# USING MEASURED DATA AND EXPERT OPINION IN A MULTIPLE OBJECTIVE DECISION SUPPORT SYSTEM FOR SEMIARID RANGELANDS

P. A. Lawrence, J. J. Stone, P. Heilman L. J. Lane

ABSTRACT. *A Decision Support System (DSS) can be used to structure information in a way that leads to improved decision making for natural resources. The decisions will only be as good as the information on which they are based. As the applications of a DSS is outpacing the available databases and simulation models, there is an increasing reliance on expert opinion for information on resource management systems. As a result, the effect of information source on the outcome from the DSS is an important issue. This article compares the outcomes from a prototype DSS (P-DSS) developed by the USDA-ARS Southwest Watershed Research Center in Tucson, Arizona, when measured data and expert opinion are used to quantify eight decision criteria in the evaluation of four management systems (yearlong and rotation grazing, each with mesquite trees (*Prosopis velutina *Woot.) retained or removed) for semiarid rangelands. The decision criteria are sediment yield, channel erosion, runoff rate and quantity, rangeland condition, aboveground net production, and wildlife habitat for quail and javelina, although the analysis is not restricted to these criteria. When measured data are used to quantify the decision criteria, rotation grazing with mesquite removed is the preferred management system; whereas, yearlong grazing is the preferred system when expert opinion is used. The experts also directly ranked the four management systems. The difference between the expert's ranking and the P-DSS results based on expert inputs is a concern for future use of decision support system technology, particularly when information sources are blended. Keywords.*

Consideration of soil, water, plants, and animals is fundamental for natural resource management. The conservation of one natural resource should not be in isolation of the other resources. When a system is managed for a single resource, for example, soil conservation, it is termed a single-objective system. However, recently there has been a growing awareness that the management of natural resources necessitates a multi-objective approach to consider more than one objective simultaneously. The Conservation Practice Physical Effects matrix (CPPE) developed by the USDA-Natural Resources Conservation Service (NRCS) is one method in which the planner considers the effect of implementing a conservation practice on a target problem as well as the other resources (Soil Conservation Service, 1990). While the approach is comprehensive, the consideration is qualitative, possibly site specific, and may not be reproducible or defensible by another expert or someone with less experience.

A second approach towards evaluating conservation systems is a multiple objective decision support system (DSS) that combines existing databases, simulation models, and multi-objective decision theory with a graphic user interface. A prototype multi-objective decision support system (P-DSS), developed by the USDA-Agricultural Research Service, Southwest Watershed Research Center in Tucson, Arizona (Lane et al., 1991; Yakowitz et al., 1992a,b), can be used to evaluate current and alternative management systems when many and possibly conflicting objectives need to be addressed. The P-DSS has the capacity to accept information from simulation models, measured data or expert opinion. Use of the P-DSS to evaluate farming practices in crop lands (Yakowitz et al., 1993; Heilman, 1995) and the design of trench caps for landfill waste (Lane et al., 1991; Paige et al., 1996) are well established, however, the application to rangelands is more recent (Renard and Stone, 1993; Lawrence, 1996). Ideally, all the necessary information to quantify decision criteria should come from a blending of measured data and simulation modeling (for example, runoff, erosion, productivity). In the absence of sufficient data, expert opinion replaces measured data as the primary source of information. However, as the costs of data collection programs rise and the demand for wider applications of the DSS outweighs the available databases and increases the reliance on expert opinion, the effect of information source on the outcome from the DSS becomes an important issue.

The purpose of this article is to compare the outcomes from the P-DSS when measured data and expert opinion are used to quantify decision criteria. Measured data are obtained from the experimental watershed study on the Santa Rita Experimental Range in southern Arizona, while expert opinion is derived from a survey of professionals and experts

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Article was submitted for publication in January 1997; reviewed and approved for publication by the Soil & Water Div. of the ASAE in August 1997. Presented as ASAE Paper No. 96-1007.

The authors are **Paul A. Lawrence**, Principal Scientist, Department of Natural Resources, Brisbane, Queensland, Australia; **Jeffry J. Stone**, Hydrologist, **Philip Heilman**, Economist, and **Leonard J. Lane**, *ASAE Member Engineer*, Hydrologist, USDA Agricultural Research Service, Southwest Watershed Research Center, Tucson, Ariz. **Corresponding author:** Paul A. Lawrence, Department of Natural Resources, Resource Sciences Centre, Indooroopilly, Brisbane, Queensland, Australia 4068; e-mail: <lawrenpa@dpi.qld.gov.au>.

in natural resource conservation. The same experts are also requested to directly rank the alternative management systems, and their responses are compared to the rank ordering of the management systems provided by the P-DSS.

