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MAPPING, ORGANIC MATTER MASS AND WATER VOLUME OF A PEATLAND IN SERRA DO ESPINHAÇO MERIDIONAL[1]

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SUMMARY

Peatlands form in areas where net primary of organic matter production exceeds losses due to the decomposition, leaching or disturbance. Due to their chemical and physical characteristics, bogs can influence water dynamics because they can store large volumes of water in the rainy season and gradually release this water during the other months of the year. In Diamantina, Minas Gerais, Brazil, a peatland in the environmental protection area of Pau-de-Fruta ensures the water supply of 40,000 inhabitants. The hypothesis of this study is that the peat bogs in Pau-de-Fruta act as an environment for carbon storage and a regulator of water flow in the Córrego das Pedras basin. The objective of this study was to estimate the water volume and organic matter mass in this peatland and to study the influence of this environment on the water flow in the Córrego das Pedras basin. The peatland was mapped using 57 transects, at intervals of 100 m. Along all transects, the depth of the peat bog, the Universal Transverse Mercator (UTM) coordinates and altitude were recorded every 20 m and used to calculate the area and volume of the peatland. The water volume was estimated, using a method developed in this study, and the mass of organic matter based on samples from 106 profiles. The peatland covered 81.7 hectares (ha), and stored 497,767 m^3 of water, representing 83.7 % of the total volume of the peat bog. The total amount of organic matter (OM) was 45,148 t, corresponding to 552 t ha^{-1} of OM. The peat bog occupies 11.9 % of the area covered by the Córrego das Pedras basin and stores 77.6 % of the annual water surplus, thus controlling the water flow in the basin and consequently regulating the water course.

Index terms: Histosols, water retention, water flow.

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RESUMO: *MAPEAMENTO, MASSA DE MATÉRIA ORGÂNICA E VOLUME DE ÁGUA DE UMA TURFEIRA DA SERRA DO ESPINHAÇO MERIDIONAL*

Turfeiras formam-se em áreas onde a produção de matéria orgânica excede as perdas por decomposição, lixiviação ou alteração do meio. Devido às suas características físicas e químicas, as turfeiras podem atuar na dinâmica da água, tendo em vista que elas estocam grandes volumes durante períodos chuvosos, sendo esta liberada gradativamente durante os outros meses do ano. Em Diamantina, Minas Gerais – Brasil, 40.000 habitantes recebem água da turfeira da Área de Proteção Ambiental Pau-de-Fruta. A hipótese deste estudo é de que a turfeira de Pau-de-Fruta atua como ambiente de estoque de carbono e como agente regulador do fluxo de água na bacia do Córrego das Pedras. Os objetivos deste estudo foram estimar o volume de água e a massa de matéria orgânica na referida turfeira e estudar a influência desse ambiente no fluxo de água na bacia do Córrego das Pedras. A turfeira foi mapeada por meio de 57 transectos, demarcados a cada 100 m. Em todos os transectos, a cada 20 m, foram determinadas a profundidade da turfeira, as coordenadas UTM e a altitude. A partir desses dados, foram calculados sua área e seu volume. Em 106 perfis, foram coletadas amostras para estimar o volume de água, por meio de método desenvolvido neste trabalho, e a massa de matéria orgânica. A turfeira estudada ocupa 81,7 ha e armazena 497.767 m^3 de água, que representam 83,7 % do volume total da turfeira. Seu estoque total de matéria orgânica (MO) é de 45.148 t, o que corresponde a 552 t ha^{-1} de MO. A turfeira ocupa 11,9 % da área da bacia do Córrego das Pedras e armazena 77,6 % do excedente hídrico anual, controlando o fluxo de água na bacia e regulando a vazão do curso d'água.

Termos de indexação: Organossolos, retenção de água, fluxo de água.

INTRODUCTION

Peatlands are ecosystems formed by the accumulation of organic matter. These ecosystems occur in locations where conditions inhibit the decomposition by microorganisms and organic matter directly affects the water flow of the system, causing the storage of a considerable volume of carbon (Silva et al., 2005).

It is estimated there are approximately 420 million hectares (ha) of peatland worldwide, equivalent to 3 % of the Earth's surface. The largest peatland area, approximately 350 million ha, is found in the northern hemisphere, and approximately 30.5 to 45.9 million ha in the tropics (Rieley et al., 2008). In Brazil, peatlands correspond to approximately 611,883 ha, covering about 0.07 % of the nation's territory (Pereira et al., 2005). In the Serra do Espinhaço Meridional (SdEM), this ecosystem are formatted by association between Histosols and other shallow and sandy soil classes on their borders. Of the 112,233 ha in this mountainous region, 12,814 ha (11.4 %) are peatlands that are associated with other soils with high levels of organic material (Silva et al., 2009a,b).

Peatlands store a large quantity of organic matter and are thus integral components of the global carbon cycle. Any alterations to these environments can cause high CO_2 levels in the atmosphere, thus contributing to the increasing global warming trend (Rieley et al., 2008).

Due to their chemical and physical characteristics, peat bogs play a fundamental role in water dynamics because they can store large volumes of water in the rainy season and gradually release this water during the other months of the year (Ingram, 1983). According to Stevenson (1994), the organic material found in peatlands can store up to 20 times its mass in water, which is retained by functional hydrophilic groups through hydrogen bonds that retain the water as part of the internal structure of the organic molecule (Silva & Mendonça, 2007).

