Southwest

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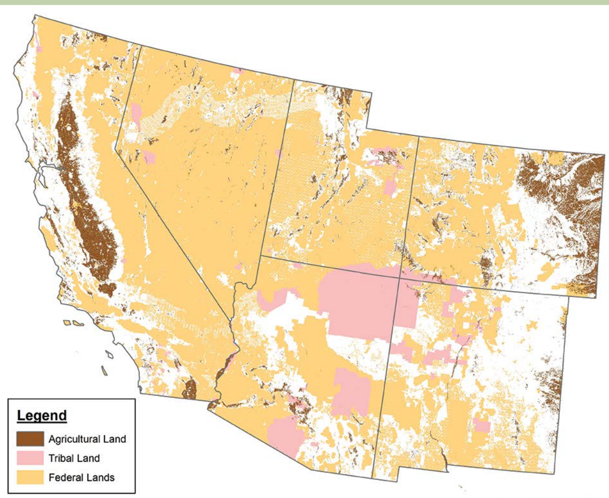
Description of the Region

The Southwest is a region defined by water scarcity. Composed of Arizona, California, Colorado,[4] Nevada, New Mexico, and Utah, this region has some of the greatest landscape and climate diversity in North America (Neary and Ffolliott 2005, Warshall 1995). Federal and tribal lands dominate the Southwest, with croplands comprising only 8 percent of the region and with the majority being located in California and eastern Colorado (fig. A.4) (USDA NRCS 2013). Agriculture is mainly confined to intermontane valleys, the broad plateaus, and plains with adequate groundwater resources or along alluvial river systems fed by mountain snowmelt. Major river systems like the Colorado, Rio Grande, and Sacramento-Feather-San Joaquin supply water to many areas with irrigated agriculture.

Figure A.4. Federal and tribal lands comprise much of the region, with cropland and pastureland limited to areas with available water resources. Rangeland grazing occurs on Federal and tribal lands and also on private rangeland (on some of the areas shown in white). Agricultural land data from Homer et al. (2015) and Federal and tribal land data from USDOI USGS (2003).



Much of the cropland in the region, outside of California, is dedicated to growing alfalfa hay. Other crops include cotton, lemons, lettuce, onions, peanuts, peppers, potatoes, tangerines, and wheat (USDA NASS 2014). Together with hay production, agriculture accounts for 79 percent of the water consumption (Garfin et al. 2014). This usage, however, is changing as urbanized areas such as Phoenix expand by securing the rights to agriculture water. The Phoenix metropolitan area has transitioned from being agricultural in the 1960s to being predominantly urban in the 21st century.

California is different from the rest of the Southwest because it ranks first in the United States for agricultural production, with a value in excess of $42.6 billion or 10.8 percent of the Nation's total agricultural sales (USDA NASS 2014). This amount is about 2.6 times the economic production of the rest of the region combined. Approximately 28 percent of California's agricultural sales is from livestock products, and the remainder is from traditional crops such as vegetables, fruit, grapes, nut crops, lettuce, and berries (USDA NASS 2014).

Rangelands comprise the largest portion of Federal and non-Federal land area in the Southwestern United States (USDA NRCS 2013), generating agricultural revenue through dairy and livestock production (USDA NASS 2014). Rangelands in the region are diverse and encompass different ecotypes from oak savanna, sagebrush steppe, and scrubland to arid grasslands (Shiflet 1994).

Forests of the region occur on rugged peaks and low ranges, over broad plateaus and isolated mesas, and along minor and major river systems (table A.3). These systems provide many ecosystem services crucial to water resource availability. Simultaneous production of wood for fiber or other tree-based benefits, forage for livestock, and traditional agricultural products has been a historical land management objective in the Southwestern United States. Livestock grazing occurs on many forest types in the region; however, these production systems may not necessarily be considered silvopasture systems by definition and practice. (See box A.1.)

[4] Eastern Colorado is best described by the conditions and considerations discussed in the Great Plains regional summary in this appendix.

Table A.3. Forests of the Southwest Region.

