

2.3 Terrestrial Ecology Observing Systems (TEOS)

The Terrestrial Ecology group applies ENS to the measurement of critical ecological processes. In 2008-09 we targeted integrated sensing systems that could measure complex phenomena, such as tree physiology (above and below ground) and soil microbial activity and respiration. One of the critical needs in this area is the ability to measure two types of information simultaneously: long-term trend analyses, and short-burst events.

Based on technical progress in previous years, the TEOS group was able to shift focus from designing networked technologies to field-testing a number of systems and evaluating their potential to measure critical ecological phenomena. Simple coupling of the physiology of trees and microbes requires a wide array of sensors (for CO₂ concentrations, temperature, and moisture at differing depths and spatial arrangements, sap-flow) coupled with nearly continuous camera observing platforms (leaf phenology, root and fungal microscope-resolution imaging, nesting bird behavior), and point measurements of taxon locations (EcoPDA), point measurements of photosynthesis under varying light regimes and among species, and bedrock/coarse root imaging (ground-penetrating radar). These coupled human/camera/sensor measurements have to be accumulated readily during long periods of relative stasis, but then have to be able to detect responses during critical events ranging from sunflecks, to freeze/thaw events, to monsoonal rains, to major storms.

An example is the relationship between soil respiration and tree dynamics (Fig 1). Sap-flow sensors were placed in the trees surrounding a soil respiration sensor network. Previous work has shown that there are both daily and seasonal lags in soil respiration. Changes in soil temperature and moisture did not explain the variation in soil respiration, the normal variables modeled for soil respiration. What does appear is that the soil respiration is low but starts increasing with melting snow, coupled with fungal growth, new roots, and increasing activity of the evergreen pines and manzanitas. The big jump in soil respiration appears to be associated with leafing in the deciduous oaks, followed by a drop as soil dries out. However, activity still remains surprisingly high even under extremely low soil moisture (<-5MPa). Soil camera systems show that fungal activity remains high and roots are relatively static. Activity appears to depend upon deep roots (found developing into fractures in the granite using GPR) and hyphae (from soil pits) within the granite matrix accessing deep water coupled to hydraulic redistribution and maintaining microbial and root respiration. Monsoonal precipitation events drive later spikes in soil respiration, although there is a slow drop in respiration as sap-flow declines in the plants indicating lower stomatal opening, which was coupled to reduced photosynthesis in spot measurements.

We are currently working to link the above data with leaf and flowering phenology measurements taken using *in situ* cameras. An example is presented of bud burst and leaf flush in rhododendron that is being expanded to the species (such as oaks) on the AMARSS transect. Further, by using these *in situ* cameras to measure leaf greening, and calibrating the camera “greenness” to satellite-based “greenness” MODIS products, the thousands of webcam images may be integrated to extract higher quality continental-to-global scale phenological data that can provide a detailed information on greening trends.

Animal behavior is dependent upon both behavioral traits that are functions of individual species or even populations. The timing of those traits also depends upon environmental cues. Nesting is an obvious behavioral

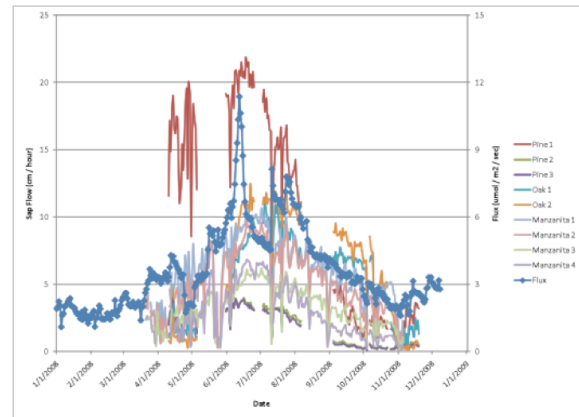


Fig 1. Results from a network of sensors showing the ability of multiple sensors to separate important ecosystem dynamics (see text). Each tree has a separate sap-flow sensor. The soil respiration is modeled from 6 CO₂ sensors, 6 T_{soil}, and 6 θ sensors with two sensors each for barometric pressure, PAR, T_{air}, and RH_{air}. Sensors data are recorded at 5min intervals. Also (not shown) are weekly observations of roots and rhizomorphs.

trait that is characteristic for a species in response to environmental cues. However, species interactions modify those behaviors making clear correlations in nesting behavior with environmental cues difficult at best. By continuous monitoring of behaviors, coupled with environmental sensors and observations, such as plant phenology, a better understanding of lags and competitive interactions may be generated.

Finally, spot observations, identifications, and measurements are absolutely essential to characterizing environmental change. But for this to be undertaken at the global scales essential to document the implications of global change, accurate identifications need to be coupled to detailed location information, by both experts and less-well trained participants. Coupling imagery, data management systems, and GPS receivers (EcoPDA) provides new linkages between human observers, camera observation systems, and large-scale data acquisition and availability. By interfacing with organizations such as Conservation International, and developing highly portable data acquisition technology, data transfer capacity, and taxonomic electronic “guidebooks”, EcoPDA provides the linkages between detailed sensor technologies with satellite information of phenological change, with a widespread human workforce to bring ecological data collection and analysis to the global scale.