tive to that of other crops total production declines. When increased prices for corn and soybeans are combined with lower production costs resulting from the use of less nitrogen, farm income increases $2 billion. The 100-pound restriction does not significantly affect producers' income.

Both the 50- and 100-pound restrictions increase consumer costs. The effect of the 50-pound restriction is more significant.

While these results indicate the general response to specific restrictions, the fact that demand curves for minor crops are not included may introduce some bias (a fixed quantity of minor crops is specified in the model under an inelastic demand curve). The model does not have as much flexibility to meet these constraints as exists in the real world. But we consider the general findings to be a reasonable reflection of what could be expected in a real situation—lower corn and soybean acreage and higher prices for these crops, resulting in improved farm income, a negative impact on consumers, and an overall impact in terms of net social costs.

Concluding Remarks

Our study shows that reasonable erosion control programs can be implemented without having serious economic impacts on the agricultural sector or consumer expenditures. Soil-loss coefficients may be low, however. If so, impacts are underestimated. Though we did not test them with this model, we consider the tolerance limits used by the SCS to be "reasonable."

Contrary to popular belief, the economic burden of the restriction falls more on consumers than on producers for many of the controls considered. This occurs because the model includes demand and supply functions for the major crops. The impacts of controls are translated into higher prices, which increase gross farm receipts. The higher receipts help offset or more than offset the higher production costs or lower yields associated with the controls. A model limited to fixed commodity prices will not demonstrate such results.

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Grazing and logging effects on soil surface changes in central Colorado's ponderosa pine type

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ABSTRACT—Measurements of soil surface elevation on ponderosa pine-bunch lands in central Colorado showed 35 years of grazing and winter logging had not caused serious erosion. All measurements indicated an aggradation of soil surface material in relation to differences in ground cover, grazing, and timber removal. Aggradation on ungrazed areas exceeded aggradation on grazed or logged areas by less than 7 millimeters.

FORESTS and rangelands may contribute to nonpoint water pollution (9). While the effects of livestock grazing and commercial logging on water quality are not well defined in most areas, public land managers need to understand the effects of such activities in order to comply with the Federal Water Pollution Control Act Amendments of 1972 (7).

Among the major nonpoint pollutants are sediment, nutrients, pathogens, and pesticides. Sediment, the most common of these, may be a product of geological erosion (7) or accelerated erosion resulting from such land use activities as timber harvesting and grazing.

Sediment from nonpoint sources is difficult to measure directly. It is possible, however, to estimate the pollution threat from sediment by measuring erosion. Such measurements require pretreatment and post-treatment evaluation of well-defined surface features by a reliable, repetitious method. Data for assessing such soil losses have been collected in Colorado's Manitou Experimental Forest.

Our report examines measured changes in soil surface elevation on a ponderosa pine-bunchgrass area that was subjected to treatment for many years. Measurements in 1976 were compared with measurements in 1941 for different ground cover, grazing, and timber harvest treatments (Figure 1).

Study Area

The Manitou Experimental Forest is located in the ponderosa pine zone 45 kilometers (28 mi) northwest of Colorado Springs. The headquarters is at an elevation of about 2,375 meters (7,800 ft). Precipitation at the headquarters averaged 40 centimeters (15.75 in) a year for the 35-year period, 1941 through 1975. About three-fourths of this precipitation falls from April through August. July normally is the wettest month with rainfall averaging 8.5 centimeters (3.33 in). Soil erosion nearly always occurs during a few severe summer storms (2).

Soils are derived from Pikes Peak granite (3). They are a sandy loam or sandy clay loam with low fertility and moderate amounts of organic matter. The soils are porous when wet and very hard when dry. They are highly erodible when plant cover, litter, and humus are removed or damaged.

Vegetation is characteristic of the ponderosa pine-bunchgrass type of the central and southern Rocky Mountains. Open grassland parks are interspersed among ir-

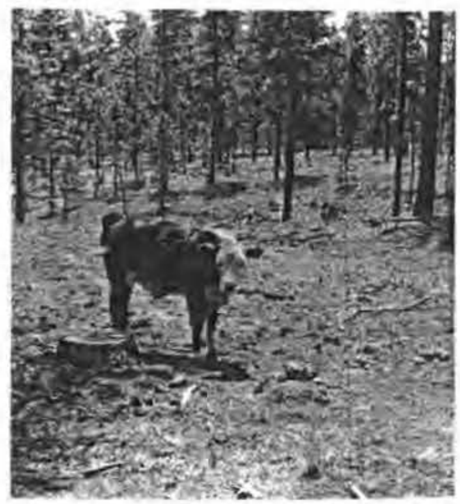

Figure 1. This ponderosa pine-bunchgrass range has been grazed by livestock since 1937. The area was logged commercially during the winter of 1967-1968. Soil surface profiles were measured systematically on different ground covers to evaluate the effects of both land uses.