Forest type	Extent	Forest management as It pertains to agroforestry
Southern Rocky Mountain forests	10.1 million ha (24.9 million ac) of mountainous terrain in Colorado, New Mexico, Arizona, Utah, and parts of Nevada.	Forage increases as forest density decreases and vice versa, making timber management a forage management tool (Clary and Ffolliott 1966). Prescribed fire is also a tool being used more recently to eliminate undesirable plants. Utilization of 30 to 40 percent of the forage growth provides a sustained level of forage resources for livestock on rangelands in good condition. Continuous yearlong grazing is practiced on lower-elevations in the southern part of the region. Fencing, strategic placement of stock tanks and salt licks, and constructing driveways to move livestock from one allotment to another are used to improve livestock distribution, attain specified stocking levels, and obtain more uniform utilization of forage resources.
Sierra coniferous forests	6.9 million ha (16.9 million ac) of mountain landscapes in California with minor occurrences in Nevada.	Forage production increases rapidly, slowly giving way to shrub species, and then to tree regeneration following harvesting of timber. Forage is almost nonexistent beneath old-growth forests but increases once overstory canopies open. Prescribed fire has also been applied to increase forage production. Utilization of 40 percent of the forage growth provides a sustained level of livestock production on rangelands in good condition. Forage on high elevation rangelands is grazed from June through late October with continuous yearlong livestock grazing on lower elevations.
Oak woodlands	Throughout California and scattered in western Colorado, Utah, and southwestern New Mexico and southeastern Arizona.	Inherently low levels of growth, irregular stem forms, and a lack of markets constrain the intensive management of oak trees for wood production, although trees are cut locally for fuelwood, and small poles and posts. Many of the rangelands are fair to poor in condition. Therefore, managers often prescribe a utilization level of forage plants that is less than 40 percent to sustained production. Selected seeding of preferred species has improved forage production on some rangelands.
Pinyon-juniper woodlands	Eastern slopes of the Sierra Nevada Mountains, eastward throughout the Great Basin, through the Rocky Mountains of Colorado, southward into New Mexico and Arizona.	A past management activity has been to control the invasion of Pinyon-Juniper Woodlands onto lower elevation grasslands to reduce competition and improve forage production. Cattle and native ungulate forage production declines rapidly as the woodlands increase in density due to low precipitation and pinyon-juniper competition. Many rangelands are only fair or poor in their condition. As a consequence, managers consider utilization of forage plants in excess of 40 percent to be detrimental to sustained forage production (Gottfried 1999).
Mesquite-dominated ecosystems	Scattered throughout the semidesert rangelands of the region, along the southern boundaries of Arizona, New Mexico, and western Texas.	Mesquite as an agroforestry resource is a source of fuelwood, poles and posts, and feed for ruminants. It also makes excellent charcoal. Small wood-producing (cottage) industries largely dependent on mesquite as the raw material have evolved into a number of profitable enterprises in the southwestern United States. Knowledge of effective silvicultural practices is limited, however, jeopardizing achieving sustainability of the wood resource (Ffolliott 1999).

ac = acre. ha = hectare.

Box A.1. But is it agroforestry?

Silvopastoral activities and food gathering within forests have been long-standing activities in the Southwest, especially on Federal lands (Bainbridge 1995). The question arises, however, regarding whether all silvopastoral and food-gathering activities are agroforestry. By definition, agroforestry must be *intentional*, *intensive*, *deliberate*, and *integrated* (Gold et al. 2000). Although it is easy to see how practices involving the introduction of trees into agricultural operations may meet this definition, it is less clear for those activities occurring on nonagriculturally managed lands. Silvopastoral systems have been described in the literature as “a form of structural agroforestry in which tree, forage, and animal components all share the same hectare of land at the same time” (Sharrow 1999: 113). Some of these systems, though, lack intentional design and/or management for the production of trees, tree products, forage, and livestock components (USDA NAC 2014). Examples of such systems would be livestock grazing that occurs on forest land where adequate forage already exists or on rangeland where trees are encroaching, which would probably reflect most of the grazing operations that occur on Federal lands. Likewise, harvesting of foods and other nontimber forest products from forested land in the Southwest and elsewhere, especially from Federal lands, is another gray area in terms of whether these activities are actually agroforestry. The question in this case becomes—Is the practice wild harvesting or is it forest farming (agroforestry)? Again, to be considered forest farming (agroforestry), deliberate management of the forested (treed) area to enhance the production of these products needs to exist. On Federal lands, agencies such as the U.S. Department of Agriculture, Forest Service are working to develop forest plans that take into account climate change impacts and the sustained production of these nontimber forest products, especially those that many Native American tribes rely on as indigenous foods (see chapter 5).

