

**GALLATIN NATIONAL FOREST**

**1990 SOIL MONITORING PROGRAM**

**SUMMARY REPORT**

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U. S. Forest Service

Bozeman, MT

February 28, 1991

## Introduction

One of the basic timber management assumptions used in the Forest Service is that of "sustainability" or the maintenance of long term productivity. The concept of sustained yield includes the maintenance or increase of site productivity. Recently, however, scientists have begun to question whether this is a valid assumption. Recent evidence suggests that in some instances, productivity decreases in intensively managed forests. Also, the unprecedented changes in global climate will certainly increase stress on mountain ecosystems, as well as change their productivity. This makes it critical to understand and preserve the non-climate portions of those ecosystems.

The long term sustainability of forest and range ecosystems depends heavily on maintaining soil productivity. Soil, along with climate, physiography, and biology sets the limits on site productivity within a region through its control of nutrients, moisture, and air supplies to plant roots. Since management influences are largely confined to soil manipulation, the soil condition is a good indicator of the status of land productivity.

Much work has shown the critical importance of the surface layer (A horizon) in maintaining healthy ecosystems. The surface soil is slow to develop, slow to recover, but also slow to reflect natural changes. In mountain environments this surface layer is where most biological activity takes place, and cannot be replaced or even approximated by deeper layers.

Soil properties that greatly influence plant growth are: soil volume, soil porosity, water availability, chemistry, biology, and ecological diversity. Changes in these properties changes plant growth potential. These properties are indicated by soil parameters such as bulk density (level of compaction), organic matter, cation exchange capacity (fertility), base saturation, texture, Ph, and evidence of plant roots. Table 1. indicates some of these parameters for a typical soil on the Gallatin National Forest. Note that there are large differences in parameters (and associated properties) between the surface layer (A horizon), and lower layers. Disturbance of the surface layer correlates with changes in soil properties, and a loss of or detrimental change in this layer has been shown to result in a reduction in productivity.

Table 1. Soil parameters for typical soils on the Gallatin National Forest,

Soil Horizon	Organic Matter (%)	Cation Exchange Capacity (meq/100 g)	Sand (%)	Silt (%)	Clay (%)	Rock Fragments (%)	Roots
A (surface layer)	4.2	24	42	38	20	15	many fine; many medium; many coarse; few very coarse
B (subsoil)	1.2	14	54	30	16	50	few coarse; few very coarse
C (substratum)	0.7	18	61	23	16	65	few very coarse

Research efforts are under way to establish better relationships between soil disturbance and site productivity. Regional standards (given below) have been developed for Region Six and One, and establish quantitative criteria relating to the current level of knowledge. Though these are broad and somewhat liberal, they are the best approximation available.

### Definitions

Site productivity is the inherent capacity of the land to produce wood. This is fixed by local climatic, topographic, and edaphic (soil) conditions, and is expressed through the genetic growth capacity of forest trees.

Soil productivity is the soil component of site productivity. It is fixed in the short term (over a rotation), but can vary over 1000's of years. Soil quality is the inherent productivity of the soil. It is measured by certain properties that influence plant growth. Soil pore space/volume relations, surface soil depth, aeration, nutrient supplying ability are important properties measured below. Significant management induced changes in these properties will affect long term site productivity.

### Objectives

We do three general kinds of monitoring relating to the forest plan. These are implementation, effectiveness, and validation. This project is in the "effectiveness" category. Given we are implementing our best management practices (BMP's), we want to know how effective they are at protecting soil quality. Future work will be concentrated in the "validation" category, where we want to know how soil disturbance will affect soil and site productivity.

Specifically, this project is to evaluate soil disturbance in clearcut harvest units. System roads are excluded. Selection criteria for sample sales are 1) used for BMP reviews in

the last two years, 2) harvested by ground skidding methods, 3) representative of the Gallatin sale program, 4) on a variety of soil types, and 5) recently harvested.

