Stemflow in low-density and hedgerow olive orchards in Portugal

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INTRODUCTION

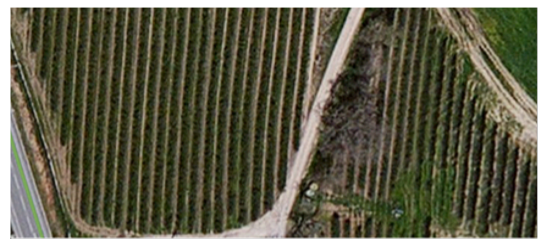
Stemflow is responsible for a localized water and solute input to soil around tree's trunks, playing an important eco-hydrological role in forest and agricultural ecosystems. However, as it is usually a small fraction of the gross precipitation (1% to 10%), it is often neglected in rainfall interception studies.

The objectives of the present study were:

- to quantify the stemflow in olive orchards managed in different ways;
- to investigate the climatic and morphological factors controlling the amount of stemflow.

MATERIAL AND METHODS

Stemflow was monitored for 7 months (Dec/2013 – Jun/2014) in 25 *Olea europaea* L. trees distributed in three orchards managed in two different ways, traditional low-density and super high density hedgerow.



SITE	VÁRZEA	AZÓIA	TAPADA
Management system	Traditional	Hedgerow	Traditional
Region	Santarém	Santarém	Lisbon
Variety	Galega	Arbequina	Picual, Negrita, Maçanilha, Cordovil, Azeiteira, Blanqueta
Age (years)	various	14	29
Density (trees ha^{-1})	28	1950	170
Number of sampled trees	7	8	10
Mean tree height (m)	4.51	2.68	4.02
Mean trunk height (m)	1.13	0.97	0.88
Mean trunk girth (m)	0.88	0.34	0.71
Mean crown diameter (m)	3.50	1.60	3.56
Mean crown projected area (m^2)	9.16	1.79	9.29
Mean crown volume (m^3)	17.43	3.42	12.57

Stemflow measurements were done by 33l plastic containers or by covered tipping-bucket rainfall recorders.

Near each orchard there were automatic weather stations measuring gross rainfall and all the micrometeorological data (radiation, temperature, humidity and wind speed) necessary to calculate the maximum evaporation rate by the Penman-Monteith equation.
Whenever possible, data analysis was carried out on an event basis. However, data collected by plastic containers had to be analyzed by groups of storms according to the frequency of measurements.

Linear regression models were fitted between stemflow (S_f) and other micrometeorological and morphological variables:

- volume (P_g), duration (D) and intensity (I) of rainfall episodes and maximum evaporation rate (E);
- canopy volume (V), tree (ha) and trunk (ht) heights and trunk perimeter at the height of the first branches (P).

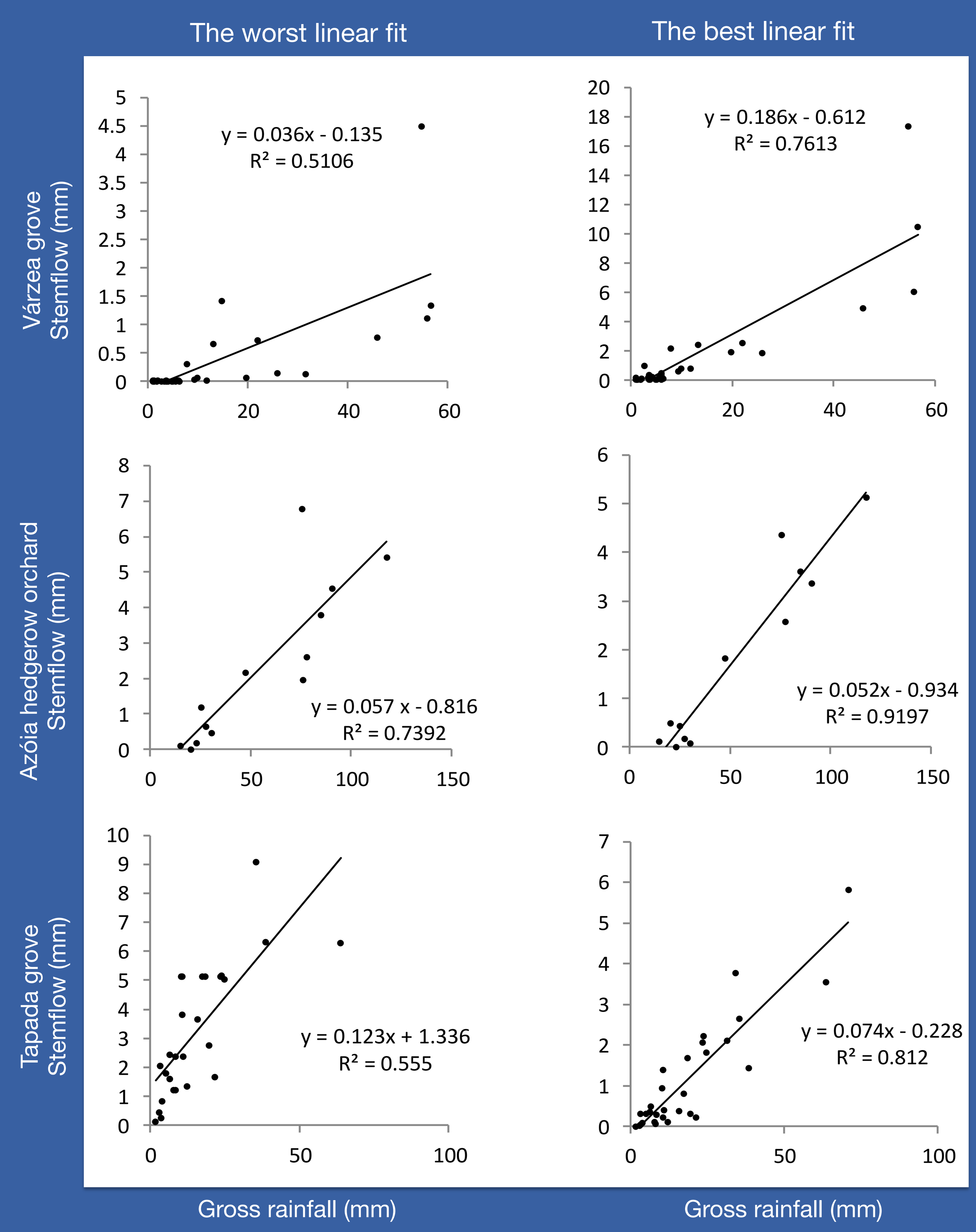
Whenever possible, the linear regression models were simplified using the backward stepwise algorithm (BSA) based on the Akaike information criterion.

