USE OF THE ANALYTIC HIERARCHY PROCESS IN FOREST BUDGET ALLOCATION IN DURANGO, MEXICO

Gustavo Perez-Verdin[1] and Aregai Tecle[1]

In the past, Mexican forest management decision makers and consultants focused primarily on allocating funds only to manage timber-related resources. Timber growth, cattle grazing, and agriculture have been the main activities in forest lands representing the primary sources of a farming community's livelihood. Recently, stakeholders have shown a growing interest in other attributes of the land, such as environmental services, water production, conservation of natural resources, biodiversity, and cultural and recreational values. More attention has been paid to the integrative management of natural resources as alternative sources of livelihood. In this context, the concept of multiple-use forestry is being revised by federal and local governments to more efficiently allocate funds for multiresource forest management and to incorporate the views and interests of all stakeholders in the management of natural resources. Representative stakeholders include common and private landowners, the logging industry, NGOs, the general public, and federal and local institutions.

A considerable portion of the necessary funds for managing Mexican natural resources comes from the National Forest Commission (CONAFOR is its Spanish acronym). CONAFOR is a new Mexican federal agency created by a Presidential Decree on April 4, 2001. Its main goals are to promote efficient forest management and restoration activities, as well as to enforce and monitor sustainable forest development policy. To achieve these goals, CONAFOR is currently using various approaches such as funding projects that increase forest stock levels through the development of plantations and management of native forests, fostering landowners' skills, promoting the management of non-timber products such as resins, oregano, and mushrooms, and recently, compensating landowners whose primary objective is to improve water quality or provide other environmental services. During the year 2003, a combination of federal and state funds equivalent to US $4.1 million supported 1200 projects in the state of Durango alone. The aims of the projects can be classified into nine categories: timber management, environmental evaluation, skill and manpower development, providing technical assistance, reducing operational costs, enhancing plantations, promoting recreation and ecotourism, managing non-timber products, improving water quality and quantity, and providing other environmental services.

According to Kangas (1994), there is limited use of proper analytical methods to multiobjective planning and budget allocation—especially methods that involve public opinion. The decision-making processes should involve all stakeholders' wishes and aspirations in developing management objectives and should exhaustively analyze all relevant alternatives (Tecle 1992). For example, landowners can use decision-making techniques to handle complex multiple resource management problems to better serve societal needs. However, there is a challenge to incorporate and measure all stakeholders' wishes and aspirations to determine the most efficient alternative forest management scheme. In this context, the theory of value has been well studied because it prescribes the best decision alternative while involving middle-ground terms such as "maximizing" value or "minimizing" costs (Kangas 1994).

In this paper we use the analytic hierarchy process (AHP) to evaluate stakeholder wishes and management objectives concerning projects funded by CONAFOR. The AHP (Saaty 1980) can evaluate such multiple-objective decision problems by incorporating public values into the decision-making process (Schmoldt et al. 2001). Due to its relative simplicity, effectiveness, and ability to deal with both quantitative and qualitative criteria, the AHP is used to determine the most efficient bud-

[1]School of Forestry, Northern Arizona University, Flagstaff

get allocation for forest multiobjective management planning. In the process, we first describe the essentials of AHP, and then we apply it to CONAFOR's budget for managing forest resources in a multiobjective decision-making framework.

METHODOLOGY

Kangas (1992, 1994, 1999), Saaty (2001), and Duke and Aull-Hyde (2002) have described the various steps involved in the application of the AHP technique to a multiobjective forest management problem. The basic principle for structuring a hierarchical problem involves describing the elements in a lower level in terms of some or all of the elements in the next higher level. The process begins by (1) formulating a problem starting from a primary objective (e.g. maximizing the overall utility); (2) identifying the interested parties, stakeholders, or decision makers involved; (3) defining objectives that represent the wishes and aspirations of all interested parties (e.g. performance objectives, improving economic benefits); and (4) articulating feasible alternatives that must be applied to achieve the objectives. Criteria and subcriteria are used to specify the objectives in step (3) when they are complex and are measured in more detailed and ordinal forms.

The theoretical foundation behind the AHP is the utility theory of value. Zahedi (1987) showed that the process of selecting alternatives is consistent with maximizing a decision maker's either single or multiple attribute utility functions. Results implied that the AHP and the utility maximization criterion can be combined to solve decision problems. Multiobjective forest management involves multi-attribute utility functions that can be evaluated using AHP by incorporating weights and relative rankings of alternatives (Duke and Aull-Hyde 2002).

