Effect of rainfall intensity, surface slope and build-up on wash-off process

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Introduction

- Wash-off is the process where accumulated dry deposition is removed from urban impervious surfaces by rainfall and/or runoff and incorporated in the flow
  - Water quality issues *(Chiew and Vaze 2004)*
  - Urban flood *(Ivan 2001)*

- The most widely used model to predict wash-off (*Sartor and Boyd 1972*)

$$w_t = w_o\left(1 - e^{-kit}\right)$$

w_t : weight of transported pollutant after time *t* (g)

w_o: initial weight of the pollutant on the surface (g)

i : rainfall intensity (mm/hr) ; and *k* : wash-off coefficient (mm^{-1}).

- Recently a capacity factor ranging from 0-1 added to the equation (*Egodawatta et al. 2007*)

$$\frac{w_t}{w_0} = C_F\left(1 - e^{-kit}\right)$$

Introduction

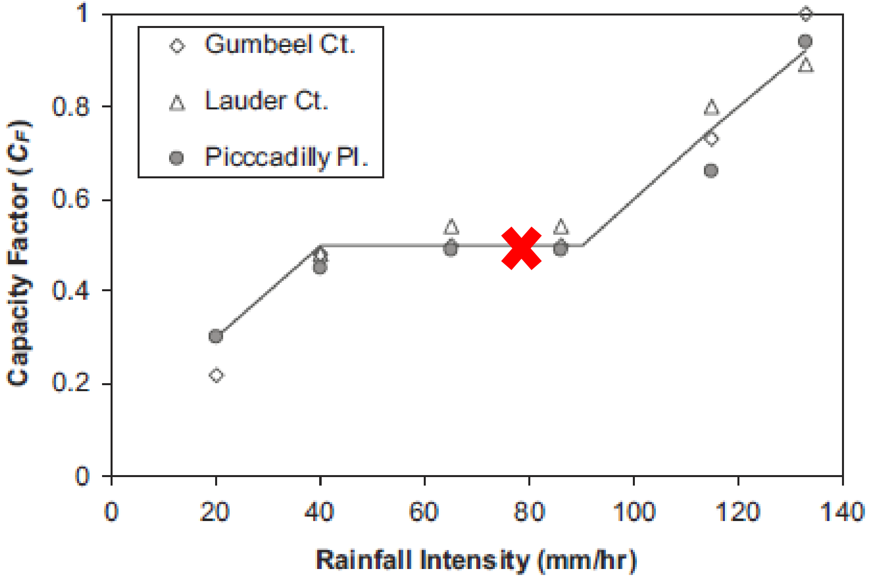
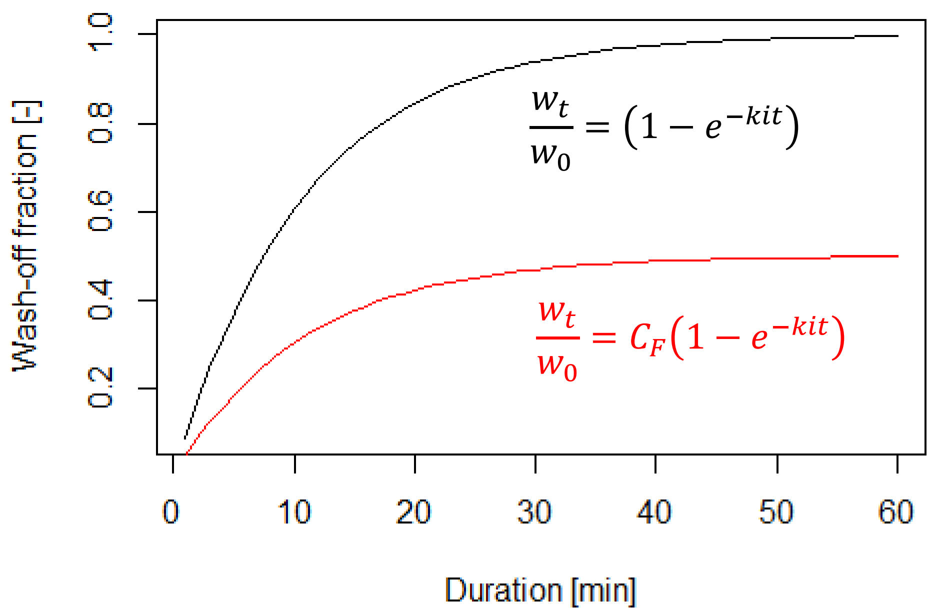


