A SPATIAL AND TEMPORAL MULTIOBJECTIVE FOREST MANAGEMENT ANALYSIS IN EJIDOS OF DURANGO, MEXICO

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Mexico hosts a unique land tenure system where the majority of its forest ecosystems belong to communities—*ejidos*—in which all forest resources are collectively owned. Ejidos, a product of a legal process called *dotacion* (endowment), were created to foster economically viable, self-sufficient communities, generally through providing land for cultivation (Barton Brady and Merino 2004). The livelihood of many ejidos, especially in northern Mexico, depends on forest management. However, though they are rich in natural resources, they face many problems associated with poor socioeconomic development, inaccessibility, and subsistence (Barton Brady and Merino 2004).

The capacity of forests to produce multiple goods and services in ejido communities has been overlooked in favor of developing alternatives that maximize timber production for economic profit alone. This approach is suboptimal; it leads to ecosystem degradation and fails to address the wishes and aspirations of all stakeholders. Maximization of timber profits still takes precedence in the majority of ejidos and some private forest lands, but the forest law indicates that all landowners must consider other uses and environmental services for the sustainable use of forest resources (SEMARNAT 2003). In spite of such official and practical recognition of the need for multiobjective management of forest systems, there are only a few signs that indicate development and use of technology that embraces multiobjective forest management and the dynamics of forests to evaluate the most preferred mix of resource outputs. Current ejido management plans do address the complex issue of managing forests for multiple objectives, but fail to put them into practice.

The objectives of this paper are threefold: (1) to provide and demonstrate a practical framework to formulate and solve an ejido forest ecosystem management problem in a multiobjective framework that includes identification of most interested parties, forest management objectives, and relevant decision variables; (2) to evaluate stand conditions in a temporal and spatial framework; and (3) to determine target forest structures as references for the multiobjective forest management. The procedure is applied to a real Mexican forest with 10 management objectives representing the most important economic, social, and environmental services currently considered as key strategic elements in the Mexican forest law. The objectives are expressed in terms of three continuous decision variables.

MULTIOBJECTIVE FOREST MANAGEMENT APPROACH

The forest system in one ejido, Los Altares, is used as a case study to formulate and solve a multiobjective forest management problem. This ejido, which is located in northern Durango, features a mix of coniferous temperate forest (*Pinus arizonica, P. durangensis, P. teocote*) and deciduous vegetation types (*Quercus* spp., *Populus tremuloides*; Figure 1). The ejido owns 17,800 ha of forest land of which 93 percent is pine-oak forests. The products/goods are equally distributed among 108 ejidatarios. The ejido's forests have been managed for more than 40 years under uneven- and even-aged management schemes, which included selection, thinning, and seed trees. The annual allowable cut has been decreasing from 16,000 m^3 per year in 1985 to its current level of 6000 m^3 per year. Part of this decline is because of the use of new, more refined forest inventory methods and restructuring of forest stands that include more small-diameter trees, and other natural and human disturbances (UAF Santiago Papasquiaro 2005).

Management Objectives

An objective is the desired direction of change of a state by a decision maker (Duckstein and Tecle 2002). In this study, we used 10 objectives that

