Elétrica – ANEEL*.

The time of transit of the flood waves was determined, thus understood as the time interval between the center of gravity of the exceeding hietograma and the peak of the hydrograph of unitary volume. It was adopted the equation of Snyder for the transit time t_p is $t_p = C_t.(L.\overline{L})^{0,3}(h)$, where:

L = length of main watercourse, since the watershed until the estuary; $\overline{L}$ = distance between the center of the basin gravity and the mouth measure throughout the main watercourse; Ct = regional constant, that, according to Snyder, varies between 1,35 and 1,65 when the distances are measured in km. For the calculation of the unitary rain period, the proposed equation was: $t_u = t_p / 5{,}5(h)$

For the calculation of discharge of peak of the unitary hydrograph of duration *tu*, correspondent to an effective precipitation of uniform 1 mm on the basin, the expression used was:

$Q_u = 0,28.C_p.A/t_p(m^3/s)$, where A is the draining area in km^2 and Cp (empiric constant regional, with between 0,56 and 0,69). A time pointer of unitary hydrograph is given by the expression: $t_b = 3 + 3.t_p / 24$ (days).

Once the unitary hydrograph is obtained, the component hydrographs were obtained, birthing one torment and putting it on the unitary hydrograph, according to the principles of the Unitary Hydrograph Theory. For studies conception, relationships intensity – duration – frequency for regional observations were used. It was applied rain in One dispersion coefficient was applied on rain in one point and one temporal distribution considered convenient according to the regional history was adopted.

The intensive rain equation for a period of return of two years (T) was Pt,2 = 54,068. $t^{0,458}$ mm (Precipitation Pt, T, t (h)) and for five years was Pt, 5 = 66,144. $t^{0,458}$.

The expressions which supply the discharge of the peak of the unitary hydrograph and the based time are:

$$Q_u = \frac{220/t_p}{t_p}(m^3/s.100km^2), t_b = 2,525t_p(h)$$

The value of tp is constant for one given unitary duration in one determined basin, and for one unitary hydrograph correspondent to one hour of effective rain. It is calculated for the expression:

$$t_p = 46,6.S^{-0,39}.(1+u)^{-1,99}.R_c^{-0,4}.L^{0,15}(h)$$, where:

L = length of the main water course in km; S = average declivity of the water course of the main course, calculated between situated points 0,1 and 0,8. L of mouth, u = degree of waterproofing of the basin; and Rc = climatic index.

The average declivity of the basin of the city of Petrópolis was calculated, transforming it into other consisting by a series of overlapping terraces delimited by curves of level of equal quota related to the level of the sea (isohypses). It was considered two curves isohypses next to lengths $\square_S$ **+** □□**e** $\square_S$ became involved in an area s, average declivity i of the part of the basin defined for two curves, through the expression: **i = □/2 (**$\square_{S}$ **+** $\square_{S}$ **+** □**) .** h_s/a_s, being hs the space between the level curves.

The average declivity of the basin became equal to the average of the average declivities; the average declivity of the basin is given by the relation between the addition of lengths of isoípsas multiplied by the equidistance between them, and the addition of the horizontal surfaces of terraces or platforms. The addition of the horizontal surfaces of the platforms is equivalent to the surface of the horizontal projection of the hydrographic basin.

The angle α that represents the average declivity calculated through the expression: tgα = equidistance x half-adds of the length of isohypses / surface of horizontal projection. The length of isohypses was obtained through one map of curvimetry and the areas by planimetry.

On the measurement of □$_s$, to simplify the calculations, a clinographical curve was built, as follows: in a two-dimensional Cartesian plane, equidistances of h on the y-axis were made, then, parallel to the x-axis, a few lengths of the isohypses from the values of h were made. The resultant curve of the interpolation of these points allowed approaching all the lengths of isohypses.