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Box A.1. But is it agroforestry? (continued)

The distinction of whether a practice is agroforestry is not an absolute one. Rather, it is one of discerning where on the continuum of design and management the practice lies and then deciding whether that is enough to qualify it as an agroforestry practice.

To complicate the discussion further, situations exist, especially on Federal lands, in which management decisions are made for a primary purpose(s) other than agricultural production, but which can then secondarily provide agricultural benefit. In the Southwest, primary goals for thinning forest stands are for watershed health services that include improvement of timber and tree health, water resource management, and/or fuel load reduction. Regardless of intent, it also generally results in forage production improvement. So the question then becomes—Was this benefit to forage growth deliberately considered and recognized in the planning process? Further, what if the intent is twofold—to increase water resources available to downstream agricultural production and to increase forage production for grazing?

With our understanding of these practices in the Southwest, we do not have the information needed to explicitly state the extent of current agroforestry activities nor that of the potential of agroforestry in the Southwest. Opportunities are emerging that suggest agroforestry may be able to play a larger role in the Southwest as other technologies come on line (more efficient and/or recycled water irrigation systems) and as the Southwest faces more pressing climate conditions.

California oak woodland management as agroforestry, where goals can include enhanced soil quality and carbon sequestration, generation of annual and longer term incomes from timber products, grazing, and potentially other operations such as mushroom production (Dahlgren et al. 2003, Frost et al. 1991). (Photo courtesy of the USDA Natural Resources Conservation Service).

Management of the region's watersheds to ensure sustainable flows of high-quality water to downstream agricultural and municipal users in this drought-prone part of the country is integral to the sustainability of this region. Climate projections of increasing and prolonged drought make this service an important consideration when determining management strategies and actions for this region.

Threats and Challenges to Agricultural Production, Forestry, and Community Sustainability

The Southwest has heated up in recent decades, and the period since 1950 has been hotter than any comparably long period in at least 600 years (Melillo et al. 2014). The 2001-to-2010 decade was the warmest in the 110-year instrumental record, with temperatures nearly 1.1 °C higher than historic averages, fewer cold air outbreaks, and more heat waves (Kunkel et al. 2013). Regional annual average temperatures are projected to rise by 1.4 to 3.1 °C by the 2041-to-2070 period (Garfin et al. 2014). Extreme daytime and nighttime temperatures have been shown to accelerate crop ripening and maturity; reduce yields from vegetables, fruit trees, and vineyards; cause livestock stress; and increase agriculture water consumption (Walthall et al. 2012). The freeze-free period throughout the Southwest is estimated to increase on average by about a month by 2055, with the largest increases (greater than 35 days) occurring in the interior of California (Kunkel et al. 2013). It is projected that required winter chill periods will fall below the number of hours necessary for many of the nut- and fruit-bearing trees of California and that yields will decline as a result (Luedeling et al. 2011). Under warmer winter temperatures, some existing agricultural pests can persist year round, while new pests may become established (Garfin et al. 2014). Pollination services by managed honey bee colonies are expected to decline under predicted climate change scenarios (Reddy et al. 2013), impacting the numerous pollinator-dependent crops in the region.

Long-term and extensive drought is the greatest threat to agricultural production and forestry in the Southwest (Garfin et al. 2014). To compound this threat, the region is projected to transition to a more arid climate (Seager et al. 2007). Drought, as expressed in Colorado River flow, is projected to become more frequent, more intense, and longer lasting, resulting in water deficits heretofore not seen in the instrumental record (Garfin et al. 2014). The current drought in California may foreshadow what is coming (fig. A.5).

The drought in California is posing community sustainability challenges. Current projections are for an unemployment rate of 50 percent in farm towns (Marois 2014). This trend threatens the viability of small farming communities that are spread throughout the agricultural region of the State. It also impacts State and national budgets, which are required to deal with unemployment. Larger cities can be affected by influxes of unemployed people from farming communities.

