Table 1: Main Ecological Hypotheses – CWT LTER 2008-14

***Question 2.5b*. How do differences in riparian and hillslope land cover, soils and infrastructure alter water quality and quantity along flowpaths from hillslopes to small streams to rivers?**

Research Theme 1: Exurban development and climate change will alter water quality and quantity in the Little Tennessee River by changing hydrologic flow paths, nitrogen cycling, channel structure, and sediment transport. Building on a long history of hydrology and biogeochemical cycling research and a 30+ yr record of stream chemistry and aquatic ecosystem responses to disturbance, we will expand our research to examine the interactive effects of exurbanization and climate change.

- **H1a**: Increased exurbanization will shift the relative importance of forms of nitrogen export (from low levels of total N dominated by organic-N to high levels of total N dominated by nitrate) and decrease the retention and transformation of N-inputs in streams.
- **H1b**: Increased frequency and intensity of winter storms and summer droughts will interact with exurbanization. In all watersheds, N-export will increase during storms that follow drought periods, but in watersheds dominated by exurban development, high N export will shift from summer to winter.
- **H1c**: Given increased hydroclimatic extremes, exurbanization will reduce water quality, increase the frequency of extreme high and low flow quantity, and increase nitrogen flushing so that watersheds with greater exurban development are more vulnerable to increased climatic variability.

Approach: Synoptic sampling of 40 streams and intensive studies at 12 locations that include semi-continuous measurements of ecosystem processes in terrestrial and stream habitats.

***Question 2.5c*. How do climate change and exurban development affect biodiversity at local to regional scales, and what are the implications for ecosystem processes?**

Research Theme 2: Species' responses to climate and land-use change will be spatially predictable and mediated by interactions among populations, communities and geomorphic position. Building on a long history of ecological research and a 70+ yr record of plant community responses to natural and anthropogenic disturbance, we will expand our research to address the consequences of a warmer, drier climate and increasing exurban development on plant and selected vertebrate communities.

- **H2a**: Drought-sensitive species (i.e., *Liriodendron tulipifera, Magnolia acuminate, M. fraseri*) and communities (e.g., cove forests) will decline on previously moist sites; species near their moisture/drought tolerance threshold will show reduced vigor, diminished recruitment, and/or increased mortality. Mid-elevation species (*Quercus alba, Q. rubra, Carya* spp) will expand to higher elevations, while high-elevation species (*Abies fraseri, Picea rubens, Betula alleghaniensis*) and communities (e.g., fraser fir-red spruce forests, northern hardwood forests) will decline in vigor, abundance, and recruitment.
- **H2b:** Species interactions will modify effects of climate change through competition for light and water, with more rapid distributional change where overstory competition is reduced.
- **H2c:** Under warmer and drier conditions, leaf area and productivity will decline and become more spatially uniform at the hillslope scale.

Approach: Tree demography censuses on existing and new plots with climate covariates plus experimental plantings along gradients and in experimental gaps. Current studies extended to consider interactions of climate to lower, higher, and wetter sites of the contemporary landscape and past land use legacies. Based on current research, demographic responses require 2-3 yr.

- **H2d:** Exurban development will be associated with (i) reduced salamander abundance and habitat occupancy and (ii) homogenization of avian communities among watersheds.
- **H2e:** Exurbanization will exacerbate the effects of increased aridity by increasing local extinction risk for native species that are drought-sensitive, have low fecundity, and limited dispersal.
- **H2f:** Climate will interact with historical land use (via persistent effects on soils and nutrient cycling) to affect the establishment and growth of native understory plants.

Approach: Synoptic and intensive sampling of 1st-order streams (for salamanders) or watersheds (for birds) that vary in amount and intensity of exurban development; these will be paired with experimental manipulations (salamanders), and field experiments along topographic gradients combined with greenhouse experiments in varying soil (reference vs. historical agriculture) and climate conditions (warmer/drier vs. ambient).

<u>Research Theme 3</u>**: Changes in tree diversity will have cascading impacts on ecosystem function.** Building on past and current CWT research showing i) that tree diversity will change with climate and pest/pathogen outbreaks, ii) that forest communities vary with historic land use, and iii) understories are being invaded by non-native species, we will expand our research to examine species-specific effects on forest ecosystem processes.