Effective surface of the basin of the city of Petrópolis was determined, evoking the expressions: $\Delta h_o = \Delta\omega - \cos\beta$, or $\Delta\omega = ho/\cos\beta = ho \cdot \sec\beta$, where β is the angle that an element of surface $\Delta\omega$ form with its horizontal projection Δ ho. Adding the expressions of all the elements, the value of the surface was obtained:

$$\Omega = \sum_{i=l}^{n} \Delta\omega = \sum_{i=l}^{n} \Delta ho.\sec\beta$$

As the angle s $\beta$are unknown, it was admitted that one angle ∂ such that: sec ∂ = $\sum_{i=l}^{n} \Delta ho.\sec\beta / \Sigma\Delta ho =$ effective surface/horizontal surface, and was considered that this angle can be assumed with enough approach equal himation to the angle of the average declivity.

The effective surface was given by: $\Omega = \sum_{i=l}^{n} \Delta\omega = Seca \sum_{i=l}^{n} \Delta ho$, therefore, the effective surface the Hydrographic Basin of the city of Petrópolis was considered equal to the product of its horizontal projection by the siccative of the average declivity of the same basin

RESULTS AND DISCUSSION

It was estimated that, at the beginning of colonization, the watershed in question possessed 100% of native arboreal vegetation coverage. The transformation process has evolved in such a way that, in 1966, there were 58% or 198,129 hectares and, in 1986, only 39% of the area covered by forests, that is, 134,714 acres. The deforestation occurred, therefore, to the approached average tax of 3000 hectares per year, during the period of 1966 to 1986 (table 1).

Table 1: Taxes of arboreal vegetal coverage of the basin of the city of Petrópolis-RJ.

Year	Surface(ha)	%
1966	198.129	58
1986	134.714	39

The infiltration capacity of the ground is lesser in one uncovered soil, but, the at least at an immediate moment after the deforestation, the infiltration tax is bigger in the uncovered soil. In principle, it was expected that the minimum outflow rate would decrease, since the water course, in time of drought, is fed by underground aquifers which, in turn, obtains water infiltration of rain on the ground. Another fact that contributes for this hypothesis is that, with the deforestation, the physical characteristics of the ground, mainly the structure, are gone degrading and becoming infiltration most difficult. The geologic and geomorphologic characteristics and the characteristics of ground of the studied area contribute so that the minimum outflow suffers addition as what it was evidenced

Table 2: Maximum rain data in one day for Region of Petrópolis, with estimated values correspondent to the periods of return of 2,5,10,25,50,75 and 100 years, by the method of Chow-Gumbel

	Reliable Interval	Minimum Precipitation	Average Precipitation	Maximum Precipitation
Return of 02 years	68%	99	104	110
	80%	97	104	112
	90%	95	104	114
	95%	93	104	116
Return of 05 years	68%	131	142	152
	80%	128	142	155
	90%	124	142	159
	95%	121	142	162
Return of 10 years	68%	152	166	181
	80%	148	166	185
	90%	142	166	190
	95%	138	166	195
Return of 25 years	68%	177	197	217
	80%	172	197	223
	90%	165	197	230
	9,5%	158	197	236
Return of 50 years	68%	196	220	244
	80%	190	220	251
	90%	181	220	260
	95%	173	220	267
Return of 75 years	68%	207	234	260
	80%	200	234	267
	90%	191	234	277
	95%	182	234	285
Return of 100 years	68%	215	243	271
	80%	207	243	279
	90%	197	243	289
	95%	188	243	298

In a general way the ground of the hydrographic basin in question has medium-argillaceous texture or Franc-argillaceous, they are well drained and porous and, therefore, they possess good capacity for infiltration of the water. The superficial draining also suffers a considerable addition, resulted of the parcel of the deviated water of the interception that does not infiltrate in the ground. This has direct action in the increase of the maximum outflows. With regard to the average outflow, the deforestation provokes a reduction of the amount of the water of the precipitation extracted by transpiration, as well as of the evaporation of the intercepted parcel. This provokes an increase of the drainings in such a way, modifying the hydric rocking of the basin. In addition, in the condition with forests, the evapotranspirated volumes are transferred to other regions, reducing the available volume for generation of the drainings.