The most general objective of a multiobjective forest management planning problem is to maximize the overall utility U of the system. Maximization of utility thus becomes the highest level in the hierarchy of the multiobjective problem formulation. A utility model is a mathematical tool that describes a problem in terms of features, such as goals or objectives that express the wishes and aspirations of individuals and/or groups. A very simple utility model can be described in terms of a utility value U that is the sum of the individual objective weights (a_i) multiplied by the decision variables X_i that represent a particular alternative i,

$$U = \sum_i a_i X_i .$$

The alternative that produces the highest utility value is the most preferred option (Schmoldt et al. 2001; Tecle 1992).

Pairwise comparisons help the decision maker to see his or her preferences by comparing two elements at a time; the weights represent the decision maker's preference structure on the objectives. Saaty (1988) used weights of 1, 3, 5, 7, and 9 to respectively represent equal, weak, essential, demonstrated, and absolute importance of one objective over the other in a pairwise comparison. The weights of 2, 4, 6, and 8 represent intermediate values of preferences. This methodology is based on extensive research on psychological behavior, which demonstrated that an individual cannot simultaneously compare more than five to nine objects without being confused (Kangas 1994). Using the pairwise comparisons, the relative weights (importance/preference) of elements at each hierarchical level are determined using the eigenvector method (Saaty 2001). To compute the eigenvector, the analyst first needs to create the matrix of pairwise comparisons A, as shown in equation [1].

$$A = a_{ij} = \begin{bmatrix} 1 & w_1 / w_2 \ldots & w_1 / w_n \\ w_2 / w_1 & 1 \ldots & w_2 / w_n \\ \vdots & \vdots & \vdots \\ w_n / w_1 & w_n / w_2 & 1 \end{bmatrix} \quad [1]$$

where a_{ij} represents the pairwise comparisons of element i and j; and when $i = j$, $a_{ij} = 1$; w_i / w_j is the relative importance of element i over element j; and n is the number of elements compared. Because the AHP involves subjective assignment of values, some inconsistency may be expected; hence Saaty (1980) proposed an eigenvector method to test for inconsistencies. If matrix A contains inconsistencies, they can be estimated using a Consistency Index (CI) described in the form of

$$CI = (\lambda_{max} - n) / (n - 1) \quad [2]$$

where λ_{max} is the largest eigenvector of the matrix A. The eigenvector value (λ_{max}) is obtained by multiplying the matrix A by the vector of relative importance weights, e.g.,

$$\lambda_{max} = \sum_i \sum_i a_{ij} w_i .$$

The vector of relative weights is obtained by normalizing each column, and then normalizing by row (Saaty 1988). Matrix A has to be estimated for each decision variable at all levels of the system; in each, the eigenvector is scaled to add up to 1 to obtain level priorities. We developed a basic program using a spreadsheet to calculate both the relative weights and the eigenvectors. If the pairwise comparisons for an $n \times n$ matrix include no inconsistencies, then $\lambda_{max} = n$; otherwise A is simply the reciprocal of the matrix (Saaty 2001). The more consistent the comparisons are, the closer the value of the computed λ_{max} is to n. A consistency ratio (CR) measures the coherence of the pairwise comparisons:

$$CR = 100(CI / ACI) \quad [3]$$

where ACI is the average consistency index for randomly generated comparisons, which varies with the size of the matrix (Saaty 1988). Kangas (1994) recommended that a CR of 0.10 or less is acceptable.

Problem Description

In the past, Mexican planners and resource managers rarely focused on developing strategies to strengthen the multiple use and sustainable development practices of landowners. Hence, federal programs resulted in poor resource management scenarios that jeopardized sustainable development and eventually led to the degradation of the environment.

> The lack of a consistent policy to strengthen *ejidos* [common properties] has grave social implications that result in the degradation of natural resources and consequently, this prevents rural communities from making s ustainable use of such resources and therefore increasing their quality of life. This creates a vicious circle of degradation and poverty.
>
> (Semarnat 2000, p. 43)

Recent changes have improved the management of natural resources by developing new forest policies that promote the sustainable management of environmental services and that encourage policy enforcement, research, and a more efficient decision-making process. These changes were necessary to alleviate the disparities between farmers and forest landowners. While farmers received a government subsidy to cultivate their lands, forest landowners never received funds to properly manage their natural resources, but instead were blamed for the deterioration of land and the poor quality of water. Therefore, the current government started four national programs to help forest landowners become more competitive and to diminish their differences from farmers. These programs are forest development (FD), development of plantations (PD), non-timber products development (NTP), and water harvesting/environmental services (WH). Table 1 shows the funds allocated to these programs in 2003.