Thus, the hypothesis of this study is that the bogs in the environmental protection area (EPA) of Pau-de-Fruta are an environment for carbon storage and act as a regulator of water flow in the watershed Córrego das Pedras, with an important contribution to in stabilize the flow of this river, which is used to supply water to approximately 40,000 people.

The objective of this study was to map the area, determine the water volume and the organic matter mass in the peatland of the EPA Pau-de-Fruta and to study the influence of this environment on the water flow of Córrego das Pedras.

MATERIAL AND METHODS

Localization and characterization of the study area

The peatland investigated in this study is located 6 km southwest from the city of Diamantina in the state of Minas Gerais, Brazil in the environmental protection area (EPA) of Pau-de-Fruta (Figure 1), in the Serra do Espinhaço Meridional (SdEM), a single Brazilian mountain chain. The area is covered by quartzitic rock formations that are associated with phyllite hematite in elevated regions (average altitude of 1.366 m), and by water-saturated depressions at locations where the peatland overlaps with sand, rivers and colluvial gravel (Saadi, 1995; Silva et al., 2005).

The peatlands of the SdEM hold the headwaters of major rivers of the semiarid region of Minas Gerais State (Jequitinhonha and Araçuaí) and major tributaries of the São Francisco and Doce rivers, two major river basins in Minas Gerais State and Brazil.

The study area has a mild climate throughout most of the year, with a historical average of 18.9 ^{o}C, oscillating between 16 ^{o}C in the coldest month (July) and 21.2 ^{o}C in the warmest month of the year (January). The average historical rainfall is 1,351 mm (Neves et al., 2005).

The vegetation type in the study area is moist meadow, characterized by herbaceous species of the families Asteraceae, Melastomataceae, Eriocaulaceae and Xyridaceae (Horak, 2010). Sparse patches of semi-deciduous seasonal forest with shrub and tree species are also found in this location (Ribeiro & Walter, 1998).

Mapping and sample collection

To map the peatland in the EPA Pau-de-Fruta, the peat bog was divided into 12 sections that were similar in width, depth and the stage of organic matter decomposition. In these sections, 57 transects, spaced 100 m apart, were outlined (Figure 2). The peat bog was georeferenced using Universal Transverse Mercator (UTM) coordinates, Datum Córrego Alegre 23. In all transects, the peat depth was determined every 20 m by a 6 m long metal rod, while the coordinates and elevation were recorded with a GPS. This procedure was performed at 402 sites.

Of 12 of the 57 transects, all points were described and sampled using a PVC sampler (a PVC tube- length 2.3 m, diameter 50 mm - with a removable lid and wooden piston) along with a 6 m long metal rod. Using the coordinates and depth of each site, a map with the limits of the peat was produced and the area and total volume were calculated using ArcGis 9.2 software.

Water volume and organic matter stock estimates

During collection, samples were compacted by expelling water from the sample as the PVC sampler entered the soil. The degree of compaction was determined by establishing the difference

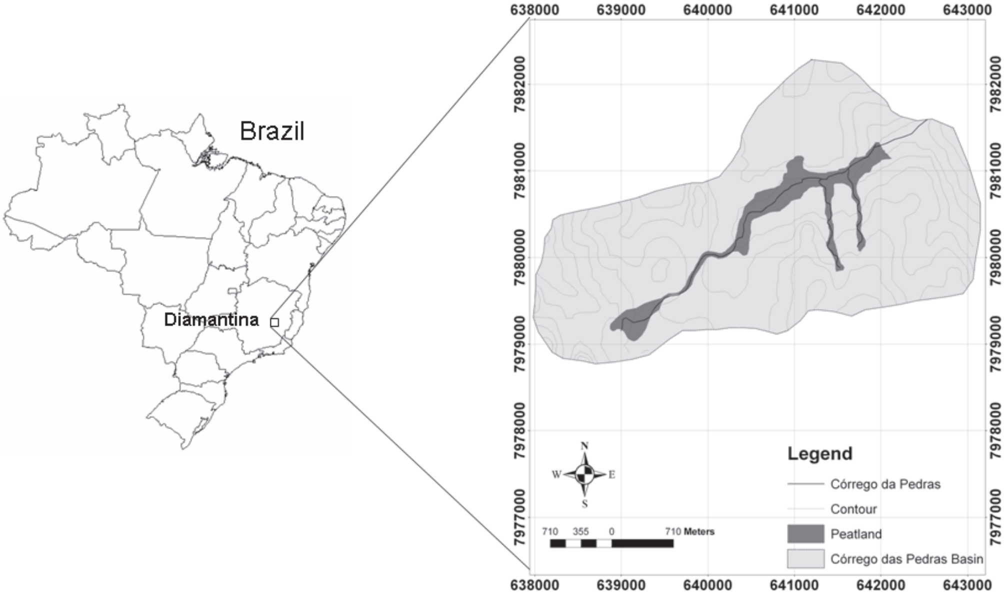

Figure 1. Location of the study area.

