Synthesizing long-term records and eco-hydrologic modeling to quantify structural legacy effects

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Meeting Approach & Goals

This meeting was held to achieve several goals. 1.) Use existing LTER data, to build, calibrate, and validate ecohydrological models representative of three LTER sites (HBR, BES, KNZ). 2.) Develop scenarios for each of the sites to examine fundamental ecosystem legacy effects imposed by land use histories and to use the model to explore eco-hydrological changes arising from the legacies. 3.) Plan for growing and expanding the effort, including the proposed follow up session at the All Scientists Meeting in September 2012.

This meeting focused on building a hillslope model for Hubbard Brook, largely as this location allowed simplicity in data access and conceptual understanding. However, all data were organized for all three sites and legacy scenarios developed as follows:

- HBR: The contemporary forest composition at Hubbard Brook does not match that existing prior to the initial European forest clearance. In particular, the abundance of coniferous species has declined since European settlement in central New Hampshire (Vadeboncouer *et al.*, in press). Coniferous and deciduous trees differ in water use and the seasonality of leaf area index. In this case, the model will be used to identify the eco-hydrological implications of this shift.

- BES: Following initial European forest clearance, large erosive events occurred, removing substantial volumes of hillslope soil and depositing them at the bottom of the slope as colluvium (Costa, 1975, *GSA Bulletin*). This soil redistribution implies altered hillslope geometry. Soil depth and slope are a first-order control on hillslope infiltration and runoff patterns. In this case, the model will be used to identify changes in soil moisture and water balance patterns resulting from this altered soil distribution.

- KNZ: Historically, the Konza Prairie regional grasslands have been burned at 1-2 year intervals and commercially grazed. Within the experimental area, removal or exclusion of natural fire and/or animal grazing has led to dramatic expansion of gallery forests and the establishment of woody shrub patches. Regionally, forest expansion has been attributed to reduced fire frequency associated with fragmentation of the original tallgrass prairie and a shift from migratory bison grazing to intensive cattle grazing (Briggs et al., 2005, *BioScience*). Tree, shrub, and grass ecosystems are each associated with different ecohydrological conditions, evapotranspiration rates, and life history strategies. Therefore, in this case, we use the model to identify the ecohydrological implications of the vegetation shifts associated with altered disturbance regimes.

Preliminary Results

A tRIBS-VEGGIE hillslope model for Hubbard Brook was built, calibrated, and validated using existing Hubbard Brook Data as follows:

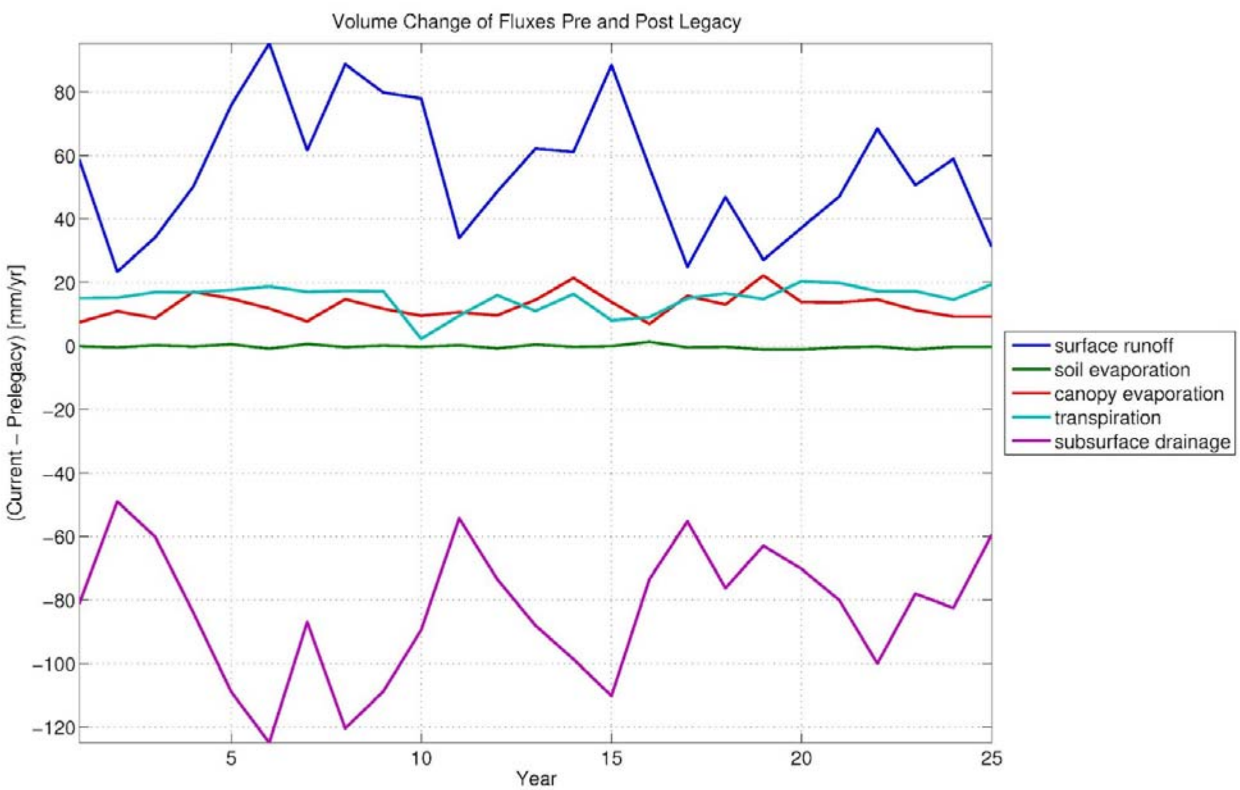
- The steepest path down WS6 was extracted from the 10m DEM and subsampled to thirty stations.
- Two plant functional types (needleleaf and deciduous) and a static leaf area index regime for each type were defined for the simulation.
- Based on historical records, a synthetic climate forcing was generated stochastically for a twenty five year period.

