TECHNICAL PAPER

POTENTIAL OF UTILIZATION OF RAIN WATER EXCESS FOR IRRIGATION OF GREEN ROOFS IN MATO GROSSO, BRASIL

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ABSTRACT: The aim of this study was to identify the relation between the evapotranspirometer demand and the supply of water from local rainfall, evaluating the possibility of using water excess for irrigation of Green Roofs in the State of Mato Grosso, in Brazil. The study was done using a series of historical data provided by the National Institute of Meteorology (INMET – Instituto Nacional de Meteorologia) which has official climatological stations in 12 cities and regions of the State. The evapotranspiration values were obtained by the Penman-Monteith method and by the Climatic Water Balance (CWB) by the Thornthwaite and Mather method using Available Water Capacity (AWC) of 12mm. With the CWB the excess and deficit were calculated, which were used for the estimative of the volume and area of a reservoir as a function of a collector area of a roof of 100m^2 and the volume of supplementary water for irrigation. With the obtained results, it was found that in most investigated regions of the State the use of green roofs is not compromised by the water deficiency. On the other hand, the use of a reservoir to accumulate the rain water excess may be impractical, because it requires a considerable area for installation and also because of the high cost of the land.

KEYWORDS: water balance, rainfall and sustainability.

POTENCIAL DE APROVEITAMENTO DO EXCESSO DE ÁGUA DA CHUVA PARA IRRIGAÇÃO DE TELHADOS VERDES EM MATO GROSSO

RESUMO: O objetivo do presente trabalho foi identificar a relação que há entre a demanda evapotranspirométrica e a oferta de água da precipitação local, avaliando a possibilidade da utilização do excesso da água para irrigação de Telhados Verdes no Estado de Mato Grosso (MT). O trabalho foi realizado utilizando uma série de dados históricos disponibilizados pelo INMET – Instituto Nacional de Meteorologia, que possui estações climatológicas em 12 regiões do Estado. Os valores de evapotranspiração foram obtidos pelo método de Penman-Monteith, e o Balanço Hídrico Climatológico (BHC), pelo método de Thornthwaite e Mather, utilizando uma Capacidade de Água Disponível (CAD) de 12 mm. Pelo BHC, foi calculado o excesso e o déficit, os quais foram utilizados para a estimativa do volume e da área de um reservatório em função da área coletora de um telhado de 100 m^2, tal como o volume de água complementar para irrigação. Com os resultados obtidos, constatou-se que ,na maioria das regiões estudadas do Estado, o uso de Telhados Verdes não é comprometido pela deficiência hídrica. Por outro lado, a utilização de um reservatório para acumular o excesso de água da chuva pode ser inviável, pois requer uma área considerável para instalação e também pelo elevado custo da terra.

PALAVRAS-CHAVE: balanço hídrico, precipitação e sustentabilidade.

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Recebido pelo Conselho Editorial em: 3-6-2011
Aprovado pelo Conselho Editorial em: 29-11-2011

INTRODUCTION

The difficulties of water scarcity, linked to misuse of potable water that reaches households, allude the study of alternative solutions to this problem. Among the most studied alternative sources there are two that stand out currently: the use of wastewater and rainwater catchment, which is considered the most viable. According to the United Nations Food and Agriculture Organization (FAO, 2008), the growth of water consumption has been more than twice the population growth of the last century. The forecast is that in 2025, about 1.8 billion people will live in regions with absolute water scarcity and two-thirds of the population will face problems with lack of this good. The advantages of the use of rainwater are many. Pluvial water represents an alternative source with reasonable quality mainly for non-potable use such as washing sidewalks and garden irrigation. Thus, the use of rainwater also helps to decrease the consumed volume of water treated, also generating savings in the treatment system and water bill of the user.

Water scarcity is mainly a consequence of population growth and pollution of water sources, the growing waste, industrial expansion and climate change, therefore, alter the distribution of rainfall regime.

