Advanced International Journal for Research (AIJFR)

E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Rainfall Interception by Six Urban Tree Combination in Vijayawada, Andhra Pradesh

Rakshenda Sajeeven [1], Kapil Natawadkar [2]

[1] Second-year, Master of Landscape Architecture, School of Planning and Architecture, Vijayawada, Andhra Pradesh, rakshenda@gmail.com

[2] Assistant Professor, School of Planning and Architecture, Vijayawada, Andhra Pradesh, kapil.natawadkar@spav.ac.in

Abstract

Urban forests in urban environments play a crucial role in mitigating the hydrological system. They help in intercepting the rainfall, enhancing infiltration, and reducing the surface runoff, thereby contributing to stormwater management. This study examines the effect of the tree characteristics on rainfall interception losses within the campus of the School of Planning and Architecture (SPAV), Vijayawada, three representing densely packed forest conditions with different species combinations, and three representing avenue plantations, in which two scenarios consist of the same tree species on both sides and one includes different species along the avenue. The rainfall was measured in seven different locations on the campus, where rainfall measurements were manually taken under the seven different selected trees during 3 different rainfall events. Across the three rainfall events, the interception rate varied notably between the vegetation types when compared to the open condition. The mixed forest setups showed the highest interception, with rainfall reduction ranging roughly between **35–63%** compared to the open area, indicating strong canopy cover and foliage density. The same plant avenue type exhibited a moderate interception range of about **4–42%**, while the mixed plant avenue showed the least interception, reducing rainfall by around **10–25%**. Overall, forest conditions demonstrated greater interception efficiency than avenue arrangements due to their denser and more layered vegetation structure. The results indicated noticeable variation among the different tree species, primarily influenced by the canopy density, tree spread, height, and tree arrangement. The finding demonstrated that the vegetation structure significantly contributes to stormwater reduction and ecological resilience in the Urban locality.

Keywords: Urban forest, interception, throughfall, Rainfall Partitioning.

1. Introduction

Urbanisation alters the hydrology of cities by reducing soil infiltration and increasing the speed of surface water movement, which raises surface runoff and peak flows (Leopold, 1968; Douglas, 1983). Impervious surfaces intensify this effect by preventing rainfall from entering the soil (Scholz, 2004). As a response, green infrastructure is being promoted to support natural hydrological functions in urban areas (R.M. Elliott et al., 2018).

Trees form an essential part of this system because their canopies intercept rainfall at various scales, decreasing throughfall and stormwater runoff (P & F, 2007). Although many studies focus on interception by individual species, fewer examine interception processes within dense urban environments (Alves, Formiga & Traldi, 2018; Nytch et al., 2019). Increased interception, evaporation, and reduced runoff are important for restoring urban water balance, particularly in highly built-up areas (Livesley et al., 2014).

The mixture of tree species in an urban forest also influences interception capacity, as each species varies in canopy form and leaf structure. These differences affect how rainfall is stored, redistributed, or transported through the canopy (Carlyle-Moses & Schellekens, 2015). This study evaluates how different combinations of vegetation at the SPAV campus in Vijayawada affect rainfall interception, by comparing mixed forest conditions with uniform avenue plantings.

Interception

Rainfall interacts with the tree canopy, where droplets may fall directly to the ground as free throughfall or become temporarily stored on leaves, branches, or bark before dripping or evaporating (Rutter, Morton & Robins, 1975). Water that passes through without contacting any plant surface is referred to as throughfall (David, Valente & Gash, 2005). The total rainfall that reaches the ground is therefore the sum of throughfall and stemflow (David, Valente & Gash, 2005).

Interception is influenced by rainfall characteristics, canopy structure, and meteorological conditions that control evaporation, and is considered a significant addition to transpiration losses (Rutter, Morton & Robins, 1975). Estimation of interception depends on comparing precipitation above the canopy with the water retained on plant surfaces (David, Valente & Gash, 2005).

Flow within the canopy is shaped by tree morphology, including leaf area, stem angles, branching patterns, and the presence of gaps. At the stand scale, interception varies with species type, tree height, canopy dimensions, and stem density (Q & EG, 2016). Broader crowns are also more affected by wind exposure, which alters how rainfall is distributed across the canopy (Q et al., 2000a). The angle at which rainfall reaches the canopy influences how drops interact with leaves and branches (Carlyle-Moses & Schellekens, 2015).

Canopy interception depends on attributes such as tree height, canopy size, leaf area, leaf angle, and leaf surface characteristics. Studies show that in low-intensity storms, urban trees can intercept a greater proportion of rainfall, particularly in woodland-type settings (Kuehler, Hathaway & Tirpak, 2017). Earlier work also notes that a single tree canopy can retain approximately 2–4 mm of rainfall before dripping occurs (Livesley et al., 2014).

Role of plants in reducing runoff

Plant characteristics play an important role in controlling runoff. Areas with a mix of species generally absorb more water because diverse vegetation creates different canopy and root structures that enhance infiltration and retention (C. Rixen, 2005). Runoff can be expressed as the remaining water after accounting for interception, retention, transpiration, and soil evaporation (Koehler, 2004, September). Higher interception and transpiration therefore lead to lower runoff (J. Lundholm, 2010).

Vegetation structure is one of the main factors influencing runoff behaviour, with greater tree and shrub cover helping reduce runoff through canopy processes and evapotranspiration (Kutay & Ekşi, May 2025). Several species, such as Cynodon dactylon, Saccharum bengalensis and Parthenium hysterophorus, have shown strong soil and water conservation performance on slopes (Srivastava & Singh, 2012). Similarly, Leonotis nepetaefolia, Cassia tora, Ageratum conyzoides and Sida acuta contribute to reducing nutrient loss and improving soil stability (Kumar, Ambasht, Srivastava, & Srivastava, 1996).

Other species including Bougainvillea spectabilis, Artemisia gmelinii, Ajania potaninii, Pulicaria chrysantha, Quercus coccifera and Pistacia lentiscus also reduce runoff and erosion under different environmental conditions (Shubhashish K, 2012; Cerdà et al., 2021; Xu, Ma, Fu, Liu, & Song, 2009). Mixed vegetation types have been observed to retain more runoff compared to monocultures, with sedum, ferns, and grasses showing varying effectiveness (Chow, BakaR, Roslan, & Fadzailah, January 2015). Canopy-dense crops such as Pomelo further reduce runoff levels (Jakati et al., 2024).

Vegetation suited to local conditions, such as Karanj, Shisham, Shirish, Neem and Eucalyptus, also helps limit runoff by increasing canopy storage and slowing peak flow (Datar, Audet, & Mulligan, August 2011). Additional species like Vitex negundo, Pennisetum purpureum and Arundo donax act as effective barriers that slow water movement (Kamboj, December 2010). Runoff can also be further reduced by species that enhance infiltration, including Sinapis alba, Brachypodium distachyon and Vicia ervilia (Ordóñez-Fernández, 2018). Combining species such as Cenchrus ciliaris with Emblica officinalis has shown strong soil-conserving and runoff-reducing effects (Meena, 2023).