The main goals of the forest development program are to promote the sustainability of primarily timber-related products, strengthen landowners' resource management skills, and reduce operational costs. It is the most important program with the largest budget allocation and the largest number of projects funded. The plantation development program is aimed at increasing forest stocks by establishing new commercial plantations, producing seedlings, and reforesting burned areas and former agricultural or pasture areas. The non-timber products development program is not as large as the first two programs, but it is focused on the development of oregano, mushrooms, fisheries, and ecotourism projects. Though it was designed to operate in only six states of Mexico, the state of Durango was included because of its enormous potential to generate these products in its semi-arid, temperate forest areas. The fourth program, water harvesting/environmental services development, is the most recent program created by the federal government to protect and enhance amenity values, improve water quality and quantity, increase carbon sequestration, promote recreation, and reduce the pressure on timber-based products. It was not funded in 2003, but both federal and state authorities expect it to develop quickly as the public becomes more familiar with it.

The mandate to develop these programs involves giving monetary resources directly to the landowners to achieve sustainable forest development. The fundamentals of these national programs are fully described in the document "2001–2006 National Forest Program," which includes seven national strategies and 14 objectives to promote sustainable forest development in Mexico

Table 1. Budget allocation of federal programs in 2003.

Program	Budget (mill $)	%
Forest development	2.16	53
Development of plantations	1.45	35
Non-timber products development	0.49	12
Water harvesting & environmental services	0	0
Total	4.10	100

(http://www.conafor.gob.mx/documentos_conafor/ENG/pdf/19.pdf, and http://www.conafor.gob.mx/documentos_conafor/ENG/pdf/01.pdf, visited June 7, 2004). To satisfy the goals and objectives identified above, we propose using the four national programs (FD, PD, NTP, and WH) as the feasible projects competing for the limited funds. We also reduced the nine categories of projects into six management objectives: (1) improving economic benefits, (2) increasing water yield, (3) increasing recreation or other environmental benefits, (4) increasing forest stocks, (5) reducing operational costs, and (6) increasing the yield of non-timber products. We have not included some biological objectives such as protecting biodiversity or wildlife habitat because they are not within CONAFOR's areas of responsibilities. However, we included all of the interested parties in Durango involved in the multiobjective forest management decision-making process. These parties are grouped into public or government sector (PUB), landowners (LND), private sector (PRV), and non-governmental organizations (NGO), which includes environmentalist groups and non-profit forest organizations. Landowners, the most dominant group in Durango, includes common and private properties. Common properties, or *ejidos*, are collectively owned expanses of land (Alcorn and Toledo 1998), which occupy up to 70 percent of forestlands. Thus, the essence of this study is to determine the most efficient budget allocation to the four national programs, taking into account the views of the four interested groups and the six management objectives.

Data Acquisition and Problem Formulation

Twenty representative persons were identified and asked to answer an online questionnaire to reveal their individual preferences for budget allocation in the management of natural resources in Durango. The individuals represented each of the four interested groups; however, seven refused to take part in the study. Thus, we used only 13 individual responses to construct the matrix for the pairwise comparisons. The 13 people consisted of four individuals from the public sector, three landowners, three non-government organizations, and three from the private sector. The questionnaire started with the identification of the respondents, followed by a question concerning their knowledge of the four national programs, and questions that asked them to compare and rank the management objectives. We then averaged the pairwise comparisons and constructed a matrix of preferences for each group. We calculated the eigenvectors and consistency indexes and checked for potential inconsistencies. A similar process was also used for the management objectives. In this case, we made the pairwise comparisons for each management objective and for each national program. The consistency indexes revealed no inconsistencies in the pairwise comparisons (see Appendix A).

In formulating the research problem, we first identified the most general objective in the hierarchical process, which is to maximize the utility of forest budget allocation in the state of Durango (first level). We estimated the relative importance of each interested party and structured their respective weights as level 2. Kangas (1994) indicated that the pairwise comparisons of interested groups may be made by the office administering the area, whose members may have a good understanding of the importance of each group. Hence, pairwise comparisons for each party were based on personal knowledge of the area and the role of the interested parties in the management of natural resources. We also considered the scope of forest law, which gives more importance to forest landowners than to any other group in the management of forest resources.

Level 3 consisted of the management objectives and their relative weights, which came from the responses to the survey questionnaires. Finally, level 4 consisted of the alternatives or national development programs. Note that not every objective has links to all four of the national development programs (Figure 1). Formulation of the problem in an analytic hierarchy process framework links each level to the immediate levels above and below it, thereby tying the entire scheme together mathematically (Saaty 1988).

