Assessment of Green Roof Substrate performance using Artificial Rainfall Simulation

TF17 Water Quality and Cost-effective Technologies
Topic Code: 6 (c)

Presented by:

Suraj Sharma (Research Scholar)

Department of Civil Engineering, Punjab Engineering College (Deemed to be University), Chandigarh, India

India Water Week 2026

❑ Outline

1 Introduction

2 Materials & Methods

3 Experimental Setup

4 Results - Runoff Quantity

5 Results - Runoff Quality

6 Conclusion - Optimum Substrate Performance

❑ Introduction

- **Rapid Urbanization** and increasing **Population Densities** have led to a surge in impervious surfaces such as concrete pavements and rooftops, which significantly affect natural hydrological cycles and ecological balance.
- In response, **Sustainable Development** has become an essential urban planning priority, emphasizing Green infrastructure as a solution to mitigate environmental degradation and climate-related risks.
- Among various Green infrastructure elements, my study focuses on Green roofs for their multi-functionality, offering ecological, social, and economical benefits.

❖ **This system usually installed on building rooftops, incorporate vegetation over engineered layers that replicate natural landscapes in urban habitat.**

Types of Green Roofs

Extensive Roof



- Shallow Soil (2–6 inches)
- Low Maintenance
- Lightweight (4.5–11.3 kg/ft²)

Semi-Intensive Roof



- Moderate Soil (6–8 inches)
- Varied Plantings
- Moderate Maintenance
- Weight (11.3–22.7 kg/ft²)

Intensive Roof



- Deep Soil (8–24 inches)
- Diverse Vegetation
- Higher Maintenance
- Heavier (22.7+ kg/ft²)