# METHODS

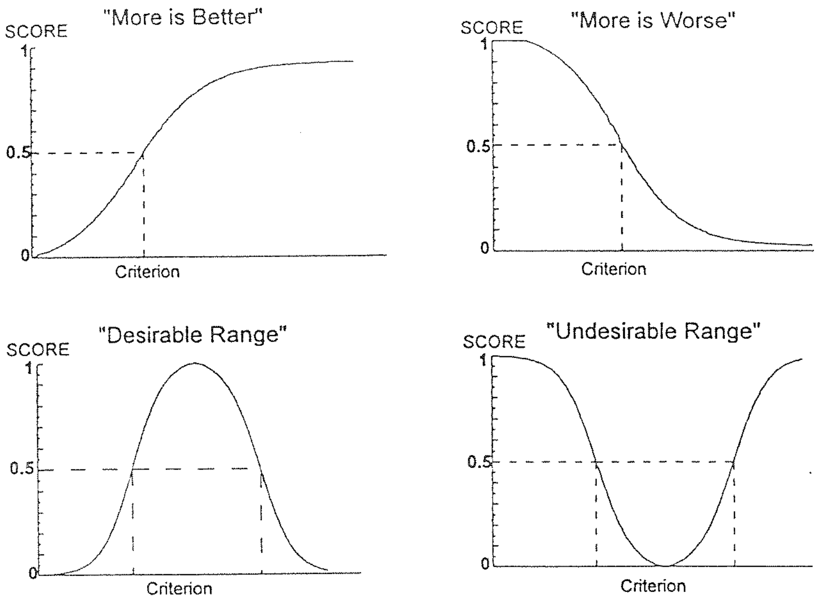
## OVERVIEW OF THE P-DSS

The P-DSS used in this study is a computer-based method to assist the decision maker when multiple, and possibly conflicting, objectives need to be addressed (Lane et al., 1991). By considering the effects of alternative management systems on a range of criteria, the decision maker is presented with a ranking of the alternatives compared to the existing management system for the given importance order of the decision criteria.

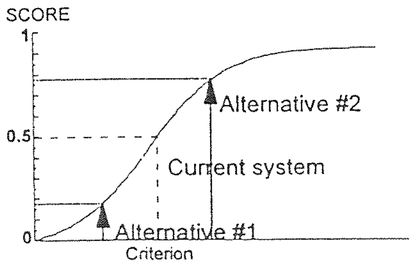
Major components of the P-DSS are the decision model, the simulation model, the input file generator for the simulation model, the graphic user interface and the report generator (Lane et al., 1994). Excluding the decision model, the remaining four components are associated with the assembly of input and output information. Within the decision model there are three sub-components: (a) the score functions and their shapes; (b) the calculation of best and worst scores; and (c) the method of ranking alternatives. A brief description of each subcomponent follows.

**Score Functions and Their Shapes.** The purpose of the score functions is to convert the numerical values for decision criteria, with different units of measure, to a dimensionless quantity or score within the range of 0 to 1. This enables all decision criteria to be compared on a common basis. For decision criteria that are expressed in qualitative terms (for example, aesthetics, wildlife habitat), a user-acceptable index is needed to convert the units of quality to a score value. The score functions are based on the 12 score function shapes proposed by Wymore (1988) and reclassified to four basic score shapes and combined with decision rules developed by Yakowitz et al. (1992a, b). The four score function shapes (fig. 1a) are: more is better (MIB); more is worse (MIW); a desirable range (DR); and an undesirable range (UDR). Further refinement of each score function shape can be achieved by specifying whether the shape is constrained by an upper and/or lower threshold.

In order to provide a reference point, the score functions are set up so that the current or conventional system scores 0.5 as a baseline for each decision criterion. Alternative systems are then scored relative to the conventional system for each decision criterion (fig. 1b). A system that performs



(a) Basic score function shapes.



(b) Scoring alternative systems relative to the current system.

Figure 1–Score functions of the P-DSS showing (a) basic score function shapes, and (b) scoring alternative systems relative to the current system.

better than the conventional system will score higher than 0.5 for that decision criterion, and one that performs worse than the conventional system with respect to the decision criterion will score less than 0.5. All of the alternatives are scored for each criterion to develop a score matrix.

**Importance Order.** Once each decision criterion is scored, aggregating the scores provides a means of ranking the current and alternative management systems. This is normally done by determining an importance order, allocating weights to each score and then summing the scores to determine the total composite score. However, assigning weights is a difficult and subjective process for the decision maker and may have a large impact on the outcome. The method of Yakowitz et al. (1993) partially overcomes this problem by calculating the best and worst possible scores for all possible weight vectors for an importance order. The P-DSS initially determines a default importance order based on the slope of the scoring function. The importance for each decision criterion is calculated by multiplying the slope of the score function at the point of average annual value by the difference between the maximum and minimum annual values. This method of determining an importance order assumes that the criterion that is most sensitive to a change in the score is the most important. However, in the majority of cases, the importance or priority order is specified by the user or community interest group. Without the need to assign explicit weights to the decision criteria, the importance order can be rearranged to undertake 'what if' scenarios using the P-DSS.