## Methods

### Sampling System

Methods were adapted from "*Guidelines for sampling some physical conditions of surface soils*"; Howes, S, J. Hazard, and J. Geist, Pacific Northwest Region, July 1983, (R6-RWM-146-1983). A randomly oriented grid with randomly oriented transects originating from each grid intersection was laid out on the sale map. The number of transects and grid spacing were determined by the unit's area and the precision desired; these calculations are discussed in the statistics section. Transect length was 100 feet, as measurements on this length interval convert directly to percentages. Random azimuths for the grid and transects were obtained by generating a series of random numbers between 0 and 1, then multiplying by 360. Random numbers were generated by an HP-28S handheld calculator with a built in random number generator.

In the field, the starting grid point was arrived at by pacing a distance and direction (measured from the grid map) from some corner or edge of the unit using a 100' tape and handheld compass. The remainder of the grid was laid out in the field in a similar manner using the compass and pacing the distance between grid points. Transects were laid out from each grid intersection at the random azimuths using the compass and 100' tape. The resulting grid over the unit often appeared to be somewhat distorted, but more accurate surveying was not warranted. In any case, the randomness with which the grid and transects were laid out on the ground were not affected by the accuracy of the grid.

### Field classification of soil surface condition

Soil surface conditions along each 100' transect were placed in one of seven visual categories at a resolution of one foot. These categories are:

- 1.) Undisturbed (UN)- this soil's mineral surface and subsurface horizons are in their natural state, or, if equipment has been on the site, has not been disturbed.
- 2.) Deposited (DE)- this soil has accumulated away from its original location either by equipment or erosion.
- 3.) Compaction Observed (CO)- this soil is observed to be compacted, but is otherwise undisturbed and the organic layer is intact.
- 4.) Displaced (DI)- this soil has been removed to another location by equipment or logs.

5.) Eroded (ER)- this soil has been detached and transported by wind, water, ice, or gravity.

6.) Burned (BD)- this soil has been charred.

7.) Puddled (PU)- this soil has been smeared and compacted, usually by equipment or log movement. It is also usually displaced or deposited.

For the purposes of this study, each of these classes are exclusive; any given portion of a transect may be assigned to only one class.

For each class except UN, the amount of vertical displacement is measured relative to the estimated original soil surface and noted. For the CO, DI, ER, and PU classes, this measurement is downward and recorded as a negative number. Vertical displacement is recorded as a positive number in the DE class.

Average depth of disturbance was estimated by using a ruler and tape. A few measurements were taken over a small transect length, and averaged. Measurements were taken to the nearest inch, and transect distance to the nearest foot.

#### **Detrimental and Severe Soil Disturbance**

Soil surface condition class alone is not used alone as an index of soil damage. Forest Service Handbook FSH 2509.18, Soil Management Handbook, outlines the criteria for detrimental changes soil properties and was used here with minor modifications and additions. For this study, the following criteria were used to assess damage in each category:

1.) UN- undisturbed soils are not considered damaged.

2.) DE- deposited soils are not considered damaged at this time.

3.) CO- compacted soils are considered damaged only if the vertical displacement exceeds one inch. This threshold was developed by assuming a 6" depth affected layer, and a 15% allowable decrease in soil volume over this depth. This is preliminary and will be measured more accurately in the future.

4.) DI- displaced soils are considered damaged if the lesser of 3 inches or 50% of the topsoil is removed. With an average topsoil depth of 9 inches, removal of 3 or more inches of topsoil constitutes damage.

5.) ER- eroded soils are considered damaged if the lesser of 3 inches or 50% of the topsoil has been removed.

6.) BD- burned soils are considered damaged if charring occurs at depths greater than 5 cm (2 in).

7.) PU- all puddled soils are considered damaged.

Total detrimental disturbance is calculated as the sum of the damaged soils in each surface condition class and expressed as a proportion of the total. Total severe disturbance is only the sum of detrimentally displaced soils, as topsoil cannot be replaced within the planning period (100 years).