The use of Green Roofs began in Germany around 1950, becoming popular all over the world, especially by the ecological appeal. According to BOCK (2008), in the United States and in Germany there are already more than 2000 companies specialized in this type of construction, and in Germany there are already 14 million square meters of roofs with grass cover. This type of coverage has been used in many countries mainly for improving environmental comfort and aesthetic purposes of valorization of the urban space.

In Brazil, the practice of Green Roofs is not widespread, but there are companies specializing in the installation of these roofs, offering different options for various types of construction. According to MELLO et al., (2010), the Green Roof is made in layers, consisting essentially of supporting structure, waterproofing layer, drainage layer, soil or substrate, cover against erosion, vegetation usually of grasses.

The use of Green Roofs has the disadvantage of the need for constant irrigation especially in the dry season. In contrast, this technology contributes to the cleaning of rainwater, reducing pollution, reducing carbon emissions, improving the thermal and acoustic comfort, lowering the temperature of the micro and macro external environment (CASTRO, 2008 apud MELLO et at., 2010).

According to the same author, the use of this type of coverage also contributes to the interception of part of the precipitation decreasing the superficial runoff, which can be used on a large scale to reduce the problem of flooding which are common in big cities like São Paulo and Curitiba, in Brazil.

In Brazil, especially in the state of Mato Grosso, throughout the year occur two well defined seasons: a rainy season and a dry one, and may have a water deficit or excess in the annual water balance. According to CAMPOS & SILVA (2010) through the Water Balance is possible to determine the regions with a water deficit or excess, using variables such as precipitation and evapotranspiration. However, according to SILVA et al., (2006), "the water balance is important to follow the dynamics of water in agricultural and natural ecosystems. They indicate, in space and time, the conditions under which plants grow and develop."

The Climatic Water Balance (CWB) of THORNTHWAITE & MATHER (1955) is used to account for the water excess and deficit and it can be applied to climatic classification, define land use and agricultural practices, as well as environmental and hydrological characterization studies for water management (DOURADO-NETO et al., 2010). According to PEREIRA (2005), to prepare the CWB, it is necessary to obtain three basic information: define the storage capacity of water in the soil (AWC), the estimate of potential evapotranspiration of each period and have the measure of the total rainfall.

Therefore, the aim of this study was to evaluate the possibility of using water excess for irrigation of Green Roofs in the state of Mato Grosso, in Brazil.

MATERIAL AND METHODS

The state of Mato Grosso has a geographical area of 903,329.700 km^2 located in the central west region of Brazil and it has 141 cities with a population of 3,033,991 inhabitants (IBGE, 2010). It has an extensive drainage system, which comprise much of the two major basins of Brazil, Amazon and Platinum. The state has three ecosystems, the cerrado, the Pantanal and the Amazon rainforest. The climate is tropical, hot and sub-humid, with rainfall mainly concentrated in the months of January, February and March with average annual temperatures ranging from 24ºC to 42ºC. "The state is considered the largest expanding agricultural frontier in Brazil, where are tourism as well, because the region is very rich in natural resources" (MISSAWA, 2008).

