The intricate veil of molecules that make up the earth’s atmosphere has been compromised over the years. Elevated emissions of carbon dioxide and other greenhouse gases are associated with fossil fuel use and industrialization. Coupled with deforestation of tropical areas, many scientists believe these factors may contribute to global warming and an increase in climate variability—the frequency and magnitude of extreme climatic events.

Range managers, meanwhile, have seen grasslands evolve into woodlands and shrublands that can constrict water flow, alter soils and ultimately change how the land can be used. Investigating how these changes in vegetation may have affected the accumulation and processing of carbon and nitrogen on southwestern range-lands has been UA plant ecologist Steve Archer’s passion for over two decades.

Mesquite (Prosopis velutina), dominates many of today’s rangelands. This plant has expanded from its historical enclaves in bosque, riparian, and arroyo ecosystems and into uplands over the past century, in part because many animals favor the sweet seed pod. For example, when cattle consume mesquite pods along with range grasses and forbs, the seeds are deposited (complete with fertilizer) wherever they range. Scientists wonder if the spread of mesquite and other woody plants might actually aid in the absorption of excess carbon dioxide.

The thorny mesquite often grows in dense thickets and, depending on soils, can reach heights of 10-20 feet with trunks 12-24 inches in diameter. This mesquite and woody shrubs such as creosote alter wildlife habitat and compete with native vegetation for water and nutrients, changing grasslands forever. Compared to grasses, woody plants typically have much greater leaf areas, meaning more potential transpirational water loss. They also have more extensive and deeper root systems able to tap sources of water that could otherwise go to groundwater recharge and affect stream flow.

“There has been a long-standing interest in how mesquite affects livestock production, wildlife habitat and water availability,” Archer says. “We know much less about how it affects the manner in which ecosystems process carbon and nitrogen, two important elements linked to climate change. We’re interested in understanding how carbon and nitrogen stocks in ecosystems change as you shift the composition from grassland to shrubland.”

The Santa Rita Experimental Range (SRER), southeast of Tucson, provides an extraordinary outdoor laboratory for studying this topic. Land use patterns have been well documented at the UA research facility for more than 100 years. Research there has included plant introduction and reseeding, invasive weed control, livestock/wildlife interactions, insect studies and the effect of livestock grazing.

For example, there are large plots of land that have been protected from livestock grazing; other plots where grazing took place for years and then was curtailed; still others with continuous or rotational grazing. This rich array of contrasts will allow Archer and colleagues to evaluate how real-world land uses might affect woody plant encroachment and its impacts on the carbon and nitrogen cycles. Furthermore, the elevation on SRER’s 51,000 acres ranges from 2,900 to 5,200 feet, with varying soil types and rainfall amounts. The results from the research can be broadly extrapolated to other areas.

For the first year of the research project Archer and his research team are measuring the carbon and nitrogen content of mesquite and other rangeland plants. They are doing this in pastures with contrasting management histories at various elevations at the SRER and are taking soil core samples as well. By measuring the carbon and nitrogen content in plants and soils, Archer hopes to provide a more complete inventory of how carbon and nitrogen pools in ecosystems will change as the vegetation changes in response to climate or land management. Previously his research was conducted in two areas of Texas—one a temperate zone in northern Texas and the other a subtropical zone near the Gulf of Mexico. Results from those studies, when combined with those from the SRER project, will enable Archer and his colleagues to make regional assessments and determine if brush en-
croachment has similar effects in different regions of the Southwest.

Carbon and nitrogen are contained in plant biomass and in soils. Biomass is defined as the weight of plants above ground (leaves, stems, trunks) and below ground (roots). Working early in the day during the warm growing season, field crews collect biomass by clipping and weighing low-growing vegetation. It is not realistic to cut and weigh the mesquite plants in an ecosystem, so their weight is predicted using equations that relate plant height, basal stem diameter and canopy dimensions to biomass. Soils contain carbon and nitrogen that is derived from the death and decomposition of plant leaves, stems and roots.

Samples of plants and soils collected in the field are taken to the laboratory, where they are ground into fine particles, using a series of mechanical grinders. These particles are then run through an elemental analyzer which determines the concentration of carbon and nitrogen. Biomass values are then multiplied by concentration values to determine how much carbon and nitrogen are in the plants and soils of an ecosystem. By making these measurements in different pastures, the effects of land use and vegetation change on carbon and nitrogen abundance can be assessed.

Recent funding from the USDA’s Managed Ecosystems Program is making possible more detailed and extensive sampling, including the use of dynamic simulation models. These models refine estimates of how the carbon and nitrogen mass in plants and soils have changed over time, as a result of woody plant encroachment and brush management practices aimed at reducing woody plant cover. Archer is also collaborating with scientists at the University of Colorado and the Carnegie Institute at Stanford University on a NASA project at the SRER.

“We are currently working on approaches that will allow us to use aerial photography and satellite imagery to make large-scale assessments of the carbon and nitrogen content of soils and vegetation,” Archer says.

Gaseous emissions of nitrogen occur through the natural decomposition process and these can contribute to greenhouse gases and to tropospheric ozone production (produced in the atmospheric layer below the stratosphere). As a result, vegetation effects on nitrogen are of interest to scientists. Plants like mesquite have the potential, through forming symbiotic relationships with bacteria, to convert atmospheric nitrogen to forms of nitrogen that can be used in plant metabolism and growth.

“Changes in vegetation from non-nitrogen fixing species such as grasses to nitrogen-fixing species such as mesquite might change fundamental ecosystem properties with regard to nitrogen availability,” Archer says. “Both ecosystem productivity and greenhouse gas concentrations are affected.”

Archer’s research ultimately will lead to some answers about how much carbon gets sequestered, or tied up, and for how long, in various vegetative types and under various land management practices. Carbon credit programs are being considered in some parts of the United States. Such programs compensate landowners and land managers for promoting vegetation growth or restoring degraded range and pasture land, to increase carbon sequestration in the ground.

“This might be a win-win situation,” Archer says, “because it could be a source of capital for range improvement practices that have many spin-off benefits such as increasing soil organic matter and improving water holding capacity and fertility.”

Livestock production, water use and the biodiversity of grassland ecosystems are at stake.

“With woody plant encroachment, we’re losing the plants and animals indigenous to our grasslands,” Archer says. “That’s one downside of woody plant encroachment that offsets the possible benefits of carbon sequestration.”

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Field work at the Santa Rita Experimental Range includes tagging trees, measuring vegetation and weighing the largest size classes of vegetation using the tripod scale (center). This is part of the mobile field lab that processes the bulk of the work.

UA students (l-r) Robert Wu, Adrian Vogel, Elsbeth Hoggett and Donna King separate leaves from small stems of mesquite collected at the Santa Rita Experimental Range.