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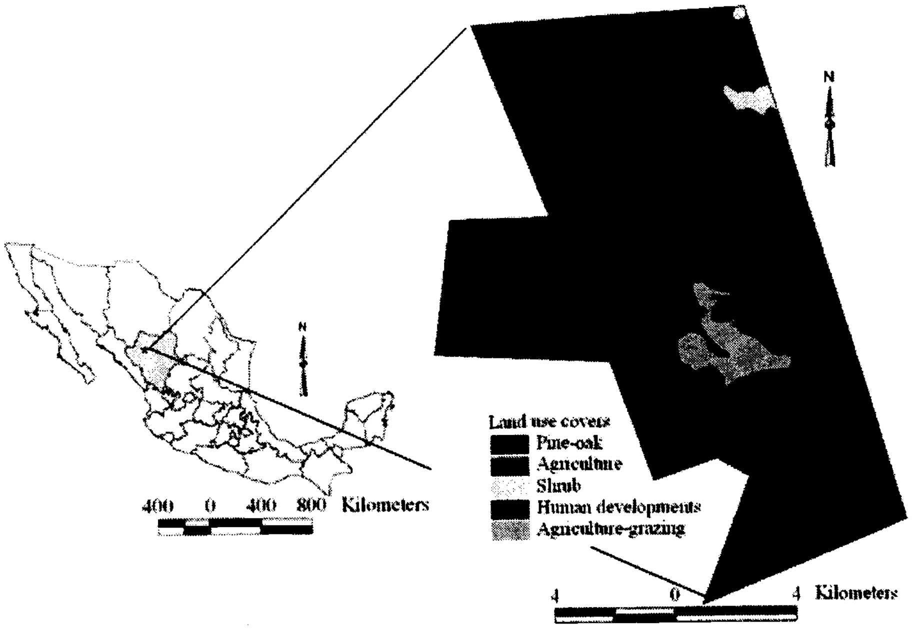

Figure 1. Location of the Ejido Los Altares in Durango, Mexico.

represent the wishes and aspirations of ejiditarios and other interested parties. The 10 objectives are biological richness, carbon sequestration and oxygen provision, fire hazard, non-timber uses (such as mushrooms and resins harvesting), forest/soil productivity, recreation, scenic beauty, soil retention, water supply (quality and quantity), and economic benefits of timber. The identification and uses of these objectives were based upon government information that describes the basis for institutional initiatives in natural resources management, the forest law and other regulations, stakeholders' wishes, and previous works involving ejido multiobjective forest management (Perez-Verdin and Tecle 2002). Four different types of stakeholders were used to generate the relative weights for the 10 management objectives. The four groups of stakeholders—landowners, forest managers, government, and non-government organizations—comprised 144 individuals.

The Decision Variables

Decision variables, which represent the numerical characteristics of the objectives, can be continuous or discrete (Duckstein and Tecle 2002). In constructing the objective functions, we used tree basal area (*ba*), number of trees per hectare (*nth*), and quadratic mean diameter (*qmd*) as the varying, continuous measures of forest conditions. We used more than one decision variable to reflect real forest conditions and to consider the diversity of stands stemming from diverse soil conditions (productivity) and vegetation density and volume. In addition, the three variables are key components in the FVS simulations (Dixon 2002). After converting system units from simulation outputs, *ba* is expressed in m^2/ha, *nth* in trees per hectare, and *qmd* in centimeters.

THE INITIAL FOREST CONDITIONS

Nine forest conditions that show different combinations of the decision variables were used in constructing the 10 objective response functions. Field observations and forest inventory data analysis showed that these forest conditions adequately represented the different forest conditions in the study area. Basal area ranged from 12 to 44 m^2/ha, number of trees varied from a minimum of 160 to a maximum of 2400 individual trees per hectare, and the quadratic mean diameter ranged from 11 to 43 cm.

We photographed each condition (C_i) and showed the pictures to a group of expert consultants to obtain their preference ratings and to construct a response function for each objective. The edited pictures also contained dasometric information. We used the information from expert consultation on the nine forest conditions to construct the response functions to each management objective. The expert information was obtained through personal interviews of 29 expert consultants working in the state of Durango. Their education and professional experience in the field of forest management ranged from doctoral to bachelor degrees and from 45 to 14 years, respectively. Participants also analyzed each photo and answered a questionnaire that relates the possibility for achievement of each objective under the different forest conditions. Rates were based on a 10-point scale where 1 means very low or very bad and 10 means very high or excellent (Table 1).