Fig.1: Types of Green Roofs

❑ Components of Green Roofs



Fig.2: Different components of Green roof

❑ Methodology based on Artificial Rainfall Simulator

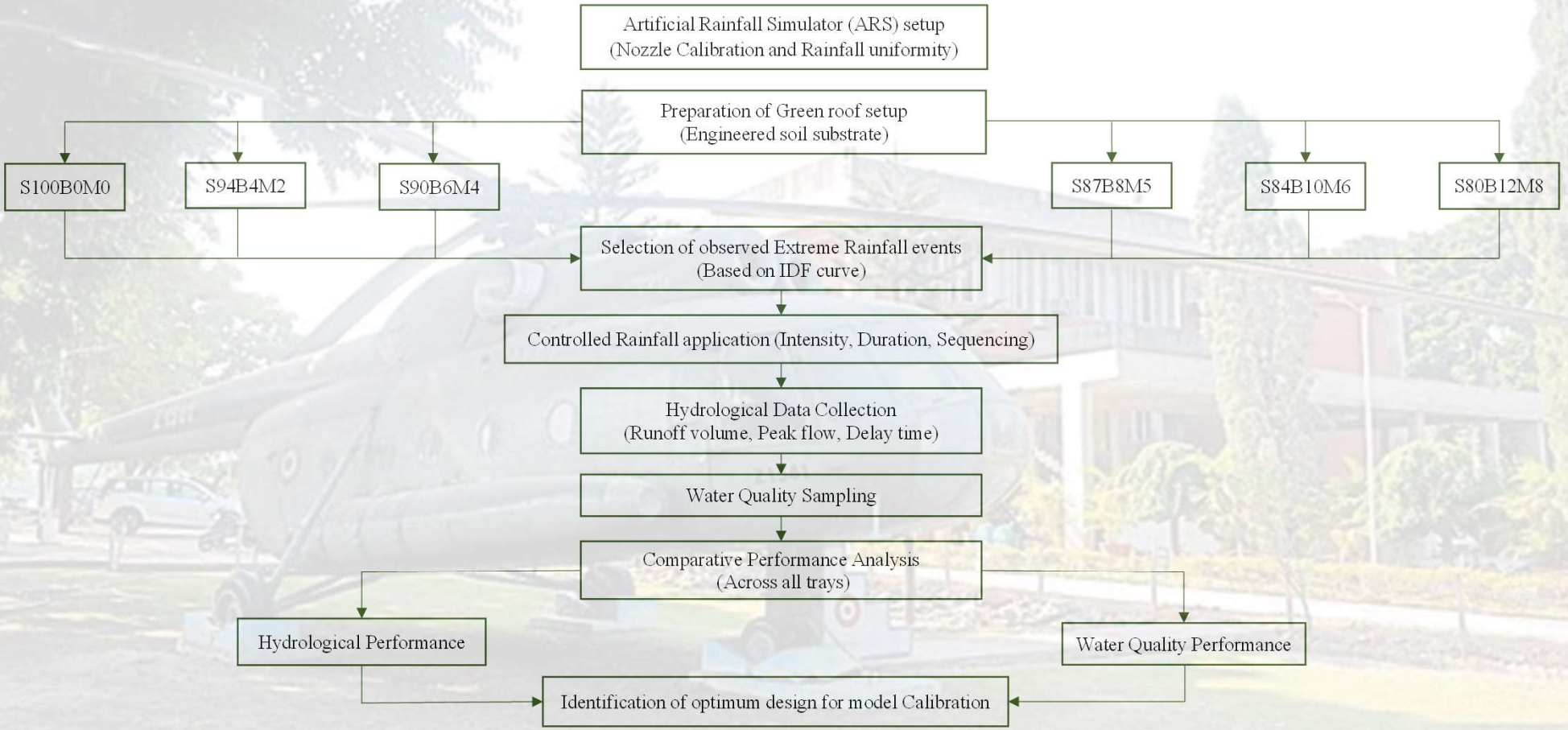


Fig. 3: Work flow chart of ARS

❑ Preparation of Green Roofs setup



Fig. 4: Set up of the Green Roofs

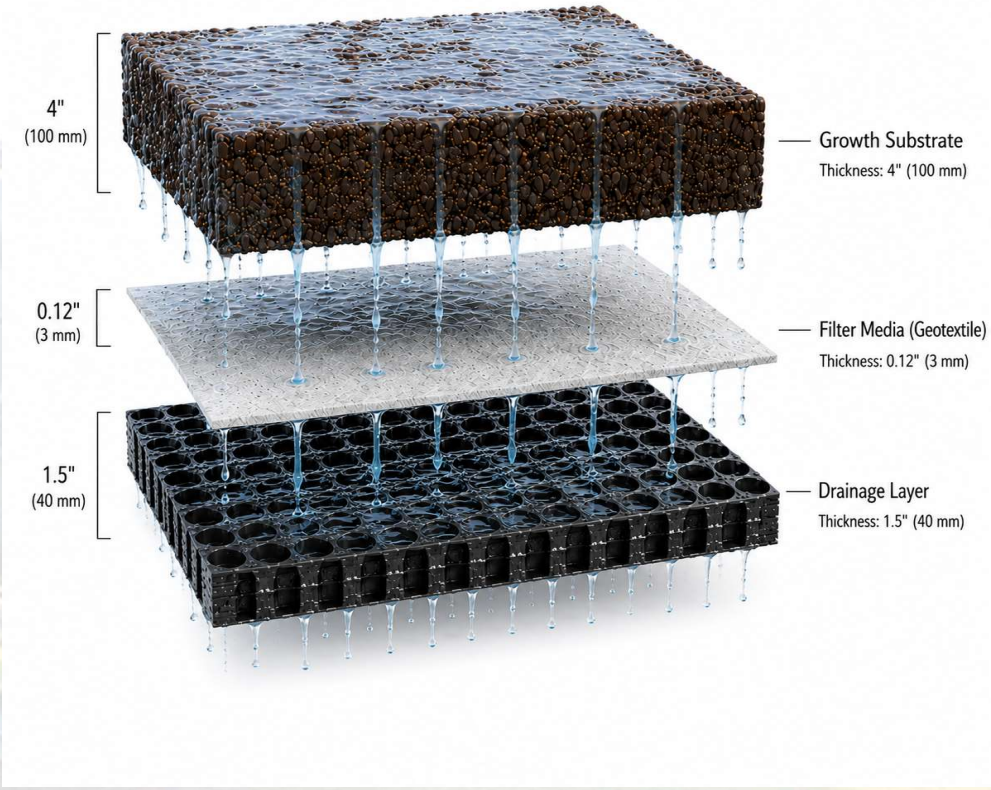


Fig. 5: Structural components of Extensive Green roofs

❑ Preparation of Green Roofs setup



Fig. 6: Artificial Rainfall Simulator



Fig. 7: Set up of T1 (S100B0M0) & T6(S80B12M8)

Rainfall Intensity Calculation for Artificial Rainfall Simulator (A

Given: $I = 292$ mm/h | $A = 0.8 \times 0.8 = 0.64$ m² | $d = 3$ mm $= 0.003$ m | $C_d = 0.65$

Calculation Steps

1	**Discharge (Q)**	$Q = I \times A = 0.292 \times 0.64 = 0.18688$ m³/h	5.191×10^{-5} m³/s
2	**Nozzle area (An)**	$An = \pi/4 \times (0.003)^2$	7.068×10^{-6} m²
3	**Corrected area (CdAn)**	$CdAn = 0.65 \times 7.068 \times 10^{-6}$	4.594×10^{-6} m²
4	**Pressure head (H)**	$H = (Q/CdAn)^2 / 2g = (11.30)^2 / 19.62$	6.51 m
5	**Pressure (P)**	$P = \rho g H = 1000 \times 9.81 \times 6.51$	63.85 kPa = 0.651 kg/cm²