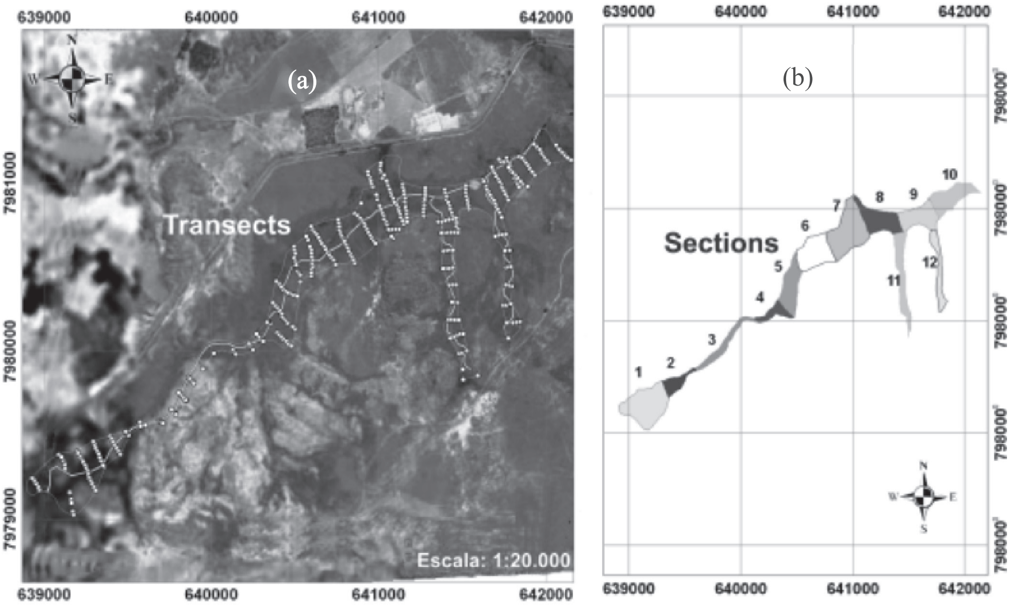

Figure 2. Satellite images of the peatland area, with the location of the transects and sampled sites (a); and Sections used to calculate the volume occupied by the peatland (b).

between the peat thickness, using the 6 m long metal rod, and by determining the length of each sample (Campos, 2009). Using this difference and the moisture (Moi) data of the sample, analyzed in triplicate by the gravimetric method (Embrapa, 2006), it was possible to calculate the volume of water expelled from the sampler (VWES), the total volume of water of the profile (TVWP) and sample compaction. The value of TVWP refers to the water content in the cylindrical sampler, introduced from the soil surface into the basal substrate. The entire volume of material that is collected in the cylinder corresponds to the solid and the water since the contribution of gases to the environment that is permanently saturated by water is minimal. The volume of water expelled from the sampler and the total volume of water of the profile were calculated as follows:

$$\text{VWES (cm}^3\text{)} = (\text{Dp} - \text{Ls}) \times 3.14 \times r^2 \quad (1)$$

where VWES = volume of water expelled from the sampler; Dp = depth reached by sampler (cm); Ls = length of sample removed from sampler (cm); and r = radius of the sampler cylinder (2.5 cm).

$$\text{TVWP (cm}^3\text{)} = (\text{VWES} + \text{VWS}) \quad (2)$$

where TVWP = total volume of water in the profile; and VWS = volume of water in the sample, using the gravimetric method (Embrapa, 2006).

Using the values of area, volume and the levels of moisture and organic matter from each peat section, the organic matter (OM) mass and the volume of water stored in the peat (TVW) were calculated as follows:

$$\text{TVW} = \text{TVS} \times \Sigma\,(\text{TVWP})/(\Sigma\,\text{Dp} \times 0.0785) \quad (3)$$

where TVW = Total volume of water in the section (m^3); TVS = Total volume of the section calculated using ArcGis 9.2 software (m^3); TVWP = total volume of water of the profile (m^3); and Dp = depth of the profile samples (m); and

$$\text{OM} = \{[\text{VS}\,(\Sigma\text{Ls} \times 0.01963 \times \text{Sd} \times \text{OMC}/100]/\Sigma\text{Vs}\}/1000 \quad (4)$$

where OM = organic matter mass of the section (t); VS = volume of the section (m^3); Ls = length of the sample (cm); OMC = organic mass content (dag kg^{-1}); Sd = soil density (g cm^{-3}); and Vs = volume sampled (m^3).

Physical characterization of the peatland

The peatland was physically characterized in a sample from the surface to the basal substrate (Campos et al., 2010). The sample was homogenized and three sub-samples were collected for physical analysis. Results refer to the mean of the three sub-samples.

The rubbed fiber (RF), soil density (Sd), mineral material (MM), moisture (Moi), color by sodium pyrophosphate, and organic material decomposition were determined according to von Post's scale and to the procedures outlined by Embrapa (2006). Organic matter levels were determined by the gravimetric method; samples were incinerated in a muffle furnace at 600 °C for 12 h (Embrapa, 2006).

Water balance of the watershed of Córrego das Pedras

The monthly rainfall and temperature data were obtained from the historical series (1993–2002) in the Climatologic Station of National Institute of Meteorology (INMET) in Diamantina (Neves et al., 2005). The evapotranspiration data was obtained according to the method proposed by Hargreaves & Christiansen (1973). This method has an appropriate accuracy for environmental studies and requires data on temperature, humidity and latitude (Gavilán et al., 2006; Borges & Mendiondo, 2007).