In this way, it is verified that the vegetation functions as if was a reservoir of containment of floods, with the advantage of being used to other ends of great environmental economic and social importance, such as the wood production, the hydric production, the biomass, the protection to other natural resources as the ground and the fauna and the banks of germplasm. In addition, the deforestation is part of the set of factors that determine the full occurrence or the biggest incidence of floods and torrents, either acting direct or indirectly. Indirectly, the withdrawal of the forest increases the erosion of the soil and the silting of the water courses. The deforestation acts directly in the increase of the draining of superficial waters and, as consequence, in the level of the water courses. Full and the torrents occur, therefore, in deforested areas, in one period of lesser time of what they would occur in areas covered for forests, due to improvement of the hydrodynamic conditions.

Table 3: Average values of precipitation, outflow and tax of draining of the periods studied in the basin of the city of Petrópolis-RJ.

	Period I	Period II	Difference	Relative Difference
Precipitation (mm)	1442,00	1347,57	-67,44	-4,7%
Minimum Outflow (m^3/s)	6,13	11,42	5,29	86,3%
Average Outflow (m^3/s)	44,40	71,03	26,63	60,0%
Maximum Outflow (m^3/s)	547,18	820,20	273,02	49,9%
Draining Tax	0,29	0,50	0,21	72,4%

It is pointed that, in the relation vegetation - water, exists a series of variables that could have been considered, such as the transport of the vegetation, the space distribution of the individuals, the type of radicular system, the external morphology and the tax of growth of the vegetable. The type of influence of each type of vegetation in the hydrologic cycle must also be distinguished. In this work, these aspects were considered in one global form. They allowed to evidence the influence of the vegetation in the hydrologic cycle, having, therefore, to be considered in any project (structural or not), especially those of torrent and floods containment (such as the barrages and dams), preventing the wastefulness of resources and the social-environmental impact of such projects

It was observed, at the level of field, that the overflow of the rivers of the cities of Petrópolis starts to occur with precipitations superior to 90 mm, in less than 3 hours. It was observed, also, that a great precipitation hardly occurs in interval superior to three hours, at least for precipitations around 90mm. With a reliable interval of 95%, a return of each 2 years of a precipitation between 93 and 116 mm is obtained. Statistically, one overflow of the rivers of Petrópolis happens each 2 years. The landslides are not necessarily related to the great precipitations in one day, but to the problems of Hydric Balance. It is observed that the Hydric Balance, in the summer, presents a great excess. This excess, however, does not represent great problem while in the period between precipitations it will have time so that the exceeding water percolates for underground layers of the soil. The danger of the landslides in the Petropolitanas hillsides becomes bigger when the amount of percolated water inside of the ground for the underground layers will be lesser to the volume precipitated in one same period. The problem becomes even more serious when the superficial draining damages or when it has infiltrations in the ground by means of small ridges. The declivity, the type of ground, its covering and its draining are very important factors to determine if a hillside is safe or not.

It was observed that it field level that small landslides start to occur from daily maximum precipitations around 140 mm, where with 160 mm these landslides start to intensify. It is standed out that this empirical data can vary sufficiently, due to the level of saturation of the ground, before a great precipitation. The obtained empirical data are valid considering one saturated soil (field capacity), condition very common in the period of summer in Petrópolis. The period of return for rains of 140 mm is five year.

CONCLUSIONES

Amongst the non-climatological that aggravate even more the consequences of great precipitations, the continuous deforestation, the increase of the constructed areas and the silting of the rivers can be cited. The deforestation is, certainly, the main of all the cited causes. As consequence of this, we have a much bigger and faster superficial draining, not causing the precipitated water to arrive in much more fast time at the rivers, provoking, then, the floods.

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