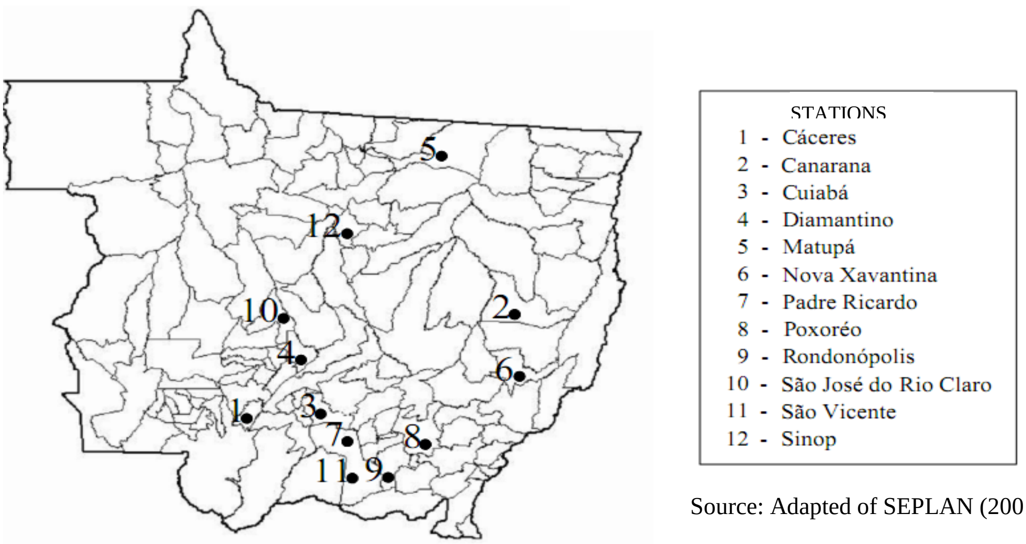
Table 1 shows the time intervals studied in each of the weather stations.

TABLE 1. Series of historical data of each studied region. Cáceres (a), Canarana (b), Cuiabá (c), Diamantino (d), Matupá (e), Nova Xavantina (f), Padre Ricardo (g), Poxoréo (h), Rondonópolis (i), São José do Rio Claro (j), São Vicente (k) and Sinop (l).

Stations	a	b	c	d	e	f	g	h	i	j	k	l
Period	1979 to 2009	1995 to 2009	1979 to 2009	1979 to 2009	1987 to 2009	1988 to 2009	1987 to 2009	1979 to 2009	1995 to 2009	1998 to 2009	1998 to 2009	1979 to 2009
Total	30	14	30	30	22	21	22	30	14	11	11	30

It was chosen to use the series with different sizes because the effect of this study has application to the urban area, being punctual. For each study area, it was used the maximum available data; limited to those 30 years in the series that exceeded this value.

The data are from the National Institute of Meteorology (INMET - Instituto Nacional de Meteorologia), which has weather stations distributed throughout the state, as shown in Figure 1.



Source: Adapted of SEPLAN (2001).

FIGURE 1. Location of the Climatologic Stations of the State of Mato Grosso.

To the agricultural planning was used one AWC of 50 to 150mm depending on the effective depth of the root system and soil depth (LEIVA et al., 2006; PORTELA et al., 2008; HEINEMANN et al., 2009). However, since the technique requires a green roof substrate in thin layer, there is no need to drastically reduce this value. Hence, in this study was used a AWC of 12mm.

It was considered as a support substrate for vegetation on the roof, a layer of soil of 8cm thickness, this being within the range recommended by MELLO et al. (2010) CORMIER & PELLEGRINO (2008), who suggest a thickness between the limits of 5 and 15cm. The study considered the use of grass as vegetation mainly for its low maintenance and resistance to drought, as well as being the species most recommended for this application.

It was performed the Climatic Water Balance considering the averages of temperature and precipitation using the method of Thornthwaite and Mather (1955). The evapotranspiration was calculated by Penman-Monteith method (MONTEITH, 1973) recommended by FAO (SMITH, 1991).

There is no available literature and information about the average area of the roofs of homes of Mato Grosso, therefore was considered in this study a hypothetical house of 100m^2 of Green Roof Area (GRA), the same being surrounded by a system of rain gutters to the collection of rain water runoff. With the amounts of excess (EXC) obtained from CWB it can dimension the volume of an accumulation reservoir to store water for the deficit period (DEF). The Reservoir Volume (RV) was obtained by Equation 1.

$$RV = EXC * GRA \quad (1)$$

in which,

RV – Reservoir volume in L;
EXC - Excess extracted from the CWB in mm = L.m^{-2} and
GRA – Green Roof Area which contributes to the rain water runoff, in m^2.

