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Land suitability analysis for the upper Gila River watershed

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Abstract

In the United States, federal management agencies, such as the U.S. Forest Service and the U.S. Bureau of Land Management are required to assess the capability of land for future use. In addition, Arizona law now requires local jurisdictions to prepare comprehensive and general plans. Suitability analysis can be used for compliance with several elements of these plans. Here, a framework for land suitability analysis is presented for the upper Gila River watershed in Arizona and New Mexico. The framework is based on a thorough ecological inventory of the watershed. A goal of suitability analysis is to explicitly identify constraints and opportunities for future land conservation and development. This is accomplished by determining the fitness of a given tract of land for a defined use. Four land uses were targeted by local officials for analysis: low-density housing, commercial development, industrial development, and recreation. The framework can be useful for natural resource management as well as town, city, county, and federal planning in the watershed.

Keywords: Suitability analysis; Watershed planning; Gila River; Arizona; New Mexico

1. Introduction

Efficient and thoughtful use of land is an important step in managing and developing any area, especially one as vast as that of the upper Gila River watershed in Arizona and New Mexico. Much of the land in this watershed is managed by federal agencies including the U.S. Forest Service and the U.S. Bureau of Land Management. These agencies are required to assess the suitability of land and other resources under their jurisdiction for future possible uses. In addition, the State of Arizona affords an opportunity to develop sound planning at a large scale in response to the citizen-mandated *Growing Smarter Initiative*. This 1998 law proposes to "strengthen the ability of Arizona's communities to plan for growth, acquire and preserve open space, and develop strategies to comprehensively address growth-related pressures" (Arizona Department of Commerce, 1998a, b). As a result, Arizona counties and cities are now required to prepare general and comprehensive plans that incorporate numerous elements including an analysis of future needs and policies for open space, coordinated growth, and future development strategies.

These statewide policies take a broad regional perspective, but also examine a more narrow focus within the constraints of counties, cities, and towns. By implementing such a comprehensive planning vision, it is hoped that effects will be seen in various urban and rural communities throughout the state. In order to determine the most desirable direction for future development, the suitability for various land

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uses should be explored in order to direct growth to the most appropriate places.

One approach to establishing appropriate land-use criteria is the construction of suitability analyses. Land suitability analysis is the process of determining the fitness of a given tract of land for a defined use (Hopkins, 1977; Steiner, 1983). Initially, this tool was developed as a means for planners to relate spatially independent factors within the environment and, consequently, provide a more holistic view of their interactions. Suitability analysis techniques integrate three factors of an area: location, development activities, and biophysical/environmental processes (Miller et al., 1998). These techniques enable planners and local decision-makers to analyze interactions in various ways. Such analysis can help elected officials and land managers make decisions and establish policies regarding the use of particular areas of land.

Even though land suitability analysis is a well-known tool among planners and landscape architects, there are relatively few documented examples where a process used in one place has been transferred or adapted in another. (The few examples include the work of McHarg, 1969 and Lyle, 1985). This paper provides such an example, as will be explained in Section 3.

Suitability techniques are essential for informed decision-making. The most important decision an analyst makes when using this tool is the determination of how relative values, or weights, are to be given to two or more combined factors. *Factors* are simply characteristics of land that are grouped as attributes (Pease and Coughlin, 1996). Slope, soil type, aquifer recharge areas, floodplains, scenic areas, and wildlife habitats are examples of such factors. Once chosen, factors are weighted; that is, they are given a numeric value that indicates their relative importance in determining the suitability of an activity in a given area. Although these judgements introduce an element of subjectivity to the analysis, weights are based on sound factual information for what the land is or is not intrinsically capable of supporting. Because these values are explicit to the given area and represent economic, environmental, and public health dimensions, weighting tries to represent the interplay among factors in a landscape.

Since watersheds consist of essential natural resources, their planning requires forethought and careful consideration. A watershed-scale suitability analysis can help local officials and private businesses avoid unnecessary expenditures while protecting valuable environmental amenities.

2. Upper Gila River watershed

The upper Gila River watershed is an area characterized by fertile valleys, mountainous terrain, and an important waterway, the Gila River (Cohen et al., 1997). The watershed basin created by the river encompasses over 62,160 km^2 and includes portions of both Arizona and New Mexico. The watershed begins ≈321 km east of Phoenix, AZ, and ≈483 km west of Santa Fe, NM. The Fort Apache and San Carlos Indian Reservations determine the western boundary for the upper watershed while the eastern boundary is determined by the Gila National Forest. Alpine, AZ, indicates the northern boundary, while the Chiricahua Mountains of Arizona and New Mexico determine the southern boundary (Fig. 1). With such a large expanse, the upper Gila River valley is a major drainage system in the Southwest.

The Gila River flows east to west from its headwaters in the Mogollon Mountains of New Mexico. The river continues across southern Arizona to Yuma where it joins the Colorado River, which eventually discharges into the Gulf of California (Fig. 2). The Gila River and some of its tributaries are perennial with flows originating from snow-packed peaks. As the river descends into the desert valley, sediment and salinity increase. This process is typical of southwestern deserts and their environs. Additionally, the primary underground sources of water are derived from an alluvial aquifer and a saline basin fill aquifer. This water is used for industrial, agricultural, and municipal demands. Diversions for these uses present complex resource management scenarios within the watershed region.