Best and worst composite scores for each alternative are determined by solving two linear programs. For a total of m decision criteria:

Best Composite Score (*Worst Composite Score*):
maximize (*minimize*):

$$\text{maximize ( } \textit{minimize}\text{):} \sum_{i=1}^{m} w(i) \times Sc(i,j) \qquad (1)$$

$$\text{subject to: } \sum_{i=1}^{m} w(i) = 1 \qquad (2)$$

$$w(1) \geq w(2) \geq \ldots \geq w(m) \geq 0 \qquad (3)$$

where

$w(i)$ = weight factor based on the importance order for decision criterion i
$Sc(i, j)$ = score of alternative j evaluated for decision criterion i

The best and worst composite scores reflect the most optimistic and pessimistic solutions consistent with the importance order, and represent the full range of possible composite scores for the given importance order.

**Ranking Alternatives.** Computation of the best and worst scores can be used to rank the management systems. By definition, Alternative j dominates all other alternatives if the worst score for Alternative j is greater than the best scores for all other alternatives. If clear dominance is not established between the alternatives (i.e., partial ranking), then a method to rank the alternatives is needed. One method to select the preferred alternative is to rank, in descending order, the average of the best and worst composite scores for the management systems (Yakowitz et al., 1993). The determination of the best and worst composite scores establishes the maximum and minimum overall score possible for any combination of weights consistent with the importance order. In addition, the difference between the best and worst composite scores is a measure of the sensitivity of the outcome to the weightings of the decision criteria.

### SELECTION OF MANAGEMENT SYSTEMS AND DECISION CRITERIA

Four rangeland management systems are evaluated for the Santa Rita Experimental Range (SRER). The grazing systems are continuous yearlong grazing (YL) and rotational grazing (ROT). Stocking rate for continuous grazing is approximately seven head per section, which is regarded as conservative. Under rotational grazing, cattle graze once during March to October and once during November to February with 12 months rest between grazing periods in a three-year rotation (Martin, 1973). Each grazing system has mesquite trees (*Prosopis velutina* Woot.) retained (+m) and removed (-m). When mesquite is controlled, herbaceous cover and grass production can increase (Parker and Martin, 1952; Martin, 1963) while soil loss and runoff can decline (Renard et al., 1991; Martin and Morton, 1993). However, the spread of introduced grasses, mostly Lehmann lovegrass (*Eragrostis lehmanniana* Nees.), to replace mesquite and revegetate degraded areas provides lower faunal diversity compared to native grasses (Anable et al., 1992) and reduces range condition (Smith, 1984). For this analysis, the yearlong grazing with mesquite retained (YL+m) is the current baseline management system to evaluate the alternative management systems (YL-m, ROT+m, ROT-m). These management systems are indicative of rangeland practices in southern Arizona.

The CPPE framework is used to identify eight decision criteria that address soil, water, plant and animal resources. The decision criteria selected are: sediment yield; channel erosion; watershed runoff; maximum peak rate of runoff; aboveground net primary production (ANPP); range condition; and wildlife habitats for javelina and Gambel's quail. These eight criteria are not exhaustive of all the considerations and problems associated with rangelands in the semiarid areas of southern Arizona, but are a subset of the variables that are important when evaluating alternative management systems. If other data are available (for example, socio-economic considerations, consumable forage, soil fertility status), then these data can also be included in the analysis using the P-DSS.

### SOURCES OF INFORMATION

Two sources of information are used to quantify the decision criteria in the P-DSS. First, measured data from four Agricultural Research Service experimental watersheds on the Santa Rita Experimental Range (fig. 2) are used to quantify the eight decision criteria (Lawrence, 1996). The watershed study has been in operation since 1976 and some physical characteristics of the watersheds are given in table 1.

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Figure 2–Santa Rita Experimental Range and location of the four experimental watersheds.

Table 1. Physical characteristics of the four ARS Santa Rita experimental watersheds

| | Watershed | | | |
|---|---|---|---|---|
| Characteristic | WS8 | WS7 | WS5 | WS6 |
| Drainage area (ha) | 1.12 | 1.06 | 4.02 | 3.08 |
| Grazing system | Yearlong | Yearlong | Rotation | Rotation |
| Vegetation type | Mesquite and grass | Grass | Mesquite and grass | Grass |
| Management system ID | YL+m | YL-m | ROT+m | ROT-m |
| Soil type | Sasabe sandy loam | Sasabe sandy loam | Sasabe sandy loam | Diaspar loamy sand |
| Watershed length (m) | 237 | 266 | 386 | 487 |
| Watershed slope (%) | 4.21 | 3.38 | 3.10 | 1.85 |
| Channel length (m) | 112 | 145 | 217 | 146 |
| Channel slope (%) | 4.95 | 4.62 | 4.55 | 4.76 |

Mean annual rainfall is 441 mm, although annual totals are variable from 273 to 711 mm (1976-1991). The watersheds are dominated by Lehmann lovegrass. Aerial coverage of Lehmann lovegrass ranges from 47 to 70%, while mesquite trees in watersheds WS8 and WS5 is approximately 20 to 25 % (Mr. Dan Robinett, pers. comm.). The watersheds are selected on the basis of their similar elevation (1170 m), and relatively uniform soils and hydrologic features (table 1).