It was also estimated the Water Complementary Volume (WCV) to attend the demand of the Green Roof during the drought period, in cases in which the deficit was higher than the excess or in which there was no excess. The WCV was obtained by the Equation 2.

$$WCV = (EXC - DEF)*GRA \quad (2)$$

in which,

WCV - Water Complementary Volume, in L;
EXC - Excess extracted from the CWB, in mm;
DEF - Deficit extracted from the CWB, in mm and
GRA - Green Roof Area, in m^2.

It was considered for the reservoir a maximum depth of 5m to minimize the effect of pump cavitation and excessive variation of the manometric height. It was estimated the Diameter (D) of the reservoir of circular section and the Width (W) of the reservoir of square section along with the surface area of the reservoir (SAR).

RESULTS AND DISCUSSION

Figure 2 shows the average rainfall for each of the 12 studied regions, which shows that the annual rainfall ranges from 1267mm in Cáceres to 2012mm in Matupá. Cáceres, the region with the lowest rainfall in this study, is located in the left margin of the Paraguay River and marks the beginning of the Pantanal of Mato Grosso. Matupá is already above the Parallel 13 in the Amazon biome. These data show the climate diversity of the state of Mato Grosso.

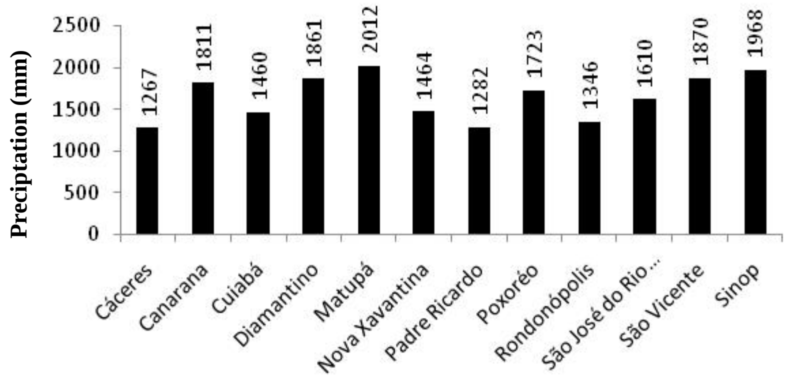


FIGURE 2. Rainfall averages for each region.

Figure 3 shows the extract of Climatic Water Balance of the studied regions. Observe the dry and rainy seasons well defined, leading to a period of drought concentrated between the months from April to December.