Fig. 5 – Variation of C_F with rainfall intensity.
(*Egodawatta et al. 2007*)

i = 80mm/hr



Wash-off process was investigated against just one parameter (i.e. rainfall intensity) in isolation and the effect and interaction of other parameters were not taken into account!
This is a common drawback in most of the experimental studies!

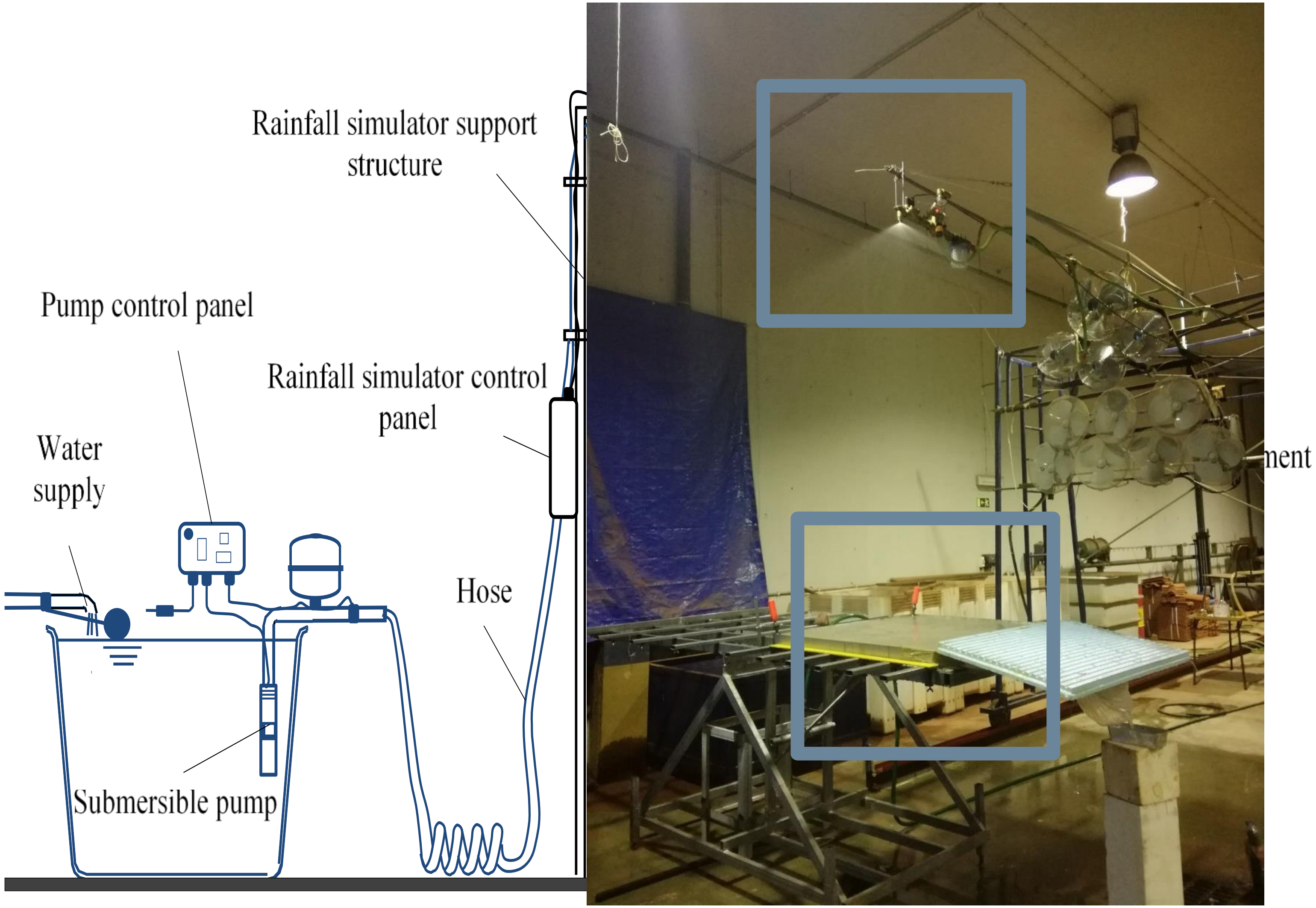
Introduction

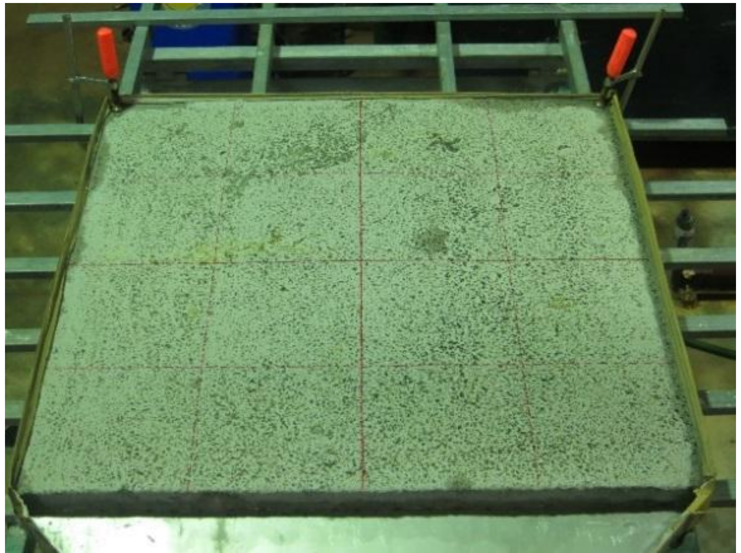
Aim

- Investigate the effect of three dominant parameters corresponds to rainfall, surface and sediment characteristics in wash-off in an integrated and systematic way.
  - Rainfall intensity, surface slope and initial load

- Improve the wash-off equation by using the experimental results focusing on the effect of the above three parameters.