The watershed consists of rugged mountain ranges, broad intermountain plains, and flat, gentle valleys. The elevation of the area ranges from 793 to 3355 m above sea level. Historically, this region has supported various human populations over time. Numerous Native American communities have occupied areas in the watershed from as early as A.D. 400 to present day (Cohen et al., 1997). In the early sixteenth century,

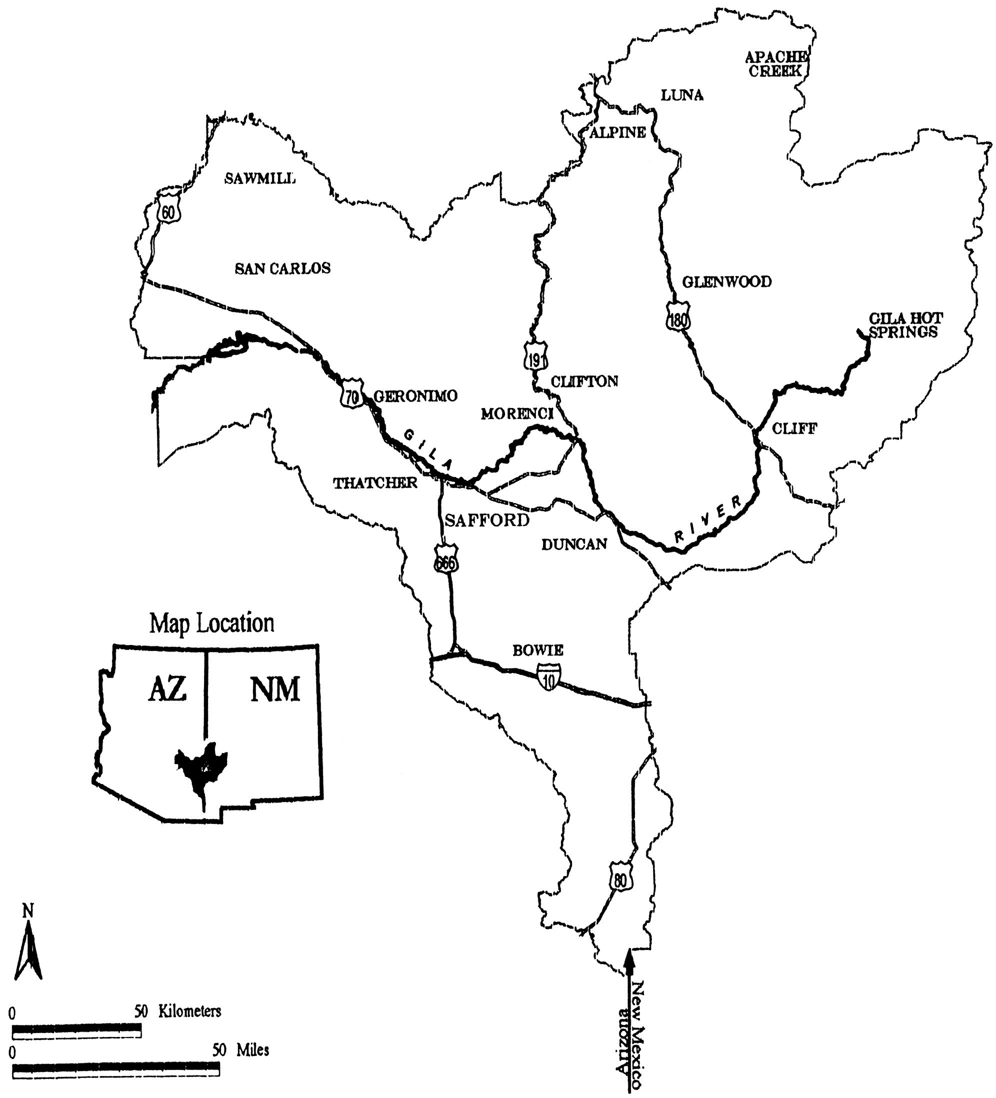

Fig. 1. Location of the upper Gila watershed.

the Spanish explored the Gila River and its valleys. Fur traders found an abundance of animals in the area. By the late nineteenth century, the Mormons began settling in the upper Gila River valley. Their advanced knowledge of building construction and town planning left an imprint on future cultural developments. The abundance of natural resources allowed these populations to prosper.

Several population concentrations exist along the primary river channels such as the Gila River, San Francisco River, and Safford Basin. The upper watershed encompasses 10 counties in both Arizona and New Mexico. Throughout the predominantly rural area are several towns and communities including Safford, Clifton, Thatcher, Morenci, and Duncan. Safford is the largest urban center with over 20,000 people and a projected growth rate of over 90% in the next 50 years (Cohen et al., 1997). The overall population in the upper portion of the watershed is currently ≈94,000 people.

Many of the towns within the region have thrived by utilizing its natural resources. Over time, agriculture

Fig. 2. Gila River.

increased to become the main economic support for the population, yet mining, logging, and recreation have also prospered in the upper Gila River watershed. Cotton has been a leading cash crop in the region since the Second World War and copper mining has occurred since the late nineteenth century. Recreation and conservation have been a consideration in the area. Much of the Gila National Forest is designated as wilderness and corridors along the Gila River have been established as riparian conservation areas. The diversity of the region's natural characteristics affords numerous opportunities for a variety of activities. Using suitability analysis as a tool, a blend of both socio-economic and ecological data can be integrated into local and agency land management plans for the upper Gila River watershed.

3. Methods

Developing an overall suitability analysis for a region as large as the upper Gila River watershed would be problematic if not unrealistic. In response, the project team designed a framework for suitability analysis for four specific land uses. As determined by members of the San Carlos/Safford/Duncan Non-Point Source Management Committee, the following land uses were examined: low-density housing, commercial development, industrial development, and recreation.

A previous analysis was conducted for Asotin County in the southeastern region of Washington bordering Idaho and Oregon (Beach et al., 1978). The rural Asotin County area is similar to the upper

Gila River watershed and was deemed transferable for modeling and analysis. Factors for the analysis were derived from a comprehensive ecological inventory of the upper Gila River watershed (Cohen et al., 1997).

The suitability analysis identified factors of primary and secondary suitability, as well as factors believed to be unsuitable for certain land uses. According to the parameters of the model, an area of primary suitability is ''one with no limitations or hazards to use'' (Beach et al., 1978). An area of secondary suitability has one or more factors that may affect future development and would require measurements to be taken in order to reduce potential problems and/or costs. Unsuitable areas are those that have severe limitations that inhibit or prohibit a particular land use.

The intended use of the Asotin (as well as the upper Gila River watershed) suitability analysis was as a tool to preserve ''prime agricultural and recreational lands, form bases for comprehensive plans, protect sensitive areas, and direct future development in such a way as to minimize environmental impacts and maximize economic and aesthetic gains'' (Beach et al., 1978). In addition to the opportunities revealed by the ecological inventory, constraints associated with land areas and land uses were also evaluated.