Soil

Runoff coefficients and infiltration capacity are strongly influenced by soil type and gravel percentage, as noted by Podwojewski et al., who explain that “soil cover and texture strongly influence water runoff and soil detachment under rainfall” (Podwojewski et al., 2011). Soil properties also determine how much water is absorbed during rainfall. Alghamdi found that adding natural clay along with fine wheat straw “significantly increases water content and reduces evaporation” in sandy soils (Alghamdi, 2023).

Vegetation improves water retention by reducing soil loss. Increasing vegetation cover beyond 10–40% leads to noticeable reductions in erosion, reaching stable conditions around 50–70% cover (Quinton, Edwards & Morgan, 1997). Root density and canopy cover also help strengthen soil structure. Liu et al. reported that broadleaf litter reduced runoff by 29.5% and sediment by 85.1%, while needle litter reduced runoff and sediment by 31.3% and 79.9%, respectively (Liu, Gao, Wang & Jiao, 2018).

Soil conditioners such as bean-straw mulch and polyvinyl acetate further improve infiltration, and have been shown to increase the time required for runoff to form (Balvaieh, Gholami & Kavian, 2022). Garg et al. found that these treatments reduced surface runoff by 15–20 mm on Alfisols and by 35–40 mm on Vertisols (Garg et al., 2022).Compaction significantly limits infiltration in urban areas. Gregory et al. reported that “urban soil compaction can reduce infiltration by up to 99% of rainfall,” which highlights the importance of maintaining soil permeability in developed regions (Gregory, Dukes, Jones & Miller, 2006).

Bioretention

Bioretention systems manage stormwater by filtering runoff through vegetation and engineered soil media, often supported by an underdrain (Slaney, 2016). The soil mix typically contains 70–88% sand, 8–18% silt, and 3–5% clay to provide adequate permeability while maintaining nutrient retention (Slaney, 2016). Coarse sand is added to improve drainage and reduce the chance of clogging (Slaney, 2016).

The upper soil layer is usually loamy sand or sandy loam, which supports root development and filtration (Slaney, 2016). Compost is commonly added at 3–5% by weight to enhance microbial activity and soil structure, though higher amounts may lead to nutrient leaching (Slaney, 2016).

For effective operation, bioretention systems require an infiltration rate between 1–2.5 cm/hr; lower rates can cause ponding, while higher rates may reduce pollutant removal efficiency (Slaney, 2016). A soil media depth of 0.75–1.2 m is recommended to sustain plant growth and maintain long-term hydraulic performance (Slaney, 2016).

Site study

The study was conducted at the School of Planning and Architecture, Vijayawada (SPAV) campus (16° 29′ 51.72″ N, 80° 29′ 57.84″ E) in the city of Vijayawada, located in the Krishna district of Andhra Pradesh in the city of Vijayawada. Vijayawada is located within the catchment area of the Krishna River, and being an urbanising city with a rapid urbanisation rate, it offers a valuable setting for the study of urban forest stormwater interactions. The region falls within a tropical monsoon climate regime with a mean annual rainfall of approximately 977.9 mm (IMD, 2025), and as a result, it is located under a tropical monsoon regime. As a result of the varying weather conditions, the temperatures vary significantly throughout the year: during the summer months, temperatures can reach the upper 30 °C range, while in the cooler months, temperatures can drop to the lower 20s °C range. Daytime wind speeds remain moderate, though vary seasonally . During the study period (September and October) rainfall is especially relevant to the significance of the study: it is typical for Vijayawada to receive around 143 mm of precipitation in September and around 158 mm in October. There is a noticeable change in rainfall intensity and frequency during these months, as the southwest monsoon has ended and the northeast monsoon has begun; rains will be heavier in October, and the intensity will vary considerably from season to season. Vijayawada and the surrounding districts have been experiencing significant flooding events in recent years due to heavy rainfall occurring during this transition period, which has resulted in significant flooding events in these areas. There is a complex vegetation network in the city of Vijayawada that consists of native and introduced tree species, distributed throughout diverse land types and development types; this network influences interception, infiltration, and runoff pathways as a key component of the city's urban system

Advanced International Journal for Research (AIJFR)
E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Figure 1: Site Plan and Selected Plant Species

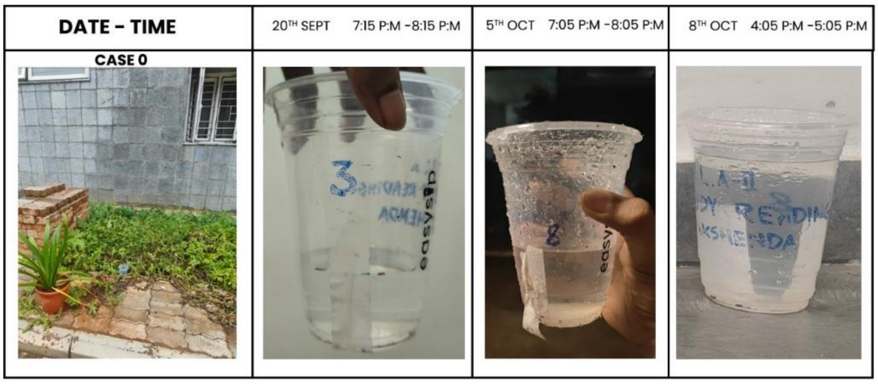
Study design and field measurements

The field investigation comprised six case-studies within the campus of School of Planning and Architecture Vijayawada (SPAV), Vijayawada. In each case, rainfall was manually measured for one-hour durations beneath specified trees or in an open reference location, in order to evaluate canopy interception and through-fall. In all six cases the measurement setup was at ground level, on plain terrain, with canopies overlapping laterally and vertically, thereby influencing intercepted rainfall. For each case a beaker was placed beneath the canopy and rainfall recorded manually for three specific events: 20th September 2025, 5th October 2025 and 8th October 2025 for 1 hour.

Case 0: Open Ground Model - Control Site

An open reference measurement 'Case 0' recorded rainfall in an un-shaded, open area for the same time periods, to quantify canopy interception as the difference between open rainfall and through-fall beneath tree-canopies. Additional plant morphological data such as leaf-area, canopy dimension, and ground cover were captured to link vegetation structure with interception efficiency. The non-intercepted rainfall was thus computed for all six cases, enabling a detailed assessment of how tree species, canopy form and spatial arrangement influence stormwater mitigation in the urban forest system.