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regular stands of ponderosa pine (1). The understory contains many grasses and forbs. Shrub species are limited. Litter and duff accumulations are common beneath the open growing pine. These accumulations form a mat 2.5 to 7.6 centimeters (1-3 in) deep beneath the denser pine stands. This mat may exclude other vegetation.

The 673-hectare (1,663-a) study area was divided into a number of pastures in 1940. Several exclosures were established to prevent livestock grazing. The pastures are grazed by cattle from June through mid-October. Until 1957, yearling cattle were used to test grazing intensities (5). Research since 1957 has centered on a cow-calf herd and rotation grazing.

Timber harvest has followed silvicultural prescriptions (4). In the winter of 1967 and 1968, 462 hectares (1,140 a) were logged commercially. One 109-hectare (269-a) pasture was left uncut as a control. About 6,490 cubic meters (2.75 million board feet) of ponderosa pine were removed from the logged area. Average basal area was reduced to 18.4 square meters per hectare (40 sq ft/a).

All logging was done when the soil was dry or frozen. Rubber-tired equipment was used for skidding and decking. An extensive permanent road system was not built. Instead, temporary roads with frequent log decks were used. Log butts were raised off the ground for skidding, and work was temporarily suspended whenever midwinter temperatures allowed the soil surface to thaw. The net effects of the timber harvest were irregular stands of ponderosa pine with a productive understory of herbaceous vegetation.

Surface Elevation

Preliminary comparisons between different intensities of grazing were made in 1947 (8). A series of 144 surface profile plots had been systematically established and measured across the study area. The plots, both grazed and ungrazed, included three cover types described as grassland, open timber, and litter. The grassland cover was composed of live and decaying herbaceous foliage. A mixture of pine needles and herbaceous plant litter characterized the ground features in the open timber. The litter plots featured heavy accumulations of pine needle litter. The unlogged control pasture for the 1976 comparisons also contained each type of cover.

The initial plots were located on a variety of landscapes ranging from ridgetops to hillsides to bottoms of drainages. The general relief of the study area is gentle. Grades are less than 15 percent.

Figure 2. Erosion profile frame illustrating placement of side frames on concrete and pipe hubs and crossmember in place on second set of holes. Individual steel pins are pushed down for firm contact with surface cover and the distance measured to the top of the pin for numerically describing the profile.

Each plot (2.33 square meters) was permanently fixed by four concrete hubs set flush with the soil surface. These hubs, 152.4 centimeters (5 ft) apart, formed a square parallel to the ground slope. A 13-millimeter (0.5 in) galvanized pipe was set in the concrete to project 5 centimeters (2 in) above the top of each hub. The elevation of each hub was referenced to an independent permanent benchmark.

Two pieces of channel iron with four holes spaced 30.5 centimeters (1 ft) apart, were used to measure the surface profile. The channel iron had swivel pins on each end that fit snugly and flush into the pipes in the concrete hubs (Figure 2). These pins were placed in the hubs on each side of the plot, parallel to the slope. A third piece of channel iron was fitted with 13-millimeter (0.5-in) steel rods at each end, exactly 152.4 centimeters (5 ft) apart. These precisely machined rods were placed in the holes in the channel iron sides.

Beginning 30.48 centimeters (1 ft) from the ends of this crossmember, seven holes, 15.2 centimeters (6 in) apart, were drilled to accommodate 45.7-centimeter-long (18-in) by 3.2-millimeter-diameter (0.125-in) steel pins. These pins moved freely through the holes but were kept in place with a small spring steel clamp. Each pin also had a 13-millimeter-diameter (0.5-in) steel foot.

Measurements were made by placing the two side channels on the concrete hubs so the pins fit firmly on the corner pipes. The crossmember was placed in the upper holes of the side pieces, and the erosion pins pushed down so the foot of each rested firmly on the ground cover (Figure 2). Profile measurements were then made from the top of the crossmember to the top of each pin and recorded to the nearest millimeter.

When measurements were completed in the top row, the pins were raised and the crossmember moved to the second holes. The pin-height measurements were then taken again. This procedure was repeated for the third and fourth sets of holes until each plot was completed (28 profile points). The procedure made it possible to repeat the erosion measurements using the same base and point locations over extended intervals with an average instrument error of less than ± 0.2 millimeter.