A basic premise of suitability analysis is that logical frameworks for considering the many opportunities and constraints for various land uses can be applied to diverse places. Landscapes differ, as do the values of people who inhabit them. However, some facts remain the same: floodplains are dangerous places to live, some soils are more productive for agriculture than others, certain areas are more costly to build upon than others, certain habitats are more valuable for wildlife than others, and so on. To test this thesis, a suitability analysis developed for one landscape was applied to another. Both Asotin County, Washington and the upper Gila River watershed in Arizona and New Mexico are large, mostly rural areas. Both face modest development pressures and have relatively few good areas to build upon. Both have significant amounts of valuable farmland and large tracts of federal lands.

In both suitability studies, a series of matrices were used. Each matrix is comprised of two groups of factors plotted against each other in a rectangular format. The three types of matrices were as follows.

3.1. Land use/land-use needs matrix

This matrix plots relationships between possible land uses and their needs. Land-use needs include all factors, both necessary and desirable, that will affect any of the possible uses. In the matrix, a solid square is indicative of a particular need required for a given land use. Needs represent values that are determined by social preferences and economic costs. If no solid square appears, a land use and land-use need are not related (Fig. 3).

3.2. Factors/land-use needs matrix

This matrix examines relationships between general factors (such as hydrology) and land-use needs. If a land-use need is affected by or dependent upon a factor, then a solid square appears. Again, an area with no solid square indicates the absence of significant relationships (Fig. 4). Both opportunities and constraints for various land uses were considered.

Constraints exist in environmentally sensitive areas where development poses a danger to human health or safety or where rare, endangered, or threatened species can be negatively impacted. Historic and archaeologically valuable sites can also present constraints to certain land uses. Constraints are described as those phenomena which are: (1) inherently hazardous to human life and property; (2) hazardous to human life and health by specific human action; (3) irreplaceably unique and scarce resources; and/or (4) vulnerable resources where unregulated utilization will result in social costs (Juneja, 1974).

There are several constraints placed on the development of lands in the upper Gila River watershed. These constraints include the designation by federal, state, and local agencies of areas of limited or restricted development. These designations include environmentally sensitive areas (such as the Gila Box Riparian Conservation Area), historic sites, and wilderness regions in the U.S. Forest Service lands. Many of these designated areas contain elements that have significant aesthetic, recreational, or historic value. Management of these areas requires co-operative planning since there are many agencies involved.

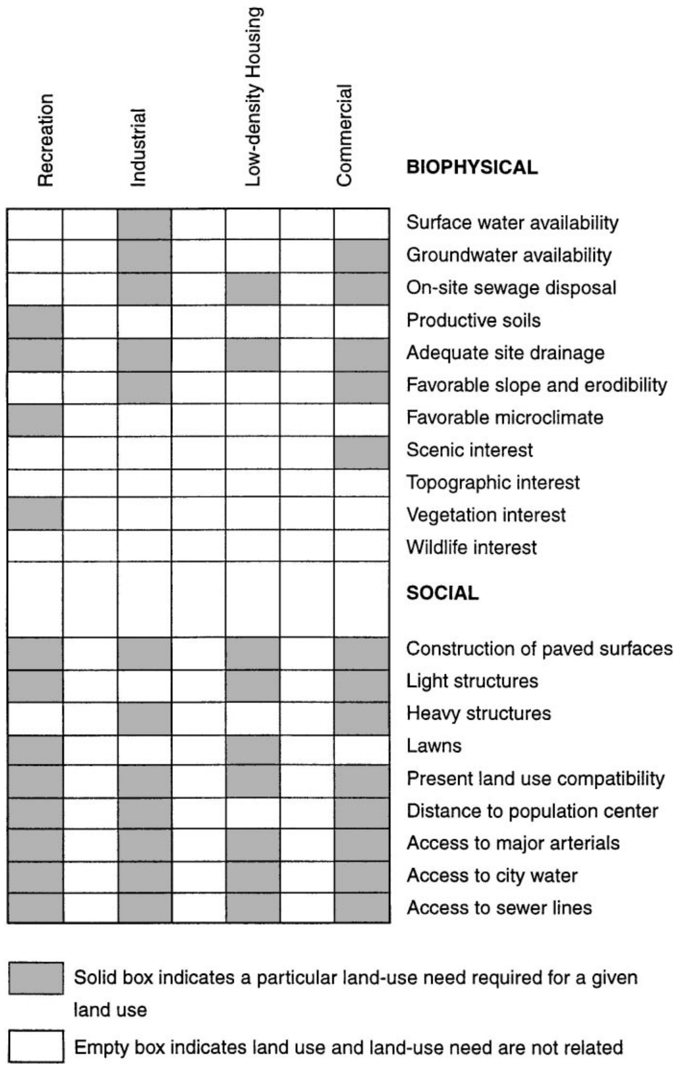

Fig. 3. Land use/Land-use needs.

3.3. Specific factors/land-use needs matrix

For each of the four land-use categories assessed, a suitability matrix was generated based on the information from the previous two matrix types. Land-use needs were plotted against specific factors (such as slope or soil type). Both suitable and unsuitable relationships are shown in the matrices. Suitable relationships (solid squares) are those that have a specific factor compatible with a land-use need. Unsuitable relationships (half solid squares) are those in which the specific factor and the land-use need are incompatible (for example, when a specific factor is not capable of supporting the land-use need and/or the land-use need has an adverse effect on that phenomenon). Areas with empty squares imply the absence of a relationship, either positive or negative. Each suitability matrix is a compilation of the suitable and unsuitable relationships between specific factors and land-use needs (Figs. 5–8). These matrices help

