AN ECOSYSTEM MANAGEMENT STRATEGY FOR THE SYCAMORE CREEK WATERSHED IN SOUTH-CENTRAL ARIZONA

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The Sycamore Canyon watershed—a diverse, hilly ecosystem in the Pajarito and Atascosa mountains of south-central Arizona bordering Sonora, Mexico—is a perfect example of the USDA Forest Service theme, "Land of Many Uses." Unfortunately, many of these uses conflict and compete with each other for the same limited resources. Activities and designations on this 63 km^2 watershed include grazing of domestic animals, wildlife habitat, recreation, mining, roads, a research natural area, and a wilderness area. Alone and combined, some of these activities may cause soil erosion, channel silting, and the loss of habitat for rare riparian plants, amphibians, and aquatic species such as the Goodding's ash (*Fraxinus gooddingii*), the Tarahumara frog (*Rana tarahumara*), and the Sonora chub (*Gila ditaenia*). The Tarahumara frog has disappeared from the United States and the Sonora chub is state listed as endangered (Arizona Game and Fish Department 1988) and federally listed as threatened (U.S. Fish and Wildlife Service 1986).

The watershed has two distinct vegetation zones that separate near Hank and Yank Spring (Figure 1). The upper watershed ranges from 1,220 m to 1,667 m above sea level. The vegetation cover varies from oak woodland to oak grassland. Below the spring the watershed follows a narrow canyon almost to the Mexico border, where the elevation is 1,035 m. The vegetation on the lower watershed is mesquite grassland-Sonoran desert scrub ectone (Toolin et al. 1979). Sycamore Creek flows primarily in response to rainfall events, except in the lower watershed where it flows perennially in places to the Mexico border. There the canyon widens and the stream sinks into deep alluvial soils. The annual average precipitation in the area is 440 mm, recorded at the Nogales weather station. The annual mean temperature is about 24.7°C, ranging from 41°C in the summer to -13° C in the winter (Sellers et al. 1985).

The characteristics of the watershed that make it a focal point of human activity include its close proximity to the large metropolitan centers of Tucson and Nogales, a moderate climate, protected canyons with slick rock chutes and totem pole spires of rhyolite, and its intermittent water supply that supports a diversity of rare and sensitive riparian species unmatched within the Coronado National Forest, and perhaps throughout the southwestern United States. The flora of Sycamore Canyon includes 624 species of vascular plants, 20 species of lichens, and 40 species of mosses (Toolin et al. 1979). Today, at least 10 sensitive plants within the canyon are candidates for federal listing, including *Agave parviflora*, *Dalea tentaculodies*, and *Fraxinus gooddingii* (Warren 1993). Toolin et al. (1979) reported that Sycamore Canyon is the northern terminus for several Mexican plant species (e.g., *Henrya brevifolia*, *Acacia smallii*, and *Psoralea pentaphylla*) and at the same time is the southern limit in the range of some northern/montane species (e.g. *Amelanchier utahensis*, *Berberis wilcoxii*, and *Philadelphus microphyllus*). Bird watchers from across the country visit Sycamore Canyon to see five-striped sparrow (*Aimophila quinquestriata*), elegant trogon (*Trogon elegans*), and other rare species. The canyon also supports whiptail lizards (*Cnemidophorus burti* and *C. sonorae*), which are found only in southern Arizona (Peterson 1961, Stebbins 1987, Warren 1993). Sycamore and nearby Peñasco creeks are the only known waters with Sonora chub in the U.S. (Arizona Game and Fish Department 1988).

People are attracted to the watershed for its unique nature. Unfortunately, many of those that use the watershed add to its deterioration by hiking, driving, and camping outside designated areas. Other activities such as grazing and mining cause channel siltation and pollution of