Required head	Required pressure	Pressure
6.51 m	63.85 kPa	0.651 kg/cm²

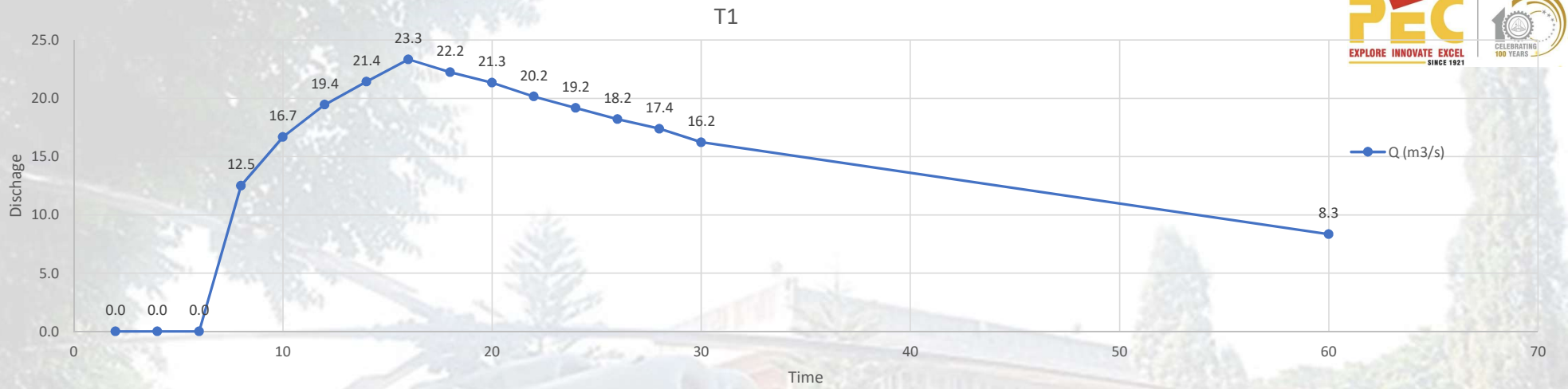


Fig. 8: Hydrograph of T1



Fig. 9: Hydrograph of T2

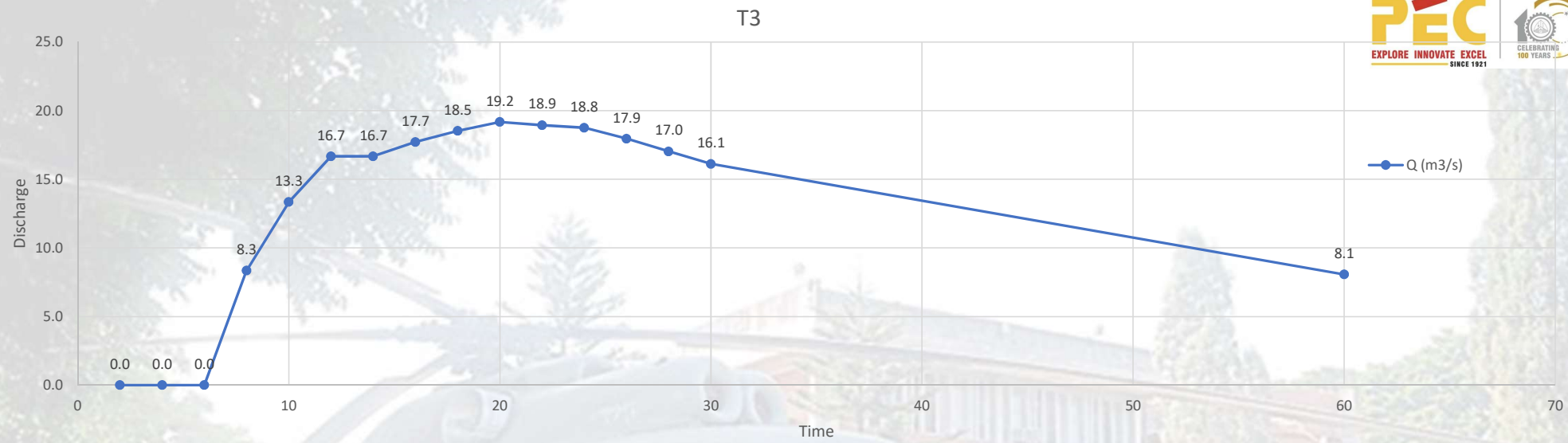


Fig. 10: Hydrograph of T3

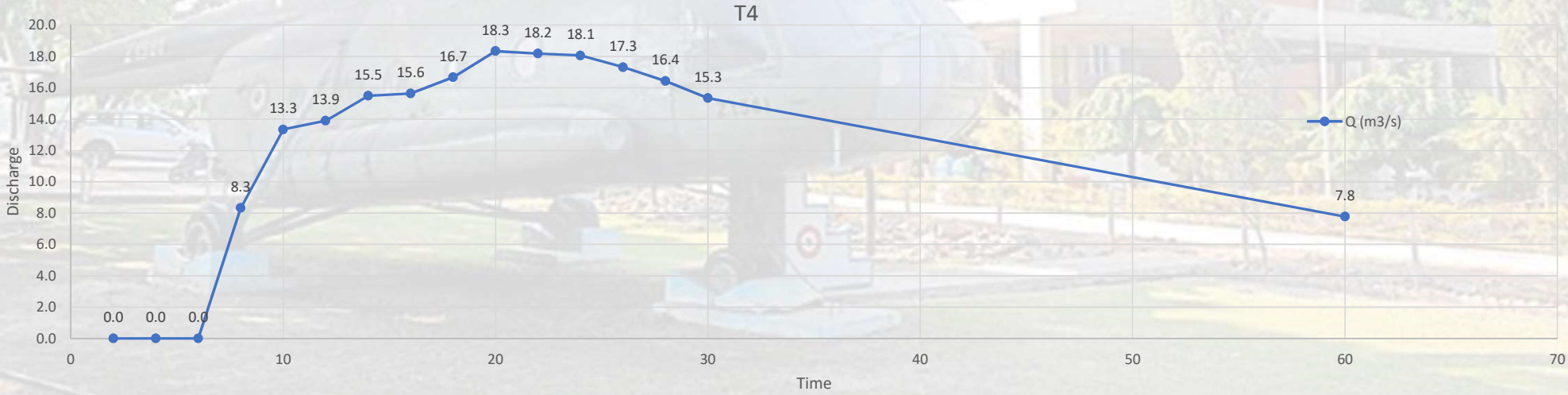


Fig. 11: Hydrograph of T4

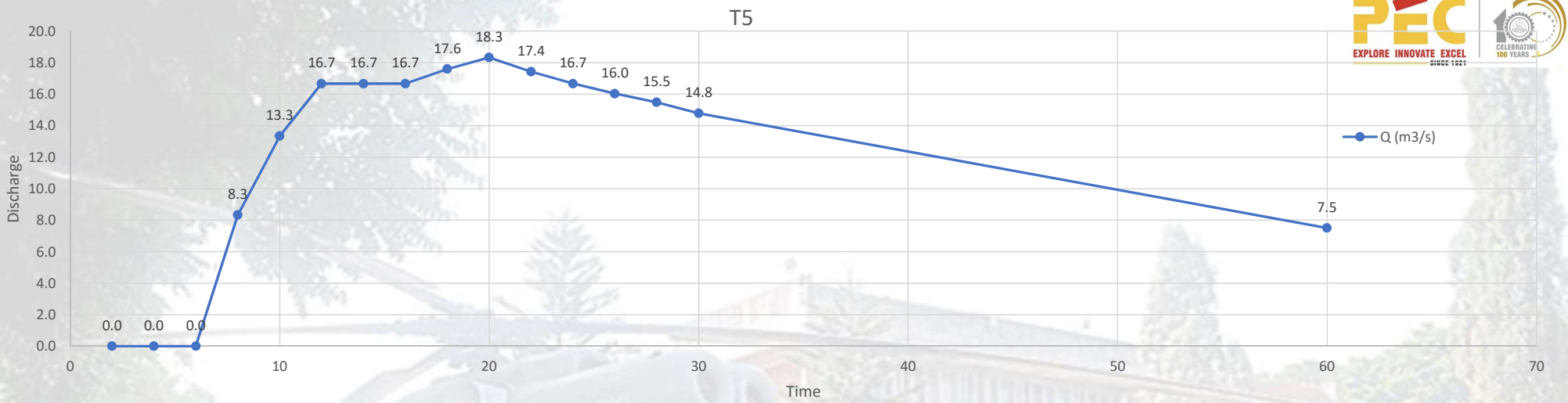


Fig. 12: Hydrograph of T5



Fig. 13: Hydrograph of T6

Water Retention Increases With Amendment

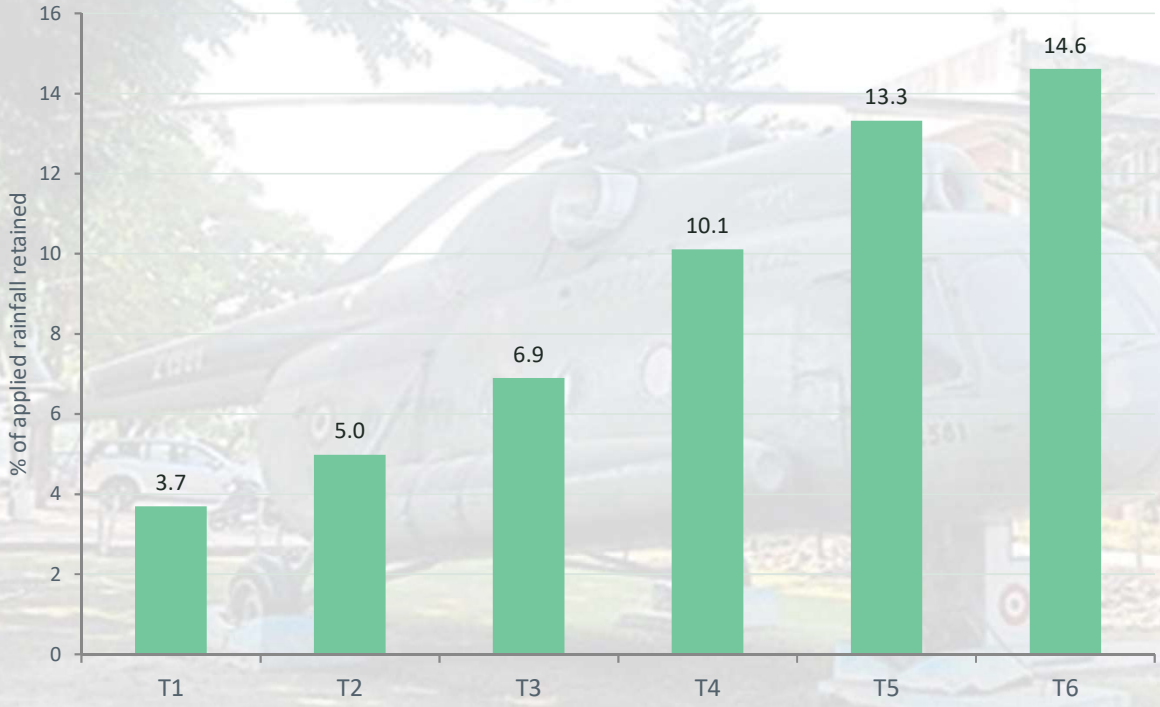


Fig. 14: Percentage of rainfall retained in different tray setups

4.55 L

retained by T6 (14.61%) — highest of all treatments, a 296% gain over T1

Trays	WHC (L)
T1	1.15
T2	1.55
T3	2.15
T4	3.15
T5	4.15
T6	4.55

RESULTS — RUNOFF QUALITY

Alkalinity Rises With Amendment (pH)



7.2 → 8.8

pH rises from T1 to T6 as amendment loading increases

Biochar ash and mineral components contribute to alkalinity and buffering; T3 (pH 7.9) stays intermediate — the 4% biochar–2% manure mix avoids the stronger alkalinity seen at higher rates.