The area of the watershed Córrego das Pedras drains into the peatland studied here, which has an area of 668 ha, which was determined using a topographic map from the IBGE (Brazilian Institute of Geography and Statistics) 1:100.000, Diamantina page (IBGE, 1977). The average monthly rainfall (RF) was calculated as a function of the area of the watershed, while evapotranspiration (EP) volume was calculated using precipitation and evapotranspiration data, respectively. The average monthly water flow rate was estimated from the water deficit or excess in that month, calculated from the monthly difference between the RF and EP. The water balance of the basin was calculated according to the model proposed by Pereira (2005).

Statistical analysis

The variables Moi, RF, MM, Sd and OM were subjected to principal component analysis (PCA) where two components were selected: Component 1 accounted for 78.88 % of the variance and component 2 for 11.70 % (Boruvka et al., 2005).

The correlation between variables was estimated by the Pearson correlation coefficient (r). The significance of r was estimated by the Student test F at a probability of 1 %.

RESULTS AND DISCUSSION

Chemical and morphological properties and soil classification

The Histosols of the peatland in the EPA Pau-de-Fruta were sampled and described at 106 sites, of which 5.6 % contained RF levels that were greater than or equal to 400 g kg^{-1}, with a Munsell color change of 10YR 7/1, caused by sodium pyrophosphate, and were classified as Hydric Haplofibrists (Estados Unidos, 1999) and Organossolo Háplico fíbrico típico (Embrapa, 2006) (Table 1). At 28.3 % of the sites, the RF levels varied between 170 and 400 g kg^{-1}, while the

Table 1. Average values of physical and chemical parameters of the transects sampled from the peatland in the environmental protection area of Pau-de-Fruta

Transect	Nr. of Points	Color by Pyrophosphate	von Post(1)	RF(2)	Sd(3)	MM(4)	OM(5)
		Munsell		g kg^{-1}	g cm^{-3}	—— g kg^{-1} ——	
1	14	10YR 4/3	Saprists	180	0.37	550	482
5	4	10YR 2/1	Saprists	60	0.13	210	663
9	2	10YR 4/6	Hemists	150	0.80	530	160
13	3	10YR 3/3	Hemists	170	0.45	740	194
17	9	10YR 3/3	Saprists	298	0.82	884	151
21	12	10YR 3/3	Saprists	131	0.25	428	576
25	19	10YR 2/2	Saprists	154	0.34	481	523
29	12	10YR 2/1	Saprists	72	0.15	377	622
33	10	10YR 7/1	Fibrists	165	0.43	484	530
37	8	10YR 2/2	Saprists	85	0.23	338	662
41	9	10YR 2/1	Saprists	240	0.55	621	356
45	4	10YR 7/3	Hemists	225	1.10	765	154
Average	9			161	0.46	534	482
Standard deviation				70.41	0.30	193.23	207.83

(1) Organic matter decomposition scale according to von Post´s scale (Embrapa, 2006). (2) Rubbed fibers. (3) Soil density. (4) Mineral material. (5) Organic matter.

Munsell color varied between 10YR 7/3 and 10YR 3/3. Consequently, these samples were classified as Hydric Haplohemists (Estados Unidos, 1999) and Organossolo Háplico hêmico típico (Embrapa, 2006) (Table 1). The great majority, 66.1 %, contained RF levels below 170 g kg^{-1}, and Munsell color between 10YR 2/1 and 10YR 4/3, and were therefore classified as Typic Haplosaprists (Estados Unidos, 1999) and Organossolo Háplico sáprico típico (Embrapa, 2006) (Table 1). The predominance of Typic Haplosaprists shows the high degree of pedogenetic evolution in this peatland.

There were large variations in soil density (Sd) at the study site. The average values observed in the transects varied between 0.13 and 1.10 g cm^{-3}, with a mean value of 0.46 g cm^{-3} (Table 1). Sd was negatively correlated with the levels of OM (r = -0.79) and with RF (r = - 0.48) and positively with mineral material (MM) (r = 0.78) (Figure 3), in agreement with previously published data by Silva et al. (2009a,); and Campos et al. (2010).

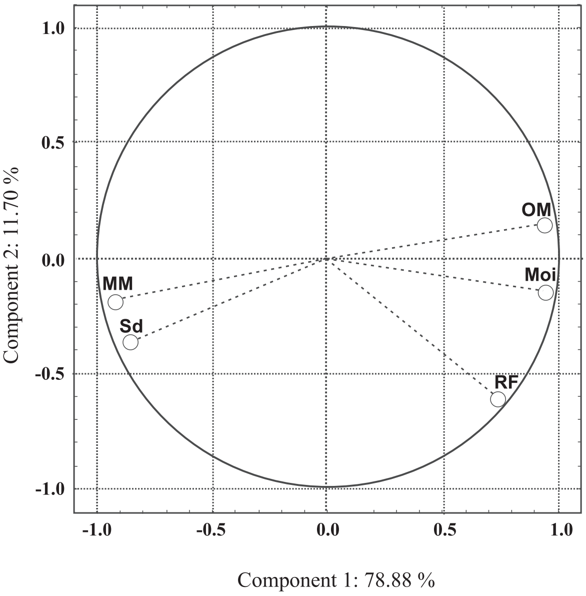

Figure 3. Correlation Circle of variables measured in the Principle component Analysis - rubbed fiber (RF), soil density (Sd), mineral material (MM), and moisture (Moi), organic matter (OM).

This variation in Sd is caused mainly by sedimentary processes, since the peatland is located in a lower part of the landscape and, in some places, receives sandy sediments from the higher parts of the landscape. Another important factor is that points along the edges of the mire have lower OM than MM levels, resulting in higher Sd values (Campos et al., 2011).