Figure 2 : Rainfall intercept data for CASE 0



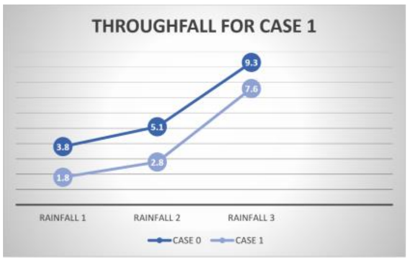
Case 1: Mixed Vegetation Model – Dominant *Ficus benghalensis* (Banyan Tree)

This case represents a mixed vegetation model characterized by multiple species with overlapping canopies, where *Ficus benghalensis* (Banyan) serves as the dominant tree. The banyan is a large, evergreen tree with broad, leathery leaves (10–15 cm long) and an expansive, dome-shaped canopy of extending height of 14m. It exhibits dense leaf structure, contributing significantly to rainfall interception. Associated species within this model include *Syzygium cumini* (Jamun), *Azadirachta indica* (Neem), and *Cassia fistula* (Golden Shower Tree). *Syzygium cumini* is a semi-evergreen tree with an average canopy height of 15 m, having opposite, glossy leaves. *Azadirachta indica* is a hardy evergreen species, about 12 tall, characterized by pinnate leaves and a moderately dense canopy that enhances water infiltration through litter accumulation. *Cassia fistula*, a deciduous tree reaching 13 m in height, bears compound leaves with smooth, glabrous leaflets and a relatively open canopy. The spatial overlap of these tree canopies creates a multilayered vegetative cover. This diverse structure serves as a functional model of forest prototype for understanding canopy interception dynamics in mixed urban vegetation conditions.

Figure 3: Elevation and view of Case-1

Figure 4: Rainfall intercept data for Case-1

Figure 5: Throughfall Data Comparison of Case -0 and Case-1



Case 2: Mixed Vegetation Model – Dominant *Tectona grandis* (Teak Tree)

This case also represents a mixed vegetation model, characterized by overlapping canopies of multiple tree species, with *Tectona grandis* (Teak) serving as the dominant species. The teak tree is a deciduous species typically reaching 10 m in height within the study area. It is distinguished by its large, ovate to elliptic leaves measuring 25–45 cm long, covered with rough, hairy surfaces that effectively intercept rainfall.The associated species within this model include *Cassia fistula* (Golden Shower Tree) and *Syzygium cumini* (Jamun). *Cassia fistula* exhibits a deciduous habit of 15 m height; its moderately open canopy allows partial throughfall. *Syzygium cumini* is a semi-evergreen species, with elliptic, glossy leaves and a dense canopy, reaching 15 m in height, contributing to the interception capacity through its dense leaf arrangement.The combination of *Tectona grandis* with *Cassia fistula* and *Syzygium cumini* creates a multi-strata vegetative layer, where varying leaf textures, canopy densities, and branching structures collectively influence rainfall partitioning.

Figure 6: Elevation and view of Case-2

Advanced International Journal for Research (AIJFR)

E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Figure 7: Rainfall intercept data for Case-2

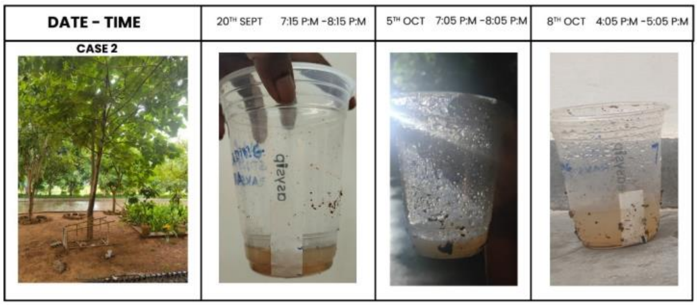
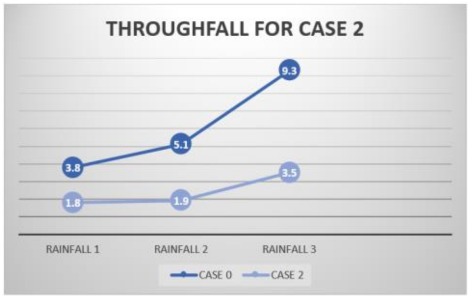


Figure 8: Throughfall Data Comparison of Case -0 and Case-2



Case 3: Mixed Vegetation Model – Dominant *Ficus religiosa* (Peepal Tree)

In this case, the dominant species is *Ficus religiosa* (Peepal tree), surrounded by sub-canopy species such as *Plumeria alba*, *Azadirachta indica* (Neem), *Acacia auriculiformis*, and *Delonix regia* (Gulmohar). *Ficus religiosa* is a large, semi-evergreen tree with a broad, spreading canopy reaching around 15m in height, and cordate leaves with long tapering tips that facilitate efficient drip-off of intercepted rainwater. The associated species form a mixed canopy layer, *Plumeria* with its thick, leathery deciduous leaves, *Neem* with fine pinnate foliage, and *Delonix regia* and *Acacia* contributing compound leaves that diffuse rainfall. Together, these trees create a diverse, overlapping canopy that enhances rainfall interception and moderates through-fall due to varied leaf textures and canopy densities.

Figure 9: Elevation and view of Case-3

Figure 10: Rainfall intercept data for Case-3

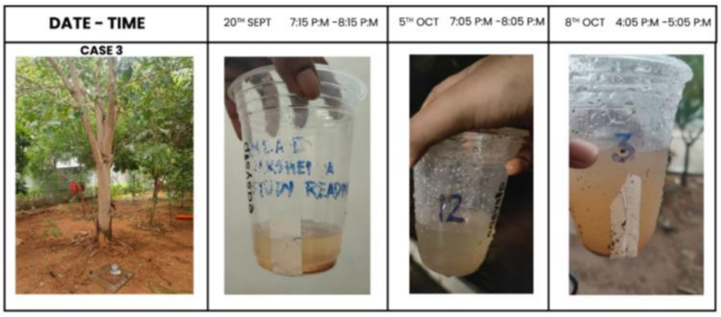
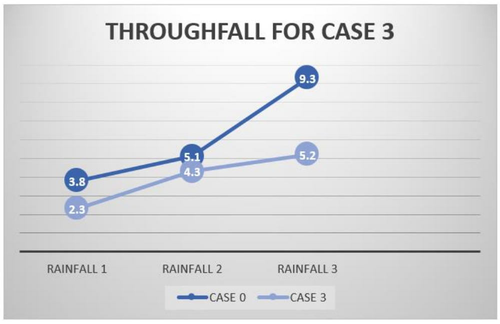


Figure 11: Throughfall Data Comparison of Case -0 and Case-3



Case 4: Uniform Avenue Model – *Lagerstroemia speciosa* (Pride of India / Jarul Tree)

The avenue consists of five trees of the same species, *Lagerstroemia speciosa* (commonly known as Jarul or Pride of India), planted in a linear arrangement. These trees are relatively short, with an height of about 7 meters, deciduous, broad, elliptic leaves that turn red before shedding. The canopy is moderately dense and rounded, allowing partial penetration while still offering interception capacity during rainfall. Due to the uniform spacing and similar canopy dimensions, this case provides consistent conditions for measuring rainfall interception and throughfall without structural variability.

