An Annotated Bibliography of Scientific Literature on Research and Management Activities Conducted in Manitou Experimental Forest

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Adams, Mary Beth; Loughry, Linda; Plaugher, Linda, comps. 2008. Manitou Experimental Forest (Colorado). In: Experimental forests and ranges of the USDA Forest Service. Gen. Tech. Rep. NE-321, revised. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 131-133. **Abstract**: The USDA Forest Service has an outstanding scientific resource in the 77 Experimental Forests and Ranges that exist across the United States and its territories. These valuable scientific resources incorporate a broad range of climates, forest types, research emphases, and history. This publication, revised in March 2008, describes each of the research sites within the Experimental Forests and Ranges network, providing information about history, climate, vegetation, soils, long-term data bases, research history and research products, as well as identifying collaborative opportunities, and providing contact information.

Alexander, Robert R. 1986. Silvicultural systems and cutting methods for ponderosa pine forests in the Front Range of the Central Rocky Mountains. Gen. Tech. Rep. RM-GTR-128. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 22 p. **Abstract**: Guidelines are provided to help forest managers and silviculturists develop even- and/or uneven-aged cutting practices needed to convert old-growth and mixed ponderosa pine forests in the Front Range into managed stands for a variety of resource needs. Guidelines consider stand conditions, and insect and disease susceptibility. Cutting practices are designed to integrate maintained water quality, improved wildlife habitat, and enhanced opportunities for recreation and scenic viewing, with providing wood products.

Asherin, Lance A. 2011. Manitou Experimental Forest hourly meteorology data, [Online]. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station (Producer). Available:http://www.fs.fed.us/rm/data_archive/dataaccess/ManitouEF_meteorology.shtml [2011, December 12]. **Abstract**: This data set contains hourly meteorological data collected at the Manitou Experimental Forest (MEF) near Woodland Park, Colorado. Measurements began in June of 1998.

Battaglia, Mike; Rhoades, Charles; Rocca, Monique E.; Ryan, Michael G. [2010]. A regional assessment of the ecological effects of chipping and mastication fuels reduction and forest restoration treatments. Final report: JFSP Project Number 06-3-2-26. [Boise, ID]: [Joint Fire Science Program]. 37 p. **Abstract**: Over the past several years, fire managers have increased their use of mastication treatments, the on-site disposal of shrubs and small-diameter trees through chipping and shredding.

Mastication is a relatively untested management practice that alters the chemical and physical conditions of the forest floor and may influence vegetation regrowth and fuel development for years or decades. Eighteen sites were established across four ecosystems of the southern Rocky Mountains and the Colorado Plateau: lodgepole pine (*Pinus contorta*), mixed conifer (*Pinus ponderosa*, *Pseudotsuga menziesii*, *Pinus flexilis*, and *Pinus contorta*), ponderosa pine (*Pinus ponderosa*), and pinyon pine/juniper (*Pinus edulis*/*Juniperus* sp.). These sites were distributed across a wide geographic range throughout Colorado and represent treatments across several federal, state, and other land agencies. The sites were mulched between 2004 and 2006 and first measured in 2007 or 2008.

Battaglia, Michael A.; Dodson, Jonathan M.; Shepperd, Wayne D.; Platten, Mark J.; Tallmadge, Owen M. 2005. Colorado Front Range fuel photo series. Gen. Tech. Rep. RMRS-GTR-155WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 40 p. **Abstract**: This photo series was developed to help fire managers estimate ground and surface fuel loads that exist in cover types of the Southern Colorado Front Range wildland-urban interface. Photos and associated data representing low, medium, and high fuel loadings from this study are presented by forest type, along with examples of typical or median fuel loadings that were encountered.

Battaglia, Mike A.; Rocca, Monique E.; Rhoades, Charles C.; Ryan, Michael G. 2010. Surface fuel loadings within mulching treatments in Colorado coniferous forests. Forest Ecology and Management. 260(9): 1557-1566. **Abstract**: Recent large-scale, severe wildfires in the western United States have prompted extensive mechanical fuel treatment programs to reduce potential wildfire size and severity. Fuel reduction prescriptions typically target non-merchantable material so approaches to mechanically treat and distribute residue on site are becoming increasingly common. We examined how mulch treatments alter the distribution of woody material by size class by comparing paired mulched and untreated sites in lodgepole pine (*Pinus contorta*), mixed conifer, ponderosa pine (*Pinus ponderosa*), and pinyon pine/juniper (*Pinus edulis*/*Juniperus sp.*) forests 2–6 years after mechanical treatment. Mulching treatments reduced tree density and canopy bulk density, and increased canopy base height, potentially lowing active crown fire risk. In general, mulching increased total woody surface fuel loadings 2–3-fold, but the magnitude differed among forest types. Average total woody surface fuel loads in the untreated areas ranged between 7 and 12 Mg ha−1, but increased to 27–63 Mg ha−1 in treated areas. Large diameter fuels (>7.62 cm) represent about 35–69% of the total woody fuel load in the untreated areas, but only about 8–14% of the total fuel load in the treated areas. Woody fuels in treated areas were dominated by material <2.54 cm diameter (i.e. 1 and 10 h fuels). In general, mulch fuelbed depth was a useful predictor of fuel loading. Mulching created a compact fuelbed (i.e. bulk density 138–150 kg m−3) that differs from pretreatment needle-dominated fuelbed and will likely change fire behavior and effects. Quantification of the mulched fuelbed characteristics within these four forest types should aid in modification of current fuel models or creation of new fire behavior fuel models.

Belsky, A. Joy; Blumenthal, Dana M. 1997. Effects of livestock grazing on stand dynamics and soils in upland forests of the Interior West. Conservation Biology. 11(2): 315-327. **Abstract**: Many ponderosa pine and mixed-conifer forests of the western, interior United States have undergone substantial structural and compositional changes since settlement of the West by Euro-Americans. Historically, these forests consisted of widely spaced, fire-tolerant trees underlain by dense grass swards. Over the last 100 years they have developed into dense stands consisting of more fire-sensitive and disease-susceptible species. These changes, sometimes referred to as a decline in "forest health," have been attributed primarily to two factors: active suppression of low-intensity fires (which formerly reduced tree recruitment, especially of fire-sensitive, shade-tolerant species), and selective logging of larger, more fire-tolerant trees. A third factor, livestock grazing, is seldom discussed, although it may be as important as the other two factors. Livestock alter forest dynamics by (1) reducing the biomass and density of understory grasses and sedges, which otherwise outcompete conifer seedlings and prevent dense tree recruitment, and (2) reducing the abundance of fine fuels, which formerly carried low-intensity fires through forests. Grazing by domestic livestock has thereby contributed to increasingly dense western forests and to changes in tree species composition. In addition, exclosure studies have shown that livestock alter ecosystem processes by reducing the cover of herbaceous plants and litter, disturbing and compacting soils, reducing water infiltration rates, and increasing soil erosion.

Bergman, Charles A. 1983. Flaming owl of the ponderosa. Audubon. 85: 66-71. **Abstract**: The author accompanies research ecologists Richard Reynolds and Brian Linkhart on a mission to attach a radio transmitter to a male flammulated owl. Behaviors and habits of flammulated owls are described.

Berndt, Herbert W. 1950. A flood control plan for the protection of Manitou Springs--Precipitation and streamflow of a Colorado Front Range watershed. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 16 p. **Abstract**: A flood control plan for the town of Manitou, CO was developed. A field examination and subsequent analysis indicated that the most feasible plan considered for the alleviation of flood damage in Manitou was a coordinated program utilizing improved land management practices, minor erosion control structures, water and sediment detention structures and channel rectification.

Berndt, Herbert W. 1960. Precipitation and streamflow of a Colorado Front Range watershed. Station Paper No. 47. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 14 p. **Abstract**: Knowledge of the water-yielding characteristics of a variety of drainages is important in watershed management. This report presents information obtained during 1940-58 from the Missouri Gulch watershed on the Manitou Experimental Forest in Colorado. The purpose of the study was to gain information on water yield and its relation to precipitation for a drainage heading in the Colorado Front Range ponderosa pine type.

Berndt, Herbert W. 1961. Some influences of timber cutting on snow accumulation in the Colorado Front Range. Research Notes No. 58. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 3 p. **Abstract**: To learn how canopy reduction by logging might influence snow accumulation in ponderosa pine-Douglas-fir stands, an exploratory study was made. The study was conducted on the Pike National Forest at 8,500 feet elevation within the Long Hollow drainage 35 miles northwest of Colorado Springs, Colorado. In the fall of 1957 six rectangular plots, 1 acre in size, were established on north-facing slopes of 10 to 30 percent. Twenty-five snow sampling points were permanently marked on each plot. At all points snow depth and moisture content were measured with a Mount Rose snow sampler after each major storm and periodically during snowmelt.