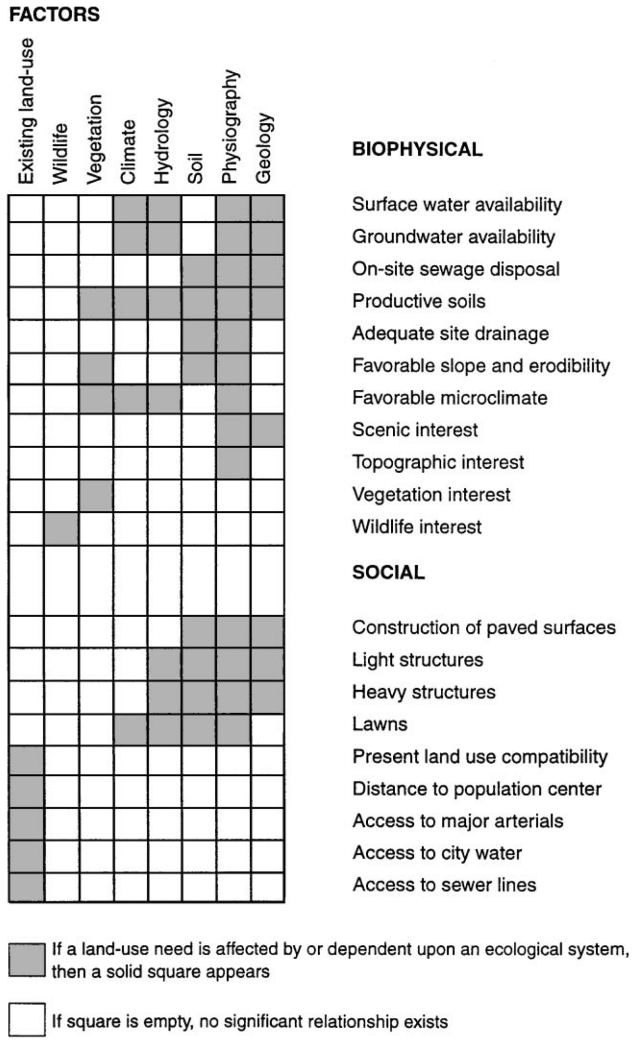

Fig. 4. General factors/land-use needs.

identify desirable areas, or opportunities, for specific land uses. Constraints to development also need to be considered.

Several constraints are imposed due to physical or biological limitations or areas that would be cost-prohibitive for development. Costs include those incurred by private individuals or companies, governments, and/or the public. One constraint is posed by slopes exceeding 25% where soils can be highly erodible. These slopes can be detrimental to sound structural development. In addition, high drainage areas may inhibit the needs of on-site sewage disposal or adequate site drainage. High erosion potential areas can be incompatible with suburban, commercial, or industrial development and can be hindered by the building of structures necessary for intensive recreational purposes. Unique geological features (such as the Gila River channel) can provide an area with identity, but can also be incompatible with some types of development.

Finally, consideration for open space and areas of abundant and sensitive flora and fauna (such as the Gila chub, peregrine falcon, and lowland leopard frog) will also place constraints on development. It should be emphasized that while these guidelines may restrict several areas within the region, they do not eliminate

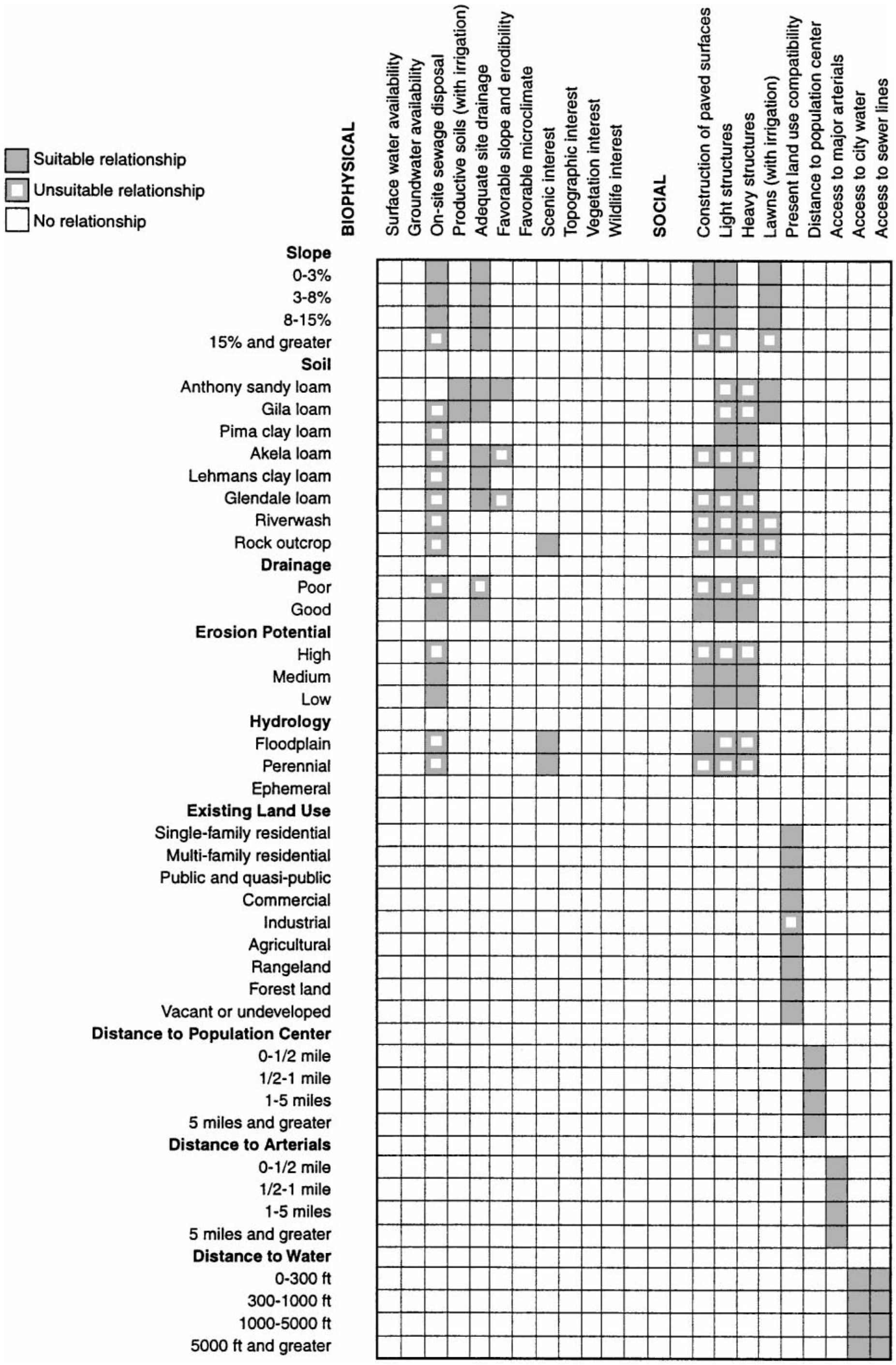

Fig. 5. Low-density housing suitability analysis.