Figure 12: Elevation and view of Case-4

Figure 13: Rainfall intercept data for Case-4

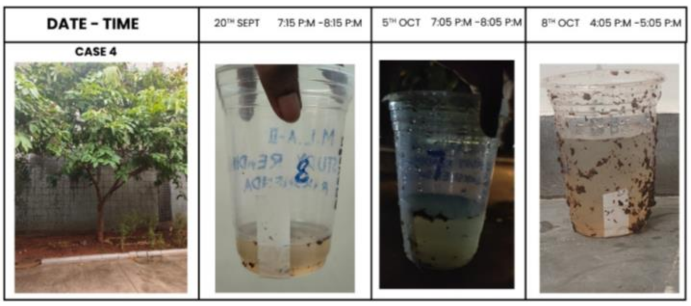
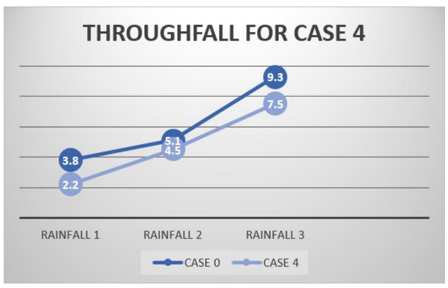


Figure 14: Throughfall Data Comparison of Case -0 and Case-4



Case 5: Uniform Avenue Model – *Albizia lebbeck* (Siris Tree)

The avenue consists of a row of *Albizia lebbeck* (Siris trees), a large deciduous species known for its wide-spreading, umbrella-shaped canopy and average height of around 15 meters. The trees feature bipinnate leaves with numerous small leaflets that create a finely textured, semi-permeable canopy. This leaf structure allows moderate light and airflow penetration while efficiently intercepting rainfall. The branches are horizontally spreading, forming a broad lateral canopy that often overlaps with adjacent trees, enhancing interception and shading. The *Albizia lebbeck* trees also exhibit rapid leaf regeneration after rainfall, which maintains consistent canopy cover during the monsoon season. Their deep root system and dense litter layer contribute to soil stabilization and improved infiltration beneath the canopy. The uniform spacing and similar canopy size in this row provide a clear condition for analysing rainfall interception, throughfall, and canopy influence on stormwater regulation.

Figure 15: Elevation and view of Case-5

Figure 16: Rainfall intercept data for Case-5

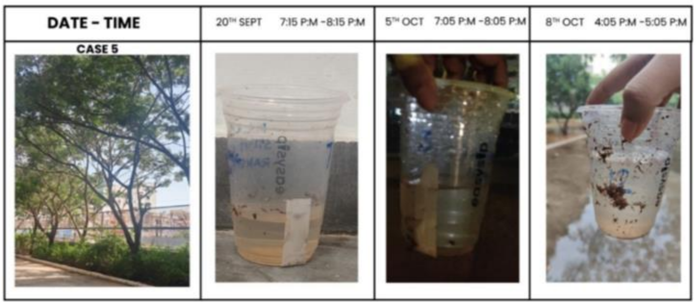
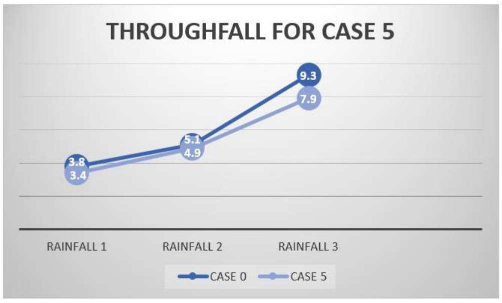


Figure 17: Throughfall Data Comparison of Case -0 and Case-5



Case 6: Mixed Avenue Model – Dominant *Samanea saman* (Rain Tree)

The dominant tree species is *Samanea saman* (Rain Tree), a large, deciduous species with a wide-spreading, umbrella-shaped canopy reaching 25 meters in height. The avenue also includes other species as *Cocos nucifera* (Coconut), *Cassia fistula* (Golden Shower Tree), *Mangifera indica* (Mango), and *Delonix regia* (Gulmohar), forming a mixed and partially overlapping canopy structure. The *Rain Tree* has finely divided bipinnate leaves that close during low light or rainfall, influencing interception. The *Coconut* contributes tall, feathery fronds, while *Cassia fistula* and *Delonix regia* add compound foliage with medium-density shade, and *Mango* provides dense, evergreen cover. Additionally, ground vegetation and herbaceous cover are present beneath the canopy, aiding infiltration and reducing surface runoff.

Figure 18: Elevation and view of Case-6

Figure 18: Rainfall intercept data for Case-6

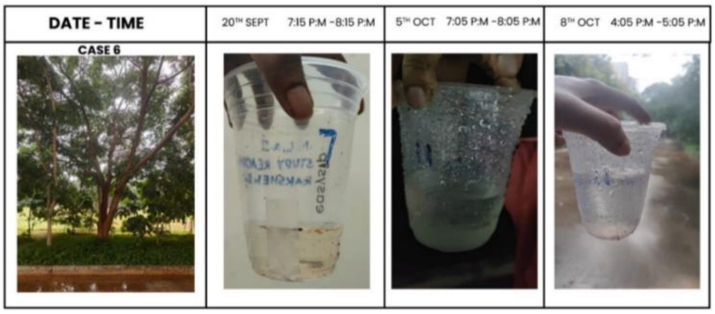
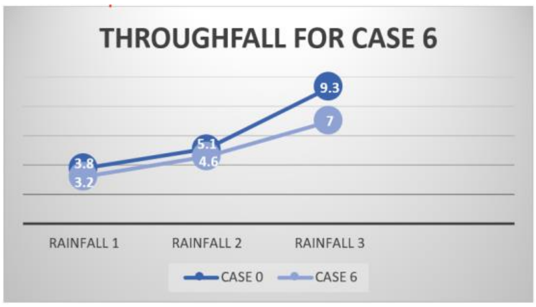