The second information source is expert opinion. Information was obtained by surveying nine experts in natural resource management for southern Arizona (Lawrence, 1996). The experts, selected from the University of Arizona and USDA, have professional experiences in watershed management, erosion processes, rangeland management, wildlife management and resource economics. Within their individual disciplines, the experts processed a working knowledge of the site conditions at figure 2 - 100%

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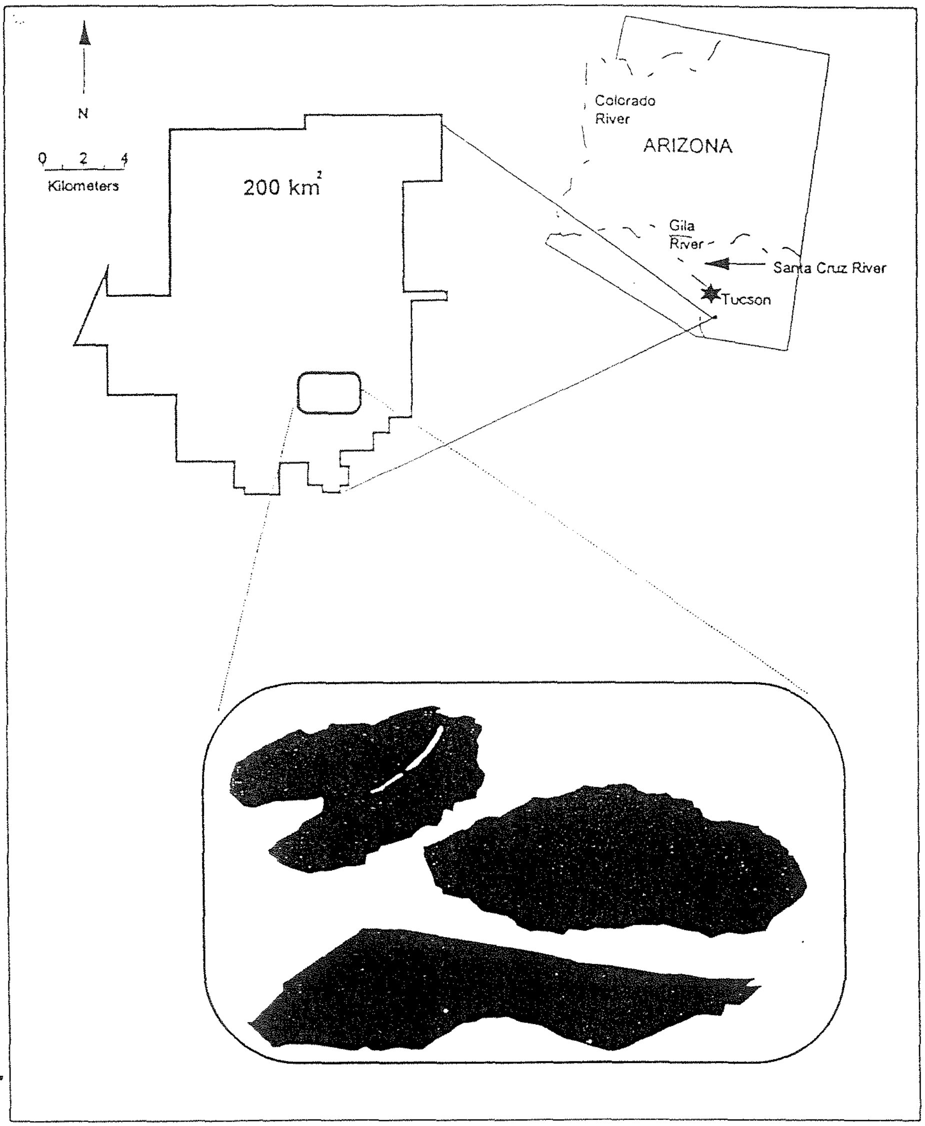

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Figure 2. Santa Rita Experimental Range and location of the four experimental watersheds.

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the SRER. Each were asked to quantify (annual minimum, maximum and average) the eight decision criteria (sediment yield, channel erosion, watershed runoff, peak rate of runoff, aboveground net primary production, range condition, and wildlife density for javelina and quail) for the current system of yearlong grazing with mesquite retained (YL+m), and to quantify the relative effect of the alternative management systems on each decision criterion. The experts also nominated an order of importance for the decision criteria and a direct ranking of the four management systems. Finally, each expert was asked to self-assess their knowledge of each decision criterion on a scale of 0 to 10. This assessment is used to arbitrarily distinguish discipline experts (with a knowledge level ≥ 7) from general experts.

## RESULTS AND DISCUSSION

### COMPARISON OF AVERAGE ANNUAL VALUES

Average annual values and coefficient of variation for six of the decision criteria are presented in figures 3(a and b), respectively. Values for javelina and quail are not included in figure 3 as the measured data source used the NRCS Wildlife Habitat Evaluation Guide while the survey values are based on the numbers of animals for a kilometer transect.