The average OM levels in the transects were between 151 and 663 g kg^{-1} soil, with a mean value of 482 g kg^{-1} (Table 1).

The results of PCA showed that OM correlated positively with Moi and RF (r = 0.84) and strongly and negatively with MM (r = - 0.83) and Sd (r = -0.71) (Figure 3). This occurs because, in the most humid layers, the microbial activity is less intense due to the low levels of dissolved oxygen, providing a greater accumulation of organic material and preserving the characteristics of the source material, in this case, plant fibers (Silva et al., 2009a; Campos et al., 2010; Horak, 2010).

Water in the peatland ecosystem

The greatest values of TVWP and VWES were observed at the deepest peat sites, which present much higher values of moisture content. Sample compaction as well as OM levels were lower at the shallow sites (Table 2).

The depth of the peat was positively correlated with the moisture levels (r = 0.82, significant by the *t* test - $p < 0.01$) and with TVWP (r = 0.99, significant by the *t* test - $p < 0.01$), indicating that the relief and slope, as well as the rainfall level in the area were the main factors controlling the water dynamics in this environment (Moore, 1997). Since the study area was flat and depressed, there is a direct relationship between the depth and water dynamics of the peatland in the EPA Pau-de-Fruta. According to Rydin & Jeglum (2006), the water storage properties of the acrotelm stabilize the water table and maintain it close to the surface, which is a requirement for the continued development of vegetation in the peat-forming cycle.

The peatland in the EPA Pau-de-Fruta covers a total area of 81.7 ha and the histosols occupy a total volume of 595,000 m^3, with an average depth of 0.22–1.50 m between sections (Table 3).

The total volume of water withheld by the peat is 497,767 m^3 (Table 3), accounting for approximately 83.7 % of the total volume of the peatland. These values are similar to those observed in peatlands of the northern hemisphere, where water is estimated to occupy an average of approximately 90 % of the total volume of the peatland (Holden & Burt, 2003; Rieley et al., 2008; Vitt et al., 2009).

Organic matter accumulation

Under natural conditions, an average of 10 % of peat consists of solid material formed by plant fibers, moss, roots, flowers and pollen, among other materials (Moore, 1997; Holden & Burt, 2003; Campos et al., 2011). In the peatland studied here,

Table 2. Sample characteristics, including average depth, sampling season, average sample compaction, volume of water in the sample (VWS), moisture, volume of water expelled from the sampler (VWES) and total volume of water in the profile (TVWP)

Transect	Average depth	Average compression	WC	VWS	VWES	TVWP
	cm	%	g kg^{-1}	cm^3		
1	112.4	60.2	4,380	636.8	1,264.4	1,901.2
5	131.3	51.4	5,020	1,054.0	1,324.7	2,378.7
9	30.5	0.0	500	352.9	0.0	352.9
13	63.7	44.6	810	299.3	556.0	855.3
17	25.6	0.0	510	261.5	0.0	261.5
21	98.2	3.2	6,930	1,555.2	60.5	1,615.7
25	132.6	42.5	7,040	1,100.7	1,105.2	2,205.9
29	122.5	58.0	7,230	786.7	1,395.0	2,181.7
33	104.5	55.7	6,230	675.6	1,142.2	1,817.8
37	106.3	53.2	6,450	771.1	1,108.8	1,879.9
41	88.3	39.0	1,880	572.6	676.0	1,248.6
45	86.3	59.4	1,380	424.1	1,005.8	1,429.9
Average	91.9	38.9	4,030	702.3	808.5	1,510.8
Standard deviation	35.65	23.79	2,802.17	383.20	505.74	319.73

Table 3. Area, average depth, total volume of water and organic matter (OM) mass in sections of the peatland in the environmental protection area of Pau-de-Fruta

Section	Area	Average depth	Volume of the section		Water volume	OM		
	ha	m	m^3		m^3 ha^{-1}	g kg^{-1}	t	t ha^{-1}
1	11.5	1.2	96,102	85,862	7,466	482	5,403	470
2	3.3	0.2	5,825	5,279	1,600	663	282	85
3	4.5	0.3	7,929	4,675	1,039	160	857	190
4	3.1	0.2	5,767	3,947	1,316	194	273	91
5	6.8	0.7	38,981	20,323	2,989	151	4,884	718
6	8.2	0.6	39,791	33,371	4,120	576	4,673	577
7	12.1	1.3	127,199	107,840	8,987	523	10,034	836
8	7.3	1.5	87,139	79,080	10,833	622	3,109	426
9	6.7	1.1	59,399	52,649	7,858	530	4,379	654
10	7.2	0.9	54,062	48,740	6,769	662	3,419	475
11	6.8	0.8	44,201	31,835	4,682	356	5,799	853
12	4.2	0.8	28,605	24,165	5,894	154	2,035	496
Average		0.9			6,092			552
Standard deviation		0.43			3,202.10			262.14
Total	81.7		595,000	497,767			45,148	

the total volume of solid material represented 16.3 % of the peatland. In this case, the highest level of solid material in the peatland in the EPA Pau-de-Fruta is possibly due to the influence of the soil along the edges of the peat, which are shallower and have lower OM and higher MM levels.