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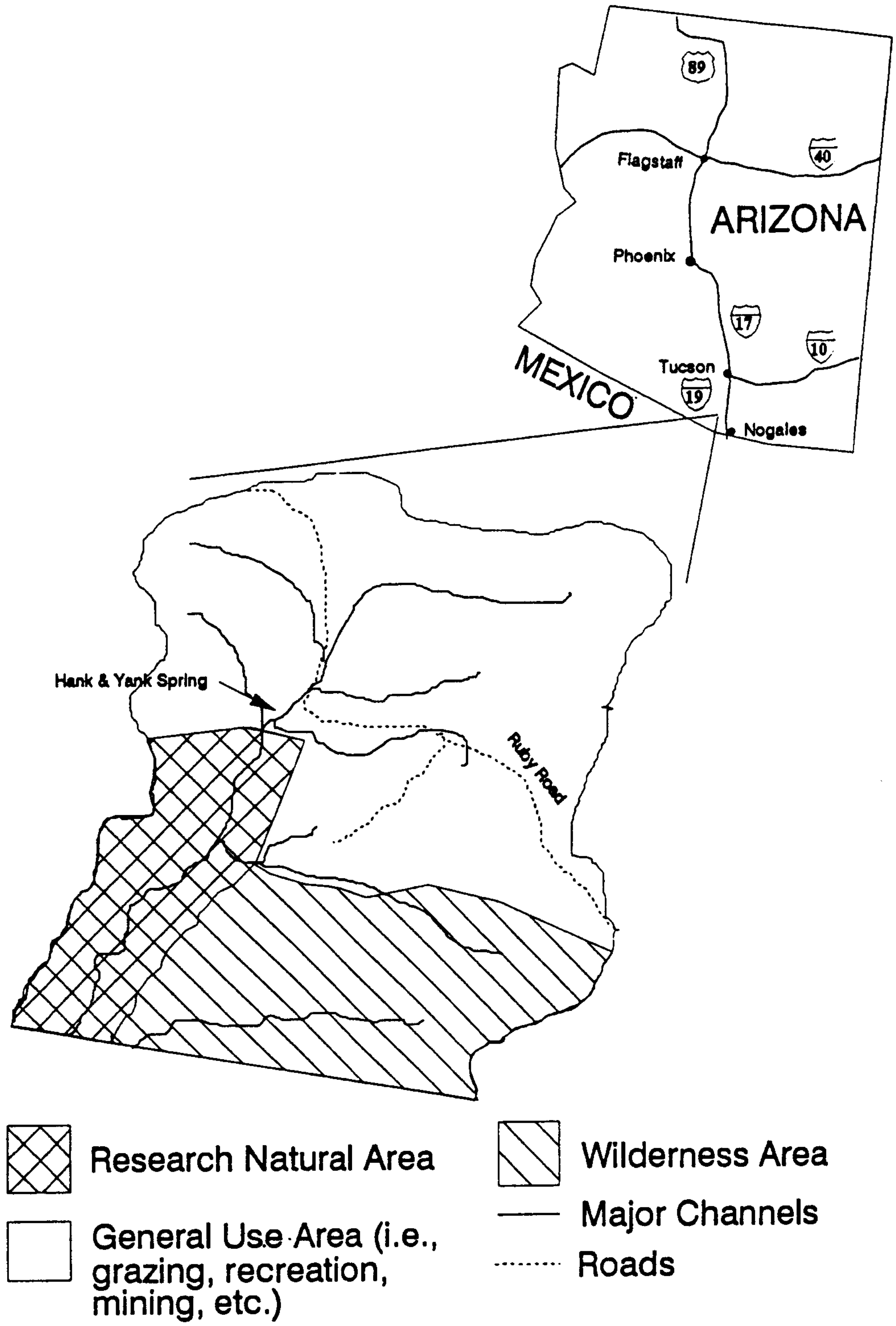

Figure 1. Location of Sycamore Canyon watershed.

aquatic habitats when practiced too close to channels and riparian areas. In view of the high potential for users to adversely affect this sensitive and unique ecosystem, the USDA Forest Service Nogales Ranger District needs to implement an ecosystem management strategy to protect the habitats of rare and sensitive plants, birds, and animals, and still permit ranchers, recreationalists, and others to enjoy the Sycamore Canyon watershed.

Background

In 1992 Dale Robertson, then chief of the USDA Forest Service, directed the agency to manage all forests and rangelands by "ecosystem management" (Gerlach and Bengston 1994). Under this policy, the Forest Service was to manage by a concept of "ecosystem sustainability" described as "the ability to sustain diversity, productivity, resilience to stress, health, renewability, and/or yields of desired values, resource uses, products, or services from an ecosystem while maintaining the integrity of the ecosystem over time" (Bormann et al. 1994).

There are many concepts, ideas, and definitions of ecosystem management (Jensen and Bourgeron 1994; Kaufmann et al. 1994; Salwasser 1994; Gerlach and Bengston 1994). On February 10, 1995, the chief of the USDA Forest Service, Jack Ward Thomas, informed the Forest Service community that he had appointed a policy team and charged them to "come up with definitive recommendations on how the federal government can take the lead in ecosystem management given its current resources" (Thomas 1995). In this paper, the following ecosystem definitions of Borman et al. (1994) are used:

Ecosystem management is a system of making, implementing, and evaluating decisions based on the ecosystems approach, which recognizes that ecosystems and society are always changing.