RESULTS

Equation [1] describes quantitatively the relative importance or weights of each interested party, management objective, and national program separately (see Appendix A). The elements of the matrix were determined by normalizing each column and then averaging across each row (Saaty 1988). The relative weights for the interested parties are 0.18 for the public sector (PUB), 0.51 for landowners (LND), 0.17 for the private sector (PRV), and 0.14 for non-government organizations (NGO). The relative importance of landowners is slightly higher than the other stakeholders (see Appendix AI). In this case, $\lambda_{max} = 4.25$, $ACI = 0.90$, CI is 0.08, and CR is 0.09. The CR

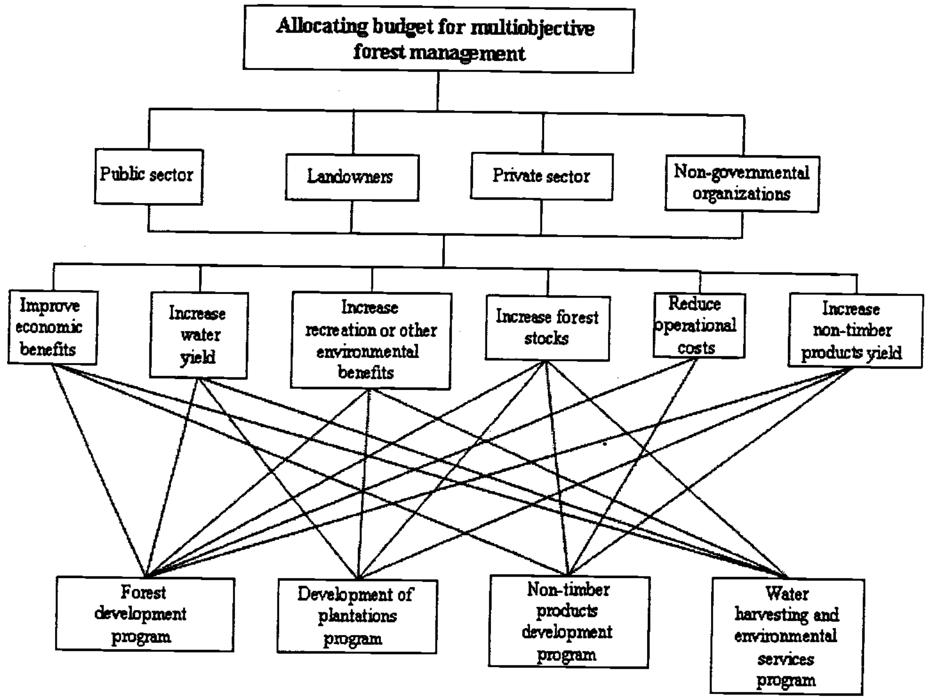

Figure 1. Hierarchies of budget allocation for the multiobjective forest management problem in Durango, Mexico.

is within the standards recommended by Kangas (1994), i.e., $CR \leq 0.1$.

The next step involves prioritization of the decision objectives for each interested party (Table 2). The decision objective that received the highest overall weight from among the four interest groups was *increasing forest stocks* (0.97), whereas *reducing operational costs* received the lowest value (0.44; see Appendix AII for individual objective pairwise values).

To optimally allocate the available budget, the four national programs (i.e., the desired management types) are evaluated with respect to their performance in achieving the desired management objectives. This evaluation assigns a preference structure or weight to each objective; an expert consultant is expected to indicate the respective weights. In this study, we assumed the role of the expert consultant and calculated the weights based on Kangas's methodology (Kangas 1994). As shown in Figure 1, the AHP includes four levels of hierarchy (an overall objective, four interested parties, six management objectives, and four types of management alternatives or national programs). Thus, the global priority (utility) of a management alternative can be calculated as

$$GP_i = \sum_{j=1}^{4}\left[LPIG_j\left\{\sum_{k=1}^{6} LPO_{jk} \times LPMS_{ik}\right\}\right]$$

where GP_i is the global priority (overall utility) of management alternative i, $LPIG_j$ is the local priority of interest group j, LPO_{jk} is the local priority of objective k from the point of view of interest group j, and $LPMS_{ik}$ is the local priority of management alternative i (national program) with respect to objective k. Special attention should be paid to determining GP_i because all management objectives do not have links to all management alternatives; therefore no $LPMS_{ik}$ values are reported for some of the cells in Table 3. In addition, the sum of all GP_i must be equal to one.

We determined the global priorities for the management alternatives using equation [4]. For example, the calculation of the global priority for the forest development program (FD) is shown below:

GP_{FD} = [0.18 ×
{(0.10 × 0.44) + (0.25 × 0.20) + (0.23 × 0.17) + (0.24 × 0.16) + (0.06 × 0.67) + (0.12 × 0.30)} + 0.51 ×
{(0.26 × 0.44) + (0.12 × 0.20) + (0.07 × 0.17) + (0.28 × 0.16) + (0.18 × 0.67) + (0.09 × 0.30)} + 0.17 ×
{(0.18 × 0.44) + (0.12 × 0.20) + (0.19 × 0.17) + (0.24 × 0.16) + (0.13 × 0.67) + (0.14 × 0.30)} + 0.14 ×
{(0.09 × 0.44) + (0.24 × 0.20) + (0.22 × 0.17) + (0.21 × 0.16) + (0.07 × 0.67) + (0.17 × 0.30)}]
= 0.307.