Based on the work of Vadeboncouer *et al.* (in press), two contrasting scenarios were defined:

1. A pre-European forest consisting of half needleleaf and half deciduous.
2. The legacy contemporary forest consisting of only twenty percent needleleaf species.

These changes result in shifts of water flux to faster flow paths (Figure 1). Due to the increased leaf area of the deciduous trees (i.e. broad-leaf versus needle-leaf shape), canopy storage and re-evaporation increased by 20%. Secondly, ~60 mm of runoff was shifted from subsurface (slow) flow-paths to surface (fast) flow-paths. Both of these changes reduce the volume of water that cycles through the soil and, thus, have the potential to affect soil processes dependent on soil moisture. These processes may include water-stressed transpiration and soil biogeochemical transformations, such as decomposition, mineralization, and denitrification.

Figure 1. Annual volume change of Hubbard Brook water balance fluxes under pre- and post-legacy conditions.



Given these preliminary findings, additional questions immediately emerge. Does the routing of water to faster flow-paths create relatively drier conditions that favor the local deciduous species? How do such shifts impact the material fluxes from the basin? Do higher discharges increase dissolved loads, sediment loads, or both? The quantification of the expected changes allows serious consideration of the implications of legacy effects.

Future Planning

With model construction experience gained at this meeting we expect to rapidly complete the BES and KNZ models. These results will form the nucleus of a manuscript expected to be completed by the end of the summer. This manuscript is intended to focus on the process of quantifying hydrologic responses to legacy impacts using historical information, contemporary observations, and physically-based models. In fact, the structure of the meeting allowed substantial portions of the manuscript to be drafted during the meeting period.

In addition, we remain committed to engaging the larger community. We plan on submitting a workshop proposal for the ASM. In this workshop, we would like to contact participants prior to the meeting and solicit additional model scenarios representing other LTER sites. This will allow us to develop LTER-driven questions prior to the meeting and to be ready to explore these questions at the hillslope scale during our proposed ASM workshop. Therefore, we would have a wide variety of models allowing LTER-scientist driven inquiry in an interactive environment. We remain hopeful that the Network office will provide funding to bring scientists to the meeting to participate in the workshop and the larger community. These details will be covered in detail in the workshop proposal.

The work and preparation to date has been focused on a representative hillslope for each of the LTER sites being considered. The reasoning behind this domain selection was for rapid model development and simulation efficiency. Ultimately, the goal is to utilize the full spatially distributed capabilities of tRIBS+VEGGIE to explore the variability in hydrologic response across the watersheds of the interest. The funding for Sivandran's student Shilling will allow the rapid transformation of these 'toy' hillslope scale realizations to watershed scales. Shilling will be responsible for the collection and processing of the spatial data sets (DEM, soil maps and parameters, vegetation maps and parameters, climate forcing variables) required to force the model.

Finally, building on the momentum built from the expected manuscript and ASM session, we envision this work will engender sponsored research in the near future. We plan to submit proposals to the DOE Terrestrial Biogeochemistry and the NSF Dynamics of Coupled Natural and Human Systems programs this year. Anticipated funds will expand and enhance the results generated to date and those to be completed in the near future.