Berndt, Herbert W.; Gibbons, Robert D. 1958. Root distribution of some native trees and understory plants growing on three sites within ponderosa pine watersheds in Colorado. Station Paper No. 37. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 14 p. **Abstract**: Lateral extent and depth of root systems for 8 plant species on 3 different soils of the Colorado Front Range were examined on the Manitou Experimental Forest near Colorado Springs, Colorado. The trees studied were between 60 and 110 years in age, 19 and 38 feet in height, and 4 to 8. 5 inches in d.b.h. Ponderosa pine, Douglas-fir, lodgepole pine, and mountain-mahogany roots reached maximum depths between 4 and 5.6 feet, except where downward penetration was limited by bedrock. Mountain muhly, Arizona fescue, and kinnikinnick roots grew to depths of between 2 and 3.4 feet. Quaking aspen roots had the greatest lateral extent, with some laterals growing 48 feet from the parent stump. Other tree species had laterals less than one-half this length.

Binkley, Dan; Kashian, Daniel M.; Boyden, Suzanne; Kaye, Margot W.; Bradford, John B.; Arthur, Mary A.; Fornwalt, Paula J.; Ryan, Michael G. 2006. Patterns of growth dominance in forests of the Rocky Mountains, USA. Forest Ecology and Management. 236(2-3): 193-201. **Abstract**: We used data from 142 stands in Colorado and Wyoming, USA, to test the expectations of a model of growth dominance and stand development. Growth dominance relates the distribution of growth rates of individual trees within a stand to tree sizes. Stands with large trees that account for a greater share of stand growth than of stand mass exhibit strong growth dominance. Stands with large trees that contribute less to stand growth than to stand mass show reverse growth dominance. The four-phase model predicts that forests move from a period of little dominance (Phase 1), with trees accounting for similar contributions to stand growth and stand mass. Phase 2 is a period of strong growth dominance, where larger trees account for a disproportionately large amount of total stand growth. Growth dominance declines during Phase 3 as growth of the larger trees slows. A final Phase 4 shows reverse growth dominance when the growth of larger trees is less than their proportional contribution to total stand mass. The datasets supported the expectation of reverse growth dominance in old forests of ponderosa pine, Engelmann spruce and subalpine fir, lodgepole pine, and mixed stands of aspen and conifers. Pure aspen stands did not show reverse growth dominance. An age sequence of lodgepole pine failed to show the

expected Phase 2 period of strongly developed growth dominance. Future work needs to combine quantitative descriptions of patterns in growth dominance with experimental manipulations of resource supplies and environmental conditions to connect forest dynamics at the scales of individual trees, groups of trees, and stands.

Booth, D. T.; Tueller, P. T. 2003. Rangeland monitoring using remote sensing. Arid Land Research and Management. 17(4): 455-467. **Abstract**: Monitoring vast landscapes has, from the beginning of rangeland management, depended on people's judgments. This is no longer tenable, but a more effective method has yet to be devised. The problem is how to do an economical inventory that will detect ecologically important change over extensive land areas with acceptable error rates. The error risk is a function of adequate sample numbers and distribution for each indicator monitored. Of all of the indicators identified for monitoring, ground cover and its inverse, bare ground, may be the most discussed. Ground-cover measurements address soil stability and watershed function which are first-priority ecological concerns; are well adapted to remote sensing frameworks thus allowing extensive, unbiased, economical sampling; and, the measurements, especially when done by computer image analysis, have the potential to reduce or avoid the human judgment factor. Data collection through remote sensing appears the most logical approach to acquiring appropriately distributed information over large areas in short time periods and on random sites far removed from easy ground access. The value of satellite and high-altitude sensors for landscape-level evaluations, such as plant community distribution, is well established but these tools are inadequate for inventory and measurement of details needed for valid conclusions about range condition.
New advances in low-altitude remote sensing may give us the ability to accurately measure bare ground and perhaps other indicators. Combining information from high and low-altitude sensors appears to offer an optimal path for developing a practical system for cost-effective, data-based, rangeland monitoring and management.

Boyden, Suzanne; Binkley, Dan; Shepperd, Wayne. 2005. Spatial and temporal patterns in structure, regeneration, and mortality of an old-growth ponderosa pine forest in the Colorado Front Range. Forest Ecology and Management. 219(1): 43-55. **Abstract**: Effective management and restoration of ponderosa pine forests requires an understanding of the heterogeneity of contemporary and historical stand structures. We assessed spatial and temporal patterns of tree establishment, mortality and size structure over a 30-year period in an old-growth ponderosa pine stand in the mid-montane zone of the Colorado Front Range. We analyzed spatial patterns and spatial associations using Ripley's K(t) and K12(t) and then modeled the patterns using point process models. Forest age structure was estimated by aging a sub-sample of trees in the stand. Climate appeared to play a significant role in the coarse-scale temporal pattern of regeneration events. Stand structure (distribution of patches, light availability, and seed trees) influenced the spatial and temporal pattern of more recent regeneration events. Patchy regeneration resulted in spatial independence and some segregation of size classes. Older trees in the stand (40-55 cm dbh) exhibited some regularity in their spatial distribution at short distances indicating that patterns of mortality had been historically patchy. Contemporary patterns of mortality were mostly

patchy, and mountain pine beetles caused a significant amount of mortality in the 1970s and 1980s. Both establishment and mortality retained spatial patterns that were somewhat consistent with pre-settlement forests, despite changes in driving processes.

Brown, Walter V. 1951. Chromosome numbers of some Texas grasses. Bulletin of the Torrey Botanical Club. 78(4): 292-299. **Abstract**: 1. The chromosome numbers of 44 species in 24 genera of Gramineae are reported. Of these the chromosome numbers of 25 species are reported for the first time. 2. The very restricted species *Distichlis texana* agrees with the wide-spread species *D. spicata* and *D. stricta* in having 2n = 40 small chromosomes. 3. *Piptochaetium fimbriatum*, the only species of the genus in the United States, agrees with South American species in having 2n = 44 and this chromosome number shows the relationship of this genus to *Stipa*, *Aristida* and *Brachyelytrum*. 4. *Stipa tenuissima* is aneuploid in a genus that is typically aneuploid. 5. The basic number in *Panicum hians*, *P. obtusum* and *P. geminatum* is x = 10. *Erianthus strictus*, the first American species in this genus to be studied cytologically has 2n = 30 indicating a basic number of 5 or 15. 6. The basic number in *Elyonurus* and *Trachypogon* is x = 10, with *Elyonurus* having, perhaps, the largest chromosomes in the Andropogoneae.

Canton, Steven P.; Cline, Leo D.; Short, Roberta A.; Ward, James V. 1984. The macroinvertebrates and fish of a Colorado stream during a period of fluctuating discharge. Freshwater biology. 14(3): 311-316. **Abstract**: 1. During a 2-year study of the fish and macroinvertebrates of a third-order montane stream, a severe drought in the first year resulted in a temporary cessation of surface flow. Flow was continuous during the second year. 2. Some taxa (e.g. *Ophiogomphus severus)* exhibited higher density during the drought year, others declined in abundance during low flow (e.g. *Baetis* spp.), whereas a few (e.g. *Tricorythodes minutus*) appeared unaffected. Total macroinvertebrate density decreased by 50% during the low flow year compared to the normal flow year. Mayflies were most severely affected, but also exhibited the most dramatic recovery. 3. The collector-gatherer functional feeding group was abundant only during the normal flow year, whereas shredders and predators exhibited increased relative abundance during low flow. 4. Fish populations were severely reduced in the low flow year. However, fishes rapidly invaded the area following resumption of normal flow.

Coltharp, George B. 1955. Estimating runoff from small watersheds. Fort Collins, CO: Colorado Agricultural and Mechanical College. 77 p. Thesis. **Abstract**: This study investigated whether infiltration data, obtained with the Rocky Mountain infiltrometer could be used to estimate surface runoff from high intensity summer storms on small watersheds covered with second growth ponderosa pine.

Costello, David F. 1944. Efficient cattle production on Colorado ranges. Colorado Agricultural Experiment Station Bulletin 383-A. Fort Collins, CO: [U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station]. 3-16. In cooperation with Colorado State College of Agriculture and Mechanic Arts. **Abstract**: This bulletin presents results of investigations made in Colorado by the Rocky

Mountain Forest and Range Experiment Station in order to increase efficiency in range cattle production. Topics of the studies reviewed include: grazing intensity, forage quality and production, seasonal forage trends, cattle stocking rates, and herd management. Recommendations for ranchers are provided.