Methodology



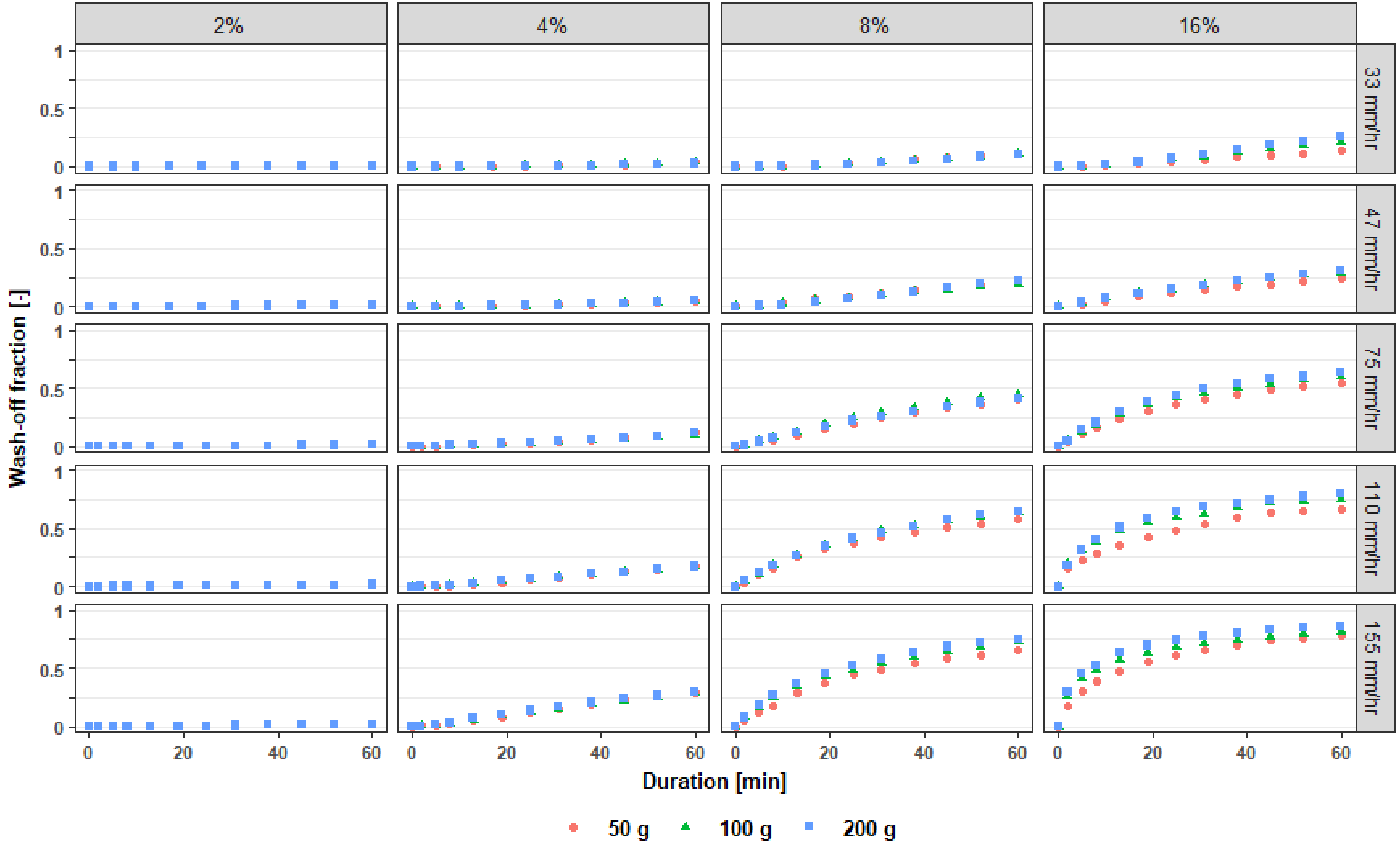


Methodology

Slope (%)	Initial load (g)	Intensity (mm/hr)				
		33	47	75	110	155
2%	200	9 samples at 5, 10, 17, 25, 31, 38, 45, 52, 60 minutes		11 samples at 2, 5, 8, 13, 19, 25, 31, 38, 45, 52, 60 minutes		
4%	50,100,200					
8%	50,100,200					