Fig. 15: pH test on different tray setup

RESULTS — RUNOFF QUALITY

Dissolved Ionic Content: EC & TDS

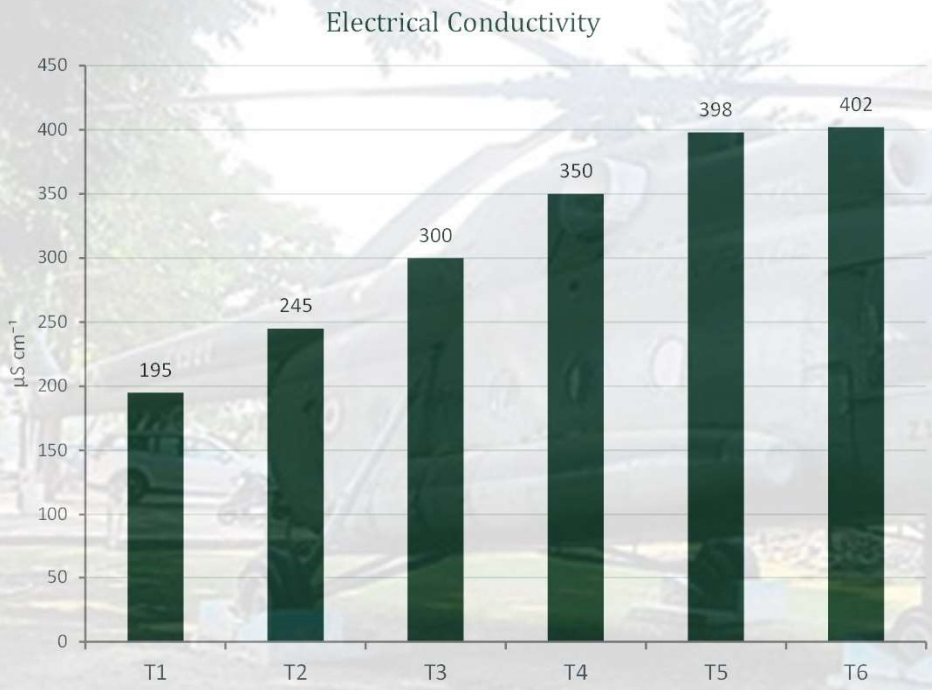


Fig. 16: Electrical Conductivity test performed on different tray set up



Fig. 17: TDS test performed on different tray set up

RESULTS — RUNOFF QUALITY

Particulate Transport & Organic Loading



Fig. 13: TSS test performed on different tray set up