Currie, P. O. 1963. Rangeland research at Manitou. In: Proceedings of the Society of American Foresters meeting; 1962 October 21-24; Atlanta, GA. Washington, DC: Society of American Foresters: 73. Abstract. **Abstract**: Seventeen years of cattle grazing on ponderosa pine-bunchgrass ranges show that a moderate grazing rate of 30-40 percent use of the dominant grasses and sedges was best for sustained forage and livestock production.

Currie, Pat O. 1966. Marking cows with human hair dye. Journal of Range Management. 19(5): 306-307. **Abstract**: Cows were marked with human hair dye. Large, easily applied numbers could be read at considerable distance for the life of the hair coat--150 for 180 days when applied in the fall.

Currie, Pat O. 1967. Seeding Sherman big bluegrass. Journal of Range Management. 20(3): 133-136. **Abstract**: Sherman big bluegrass was successfully established by planting into summer-fallowed land with a double-disc, depth-band drill to control seeding depth at 5/8-inch. Planting during July and August into a moist seedbed gave optimum seedling establishment. Weed competition and erosion on the summer-fallowed land was reduced by leaving the ground in rough-plowed condition until immediately before seeding.

Currie, Pat O. 1969. Use seeded ranges in your management. Journal of Range Management. 22(6): 432-434. **Abstract**: Seeded ranges in conjunction with native range can effectively increase productivity and income from ponderosa pine ranges of Colorado. Average weight of weaned calves was 33 lb higher, and gross income per calf $8.95 larger from combined use of seeded and native range than from native range alone. Cows received better nutrition on seeded ranges, which may increase their lifelong production. Similar benefits can be expected by grazing yearlings. Seeding requires an initial investment of about $8.50 per acre which can be repaid within 3 years as a result of increased grazing capacity. Several grasses are recommended for seeding on the basis of their proven performance to meet specific forage needs.

Currie, Pat O. 1969. Plant response and cattle gains on Sherman big bluegrass. Journal of Range Management. 22(4): 258-261. **Abstract**: Under season-long grazing of Sherman big bluegrass, utilization to a 4-inch stubble height was better than lighter or heavier grazing for sustained forage production and ground cover. Heavy grazing associated with drought resulted in severe deterioration of the grass stands. Beef gains from the recommended rate of grazing averaged 78 lb/acre. This beef gain was higher than for any other seeded or native species tested at the Manitou Experimental Forest, Colorado.

Currie, Pat O. 1970. Influence of spring, fall, and spring-fall grazing on crested

wheatgrass range. Journal of Range Management. 23(2): 103-108. **Abstract**: Grazing crested wheatgrass during spring only, fall only, and spring and fall to a 1-inch stubble height for 10 years had little effect on vegetative characteristics of the seeded stands. Invasion of the stands by other species was greater with spring or spring-fall use than with fall use. Litter decreased with all seasonal treatments, but decreased most under spring-fall use. Drought and growing-season moisture were the critical factors in determining forage yields. The spring-fall pastures produced more forage, provided more days of grazing, and gave the highest average beef production, 177 lb/season. Spring grazing was next and fall grazing the least productive for animal weight gains.

Currie, Pat O. 1974. The effect of timber harvest on the range resource. In: Forest industry's role in land use. Proceedings, Rocky Mountain forest industries conference; 1974 March; Cheyenne, WY. [Place of publication unknown]: [Publisher name unknown]: 82-83. **Abstract**: The balance of multiple land uses in Manitou Recreational Forest and Fraser Experimental Forest is discussed. At Manitou, leaving approximately 50-60 square feet per acre of timber is an optimum balance that maximizes timber harvest, grazing, and recreation activities. At Fraser Experimental Forest, small clearcut openings were used more by mule deer and had more forage than forested areas.

Currie, Pat O. 1975. Plant response and livestock weight changes on big bluegrass range grazed during late fall, winter, and early spring. Journal of Range Management. 28(5): 340-343. **Abstract**: Yearling heifers grazing Sherman big bluegrass ranges in Colorado during the cold winter period gained weight during late fall with or without a protein supplement, but they gained less than animals that grazed native range and received 1/2-lb protein/day. During winter and early spring, animals lost weight in most pastures. Exposure as well as kind and quantity of forage and feed available evidently influenced livestock weights. Grazing was not detrimental to Sherman big bluegrass during any period from late fall to early spring, and stands improved during the study. For most effective use, big bluegrass should replace native range for fall grazing in a management system. More animals could be carried over winter, or a set number of animals could be overwintered on fewer acres.

Currie, Pat O. 1975. Grazing management of ponderosa pine-bunchgrass ranges of the central Rocky Mountains. Research Paper RM-159. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 24 p. **Abstract**: Pine-bunchgrass ranges have historically been important livestock-producing areas in the central Rocky Mountains. Grazing will continue to be important, but in conjunction with other uses of the land. Livestock management techniques are well developed and soundly based on research within the pine-bunchgrass type. There is a need, however, to understand the interrelationships of other land uses, particularly as they relate to human population pressures. Research needs, as well as what is known, are described for several vegetation cover types. Other resources, such as timber, soil, and water, are evaluated in relation to grazing.

Currie, Pat O. 1976. Recovery of ponderosa pine-bunchgrass ranges through grazing

and herbicide or fertilizer treatments. Journal of Range Management. 29(6): 444-448. **Abstract**: Protection from grazing, alternate rest, or seasonal spring or fall grazing did not promote recovery of pine-bunchgrass range in Colorado which had been grazed heavily for more than 23 years. Application of 2,4-D herbicide or NPK fertilizer significantly changed vegetative composition and increased herbage yields of these rangelands under all grazing treatments. The herbicide reduced competition from forbs and permitted the grass species to increase in basal area and produce more herbage than plants on unsprayed, unfertilized control plots. Addition of NPK fertilizer stimulated production of all species and increased yields an average of 500 lb per acre. A combination fertilizer-herbicide treatment increased average yields a comparable amount, with the increase coming mostly from grasses and a few forbs not killed by the herbicide.

Currie, Pat O. 1978. Cattle weight gain comparisons under seasonlong and rotation grazing systems. In: Hyder, Donald N., ed. Proceedings of the first international rangeland congress; 1978 August 14-18; Denver, CO. Denver, CO: Society for Range Management: 579-580. **Abstract**: A carefully designed 6-year study showed cows and calves gained the same amount of weight, whether they grazed pastures seasonlong or under a rotation management system. A complex cross-over statistical design minimized variation from changes in vegetation or differences in range improvements. These results, along with results from earlier studies on effects of livestock management on rates of range recovery, indicate that complex rotation-grazing systems are of questionable value on ponderosa pine-bunchgrass ranges in Colorado.

Currie, Pat O.; Edminster, Carleton B.; Knott, F. William. 1978. Effects of cattle grazing on ponderosa pine regeneration in central Colorado. Res. Pap. RM-201. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 7 p. **Abstract**: Effects of cattle grazing on ponderosa pine regeneration were evaluated on pine-bunchgrass ranges in central Colorado. Good range management practices of grazing at light to moderate rates and providing adequate water supply to livestock resulted in negligible damage to natural and artificial regeneration. A single planting of 1,200 seedlings per acre, or an initial planting of 500 to 600 seedlings per acre and replanting areas of high mortality is recommended to increase pine regeneration.

Currie, Pat O.; Gary, Howard L. 1978. Grazing and logging effects on soil surface changes in central Colorado's ponderosa pine type. Journal of Soil and Water Conservation. 33: 176-178. **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.

Currie, Pat O.; Hammer, F. L. 1965. An improved gate fastener for range fences. Journal of Range Management. 18(2): 98. **Abstract**: This article describes how to

construct a gate fastener for range fences. The use of this gate fastener has reduced the number of gates left open and prevented accidental straying of cattle.

Currie, Pat O.; Hammer, Frederick L. 1979. Detecting depth and lateral spread of roots of native range plants using radioactive phosphorus. Journal of Range Management. 32(2): 101-103. **Abstract**: Radioactive phosphorus (P32) was used to measure root depth and lateral spread of tour native plant species which had been subjected to heavy grazing for many years. Compared with root excavation measurements from an earlier study on the same area, rooting depths of all species tested were found to be quite similar by the two methods. Lateral spread differed substantially, however. Roots were found to have a greater lateral spread by the P32 estimate. The isotope method using autoradiography was found to be a sensitive method of determining depth and lateral spread of in situ plant roots in a mixed plant community.