Ecosystem approach is a "system" in ecosystem that embodies three fundamental concepts: designating the physical boundary of the system and its parts, understanding the interactions of the parts as a functioning whole, and understanding the relation between the system and its context. Context means both the external factors that influence the system and also internal information that must be synthesized to be understood at the scale of the defined system.

Ecosystem sustainability is the degree of overlap between what people collectively want—reflecting social values and economic concerns—and what is ecologically possible in the long term (Figure 2). The overlap is dynamic because societal values and ecological capacity continually change. The desires of future generations can be protected by maintaining options for unexpected future ecosystem goods, services, and states.

Numerous ecosystem management efforts are in progress around the United States even as the USDA Forest Service team works to come up with definitive recommendations (Jensen and Bourgeron 1994; Richardson 1994; USDA Forest Service 1992). One example of a successful effort is on the Hoosier National Forest, where managers from the forest and researchers from the North Central Experiment Station developed a GIS-based harvest allocation model enabling managers to assess harvest strategies on forest structure and bird populations as far as 150 years into the future (USDA Forest Service 1995). Another example is on the Ouachita National Forest, where forest managers and researchers from the Southern and Southeast Experiment Stations are working to develop ecologically viable silvicultural techniques for regeneration of shortleaf pine/hardwood forests incorporating public involvement in the planning and decision-making process (USDA Forest Service 1995b).

Each ecosystem management effort differs in management objectives but the challenges that they must overcome are similar: (1) coordination across established administrative borders, institutional cultures, and other differences; (2) coordination across time horizons different from and longer than those of conventional decision making; (3) holistic coordination of solutions to reduce the likelihood that solutions to one problem will cause new problems; (4) decisions based on ambiguous and uncertain information; (5) public support and participation; (6) changes in rights and duties regarding natural resources; (7) fair distribution of costs and benefits of natural resource use; (8) sustainable development; (9) institutionalization of interdependence democratically; (10) conflict management; and (11) integration of human and biophysical factors (Gerlach and Bengston 1994).

Currently, Forest Service land managers develop and implement management practices

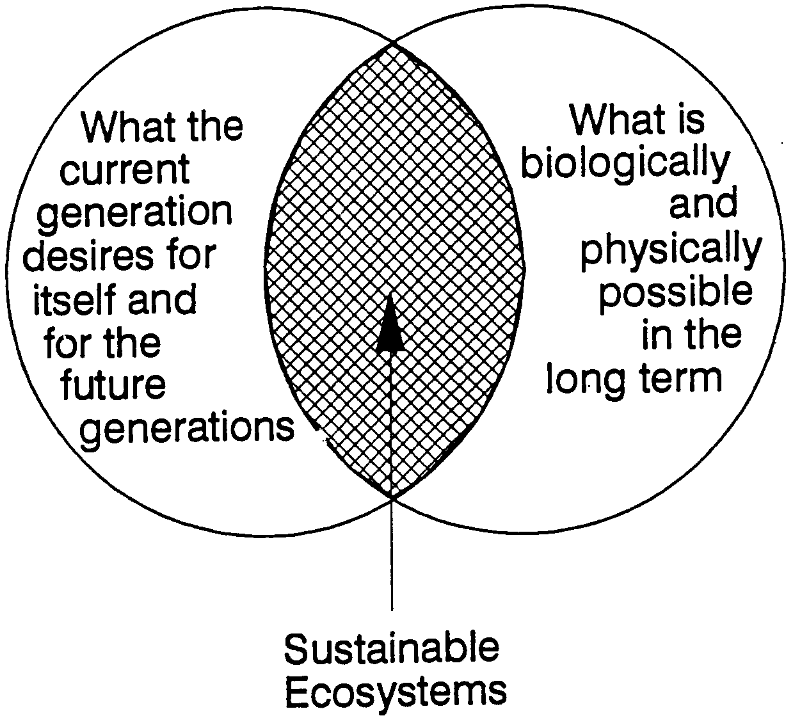

Figure 2. The elements of ecosystem sustainability (from Bormann et al. 1994).