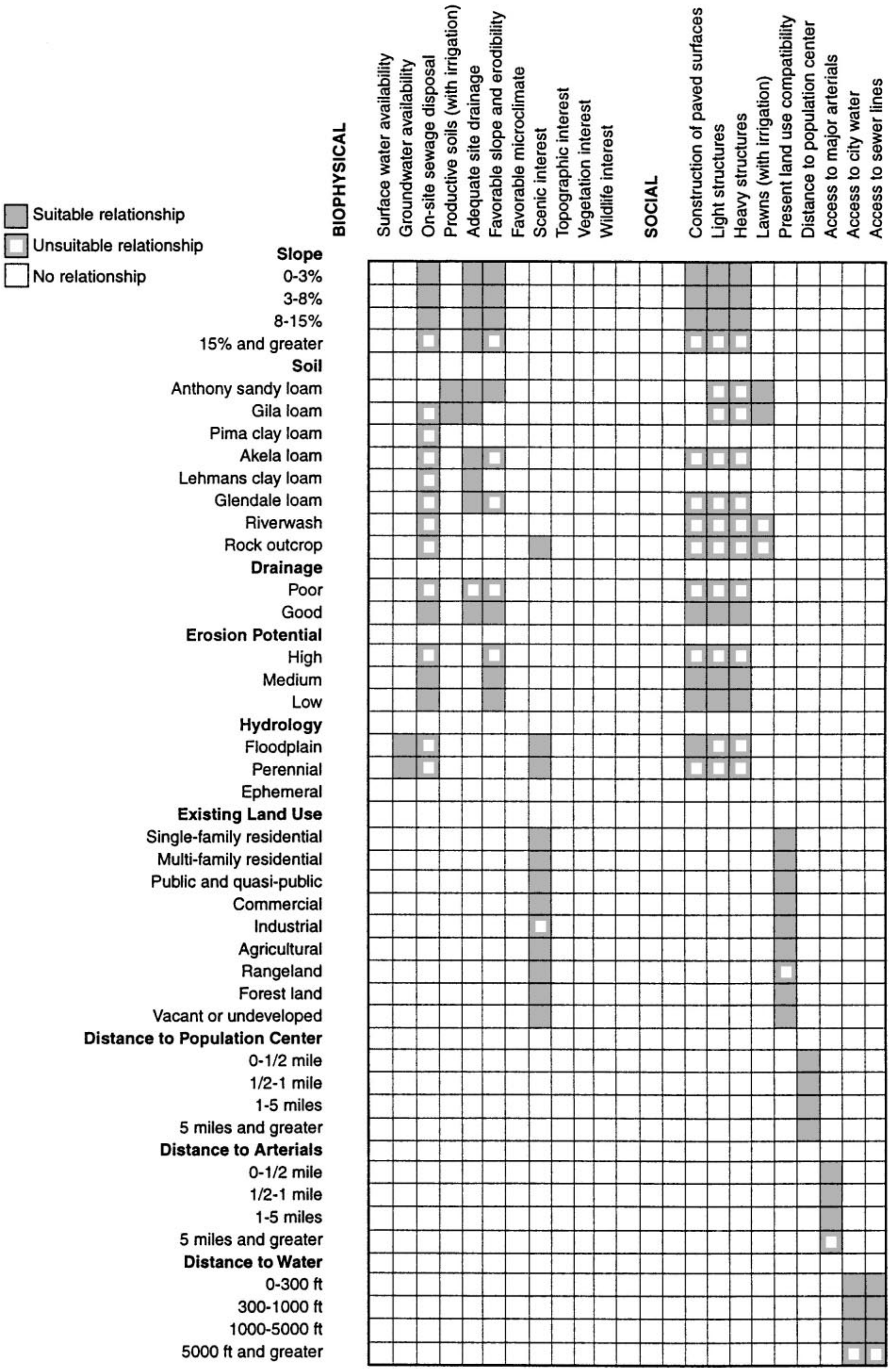

Fig. 6. Commercial development suitability analysis.