### Statistics

#### *Sample Size and Spacing*

For statistical reliability, a sampling density of 1 point per 2 acres was used. From 15 to 17 transects were used in each sample unit. Grid spacing with the formula:

$I = (A/n)^{(1/2)}$ , where:

A = area in square feet

n = sample size

I = spacing interval

#### *Tests of Statistical Significance (T tests)*

Tests of statistical significance (T tests) were performed to establish the "reality" of results. The T test is performed as follows:

If  $t$  (calculated) > or = to  $t$  (tabular), where

$$t \text{ (calculated)} = (TDD - 30) / (v(Pi)/n)^{0.5}$$

$$t \text{ (tabular)} = \alpha/2, n-1 \text{ df}$$

TDD = Total Detrimental Disturbance

30 = Regional standard

$v(Pi)$  = sample variance      n = sample size

then the standard has been exceeded (at an alpha level of 0.2).

### Results

#### Sample Harvest Unit Descriptions

The Bear-Chestnut timber sale is located on the Bozeman District of the Gallatin National Forest. Unit 13 is located approximately at SE1/4 Sec 10 R7E T3S at an elevation of about 6800 feet ASL. Aspect is NNE and slopes are generally in the 10%-30% range. Soils occurring in the unit are classed in soil map units 84-1A (NW2/3 of unit) and 86-2A (SW1/3 of unit) as described in the Gallatin National Forest Soil Survey. This unit appeared to be in "good shape" after clear-cutting.

The Cooke City Salvage timber sale is located on the Gardiner District of the Gallatin National Forest. Unit 4 is located approximately at SW1/4 Sec 19 T9S R15E at an elevation of about 8400 feet ASL. Aspect is S-SE and slopes are in the 10%-25% range. Soils found on the unit are classed in map unit 71-1C. This unit, as part of a salvage sale, was entirely burned during the Yellowstone fires of 1988. As such, this unit is substantially larger than other units in this survey.

The East Boulder timber sale is located on the Big Timber District of the Gallatin National Forest. Unit 8 is located at approximately SW1/4 Sec 10 T4S R13E at an elevation of about 7500 feet ASL. Aspect is N and slopes are in the 15%-25% range. Soils in the sample unit are classed in map unit 34-1C. This unit appeared to be in particularly difficult terrain as far as ground skidding is concerned. Both live and ephemeral drainages were used as skid roads, while much of the rockier terrain was left untouched by fallers and skidders.

The Iron Mountain timber sale is located on the Big Timber District of the Gallatin National Forest. Unit 13 is located at approximately SW1/4 Sec 10 T3S R14W at an elevation of about 6600 feet ASL. Slopes are in the 30% range, and aspect is E-SE. Soils occurring in the unit are classed in map unit 54-5C. This unit appeared steep with regard to ground skidding, yet severe disturbance appeared limited to localized areas.

The Portal Salvage timber sale is located on the Bozeman District of the Gallatin National Forest. Unit 3 is located at approximately SE1/4 Sec 20 T6S R5E at about 7300 feet ASL. Slopes are generally in the 20% range, and aspect is southwest. Soils occurring in the Unit are classed in map unit 71-2B. This unit contained a designated streamcourse (included in the monitoring) and a permanent road (not included in the monitoring). The sale operator scarified the entire unit with a D-7 prior to soil monitoring. It seems plausible that these scarification efforts significantly increased soil damage above that caused by felling and skidding. Also, fallers returned to drop additional timber after the scarification was completed and as the soil monitoring field work was nearing completion.

The West Hebgen timber sale is located on the Hebgen Lake District of the Gallatin National Forest. Unit 26 is located at approximately NW 1/4 Sec 31 T13S R44E at an elevation of about 7600 feet ASL. Slopes are in the 20%-25% range, and aspect is east. Soils in this unit are classed in map units 54-1G. Assessing the degree of soil disturbance was complicated due to weeds and grasses were well established on the site.

Table 2 summarizes properties of selected sales and harvest units. One objective of this study was to represent the range of conditions occurring on the Gallatin National Forest. The sample sites represent four of five ranger districts, a wide range in size, the elevation range of most commercial timber land on the Gallatin, the slope range of most tractor sales, and recent sales. Soils texture ranges from moderately fine to moderately coarse. All sales passed BMP implementation reviews in 1989 or 1990.

Table 2. Harvest Unit Parameters (all clearcut, tractor logged) for monitored units.