Currie, Pat O.; Morris, M. J.; Neal, D. L. 1973. Uses and capabilities of electronic capacitance instruments for estimating standing herbage. Grass and Forage Science. 28(3): 155-160. **Abstract**: An electronic capacitance meter was used to estimate herbage yield from sown ranges in western USA. On an area in Arizona where the grass stand had been sown broadcast, an r^2 of 0.47 was obtained between the meter value and oven-dry weight estimate. Excluding those plots with very large amounts of standing dead organic matter (OM), or very succulent plants which had not been sown, improved yield estimates.
Tests on pastures in Colorado in which seed had been drilled and the meter tested to evaluate performance in relation to drill rows showed that a common regression could be used for estimating yield. Methods of placing the meter in relation to row directions are described which avoid a biased estimate of total pasture yield. Cutting the herbage in a 3-dimensional manner improved the r^2 values over those obtained by the usual 2-dimensional cutting procedure. Separation of dead OM from living plant material did not significantly change the r^2 values and showed that dead OM bad very little influence on the meter reading. This dead OM can contribute significantly to variation of the estimate about the regression line, however, and if differences in dead OM are substantial, sample sizes may need to be increased or sampling stratified to obtain an accurate yield estimate.
Pertinent literature on the evolution of electronic capacitance instruments for estimating herbage yields has been presented in Part 1 of this series (3). The present evaluation is restricted to the herbage yield estimates from mechanically sown pastures. The Neal Electronics Model 18–612 meter was used to make the yield estimates.

Currie, Pat O.; Peterson, Geraldine. 1966. Using growing-season precipitation to predict crested wheatgrass yields. Journal of Range Management. 19(5): 284-288. **Abstract**: Forage available for use by livestock varies with the season in which ranges are used. Specific precipitation patterns accounted for 87% or more of the variation in forage yields of crested wheatgrass grazed at different seasons in the Front Range of Colorado. Rainfall in April determined forage yields of ranges grazed in the spring; May and July rain-fall determined forage yields for fall-grazed ranges. Expected forage yields and stocking rates can therefore be predicted from precipitation measurements.

Currie, P. O.; Reichert, D. W.; Malechek, J. C.; Wallmo, O. C. 1977. Forage selection comparisons for mule deer and cattle under managed ponderosa pine. Journal of Range Management. 30(5): 352-356. **Abstract**: Cattle and mule deer competed very little for forage on a central Colorado ponderosa pine-bunchgrass range during the spring-summer-fall grazing season. Species they selected for the bulk of their diets were quite different. Diets overlapped most for fringed sagebrush and sunsedge. Fringed sagebrush was used heavily by both deer and cattle in April-May. Sunsedge was consumed in small amounts by both animals throughout most of the grazing season. Management of the timber stand increased forage for both types of animals. Also, timber stand improvement practices resulted in short-term availability of dried pine needles, a preferred deer food.

Currie, Pat O.; Smith, Dwight R. 1970. Response of seeded ranges to different grazing intensities in the ponderosa pine zone of Colorado. Production Research Report No. 112. Washington, DC: U.S. Department of Agriculture, Forest Service. 41 p. **Abstract**: Abandoned fields at Manitou Experimental Forest were seeded with crested wheatgrass, intermediate wheatgrass, smooth brome, Russian wildrye, and a mixture of crested wheatgrass, smooth brome, and yellow sweetclover. This report describes the merits of several seeded species as expressed by (1) vegetative characteristics and associated range condition resulting from different intensities of grazing, and (2) the cattle weight gains associated with the use of each species.

DiGangi, J. P.; Boyle, E. S.; Karl, T.; Harley, P.; Turnipseed, A.; Kim, S.; Cantrell, C.; Maudlin Iii, R. L.; Zheng, W.; Flocke, F. 2011. First direct measurements of formaldehyde flux via eddy covariance: implications for missing in-canopy formaldehyde sources. Atmospheric Chemistry and Physics. [In review]: 18729-18766. **Abstract**: We report the first observations of formaldehyde (HCHO) flux measured via eddy covariance, as well as HCHO concentrations and gradients, as observed by the Madison Fiber Laser-Induced Fluorescence Instrument during the BEACHON-ROCS 2010 campaign in a rural, Ponderosa Pine forest northwest of Colorado Springs, CO. A median noon upward flux of ~80 μgm−2 h−1 (~24 pptv ms−1) was observed with a noon range of 37 to 131 μgm−2 h−1. Enclosure experiments were performed to determine the HCHO branch (3.5 μgm−2 h−1) and soil (7.3 μgm−2 h−1) direct emission rates in the canopy. A zero-dimensional canopy box model, used to determine the apportionment of HCHO source and sink contributions to the flux, underpredicts the observed HCHO flux by a factor of 6. Simulated increases in concentrations of species similar to monoterpenes resulted in poor agreement with measurements, while simulated increases in direct HCHO emissions and/or concentrations of species similar to 2- methyl-3-buten-2-ol best improve model/measurement agreement. Given the typical diurnal variability of these BVOC emissions and direct HCHO emissions, this suggests that the source of the missing flux is a process with both a strong temperature and radiation dependence.

Dominguez, F.; Gochis, D. J.; Harley, P. C.; Turnipseed, A.; Hu, J. 2010. Transpiration and evaporation measurements in a mountain ecosystem using real-time field-based

water vapor isotopes. In: American Geophysical Union, fall meeting 2010; 2010 December 13-17; San Francisco, CA. Washington, DC: Eos Transactions, American Geophysical Union: U33B-05. Abstract. **Abstract**: The partitioning of evapotranspiration between evaporation from bare soil and transpiration by vegetation is not adequately represented in land surface models coupled to atmospheric models. In this work we present measurements of stable water vapor isotopes (δD and δ18O) in Manitou Experimental Forest. At an elevation of approximately 2,400m in the Rocky Mountain foothills-pediment region the site is characterized by Ponderosa pine and a grass understory. We use a portable real time isotopic water vapor analyzer that allows us to partition evapotranspiration from the vegetated region into transpiration from plants and direct evaporation from the soil and canopy. The isotopic measurements are complementary to data from a network of eddy covariance towers and soil moisture measurements. We give particular emphasis to the temporal variability of the isotopic signature of transpiration presenting simultaneous measurements of water vapor isotopes, net photosynthesis, evapotranspiration and stomatal conductance measured using a dynamic flow-through gas exchange system. These observations are the first step towards improving our understanding and numerical modeling of the partitioning between evaporation and transpiration.

Dortignac, E. J. 1951. Design and operation of Rocky Mountain infiltrometer. Station Paper No. 5. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 68 p. **Abstract**: The design and operation of a modified version of the Rocky Mountain infiltrometer is presented. All equipment has been streamlined and lightened for ease in handling and carrying. In addition, a plan for placement of equipment on the 1.5-ton truck simplifies and speeds up repeated loading and unloading of equipment, allowing a greater number of samples per unit time. Another innovation is the use of this instrument for measurement of rates of erosion in addition to infiltration rates. This infiltrometer can be used successfully for measuring erosion though the standard deviation of measurement is greater than for infiltration rates. These larger variations are no doubt associated with variations in slope and rain intensity. Whereas these factors do not influence water-absorption rates, it has been demonstrated that they do influence erosion losses.

Dortignac, E. J.; Love, L. D. 1960. Relation of plant cover to infiltration and erosion in ponderosa pine forests of Colorado. In: Annual meeting of the American Society of Agricultural Engineers; 1958 June; Santa Barbara, CA. [Place of publication unknown]: [Transactions of the American Society of Agricultural Engineers]: 58-61. **Abstract**: The Rocky Mountain infiltrometer was used to evaluate infiltration and erosion of the most common cover types found in the ponderosa pine forests of Colorado. It was found that infiltration rates varied with cover type. Large pore space of the upper 2 inches of the soil and the quantity of dead organic materials were the two properties that accounted for most of the variation in infiltration rates among cover types. Erosion indices also varied with cover type, but soil origin and the amount of exposed or bare soil were the main factors affecting erosion. Infiltration rates increased 1.31 inches per hour is grassland and 1.01 inches per hour in pine-grass after 14 years of protection from grazing at Manitou Experimental Forest. Additionally, infiltration and erosion indices

measured with the infiltrometer in range pastures were compared with rates computed from adjacently located runoff plots.

Dortignac, E. J.; Love, L. D. 1961. Infiltration studies on ponderosa pine ranges of Colorado. Station Paper No. 59. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 34 p. **Abstract**: The purpose of this paper is to present results of infiltrometer studies designed to evaluate the relationships between soil, vegetation, and infiltration. These studies were conducted at the Manitou Experimental Forest from 1941 through 1954, and on the Elk Ridge Allotment in the Roosevelt National Forest in 1950.