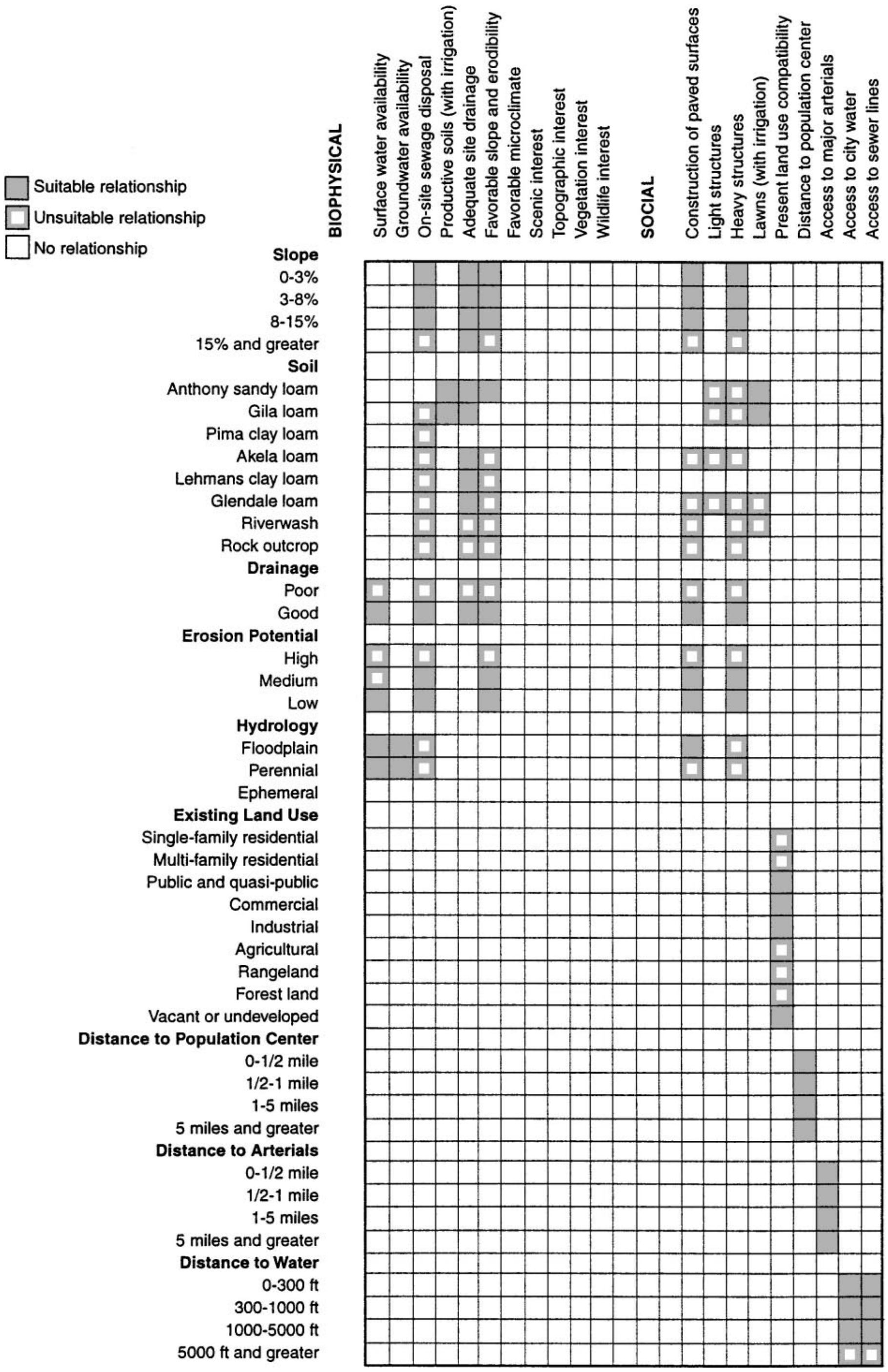

Fig. 7. Industrial development suitability analysis.

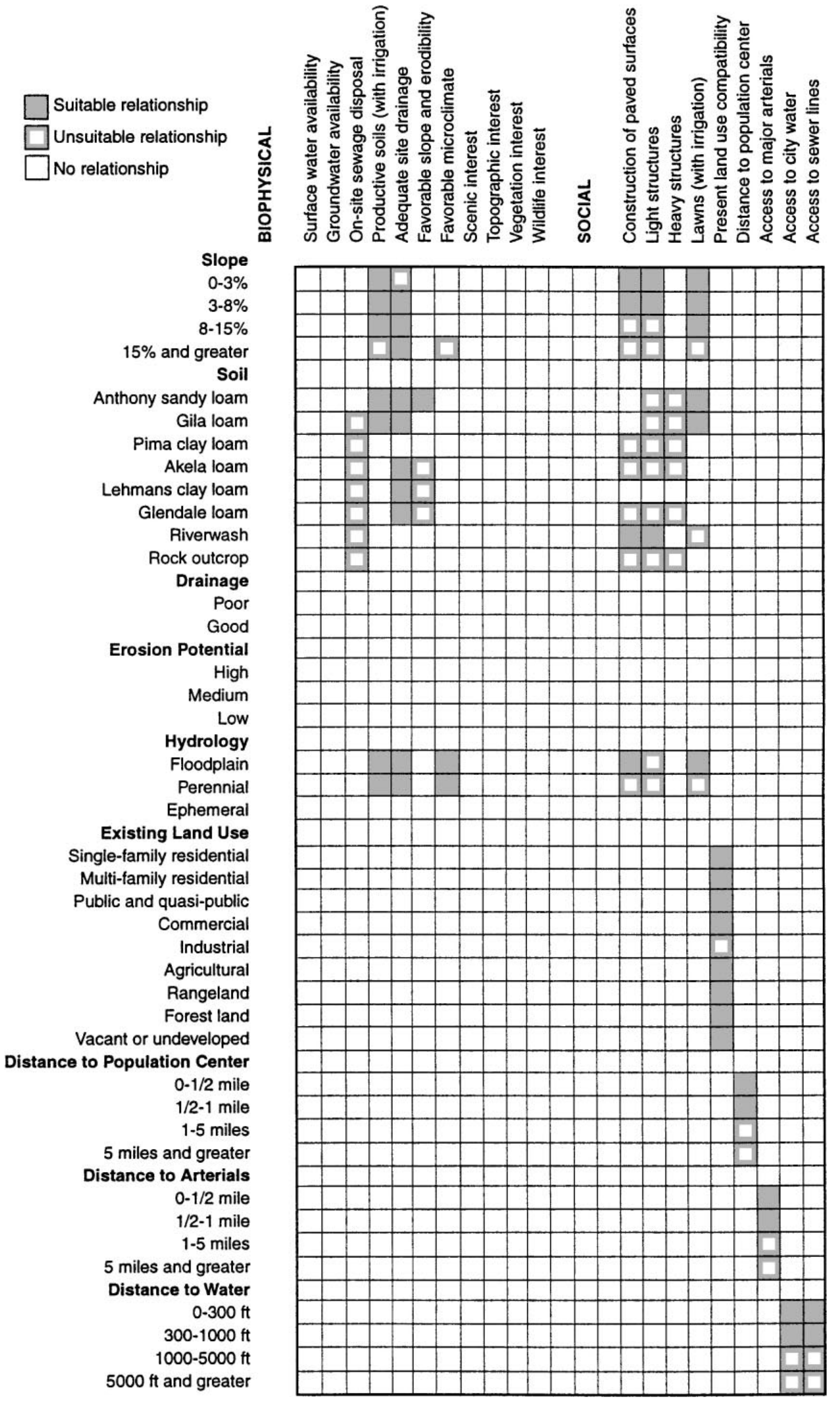

Fig. 8. Recreation suitability analysis.