- **H3a:** Tree community changes that reduce leaf litter quality (e.g., increase lignin:N ratio) will reduce decomposition and nutrient cycling rates in terrestrial and aquatic habitats, and affect higher trophic levels, e.g., amphibians.

***Approach*:** Experimental manipulation of deciduous leaf litter (based on species expected to increase or decrease) in terrestrial and stream habitats.

- **H3b:** Historical land use related increases in non-native species in the forest understory have altered forest community composition and changed litter quantity, litter quality and soils.

***Approach*:** Reciprocal transplant experiments of *Celastrus orbiculatus* in historical agriculture (*L. tulipifera* abundant) and reference stands (*Quercus* sp. abundant).

Reduced vigor and/or mortality in *Q. rubra* and *Rhododendron maximum* are expected if sudden oak death infects Southern Appalachian forests.

- **H3c:** Loss of *R. maximum* will homogenize soil C and N dynamics. A more favorable microclimate will increase C and N mineralization, and increased exposure to rainfall will increase erosion. Water flux will decrease, but nutrient flux will increase.
- **H3d:** Loss of *Q. rubra* and its subsequent replacement by *L. tulipifera* will alter terrestrial nitrogen cycling by increasing the production and loss of NO_3^- and decrease soil moisture and streamflow due to higher transpiration by *L. tulipifera.*

Approach: Experimental manipulations to simulate sudden oak death by girdling *Q. rubra* and removing *R. maximum;* process studies of C and N pools, cycling rates, and controls; and species-based sapflow measurement and scaling to predict soil moisture and hydrologic flux.

Expansion of *Microstegium vimineum* with exurban development and warm/dry conditions may profoundly affect biogeochemical processes.

- **H3e:** Increased inputs of high-quality, nonnative *M. vimineum* litter will: (a) reduce soil organic C and N stocks because *M. vimineum* litter inputs will ‘prime’ microbial decomposers, or alternatively (b) increase soil organic C and N stocks because *M. vimineum* litter inputs will be ‘preferentially used’ by microbial decomposers.

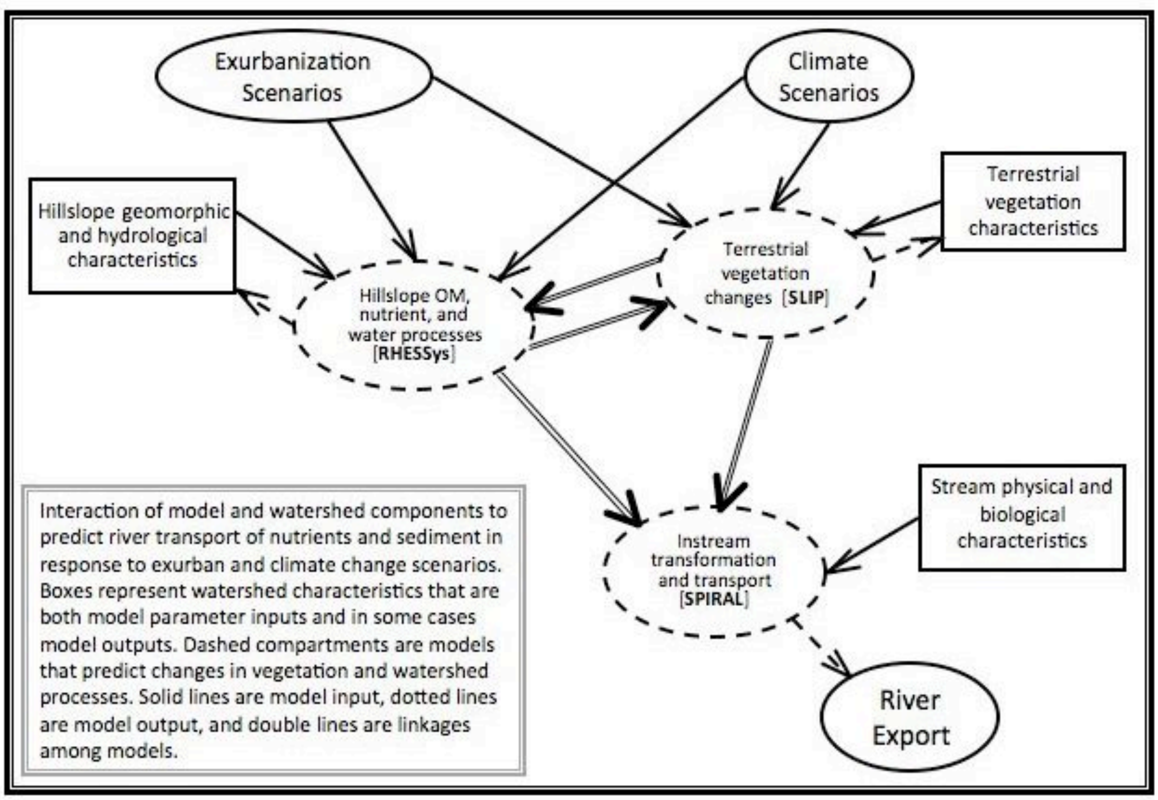
- **H3f**: Because (a) and (b) will both result in increased activity of microbial decomposers, the transfer rate of microbial nitrogen to plants will also increase.