16%	50,100,200					

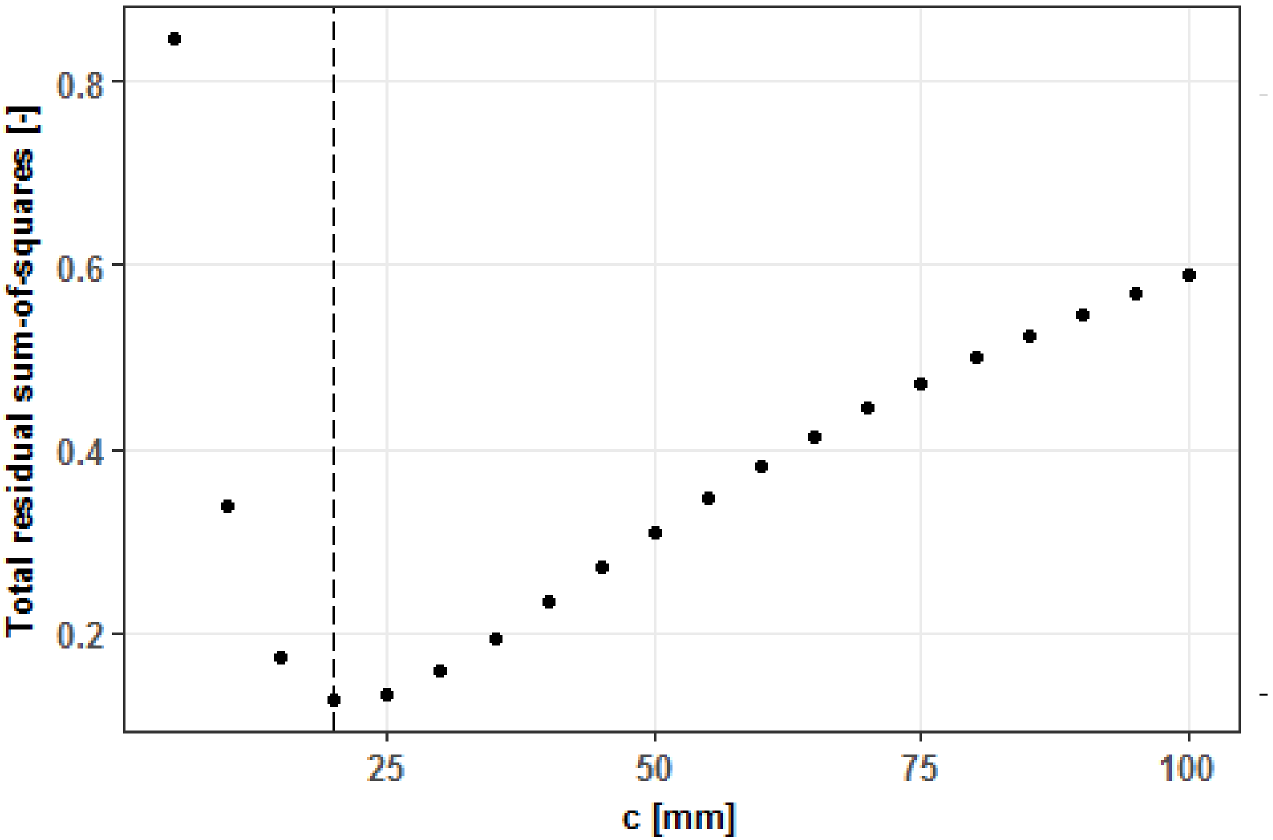
- Sediment size : 300-600 µm
- Each experiment was carried out for 60 min
- Quality control
  - Repeated experiments to check consistency in the results – difference was within ±2%
  - Mass balance check after each experiment – maximum 2% mass loss