Factor	1 = least desirable 10 = most desirable	Recreation	Industrial	Commercial	Low-density Housing
Slope	0-3%	1	9	10	10
	3-8%	1	8	9	7
	8-15%	7	8	5	5
	15% and greater	10	1	3	1
Soil	Anthony sandy loam	4	7	1	1
	Gila loam	4	7	1	1
	Pima clay loam	4	4	4	4
	Akela loam	1	1	1	1
	Lehmans clay loam	1	1	1	1
	Glendale loam	4	4	4	4
	Riverwash	8	1	1	1
	Rock outcrop	1	5	1	1
Drainage	Poor	5	1	1	1
	Good	5	10	10	10
Erosion Potential	High	1	1	1	1
	Medium	5	1	1	5
	Low	10	10	10	10
Hydrology	Floodplain	5	1	1	1
	Perennial	5	1	1	5
	Ephemeral	5	10	10	10
Existing land use	Single-family residential	1	1	1	10
	Multi-family residential	1	1	5	5
	Public and quasi-public	10	10	3	1
	Commercial	1	10	10	3
	Industrial	1	10	5	1
	Agricultural	1	5	3	5
	Rangeland	1	5	1	5
	Forest land	5	1	1	1
	Vacant or undeveloped	10	10	5	7
Distance to Population	0-1/2 mile	1	5	10	10
	1/2-1 mile	1	5	9	7
	1-5 miles	5	5	1	5
	5 miles and greater	10	5	1	3
Distance to arterials	0-1/2 mile	1	5	10	10
	1/2-1 mile	1	5	9	7
	1-5 miles	5	5	1	5
	5 miles and greater	6	5	1	3
Distance to water	0-300 ft	5	10	10	10
	300-1000 ft	5	9	9	7
	1000-5000 ft	5	8	8	5
	5000 ft and greater	5	7	7	3
Biophysical	Surface water availability	10	1	1	3
	Groundwater availability	5	5	1	5
	On-site sewage disposal	1	5	7	5
	Productive soils	1	1	1	5
	Adequate site drainage	5	10	10	10
	Favorable slope and erodibility	10	10	10	10
	Favorable microclimate	10	1	3	3
	Scenic interest	10	1	3	3
	Topographic interest	10	5	1	3
	Vegetation interest	10	1	1	3
	Wildlife interest	10	1	1	3
Social	Construction of paved surfaces	3	7	10	10
	Light structures	1	1	5	10
	Heavy structures	1	10	5	1
	Present land use compatibility	10	10	10	10
	Distance to population center	3	5	10	5
	Access to major arterials	10	5	10	5
	Access to city water	1	5	10	10
	Access to sewer lines	1	5	5	7

note: soil ratings are from soil survey and expert review

Fig. 9. Factor weighting.

use completely, but require careful planning and site design.

In order to apply the necessary information into the matrices, the data were evaluated and weighted. This weighting was accomplished through expert evaluation of the given parameters. Members of the Non-Point Source Management Committee, who call themselves the 'Gila monsters', ranked the factors associated with the given specific factors and land-use needs. These assessments were based on a sound knowledge of the area and the various requirements necessary for development in each of the given categories (Fig. 9).

4. Results

The Asotin County method was adapted for the four land uses identified by the local 'Gila-monster' committee. The results of that adaptation are reported below. Initially, a map was going to be produced for each land use. However, because of the scale of the watershed and incomplete data, maps were not produced. Local officials found the framework matrices less 'prescriptive looking' and, thus, potentially more effective for their planning efforts.

4.1. Low-density housing suitability analysis

The region is rural and low-density residential land use is the prevalent development type in the upper Gila River watershed, and has been since the Apache dominated the area. The purpose of the research was not to question the wisdom of such development, but rather to help local officials locate it in safer, more cost-effective places. The dwelling units are primarily detached single-family houses with a minimum lot size of 930 m^2. This allotment produces up to five dwelling units per acre of land (Peterson et al., 1987; City of Safford, 1996). Low-density housing requires foundations for light structures and good drainage.

Land-use needs for low-density housing include:

- access to municipal sewers or on-site sewage disposal
- access to public water systems
- light structures
- construction of paved surfaces
- compatibility with existing land uses
- adequate site drainage

Natural and social factors used in the low-density housing suitability analysis include:

- slope
- flood hazard
- drainage
- erosion potential
- soil type
- existing land use
- proximity to existing roads
- proximity to sewer and water systems

Unsuitable areas are those regions with slopes >15%, soils unsuitable for light structures and paved surfaces, floodplains and drainage areas of perennial flows, areas of high erosion potential, and areas of incompatible land uses. Suitable areas include those that are not restricted by the specified natural and social factors.

4.2. Commercial development suitability analysis

Commercial classifications include all the commercial indices listed in the City of Safford Planning and Zoning Ordinance (City of Safford, 1996). These guidelines were chosen since the City of Safford serves as the primary service center for the Safford Valley region. Commercial types include general, light, and highway. Similar requirements for development can be applied to all of these depending on the size and extent of the development. General commercial facilities, such as a restaurant, could be developed in areas near major roadways. A light structure, such as a small store, could be directed toward suburban areas that are also prime areas for commercial uses.

When considering land-use needs for commercial development, certain aspects are more heavily weighted than others. These include such factors as slope, soil stability, compatibility with existing land uses, proximity to existing roads, and the ability to construct paved surfaces, light structures, and heavy structures. In addition to these physical components, demographic information needs to be incorporated into the suitability analysis.

Unsuitable areas are found in locations with poor soil drainage, high erosion potential areas, floodplains, perennial streams, existing rangeland areas, and slopes >15%. Secondary suitable areas are those sites with moderate erosion potential, slopes from 3 to 15%, and existing commercial and industrial areas. Areas further than 915 m from major arterials are also considered secondary suitable areas. Primary suitable areas are those deemed to have few or no negative relationships.

4.3. Industrial development suitability analysis

Light and heavy industry were combined for the purpose of this study. Industrial uses include research and testing laboratories, distribution plants, and freighting or truck yards. It is presumed that most of the industrial development will continue to be concentrated in the more populated areas surrounding Safford (such as that along Arizona State Highway 70). As a result, these areas merit more attention and more detailed study.

Phenomena more appropriate for consideration include present land use on adjacent or nearby properties, access to major and minor arterials, and availability of public utilities. Unsuitable areas for industrial development include those with slopes >15%, poor soil drainage areas, high erosion potential, and floodplains. Secondary suitable areas include those with moderate erosion potential, slopes from 3 to 15%, and existing residential or agricultural land uses. Primary suitable areas are those with slopes <3%, good soil drainage, low erosion potential, and access to public utilities.