There appears to be good agreement between measured and expert opinion for average annual values of ANPP and sediment yield (fig. 3a). The discipline experts' estimate of runoff depth and maximum peak rate of runoff appear to underestimate the time series measurements for these hydrological properties. However, when information from all the experts is used, there is closer agreement with measured data for runoff and maximum peak runoff. The expert opinion value for range condition is approximately three times the magnitude of the field determination. Reasons for the differences may be associated with the unfamiliarity of some of the experts with the extent of intrusion of Lehmann lovegrass at the experimental watersheds which impacts on the value of range condition. For two experts quite familiar with the experimental watersheds, there was very close agreement between their judgement and field measurements for range condition. ANPP represents the closest agreement between measured values and expert opinion and the least variable among the experts. Figure 3(b) shows there is greater variation among the discipline experts than among all experts for peak runoff, sediment yield, range condition and wildlife habitat. Sediment yield displays the largest variation for both all experts (134%) and the discipline experts (171%) (fig. 3b).

### IMPORTANCE ORDERS

A distinguishing feature of the P-DSS is the use of an importance order to partially overcome the difficulty of assigning individual weights to the decision criteria. For this analysis, five importance orders are used. In addition to the two default importance orders (one for measured data and one for expert opinion), the analysis included an equal weighting vector importance order (IO No. 2), and three importance orders determined by the experts. Importance order IO No. 3 is defined as the aggregate of the rankings of the decision criteria as provided from the survey responses. The fourth importance order (IO No. 4) is defined as the aggregate of the ranked decision criteria weighted by the self-assessed knowledge level of each expert. Finally, the fifth importance order (IO No. 5) is defined as the aggregate of the ranked decision criteria for experts with a self-assessed knowledge level for the decision criterion of 7 or greater. The default importance orders and the three expert survey importance orders (IO No. 3-IO No. 5) are given in table 2.

There is some consistency among the experts to identify important criteria to evaluate resource management systems. Table 2 shows that sediment yield is the single most important criterion. The experts place greatest importance on this decision criterion even though the aggregated knowledge level of the experts is greater for range condition and ANPP than for sediment yield. This suggests that the determination of the importance order is not biased by the background and knowledge level of the experts. After sediment yield, the experts place greater importance on channel erosion, ANPP and range condition than on runoff, peak rate of runoff and wildlife habitat.

### SURVEY RESPONSES FOR THE PREFERRED MANAGEMENT SYSTEM

The survey requested the experts to directly rank the four resource management systems from society's viewpoint. The responses are analyzed by: (1) aggregating the rank order of each management system for all the experts; (2) aggregating the rank order for each management system for those experts with a total self-assessed knowledge level of 40 or greater (i.e., average knowledge level of 5 or greater per decision criterion); and (3) using the opinion of the expert with the highest self-assessed knowledge level. This expert had a self-assessed knowledge level of 57. The results of the analysis to identify the preferred resource management system are given in table 3.

The results indicate that the experts favor the use of rotation grazing systems over yearlong grazing system. There is no difference in the rank order of the management systems between the collective wisdom of all the experts and the subset of discipline experts. The expert with the highest knowledge level, however, placed greater preference on the control of mesquite than on the grazing system. This preference may be associated with the light stocking rates for continuous and rotational grazing, and where the impact of mesquite control can lead to significant improvement in grass growth (Martin 1963; Martin and Morton, 1993). Assuming the highest rank order represents the "best" management system, table 3 indicates the expert survey identified ROT-m as the preferred natural resource management system for this site.

### IDENTIFYING THE PREFERRED MANAGEMENT SYSTEM

Resulting composite scores from the P-DSS evaluation of the management systems, where the decision criteria are quantified using measured data and expert opinion, are given in figures 4 and 5, respectively. Outcomes using Importance Order No. 4 are identical to Importance Order No. 5, and so are not presented. In figures 4 and 5, the best and worst composite scores for the YL+m (conventional) system are both 0.5 because this practice scores 0.5 for all criterion. The upper and lower bounds of each bar define the best and worst composite scores, respectively, while the height of the bar indicates the sensitivity of the total score to the possible weights (consistent with the importance

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(a) Quantifying decision criteria.

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(b) Variation in decision criterion values.

**Figure 3–Comparison of measured data and expert opinions for (a) quantifying the decision criteria, and (b) variation within the decision criterion.**

order). When the decision criteria are of equal importance (IO No. 2) and there is no weighting vector, the best score equals the worst score and so a line rather than a bar is shown in figures 4(b) and 5(b).

Using measured data to quantify the decision criteria, rotation grazing with mesquite removed (ROT-m) appears to be the preferred management system (fig. 4). The ROT-m system is slightly better than the YL-m system. This outcome is consistent for all importance orders with the exception of the equal importance IO No. 2 assessment (fig. 4b). For all importance orders, the mesquite removed treatments (i.e., YL-m and ROT-m) are preferred to the conventional system of yearlong grazing with mesquite retained (YL+m). Rotation grazing with mesquite retained (ROT+m) is the least preferred management system (fig. 4).