RESULTS AND DISCUSSION

Total gross rainfall (P_g) and stemflow (S_f, on a tree crown coverage basis) measured during the experimental period.

SITE	VARIETY	P_g (mm)	S_f RANGE (%P_g)	
Várzea	Galega	648.0	1.15	12.49
Azóia	Arbequina	713.3	3.02	8.04
Tapada	Picual	650.9	5.55	7.76
	Cordovil		5.20	5.75
	Azeiteira		9.91	16.73
	Maçanilha		5.39	6.53
	Negrinha		12.46	
	Blanqueta		9.60	

The proportion of S_f in relation to P_g varied greatly in the trees of the 3 studied orchards (from 1.1 to 16.7%). On average, the traditional olive grove of Tapada had a higher percentage of stemflow (8.5%) than the other two orchards (approximately 5%).



Like many other stemflow studies, a linear relationship between S_f and P_g was found in this study, stronger in the high density hedgerow olive orchard (with R^2 between 0.74 and 0.92) than in the traditional low-density groves (R^2 between 0.51 and 0.81).

RESULTS AND DISCUSSION

To understand better the variables that affect S_f and to improve modelling quality in each tree/orchard, other sets of explanatory variables were added to the linear regressions:

Multiple linear regression sub-models with the highest and lowest values of the coefficient of determination (R^2) obtained by the BSA for the stemflow of each tree (S_f, mm) in the 3 sites (P_g – gross precipitation, mm; I – rainfall intensity, mm 10min^{-1}; D – rainfall length, min; E – maximum evaporation ratio, mm h^{-1}).

SITE	Equation of the selected sub-model	R^2
VÁRZEA	$S_f = 0.12 + 0.03\ P_g - 0.34\ I - 1.24 \times 10^{-4}\ D$	0.606
	$S_f = 1.68 + 0.32\ P_g - 2.50\ I - 2.26 \times 10^{-4}\ D$	0.874
AZÓIA	$S_f = 0.22 + 0.05\ P_g - 0.18\ E$	0.785
	$S_f = 0.14 + 0.11\ P_g - 8.48\ I + 3.06 \times 10^{-4}\ D$	0.962
TAPADA	$S_f = 2.54 + 0.12\ P_g - 7.76\ E$	0.667
	$S_f = 0.24 + 0.07\ P_g - 2.94\ E$	0.853

Multiple linear regression sub-models, and their R^2, obtained by the BSA for the stemflow of each tree in each site (V, canopy volume, m^3; P – trunk perimeter at the height of the first branches, m; ha – tree height, m; ht– trunk heigth, m).

SITE	Equation of the selected sub-model	R^2
VÁRZEA	$S_f = 16.08 + 0.11\ P_g - 1.02\ I - 5.61 \times 10^{-4}\ D + 0.82\ V - 0.28\ P - 7.51\ ha + 4.69\ ht$	0.515
AZÓIA	$S_f = 1.11 + 0.09\ P_g - 7.94\ I + 0.82\ ha - 2.44\ ht$	0.761
TAPADA	$S_f = 5.55 + 0.07\ P_g + 1.05 \times 10^{-4}\ D - 3.48E + 0.18\ V - 0.85\ P - 1.39\ ha - 1.08\ ht$	0.642

CONCLUSIONS

- The proportion of gross rainfall that reaches the ground as stemflow in olive trees is high and should not be neglected.
- For the traditional olive groves, the quality of the linear fit between S_f and the P_g was in general moderate compared with the results of the intensive olive orchard. The inclusion of other predictive meteorological variables only slightly improved the fitted linear regressions. Contrary to what might be expected, an increase in the intensity and duration of rainfall events seems to result in a smaller amount of stemflow.
- The inclusion of morphological tree variables to try to explain the variability of S_f between trees showed that the heights of the trunk and the tree were the most important variables in this study. However, linear regressions fitted for each grove had only moderate quality (R^2 between 0.52 and 0.76).
- Although the use of simple and general statistical models may be an attractive option, their precision may be small, making direct measurements or conceptual modelling preferable methods.

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