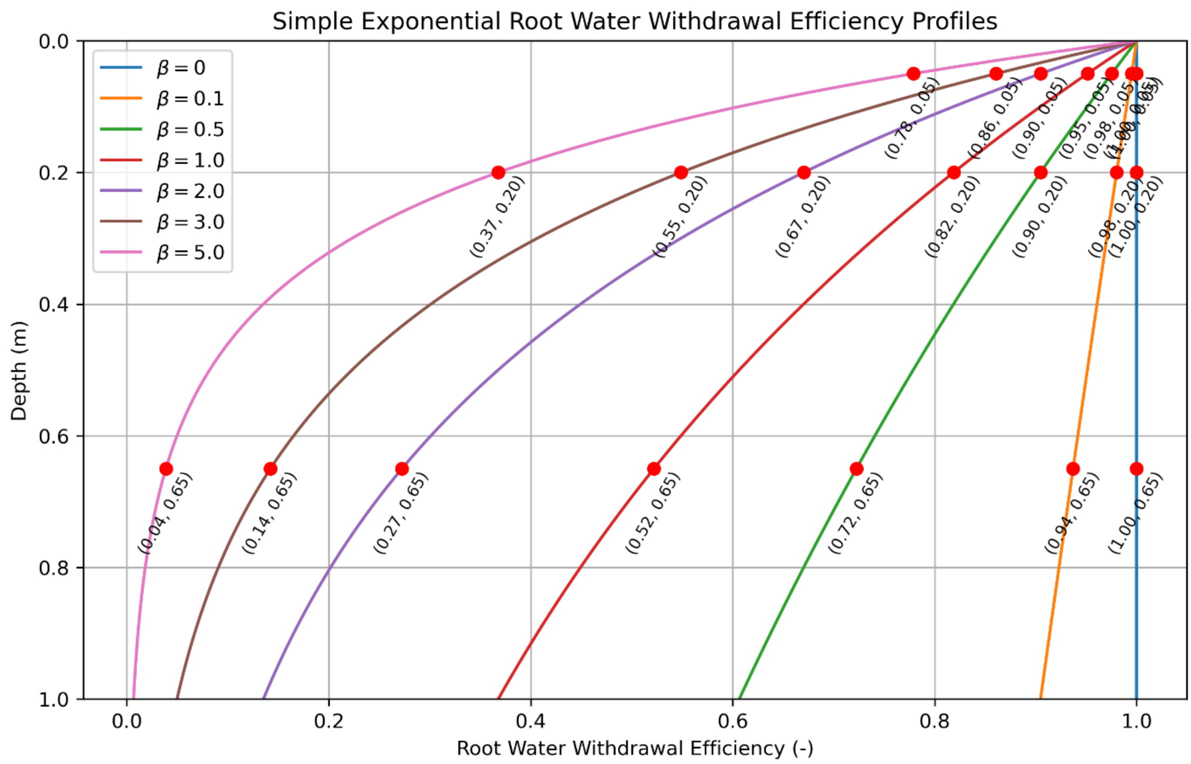

Figure S1. Exponential root water withdrawal efficiency function and profiles for different β values. β = 0 represents a deep-rooted system, while a larger β indicates a shallow-rooted system with root activity concentrated near the surface.

Table S1. Soil Moisture Measurement Devices and Aggregation Methods

Land Use Type	Device Type	Measurement Depths (cm)	Frequency	Aggregation Method
Surface Soil	Handheld soil moisture device	0–10	Monthly	-
Subsurface Soil	Permanently installed probes	Forest & Grassland: 20, 60, 100	15-minute intervals	Lower soil (10–30 cm): 20 cm Deeper soil (30–100 cm): mean(60 cm, 100 cm)
		Agroforestry: 20, 40, 80		Lower soil (10–30 cm): 20 cm Deeper soil (30–100 cm): mean(40 cm, 80 cm)
		Cropland: 15, 40, 60, 100		Lower soil (10–30 cm): 15 cm Deeper soil (30–100 cm): mean(40 cm, 60 cm, 100 cm)