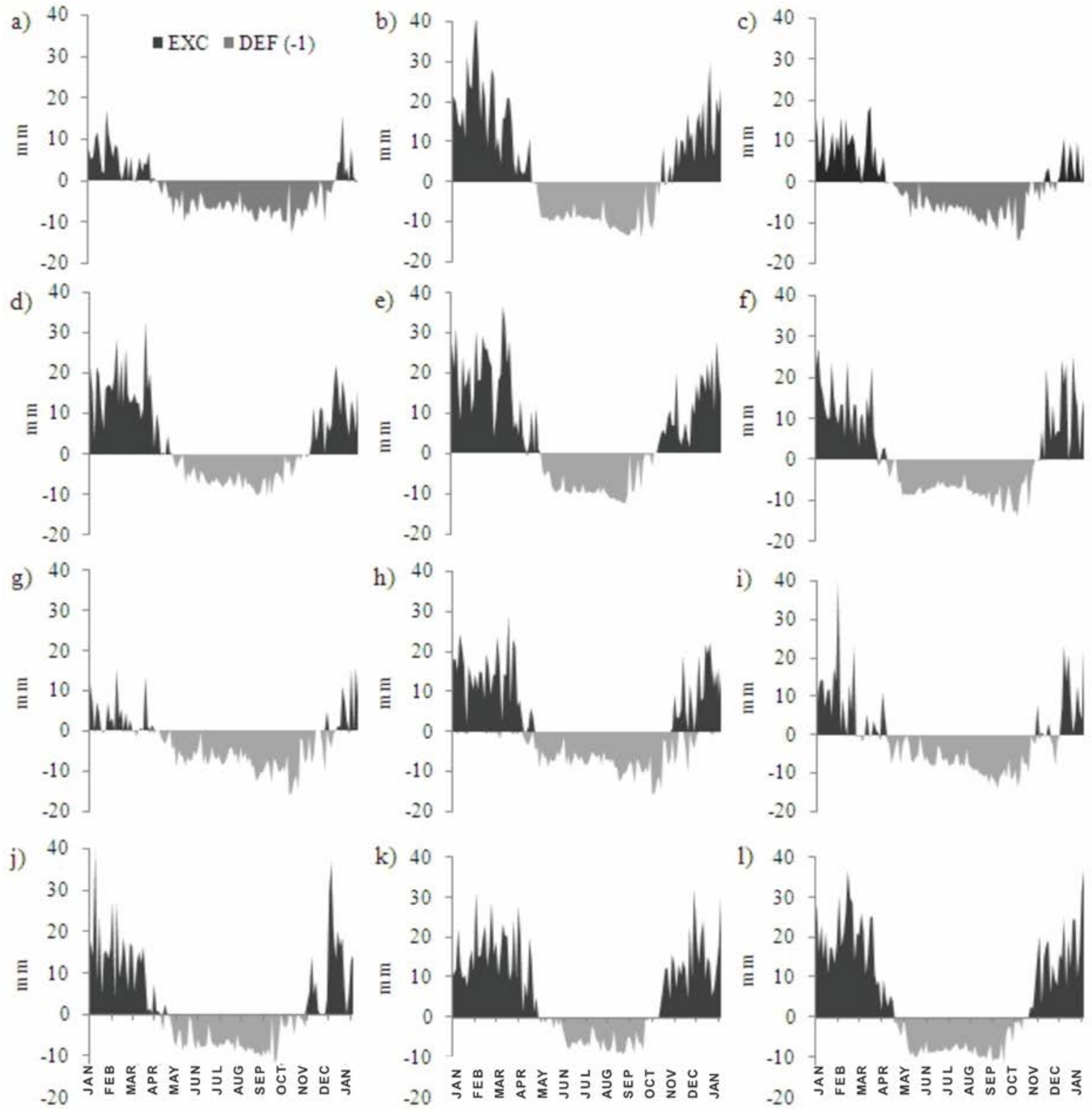


FIGURE 3. Climatic Water Balance. Cáceres (a), Canarana (b), Cuiabá (c), Diamantino (d), Matupá (e), Nova Xavantina (f), Padre Ricardo (g), Poxoréo (h), Rondonópolis (i), São José do Rio Claro (j), São Vicente (k) and Sinop (l).

Table 1 shows the values obtained by CWB to the sizing of the reservoir.

TABLE 1. Excess (EXC), Deficit (DEF), Green Roof Area (GRA), Reservoir Volume (RV), Water Complementary Volume (WCV), Diameter of the Circular Reservoir (D), Width of the Square Reservoir (W), Surface Area of the Reservoir (SAR) and Relation SAR/GRA.

Stations	EXC (mm)	DEF (mm)	GRA (m²)	RV (m³)	WCV (m³)	D (m)	L (m)	SAR (m²)	SAR/GRA
Cáceres	192.86	471.09	100	19.29	27.82	2.46	1.93	3.86	0.0386
Canarana	896.48	508.97	100	89.65	-	11.42	8.96	17.93	0.1793
Cuiabá	312.79	428.55	100	31.28	11.58	3.98	3.13	6.26	0.0626
Diamantino	723.20	331.10	100	72.32	-	9.21	7.23	14.46	0.1446
Matupá	981.49	402.29	100	98.15	-	12.50	9.81	19.63	0.1963
Nova Xavantina	602.56	480.39	100	60.26	-	7.68	6.03	12.05	0.1205
Padre Ricardo	155.97	514.73	100	15.60	35.88	1.99	1.56	3.12	0.0312
Poxoréo	704.92	299.72	100	70.49	-	8.98	7.05	14.10	0.1410
Rondonópolis	372.29	493.28	100	37.23	12.10	4.74	3.72	7.45	0.0745
S. José do Rio Claro	651.11	381.51	100	65.11	-	8.29	6.51	13.02	0.1302
São Vicente	965.51	245.04	100	96.55	-	12.30	9.66	19.31	0.1931
Sinop	1016.67	412.74	100	101.67	-	12.95	10.17	20.33	0.2033