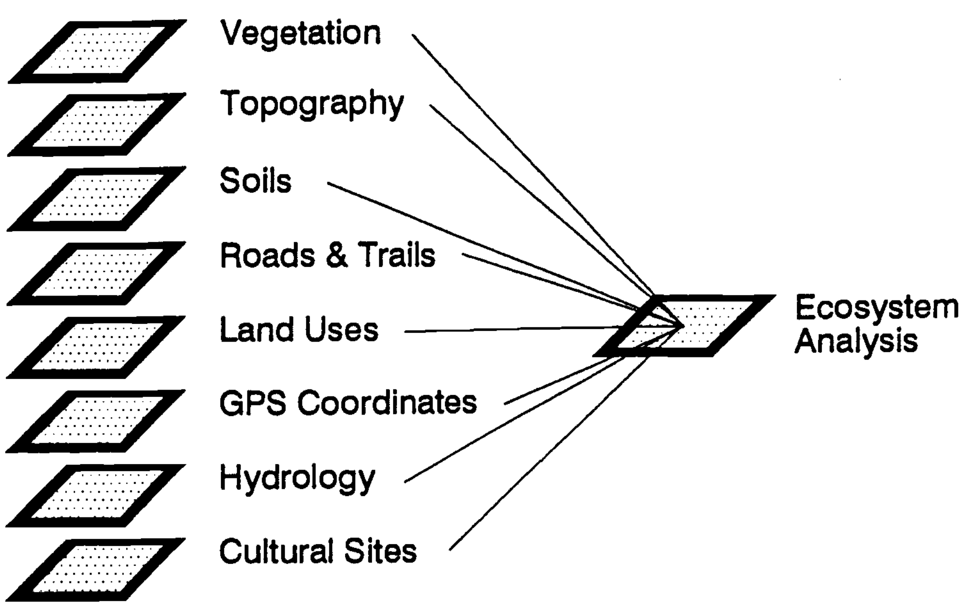

Figure 3. GIS elements of an ecosystem management analysis.

to provide sustainable opportunities including recreation, timber, research, and grazing for forest users while protecting the natural resources of watersheds. Practices and policies are often developed in conjunction with the United States Fish and Wildlife Service, the Bureau of Land Management, the Nature Conservancy, and other federal, state and private agencies, with some public participation and review.

Ecosystem management plan development, review, and updates include collection, analysis, and presentation of large data sets, reports, maps, slides, and videos. This process incorporates all the players of the traditional management plan development process, except now they will be called on to be more active participants. Depending on the project, this process can take weeks, months, or years to complete. Often times, duplication of previous data entry, reports, and manually produced work will take place. Finally, a thorough objective review of the finished product can be overwhelming, if not impossible, simply because of the quantities of materials produced.

Geographical information systems (GISs) can accelerate and clarify, through visualization, ecosystem management plan development, review, implementation, tracking, and updating. A GIS is a computer-based software program that allows aerial photos, topographic maps, text, satellite images, global positioning satellite (GPS) coordinates and other forms of data to be organized, analyzed, stored, and presented in graphical formats to help managers, decision makers, and other interested parties understand how ecosystem parameters and management options interact (McLean 1995; Naiman and Decamps 1991; USDA Forest Service 1994). Past, current, and projected data (soils, vegetation, topography, land uses, wildlife habitat, and climatic conditions) can be incorporated to create data layers that are used to make composite images and data summaries that display the interactions between ecosystem parameters (Figure 3). Image combinations are only limited by having the information needed to make informed decisions, cost, and the number of layers that can be interpreted and presented clearly together (McLean 1995).

Plan Development and Implementation

The Sycamore Canyon watershed offers an excellent opportunity for the Coronado National Forest to develop and implement an ecosystem management plan in an area where needed. Located 40 km west of Nogales and 93 km south Tucson with a regional population in excess of one million people, the area has the potential to be irreversibly degraded, leading to the loss of many rare and sensitive species, if an ecosystem management strategy is not implemented soon. Current land uses and designations are summarized in Figure 1.