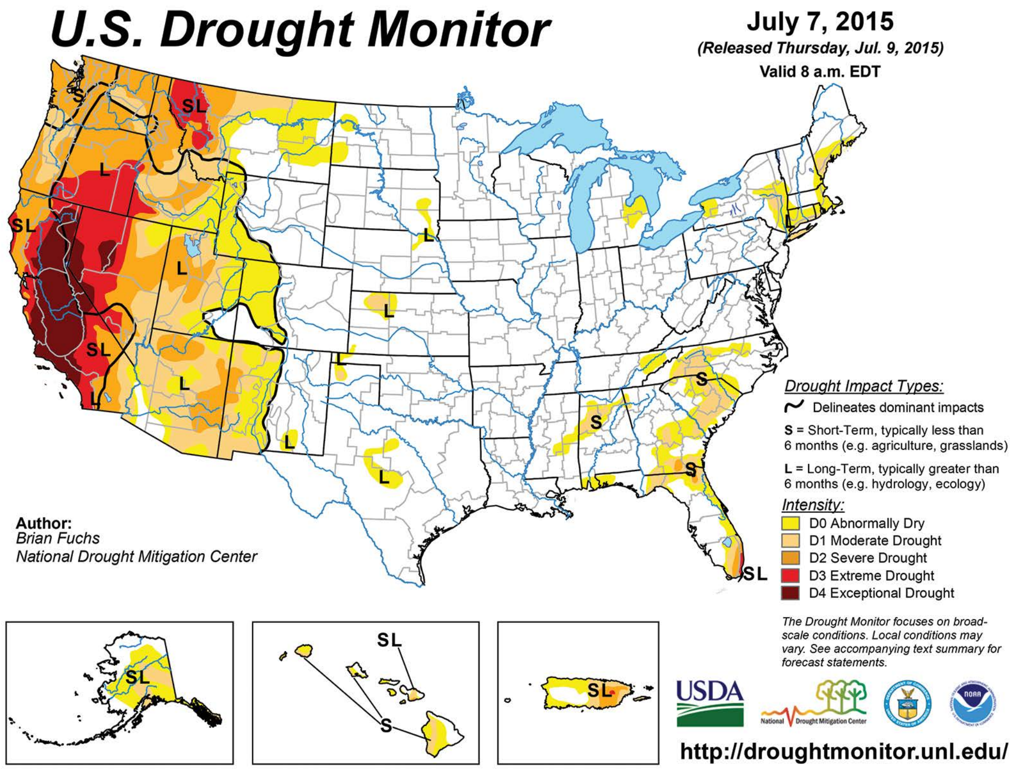
Numerous threatened and endangered (T&E) species reside in the region and likely will experience increasing pressure under climate change (Staudinger et al. 2012). Rangeland grazing historically has contributed to impacts on T&E species (Flather and Joyce 1994). Negative impacts to 22 percent of federally listed T&E species have been attributed to livestock grazing in Southwest forests (Wilcove et al. 1998). Because of T&E species concerns and other environmental issues, public land grazing is a contentious issue that will likely escalate under climate change, and strategies to reduce impacts will need to be implemented (Brown and McDonald 1995).

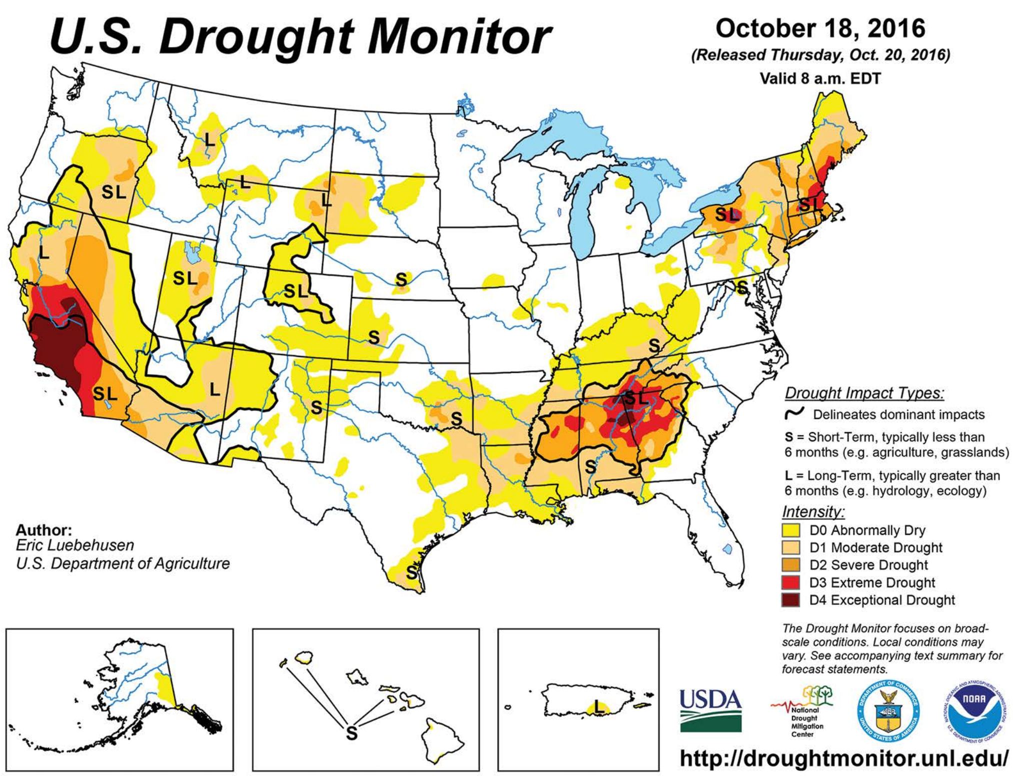
Agroforestry as an Opportunity To Build Resilience