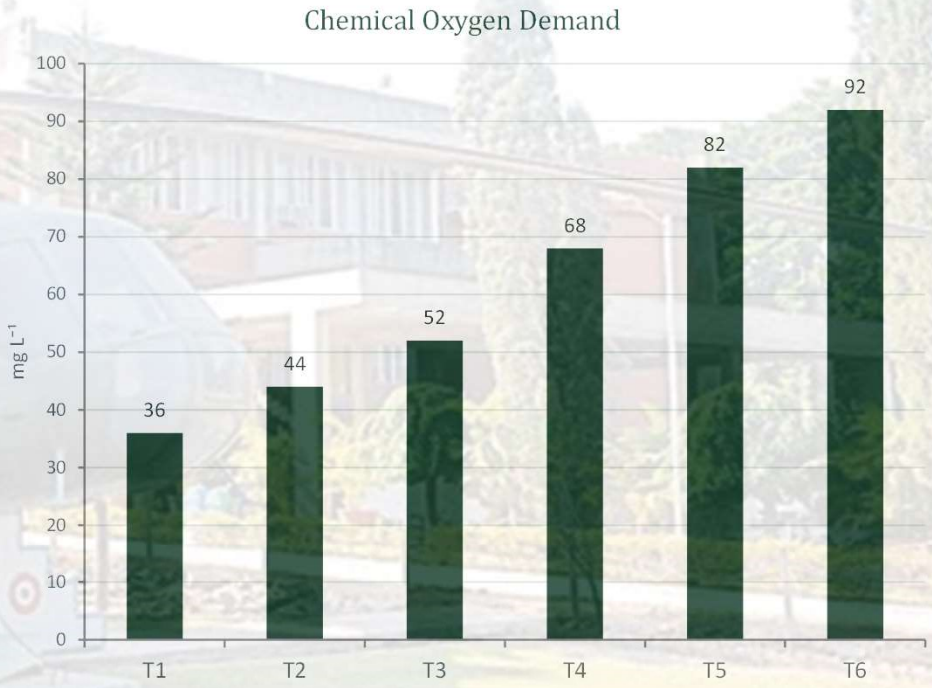


Fig. 14: COD test performed on different tray set up

RESULTS — RUNOFF QUALITY

Nutrient Leaching: TN & TP

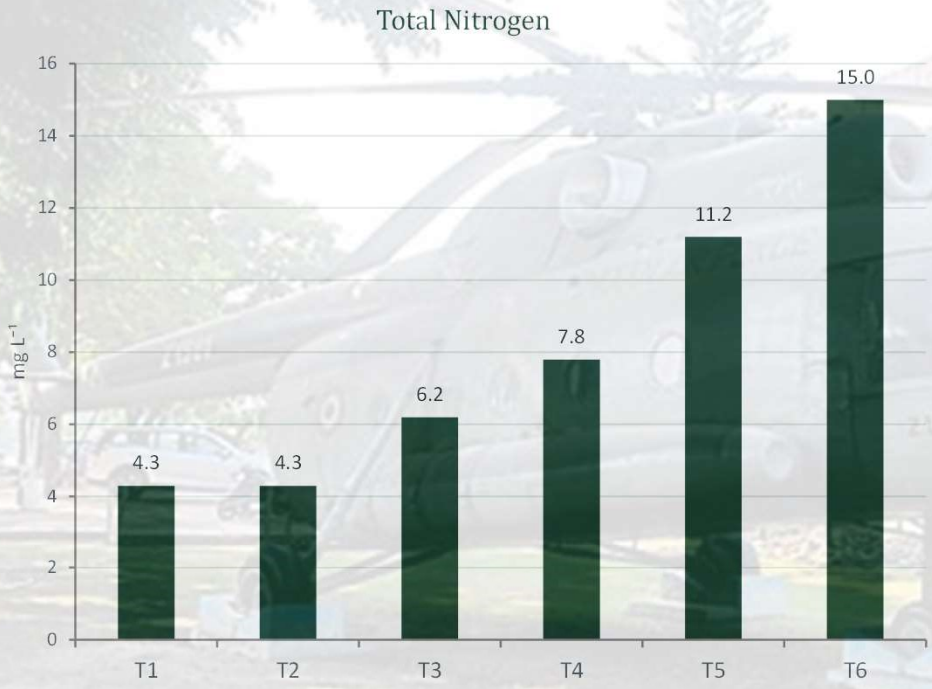


Fig. 18: Total Nitrogen performed on different tray set up

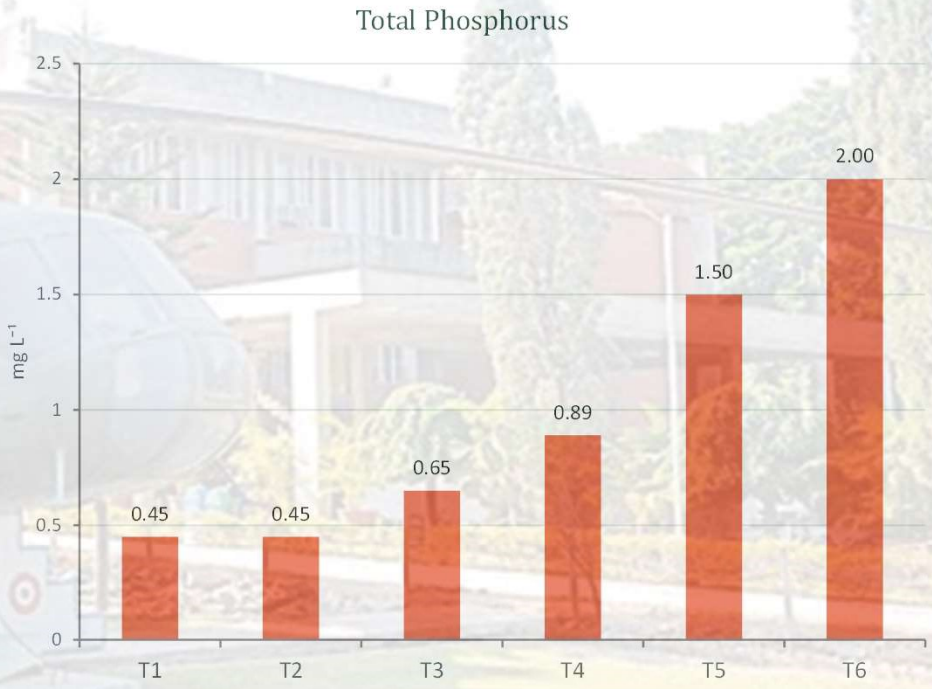
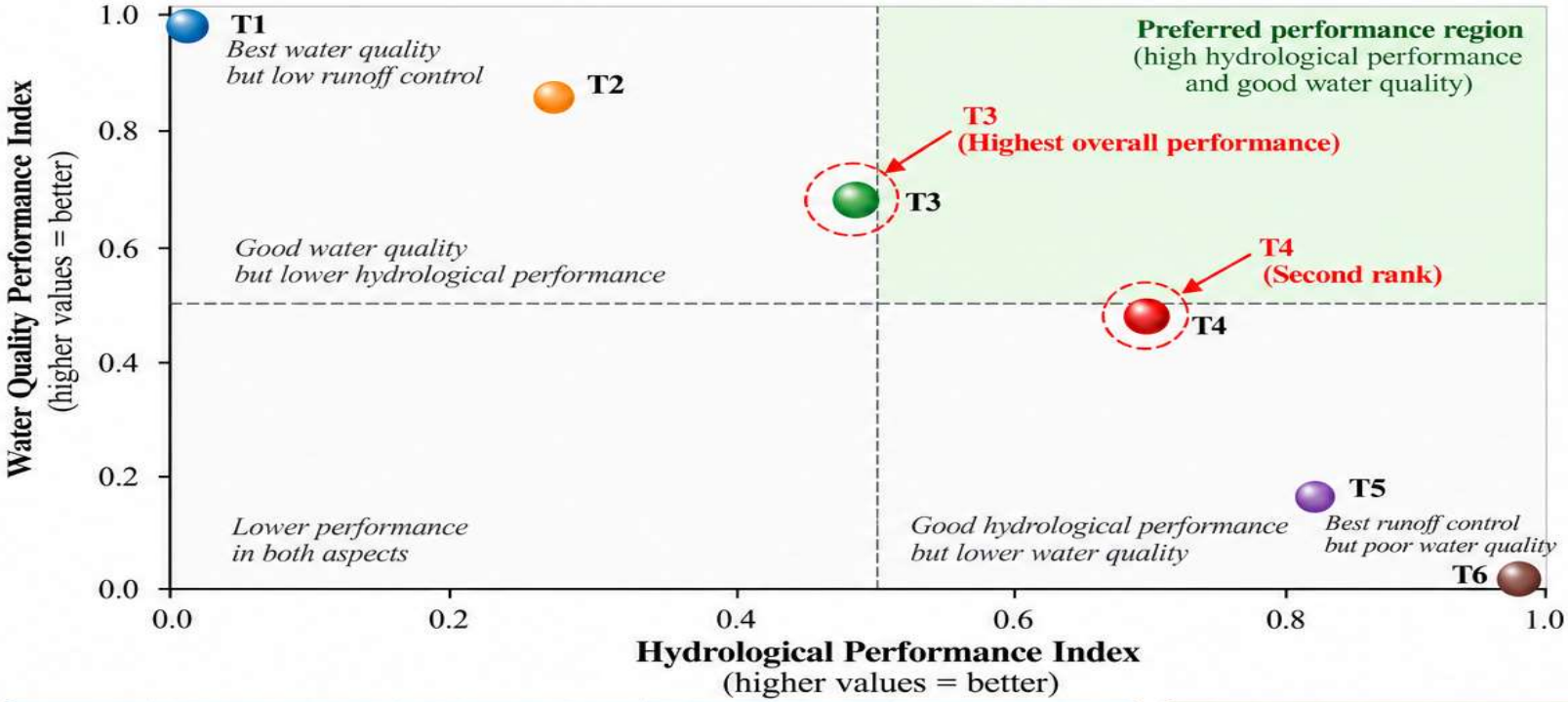


Fig. 19: Total Phosphorus test performed on different tray set up

Integrated Evaluation of Green Roof Substrate Trays

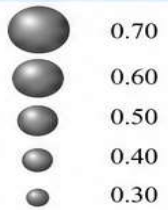
(Balancing Runoff Quantity and Runoff Water Quality)



Tray (Substrate composition)

- T1 (100% soil)
- T2 (90% soil, 6% biochar, 4% manure)
- T3 (94% soil, 4% biochar, 2% manure)
- T4 (85% soil, 10% biochar, 5% manure)
- T5 (80% soil, 12% biochar, 8% manure)
- T6 (75% soil, 15% biochar, 10% manure)