Sale	District	Area (ac)	Elevation	Slope	Dates	Soils (texture, coarse frag.)
Bear Chestnut	Bozeman	18	6800'	10-30%	87-91	mod. fine; few c. f.
Cooke City	Gardiner	35	8400'	10-25%	89-91	med. - mod. fine; many c. f.
East Boulder	Big Timber	133	7500'	15-25%	85-90	mod. coarse; many c. f.
Iron Mountain	Big Timber	42	6600'	10-30%	88-90	medium; few - many c. f.
Portal Salvage	Bozeman	25	7300'	10-25%	86-90	mod. fine; few c. f.
West Hebgen	Hebgen Lake	33	7600'	0-25%	86-89	mod coarse; few - many c. f.

### Transect Data

Data for each sample site are given in Table 3. The raw data in each class was filtered using regional standards for "detrimental disturbance" and severe disturbance" defined above. These data were subjected to the T test to determine whether Regional standards were exceeded for total detrimental disturbance. No statistical tests were run on severe disturbance because values were all well below the cutoff of 15%.

Table 3. Proportions by Disturbance Class by Harvest Unit

Harvest Unit	Detri-mentally Disturbed (%)	Regional Standard Exceeded	Severely Disturbed (%)	Undis- turbed (%)	Deposited (%)	Compacted (%)	Displaced (%)	Puddled (%)	Burned or Eroded (%)
Bear Chestnut	24.4	NO	1.5	73.0	2.4	14.6	1.6	8.2	0.1
Cooke Salvage	38.6	YES	4.5	50.7	8.8	25.3	6.5	8.6	0.1
East Boulder	43.2	YES	1.9	55.2	1.6	31.3	1.9	9.5	0.5
Iron Mountain	23.9	NO	1.0	70.7	3.6	17.8	2.2	5.8	0.0
Portal Salvage	27.0	NO	0.1	57.9	3.2	26.9	1.3	10.8	0.0
West Hebgen	42.6	YES	2.2	49.6	4.2	31.6	5.2	8.7	0.6
Average	33.3		1.9	59.5	4.0	24.6	3.1	8.6	0.2

Table 4. gives a different perspective on the transect data. Soil removal or deposition in the first two columns are calculated as a proportion of the area affected by each. Therefore they cannot be compared across sales. This shows that, when compared to those given as proportion of the entire sale area, disturbed areas are characterized as having a relatively small extent with a large disturbance. For example, harvest activities in the Bear Chestnut unit have either removed or compacted an average of three inches of soil over the entire disturbed area. This is about 1/3 of the average surface soil



depth. When calculated as proportion of the entire sale area, (Table 2) an equivalent average of 0.7 inch of surface soil has been removed or compacted over the entire sale area. Only 0.1 inch has been deposited, leaving a net loss of 0.6 inch.

Table 4. Average Vertical Displacement by Harvest Unit

Harvest Unit	As Proportion of Disturbed Area		As Proportion of Entire Unit Area	
	Soil Removal or Compaction (in)	Soil Deposition (in)	Soil Removal or Compaction (in)	Soil Deposition (in)
Bear Chestnut	-3.0	4.5	-0.7	0.1
Cooke Salvage	-2.9	5.5	-1.2	0.5
East Boulder	-3.3	8.3	-1.4	0.1
Iron Mountain	-2.9	3.7	-0.7	0.1
Portal Salvage	-2.0	3.0	-0.8	0.3
West Hebgen	-1.8	3.2	-0.8	0.1
Average (in)			-0.9	0.2

Figure 1. graphically depicts the raw data before filtering. Figure 2. portrays that information after the "detrimental" and "severe" filter. Note that the totals are less in the latter. Disturbance data were retained only if there is a probable effect on long term productivity.