Bainbridge (1995) describes a variety of opportunities for agroforestry practices in the Southwest. In this summary, we highlight a few. Numerous adaptation strategies exist for managing grazing lands under climate change (Joyce et al. 2013), and managing forested rangeland grazing as silvopastoral agroforestry systems can offer another option for enhancing stability and resilience in the agriculture and forestry economies (Bainbridge 1995). The greater diversity of enterprises that can be incorporated with the livestock grazing, beginning with timber products but extending to nontimber products (e.g., mushroom production) (Harper et al. N.d.) and hunting and recreational operations (Standiford and Howitt 1991), can reduce risk under variable climate. In addition, this type of operation may also provide other ecosystem services and goods, such as improved soil health, carbon sequestration, and long-term productivity (Dahlgren et al. 2003, Frost et al. 1991).

During the next several decades, many Southwest forests will be going through restoration treatments to reduce fuels and to manage stands at an appropriate density to withstand frequent, low-severity fires. Overstocked forests have led to large, high-severity, landscape-level wildfires. The Four Forest Restoration Initiative is an example of the type of programs that need to be initiated to restore ponderosa pine ecosystems to properly functioning conditions (Covington et al. 1997). After the restoration thinning treatments, higher densities of grasses and forbs will provide significantly greater forage resources to support silvopastoral agroforestry. Judicious management of animal-stocking levels should be able to provide adequate livestock forage, and, in combination with prescribed fire, ensure ecological goals (Laughlin et al. 2006, Moore et al. 2006). Because forest harvesting will be episodic after the restoration treatments are complete, silvopastoral agroforestry has the potential to provide economic resilience for both Federal land managers and grazing permittees (Sharrow et al. 2009).

Figure A.5. The State of California recently experienced exceptional drought of prolonged duration, the third most severe on record (Howitt et al. 2014). Stream and irrigation flows to the Central Valley were reduced by 30 percent, and California's water reservoirs statewide were at 28 percent of total capacity and 49 percent of normal (Howitt et al. 2014). Snowpack levels in the Sierra Nevada's forests were estimated at a 500-year low in 2015 (Belmecheri et al. 2016). Reductions in snowpack and rainfall mirrored in depleted water reservoirs impacted the productivity of oak woodlands that sustain silvopastoral agroforestry in California (Asner et al. 2016). Surface water losses in California have been offset by unsustainable groundwater pumping at an additional cost of $0.5 billion to the State's agricultural sector (Howitt et al. 2014). (From USDA Drought Monitor, http://droughtmonitor.unl.edu/).





The Southwest also affords several other potential agroforestry endeavors tied to nut production. Such endeavors could be the deliberate establishment of nut trees, such as pecan, into operations or the deliberate management of lands, such as the pinyon-juniper rangelands, for pine-nut production, along with ongoing grazing activities (Sharashkin and Gold 2004). Tribes in the Southwest, as elsewhere, have long depended on foods they could harvest from the forests (Bainbridge 1995). Given the potential impacts of climate change, such as fire and species shifts, using an agroforestry approach for these nontimber forest products, even on Federal lands, may need to occur to sustain and/or replace production. (See chapter 5 and box A.1.)