The total mass of OM stored in the 81.7 ha peatland was 45.148 t, corresponding to an average accumulation of 552 t ha^{-1}. However, in the deepest sections of the peatland, storage levels in the OM can reach 853 t ha^{-1}, while storage levels in the shallow areas were as low as 85 t ha^{-1} (Table 3). According to Mitsch & Gosselink (1993), hydrology controls the chemical and biotic processes in peatlands and may be the most important process regulating wetland function and development. The hydrology of peatlands influences landform development by regulating interactions among vegetation, and OM stock (Mitsch & Gosselink, 1993; Reeve et al., 2000).

The water in the Córrego das Pedras basin

The water balance in the Córrego das Pedras basin is positive for five months of the year, and is negative in the other seven (Table 4). This indicates that for seven months of the year, the volume of water lost to the atmosphere is greater than the water volume entering the system. However, this water deficit is compensated between November and March, when the pluvial precipitation is higher than the evapotranspiration volume. The annual balance calculated for the basin indicated water excess in the order of 641.354 m^3 (Table 4).

As indicated by the water balance, the values of the estimated water flow (Table 4) were negative between April and October, suggesting that the Córrego das Pedras basin could dry up in this period. However, a study by Copasa (Sanitation Department of the State of Minas Gerais; 2009) showed that at an inflow at the treatment plant of the EPA Pau-de-Fruta, the Córrego das Pedras basin has a minimal water flow rate of 35 L s^{-1} and a maximum of 424 L s^{-1}. The average monthly flow rate calculated in this study for months with water excess is within the interval determined by Copasa (2009), with the exception of December, which is slightly higher than the maximum flow.

The relationship between water flow and volume change in peatland has been examined in the laboratory (Ilnicki, 1967; Graham & Hicks, 1980; Szymanowski, 1993) and in the field (Szuniewicz, 1989; Gilman, 1994; Oleszczuk et al., 1999). All the aforementioned authors found that the complex system of pores formed by fibers at different stages of decomposition has a high capacity to retain water and acts directly as a regulator of water flow in the environment.

The calculated annual average water flow rate is 20.6 L s^{-1} and is below the minimum flow value determined by Copasa (2009). The peatland in the EPA Pau-de-Fruta drains 686 ha of the watershed Córrego das Pedras, which corresponds to 59.6 % of the retention capacity of the basin 1,1050 ha (Copasa, 2009). For the whole basin, the calculated annual average is 35.0 L s^{-1}, indicating that the estimates are accurate. These results are in agreement with other studies (Brooks, 1992; Verry, 1997), which mention that peatlands are of particular interest for water resource management because they occur extensively in the headwater

Table 4. Average monthly meteorological data of the inflow area of peatland in the environmental protection area of Pau-de-Fruta

Month	RH(1)	Temperature(2)	MR(3)	PE(4)	RF(5)	EP(6)	RF-EP(7)	WF(8)
	%	ºC	mm		m^3			L s^{-1}
Jan.	81	21.3	231.4	134.8	1,587,404	924,809	662,595	255.6
Feb.	78	18.9	134.4	115.3	921,984	790,901	131,083	50.6
Mar.	83	20.2	211.7	103.0	1,452,262	706,376	745,885	287.8
Apr.	79	19.7	48.7	91.2	334,287	625,578	-291,290	-112.4
May	78	17.2	21.3	74.6	146,118	511,486	-365,368	-141.0
Jun.	75	17.3	5.3	69.4	36,220	476,380	-440,159	-169.8
Jul.	75	16.1	4.1	72.4	27,920	496,887	-468,967	-180.9
Aug.	69	16.8	15.4	97.5	105,712	669,157	-563,444	-217.4
Sep.	72	18.5	33.7	114.0	231,044	781,938	-550,893	-212.5
Oct.	73	20.0	107.2	139.9	735,529	959,742	-224,212	-86.5
Nov.	83	19.0	237.2	114.4	1,627,192	784,923	842,268	324.9
Dec.	83	20.5	301.0	131.3	2,064,860	901,000	1,163,859	449.0
Total	-	-	1,351.4	1,257.8	9,270,535	8,629,180	641,354	-
Annual average	77	18.8	112.6	104.8	-	-	-	20.6
Standard deviation	4.68	1.64	107.38	24.45				242.48

(1) RH: relative humidity. (2) Temperature: average monthly temperature. (3) MR: monthly average rainfall. (4) PE: average monthly potential evapotranspiration. (5) RF: average monthly rainfall volume. (6) EP: average monthly evapotranspiration volume. (7) RF-EP: balance between RF and EP in the watershed in Córrego das Pedras. (8) WF (water flow rate): average monthly water flow rate estimated for this body of water. (1) (2) and (3) Neves et al. (2005). (4) Calculated according to methods described by Hargreaves & Christiansen (1973).

areas of many streams and rivers. Peatlands can have large impacts on the quantity and quality of the water courses they feed.

The elevated capacity of water retention and the sponge-like behavior (Ingram, 1983; Holden & Burt, 2003) of the peatland in the EPA Pau-de-Fruta suggest that this area has direct effects on the monthly flow regulation of the Córrego das Pedras stream. Excess water is stored from November through March, and prevents the stream from drying out between April and October.

According to Rydin & Jeglum (2006), the response of peatlands to heavy rainstorms is different from that of mineral upland soils. The mild relief, the absence of well-defined channels and the shallow water tables all combine to make peatlands behave hydrologically like unregulated, shallow reservoirs. Some peatlands regulate the water flow of a landscape by attenuating the flow under wet conditions and releasing water under dry conditions.