Results



$$washoff\ fraction = \frac{w_t}{w_0}$$

Results



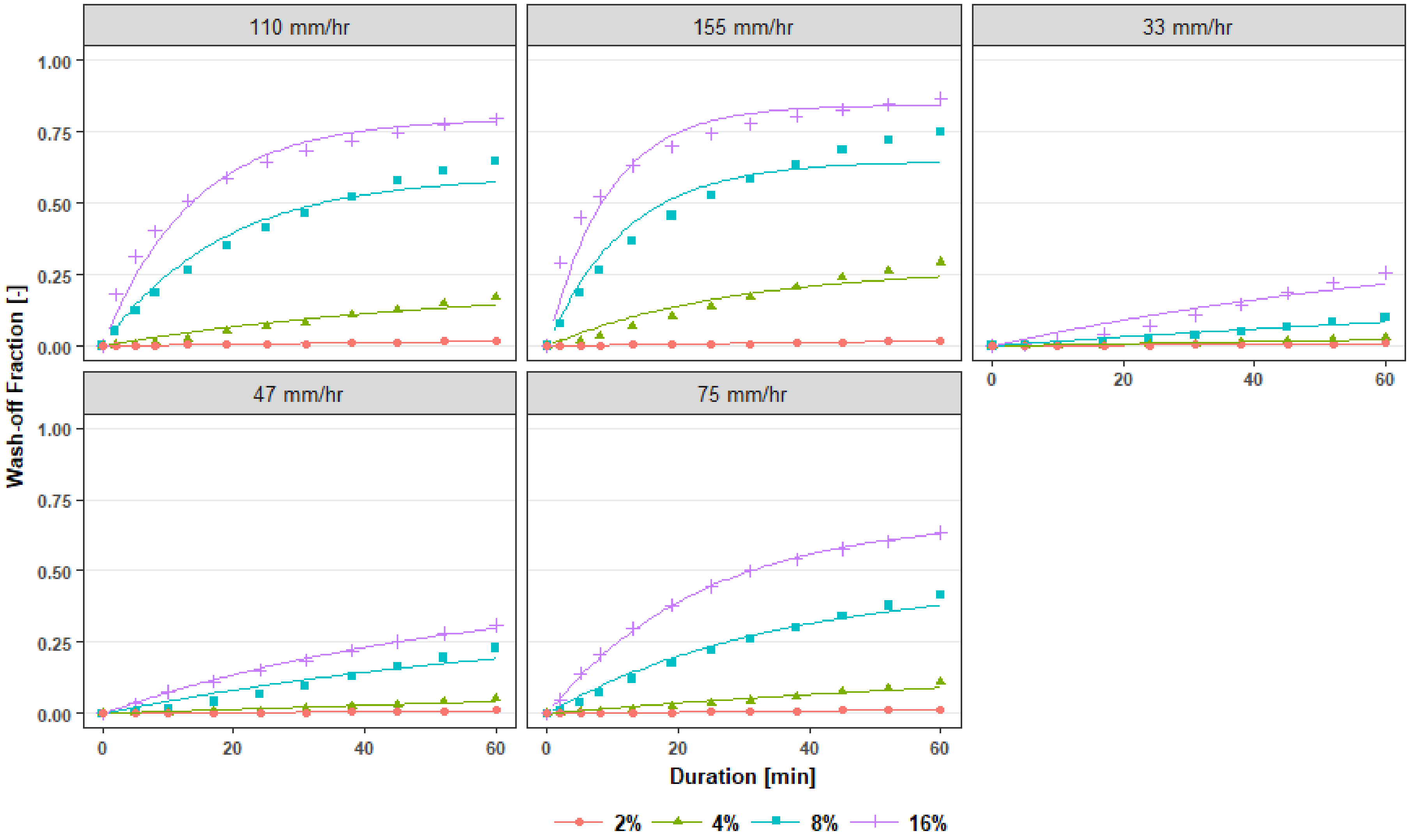
$$\frac{w_t}{w_0} = C_F\left(1 - e^{-kit}\right)$$