Figure 19: Throughfall Data Comparison of Case -0 and Case-6



Results

Average interception losses

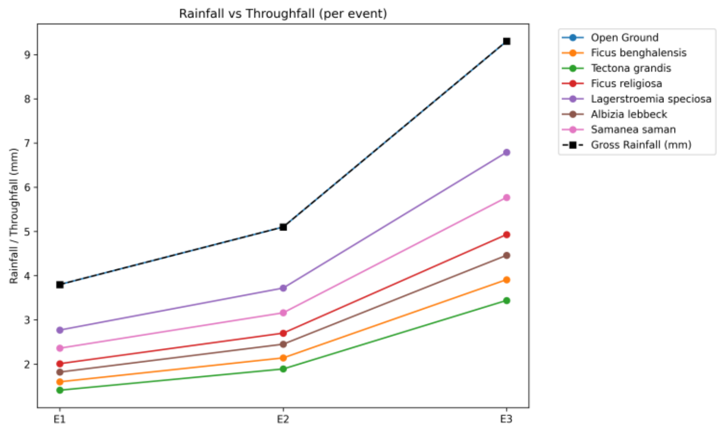
Across the three recorded rainfall events 20 September, 5 October, and 8 October 2025, interception varied noticeably between vegetation Model. When compared to the open condition 'Case 0', all vegetative cases exhibited reduced throughfall, indicating canopy interception losses. The mixed vegetation models (Cases 1, 2 and 3) showed the highest interception, with rainfall reduction ranging from 35% to 63%, depending on canopy density and leaf morphology. The avenue plantations (Cases 4–6) exhibited moderate interception values between 10% and 42%, influenced by canopy height, spacing, and uniformity. The open ground model (Case 0) recorded full rainfall, serving as a baseline for comparison.

Table 1: Average Interception Losses

CASES	Dominant Species	Vegetation Type	Rainfall 1 (20/09) (mm)	Rainfall 2 (05/10) (mm)	Rainfall 3 (08/10) (mm)	Interception Range (%)
Case 0 (Control)	None	Open Ground	5	9.5	12	0%
Case 1	Ficus benghalensis	Mixed Forest	3.2	5.1	5.8	36% - 52%
Case 2	Tectona grandis	Mixed Forest	3	3.5	7.2	40% -63%

Case 3	Ficus religiosa	Mixed Forest	3.1	5.3	6.2	38% - 48%
Case 4	Lagerstroemia speciosa	Uniform Avenue	4.8	5.5	8.3	4% - 42%
Case 5	Albizia lebbeck	Uniform Avenue	4.1	7.3	9.2	18%- 23%
Case 6	Samanea saman	Mixed Avenue	4.5	7.1	9	10% - 25%

Figure 20: Throughfall comparison between all the cases

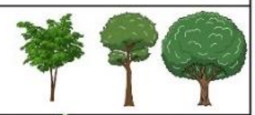


Morphological influence on interception and throughfall

Canopy Form and Height

Ficus benghalensis and Ficus religiosa with their broad, horizontally spreading crowns, intercepted the highest rainfall (63% and 48%, respectively). Their umbrella-shaped forms increase lateral interception, prolonging canopy storage time. In contrast, Lagerstroemia speciosa and Albizia Labek, which have upright and discontinuous crowns, allowed greater throughfall (28% and 48%). The limited overlap and smaller canopy projection reduce interception efficiency.

Table 2: Canopy Form in each case

CASES	TREE SPECIES	OBSERVED INTERCEPTION	CANOPY FORM	
CASE 1	FICUS BENGHALENSIS DELONIX REGIA SYZYGIUM CUMINI AZADIRACHTA INDICA	40 - 63%	-BROAD, -HORIZONTALLY SPREADING CROWNS - ROUNDED CANOPY	
CASE 2	TECTONA GRANDIS CASSIA FISTULA SYZYGIUM CUMINI AZADIRACHTA INDICA	40 - 52%	- UPRIGHT SEMI-SPREAD - LIGHT OPEN-SPREAD -SEMI-SPHERICAL SPREADINGSEMI -SPHERICAL SPREADING	
CASE 3	FICUS RELIGIOSA DELONIX REGIA ACACIA AURICULIFORMIS, AZADIRACHTA INDICA	38 - 48%	- DOME-SHAPED SPREADING - NARROW DENSE CROWN	
CASE 4	LAGERSTROEMIA SPECIOSA	4 - 42%	- UPRIGHT COMPACT	
CASE 5	ALBIZIA LEBBECK	18 - 23%	- WIDE, UMBRELLA-LIKE CROWN -- FINE BIPINNATE LEAVES	
CASE 6	SAMANEA SAMAN DELONIX REGIA CASSIA FISTULA COCOS NUCIFERA	10 - 25%	- WIDE-SPREADING CANOPY. - OPEN, IRREGULAR, - VASE-SHAPED CANOPY	

Overall, interception efficiency followed the order: Tectona grandis > Ficus benghalensis > Ficus religiosa> Lagerstroemia speciosa > Albizia lebbeck > Samanea saman. Broad-leaved and evergreen trees achieved the highest interception. Mixed vegetation types (Cases 1-3) displayed greater interception consistency compared to avenue types (Cases 4-6), where spacing and canopy discontinuity reduced rainfall retention. Maximizing rainfall interception in an urban environment, the ideal tree morphology would be:

Dense, multi-layered canopy: prefer trees that when planted together, form an overlapping, multi-strata canopy.

Broad, spreading, or dome-shaped crowns: canopy forms like those of Ficus benghalensis (broad, horizontally spreading crowns) or Ficus religiosa (dome-shaped spreading) are associated with higher interception.

Large, rough, hairy, or leathery leaves: species like Tectona grandis with "large, ovate to elliptic leaves measuring 25-45 cm long, covered with rough, hairy surfaces" are described as "effectively intercept rainfall." Ficus species with "broad, leathery leaves" also perform well. These characteristics likely increase surface area for water retention and reduce immediate drip-off.

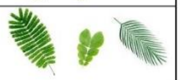
Evergreen or semi-evergreen: while deciduous trees (like Tectona grandis) can be very effective when in leaf, evergreen or semi-evergreen species (like Ficus benghalensis or Syzygium cumini) ensure year-round interception benefits, which is crucial for consistent stormwater management.

Upright semi-spread/compact where space is limited: for areas like avenues where space might constrain very broad canopies, species with an "upright semi-spread" (Tectona grandis) or "upright compact" (lagerstroemia speciosa) form that still achieve good density and leaf characteristics can be effective interceptors.

Leaf Morphology

Ficus benghalensis has large, thick leaves (10-15 cm) with waxy surfaces that can hold water effectively before drip formation. Albizia lebbeck and Samanea saman both have compound bipinnate leaves with numerous small leaflets, giving them fine-textured foliage; however, their leaflets close when they come into contact with rain (Dreyer & Vergara-Valladares, 2023). Tectona grandis also has large leaves, providing a broad surface area for rainfall interception.