Response Functions

Using the information from expert consultation and the initial forest conditions, we constructed a multivariate response function for each management objective i. Each objective function is expressed in terms of the three decision variables as follows:

$$y_j = f_i\,(ba, nth, qmd)\ \forall_i \qquad [1]$$

where ba, nth, and qmd are as defined previously. We used the first partial derivative for each multivariate objective response function i to determine the local maxima y_i^* and minima y_i^{**} of the objectives (Baker 2006) using the following expression:

$$y_i^* = \frac{\partial V_i}{\partial ba_i}; \frac{\partial V_i}{\partial nth_i}; \frac{\partial V_i}{\partial qmd_i}, \forall_i. \qquad [2]$$

Equation 2 was repeated to find the local minima y_i^{**}. This approach requires first that each objective function i be optimized separately to determine y_i^* and y_i^{**} and by looking at the signs of the variables, we were able to determine the maximum or minimum values of each objective function. A step-by-step process to determine both y_i^* and y_i^{**} for one management objective is presented later in the results section. We used the Excel Solver package to determine local maxima and minima values for the rest of the management objectives (Baker 2006). After the local maxima and minima were estimated, we used a distance-based MODM technique called Compromise Programming (CP) to determine the set of nondominated solutions.

COMPROMISE PROGRAMMING

Compromise programming seeks management strategies that minimize the distance between the efficient frontier and a reference point outside the objective space (Krcmar et al. 2005). The solutions closest to the ideal are called compromise or nondominated solutions (Goicochea et al. 1982), which means a solution to a multiobjective problem for which there exists no other feasible solution that will cause improvement in any of the objectives without making at least one other objective worse (Tecle et al. 1998). The procedure for evaluation of the set of nondominated points is to measure how close these points are to the ideal solution. The measure of closeness is defined by a family of distance metrics, d_p (Zeleny 1982), and any point in the objective space can be a compromise solution if it minimizes

$$d_p = \left[\sum_{i=1}^{I} \lambda_i^p \left(y_i^* - y_i\right)^p\right]^{1/p},$$

$$\forall_i, \lambda_i > 0, 1 < p < \infty, \text{ and } \sum_{i=1}^{I} \lambda_{i=1} \qquad [3]$$

where p is the distance parameter, y_i^* is the best or maximum value (local maxima) for objective i, y_i is the value of objective i, and I is the number of objectives considered. The parameter λ_i is the relative weight of objective i. Varying the value of p between 1 and infinity allows one to move from minimizing the sum of individual regrets (i.e. having a perfect compensation among the objectives) to minimizing the maximum regret (i.e. having no compensation among the objectives) in the decision-making process (Tecle et al. 1998). To minimize the scale effects in the compromise solutions, a standardized equation in which distance values use relative rather than absolute deviations is proposed (Zeleny 1982; Tecle et al. 1998). The standardized form of equation 3 is expressed as follows:

$$d_p = Min\left[\sum_{i=1}^{I} \lambda_i^p \left(\frac{y_i^* - y_i}{y_i^* - y_i^{**}}\right)^p\right]^{1/p} \qquad [4]$$

where y_i^{**} represents the worst or minimum value (local minima) for objective i. The notion of p represents the emphasis given to the size of individual deviations on the outcome. The three most common p values used in computing compromise solutions are 1, 2, and ∞. A sensitivity analysis is performed to verify the consistency of the nondominated solutions under varying values of p and objective weights λ_i (Goicochea et al. 1982; Zeleny 1982; Krcmar et al. 2005). Having λ_i in equations 3 and 4 represents the decision maker's

Table 1. Standardized weights, means, and standard deviations (in parentheses) for the management objectives and forest conditions derived from expert consultation.