The global priorities for the rest of the national programs are PD 0.214, NTP 0.177, and WH 0.303. The management alternative with the highest global priority (i.e., utility) is *forest development*, which is followed closely by *water harvesting*. Since these results are based on the wishes and aspirations of representative groups of the society, the government may allocate its budget for forest resources management among the four national programs in accordance with the resulting global utility values to best achieve the overall management objectives. In the past, budget allocations followed no systematic approach. In 2003, for example, 53 percent of the forest budget went to forest development, 35 percent to plantations development, 12 percent to non-timber products, and nothing to water harvesting. However, if current policies were designed to satisfy the overall social benefits, the government would need to redistribute the budget among all national programs to meet the needs of all interested parties. According to these results, government planners would need substantial financial resources to develop water harvesting and environmental service programs while reducing the proportional budget allocation to the forest development program. Figure 2 compares the desired budget allocation with the actual budget distribution for fiscal year 2003. The desired budget was obtained by multiplying the global priorities and the total budget assigned in 2003 (i.e., US $4.1 million).

We performed a sensitivity analysis to evaluate the effect of changes in local proprieties on the decision outcomes. The analyst can manipulate a decision maker's preference structure to test its robustness in selecting the preferred management alternative. To demonstrate the sensitivity of the model in this study, we evaluate any changes to the global priority values by varying the landowners' preference structures while keeping constant the other interested parties' weights. When the utility values of the landowners are less than 0.50, *water harvesting* obtains the highest priority values. However, *forest development* would become the most preferred alternative if the landowners' utility values were greater than 0.5 (Figure 3). The basis for accepting the desired budget allocation is related to the land tenure system existing in Durango. As expressed earlier, the new forest policies are structured to help the landowners, so it is unlikely that the preference of any other group could prevail. Hence, we can conclude that the global priority values of the national programs are not sensitive to changes in group preferences, as the two top management alternatives differ little from each other with such changes.

To corroborate the differences from the sensitivity analysis, we performed a *t*-test, along with a test for homogeneity of variances, by dividing the landowners' utility values into two classes: those

Table 2. Objective weights according to each interest group involved in the multiobjective forest management process.

Objectives	PUB	LND	PRV	NGO	Overall Weight
Improving economic benefits	0.10	0.26	0.18	0.09	0.63
Increasing water yield	0.25	0.12	0.12	0.24	0.73
Increasing recreation or other environmental benefits	0.23	0.07	0.19	0.22	0.71
Increasing forest stocks	0.24	0.28	0.24	0.21	0.97
Reducing operational costs	0.06	0.18	0.13	0.07	0.44
Increasing non-timber products yield	0.12	0.09	0.14	0.17	0.52
λ_{max}	6.50	6.37	6.60	6.16	—
CR	0.08	0.06	0.10	0.03	—

Table 3. Local priorities of management alternatives (national programs) with respect to decision objectives (levels 3 to 4).

Management Alternatives (National Programs)* Objectives	FD	PD	NTP	WH	λ_{max}	*CR*
Improving economic benefits	0.44	—	0.17	0.39	3.03	0.02
Increasing water yield	0.20	0.20	—	0.60	3.00	0.00
Increasing recreation or other environmental benefits	0.17	0.39	—	0.44	3.03	0.02
Increasing forest stocks	0.16	0.42	0.14	0.27	4.07	0.03
Reducing operational costs	0.67	—	0.33	—	2.00	0.00
Increasing non-timber products yield	0.30	0.16	0.54	—	3.01	0.01

* Blank cells represent the management objectives that do not have costs associated with a particular national program.

having utility values less than 0.50 are in class 1 and those with utility values greater than or equal to 0.50 in class 2. We identified the four management alternatives (national programs) as dependent variables and their utility values classes as the factors or independent variables. The *t*-test showed no significant differences among the two classes; this means that changing the utility values of landowners has no effect on the global priorities of each management alternative.

CONCLUSIONS AND RECOMMENDATIONS

This study used the AHP to optimally distribute a forest management budget among different programs in the state of Durango, Mexico. We analyzed the perceptions of four representative groups, four national programs, and six management objectives to allocate the budget for multiobjective forest management. Two programs—*forest development* and *water harvesting/environmental services*—are preferred and should therefore receive the highest budget allocation. Since water harvesting/environment services is a new program, authorities should redirect future budget distributions by reducing the budget designated to the other programs, especially to forest development. This should lead to a fair and optimal allocation of the entire budget among all the national programs.