Driscoll, Richard S. 1970. Identification and measurement of shrub type vegetation of large-scale aerial photographs. In: Third annual earth resources program review. Volume II. Agriculture, forestry, and sensor studies; 1970 December 1-3; Houston, TX. [Washington, DC]: [National Aeronautics and Space Administration]: 32:1-32:15. **Abstract**: Important range-shrub species were identified at acceptable levels of accuracy on large-scale (1:600 to 1:1,500) 70 mm color and color infrared aerial photographs (positive transparencies). Identification of individual shrubs was significantly higher, however, on color infrared. Eight of 11 species were identified correctly more than 80 percent of the time on color infrared and two species were correctly identified 100 percent of the time. Six species were identified more than 80 percent correctly on color photographs but none were identified 100 percent correctly. Photoscales smaller than 1:2,400 had limited value except for mature individuals of relatively tall species, and then only if crown margins did not overlap and sharp contrast was evident between the species and background. Larger scale photos (1:800 or less) were required for low-growing species in dense stands. The crown cover for individual species was estimated from the aerial photos either with a measuring magnifier or a projected-scale micrometer. Photo measurements were significantly correlated with ground measurements. These crown cover measurements provide techniques for earth-resource analyses when used in conjunction with space and high-altitude remotely procured photos.

Driscoll, Richard S. 1971. Color aerial photography: A new view for range management. Research Paper RM-67. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 11 p. **Abstract**: Shrubs such as antelope bitterbrush, big sagebrush, snowberry, and true mountain mahogany can be identified more consistently on large-scale (1:600-1:1,200) color infrared aerial photographs than on the same scale color aerial photographs. Identification of relatively large forbs, including Fremont geranium and orange sneezeweed, is also easier on large scale color infrared. Neither film type appeared to give improved information regarding site delineation on smaller scale photographs. Other features of the range environment, including rodent disturbances, can best be identified on color infrared at photo scales up to 1:2,400. All of this depends on obtaining photographs at the right time of year in respect to phenology of the vegetation.

Driscoll, Richard S. 1972. Pattern recognition of native plant communities-- Manitou

Colorado test site. In: 4th Annual earth resources program review. Volume V: Agriculture and forestry programs; 1972 January 17-21; Houston, TX. [Washington, DC]: [National Aeronautics and Space Administration]: 123:1-123:12. **Abstract**: Optimum channel selection among 12 channels of multispectral scanner imagery identified six as providing the best information about 11 vegetation classes and two nonvegetation classes at the Manitou Experimental Forest (NASA Test Site 242). Intensive pre-processing of the scanner signals was required to eliminate a serious scan angle effect. Final processing of the normalized data provided acceptable recognition results of generalized plant community types. Serious errors occurred with attempts to classify specific community types within upland grassland areas. The consideration of the convex mixtures concept--effects of amounts of live plant cover, exposed soil, and plant litter cover on apparent scene radiances significantly improved the classification of some of the grassland classes.

Driscoll, Richard S. [1970]. Aerial color and color infrared photography-- some applications and problems for grazing resource inventories. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 140-149. **Abstract**: Initial results with large-scale (1:600-1:4600) 70 mm color aerial photography for identifying native plant species, communities, and other habitat features in the range environment are reported. Some potential values of small-scale photographs (1:135,000) are also defined.

Driscoll, R. S.; Currie, P. O.; Morris, M. J. 1972. Estimates of herbaceous standing crop by microdensitometry. In: Proceedings of the 38th annual meeting American Society of Photogrammetry; 1972 March 12-17; Washington, DC. Falls Church, VA: American Society of Photogrammetry: 358-364. **Abstract**: Green standing herbage was estimated from large-scale color infrared aerial photographs. Green standing herbage of seeded big bluegrass (*Poa ampla*) and corresponding dry weight were each regressed as dependent variables (Y) on color infrared photo image density (X) obtained from two photoscales: 1:563 and 1:3855. Standing crop biomass expressed by the linear equation: $Y = a + b(X)$ was from the 1:563 photoscale. The coefficient of determination ($R^2 = 0.752$) between image density and harvested dry weight was highly significant ($P = 0.01$). The same regression using the smaller photoscale (1:3855), although significant ($P = 0.05$), was not as good ($r^2 = 0.639$). Mean image density of six simulated productivity levels was significantly different ($P = 0.05$) among most levels of production represented in both photo scales.

Driscoll, Richard S.; Francis, Richard E. 1972. Multistage, multiband and sequential imagery to identify and quantify non-forest vegetation resources. Remote sensing applications in forestry. Final Report. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 49 p. (+appendices). In cooperation with University of California at Berkeley, Forestry Remote Sensing Laboratory. **Abstract**: This is the fifth and final report to assess the merits of multiband photography from aircraft and spacecraft and multispectral scanner imagery for the interpretation and analysis of nonforest (shrubby and herbaceous) native vegetation. Significant findings include: 1. A multiple sampling technique was developed

whereby spacecraft photographs supported by aircraft photographs -could be used to quantify plant communities. 2. Large-scale (1:600 - 1:2,400) color infrared aerial photographs were required to identify individual shrub and herbaceous species. 3. Herbaceous standing crop biomass was successfully estimated by measuring optical density of film images in large-scale color infrared aerial photographs. 4. Microdensitometry, to measure film image optical density, was used to discriminate among specific plant communities (habitat type) and individual plant species on color infrared aerial photographs. 5. Recognition processing of multispectral scanner imagery resulted in discrimination of native plant communities provided the communities were quite homogeneous such as willow meadows, sedge/rush/bulrush meadows, bluegrass meadows, or coniferous tree canopy. 6. A method to estimate overwinter death losses of mule deer was developed using 1:2,000 scale color infrared photos secured of a small area after snowmelt but before severe carcass degradation occurs. 7. A technique was developed to estimate population density of northern pocket gophers, a small burrowing rodent. 8. The effects of solar radiation, air temperature, and atmospheric water vapor pressure on the effective radiant temperature (ERT) of deer and the relations between deer ERT and the ERT of bare soil, snow, and sagebrush considering the environmental effects with respect to time of day was determined.

Driscoll, Richard S.; Francis, Richard E. 1975. Range inventory: classification of plant communities. In: Heller, Robert C., tech. coord. Evaluation of ERTS-1 data for forest and rangeland surveys. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 26-43. **Abstract**: The primary objective of this test was to determine at what level in an accepted hierarchy of plant community classification ERTS-1 imagery could be successfully used in a central Colorado mountainous area. A further objective was to determine the kind of aircraft support photography that would be needed to extend the classifications to the degree of detail required in range resource inventory.

Driscoll, Richard S.; Reppert, Jack N.; Heller, Robert C. 1974. Microdensitometry to identify plant communities and components on color infrared aerial photos. Journal of Range Management. 27(1): 66-70. **Abstract**: Image density differences in color infrared aerial photos can be used to discriminate individual shrub and tree species of a pinyon pine-juniper plant community. In addition, image density was used successfully to identify six general plant communities: ponderosa pine, spruce-fir, aspen, big sagebrush, native grasslands, and seeded grasslands. However, different sites and cultural treatments within native grasslands and ponderosa pine forest could not be so easily discriminated, even though visual differences were apparent in the photos.

Driscoll, Richard S.; Reppert, Jack N.; Heller, Robert C.; Carneggie, David M. 1970. Identification and measurement of herbland and shrubland vegetation from large scale aerial colour photographs. In: Proceedings of the XI international grassland congress; 1970 April 13-23; Surfers Paradise, Queensland, Australia. [Place of publication unknown]: [Publisher name unknown]: 95-98. **Abstract**: Individual herbaceous and shrubby species can be identified most accurately on large scale (1: 600-1: 1,100) color infra-red aerial photographs. There was no apparent advantage of this film type as

compared with normal color film for identifying non-vegetation characteristics in herbaceous and shrubby plant communities. Site delineation, as inferred by the plant community, can be equally well defined on either film type at a scale of 1:4,200. Species density and foliar cover can be estimated from this type of aerial photography within acceptable error limits. Color infra-red photographs should be used for this purpose owing to the increased accuracy of individual species identification. A scanning microdensitometer can be used for automated interpretation to measure total vegetation cover and to discriminate between broad vegetation types. The microdensitometer does not yet seem suitable to identify individual species.

Driscoll, R. S.; Spencer, M. M. 1972. Multispectral scanner imagery for plant community classification. In: 8th International symposium of remote sensing and environment; 1972 October; Ann Arbor, MI. [Tucson, AZ]: [International Symposium on Remote Sensing of Environment]: 1259-1278. **Abstract**: Optimum channel selection among 12 channels of multispectral scanner imagery identified six as providing the best information for computerized classification of 11 plant communities and two nonvegetation classes. Intensive preprocessing of the spectral data was required to eliminate bidirectional reflectance effects of the spectral imagery caused by scanner view angle and varying geometry of the plant canopy. Generalized plant community types--forest, grassland, and hydrophytic systems--were acceptably classified based on ecological analysis. Serious, but solvable, errors occurred with attempts to classify specific community types within the grassland system. However, special clustering analyses provided for improved classification of specific grassland communities.