Table 3: Leaf Morphology in each case

CASES	TREE SPECIES	OBSERVED INTERCEPTION	LEAF MORPHOLOGY	
CASE 1	FICUS BENGHALENSIS DELONIX REGIA SYZYGIUM CUMINI AZADIRACHTA INDICA	40 - 63%	-LARGE LEATHERY -FINE BIPINNATE - ELLIPTIC GLOSSY - SERRATED PINNATE	
CASE 2	TECTONA GRANDIS CASSIA FISTULA SYZYGIUM CUMINI AZADIRACHTA INDICA	40 - 52%	- ULARGE ROUGH-TEXTURED - SMOOTH PINNATE - ELLIPTIC GLOSSY -SERRATED PINNATE	
CASE 3	FICUS RELIGIOSA DELONIX REGIA ACACIA AURICULIFORMIS, AZADIRACHTA INDICA	38 - 48%	- BROAD HEART-SHAPED - FINE BIPINNATE - FINE BIPINNATE - SERRATED PINNATE	
CASE 4	LAGERSTROEMIA SPECIOSA	4 - 42%	- OVAL SMOOTH	
CASE 5	ALBIZIA LEBBECK	18 - 23%	- FINE BIPINNATE	
CASE 6	SAMANEA SAMAN DELONIX REGIA COCOS NUCIFERA	10 - 25%	- WIDE BIPINNATE - FINE BIPINNATE - LONG PINNATE	

Evergreen vs. Deciduous Nature

Evergreen species (*Ficus benghalensis*, *Ficus religiosa*) maintained canopy density throughout the study period, ensuring stable interception even in multiple rainfall events. Deciduous species (*Tectona grandis, Lagerstroemia speciosa*) displayed lower interception due to partial leaf shedding, which increased the proportion of direct throughfall.

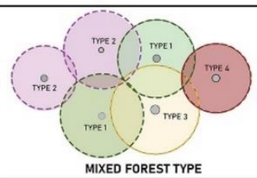
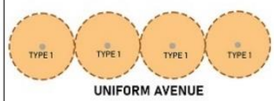
Table 4: Evergreen, Deciduous composition in each case

CASES	TREE SPECIES	OBSERVED INTERCEPTION	EVERGREEN / DECIDUOUS NATURE
CASE 1	FICUS BENGHALENSIS DELONIX REGIA SYZYGIUM CUMINI AZADIRACHTA INDICA	40 - 63%	75 % / 25 %
CASE 2	TECTONA GRANDIS CASSIA FISTULA SYZYGIUM CUMINI AZADIRACHTA INDICA	40 - 52%	50 % / 50 %
CASE 3	FICUS RELIGIOSA DELONIX REGIA ACACIA AURICULIFORMIS, AZADIRACHTA INDICA	38 - 48%	50 % / 50 %
CASE 4	LAGERSTROEMIA SPECIOSA	4 - 42%	0 % / 100 %
CASE 5	ALBIZIA LEBBECK	18 - 23%	0 % / 100 %
CASE 6	SAMANEA SAMAN DELONIX REGIA COCOS NUCIFERA	10 - 25%	66.6 % / 33.3 %

Canopy Overlap and Layering

Mixed vegetation plots (Cases 1-3) exhibited higher overall interception compared to avenue models (Cases 4-6). Overlapping canopy layers created by multiple species enhanced rainfall capture, promoted drip redistribution, and slowed throughfall movement. In avenue alignments, uniform spacing and one-directional canopies resulted in reduced interception and higher variability in throughfall, influenced by wind exposure and canopy gaps.

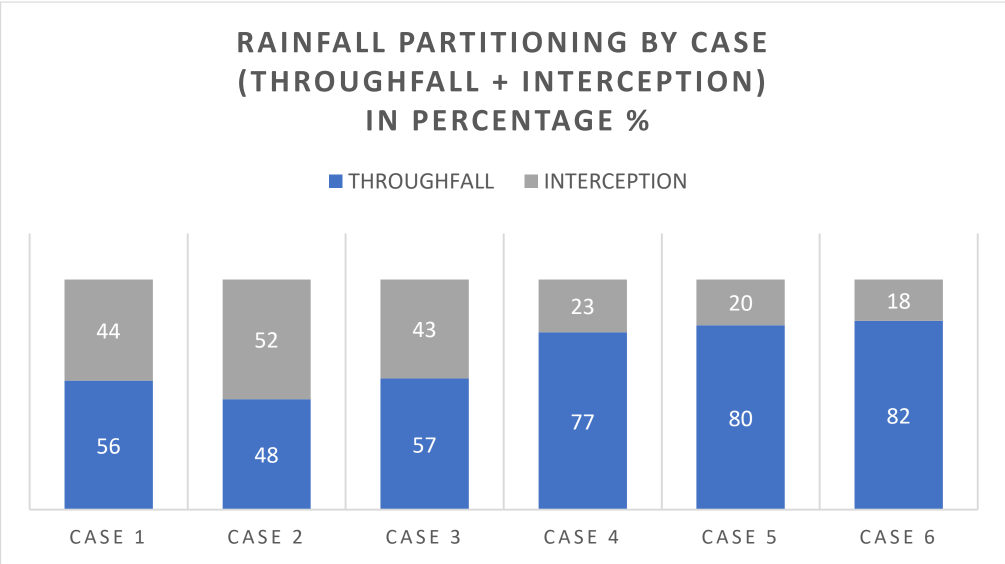
Table 5: Canopy Overlap and Layering in all category

CATEGORY	CASES	VEGETATION TYPE	AVERAGE INTERCEPTION (%)	FINDINGS
CATEGORY 1 – MIXED FOREST CANOPY	CASE 1 (FICUS BENGHALENSIS) CASE 2 (TECTONA GRANDIS) CASE 3 (FICUS RELIGIOSA)	 TYPE 2, TYPE 2, TYPE 1, TYPE 4, TYPE 1, TYPE 3 — MIXED FOREST TYPE	46%	Highest interception efficiency due to crown overlap, large leaf surface area, and multilayered foliage.
CATEGORY 2 – UNIFORM AVENUE PLANTATION	CASE 4 (LAGERSTROEMIA SPECIOSA) CASE 5 (ALBIZIA LEBBECK)	 TYPE 1, TYPE 1, TYPE 1, TYPE 1 — UNIFORM AVENUE	22%	Uniform canopy limits lateral overlap, but Albizia lebbeck's broad crown improves performance slightly. Leaf size and canopy density are major factors here.
CATEGORY 3 – MIXED SPECIES AVENUE	CASE 4 (SAMANEA SAMAN MIXED AVENUE)	 TYPE 1, TYPE 2, TYPE 3, TYPE 4, TYPE 2 — MIXED AVENUE	17.5%	though Samanea saman has a wide canopy, the linear spacing and lack of understorey reduce cumulative interception and canopy storage capacity.

