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Turning rain into internal precipitation and stem flow: observations of palm trees in an urban environment

Transformando chuva em precipitação interna e escoamento pelo caule: observações de palmeiras situadas em um ambiente urbano

Luiz Felippe Salemi[1]

[1] Professor Adjunto II da Universidade de Brasília, Faculdade de Planaltina, Área de Ciências da Vida e da Terra.
E-mail: lfsalemi@unb.br

Abstract: Numerous articles have quantified rainfall, internal precipitation and stem flow. However, few have documented how, in fact, rain turns into internal precipitation and stem flow. Given this gap, this note used palm trees (*Roystonea regia*) to illustrate how such a phenomenon occurs. When photographing rain events below the canopy, it is shown that effective precipitation reaches the ground mainly through water flowing from leaflets to the rachis and petiole. As water flows through the rachis and petiole, one portion becomes internal precipitation and another portion follows a path accumulating in the sheath and, after such compartment is full, it is drained toward the soil surface. Another variation of stem flow generation occurs when sheaths overlap.
Keywords: Water. Vegetation. Canopy. Interception. Wet Canopy Evaporation.

Resumo: Inúmeros artigos quantificaram chuva, precipitação interna e escoamento pelo caule. No entanto, poucos documentaram como, de fato, a chuva se transforma em precipitação interna e escoamento pelo caule. Diante tal lacuna, a presente nota usou palmeiras (*Roystonea regia*) para exemplificar como tal fenômeno ocorre. Ao fotografar eventos de chuva abaixo do dossel, mostra-se que a precipitação efetiva atinge o solo principalmente através da água que flui dos folíolos para a ráquis e o pecíolo. Conforme a água flui através da ráquis e pecíolo, uma porção se torna precipitação interna e outra porção segue um caminho se acumulando na bainha e, após tal compartimento se apresentar cheio, drena em direção à superfície do solo. Outra variação da geração de escoamento pelo caule ocorre quando há sobreposição de bainhas.
Palavras-chave: Água. Vegetação. Dossel. Interceptação. Evaporação do Dossel Molhado.

Introduction

Throughfall and stemflow are important hydrological processes in ecosystems. The former can be defined as the portion of rainfall which reaches the ecosystem floor as crown drip whereas the latter may be defined as the portion of rainfall which reaches the ecosystem floor through the stem of trees and shrubs.

Knowledge about throughfall and stemflow is essential in order to understand the actual water inputs into the soil in areas covered with different types of vegetation. Studies that quantified stemflow and throughfall in different types of vegetation such as crops (BÄSE et al., 2012; FERNANDES et al., 2017), planted forests (BUTTLE et al., 2014; BENYON; DOODY, 2015) and natural forests (GERMER; WERTHER; ELSENBEER, 2010) abound in the literature. However, basic, simple and direct observations of the actual paths that rain water takes on a leaf or a stem of trees, though very interesting, are still lacking. Thus, the present paper aimed to answer the following question: how rainfall is transformed into throughfall and stemflow?

In this paper, we used photographs taken during rain events to document the transformation of rainfall into stemflow and throughfall in palms located in an urban area. Though very simple, such approach can provide interesting records of the paths that water takes as running towards the soil. This, in turn, may provide interesting insights to improve our understanding of the actual paths through which rainwater converts into stemflow and throughfall.