With the results of the CWB (Attachments) shown in Table 1, we observed that, Canarana, Diamantino, Matupá, Nova Xavantina, Poxoréo, São José do Rio Claro, São Vicente and Sinop, presented water excess greater than water deficit, however, Cáceres, Cuiabá, Padre Ricardo and Rondonópolis presented water excess lower than the water deficit. The region of Padre Ricardo presents the most critical case with excess of 155.97mm and 514mm, 73mm of deficit, and the water deficit is more than three times greater than the surplus, thus the excess of this region can only supply 30% of water deficit and the rest needs supplementary irrigation. The same can be seen in the cities of Cáceres, Cuiabá and Rondonópolis which present a deficit greater than the water excess, and the excess of each of these cities can only supply 40, 73 and 75% water deficit, respectively. One option to solve this problem would be the use of domestic water, for example, the water used in the family bathroom, or make deficit irrigation just to keep the plant alive during the drought period. However, it is noteworthy that deficit irrigation can decrease the vegetative grass development reducing the beneficial effects of green roof, and the aesthetics of them.

The other regions present excess higher than the deficit capacity to supply 100% of water deficiency. The city of Sinop, for example, shows an excess of 1016.67mm and a deficit of 412.74mm, considering a storage capacity of 100% this deficit would be supplied and there would still be a surplus of 146%.

The rains in the state of Mato Grosso are concentrated in periods ranging between 4 and 7 months starting in most cases in November and ending in April when the dry season begins. This shows that the state as well as in much of Brazil, presents two distinct and well-defined seasons: one dry and one wet.

Considering a hypothetical house of 100m^2, the estimated volume of the reservoir to collect excess rainwater from all regions was high, some of them having greater than 70m^3, such as the cities of Canarana Diamantino, Matupá, Poxoréo, Sinop and the region of São Vicente. In fact, with these values, the area to be used for allocation of reservoirs tends to be high. The surface areas calculated from the reservoir to the aforementioned regions are 17.93m^2, 14.46m^2, 19.63m^2, 14.10m^2, 20.33m^2 and 19.31m^2 respectively. These values also represent equivalence percentage of the surface area of the reservoir over the area of the green roof, since in this study was used a hypothetical 100m² home coverage area.

The other regions have a required volume reservoir of 19.29m^3, 31.28m^3, 60.26m^3, 37.23m^3, 65.11m^3 and 15.60m^3 to the cities of Cáceres, Cuiabá, Nova Xavantina, Rondonópolis, São José do Rio Claro and the region of Padre Ricardo, respectively.

The results obtained from the 12 studied regions shows that even for the region of Padre Ricardo wherein the surface area of the reservoir is the lowest compared to the green roof area (3.12%), the use of it may be compromised because this fact may be a limiting factor to the use of the reservoir, because requires a considerable area for installation and have a high cost land. A reasonable solution would be to reduce the surface area of the reservoir and increase the depth, but that decision may create problems for the pumping system, such as pump cavitation and excessive manometric height variation.

CONCLUSION

It was concluded that:

- In most studied regions of Mato Grosso the use of Green Roofs is not compromised by water deficit;

- The state of Mato Grosso has the potential for the use of rainwater for irrigation of Green Roofs;

- The estimated volume of the reservoir to accumulate excess rainwater to a house of 100m² of collecting area varies from 15,60m³ to 101,67m³.

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