Figure 1. Transect Data for

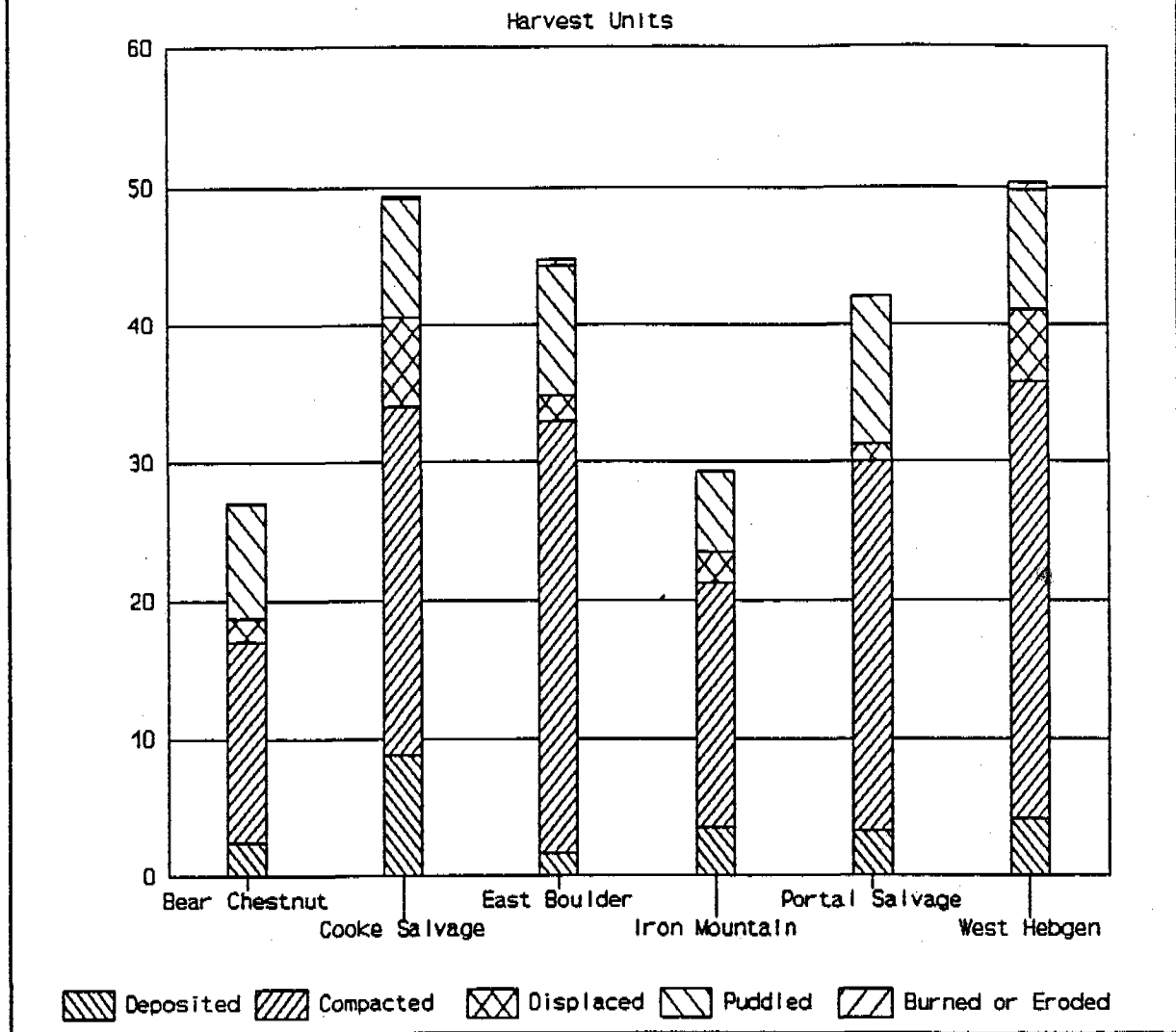
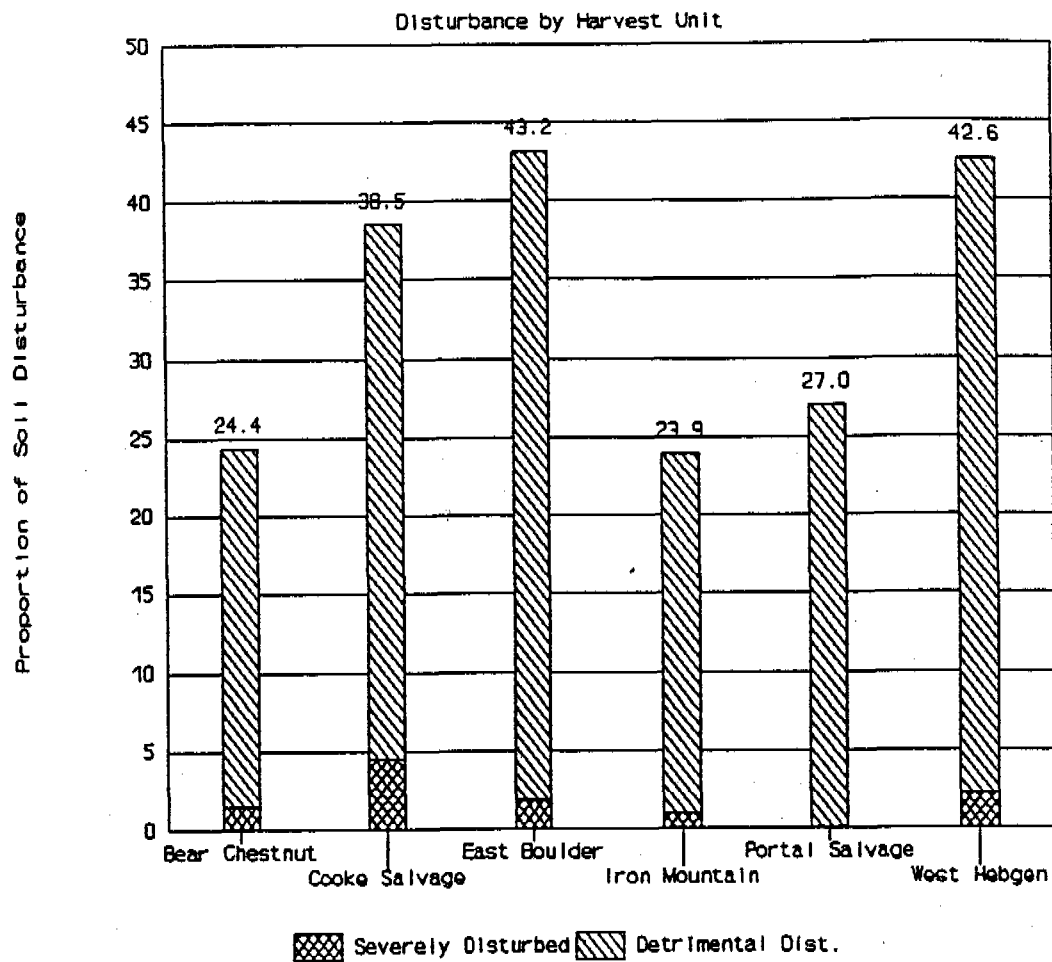