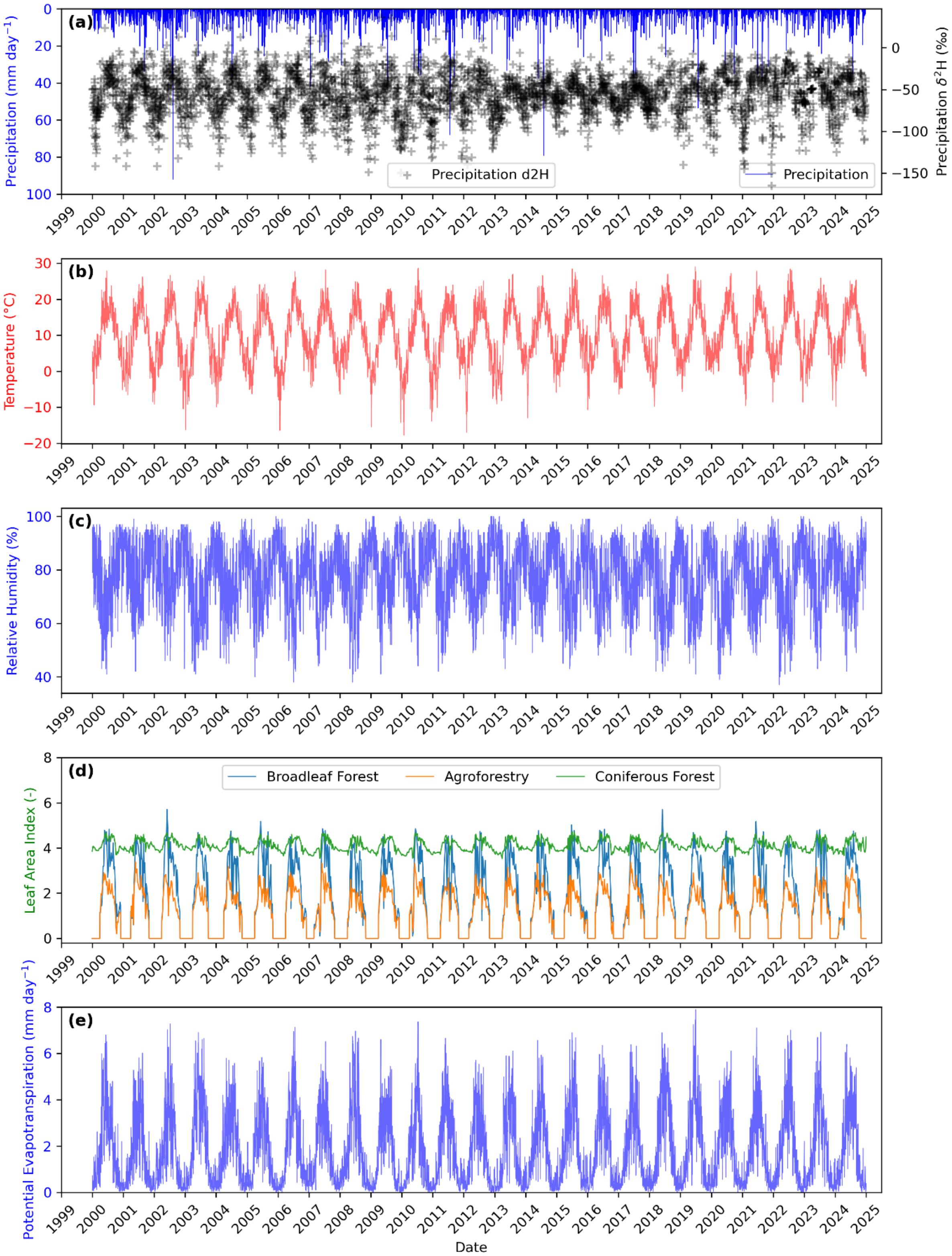

Figure S2. Input data for EcoPlot-iso long-term simulations (2000–2024) in the Demnitzer MillCreek Catchment: (a) Daily precipitation (mm day⁻¹) and precipitation δ²H (‰); (b) Air temperature (°C); (c) Relative humidity (%); (d) Leaf Area Index (LAI); (e) Potential evapotranspiration (PET) (mm day⁻¹).

Table S2. EcoPlot-iso parameters and initial ranges for calibration. BF: Broadleaf Forest, GL: Grassland, CL: Cropland, AF: Agroforest.