Dunford, E. G. 1949. Relation of grazing to runoff and erosion on bunchgrass ranges. Research Notes No. 7. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 2 p. **Abstract**: Runoff and erosion from six 1/100-acre plots have been measured for 12 years at Manitou Experimental Forest near Colorado Springs. The object has been to determine how two different degrees of grazing affect watershed values on a Front Range bunchgrass site.

Dunford, E. G. 1954. Surface runoff and erosion from pine grasslands of the Colorado Front Range. Journal of Forestry. 52(12): 923-927. **Abstract**: The influence of cattle grazing and timberland disturbance on runoff and erosion was examined with two studies (in bunchgrass habitat and ponderosa pine forest, respectively). On the bunchgrass study, a significant increase in erosion resulted from heavy grazing while erosion from moderately grazed plots remained near normal. On the ponderosa pine sites, removal of litter and removal of litter and trees produced substantial erosion and surface runoff following summer storms.

Eav, Jenny. 2011. Comparison of monoterpene oil composition and volatile emissions from ponderosa and Austrian pine, [Online]. National Center for Atmospheric Research (Producer). Available:http://nldr.library.ucar.edu/repository/assets/soars/SOARS-000-000-000-226.pdf [2011, September 22]. **Abstract**: Monoterpenes (C10H16) are volatile organic compounds (VOCs) naturally emitted into the atmosphere from vegetation, especially

flowering plants and conifers. VOCs play a role in controlling atmospheric chemistry and they participate in the formation of air pollutants, such as ozone. Monoterpene emissions from vegetation are species-specific and strongly dependent on temperature. There have been no detailed studies that correlate monoterpene emissions into the atmosphere with monoterpenes found in storage reservoirs in plant foliage nor are there detailed studies that describe the variability of monoterpene composition within individual plants and between plants of the same species. Using a gas chromatograph equipped with a mass spectrometer and flame ionization detector, this study surveyed the variation in concentration and composition of monoterpenes in *Pinus ponderosa* and *Pinus nigra* needles to determine (1) whether variation occurs between needle orientation (e.g., north-, east-, west-, south-facing) or needle age within individual trees (new, one-, and two-year-old needles); (2) whether variation of oil composition exists among different trees of the same species, and (3) whether differences occur between monoterpene composition stored within needles and emissions. Results show that compositions and concentrations did not differ in samples taken from different positions within a tree, but they do differ between age groups in ponderosa pine. Additionally, sabinene and myrcene were found in emission samples in the presence of light, but not in monoterpene pools of Austrian pine needles, suggesting that they are produced and emitted immediately and not stored. Future study will develop a numerical model for emissions incorporating temperature and concentrations.

Erickson, David C.; Gary, Howard L.; Morrison, S. M.; Sanford, Glen. 1982. Pollution indicator bacteria in stream and potable water supply of the Manitou Experimental Forest, Colorado. Research Note RM-415. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 7 p. **Abstract**: Shallow groundwater flow diverted for domestic use indicated low fecal coliform numbers, and no consistent source of warm-blooded animal fecal material in stream water. Total coliforms and fecal streptococci were observed frequently and increased temporarily in both stream and domestic water supply after summer rains.

Finney, Mark A.; McHugh, Charles W.; Bartlette, Roberta; Close, Kelly; Langowski, Paul. 2003. Fire behavior, fuel treatments, and fire suppression on the Hayman Fire - Part 2: Description and interpretations of fire behavior. In: Graham, Russell T., tech. ed. Hayman Fire case study. Gen. Tech. Rep. RMRS-GTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 59-95. **Abstract**: This report summarizes the progress of the Hayman Fire, its behavior, and the influence of environmental conditions. Data were obtained from narratives from fire behavior analysts assigned to the fire management teams, discussions with fire management staff, meteorology from local weather stations and Bradshaw and others (2003), photographs, satellite imagery, and public internet sites. Possible explanations are advanced for observed fire behavior and effects. A fire chronology details as fully as possible the fire behavior and progress associated with specific days and weather conditions.

Francis, Richard E. 1970. Ground markers aid in procurement and interpretation of large-scale 70 MM aerial photography. Journal of Range Management. 23(1): 66-68.

Abstract: Butcher paper, surveyor stakes, lath strips, plastic letter-number codes, paper plates, and drop-panel markers were all useful for marking range ground features, providing strict flight-line control, and interpreting resultant aerial photographs. All markers were both highly detectable and resolvable at the largest scale of 1:600. All markers remained visible, yet some became less resolvable, at the smaller scales of 1:2400 and 1:4600.

Francis, Richard E.; Driscoll, Richard S. 1976. Range inventory: classification and mapping of plant communities. In: Aldrich, Robert C., tech. coord. Evaluation of Skylab (ERAP) data for forest and rangeland surveys. Research Paper PSW-113. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 74 p. **Abstract**: The primary objective of the research at the Manitou site was to determine at what classification level Skylab photographic products, or their equivalent, can be used for plant community classification in a central Colorado mountainous area. Secondary objectives were (1) to determine the kind of aircraft support photography needed to extend these classifications to other levels in the hierarchy, (2) to determine how both Skylab and aircraft support photography can be used to detect and identify cultural features of a mountainous landscape that could affect resource management alternatives, and (3) to make quantitative estimates of certain plant community characteristics from large-scale aircraft photography.

Garcia, E.; Prenni, A. J.; Prenni, J.; Rivest, J.; Demott, P. J.; Kreidenweis, S. M. 2010. Characterizing biological particles in the atmosphere at two sites in Colorado. In: American Geophysical Union, fall meeting 2010; 2010 December 13-17; San Francisco, CA. Washington, DC: Eos Transactions, American Geophysical Union: A21F-0160. Abstract. **Abstract**: The composition and distribution of primary biological aerosol particles (PBAPs) in the atmosphere is constantly changing due to both natural and anthropogenic activities. In this presentation, we will describe measurements aimed at better characterizing this population at Manitou Experimental Forest, in Pike National Forest in Colorado and in Fort Collins, CO. This work is part of the larger Biosphere-atmosphere Exchange of Aerosols within Cloud, Carbon and Hydrologic cycles, including Organics and Nitrogen (BEACHON) field study program, which is aimed at studying the connections between the biogeochemical cycling of carbon and water in semi-arid regions of the Western U.S. To this end, we are collecting PBAP with SKC impingers into water, which are subsequently analyzed by flow cytometery to determine the atmospheric biological particle concentration. Further, we are generating a gene library of the small subunit RNA genes to speciate the PBAPs in our collected samples using Sanger sequencing. These experiments are performed throughout the year to better understand seasonal variability of atmospheric microbial communities at the selected sites. A small handful of PBAPs have been found to be some of the best ice nucleators in the atmosphere, inducing ice nucleation as high as -2oC; these particles may play pivotal roles in influencing ice formation in cold clouds and, thereby, climate. Preliminary data will be presented aimed at better characterizing this important subset of biological particles.

Gary, Howard L. 1975. Watershed management problems and opportunities for the

Colorado Front Range zone: the status of our knowledge. Research Paper RM-139. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 32 p. **Abstract**: The east flank of the Continental Divide consists largely of open timber stands and grasslands. Soils erode easily after abuse. Precipitation ranges from 15 to 20 inches, about two-thirds from high intensity storms from April to September. Guidelines are provided for maintaining satisfactory watershed conditions. The 3- to 5-inch water yields are comparatively small in contrast to yields of 12 to 25 inches from the high-altitude subalpine forests, but are important to development along the Front Range. Watershed management practices can be expected to provide practical alternatives for increasing water supplies.

Gary, Howard L. 1982. Stream water quality in a small commercial campground in Colorado. Journal of Environmental Health. 45(1): 5-12. **Abstract**: Selected physical, chemical and bacteriological qualities of stream water entering and leaving a campground were examined during the summer of 1978 to investigate the influence of recreational use. Water samples were collected and analyzed at approximately biweekly intervals, and also three times daily before and after the Memorial Day, Fourth of July, and Labor Day weekends. Chemical and physical quality remained unchanged and densities of indicator bacteria in surface water were not significantly increased by recreational use of a campground equipped with modern sanitation facilities.

Gary, Howard L. 1985. A summary of research at the Manitou Experimental Forest in Colorado, 1937-1983. Gen. Tech. Rep. RM-116. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 15 p. **Abstract**: Results of selected studies for range, watershed, timber and wildlife management research are summarized to provide land managers, land-use planners, and land-use researchers with information to help evaluate consequences of land management practices in the Colorado Front Range ponderosa pine zone.