Three major reasons favor this distribution of the desired budget allocation. First, the money comes from taxes and a proper distribution of funds should involve public participation. Second, the desired distribution of the budget tends to be optimal because resource managers know where it is most needed and where it can benefit the most. Third, the method used to determine this distribution is based on multiple use of resources, disregarding past misinterpretations of the single use of forest resources. For example, water harvesting and environmental services should be rated similar to forest development because both would produce benefits not only to the landowners but to society as a whole. We recommend use of the AHP in a more comprehensive manner, including public opinions as much as possible, as well as other objectives such as wildlife habitat and biodiversity. The AHP is suitable for handling qualitative and quantitative data coming from public opinions or any other measured social or biological entity. However, we also recommend caution in using the AHP because it requires normalization of all data to a common scale; it needs to have diverse and representative value functions in the decision-making process. Studies like the one by Duke and Aull-Hyde (2002) can be implemented to gather a large number of public opinions by using survey instruments and can facilitate a more reliable and fair decision-making process.

In addition, the AHP by no means should be used as the only tool suitable for decision-making analysis (Tecle 1992), nor should it be used to replace public participation; on the contrary, both approaches should be considered in a complementary sense. The final decision should incorporate an integrative assessment and sensitivity analysis. Sensitivity analysis reveals model reliability and gives valuable information concerning the effects of varying utility values and weights on the choice of management alternatives (Kangas 1994). Likewise, integrative assessment helps decision makers consider the interactions and feedback of the various facets of a decision problem as well as identifying and exploring different sources of risk and

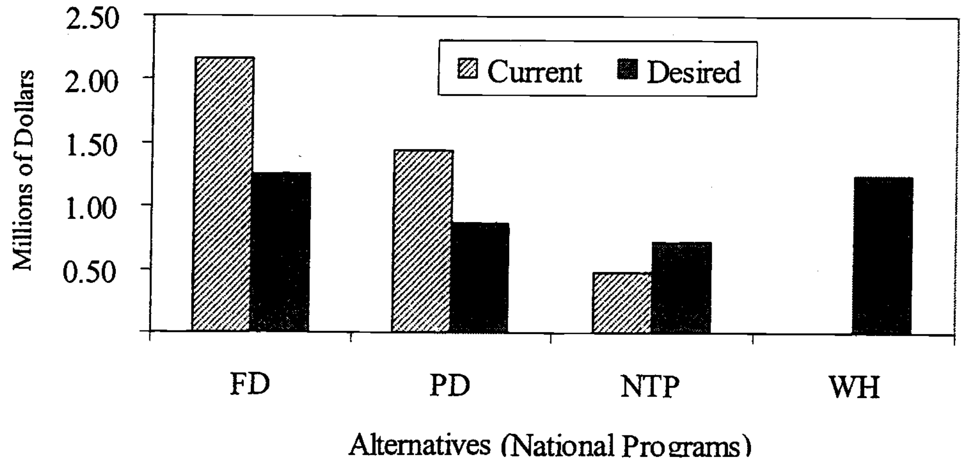

Figure 2. Budget allocation to national programs in the state of Durango, Mexico. In 2003, no funds were allocated to the water harvesting program.

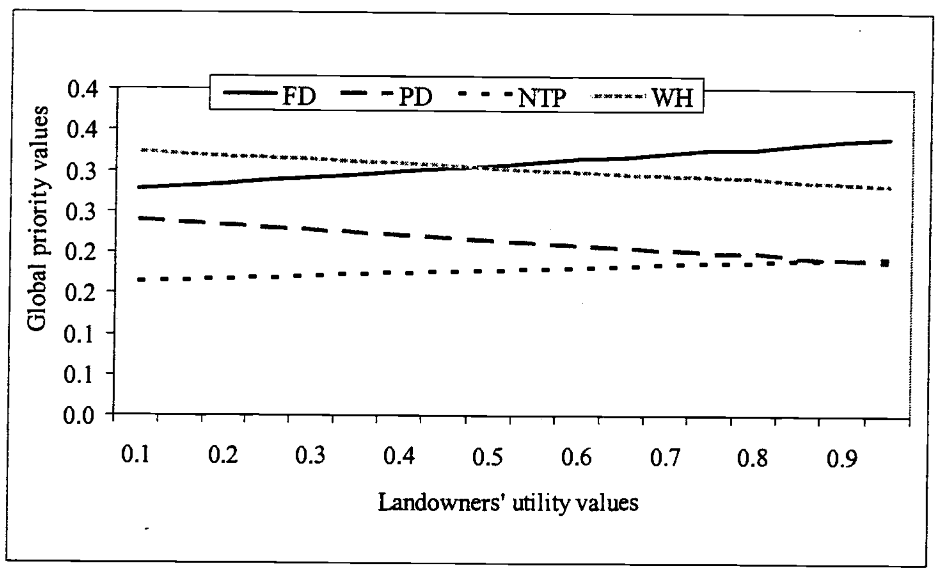

Figure 3. Changes in global priority values with varying landowners' utility values. In this case, the utility values of the other interested parties are assumed to be equal.