Parameter	Description	Sites	Initial range	Calibrated range
rE	Radiation extinction factor (dimensionless)	BF	[-0.6, -0.1]	[-0.6, -0.1]
		GL		[-0.6, -0.1]
		AF		[-0.6, -0.1]
		CL		[-0.6, -0.1]
α	Interception storage capacity parameter (mm per unit of LAI)	BF	[0.1, 2.0]	[0.1, 2.0]
		GL		[0.1, 2.0]
		AF		[0.1, 2.0]
		CL		[0.1, 2.0]
Smax	Maximum soil moisture content in the upper soil compartment (mm)	BF	[40, 60]	[40, 60]
		GL		[40, 60]
		AF		[40, 60]
		CL		[40, 60]
Ic	Soil infiltration capacity (mm/day)	BF	[40, 60]	[40, 60]
		GL		[40, 60]
		AF		[40, 60]
		CL		[40, 60]
ks1	Saturated hydraulic conductivity of the upper soil compartment (mm/day)	BF	[1, 20]	[1, 20]
		GL		[1, 20]
		AF		[1, 20]
		CL		[1, 20]
ks2	Saturated hydraulic conductivity of the lower soil compartment (mm/day)	BF	[1, 20]	[1, 20]
		GL		[1, 20]
		AF		[1, 20]
		CL		[1, 20]
ks3	Saturated hydraulic conductivity of the deeper soil compartment (mm/day)	BF	[1, 20]	[1, 20]
		GL		[1, 20]
		AF		[1, 20]
		CL		[1, 20]
GWmax	Maximum soil moisture content in the lower soil compartment (mm)	BF	[50, 100]	[50, 100]
		GL		[50, 100]
		AF		[50, 100]
		CL		[50, 100]
Lmax	Maximum soil moisture content in the deeper soil compartment (mm)	BF	[150, 450]	[150, 350]
		GL		[150, 350]
		AF		[250, 450]
		CL		[250, 450]
g1	Nonlinear scaling parameter for the upper soil compartment	BF	[1, 5]	[1, 5]
		GL		[1, 5]
		AF		[1, 5]
		CL		[1, 5]
g2	Nonlinear scaling parameter for the lower soil compartment	BF	[1, 5]	[1, 5]
		GL		[1, 5]
		AF		[1, 5]
		CL		[1, 5]
g3	Nonlinear scaling parameter for the deeper soil compartment	BF	[1, 5]	[1, 5]
		GL		[1, 5]
		AF		[1, 5]
		CL		[1, 5]
PFScale	Preferential flow path parameter (dimensionless)	BF	[0.1, 0.9]	[0.1, 0.9]
		GL		[0.1, 0.9]
		AF		[0.1, 0.9]
		CL		[0.1, 0.9]
IntSp	Passive interception storage mixing volume (mm)	BF	[0.5, 1]	[0.5, 1]
		GL		[0.5, 1]
		AF		[0.5, 1]
		CL		[0.5, 1]
StoSo	Passive upper soil storage mixing volume (mm)	BF	[1, 20]	[1, 20]
		GL		[1, 20]
		AF		[1, 20]

		CL		
gwSp	Passive lower soil storage mixing volume (mm)	BF	[3, 40]	[3, 40]
		GL		[3, 40]
		AF		[3, 40]
		CL		[3, 40]
lowSP	Passive deep soil storage mixing volume (mm)	BF	[10, 100]	[10, 100]
		GL		[10, 100]
		AF		[10, 100]
		CL		[10, 100]
k	Seasonality factor in the Craig-Gordon model (dimensionless)	BF	[0.25, 0.9]	[0.25, 0.9]
		GL		[0.25, 0.9]
		AF		[0.25, 0.9]
		CL		[0.25, 0.9]
x	Water vapor mixing ratio in the Craig-Gordon model (dimensionless)	BF	[0.25, 0.75]	[0.25, 0.75]
		GL		[0.25, 0.75]
		AF		[0.25, 0.75]
		CL		[0.25, 0.75]
β	Root distribution factor (dimensionless)	BF	[0, 1.0]	[0, 0]
		GL		[0, 1.0]
		AF		[0, 0]
		CL		[0, 1.0]