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(a) Quantifying decision criteria

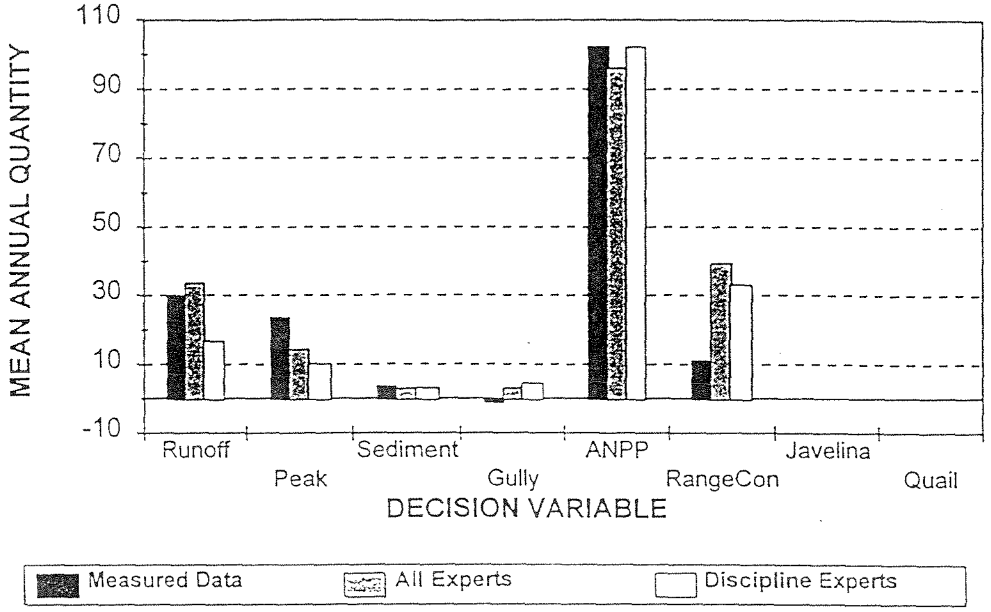

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fig 3a - 100%

(b) Variation in decision criterion values

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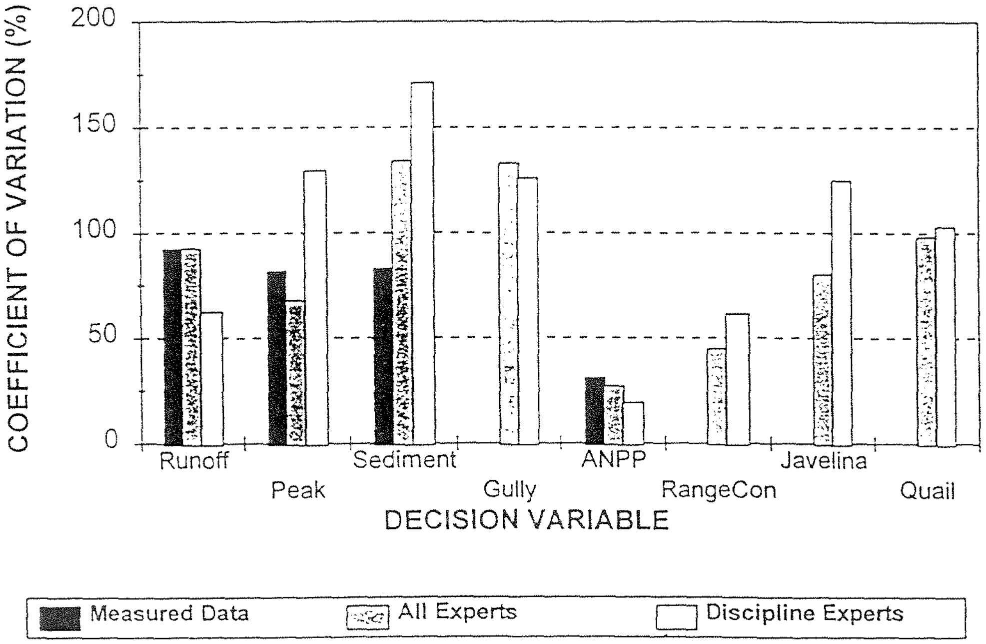

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fig 3b - 100%

Figure 3. Comparison of measured data and expert opinions for (a) quantifying the decision criteria and (b) variation within the decision criterion.

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Table 2. **Importance orders for the decision criteria used in the P-DSS (IO No. 1 based on quantities obtained from measured data and expert opinion, IO No. 2 is an equal weighting vector, and IO No. 3 to IO No. 5 based on expert survey)**

| Rank | Importance Order IO No. 1 (Based on Measured and Expert Values) | | Importance Order (Based on Expert Survey) | | |
|---|---|---|---|---|---|
| Order | Measured | Expert | IO No. 3 | IO No. 4 | IO No. 5 |
| 1 | RangeCon* | Runoff | SedYield | SedYield | SedYield |
| 2 | Channel | Quail | RangeCon | Channel | Channel |
| 3 | Runoff | Channel | Channel, ANPP† | RangeCon | ANPP |
| 4 | Qpeak | SedYield | - | ANPP | RangeCon |
| 5 | SedYield | Javelina | Runoff | Qpeak | QPeak |
| 6 | ANPP | QPeak | QPeak | Runoff | Javelina |
| 7 | Quail | RangeCon | Quail | Quail | Quail |
| 8 | Javelina | ANPP | Javelina | Javelina | Runoff |

* RangeCon = NRCS range condition.
Channel = channel erosion.
Runoff = annual runoff.
Qpeak = annual maximum peak runoff rate.
SedYield = annual sediment yield.
ANPP = aboveground net primary production.
Quail = NRCS wildlife habitat index for Gambels quail.
Javelina = NRCS wildlife habitat index for javelina.
† Channel erosion and ANPP given equal importance.