Material and Methods

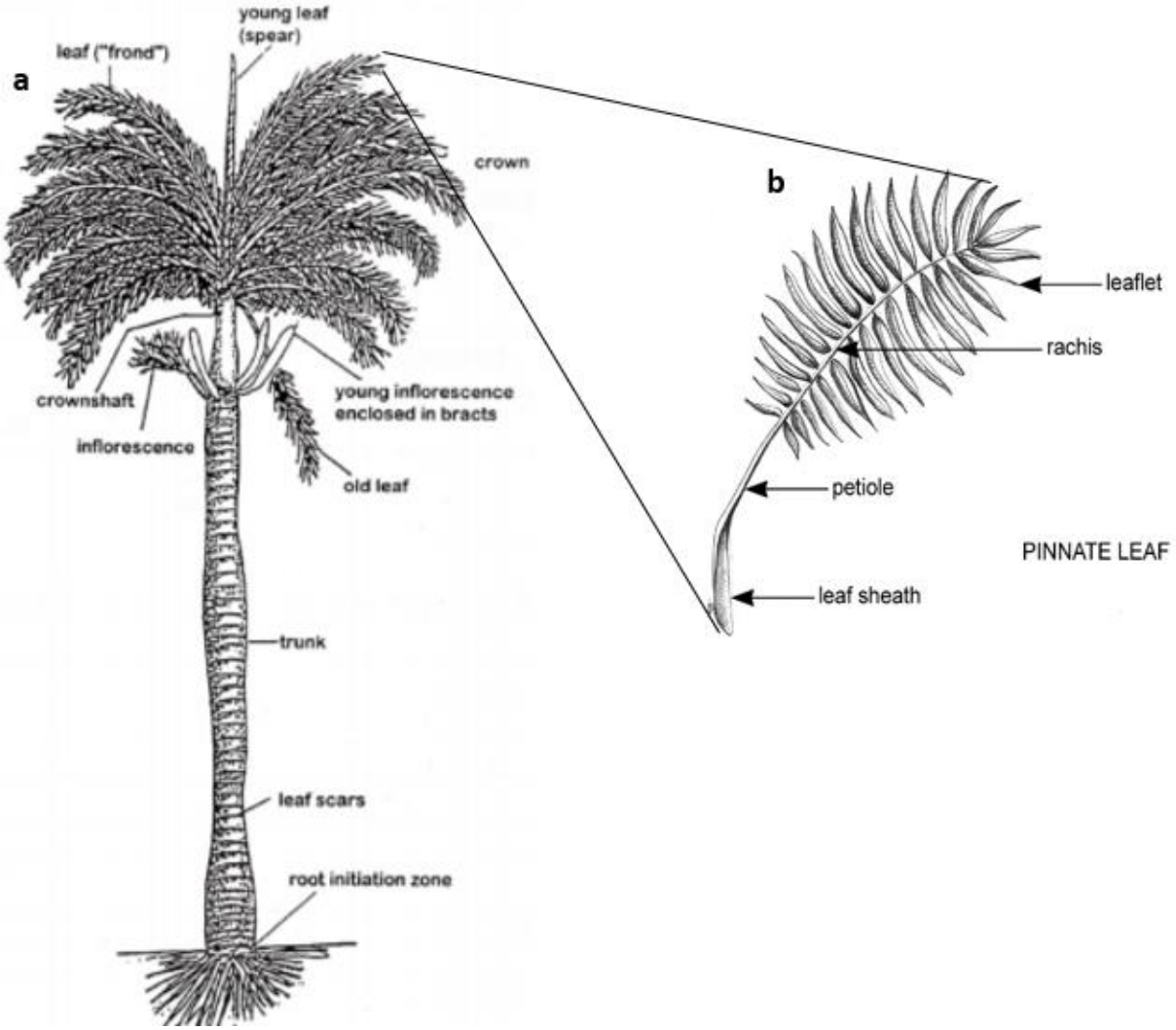
Study area

The study was carried out in a periurban area in Brasília, Distrito Federal, Brazil (15°40'21.99"S and 47°51'10.86"O). Ornamental palm trees (*Roystonea regia*, Arecacea) are present in such area. Tree height was about 10-15 meters and diameter at breast height was about 51 ± 3,8 cm (mean ± standard deviation).

Palm trees morphology in brief

Palms differ substantially in their overall form and structure (morphology) (LORENZI et al., 2010). In the case of *Roystonea regia*, leaves are generally pinnate (feather-like leaves) (Figure 1 and stems present leaf scar rings (Figure 1A and 1B).

Figure 1. Palm morphology (A). Palm leaf morphology (B) (credits for (A) A.W.



Meerow – University of Florida and for (B) to http://idtools.org/id/palms).

Photographs of water flowing through the leaves and stems have been recorded during five rainfall events using Samsung 8 GB A5 Camera. Rainfall events were not measured using rain gauges. Thus, unfortunately there is no information on rainfall amount and intensity for such events.

Results and Discussion

To the best of our knowledge, there is no clear visual description of rainfall pathways once reaching a tree crown. Though conceptually well described in papers and many textbooks, most studies focused solely in describing throughfall and stemflow amounts (see GERMER; WERTHER; ELSENBEER, 2010; BÄSE et al., 2012; BUTTLE et al., 2014; BENYON; DOODY, 2015; FERNANDES et al., 2017). So, to the best of our knowledge, this is a first paper clearly dedicated to the photographed description of such canopy pathways.