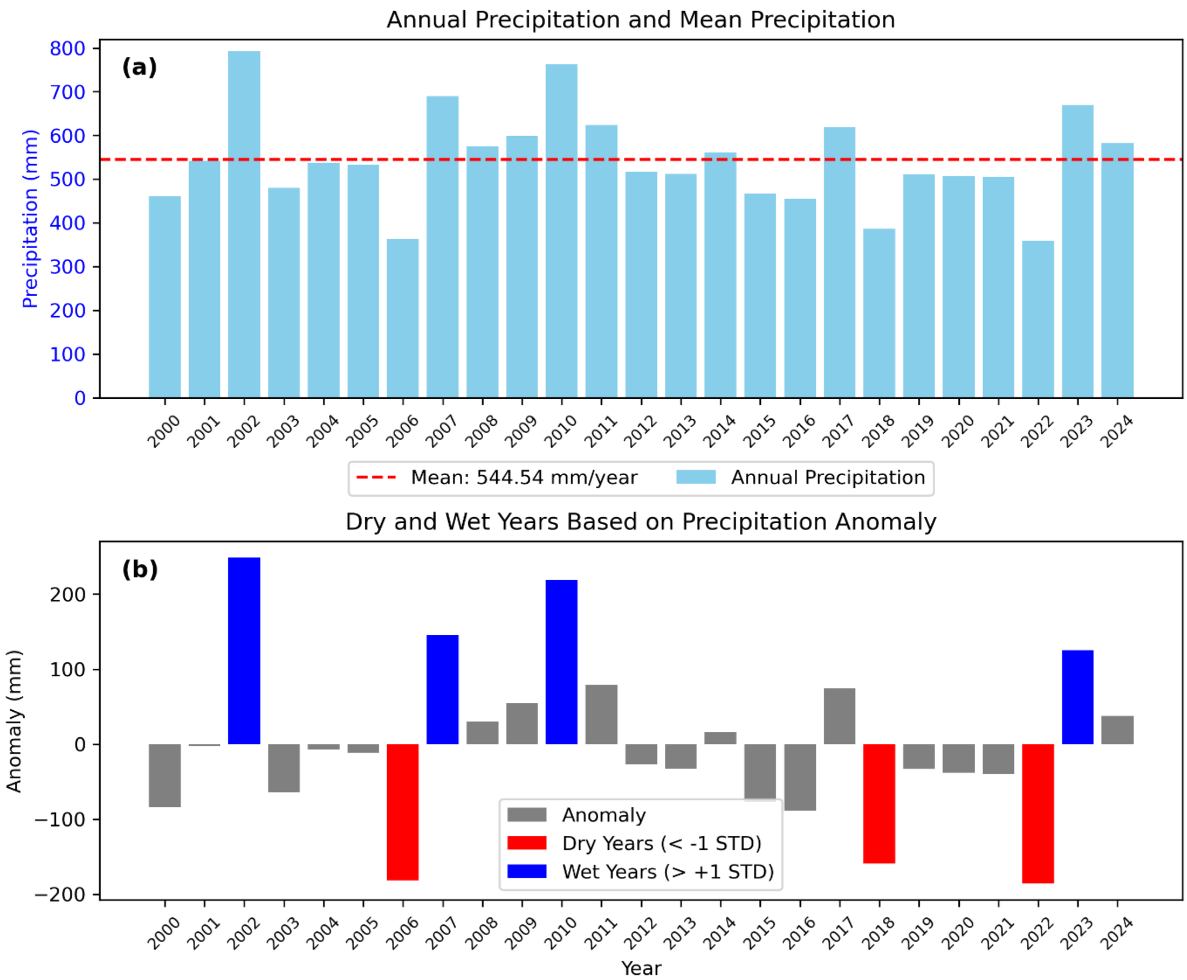

Figure S3. Annual precipitation and anomalies for the DMC. (a) Annual precipitation with the long-term mean (red dashed line). (b) Precipitation anomalies highlighting dry (red, anomaly < −1 standard deviation) and wet (blue, anomaly > +1 standard deviation) years.