Figure 2. Severe and Detrimental



## Conclusions and Recommendations

There were significant detrimental soil effects on all sample sites. Three of the six exceeded Regional standards. An average of 1/3 of all sites was detrimentally disturbed. This relatively high disturbance is surprising. No attempt is made to separate effects of harvest from those of site preparation. Methods used were preliminary and variability is high. Therefore limited use should be made of the data from any one sample site. However, the methods appear to be appropriate for measurement of disturbance in forested environments and the following conclusions are warranted.

1. Soil Disturbance is high on recent tractor sales on the Gallatin Forest. Disturbance is higher than expected, since these sales represent relatively current practices.
2. Regional standards have been exceeded in one-half the cases, by a statistically significant amount. There is significant "detrimental" and some "severe" disturbance. There has been a significant decrease in soil quality.
3. Long term soil productivity has very probably been affected, as well as long term site productivity.

Changes in harvest and site preparation practices may be needed. However, with the present accuracy of data it is difficult to tell what kind and amount should change. A more detailed monitoring effort should be completed in FY 1991 to better define the problem and eliminate potential errors in methods. This project should concentrate on reducing variability, establish the kinds of practices causing the problem, measure compaction with standard methods, and select a wider range of site/soil combinations.

Finally, other resource uses should be monitored. Trails, especially in the wilderness are both over-used and under-maintained. Range allotments have areas of compacted, smeared soils, especially near streams. We should make an effort to systematically monitor these areas as those activities also affect long term soil productivity.