Table 3. **Rank order of the preferred resource management systems obtained by direct questioning of experts**

| | Aggregate Score | | |
|---|---|---|---|
| Rank | All Experts | KL* ≥ 40 | Expert with Highest KL |
| 1 | ROT-m | ROT-m | ROT-m |
| 2 | ROT+m | ROT+m | YL-m |
| 3 | YL-m | YL-m | ROT+m |
| 4 | YL+m | YL+m | YL+m |

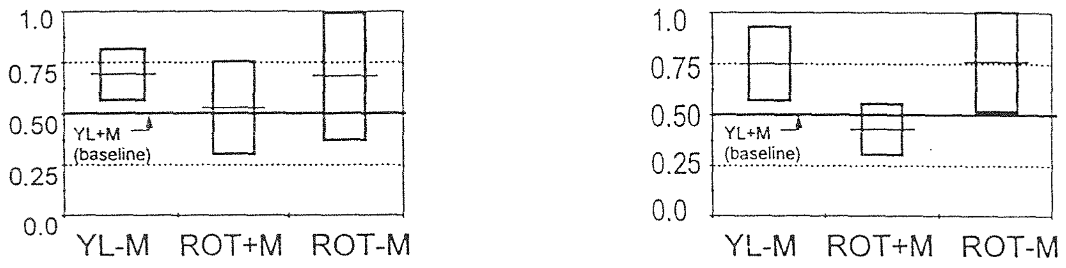
* Self-assessed knowledge level by expert (scale 0-10 for each decision criterion).

When expert opinion is used to quantify the decision criteria, yearlong grazing with mesquite removed (YL-m) is the preferred management system (fig. 5). With the exception of the default importance order (fig. 5a), the average of the best and worst composite score for YL-m is greater than the other alternatives.

The length of the bars in figures 4 and 5 reflects the difference in scores of the decision criteria and the sensitivity of the outcome to the possible weighting vector. The measured data scores are more sensitive to any particular weighting vector than those from the expert opinion. The reasons for this outcome may be associated with the experts being more conservative in defining the full range of values (minimum to maximum) for the decision criteria compared to the actual variability which exists in the measured values for the decision criteria. For example, measured annual runoff for YL+m was 0-115 mm $yr^{-1}$ (1976-1991), while the responses from the expert survey for annual runoff ranged from 0 to 37 mm $yr^{-1}$. This represents one of the differences between time-series information (measured data) and the nature of point of time information provided by experts.

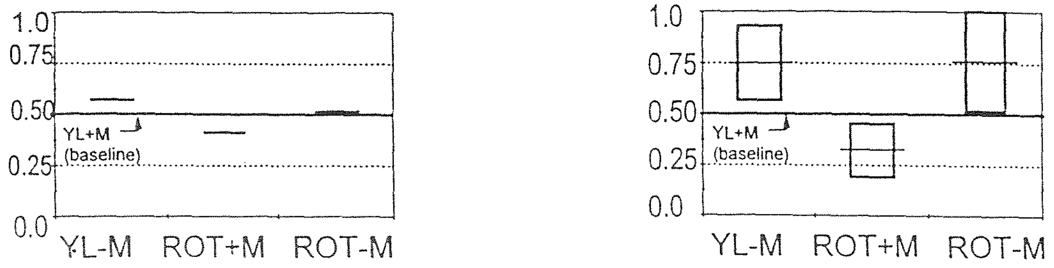
### THE P-DSS AND RANKING BY EXPERTS

A frequency of rank method (Imam, 1994) is used to aggregate the five importance orders for the two information sources. This method determines the frequency with which an alternative occupies a rank order for each importance order, divided by the total number of ranking vectors (in this case, 4 rankings * 5 importance orders) as a means of identifying preference. The results are given in table 4 and compared to the direct ranking of the four management systems determined by the expert survey. The expert opinions are given in three forms, namely: (1) the opinion of all the experts; (2) the opinion of the discipline



(a) Importance order no. 1.

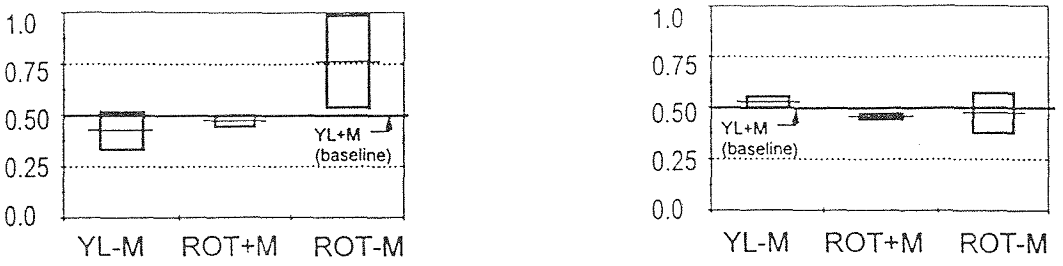
(c) Importance order no. 3.