Objective	Weights	Forest Conditions								
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
Biodiversity richness	0.104	7.8 (1.6)	6.9 (1.1)	6.8 (1.7)	7.1 (1.7)	6.5 (1.1)	5.3 (1.3)	5.7 (1.2)	6.6 (1.5)	6.6 (1.4)
Carbon sequestration	0.100	8.8 (1.3)	8.2 (1.0)	7.7 (1.0)	8.0 (1.3)	6.9 (0.7)	5.9 (1.2)	5.7 (1.2)	7.3 (1.3)	6.9 (1.3)
Fire hazard	0.108	7.4 (1.1)	7.1 (0.9)	7.2 (1.3)	7.2 (0.8)	6.8 (1.4)	5.9 (1.6)	5.9 (1.6)	7.5 (1.3)	7.0 (1.0)
Non-timber products	0.082	6.9 (1.8)	7.0 (1.6)	6.3 (1.4)	7.3 (1.5)	6.6 (1.2)	6.4 (1.3)	6.3 (1.2)	5.8 (1.4)	7.2 (1.7)
Forest productivity	0.106	8.5 (1.2)	8.1 (1.1)	7.3 (1.5)	8.1 (0.8)	7.2 (0.8)	5.7 (1.2)	5.8 (1.4)	6.6 (1.4)	7.0 (1.5)
Recreation	0.093	6.5 (1.9)	7.2 (1.9)	5.6 (1.8)	7.8 (1.6)	6.4 (1.5)	6.2 (1.3)	5.7 (1.5)	5.0 (1.6)	6.9 (1.5)
Scenic beauty	0.094	6.8 (1.5)	7.3 (1.7)	5.9 (1.5)	7.7 (1.2)	6.6 (1.3)	6.2 (1.3)	5.8 (1.6)	4.8 (1.6)	7.0 (1.4)
Soil retention	0.104	8.6 (0.9)	7.9 (0.9)	7.3 (1.3)	7.5 (1.3)	7.1 (1.2)	6.5 (1.3)	6.2 (1.2)	7.9 (1.2)	6.9 (1.6)
Timber economic benefits	0.102	7.9 (1.1)	7.9 (1.8)	6.1 (1.3)	7.8 (1.3)	6.9 (1.1)	5.9 (1.2)	5.7 (1.4)	5.2 (1.3)	7.4 (1.9)
Water supply	0.107	6.6 (1.7)	6.9 (1.4)	6.7 (1.3)	6.9 (1.3)	6.9 (1.0)	7.1 (1.2)	7.5 (1.6)	6.3 (1.3)	7.4 (1.3)

preference structure among the objectives (Goicochea et al. 1982). Thus, a double-weighting scheme to verify the consistency of the nondominated solutions exists. The parameter p reflects the importance of the maximal deviation and the parameter λ_i reflects the importance of the different objectives relative to each other (Goicochea et al. 1982).

SPATIAL AND TEMPORAL ANALYSIS OF THE MODM APPROACH

We used a cluster analysis to group sampled forest conditions according to the decision variables (number of trees per hectare, quadratic mean diameter, and basal area) plus age, and species composition. Any variation due to location of stands with similar forest characteristics should be reflected in the clustering scheme. We identified the clusters using the average within-groups linkage method, measured by the Euclidian distance (Romesburg 1990), which produced 15 groups. Within each cluster we identified the single stand that most represented the average characteristics of the cluster. This stand was then used in the temporal analysis of the problem. Stand information consisted of site index, tree density, slope, elevation, and factor numbers that converted data from 0.1 ha, fixed-sized plots to units per acre. Tree information included type of species, diameter, and height. The results for a stand were generalized to the cluster it represented.

The Forest Vegetation Simulator (FVS), Central Rockies variant, simulated forest growth, regeneration, and mortality of the representative stands that resulted from the spatial clustering. FVS relies on a family of forest growth simulation models derived from individual-tree, distance-independent data that simulate a wide variety of forest types, stand structures, and pure or mixed species stands (Crookston and Dixon 2005). We used the FVS Central Rockies variant in Durango's forests because of the similarities in vegetation types between the U.S. Southwest and the study area, and the flexibility of the simulator. Also the ecosystems in the U.S. Rocky Mountain region and those in northern Mexico share similar characteristics in terms of species composition and growth patterns (Richardson 1998).

We considered the following parameters in the FVS simulation. A planning period of 100 years was divided into 10-year cycles. The planning period of 100 years is the average time a typical tree would need to mature in the study area. Regeneration of the dominant species (i.e., *Pinus arizonica* and *Quercus* spp.) was established at 340 and 140 trees per ha at age 5, respectively. The rotation cycle for uneven-aged stands was determined to be 13 years with a slope (q) of the inverse J-shaped diameter distribution equal to –1.4 (Meyer 1952; UAF Santiago Papasquiaro 2005). Using the FVS tool we simulated various forest scenarios and examined the results for each 10-year time step until an optimal solution—that is, the closest distance to the ideal—was found. This procedure was repeated for each of the 16 clusters.

