Sensitivity analysis on hygrothermal properties and thickness of green roof layers, including recycled and artificial materials

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1. ABSTRACT

This study analyses the sensitivity of green roof drainage and substrate layers' thermal resistance to artificial and recycled materials' physical properties, and layers' thickness. The hygrothermal characteristics of green roof materials and layers play a fundamental role in the thermal performance of green roof systems. The focus of this study is therefore to determine how much the variation of water content, density, thermal conductivity and thickness of substrate and drainage layers (independent variable) may influence the heat flux dispersion (dependent variable).

2. KEYWORDS

Heat flux, drainage layer, substrate layer, local and global methods

3. OBJECTIVE

Evaluating the heat flux sensitivity to the thickness and physical characteristics of green roofs with artificial and recycled materials.

4. RESEARCH QUESTION

To what extent is green roofs' thermal resistance sensitive to drainage and substrate layer characteristics, including artificial and recycled materials?

5. METHODOLODY

Relationship between dependent and independent variables:

$$q = \lambda_0\left(1 + \frac{W}{\rho}\right)\frac{\Delta T}{L}$$

Dependent variable: heat flux (**q**) in W/m^2

Independent variables: thermal conductivity in dry condition (**λ_0**) in W/m·K, water content (**W**) in kg/m^3, density (**ρ**) in kg/m^3 and layer's thickness (**L**) in m

Equation for sensitivity analysis:

g(f(x, μ, σ), μ, σ)=√2σ⟦(Ln (√2π.σ.f (x,μ,σ))⟧^2+μ

- g(…): Inverse of the normal distribution function
- μ: Mean of the distribution
- σ: Standard deviation
- f (x,μ,σ): Normal distribution function

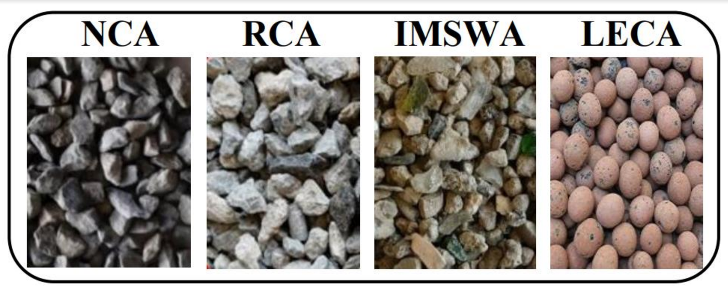
Sensitivity analysis methods:

- ✓ **Local method**: a single independent variable change
- ✓ **Global method**: all parameters change

6. MATERIALS

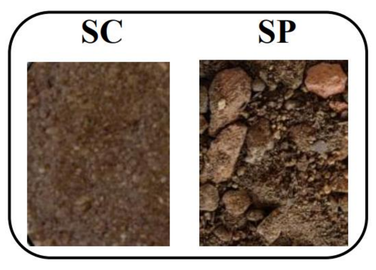
Drainage materials:

- Natural Coarse Aggregate (**NCA**)
- Recycled Coarse Aggregate (**RCA**)
- Incinerated Municipal Solid Waste Aggregate (**IMSWA**)
- Lightweight Expanded Clay Aggregate (**LECA**)



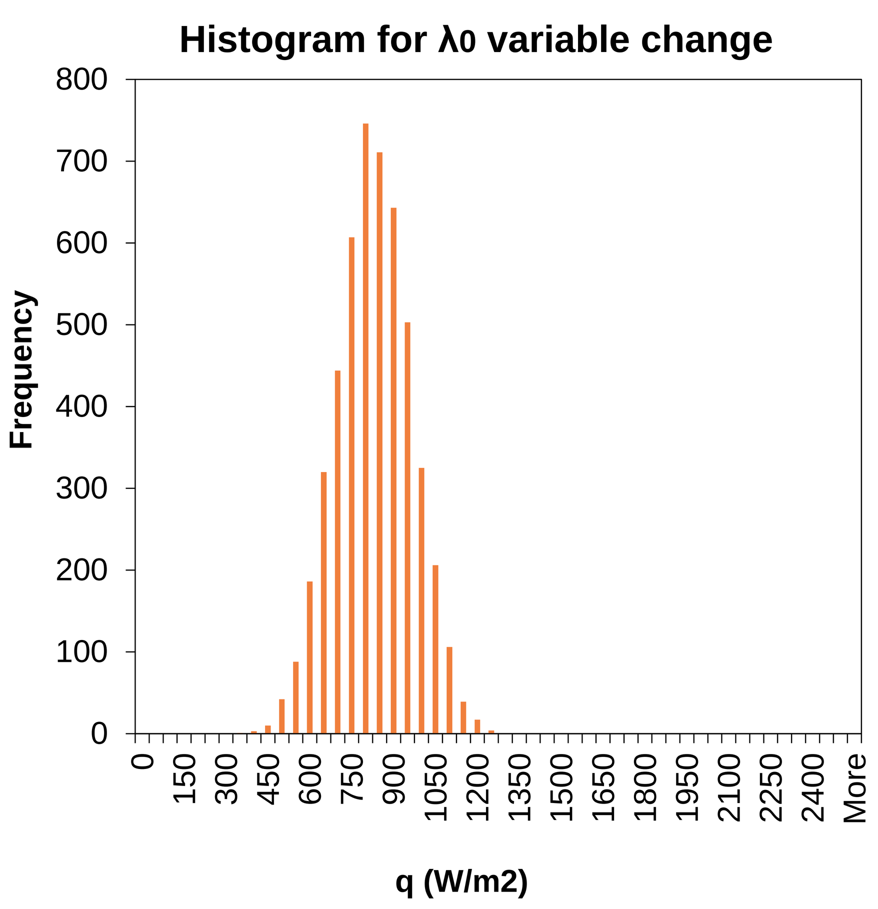
Substrate materials:

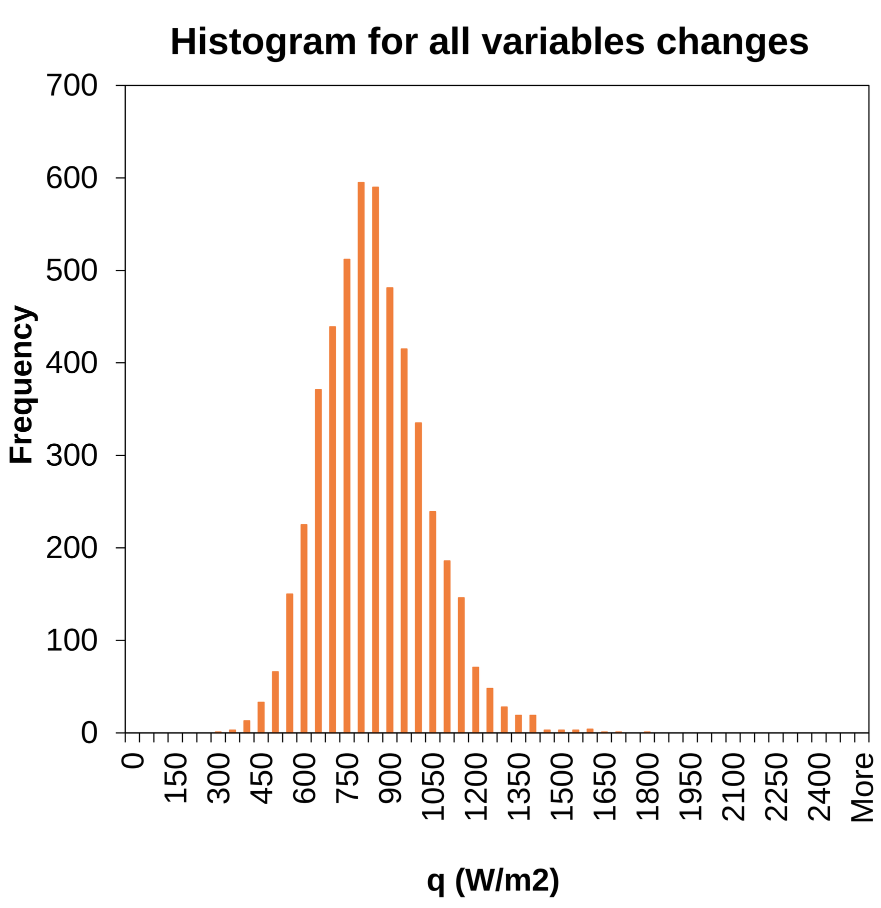
- Substrate *without* coarse recycled materials, Control Substrate (**SC**)
- Substrate *with* coarse recycled materials, Proposed Substrate (**SP**)



Green roof layers	Independent variables	λ_0 (W/m·K)	L (m)	W (kg/m^3)	ρ (kg/m^3)
Drainage layer	Max	0.15	0.06	200	1500
	Min	0.05	0.04	0	400
	Mean (μ)	0.1	0.05	100	950
	Standard deviation (σ)	0.0167	0.0033	33.33	183.33
Substrate layer	Max	0.3	0.15	500	1400
	Min	0.1	0.09	0	800
	Mean (μ)	0.2	0.12	250	1100
	Standard deviation (σ)	0.033	0.01	83.33	100

7. RESULTS





Green roof layers	Sensitivity analysis method	Independent variables	COV of independent variables	COV of q	$\frac{\text{COV of dependent variable (q)}}{\text{COV of independent variables}}$
Drainage layer	Local	λ_0	0.167	0.167	1
		L	0.067	0.067	0.97
		W	0.34	0.1	0.29
		ρ	0.19	0.055	0.29
	Global	λ_0	0.167	0.18	1.08
		L	0.067		2.69
		W	0.34		0.53
		ρ	0.19		0.95
Substrate layer	Local	λ_0	0.165	0.165	1
		L	0.083	0.079	0.952
		W	0.333	0.161	0.48
		ρ	0.091	0.044	0.48
	Global	λ_0	0.165	0.21	1.27
		L	0.083		2.53
		W	0.333		0.63
		ρ	0.091		2.31

8. CONCLUSIONS

- ✓ According to the local method analysis, scattering thermal conductivity and layer thickness led to the highest dispersion of heat flux for the green roof layers. However, the latter was less affected by the water content and density scatter.
- ✓ Scattering thermal conductivity and layer thickness in the global method influenced the dispersion of heat flux for the green roof layers, similarly to the local method.
- ✓ Contrary to the local method, the heat flux was scattered as much as density in the global method due to the hidden interaction among independent variables. Therefore, with the presence of recycled and artificial materials, the density effect on the thermal resistance of substrate materials should be taken into account more than that of drainage materials.
- ✓ Scattering layer thickness dispersed and impacted heat flux more in the global method than in the local method.

REFERENCE

Kazemi, M., Rahif, R., Courard, L., & Attia, S. (2023). Sensitivity analysis and weather condition effects on hygrothermal performance of green roof models characterized by recycled and artificial materials' properties. *Building and Environment*, *237*, 110327. https://doi.org/10.1016/j.buildenv.2023.110327

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