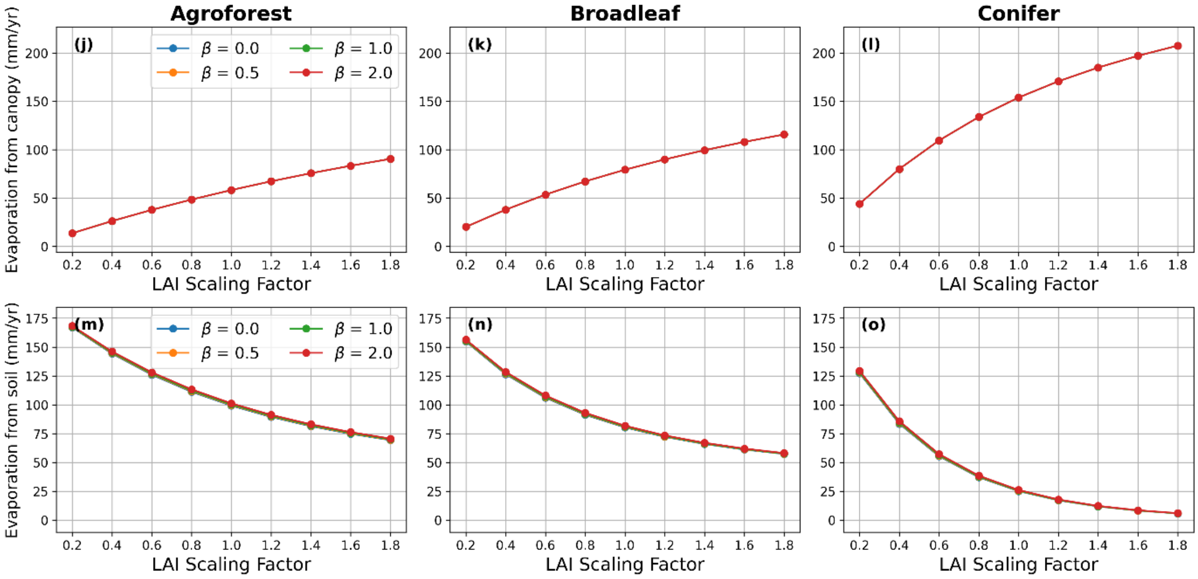

Figure S4. Annual mean evaporation components from (j)–(l) the canopy (Ei) and (m)–(o) the soil surface (Es) across different forest types (Agroforest, Broadleaf, Conifer) and LAI scaling factors. Lines indicate results for different forest age classes (β values).

