Development and Initial Application of an Integrated Linear Programming/Social Accounting Model: Rangeland Livestock Application

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Introduction

Leased Bureau of Land Management (BLM) and United States Forest Service (USFS) land are an integral part of ranch production in Elko County, Nevada. The area of Elko County is approximately 11,000,000 acres, of which over 70 percent or nearly 8,000,000 acres are federal lands (Zimmerman and Harris, 2000). A previous survey of ranches in northeastern Nevada found only 4 out of 56 ranches that did not use federal land for grazing. On average, the ranches used federal rangeland to provide 49 percent of the feed requirements for their animals (Torell et al., 1981).

Because of the multiple use character of Federal BLM and USFS lands, reduction of availability of federal grazing is often under consideration. For example, recently, changes in federal grazing land management have been under consideration in Elko County because of concerns over wildlife habitat for Lahontan cutthroat trout, sage grouse, and other species (Bureau of Land Management, 2006, Harding, 2006). It is clear that reducing access to available animal unit months (AUMs) of grazing will impact ranchers in Elko County. With changes in ranching activity, the economy of Elko County will also be impacted.

Past studies have investigated the impacts of federal grazing policies on western ranches by using linear programming models (Oleson and Jackson, 1975; Peryam and Olson, 1975; Gee, 1981; Torell et al., 1981; Wilson et al., 1975; Torell and Drummond, 1977). In some cases, results of these linear programming models are incorporated into county input-output models to derive regional impacts of changes in federal public lands policies. Foulke et al. (2006) and Alevy et al. (2007) generated ranch level results from alternative public lands models and incorporated results into an input-output model for county-wide impacts. This two-step approach is quite time burdensome and clumsy. This approach also hampers analysis of alternative public lands policies.

Previous studies by Brink and McCarl (1974) and Everett and McCarl (1976) show how to link firm level linear programming models with input-output models to simultaneously derive firm and county level impacts. Bowker and Richardson (1989) employed farm level linear programming and input-output models to simultaneously derive farm level and county level impacts from alternative farm policies. However, input-output models do not provide institutional impacts from alternative federal policies. For this paper, an integrated linear programming/social accounting matrix model will be developed to estimate ranch level and county level impacts of alternative public lands policies.

Linear Programming/Social Accounting Matrix Integrated Model

To derive distributional impacts of alternative public land management policies on county/regional economics, Social Accounting Matrices (SAM) models can be employed. SAM models have been applied for impact analysis of income distribution and employment in developing countries (Pyatt and Round, 1985; Cohen, 1989). In addition, a few linear programming models have been applied to problems of regional economic planning (Everett and McCarl, 1978; Bowker and Richardson, 1981).

Linking linear programming and input-output models has some advantages, particularly its capability in providing optimum solutions by considering resource limitations and conflicting objectives. However, optimal solutions which show household income distributional impacts are not available through LP/I-O modeling. Thus, an integrated linear programming/SAM model would have the distinctive advantage compared to other modeling approaches. The integrated linear programming/SAM model for analysis of public land management policies can be stated below:

$$\text{Max: } Z_0 = C^1 X + 0X^1 + 0X^{11} \tag{1}$$

Subject to:

$$DX \leq B \tag{2}$$

$$VX - X^1 = 0 \tag{3}$$

$$-PX^1 + (I - S)X^{11} \leq Y \tag{4}$$

Where:

C is a vector of net returns to ranch level activities,

X is a vector of ranch level activities,

D is a matrix of technical coefficients of inputs used by the ranch,

B is resource availabilities,

P is a matrix of ranch per unit use of each social accounting sector,

V is a vector to change input-output sector commodities to input-output sector industries,

X^1 is a vector of ranch level sector industry outputs,

X^{11} is a vector of social accounting sector outputs for the county/region,

Through the social accounting sector, proprietor income will be estimated. Since a rise in the grazing fee may not change the level of output but will reduce ranch sector incomes, these county/regional impacts are derived in equation 4. Also, by reducing grazing rights, the ranch level linear programming model is used to derive levels of ranch production. By integrating the SAM model, not only are economic sectoral impacts derived but also impacts to county/regional employee compensation, proprietor income and alternative levels of household incomes estimated through the integrated LP/SAM, the distributional impacts of alternative public land management policies is estimated.

An Application of the LP-SAM Model for Public Lands Management

The application developed below is derived from a model of ranching activities in Elko County, Nevada. In this model, the S matrix of SAM direct coefficients (equation 6) is of dimension 22 by 22 and contains the following elements:

1. *A* is a 9 by 9 matrix of technical coefficients which aggregates economic activity into the (i) hay, (ii) cattle, (iii) other agriculture, (iv) mining, (v) utilities, (vi) construction, (vii) manufacturing, (viii) trade, and (ix) service sectors.
2. *V* is a 4 by 9 matrix consisting of the components of value-added with the four rows consisting of (i) employee compensation, (ii) proprietary income, (iii) other property income and (iv) indirect taxes. The matrix contains columns for each of the nine activities.
3. *Y* is a 9 by 4 matrix containing the distribution of value-added to households, with the 9 rows corresponding to different ranges of household income. The four columns of *Y* include the components of value-added, delineated in 2.
4. *C* is a 9 by 9 matrix of expenditure coefficients of the households for each of the activities.
5. *H* is a 9 by 9 matrix of inter-household distribution coefficients.

The *S* matrix is therefore a 22 by 22 matrix of the endogenous components of the SAM for the county. Table 1 presents the matrix components along with their IMPLAN codes.

Table 1: Sectors in Regional Model.