uncertainty. The use of AHP can clarify public preferences in a schematic manner and delineate the initial links among management objectives, alternatives, and public preferences. In this manner, the AHP helps to understand and clarify a complex problem with many interacting components and to formulate it in a multiobjective framework. The multiobjective forest management case study in Durango is a good example of a successful application of the AHP to solve a budget allocation problem.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Dr. Ciro Hernandez-Diaz of Silviculture and Wood Research Institute and Ramon Silva-Flores, a resource planner with CONAFOR-Durango, for their invaluable help in getting the data used in the pairwise comparison matrices and making the CONAFOR budget available. This project was partially funded by the state of Arizona's Prop. 301 funding and CONACYT.

LITERATURE CITED

Alcorn, J. B., and V. M. Toledo. 1998. Resilient resource management in Mexico's forest ecosystems: The contribution of property rights. In Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience, edited by F. Berkes and C. Folke, pp. 216–249. Cambridge University Press, Cambridge UK.

Duke, J. M., and R. Aull-Hyde. 2002. Identifying public preferences for land preservation using the analytic hierarchy process. Ecological Economics 42: 131–145.

Kangas, J. 1992. Multiple-use planning of forest resources by using the analytic hierarchy process. Scandinavian Journal of Forest Research 7: 259–268.

Kangas, J. 1994. An approach to public participation in strategic forest management planning. Forest Ecology and Management 70: 75–88.

Kangas, J. 1999. The Analytic Hierarchy Process (AHP): Standard version, forestry applications and advances. In Multiple Use of Forests and Other Natural Resources, edited by F. Helles, P. Holten-Andersen, and L. Wichmann, pp. 96–105. Kluwer Academic Publishers, Norwell, MA.

Schmoldt, D. L., J. Kangas, and G. A. Mendoza. 2001. Basic principles of decision making in natural resources and the environment. In The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making, edited by D. L Schmoldt, J. Kangas, G. A. Mendoza, and M. Pesonen, pp. 1–13. Kluwer Academic Publishers, Norwell, MA.

Semarnat. 2000. Strategic Forest Program 2025. Secretaria de Medio Ambiente y Recursos Naturales. Available http://www.conafor.gob.mx/documentos_conafor/ENG/pdf/19.pdf (accessed June 7, 2004).

Saaty, T. 1980. The Analytic Hierarchy Process. Planning Priority Setting, Resource Allocation. McGraw-Hill, New York.

Saaty, T. 1988. Multicriteria Decision Making: The Analytic Hierarchy Process. RWS Publications, Pittsburgh, PA.

Saaty, T. 2001. Fundamentals of the analytic hierarchy process. In The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making, edited by D. L Schmoldt, J. Kangas, G. A. Mendoza, and M. Pesonen, pp. 15–35. Kluwer Academic Publishers, Norwell, MA.

Tecle, A. 1992. Selecting a multicriterion decision making technique for watershed resources management. Water Resources Bulletin 28(1): 129–140.

Zahedi, F. 1987. A utility approach to the analytic hierarchy process. Mathematical Modeling 9: 387–395.

Appendix A

AI. Pairwise comparisons (A) of stakeholders' utilities and vector of relative importance (w)

$$Aw = a_{ik} = \begin{bmatrix} & PU & LD & PR & NG \\ PU & 1 & 1/4 & 2 & 1 \\ LD & 4 & 1 & 3 & 3 \\ PR & 1/2 & 1/3 & 1 & 2 \\ NG & 1 & 1/3 & 1/2 & 1 \end{bmatrix} \times \begin{bmatrix} 0.18 \\ 0.51 \\ 0.17 \\ 0.14 \end{bmatrix}; \lambda_{max} = 4.25; CR = 0.09$$

PU = Public Sector; LD = Landowners; PR = Private Sector; and NG = Non-government organizations

AII. Pairwise comparisons of stakeholders' utilities of management objectives and vector of weights