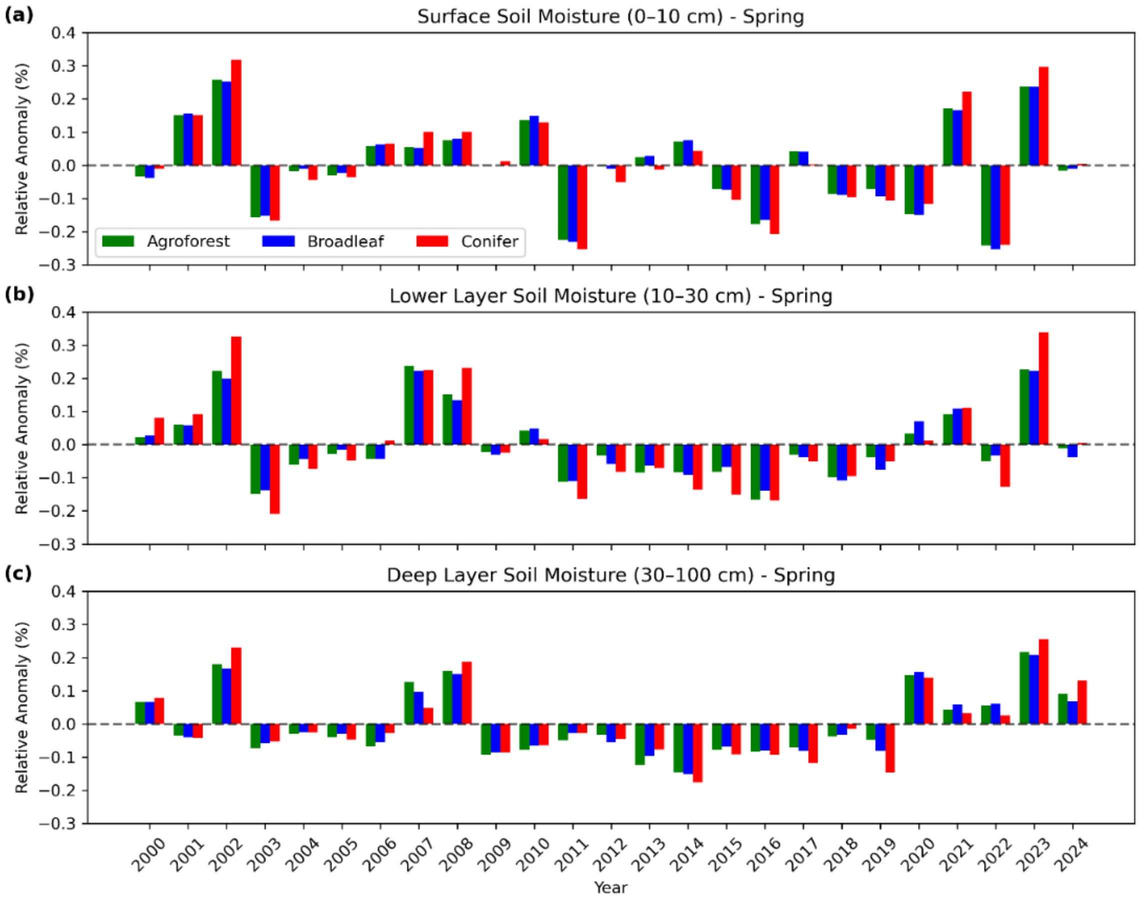

Figure S5. Relative soil moisture anomalies for spring (March–May) across three soil layers: (a) surface (0–10 cm), (b) lower layer (10–30 cm), and (c) deep layer (30–100 cm) for three forest types (Agroforest, Broadleaf, Conifer).