RESULTS AND DISCUSSION

The expert opinion values on the initial forest conditions with the three decision variables (*ba*, *nth*, and *qmd*) were used to construct the response functions for all management objectives. A test of normality of residuals, using the Shapiro-Wilk test, and other statistical parameters (R^2 and p values) were considered in determining model fitness. We solved the partial derivatives of the different objective functions to find their local maxima y_i^* and minima y_i^{**} values (Baker 2006; see equations 6 through 15 in Table 2). The vector of y_i^* and y_i^{**} values constitutes, respectively, the ideal and the worst points needed to solve the problem using compromise programming (equation 4).

After we constructed the response functions and determined the local maxima and minima values for all objectives, we used equation 4 to determine the set of compromise solutions. This involved finding the closest distance between the efficient frontier and the ideal point for each time step (one 10-year cycle) and cluster. In this case, an iterative process was performed for each time step and cluster by simulating different forest scenarios until stand structures approached the ideal solution as closely as possible. The ideal point corresponds to a vector of the maximum values of the different objective response functions.

Simulation of forest growth using FVS to approach the ideal point was not easy. Some clusters were understocked in terms of basal area, but overstocked with regard to number of trees per hectare. FVS simulations considered various silvicultural treatments, such as thinning from above, thinning from below, individual selection, and seed trees, and leaving different levels of residual density. Outcome simulations were analyzed through the statistical report and the postprocessor stand visualization system, which generates three-dimensional drawings of FVS outputs (Crookston and Dixon 2005). Unfortunately, FVS does not support more than one target goal during simulations, so in some clusters the process was repeated for each decision variable. Tables 3, 4, and 5 show the results of the compromise solutions for each time step and cluster and for each decision variable.

Sensitivity Analysis

A sensitivity analysis was conducted to test the robustness of the algorithm with respect to any changes in p and the weights of the objectives, λ_i. Since the process consisted of examining continuous and multiple decision variables, we used Excel solver to determine the robustness of the model when the values of the parameters p equal 1, 2, and ∞. The results show no changes in the compromise solution for $p = 2$ and ∞ and only a slight change in the value of *nth* for $p = 1$.

The second sensitivity analysis consisted of examining the effects of changing the weights of objectives, λ_i. Different weights representing the preference structures of various landowners and other stakeholders on the objectives were keyed into the compromise programming algorithm. The results showed no significant changes in the CP (compromise programming) solutions with changes in the weights.

To further verify that the solution was not sensitive to changes in the objective weights, we performed two additional tests. The first one involved use of different weights for the objectives, and the second one consisted of assigning equal weights to each management objective when determining the preferred solution. In both cases, target forest structures remained unchanged, that is, there was no model sensitivity to changes in the values of the parameters, λ_i. We believe that the results are not sensitive to changes in p or λ_i values because the difference between the objective response functions and the ideal point is so big that any change in these two parameters does not affect the results.

SUMMARY AND CONCLUSIONS

This study described a practical approach to a dynamic formulation and solution to a multiobjective forest management problem in the Ejido Los Altares, Mexico. Various management objectives, decision variables, and opinions of stakeholders were used to solve the multiobjective forest

Table 2. Objective response functions, statistical fitness of models, and local maxima and minima values.