$$\frac{w}{w_0} = f(k)\left(1 - e^{-kit}\right)$$

$$\frac{w}{w_0} = ck'\left(1 - e^{-k'it}\right)$$

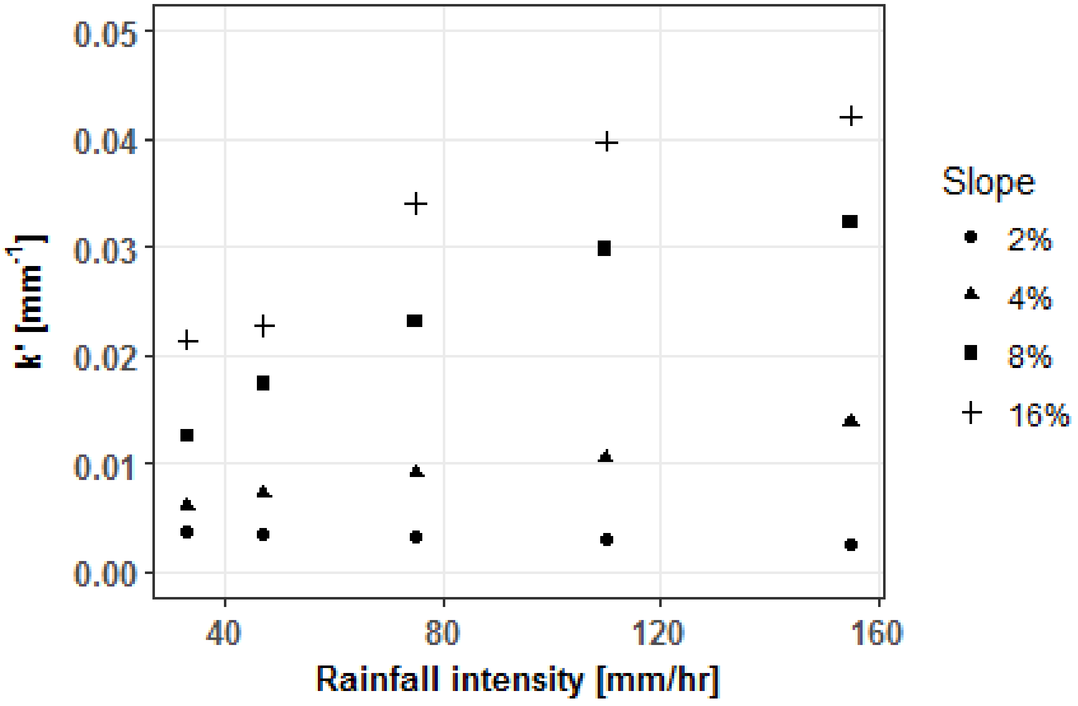
$$\frac{w}{w_0} = 20k'\left(1 - e^{-k'it}\right)$$