Throughfall

Throughfall was most uniform under dense, multi-tiered canopies (*Ficus benghalensis*, *Ficus religiosa*) and highly variable under fragmented canopies (*Lagerstroemia speciosa*, *Samanea saman*). Mixed Forest" cases (1-3) show higher interception (43-52%) and lower throughfall, indicating denser canopies. "Avenue" cases (4-6) show much lower interception (18-23%) and higher throughfall, suggesting more open canopies. This highlights how tree type and planting density significantly influence how much rain reaches the ground.

Figure 21: Throughfall and interception percentage in all the cases



IEI (Interception Efficiency Index)

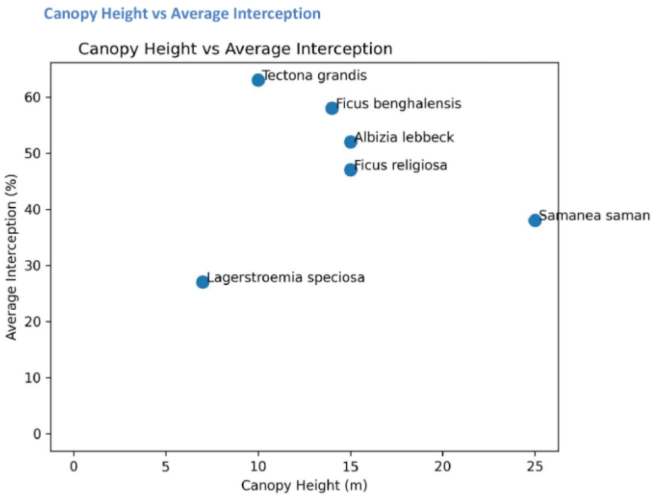
Interception Efficiency Index (IEI): Measures how effectively a tree canopy intercepts rainfall, normalizing for its height and leaf density (LAI). Higher IEI means more efficient interception per unit of canopy structure. Tectona grandis (Teak) to be the most efficient, showcasing exceptional interception for its size and leaf characteristics, followed by Lagerstroemia speciosa which performs remarkably well despite its moderate stature. Conversely, Ficus benghalensis and Ficus religiosa exhibit moderate efficiency, leveraging their large canopies for significant interception volume but not unique efficiency per structural unit, while Albizia lebbeck demonstrates lower efficiency due to its permeable canopy. Samanea saman (Rain Tree), despite being the tallest, proves least efficient, suggesting its vast but open canopy is less effective when normalized by its dimensions. Ultimately, the IEI underscores that canopy architecture and specific leaf traits are more critical determinants of interception efficiency than a tree's overall size, providing crucial guidance for selecting optimal tree species in urban water management strategies.

$$\text{INTERCEPTION EFFICIENCY INDEX (IEI)} = \frac{\text{INTERCEPTION (\%)}}{\text{CANOPY HEIGHT (M) X LEAF AREA INDEX}}$$

Table 6: IEI value in all Cases

Case	**Dominant Species**	**Canopy Height (m)**	**Average Interception (%)**	**LA I**	**IEI Calculation (Avg. Int. / (Height X LAI))**	**Intercep tion Efficiency Index (IEI)**
1	Ficus benghalensis	14	44	6	0.44 / (14 X 6) = 0.44 / 84	**0.0052**
2	Tectona grandis	10	51.5	4.5	0.515 / (10 X 4.5) = 0.515 / 45	**0.0114**
3	Ficus religiosa	15	43	5.5	0.43 / (15 X 5.5) = 0.43 / 82.5	**0.0052**
4	Lagerstroe mia speciosa	7	23	3.5	0.23 / (7 X 3.5) = 0.23 / 24.5	**0.0094**
5	Albizia lebbeck	15	20.5	4	0.205 / (15 X 4) = 0.205 / 60	**0.0034**
6	Samanea saman	25	17.5	5	0.175 / (25 X 5) = 0.175 / 125	**0.0014**

Figure 22: Canopy height and interception relation in all the cases



Conclusion & landscape arrangement recommendations

Forest settings

Dense, multi-layered, and overlapping canopies should be prioritized, as the study showed that these structures provide the highest rainfall interception by increasing canopy storage, slowing raindrop fall speed, and reducing direct throughfall. Species with broad, spreading crowns and large, rough, or leathery evergreen leaves such as Ficus species performed consistently well in mixed forest settings. The combination of vertical layering and evergreen dominance helped maintain strong interception across different rainfall events. Although Tectona grandis is deciduous, its large leaf size still contributes significantly to interception.

Landscape settings (avenue arrangements)

For avenue or linear planting patterns, choosing species with dense individual crowns, favourable leaf morphology, and a strong evergreen presence ensures more reliable interception year-round. Tectona grandis and Lagerstroemia speciosa showed efficient performance even at moderate canopy sizes in such arrangements.

Landscape arrangement recommendations

Densely planted areas / parks (natural arrangement)

In densely planted parks, the main objective is to maximize stormwater capture, enhance evaporative cooling, and delay runoff. Mixed Forest Models are recommended, especially those using species with broad, dome-shaped crowns and large, rough-textured, preferably evergreen leaves such as Ficus benghalensis. Although Tectona grandis is deciduous, its high Interception Efficiency Index (IEI) makes it valuable in mixed clusters. When planted in groups, these species form an overlapping multi-layered canopy that supports high interception rates, consistently around 38–63%.

Urban streetscapes / Avenues (linear landscape arrangement)

For streetscapes and avenues, the focus should be on species with high IEI values. Trees such as Lagerstroemia speciosa are suitable because they offer excellent interception relative to their canopy size. The arrangement should favour evergreen trees or species with dense, upright to semi-spreading crowns to maintain steady interception benefits throughout the year.

References

1. Alghamdi, S. A.-G.-Z.-G. (2023). Modifying of calcareous soil with some acidifying materi-als and its effect on Helianthus annuus (L.) growth. . Saudi Journal ofBiological Sciences,30, 103568.
2. Alves, P., Formiga, K.T.M, & Traldi, M. (2018). Rainfall interception capacity of tree species used in urban afforestation. Urban Ecosyst 21, 697–706 .
3. Balvaieh, A., Gholami, L., & Kavian, F. S. (May 2022). Effects Study of Individually and Combinied of Soil Conditioners on Response of Soil Loss and Surface Runoff. Journal of watershed management research 13(25):21-29.
4. C. Rixen, C. M. (2005). Improved the water retention links high species richness with increased productivity in arctic tundra moss communities. Oecologia, 146 (2), 287-29.
5. Carlyle-Moses DE, S. J. (2015). Tree traits and meteorological factors influencing the initiation and rate of stemflow from isolated deciduous trees. Hydrol Process , 29:4083–4099.

6. Cerdà, A., E, L.-B. M., I, F.-P., Úbeda, X., Novara, A., López-Vicente, M., . . . & Pulido, M. (2021). The role of plant species on runoff and soil erosion in a Mediterranean shrubland. The role of plant species on runoff and soil erosion in a Mediterranean shrubland. Science of The Total Environment, 799, 149218.