Objective	Model[1]	Equation	p value	R^2	Residuals Test[2]	Max[3]	Min[3]
Biodiversity richness	$y_1 = 4.01 + 0.05(ba) + 2.6E^{-4}(nth) + 0.029(qmd)$	[5]	0.008	0.84	0.67	8.08	4.99
Carbon sequestration	$y_2 = 3.67 + 0.074(ba) + 0.0004(nth) + 0.044(qmd)$	[6]	0.02	0.78	0.71	9.81	5.15
Fire hazard	$y_3 = 5.64 + 0.004(ba) + 0.0007(nth) + 0.043(qmd) - 14.16(1/ba)$	[7]	0.02	0.85	0.56	5.144	9.034
Non-timber products management	$y_4 = 5.23 + 0.009(ba) - 8.0E^{-5}(nth) + 0.043(qmd)$	[8]	0.002	0.92	0.88	7.47	5.63
Forest productivity	$y_5 = 3.76 + 0.074(ba) + 6.8E^{-5}(nth) + 0.045(qmd)$	[9]	0.009	0.83	0.71	9.12	5.19
Recreation	$y_6 = 3.82 + 0.01(ba) - 5.2E^{-5}(nth) + 0.081(qmd)$	[10]	0.004	0.91	0.87	7.75	4.72
Scenic beauty	$y_7 = 4.41 + 0.02(ba) - 4.15E^{-4}(nth) + 0.06(qmd)$	[11]	0.002	0.90	0.62	7.82	4.33
Soil retention	$y_8 = 5.022 + 0.04(ba) + 4.9E^{-4}(nth) + 0.023(qmd)$	[12]	0.05	0.69	0.75	8.96	5.85
Timber economic benefits	$y_9 = 3.88 + 0.046(ba) - 0.00034(nth) + 0.064(qmd)$	[13]	0.02	0.82	0.97	8.66	4.45
Water supply	$y_{10} = 6.95 - 0.021(ba) - 3.7E^{-4}(nth) + 0.058(qmd) + 0.104(\log nth)$	[14]	0.05	0.79	0.74	9.68	6.59

[1] Models include the following variables: y_i = values of forest conditions; *ba* = basal area; *nth* = number of trees per ha; and *qmd* = quadratic mean diameter.

[2] Based on the Shapiro-Wilk test for normality of residuals.

[3] The maximums and minimums were determined using partial derivatives of the models.

Table 3. Target forest conditions (compromise solution) in basal area (m^2/ha).

	Time step (years)									
Cluster	10	20	30	40	50	60	70	80	90	100
0004	9.9	10.1	10.8	11.2	11.7	11.7	10.1	10.8	11.5	11.7
0238	19.3	17.2	18.1	18.8	19.3	19.3	19.3	19.1	19.1	18.8
0245	5.7	1.8	2.5	3.2	4.1	5.3	6.7	7.6	9.0	9.9
0291	20.2	20.2	21.8	21.4	21.8	22.3	22.3	22.3	22.3	22.5
0537	14.5	17.4	20.4	23.4	25.9	27.3	28.5	29.6	30.5	31.7
0601	17.2	18.1	18.4	18.6	18.8	19.3	19.5	19.5	19.7	19.7
0788	15.4	14.5	13.5	13.1	13.8	14.7	15.4	15.6	15.8	15.8
0958	16.8	18.6	18.8	18.8	19.1	21.1	23.2	24.8	26.6	27.5
1043	18.6	17.0	16.3	17.4	18.4	18.6	18.8	17.4	18.1	18.6
1119	17.2	16.8	15.8	16.5	17.4	18.1	18.4	18.4	18.6	18.6
1122	23.4	23.2	22.7	23.4	23.9	23.9	23.9	24.1	24.1	24.1
1142	5.5	2.1	2.8	3.7	5.1	6.4	7.1	8.5	8.7	9.4
1309	12.9	14.9	17.0	17.2	17.2	17.0	17.0	17.2	17.2	17.2
1411	19.3	18.8	17.7	17.0	17.9	18.8	19.7	20.0	20.0	19.7
1452	6.4	3.4	7.6	12.2	13.3	12.4	12.2	11.9	13.1	13.5

Table 4. Target forest conditions (compromise solution) in number of trees per hectare.