Gary, Howard L.; Currie, Pat O. 1977. The Front Range pine type: A 40-year photographic record of plant recovery on an abused watershed. Gen. Tech. Rep. RM-46. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 17 p. **Abstract**: Photographic comparisons revealed the relative success of plant recovery was mainly from tree planting with ponderosa pine in the early 1930's by the Civilian Conservation Corps. Shrubby and herbaceous ground cover showed only slight improvement. Potential for sheet and gully erosion also remained about the same, although excessive erosion has not occurred during the last 40 years.

Gary, Howard L.; Johnson, Steven R.; Ponce, Stanley L. 1983. Cattle grazing impact on surface water quality in a Colorado Front Range stream. Journal of Soil and Water Conservation. 38(2): 124-128. **Abstract**: Cattle grazing in pastures bisected by a small perennial stream in central Colorado had only minor effects on water quality during two years of study. Suspended solids and nitrate nitrogen did not increase significantly, and ammonia nitrogen increased significantly only once under moderate rates of grazing. Indicator bacteria densities in the stream water were significantly higher when at least

150 cattle were grazing. After removal of cattle or when 40 head of cattle were grazing, bacterial counts dropped to levels similar to those in an adjacent, ungrazed pasture. About 5 percent of the total manure produced by cattle contributed to pollution and/or enrichment of the stream.

Gary, Howard L.; Morris, Meredith J. 1980. Constructing wooden boxes for cavity-nesting birds. Research Note RM-381. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 7 p. **Abstract**: Nest boxes will never replace natural cavities found in live trees and snags. However, when few or no trees with natural cavities are available, nest boxes can help meet cavity requirements and help maintain diversity and populations of cavity-nesting birds.

Gowen, Peter J. 1981. Composite land use impacts on water quality on a diversely developed watershed. Fort Collins, CO: Colorado State University. 112 p. Thesis. **Abstract**: The purpose of this study was to assess the composite land use effects on water quality on a diversely developed tributary to the South Platte River in the Colorado Front Range. Data were collected over a two-year period to assess impacts of mountain home development, grazing and lake-based recreation on suspended solids, specific conductance, total dissolved solids, nitrate, chloride, fecal coliform and fecal streptococcal bacteria. Findings at the four treatment sites showed significant increases in fecal streptococcal bacteria densities at the grazing sites, considerable suspended solids delivered to the creek during runoff events at the road sites, no substantial effect on stream water quality from lake-based recreation and significant increases in suspended solids, total dissolved solids, specific conductance, nitrate and chloride at the sewage lagoon treatment sites.

Graham, Russell T., tech. ed. 2003. Hayman Fire case study. Gen. Tech. Rep. RMRS-GTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 396 p. **Abstract**: In 2002 much of the Front Range of the Rocky Mountains in Colorado was rich in dry vegetation as a result of fire exclusion and the droughty conditions that prevailed in recent years. These dry and heavy fuel loadings were continuous along the South Platte River corridor located between Denver and Colorado Springs on the Front Range. These topographic and fuel conditions combined with a dry and windy weather system centered over eastern Washington to produce ideal burning conditions. The start of the Hayman Fire was timed and located perfectly to take advantage of these conditions resulting in a wildfire run in 1 day of over 60,000 acres and finally impacting over 138,000 acres. The Hayman Fire Case Study, involving more than 60 scientists and professionals from throughout the United States, examined how the fire behaved, the effects of fuel treatments on burn severity, the emissions produced, the ecological (for example, soil, vegetation, animals) effects, the home destruction, postfire rehabilitation activities, and the social and economic issues surrounding the Hayman Fire. The Hayman Fire Case Study revealed much about wildfires and their interactions with both the social and natural environments. As the largest fire in Colorado history it had a profound impact both locally and nationally. The findings of this study will inform both private and public decisions on the management of

natural resources and how individuals, communities, and organizations can prepare for wildfire events.

Graham, Russell T.; Jain, Theresa B.; Matthews, Susan. 2010. Fuel management in forests of the Inland West. In: Elliot, William J.; Miller, Ina Sue; Audin, Lisa, eds. Cumulative watershed effects of fuel management in the western United States. Gen. Tech. Rep. RMRS-GTR-231. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 19-68. **Abstract**: This chapter discusses forest treatments that influence watershed processes, defined as those that occur when water transports sediment, woody debris, chemicals, heat, flora, or fauna away from a site and deposits it on another site. Forest treatments applicable for use in the cold, dry, and moist forests of the inland western United States are emphasized.

Graham, Russell T.; McCaffrey, Sarah; Jain, Theresa B., tech. eds. 2004. Science basis for changing forest structure to modify wildfire behavior and severity. Gen. Tech. Rep. RMRS-GTR-120. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 43 p. **Abstract**: This report describes the kinds, quality, amount, and gaps of scientific knowledge for making informed decisions on fuel treatments used to modify wildfire behavior and effects in dry forests of the interior Western United States (especially forests dominated by ponderosa pine and Douglas-fir). A review of scientific principles and applications relevant to fuel treatment primarily for the dry forests (ponderosa pine and Douglas-fir dominated) of the Western United States is provided for the following topics: fuels, fire hazard, fire behavior, fire effects, forest structure, treatment effects and longevity, landscape fuel patterns, and scientific tools useful for management and planning.

Haferkamp, Marshall R. 1969. Effect of fertilizer on big bluegrass. Fort Collins, CO: Colorado State University. 63 p. Thesis. **Abstract**: Sherman big bluegrass (*Poa ampla* Merr.) is a long-lived bunchgrass native to the Pacific Northwest. This species has been seeded in the Rocky Mountains and in some areas has produced greater livestock gains than native range during spring, summer, and late fall. Unfortunately, big bluegrass has an undesirable characteristic that reduces its value and use; plants are frequently pulled up by grazing animals. This occurs because the root system breaks at the crown to 7 to 10 cm below the soil surface. Low soil fertility was suspected as a possible cause of root breakage. To evaluate this factor, 96 vernalized and unvernalized big bluegrass plants were grown in two sets of 24 glass-faced planter boxes, one set containing new soil, and one set containing soil that was stored for a year. Plants received one of four treatments; a check, with no fertilizer, 56 kg/ha elemental N, 56 kg/ha elemental P, or both N and P at the 56 kg/ha rate. Foliage and roots were measured to establish what effect the fertilizers had on growth, and how breakage of root systems was altered. Pullup tension appeared to be closely correlated with total root weight, and results indicate that fertilizers can be used to reduce root breakage. N fertilizer produced significant increases in total number of vegetative and reproductive shoots, number of tillers, pullup tension, foliage weight, and total root system weight and length. P fertilizer produced a significant increase in the total number of vegetative and reproductive shoots, while the N-P interaction produced significant increases in total

root system weight and length, and the weight of roots pulled with the plants. Plants grown on stored soil out-produced plants grown on new soil. This was probably due to nitrification that occurred to the organic matter during storage. Vernalized plants consistently outproduced non-vernalized plants, indicating that annual cold stratification is needed for optimum production.

Haferkamp, M. R.; Currie, P. O. 1973. Effects of fertilizer on root strength of Sherman big bluegrass (*Poa ampla* Merr.). Agronomy Journal. 65(3): 511-512. **Abstract**: Pulling of plants by grazing animals has been a common problem on 'Sherman' big bluegrass (*Poa ampla* Merr.) pastures in Colorado. Fertilizers were applied to individual plants in a greenhouse study to evaluate their influence on plant resistance to pullup. The fertilizer treatments were 56 kg/ha N, 56 kg/ha P, or 56 kg/ha of each element as an N+P combination. Fertilizer treatments were applied to vernalized and nonvernalized plants grown in two soils.
Tensions required for pullup in the greenhouse were correlated with total root weight (r = .75**) and significantly increased with N fertilization. Plants fertilized with N produced more vegetative and reproductive shoots, tillers, foliage weight, and root system weight and length. Phosphorus fertilization produced a significant increase in vegetative and reproductive shoots, and a significant interaction between N and P was found for root system size and the amount of roots that were pulled from the soil with the plants.