The peatland in the EPA Pau-de-Fruta stores 497,767 m^3 of water in its 81.7 ha area (Table 4) which represents 11.9 % of the area covered by the Córrego das Pedras basin. The volume of water stored by this peatland corresponds to 77.6 % of the annual excess of water received by the capture area.

The high capacity of water retention and high levels of organic matter are characteristics of peatlands that make this ecosystem an important regulator of water flow (Ilnicki, 1967; Holden & Burt, 2003). Moreover, this high capacity of water retention reinforces the environmental and social importance of the peatland in the EPA Pau-de-Fruta.

CONCLUSIONS

The peatland in the environmental protection area of Pau-de-Fruta occupies 81.7 ha, storing 45,148 t of organic matter (552 t ha^{-1} of OM) and 595,000 m^3 of water (6,092 m^3 ha^{-1}). The peatland covers 11.9 % of the area corresponding to the watershed of Córrego das Pedras and stores 77.6 % of the annual water excess of this basin. It also plays an important role in maintaining the water flow of the Córrego das Pedras basin, besides acting as an important environment for carbon storage.

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LITERATURE CITED

BORGES, A.C. & MENDIONDO, E.M. Comparação entre equações empíricas para estimativa da evapotranspiração de referência na Bacia do Rio Jacupiranga. R. Bras. Eng. Agric. Amb., 11:293-300. 2007.

BORUVKA, L.; VACEK, O. & JEHLICKA, J. Principal component analysis as a tool to indicate the origin of potentially toxic elements in soils. Geoderma, 128:289-300, 2005.

BROOKS, K.N. Surface hydrology. In: WRIGHT, H.E.; COFFIN, B.A. & BASSENG, N.E.P., eds. The patterned peatlands of Minnesota. Minnesota, University of Minnesota Press, 1992.

CAMPOS, J.R.R. Caracterização, mapeamento, volume de água e estoque de carbono da turfeira da área de proteção ambiental Pau-de-Fruta, Diamantina – MG. Diamantina, Universidade Federal dos Vales do Jequitinhonha e Mucuri, 2009. (Tese de Mestrado)

CAMPOS, J.C.; SILVA, A.C.; VIDAL-TORRADO, P. & FERREIRA, M.M. Water retention in a peatland containing organic matter in different decomposition stages, Brazil. R. Bras. Ci. Solo, 35:943-950, 2011.

CAMPOS, J.R.R.; SILVA, A.C.; VASCONCELOS, L.L.; SILVA, D.V.; ROMÃO, R.V.; SILVA, E.B. & GRAZZIOTTI, P.H. Pedochronology and development of peat bog in the environmental Protection Area Pau-de-Fruta – Diamantina, Brazil. R. Bras. Ci. Solo, 34:1965-1975, 2010.

COMPANHIA DE SANEAMENTO DE MINAS GERAIS – COPASA. Programa de Ação Social em Saneamento PASS/BID. Projeto Básico do Sistema de Abastecimento de Água de Diamantina. Diamantina, 2009. v.1.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. Centro Nacional de Pesquisa de Solos. Sistema Brasileiro de Classificação de Solos. Brasília, Embrapa Produção de Informação; Rio de Janeiro, Embrapa Solos, 2006. 306p.

ESTADOS UNIDOS. United States Department of Agriculture. Natural Resources Conservation Services. Soil taxonomy: A basic system of soil classification for making and interpreting soil survey. 2.ed. Washington, D.C., 1999. 869p. (Agricultural Handbook, 436)

GAVILÁN, P.; LORITE, I,J.; TORNERO, S. & BERENGENA, J. Regional calibration of Hargreaves equation for estimating reference ET in a semiarid environment. Agric. Water Manag., 81:257-281, 2006.

GILMAN, K. Hydrology and wetland conservation. Chichester, John Wiley & Sons, 1994. 101p.

GRAHAM, R.B. & HICKS, W.D. Some observations on the changes in volume and weight of peat and peat moss with loss of moisture. In: INTERNATIONAL PEAT CONGRESS, 6., Duluth, 1980. p.554-558.

HARGREAVES, G.H. & CHRISTIANSEN, J.E. Production as a function of moisture availability. In: GORE, A.J.P., ed. Ecosystems of the world 4A, mires: Swamp, bog, fen and moor. Oxford, Elsevier, 1973. p.67-158.

HOLDEN, J. & BURT, T.P. Hydraulic conductivity in upland blanket peat: Measurement and variability. Hydrol. Process, 17:1227-1237, 2003.

HORAK, I. Relações pedológicas, isotópicas e palinológicas na reconstrução paleoambiental da turfeira da Área de Proteção Especial (APE) Pau-de-Fruta, Serra do Espinhaço Meridional - MG. Piracicaba, Escola Superior de Agricultura Luiz de Queiroz, 2010. 281p. (Tese de Mestrado)

ILNICKI, P. Shrinkage of peat soils during drying depends on soil structure and physical properties. Zeszyty Problemowe Postepow Nauk Rolniczych, 76:197-311, 1967.

INGRAM, H.A.P. Hydrology. In: GORE, A.J.P., ed. Ecosystems of the World 4 A, mires**,** swamp, bog, fen and moor. Oxford, Elsevier, 1983. p.67-158.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. Carta Topográfica de Diamantina, Folha SE-23-Z-B-I. Escala de 1:100.000. Diamantina, 1977.