Integrated Performance Index

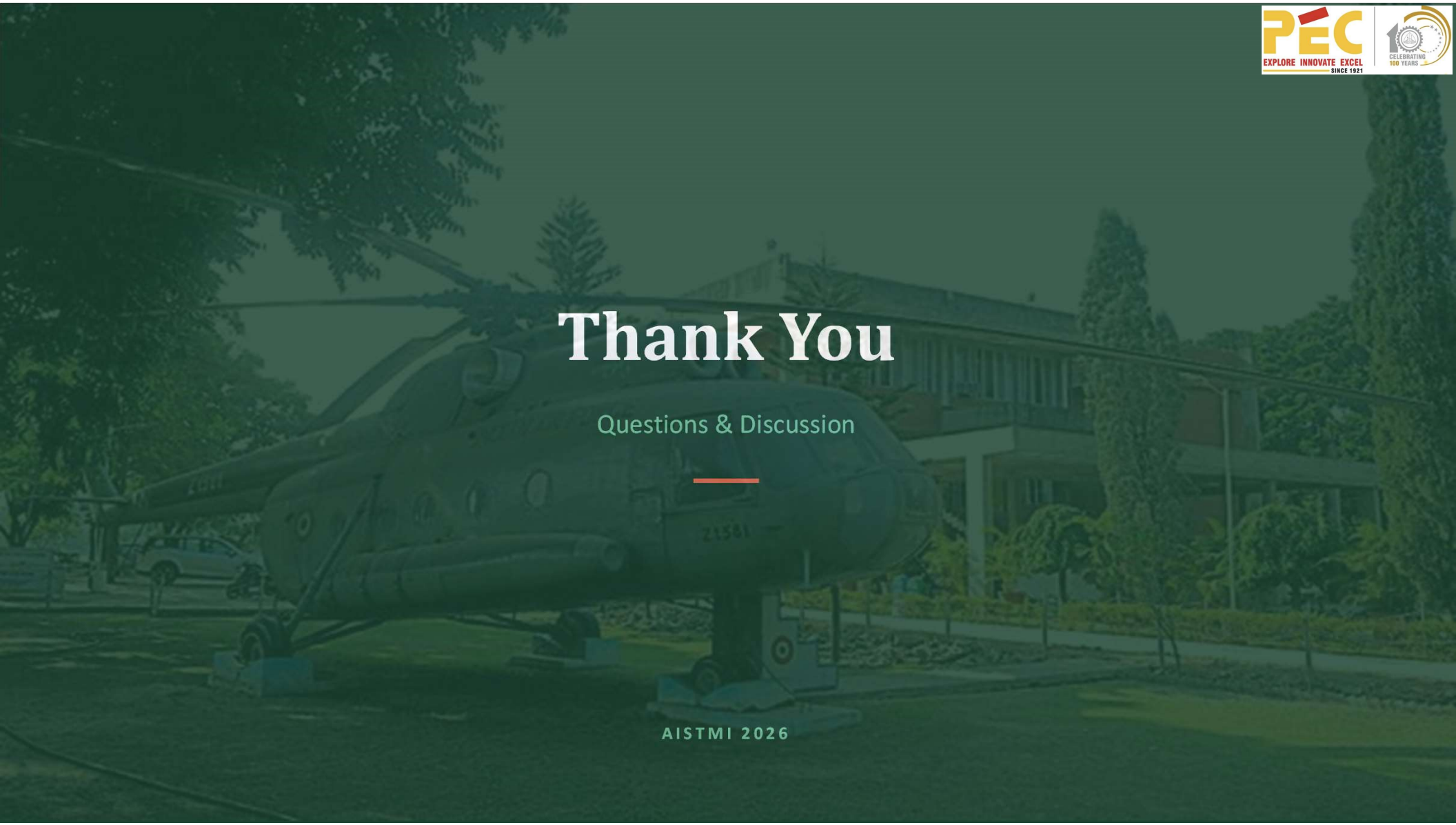


(larger size = higher overall performance)

Tray	Hydrological Index (HPI)	Water Quality Index (WQI)	Integrated Index (IPI)	Rank
T1	0.000	1.000	0.500	5
T2	0.246	0.859	0.553	3
T3	**0.460**	**0.668**	**0.564**	**1**
T4	**0.669**	**0.450**	**0.560**	**2**
T5	0.816	0.144	0.480	6
T6	1.000	0.007	0.504	4

Key Findings

- **T3** (94% soil, 4% biochar, 2% manure) provides the best balance between hydrological performance (runoff quantity) and runoff water quality, with the highest integrated performance index (IPI = 0.564).
- **T4** (85% soil, 10% biochar, 5% manure) ranks second (IPI = 0.560), which is higher than T2, indicating improved overall performance.
- **T1** shows the best water quality but the lowest runoff control.
- **T6** achieves the highest runoff control but the poorest water quality.


Thank You
Questions & Discussion
AISTMI 2026