4.4. Recreation

In this study, recreation was classified as intensive with higher associated land-use needs. This type of recreation includes such activities as organized sports and the use of parks and playgrounds, all of which require alterations to the landscape as well as irrigation. The critical requirements for intensive forms of recreation include generally flat land with good drainage and ease of lawn cover maintenance (Juneja, 1974).

Land-use needs for intensive recreation include light structures (such as restrooms and pavilions), paved surfaces (such as parking lots and tennis courts), lawns (for parks and playing fields), utility availability (sewer, water, and electricity), proximity to roads, compatibility of present land use, adequate site drainage, and distance to population centers. Distance to population centers is weighted more heavily since most of this type of recreation occurs near these areas. Demographic information must also be considered.

Areas deemed unsuitable are those with slopes >15%, those with rock outcrops, and those >915 m from existing roads. Suitable areas are those with slopes up to 3%, those with moderate drainage and erosion hazards, those with compatible land uses, and those within 915 m of utility lines.

5. Discussion

The framework for a suitability analysis rests heavily on the data available. Comprehensive information needs to be available for each of the factors applied in the analysis. This information includes accurate floodplain mapping, delineated city boundaries, current zoning restrictions, and current infrastructure assessments. Demographic information such as population density and market area analyses becomes important as a means of evaluating the relative weight of factors. Comprehensive soil, vegetation, and geologic data are also necessary.

In an area such as the upper Gila River watershed, a large database can be incorporated into a holistic planning approach. The use of computer-based geographic information systems (GIS) provides a means for integrating and displaying the various data. While much of this data are available, several elements are either presently lacking or limited in their scope. Although the necessary framework has been developed, as noted actual suitabilities were not mapped.

6. Conclusion

For Arizona counties with a population of >100,000 people, the *Growing Smarter* legislation requires that comprehensive plans must address land uses. These land-use elements need to address the general distribution and location for housing, commerce, industry, agriculture, recreation, education, public buildings and grounds, and open space (Arizona Department of Commerce, 1998a). Furthermore, the legislation requires that all zoning and rezoning ordinances need to be consistent with the adopted county comprehensive plan. Counties in the upper Gila River watershed do not have the population levels sufficient to enact the *Growing Smarter* requirements. However, people are moving to the watershed. Suitability analysis can help counties achieve these new planning and zoning objectives as populations increase.

The *Growing Smarter* law requires that every general plan for communities with more than 2500 residents include an open space element, a growth area element, an environmental planning element, and a cost of development element. This pertains to the communities of Safford, Thatcher, Clifton, and Pima. These four new elements are in addition to the existing required land-use elements for communities. The new law contains specific requirements for inventories (such as the Cohen et al., 1997 report) as well as for directing growth to the most suitable and cost-effective locations (Arizona Department of Commerce, 1998b).

Suitability analysis can help towns such as Safford, Thatcher, Clifton, and Pima to comply with this new state requirement. The framework could also be used for performance zoning. In contrast to traditional, prescriptive zoning, this approach is based on performance standards derived from suitability analysis. Performance standards are criteria that must be met before a certain use will be permitted. These criteria may be any combination of environmental, fiscal, economic, or social factors.

The overall purpose of suitability analysis is indeed to help communities grow smarter. The values used for decision-making can be made explicit and replicable. Such analysis can help a community protect the health, welfare, and safety of its citizens. The appeal of the Southwest and the upper Gila River watershed depends on the sound planning and development of this region.

In order to advance the art of land suitability analysis, it is important that the results are not only replicable within a study area but also transferable, or at least, adaptable in other places. By using the Asotin County process, this Gila study provides an example of such transferability. From this work, we are able to suggest that the frameworks provided by the Asotin and Gila matrices can be adapted in other rural regions of the American West.

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References

Arizona Department of Commerce, 1998a. Growing Smarter Legislation: A Summary for Counties. Arizona Department of Commerce, Phoenix.

Arizona Department of Commerce, 1998b. Growing Smarter Legislation: A Summary for Cities and Towns. Arizona Department of Commerce, Phoenix.

Richard, B., Benson, D., Brunton, D., Johnson, K.L., Knowles, J., Michalovic, J., et al. 1978. Asotin County Ecological Inventory and Land Use Suitability Analysis. Cooperative Extension Service, Washington State University, Pullman, WA.

City of Safford, 1996. City of Safford Planning & Zoning Ordinance, Resolution No. 96-1128. City of Safford, AZ.

Cohen, J., Dahnad, S., Dommisse, L., Fang, Z., Keener, K., Smith, S., Stevens, D., 1997. Upper Gila River Watershed Inventory & Analysis. School of Planning and Landscape Architecture, Arizona State University, Tempe, AZ.

Hopkins, L.D., 1977. Methods for generating land suitability maps: a comparative evaluation. J. Am. Inst. Planners 43 (4), 386–400.

Juneja, N., 1974. Medford. Center for Ecological Research in Planning and Design, University of Pennsylvania, Philadelphia, PA.

Lyle, J.T., 1985. Design for Human Ecosystems: Landscape, Land Use, and Natural Resources. Van Nostrand–Reinhold, New York.

McHarg, I., 1969. Design with Nature. Doubleday/Natural History Press, Garden City, NY.

Miller, W., Collins, M., Steiner, F., Cook, E., 1998. An approach for greenway suitability analysis. Landsc. Urban Plann. 42 (2-4), 91–105.

Pease, J.R., Coughlin, R.E., 1996. Land Evaluation and Site Assessment: A Guidebook for Rating Agricultural Lands,

Second Edition. Soil and Water Conservation Society, Ankeny, IA.
Peterson, G.G., Cheff, B.S., Krauklis, M.D., Smyth, C.K., Weiler, C.S., 1987. City of Safford Comprehensive Plan. Drachman Institute for Land & Regional Development Studies, University of Arizona, Tucson, AZ.
Steiner, F., 1983. Resource suitability: methods for analysis. Environ. Manage. 7 (5), 401–420.

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