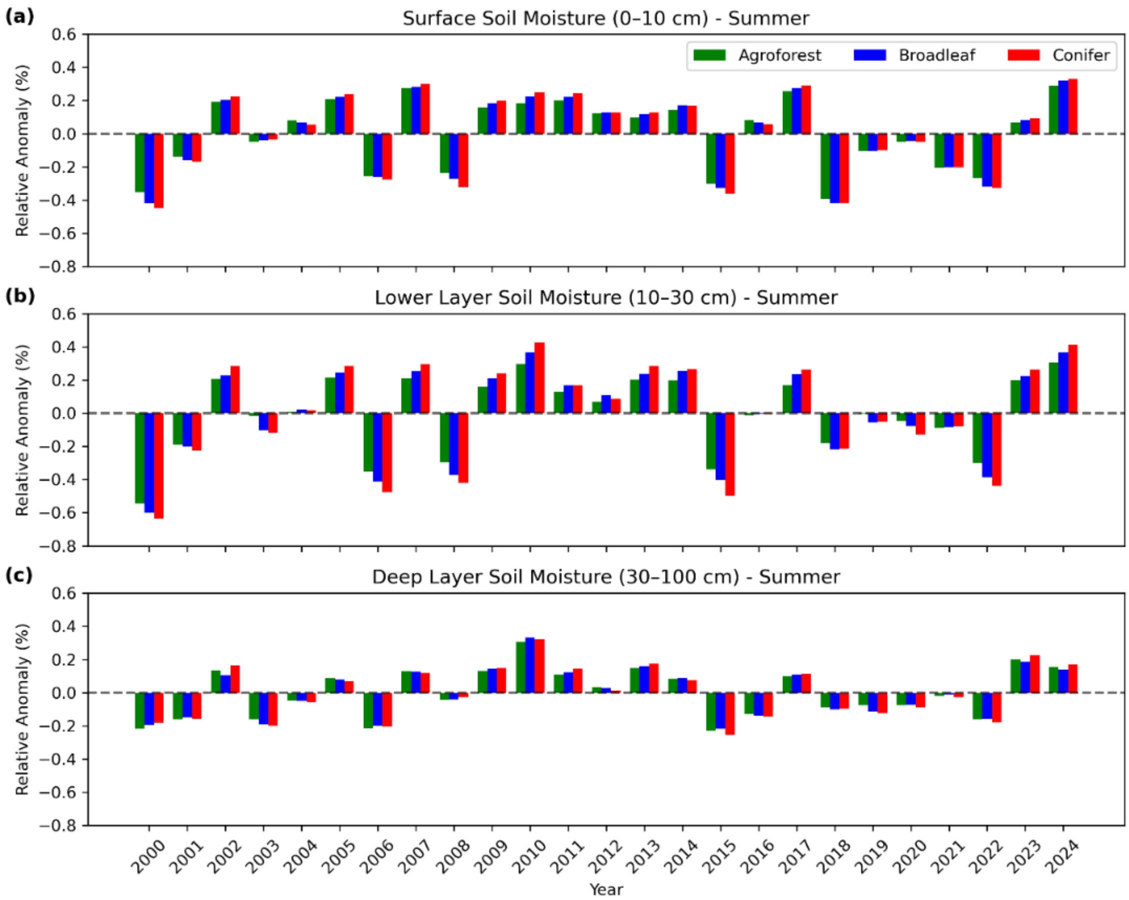

Figure S6. Same as Figure 11 but for forests with a shallow root system (root parameter $\beta = 2.0$).

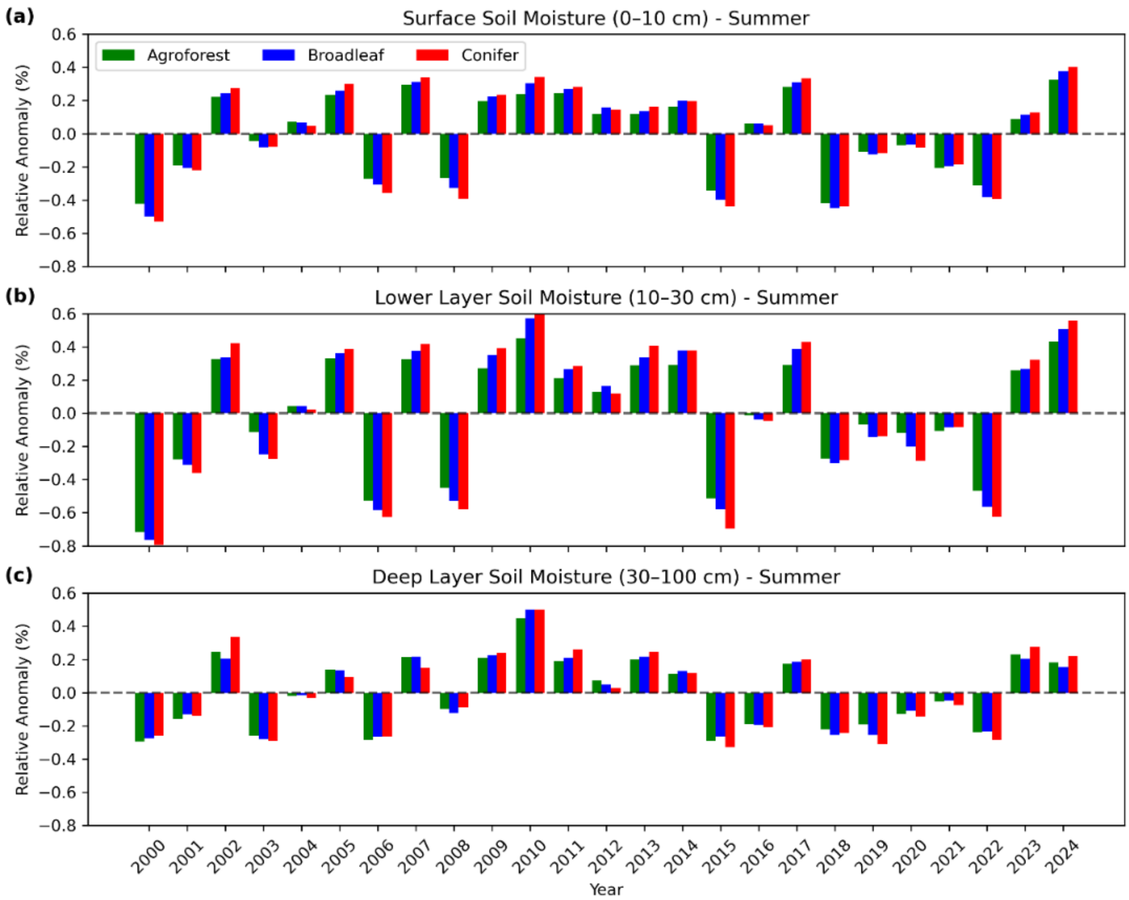

Figure S7. Same as Figure 11 but for forests with a higher density (LAI scaling factor = 1.6).