The development and implementation of a GIS-based ecosystem management strategy for Sycamore Canyon watershed by the Nogales Ranger District (NRD) will require district personnel to pool their efforts and resources. Wildlife biologists, hydrologists, range conservationists, forest engineers, soil scientists, recreation specialists, and others will need to provide the data and information for and help create GIS data layers in their areas of expertise. The Forest resource staff has and/or collects much of the information required to develop the basic data layers of a GIS-based ecosystem management system (USDA Personal Communications 1994; Goldman 1993). These data and information include soils, vegetation, roads, infrastructure, land uses, topography, land ownership, cultural resources, and grazing allotment management plans. There have also been a number of studies and reports done on different aspects of the watershed vegetation (Toolin et al. 1979), aquatic habitats (Carpenter 1992, 1993), and geology (Riggs 1985) that can provide valuable information. Some of the information required to create data layers or completed layers may be available to the Forest from other agencies, such as the distribution of rare species from the Arizona Game and Fish Department, topography and geology from the U.S. Geological Survey, land ownership and resources information from the Arizona Land Department, and the distribution of riparian habitats from the Arizona Department of Water Resources. The public should also be considered in this process, so that their needs, desires, contributions, and influences on the Sycamore Creek ecosystem can be taken into account.

A GIS administrator (applications programmer and/or database specialist) should be designated to work with resource managers to ensure that data are collected, formatted, and stored on the computer system in appropriate formats for maximum use. In addition, the system administrator must work with the resource teams to understand the types of information (composite maps, data summaries, etc.) needed to make their management decisions, and then to develop applications (macros) to query the GIS databases for this information. The resource management teams and the system administrator should collectively determine the look and feel of the GIS user-interface so that everyone is familiar and comfortable with the system. It should always be kept in mind that the GIS is a tool that is only as good as the data put into it and the macros created to analyze, combine, and extract information from the databases.

Composite images, data conversions and summaries, and other GIS outputs can help the Nogales Ranger District resource managers more effectively identify opportunities and locations of potential land use conflicts, soil erosion, non-point source pollution, recreation, habitat protection, and infrastructure. Depending on the data available, past, present, and future site comparisons and projections can be made, allowing resource managers to compare potential outcomes of their management recommendations in advance. An application that Forest personnel have already recognized as a time-saving use of GIS is locating roads, trails, recreation areas, range improvement sites, and OHV loading/off-loading sites (Goldman 1993). The system could be queried for potential sites based on user specified criteria (e.g., access, slopes, ownership, and proximity to rare and sensitive species and other selected resources). The outputs from the query could include maps showing potential locations, acreage summaries, current uses, and site conditions. Another application of the system is locating the sources of sediments that are silting in sections of the Sycamore Creek channel, near the Ruby Road crossing (Figure 1). In this case the output could be a composite map of the channel sections in question, soils, topography, and land uses. A general but effective use of the system would be easy storage, access, and updating of all forest resource information including mining claims, grazing allotments, archaeological sites, and other special use areas.

The hardware and software needed to develop and operate a GIS-based ecosystem management system will depend on the degree to which the forest elects to become involved. A basic system could be developed and implemented on a personal computer (PC) with a 486/66 or better computer chip, 8 megabytes of RAM (random access memory), and a 500-megabyte hard drive for general storage. Peripherals should include a color printer and a digitizer. Hardware purchases should be considered only after deciding upon the GIS software to be used for the project. There are numerous sources of hardware, software, and system development information (McLean 1995; USDA Forest Service 1994). The forest can also get recommendations from other national forests and government agencies with GIS technology in place.

Summary and Conclusions

The Sycamore Canyon watershed in south-central Arizona is a "Land of Many Uses" that conflict and compete for the same limited resources. Uses include grazing of domestic animals, wildlife habitat, recreation, mining, a research natural area, and a wilderness area. In addition, this area is home to numerous rare and sensitive riparian plants, amphibians, and aquatic species. The integration of these activities is degrading the ecosystem and causing the loss of habitat and species such as the Tarahumara frog which has disappeared from the U.S.

Ecosystem management and GIS can provide a method by which the resource managers of the NRD can manage this watershed with a holistic approach. Ecosystem management recognizes that all elements of an ecosystem are interconnected and should therefore be managed together, rather than concentrating on one theme such as aquatic habitat, grazing of domestic animals, or recreation. GIS is a computer software tool that permits image and information integration, management, analysis, and presentation through visualization. The combination of ecosystem management and GIS is very natural. Macros developed to query the GIS databases can facilitate resource managers' selection of program sites, tracking of land uses, and identification of problem sources, such as the origin of materials causing channel siltation in Sycamore Creek.

The metropolitan areas of Tucson and Nogales are rapidly expanding, and the Sycamore Canyon watershed is a focal point for recreationalists from these areas because of its close proximity and unique riparian plant, animal, and physical features. If the NRD is going to protect and preserve the habitat for rare and sensitive species of this ecosystem into the future, a GIS-based ecosystem management strategy should be developed and implemented now, before more species are lost.

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