Approach: ^{15}N stable isotope tracer studies, effects on plant-microbe partitioning of soil N, measurement of DON in soil, and SOC fractionations across advancing invasion fronts.

Table 2: Relations between Hypotheses, Models, Parameterization and Data

Relation to Hypotheses	Data for Parameterization	Data for Validation
RHESSys is a nested ecohydrologic model that resolves hydrologic flowpaths and connectivity at hillslope to watershed scales, and dynamics of biogeochemical cycling and ecosystem productivity at the patch scale. The validated model will be used to explore scenarios of exurbanization and climate change at catchment levels to regional watersheds and decadal time scales in evaluating predictions from H1c and H2c.	1. Automated TDR plots and portable TDR sampling 2. Groundwater levels in riparian wells 3. Soil and forest floor C and N 4. Soil solution and riparian well chemistry 5. Hillslope to stream vegetation transects, and plot LAI (from plot measurements, remote sensing, and SLIP model predictions) 6. Productivity from tree rings 7. Distributed meteorologic stations and topoclimate interpolation	Catchment stream discharge, nutrient concentrations, and TDR from long-term measurement records; past Coweeta sampling initiatives and synoptic sampling in this proposal; spatial pattern of LAI and aboveground biomass.
SPIRAL will be used to predict regional scale export of nitrogen and sediment in response to scenarios of exurbanization and climate change. This model will be used to evaluate predictions of H1b and H1c at the regional level.	1. Spatially explicit predictions of riparian vegetation (from SLIP model) to estimate allochthonous inputs and light to streams 2. Spatially explicit predictions of water, nitrogen, and sediment inputs to streams (from RHESSys) 3. Measurements of instream metabolic, nitrogen, and sediment process and how they are modified by exurbanization and climate change 4. Physical characteristics of streams and the stream network in the Upper Little Tennessee watershed	Measurements of discharge, nitrogen concentration, and sediment load in the Little Tennessee River from long-term measurement records, past Coweeta sampling initiatives and synoptic sampling in this proposal.

SLIP incorporates demographic responses to climate variables in the context of competition for light and moisture, with full accounting of uncertainty. Predictive modeling will test diversity level responses to warming winters and summer drought that result from the interactions with competition, as predicted in H2a and H2b. They will provide the basis for the next generation of experiments.	1. Experimental plantings and observational data across microclimate gradients, including outside current climate envelopes where models predict species will do better and worse in the future (elevation by moisture status). 2. New sampling on existing sites and establishment of new sites at higher/lower elevation; more mesic than currently studied. 3. Canopy manipulation experiments including light by climate interactions. 4. Census data including fecundity, growth, mortality, dispersal; monitoring of climate variation in space and time - parameterization as in *Global Change Biol* (in press), *Ecol Appl* (in press), *Ecol Mongr* 77:163.	Long-term data plots initiated at Coweeta in the 1930's; stand structure and composition at sites intermediate in elevation and not included in parameterization; responses to oak girdling experiments.



Interaction of model and watershed components to predict river transport of nutrients and sediment in response to exurban and climate change scenarios. Boxes represent watershed characteristics that are both model parameter inputs and in some cases model outputs. Dashed compartments are models that predict changes in vegetation and watershed processes. Solid lines are model input, dotted lines are model output, and double lines are linkages among models.