Woody species generally used in Southwest agroforestry may also be well suited to producing biofeedstock for heat and power generation (Kirmse and Fisher 1989). Agroforestry could serve as the means for building a viable feedstock supply by augmenting the biofeedstock generated from forest operations (i.e., fuel load reductions). Use of agroforestry for this purpose has some potential in the Southwest, as evidenced in California, where short rotation biomass efforts are already in progress (Standiford 2014).

Agroforestry also can reduce climate change impacts on agricultural production by supporting biological pest control and pollination services for high-value crops in the region, while creating critical habitat for a diversity of wildlife species. (See chapter 2 and box A.2.)

Box A.2. California: buffers, bees, biocontrol, and bucks

One-third of California's agricultural returns come from pollinator-dependent crops (e.g., sunflower, almonds, melons, and many other vegetable crops) making pollinators key players in California's agricultural economy. Pollinator services needed for this crop production are by managed honey bees and also by native bees (Chaplin-Kramer et al. 2011). Given the continuing dilemma of colony collapse, dependence on the honey bee, which is a single species, represents a significant vulnerability in the agricultural sector. In addition, abundance and numbers of native bee species continue to decline as agricultural operations intensify. Shifting climate is expected to impact the quality, quantity, and timing of habitat components critical to the survival and functioning of pollinators.

Hedgerows, windbreaks, and other agroforestry buffer practices that are established to provide nonpollinator services, such as air-, soil-, and water-quality protection, can be used to increase the diversity and abundance of habitat features native bees and honey bees need for survival. These plantings have also been found to enhance beneficial (biocontrol) insects that can help control levels of insect damage to some of these crops in California (Long and Anderson 2010, Morandin et al. 2014).

With appropriate planning and management, these plantings can enhance habitat for both pollinators and biocontrol insects by producing the strategic diversity (i.e., a variety of flowering plants with overlapping blooming times, a diversity of protected and suitable nesting and overwintering sites) that will be needed to create resilience under the unpredictable impacts of changing climate (see chapter 2).

Blue blooms of native California lilac and other native shrubs and perennials form part of a 1-mile-long hedgerow in Yolo County, CA. Hedgerows have been shown to increase pollination activity from native bees and provide crop protection by harboring beneficial native insects over crop pests by a margin of three to one (Morandin et al. 2011). (Photo courtesy of Jessa Cruz, the Xerces Society for Invertebrate Conservation).

Challenges to Agroforestry Adoption

Although agroforestry is often viewed as a potential mitigation measure for climate change in both the agricultural and forestry sectors (Nair 2012), the practice is also threatened by climate change (Pachauri 2012). The big threat that will challenge both agroforestry and conventional agriculture in the Southwest far beyond any other is drought.

One challenge to silvopastoral agroforestry adoption in the Southwest will be T&E species interactions and controversy over grazing impacts on the environment. Federal lands that make up the bulk of Southwest forests are much more prone to this challenge than are private lands. Care will be needed to balance stock numbers with productivity potential. Fluctuating aridity can cause large changes in forage vegetation productivity. The key to success will be preventing irreversible damage to vegetation and site productivity. Because of increasing arid conditions, attention will have to be paid to providing adequate watering resources for livestock.

The adoption of conventional agroforestry practices on private agricultural lands will have the challenge of convincing landowners and managers that the economic and ecosystem services provided by agroforestry in a drying environment are worth the efforts and risk. Because irrigation is an important component of agriculture in the Southwest, the issue of increased water consumption by tree crops in an environment where water is becoming increasingly scarce will remain a stumbling block to agroforestry expansion (see chapter 2). On the other hand, greater harvesting of recycled water, including greywater, may provide an opportunity for use in more innovative agroforestry operations, such as plantation pinyon pine nut production, in this region.

Key Information Needs

- Create an understanding of tree/forage/grazing interactions to develop silvopasture management options that reliably provide sustained and profitable operations in the various situations in which they can be placed in the Southwest.
- Identify climate change impacts on the dynamics and composition of woody and herbaceous plants to determine how sustainable agroforestry production systems will be in the Southwest under projected conditions.
- Identify pollinator populations and habitat requirements for these species in this region to provide planning and design criteria to establish the most effective agroforestry plantings for pollinators.
- Initiate markets and program support for agroforestry endeavors to develop sustainable levels of operations for producers.

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