MITSCH, W. & GOSSELINK, J. Wetlands, 2º.ed. Van Nostrand Reinhold, 1993. 722p.

MOORE, D.P. Bog standards in Minnesota. Nature, 386:655-657, 1997.

NEVES, S.C.; ALMEIDA-ABREU, P.A. & FRAGA, L.M.S. Fisiografia. In: SILVA, A.C.; PEDREIRA, L.C.V.S.F. & ALMEIDA-ABREU, P.A, eds. Serra do Espinhaço Meridional: Paisagem e ambiente. Belo Horizonte, O Lutador, 2005. p.137-147.

OLESZCZUK, R.; SZATYLOWICZ, J. & BRANDYK, T. Prediction of vertical peat-moorsh soil profile movements caused by moisture content changes. Roczniki Akad. Rolniczej Poznaniu CCCX, Melioracje i Inzynieria Srodowiska, 20:139-150, 1999.

PEREIRA, M.G.; ANJOS, L.H.C. & VALLADARES, G.S. Organossolo: Ocorrência, gênese, classificação, alterações pelo uso agrícola e manejo. In: VIDAL-TORRADO, P.; ALLEONI, L.R.F.; COOPER, M.; SILVA, A.P. & CARDOSO, E.J., eds. Tópicos em ciência do solo. Viçosa, MG, Sociedade Brasileira de Ciência do Solo. 2005. v.4. p.233-277.

PEREIRA, A.R. Simplifying the Thornthwaite-Mather water balance. Bragantia, 64:311-313, 2005.

REEVE, A.S.; SIEGEL, D.I. & GLASER, P.H. Simulating vertical flow in large peatlands. J. Hydrol., 227:207-217, 2000.

RIELEY, J.O.; WUST, R.A.J.; JAUHIAINEN, J..; PAGE, S.E.; WOSTEN, H.; HOOIJER, A.; SIEGERT, F.; LIMIM, S.H.; VASANDER, H. & STAHLHUT, M. Tropical Peatlands: Carbon stores, carbon gas emissions and contribution to climate change processes. In: STRACK, M., ed. Peatlands and climate change. Calgary, Peat Society, 2008. p. 44-70.

RIBEIRO, J.F. & WALTER, B.M.T. Fitofisionomias do Bioma Cerrado. In: SANO, S.M. & ALMEIDA, S.P., eds. Cerrado: Ambiente e flora. Planaltina, Embrapa. 1998. p.89-166.

RYDIN, H. & JEGLUM, J.K. The biology of Peatlands. New York, Oxford University Press, 2006. 353p.

SAADI, A.A. Geomorfologia da Serra do Espinhaço em Minas Gerais e de suas margens. Belo Horizonte. Geonomos, 3:41-75, 1995.

SILVA, A.C. Solos. In: SILVA, A.C.; PEDREIRA, L.C.V.S.F. & ALMEIDA-ABREU, P.A., eds. Serra do Espinhaço Meridional: Paisagens e ambientes. Belo Horizonte, O Lutador, 2005. p.50-78.

SILVA, A.C.; HORAK, I.; MARTINEZ-CORTIZAS, A.; VIDAL-TORRADO, P.; RODRIGUES-RACEDO, J.; GRAZZIOTTI, P.H.; SILVA, E.B. & FERREIRA, C.A. Turfeiras da Serra do Espinhaço Meridional - MG. I – caracterização e classificação. R. Bras. Ci. Solo, 33:1385-1398, 2009a.

SILVA, A.C.; HORAK, I.; VIDAL-TORRADO, P.; MARTINEZ-CORTIZAS, A.; RODRIGUES-RACEDO, J. & CAMPOS, J.R.R. Turfeiras da Serra do Espinhaço Meridional - MG. II – Influência da drenagem na composição elementar das substâncias húmicas. R. Bras. Ci. Solo, 33:1399-1408, 2009b.

SILVA, I.R. & MENDONÇA, E.S. Matéria orgânica do solo. In: NOVAIS, R.F.; ALVAREZ V., V.H.; BARROS, N.F.; FONTES, R.L.F.; CANTARUTTI, R.B. & NEVES, J.C.L., eds. Fertilidade do Solo. Viçosa, MG, Sociedade Brasileira de Ciência do Solo, 2007. p.374-470.

STEVENSON, F.J. Humus chemistry: Genesis, composition and reaction. 2.ed. New York, John Wiley & Sons, 1994. 496p.

SZUNIEWICZ, J. Pulsation retention and formation of water conditions in dry years in reclamated sedge-moss peats. Wiadomosci Instytutu Melioracji i Uzytkow Zielonych, 2:169-183, 1989.

SZYMANOWSKI, M. Shrinkage of low-ash peat soils and evaluation of moisture under the field conditions, using curves of water sorption. Wiadomosci Instytutu Melioracji i Uzytkow Zielonych, 3:175-189, 1993.

VERRY, E.S. Hydrological processes of natural, northern forested wetlands. In: ED, C.C.; TRETTIN, M.F.; JURGENSEN, D.F.; GRIGAL, M.R. & GALE, J.K., eds. Northern forested wetlands: Ecology and management. Boca Raton, CRC Press, 1997. p.163-88.

VITT, D.H.; WIEDER, R.K.; SCOTT, K. D. & FALLER, S. Decomposition and peat accumulation in rich fens of Boreal Alberta, Canada. Ecosystems, 12:360-373, 2009.