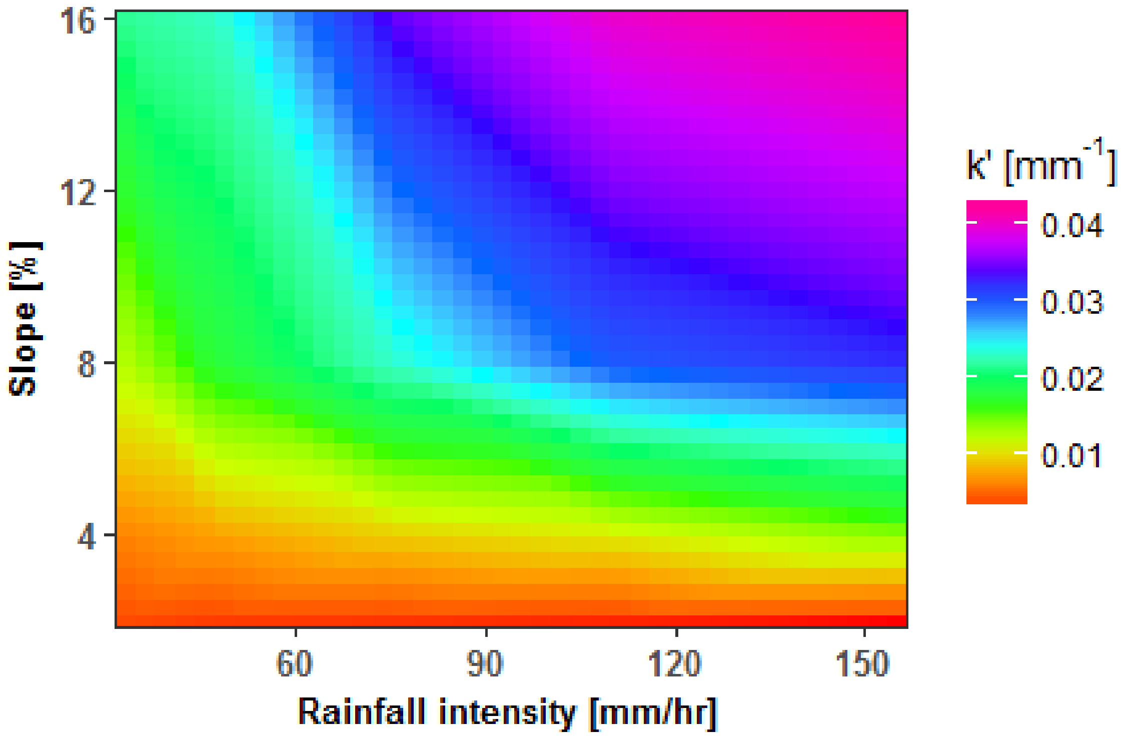
Results



110 mm/hr
155 mm/hr
33 mm/hr
47 mm/hr
75 mm/hr
1.00
0.75
0.50
0.25
0.00
Wash-off Fraction [-]
0
20
40
60
Duration [min]
2%
4%
8%
16%

Results





This improved model can be accessed at : https://washoffmodelling.shinyapps.io/washoffmodelling-app/

Conclusion and Outlook

- A rainfall event has the capacity to mobilise only a fraction of sediment from the road surface and once it reaches that capacity, as observed during the experiments, wash-off becomes almost zero even though a significant fraction of sediment is still available on the surface.

- This maximum fraction increases with both rainfall intensity and the surface slope.

- The capacity factor which represents this maximum fraction is derived as a function of wash-off coefficient making use of the correlation between maximum fraction and the wash-off rate.

- Values for the wash-off coefficient is derived for combinations of rainfall intensity and slope which can be transferred to other urban catchments with similar conditions.

- It is important to take into account the effect of other parameters such as sediment size and surface roughness in future investigations on wash-off process.

Reference

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Thank you!