(b) Importance order no. 2

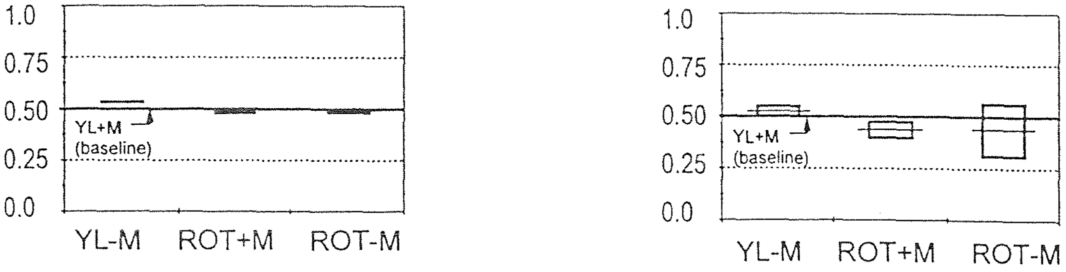
(d) Importance order no. 5.

Figure 4–Composite scores of the alternatives using measured data to quantify the decision variables with four different importance orders (see table 2).



(a) Importance order no. 1.

(c) Importance order no. 3.



(b) Importance order no. 2.

(d) Importance order no. 5.

Figure 5–Composite scores of the alternatives using expert opinion to quantify the decision variables with four different importance orders (see table 2).

Table 4. Comparison of preferred resource management systems obtained from the expert survey and for measured data and expert opinion information sources

| Rank of Management System | Results from Expert Survey | | | Results from P-DSS | |
|---|---|---|---|---|---|
| | All Experts | Discipline Experts | Highest KL Expert | Measured Data | Expert Opinion |
| 1 | ROT-m | ROT-m | ROT-m | ROT-m | YL-m |
| 2 | ROT+m | ROT+m | YL-m | YL-m | YL+m |
| 3 | YL-m | YL-m | ROT+m | YL+m | ROT-m |
| 4 | YL+m | YL+m | YL+m | ROT+m | ROT+m |

experts; and (3) the opinion of the expert with the highest knowledge level (KL) of the decision criteria.

A comparison of the information sources shows that ROT-m is the preferred management system among all the direct forms of expert opinion and the measured data as an information source. Table 4 also shows that the preference ranking of management systems for all experts and the subset of discipline experts are identical. Further, the most knowledgeable expert recommends ROT-m and YL-m as the two preferred systems, and this is also identified by the P-DSS using measured data as the information source.

Ranking of the management systems using expert opinion as the information source in the P-DSS did not match the direct ranking provided by the same experts (table 4). When the information from experts is used, the preference is for yearlong grazing systems rather than rotation grazing systems. This outcome may be associated with the form of the survey and the absence of follow-up discussions with the experts to clarify their responses.

## CONCLUSIONS

The prototype multi-objective decision support system (P-DSS) developed by the Southwest Watershed Research Center in Tucson, Arizona, is used to select the preferred management system from four feasible grazing and vegetation manipulation systems. The evaluation incorporates eight decision criteria quantified using information from measured data sources and judgments obtained from a survey of nine experts, and five importance orders. The importance orders are based on a default importance order, an equal weighting of importance, and the opinion of experts and their level of knowledge about the decision criteria.

Information source influences the outcome from the P-DSS. When measured data are used, ROT-m and YL-m are the two preferred management systems, whereas YL-m and YL+m are the preferred systems when expert opinion is used. The former favors the control of mesquite while low input grazing management is emphasized using expert opinion. When compared to direct ranking by experts, the outcomes using measured data agree with the preferred choice by the experts and the two highest ranked systems recommended by the most knowledgeable expert. However, the use of information obtained from experts to quantify the decision criteria did not match their direct ranking of the four management systems. This discrepancy between the expert's ranking and the P-DSS's ranking based on expert inputs represents a concern for future use of the technology, particularly when information sources are blended. This issue may be addressed by making experts more familiar with the site where the P-DSS is to be applied, and by follow-up consultation with the experts regarding their survey responses. It is recommended that experts be involved early in the discussions to assist in identifying appropriate decision criteria, the relative importance ranking of these criteria, and to validate the outcomes from the P-DSS.

**ACKNOWLEDGMENTS.** The contributions from the nine experts at the University of Arizona School of Renewable Natural Resources, USDA-ARS and NRCS, are gratefully appreciated. The authors wish to thank field and data processing staff at the Southwest Watershed Research Center for maintaining the Santa Rita experimental watersheds, and Dr. Diana Yakowitz for discussions on this article. Support from the Queensland Department of Natural Resources and the Rural Industries Research and Development Corporation, Australia, which allowed the first author (PAL) to undertake graduate studies at the University of Arizona, is gratefully acknowledged.

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