Public sector preferences

	EE	WY	REC	FS	OPC	NTP	w
EE	*1.00*	0.33	0.33	0.33	3.00	1.00	0.10
WY	3.00	*1.00*	2.00	0.50	3.00	3.00	0.25
REC	3.00	0.50	*1.00*	2.00	4.00	1.00	0.23
FS	3.00	2.00	0.50	*1.00*	3.00	2.00	0.24
OPC	0.33	0.33	0.25	0.33	*1.00*	0.50	0.06
NTP	1.00	0.33	1.00	0.50	2.00	*1.00*	0.12

$\lambda_{max} = 6.50$; $CR = 0.08$

Landowners preferences

	EE	WY	REC	FS	OPC	NTP	w
EE	*1.00*	3.00	3.00	1.00	2.00	2.00	0.26
WY	0.33	*1.00*	2.00	0.50	0.33	2.00	0.12
REC	0.33	0.50	*1.00*	0.25	0.33	1.00	0.07
FS	1.00	2.00	4.00	*1.00*	3.00	2.00	0.28
OPC	0.50	3.00	3.00	0.33	*1.00*	2.00	0.18
NTP	0.50	0.50	1.00	0.50	0.50	*1.00*	0.09

$\lambda_{max} = 6.37$; $CR = 0.06$

Private Sector preferences

	EE	WY	REC	FS	OPC	NTP	w
EE	*1.00*	3.00	1.00	1.00	0.50	1.00	0.18
WY	0.33	*1.00*	1.00	0.50	1.00	1.00	0.12
REC	1.00	1.00	*1.00*	0.50	3.00	2.00	0.19
FS	1.00	2.00	2.00	*1.00*	3.00	1.00	0.24
OPC	2.00	1.00	0.33	0.33	*1.00*	1.00	0.13
NTP	1.00	1.00	0.50	1.00	1.00	*1.00*	0.14

$\lambda_{max} = 6.60$; $CR = 0.10$

Non-governmental organizations preferences

	EE	WY	REC	FS	OPC	NTP
EE	*1.00*	0.33	0.33	0.33	1.00	1.00
WY	3.00	*1.00*	1.00	1.00	3.00	2.00
REC	3.00	1.00	*1.00*	1.00	4.00	1.00
FS	3.00	1.00	1.00	*1.00*	3.00	1.00
OPC	1.00	0.33	0.25	0.33	*1.00*	0.33
NTP	1.00	0.50	1.00	1.00	3.00	*1.00*

$\times \begin{bmatrix} 0.09 \\ 0.24 \\ 0.22 \\ 0.21 \\ 0.07 \\ 0.17 \end{bmatrix}; \lambda_{max} = 6.16; CR = 0.03$

EE = Improve economic benefits; WY = Improve water yield; REC = improve recreation/environmental services; FS = Increase forest stocks; OPC = Reduce operational costs; and NTP = increase non-timber products yield.

AIII. Pairwise comparisons of management objectives' utilities and vector of weights (w)

Improve Economic Benefits

	FD	NTP	WH	w
FD	*1.00*	3.00	1.00	0.44
NTP	0.33	*1.00*	0.50	0.17
WH	1.00	2.00	*1.00*	0.39

$\lambda_{max} = 3.03$; $CR = 0.02$

Improve Water Yield

	FD	PD	WH	w
FD	*1.00*	1.00	0.33	0.20
PD	1.00	*1.00*	0.33	0.20
WH	3.00	3.00	*1.00*	0.60

$\lambda_{max} = 3.00$; $CR = 0.00$

Improve Recreation and Environmental Services

	FD	PD	WH	w
FD	*1.00*	0.50	0.33	0.17
PD	2.00	*1.00*	1.00	0.39
WH	3.00	1.00	*1.00*	0.44

$\lambda_{max} = 3.03$; $CR = 0.02$

Increase forest stocks

	FD	PD	NTP	WH	w
FD	*1.00*	0.50	1.00	0.50	0.16
PD	2.00	*1.00*	3.00	2.00	0.42
NTP	1.00	0.33	*1.00*	0.50	0.14
WH	2.00	0.50	2.00	*1.00*	0.27

$\lambda_{max} = 4.07$; $CR = 0.02$

Reduce operational costs

	FD	NTP	w
FD	*1.00*	2.00	0.67
NTP	0.50	*1.00*	0.33

$\lambda_{max} = 2.00$; $CR = 0.00$

Increase non-timber products

	FD	PD	NTP	w
FD	*1.00*	2.00	0.50	0.30
PD	0.50	*1.00*	0.33	0.16
NTP	2.00	3.00	*1.00*	0.54

$\lambda_{max} = 3.01$; $CR = 0.01$

FD = Forest Development; PD = Plantations Development; NTP = Non-timber products; WH = Water Harvesting