One-half the original plots were selected for measurements in 1976 to determine if there were any major differences in soil surface profile elevations. A few of the plots had been damaged or destroyed by logging operations. Some simply could not be found. Measurements thus were made on 59 plots. Differences between 1941 and 1976 were compared by covariance analysis and fitting of least squares for the disproportionate sample sizes for treatment comparisons.

Results and Conclusions

The repeatability and low error associated with the profile frame method of analysis showed it to be an effective, efficient method of detecting soil surface changes. For example, the statistical analysis showed that a 4-millimeter dif-

Table 1. Average change in erosion plot elevations (millimeters) in relation to ground cover, type, timber harvest, and grazing treatments.

Treatments	*Plots Sampled*	*1941*	*1976*	*Change**
Ground cover	59			
Heavy pine litter	21	322	342	+ 19*
Grass-needle litter	21	329	346	+ 17
Grass litter	17	332	345	+ 13
Timber harvest	59			
Not cut	21	332	351	+ 19
Cut	38	325	340	+ 15
Grazing	59			
Not grazed	10	317	339	+ 22
Grazed	49	330	345	+ 15

*All changes significant at p = .01.

ference in soil profile elevation between the logged and unlogged areas and a 2-millimeter difference between a ground cover of heavy pine litter and grass-needle litter were significant (Table 1). Significant differences existed among years and among all treatments of ground cover, timber harvest, and grazing. Detecting such differences speaks well for the methodology, but a forthright comparison of the mean measurements provides a more useful interpretation of the changes that occurred and their relationship to land management activities.

From 1941 to 1976, measured elevations of the soil profiles increased under all treatments (Table 1). The most substantial increase, 22 millimeters, was in exclosures that had been protected from grazing for more than 35 years. Grazing the pastures during all of these years, however, was not unduly detrimental to soil surface features. Profile elevations increased 15 millimeters on grazed areas. This suggests that areas were not being severely damaged by livestock use. It also demonstrates that surface accumulations were slightly more rapid under ungrazed conditions.

Profile elevations generally increased on all plots over the 35-year period. This suggests that the soil surface was not being degraded on some sites and redeposited on others. The lack of interaction in the statistical analysis supports this theory. The theory also explains why small differences in treatments were highly significant.

Soil surface cover types had different effects on profile elevation changes. The largest change, 19 millimeters, came from the deposition of needles and duff on plots referred to as heavy pine litter cover. This accumulation occurred under the more dense tree canopies, which had a higher rate of needle deposition.

The next highest rate was on plots referred to as the grass-needle cover treatments. These areas are characterized by open-growing ponderosa pine.

The least accumulation, an elevation increase of 13 millimeters, occurred on the grass cover type. This small increase reflects two features, the absence of needles and the reduction of aerial grass cover each year by grazing animals.

Logging was not detrimental to the soil surface. The average profile elevation in the logged area increased from 325 millimeters in 1941 to 340 millimeters by 1976. This increase of 15 millimeters was only 4 millimeters less than that for the uncut area. This suggests that timber can be harvested without increasing the erosion hazard significantly.

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The USDA Land Capability Classification and Storie Index rating: A comparison

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ABSTRACT—Definitions of prime agricultural land often start with a soil rating or land capability classification system. The U.S. Department of Agriculture's Land Capability Classification (LCC) and the Storie Index Rating (SIR) are two soil rating systems used in California as part of the legal definitions of prime agricultural land. Although similar, the two systems differ in the soil properties rated, rating methods, and weighting of soil criteria. The systems are not interchangeable. Class I soil mapping units in eight soil survey reports have an average SIR of 91.3. Class II units have an average SIR of 68. A few mapping units with an SIR greater than 60 have LCC ratings of III, IV, and VI. Methods of rating available water-holding capacity, slope, salinity, and climate account for most differences in the LCC and SIR ratings. Productivity functions for various cropping systems need to be combined with these two rating systems to determine more quantitatively what is prime agricultural land.

PRIME agricultural land, its definition, and its preservation have become major topics of concern. Some researchers attempt to explain the loss of agricultural land in terms of social, political, and economic factors (*3*). Others consider the acreages of land in various uses relative to the world's food production potential (*7*). Several recent articles discuss means of retaining land in agriculture (*4, 14*).

Economist Philip Raup (*13*), in a recent editorial, asked the fundamental question, "What is prime land?" Raup proceeded to enumerate three alternatives for defining prime agricultural land. His third alternative was to grade land by the physical characteristics of soil and climate, but he cautioned against using the U.S. Department of Agriculture's Land Capability Classification (LCC) as the single determinate of prime agricultural land.

In California, as in other states, there have been numerous attempts to pass legislation that would involve the state in agricultural land preservation. One successful effort produced the California Land Con-

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