Throughfall

Throughfall reached the floor mainly running on the surface of leaflets towards the rachis and petiole. Leaflet paralell venation may generate small surface depressions which contributed to direct water to the rachis. As water flows through the rachis and petiole, the excess water overflowing the small depression falls as throughfall (Figure 2A). The water in a straight line on the floor clearly indicated concentration of thoughfall falling along the rachis/petiole (Figure 2B).

Figure 2. Water falling through rachis and petiole leaves straight lines in the soil surface (A). The same pattern is shown highlighted in blue lines (B).

Stemflow

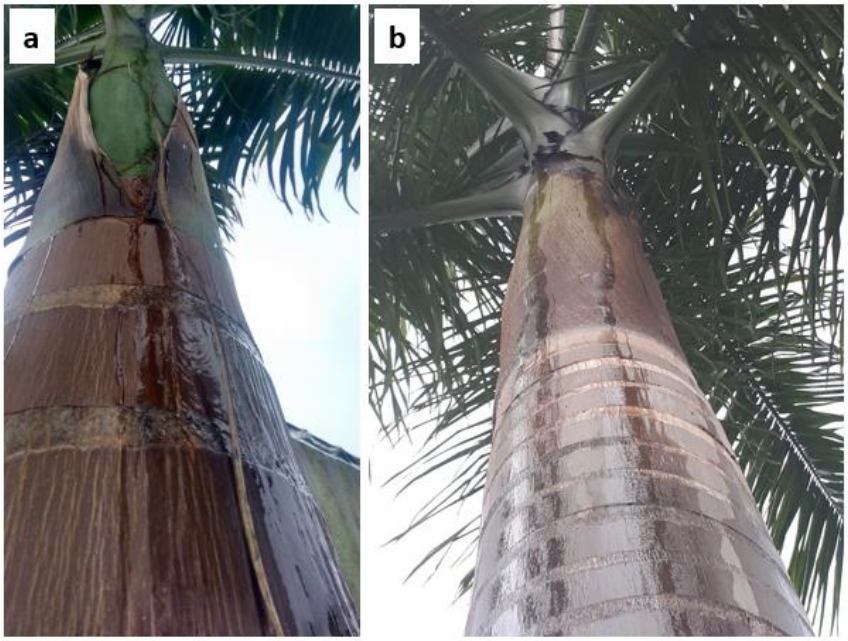
As water flows through the rachis/petiole, one part falls as throughfall (as previously described) and the other not overflowing part follows a downward path through the rachis/petiole towards the leaf sheath where it accumulates. When such compartment between leaf sheath and stem is completely filled, water finally flows into the stem (Figure 3A).

Other variation of stemflow generation might be through the crownshaft where stemflow may arise from the individual leaf sheaths superimposing each other (Figure 3B).

Once flowing through the stem, stemflow tends to spread towards the stem basis (Figure 2A and 2B). That is, the area used to flow downward is increased (Figure 2A and 2B). In this pathway, water retention may occur in stems possibly increasing interception.

Field observations during rainfall events also showed that, in isolated trees such as the ones shown here, direct horizontal rainfall may also become stemflow through falling directly into the stem (that is, not being channelized through the canopy). While such process might not be important in the interior of closed canopy forest ecosystems, it may be important in closed forest edges and open forests as well as savannas.

Figure 3. Stemflow originating from the terminal end of leaf sheath (A). Two main flows from the crownshaft where leaves sheath superimpose (B).



Finals remarks

This paper was the first photographed documentation of rainfall transforming into stemflow and throughfall. Moreover, it is an attempt to join inherently related subjects often considered very distant in science: hydrology and plant morphology. Rain water is transformed into throughfall mainly overflowing as travelling through the leaf rachis/petiole. Furthermore, other part follows directly towards the leaf sheath where it is transformed into stemflow. Though descriptive, the present study may offer insights that may improve our understanding of canopy hydrological processes which, in turn, also have implications for modelling at the canopy, plot, and watershed scales. Likewise, it illustrates plant hydrology to all level students. We encourage other authors to also photograph all types of hydrological pathways normally neglected in hydrological papers.

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