IMPLAN Number	Sector	
1	Agfood	Activities
10	Hay	
11	Cattle	
19	Mining	
30	Utilities	
33	Construction	
46	Manufacture	
390	Trade	
391	Service	
5001	Employee Compensation	Value Added
6001	Proprietary Income	
7001	Other Property Income	
8001	Indirect Business Taxes	
10001	Households LT10k	Households
10002	Households 10-15k	
10003	Households 15-25k	
10004	Households 25-35k	
10005	Households 35-50k	
10006	Households 50-75k	
10007	Households 75-100k	
10008	Households 100-150k	
10009	Households 150k+	

The endogenous sectors captured in the SAM are integrated in the LP-SAM model as shown in equations 1-4. Equation 1 is the objective function for the cattle sector with X the production activities for cattle and hay and *C* their net returns. The resource constraints represented by equation 2 incorporate equations for hay purchases and sales so that alternative sources of feed are available when policy alternatives regarding the availability of federal AUMs are considered. Similarly, the model contains flexibility to change relevant parameters related to cow-calf production. Importantly, the model incorporates seasonal variability in the availability of AUMs and variation in the types of federal AUMs available in order to reflect differences in ranch types. The LP determines solutions at the level of each of five ranch types. These five ranch types were for season of use and under alternative federal agency administration (table 2).

Equation 3 transforms the outputs of ranch activity using *V*, a commodity to industry conversion vector which accounts for the fact that an industry can produce more than one commodity. Translating ranch activities by this vector yields the ranch level activities at the industry level, that is, in terms of X^1.

Ranch production in these sectors, along with proprietor income, is transformed by *V* and used in equation 4 to measure the impact of policy changes on the regional outputs, X^{11}. This formulation allows for the direct measurement of the ranch- level policy impacts on the regional output

Table 2. Federal AUMs & private acreage by ranch type

Ranch Type	Total BLM (AUM's)	Total Forest Service (AUM's)	Total Deeded Range (AUM's)
Fall	2300	1740	1300
Spring	2300	1740	1300
Winter	9600	-	-
Fall NFS	4239	-	1102
Spring NFS	4239	-	1102

NFS = No Forest Service lands
SOURCE: Torell et al., 1979.

Results

Table 3 shows results of the integrated LP/SAM model for Elko County. The Base column is for no change in public land policies. The Percentage Reductions represent decreases in grazing permits and Fee Increases represents increases in current grazing fees. From table 3, the Livestock Sector realizes a decrease in value of output from $155,899 to $89,818 at a 50 percent reduction in grazing permits or a decrease in value of output of 42 percent. Even with a 50 percent reduction in grazing permits, Elko County ranchers have private land, alfalfa hay production, and the opportunity to import alfalfa hay to supplement livestock so to reduce impacts of production decreases from grazing permit limitations. The Elko County households of $50,000 to $75,000 realized the largest impacts from these decreases in grazing permits.

Of interest are the minimal impacts of grazing fee increases. With doubling of grazing fees, the Livestock Sector realizes only a 0.02 percent decrease in value of production. The primary impact on increased grazing fees is its impacts on incomes to the livestock producer. The livestock producer will realize lower returns but the production levels of this sector do not decrease.

Table 3: Results from Integrated Ranch Level Linear Programming and SAM Model Under Alternative Public Land Management Scenarios, Elko County, Nevada.

Sector	Base	Reductions in Grazing Permits					Increases in Grazing Fees		
		10%	25%	50%	75%	100%	Double	Triple	Quadruple
ag	11883	11213	9848	7357	4866	1390	11748	10973	10849
hay	136718	128641	111457	79708	47958	2654	136712	126911	126906
cattle	155899	146579	126659	89818	52978	211	155875	144229	144207
min	25616	24272	21668	16981	12295	5981	25175	23868	23465
util	25493	24080	21294	16265	11236	4315	24913	23232	22702
cons	7529	7112	6275	4756	3236	1135	7419	6950	6850
manu	20388	19325	17264	13553	9842	4851	20066	19064	18770
trade	79220	74861	66577	51831	37086	17069	76216	70605	67860
service	359362	339743	302838	237376	171915	83560	344887	319733	306507
ind_tax	63239	59836	53189	41211	29234	12934	61976	58311	57157
hh_lt10	1928	1824	1652	1363	1074	705	1762	1597	1446
hh_1015	3562	3371	3054	2521	1988	1308	3254	2948	2667
hh_1525	11711	11083	10041	8290	6538	4303	10698	9692	8765
hh_2535	21612	20452	18530	15299	12067	7944	19740	17883	16173
hh_3550	42266	39998	36238	29920	23601	15538	38604	34973	31627
hh_5075	111261	105291	95394	78764	62133	40913	101618	92057	83247
hh_75100	59069	55900	50646	41817	32988	21723	53949	48873	44195
hh_100150	47853	45286	41029	33877	26725	17599	43705	39593	35803
hh_grt150	15295	14475	13114	10828	8542	5625	13969	12655	11443

Conclusions

For many western United States counties, changes in public land policies not only impact the firm but also the county economy. This paper presents initial results of an integrated linear programming/SAM model. Model results indicate that ranch level and county level impacts are realized more severely from grazing permit reductions than from grazing fee increases. Further analysis can be preformed using this model.   First step is to derive from the ranch models, regional output changes for the Range Livestock Sector. Given the detailed ranch level linear programming, ranch and county level impacts can be made from changes in seasonal use or by different federal land agencies.

Analysis also can derive through time by using a multi-year linear programming/SAM integrated model. Risk analysis could additionally be completed by developing stochastic annual grazing permits. Lastly through a multi-year model, impacts of rangeland fires could be estimated at the ranch and county level.

The ranch level linear programming and SAM model could also incorporate recreational and environmental concerns. Showing trade-offs between environmental and recreation activities and range cattle operations and impacts to the local economy. Ultimately, incorporation of the ranch level linear programming model into Computable General modeling framework is desired.

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