7. Chow, M. F., BakaR, M. F., Roslan, M., & Fadzailah, F. (January 2015). Hydrological performance of native plant species within extensive green roof system in Malaysia. ARPN Journal of Engineering and Applied Sciences.

8. Datar, A., Audet, P., & Mulligan, D. (August 2011). Post-mined land rehabilitation in India: Cataloguing plant species used in land revegetation. Australian Mine Rehabilitation. Australian Mine Rehabilitation Workshop .

9. David, J., Valente, F., & Gash, J. (2005). Evaporation of intercepted rainfall. M. Anderson (Ed.), Encyclopedia of Hydrological Sciences, John Wiley and Sons. Ltd.,, 627-634 (Chapter 43).

10. Douglas, I. (1983). Edward Arnold, London. an Savannah.

11. Dreyer, I., & Vergara-Valladares, F. (2023). Temperature sensing: A potassium channel as cold sensor in the rain tree Samanea saman. Current Biology, R1298-R1300.

12. Garg, K. K., Anantha, K., Dixit, S. N., R., V., A., W., P., B. N., & Singh, R. (2022). Impact of raised beds on surface runoff and soil loss in Alfisols and Vertisols. CATENA, 211, 105972: https://doi.org/10.1016/j.catena.2021.105972.

13. Gregory, J., Dukes, M., Jones, P., & Miller, G. (2006). Effect of urban soil compaction on infiltration rate. J. Soil Water Conserv., 61, 117-124.

14. Hu, Y., Zhang, F., Luo, Z., Badreldin, N., Benoy, G., & Xing, Z. (October 2023). Soil and water conservation effects of different types of vegetation cover on runoff and erosion driven by climate and underlying surface conditions. CATENA, 107347.

15. IMD. (2025). Rainfall information: District-wise and station-wise data. Retrieved from Ministry of Earth Sciences, Government of India: https://mausam.imd.gov.in/

16. J. Lundholm, J. M. (2010). Plant species and functional group combinations affect green roof ecosystem functions. PLoS ONE, 5 (3), p. e9677.

17. Jakati, S. P., Murukannappa, Rajashekarappa, K. S., Devaraja, K., & H, M. M. (2024). Effects of Crop Canopy and Rainfall Intensities on Runoff in Alfisols of Eastern Dry Zone of Karnataka. International Journal of Environment and Climate Change, 722-734.

18. Kamboj, N. (December 2010). Effects of vegetative barriers for channelization of shiwalik torrent at Sabhawala in Doon Valley. Environment Conservation Journal , 99-102.

19. Koehler, M. (2004, September). Energetic effects of green roofs on the urban climate near to the ground and to the building surfaces. Proceeding of international green roof congress, International Greenroof Association, Nürtingen.

20. Kuehler, E., Hathaway, J., & Tirpak, A. (2017). Quantifying the benefits of urban forest systems as a component of the green infrastructure stormwater treatment network. Ecohydrology , p. 10.

21. Kumar, R., Ambasht, R., Srivastava, A. K., & & Srivastava, N. (1996). Role of some riparian wetland plants in reducing erosion of organic carbon and selected cations. . Ecological Engineering, 6(4), 227-239.

22. Kutay, M. E., & Ekşi, M. (May 2025). Investigation of the effects of different plant groups on surface runoff. Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi 26(1):191-201.

23. Leopold, L. (1968.). Hydrology for Urban Land Planning – A Guidebook on the. Washington, DC.: United States Department of the Interior,.

24. Liu, J., Gao, G., Wang, S., & Jiao, L. (January 2018). The effects of vegetation on runoff and soil loss: Multidimensional structure analysis and scale characteristics. Journal of Geographical Sciences 28(1), 59-78.

25. Livesley SJ, B. B. (2014). Rainfall interception and stem flow by eucalypt street trees—the impacts of canopy density and bark type. Urban For Urban Green , 13:192–197.

26. Meena, G. L. (2023). Quantification of Impact of Land Use Systems on Runoff and Soil Loss from Ravine Ecosystem of Western India. . Agriculture, 13(4).

27. Nytch, C.J., Meléndez-Ackerman, E.J., Pérez, & ME. (2019). Rainfall interception by six urban trees in San Juan, Puerto Rico. Urban Ecosyst 22,, 103–115.

28. Ordóñez-Fernández, R. G.-G.-B. (2018). Efficiency of four different seeded plants and native vegetation. Land Degradation & Development, 2278-2290.

29. P, L., & F, D. (2007). Rainfall partitioning by vegetation under. J Hydrol, 335:37–54.

30. Podwojewski, P., Janeau, J. L., Grellier, S., Valentin, C., Lorentz, S., & Chaplot, V. (11 January 2011). Influence of grass soil cover on water runoff and soil detachment under rainfall simulation in a sub-humid South African degraded rangeland. Earth Surface Processes and Landforms, 911-922.

31. Q, X., & EG, M. (2016). Surface water storage capacity of twenty tree species in Davis, California. J Environ Qual, 45:188–198.

32. Q, X., EG, M., SL, U., ME, G., & JR, S. (2000a). Winter rainfall interception by two mature open-grown trees in Davis, California. Hydrol Process, 14:763–784.

33. Quinton, J. N., Edwards, G. M., & Morgan, R. P. (September 1997). The influence of vegetation species and plant properties on runoff and soil erosion: results from a rainfall simulation study in south east Spain. British Society of Soil Science Journals,Soil Use and Management, Volume 13, Issue 3 pp. 143-148.

34. R.M. Elliott, E. A. (2018). Stormwater infiltration capacity of street tree pits: quantifying the influence of different design and management strategies in New York City. Ecol. Eng.,, 157-166.

35. Rutter, A., Morton, A., & Robins, P. (1975). A predictive model of rainfallinterception in forests. II. Generalization of the model and comparison with observations in some coniferous and hardwood stands. J Appl Ecol, 12:367–380.

36. Scholz, M. (2004). Case study: Design, operation, maintenance and water quality management of sustainable storm water ponds for roof runoff. Bioresource Technology,95, pp. 269-279.

37. Shubhashish K, P. R. (2012). The role of catchment vegetation in reducing atmospheric inputs of pollutant aerosols in Ganga river. Bull Environ Contam Toxicol., 89(2):362-7.

38. Slaney, S. (2016). Stormwater Management for Sustainable Urban Environments. Images Publishing Group.

39. Srivastava, P., & Singh, S. (2012). Conservation of soil, water and nutrients in surface runoff using riparian plant species. Journal of environmental Biology.

40. Xu, X.-L., Ma, K.-M., Fu, B.-J., Liu, W., & Song, C.-J. (2009). Soil and water erosion under different plant species in a semiarid river valley, SW China: the effects of plant morphology. Ecol Res, 24, 37–46.