	Time step (years)									
Cluster	10	20	30	40	50	60	70	80	90	100
0004	512	432	356	292	240	618	427	341	274	227
0238	897	665	556	482	430	390	353	319	282	250
0245	519	971	867	613	554	440	403	336	316	282
0291	168	138	642	581	516	457	388	331	287	252
0537	306	301	297	292	287	277	267	257	250	242
0601	635	588	536	492	450	413	381	343	314	277
0788	662	949	1068	717	558	445	361	289	237	193
0958	242	235	222	208	195	190	188	183	180	173
1043	808	1028	670	524	420	343	746	531	440	358
1119	744	1112	783	598	499	430	373	324	287	250
1122	358	776	655	571	507	432	366	309	259	222
1142	418	761	746	731	660	600	445	408	316	274
1309	166	163	161	151	368	343	321	304	287	274
1411	652	993	1156	788	625	509	425	348	292	240
1452	492	848	635	492	803	914	961	502	336	237

Table 5. Target forest conditions (compromise solution) in quadratic mean diameter (cm).

	Time step (years)									
Cluster	10	20	30	40	50	60	70	80	90	100
0004	15.7	17.3	19.6	22.4	24.9	15.5	17.5	20.1	23.1	25.7
0238	16.5	18.0	20.3	22.4	23.9	25.1	26.4	27.7	29.2	31.0
0245	11.7	4.8	5.8	8.1	9.9	12.4	14.5	17.0	19.1	21.3
0291	38.9	42.9	20.8	21.6	23.1	24.9	27.2	29.2	31.5	33.8
0537	24.4	27.2	29.7	32.0	34.0	35.6	36.8	38.1	39.6	40.9
0601	18.5	19.8	20.8	22.1	23.1	24.4	25.7	26.9	28.4	30.0
0788	17.3	14.0	12.7	15.2	17.8	20.6	23.4	26.2	29.2	32.3
0958	29.7	31.8	32.8	34.0	35.3	37.6	39.6	41.7	43.4	45.2
1043	17.0	14.5	17.8	20.6	23.6	26.2	17.8	20.6	22.9	25.7
1119	17.3	14.0	16.0	18.8	21.1	23.1	24.9	26.9	28.7	30.7
1122	29.0	19.6	21.1	22.9	24.6	26.4	29.0	31.5	34.5	37.3
1142	13.0	5.8	6.9	8.1	9.9	11.7	14.2	16.3	18.8	21.1
1309	31.2	34.0	36.8	38.1	24.4	25.1	25.9	26.9	27.7	28.4
1411	19.3	15.5	14.0	16.5	19.1	21.6	24.4	26.9	29.5	32.3
1452	13.0	7.4	12.4	17.8	14.5	13.2	12.7	17.5	22.4	26.9

management problem in a spatial and temporal framework. We used an MODM tool known as compromise programming to determine the preferred solutions (Tecle 1992; Tecle et al. 1998; Srinivasa and Pillai 1999; Krcmar et al. 2005). Tree and stand data were dynamically assessed using the forest vegetation simulator for each 10-year step of the 100-year planning period.

Target forest structures were determined for each of the 15 clusters in which the study area was divided. As noted in the sensitivity analysis, target forest structures were generally above current stand conditions, particularly in terms of basal area and quadratic mean diameter. Many factors might have contributed to the differences between current and target conditions in the study area. For instance, forests have been managed for timber harvesting purposes only in which intensive selection cuttings, oriented to the best individuals, have decreased the stocking and quality of residual trees. Gaps and edges have produced unbalanced or pulsated diameter distributions (Gingrich 1993), which caused some complications in determining the target structures. Another factor is the required human activity to clear the forest areas for other purposes such as agriculture, roads, and grazing. Cattle are also evident throughout the study area, and all these factors together are jeopardizing the forest's capacity to fully regenerate.

The differences between reference conditions and current stand characteristics show that managing the forests for multiple objectives is different from the traditional way of managing forest systems for timber production alone. Traditional forest management for the sole objective of maximizing profit from timber production resulted in unbalanced diameter distributions, low stocking, and bad product quality. We believe that the transition to this new approach will gradually occur as the ejidos, their forest managers, and environmental groups and other institutional agencies recognize the importance of other forest resources. The methodology presented in this study may serve as the initial tool to transit to this new paradigm.

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