Course syllabus

Department of Civil Engineering, Indian Institute of Technology Madras

CE6215 – Soil-Plant-Atmosphere continuum

Credit Distribution: C:9 L:3 T:0 P:0 E:0 O:6 TH:0

Course Type: Theory

Description: 1) Characterize and quantify the fluxes of carbon, water, energy, and nutrients in the soil-plant-atmosphere continuum through a coupled integrated framework. 2) Develop computational point scale eco-hydrological models that predict the impact of different aspects of global climate change on natural and agroecosystems and quantify its effect on mass and energy fluxes. 3) Apply the principles of eco-hydrology and identify strategies to mitigate climate change.

Course Content: 1) Vadose zone hydrology: Soil water characteristic curve, hysteresis, hydraulic conductivity in unsaturated porous media, Richards equation and soil moisture transport, solution to Richards equation (moisture content, water potential, and mixed formulation), boundary conditions (soil evaporation, infiltration and drainage), hydrologic variability, measurement techniques, HYDRUS1D, and SWMS models. 2) Soil carbon and nutrient cycle: Solute transport in soil (equations and modeling), root exudation, carbon and nitrogen pools, soil carbon flux, aerobic and anaerobic processes, plant nutrient uptake, and CENTURY model. 3) Plant hydraulics: Root water uptake modeling, axial and radial hydraulic conductivity, xylem vessel and sieve elements, components of water potential (gravitational, metric, osmotic, turgor), cohesion-adhesion theory, water potential gradients, hydraulic redistribution, and plant water potential measurement. 4) Transpiration: Drivers for root water uptake, stomatal conductance and control of plant water loss, Ball-Berry model of stomatal conductance, transpiration under drought, leaf water potential influence on stomatal conductance, Tuzzet model and hysteresis, scaling from leaf to canopy, and canopy micro environment. 5) Canopy photosynthesis and carbon exchange: Coupled photosynthesis-transpiration process, (PCR) Calvin cycle, C3, C4, and CAM photosynthetic pathways, models of C3 and C4 photosynthesis, phloem loading, e-photosynthesis model, measuring leaf and canopy photosynthesis and transpiration, eddy covariance and flux tower measurement of CO2, water vapor and sensible heat, and eco-hydrological modeling. 6) Radiation balance: Basics of radiation physics, canopy radiation balance models, big leaf versus multi-layer approach, PAR, NIR, versus long wave radiation balance, soil radiation balance, effect of zenith and leaf angles, diffuse versus beam radiation, isotropic versus anisotropic scattered radiation, horizontal homogeneity, 3D ray tracing models of radiation, and eco-hydrological models (virtualPlant, MLCan, BioCro, CanVEG). 7) Energy balance: Sensible and latent heat partitioning, canopy micro environment and turbulent mixing, sun-versus shade leaf temperature, temperature effect on photosynthesis, ground heat flux and soil temperature. 8) Climate change impact: Instantaneous response to CO2 change, acclimation response to CO2 change, progressive nitrogen limitation, evolutionary response to CO2 change (C4 and CAM photosynthetic pathway), cold versus warm climate warming effect in plants, temperature optimum, ecosystem feedback and herbivory, ozone damage in plants, mechanisms of ozone tolerance, positive and negative feedback from interactions of various aspects of climate change, climate change mitigation, and eco-hydrological model predictions. 9) Implications: Food-water-energy security, biotechnological

solutions to mitigating climate change, ecological resilience and vulnerability, biodiversity, tipping points, and lingocellulosic biofuel production.

Text Books: Please see references

Reference Books

- Gaylon S. Campbell and John M. Norman, An Introduction to Environmental Biophysics (2nd edition), Springer-Verlag, New York, 1998.
- Park S. Nobel, Physicochemical and environmental plant physiology (4th edition), Academic press, Elsevier Inc., 2009.
- William G. Hopkins and Norman P.A. Huner, Introduction to Plant Physiology (3rd edition), John Wiley and sons Inc., 2018.

Prerequisite: NIL