Hall, S. A.; Burke, I. C.; Hobbs, N. T. 2006. Litter and dead wood dynamics in ponderosa pine forests along a 160-year chronosequence. Ecological Applications. 16(6): 2344-2355. **Abstract**: Disturbances such as fire play a key role in controlling ecosystem structure. In fire-prone forests, organic detritus comprises a large pool of carbon and can control the frequency and intensity of fire. The ponderosa pine forests of the Colorado Front Range, USA, where fire has been suppressed for a century, provide an ideal system for studying the long-term dynamics of detrital pools. Our objectives were (1) to quantify the long-term temporal dynamics of detrital pools; and (2) to determine to what extent present stand structure, topography, and soils constrain these dynamics. We collected data on downed dead wood, litter, duff (partially decomposed litter on the forest floor), stand structure, topographic position, and soils for 31 sites along a 160-year chronosequence. We developed a compartment model and parameterized it to describe the temporal trends in the detrital pools. We then developed four sets of statistical models, quantifying the hypothesized relationship between pool size and (1) stand structure, (2) topography, (3) soils variables, and (4) time since fire. We contrasted how much support each hypothesis had in the data using Akaike's Information Criterion (AIC).
Time since fire explained 39–80% of the variability in dead wood of different size classes. Pool size increased to a peak as material killed by the fire fell, then decomposed rapidly to a minimum (61–85 years after fire for the different pools). It then increased, presumably as new detritus was produced by the regenerating stand. Litter was most strongly related to canopy cover (r^2 = 77%), suggesting that litter fall, rather than decomposition, controls its dynamics. The temporal dynamics of duff were the hardest to predict. Detrital pool sizes were more strongly related to time since fire than to environmental variables. Woody debris peak-to-minimum time was 46–67 years,

overlapping the range of historical fire return intervals (1 to >100 years). Fires may therefore have burned under a wide range of fuel conditions, supporting the hypothesis that this region's fire regime was mixed severity.

Hamre, R. H. 2005. Changing times at the Rocky Mountain Forest and Range Experiment Station. Gen. Tech. Rep. RMRS-GTR-146. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 66 p. **Abstract**: Changing Times includes a review of early Station history, touches on changing societal perspectives and how things are now done differently, how the Station has changed physically and organizationally, technology transfer, a sampling of major characters, how some Station research has been applied, and a timeline of significant and/or interesting events. It includes references to a number of significant publications, and a listing of all personnel from 1976 through 1997.

Hao, Wei Min. 2003. Daily emissions. In: Graham, Russell T., tech. ed. Hayman Fire case study, Gen. Tech. Rep. RMRS-GTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 145-180. **Abstract**: Daily emissions of carbon monoxide (CO) and particles less than 2.5 μm (PM2.5) from the Hayman Fire from June 9 to June 27, 2002, when approximately 138,000 acres were burned, were estimated using data gathered daily from burned areas by MODIS satellite.

Hawkins, Richard H. 1961. A study to predict storm runoff from storm characteristics and antecedent basin conditions. Fort Collins, CO: Colorado State University. 76 p. Thesis. **Abstract**: This study assesses the runoff characteristics on the Missouri Gulch watershed and evaluates suitable methods for predicting storm runoff. It was found that less than one percent of storm rainfall on Missouri Gulch becomes storm runoff. Losses to runoff could not be explained through vegetative interception and could not be accounted for entirely through channel interception. It was postulated that losses to storm runoff could be explained in terms of the nature of the predominant soil mantle on the watershed.

Hawksworth, Frank G. 1968. Ponderosa pine dwarf mistletoe in relation to topography and soils on the Manitou Experimental Forest, Colorado. Research Note RM-l07. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 4 p. **Abstract**: This study was undertaken to determine if there was a relationship between frequency and abundance of Southwestern dwarf mistletoe on ponderosa pine and soil types on the Manitou Experimental Forest, Colorado. The marked variations in frequency of dwarf mistletoe found on three soil types studied (granitic, limestone, and arkose) apparently were related to variation in slope steepness, with frequency highest on areas with gentle slopes. Stands on soils with a high proportion of gentle slopes (for example, arkose) had the most dwarf mistletoe; those on predominately steep slopes (for example, granite) had much less infection.

Heede, Burchard H. 1960. A study of early gully-control structure in the Colorado Front

Range. Station Paper No. 55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 42 p. **Abstract**: The control of gullies is an important step in watershed rehabilitation. Gully control designed to fix valley bottoms at a certain base level stabilizes the valley floor through sediment accumulation in the gully channel. This reduces sediment deposition in river streambeds and enhances the quality of water supplies. The purposes of this study were: 1. To evaluate gully-control structures installed 20 to 25 years ago on the Pike and San Isabel National Forests. 2. To show the role of check dams in gully control.

Heede, Burchard H. 1967. The fusion of discontinuous gullies. International Association of Scientific Hydrology. Bulletin. 12(4): 42-50. **Abstract**: This case study demonstrates the fusion of two discontinuous gullies in the Colorado Front Range and relates storms and flows to the erosion events. In 7 years, only 5 storms produced runoff in a gully system in the Colorado Front Range of the Rocky Mountains. Storm intensities for periods of 10 minutes influenced runoff production; antecedent precipitation was of no benefit to forecast gully flows. Neither the upstream progression of the head cut nor the amounts of net erosion caused by the individual flows could be related to storm parameters. Stability conditions changed with time but dit not necessarily improve during shorter periods; in fact at times, instability increased and set the stage for more intense future erosion. Applying results from gully-control studies, the author speculates that an early nominal expenditure of funds would have prevented the fusion of the two discontinuous gullies and the displacement of all or most of the soil.

Heller, Robert C., tech. coord. 1975. Evaluation of ERTS-1 data for forest and rangeland surveys. Res. Pap. PSW-RP-112. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 67 p. **Abstract**: Tests used data gathered by the first Earth Resources Technology Satellite. Results on sites in Georgia, Colorado, and South Dakota indicated that ERTS enlargements, preferably color, would be useful to forest managers of large ownerships for broad area planning. Forest land was distinguished from nonforest land with 90 to 95 percent accuracy, in both photointerpretation and computer-assisted analysis. Further breakdowns of cover types could not be made with acceptable accuracy by either method. Forest disturbances from natural causes or human activity could be detected with 90 percent accuracy when ERTS imagery was compared with 6-year-old aerial photos. Stress from mountain pine beetle could not be detected; ERTS wavebands are too broad to identify dying foliage.

Hernandez, Mark T.; Handorean, Alina M.; McCabe, Kevin M.; Ling, Alison. 2010. Seasonal variations in microbial phylogeny and the atmospheric pools of primary biopolymers in temperate sub-alpine settings, Colorado USA. In: American Association for Aerosol Research, 29th annual conference; 2010 October 25-29; Portland, OR. [Place of Publication unknown]: American Association for Aerosol Research: 728. Abstract. **Abstract**: While generally considered oligotrophic, the atmosphere carries biochemical hallmarks of life – both in primary and weathered forms. The contribution of the most primary biopolymers — DNA, lipids, carbohydrates and proteins — to the pool of atmospheric organic carbon remains relatively unknown, as is their potential to

participate in secondary aerosol formation in different environments.
We report here, the first phylogenetic characterization of atmospheric DNA pools juxtaposed to the carbohydrate, proteins and phospholipids content of airborne particulate matter in samples from the Manitou Experimental Forest (Colorado, USA). Size segregated PM10, retained on 90 mm quartz filters were extracted with chloroform-isopropanol mixtures, and airborne genomic DNA was precipitated with ammonium acetate using glycogen as a carrier. DNA was amplified by polymerase chain reaction using universal ribosomal subunit primers for bacteria and fungi. These PCR products were cloned, sequenced and compared to the NCBI sequence database for genus level identification. We report the diversity of the microbiological populations present in air during summer 2008 to be remarkably low, exhibiting near daily variation, and dominated by only a few genera. In a source-tracking paradigm, we correlated the presence of specific genera with a suite of meteorological data including air temperature, wind speed and direction, humidity, and precipitation collected onsite by National Center for Atmospheric Research, which oversees the Manitou Experimental Forest.
Aerosol biodiversity was compared to primary pools of water-soluble carbohydrate, proteins and solvent-extracted phospholipids from the same filters. The mass and OC fraction of these biopolymers is presented as an index of vegetative materials and microbial biomass (PMBIO) comprising total bioaerosol loads and correlated to the types of microorganisms present in this unique and pristine setting.

Hervey, D. F.; Johnson, W. M. 1954. Don't overlook Russian wild rye. Colorado Farm and Home Research. 5: 3-4,11. **Abstract**: This article reviews the merits and drawbacks of seeding Russian rye grass on pasture that is used as livestock forage. Russian wild rye offers drought resistance, early spring pasture, regrowth with summer rains, palatable and nutritious winter pasture, and tolerance to moderately alkaline dry soils.

Hollenstein, K.; Graham, R. L.; Shepperd, W. D. 2001. Biomass flow in western forests: simulating the effects of fuel reduction and presettlement restoration treatments. Journal of Forestry. 99(10): 12-19. **Abstract**: Fuel treatment silviculture and the resulting long-term flow of biomass were examined using data from selected western stands. An uneven-aged management regime with reserve trees was modeled, using a canopy closure of 40 percent for the dominant trees as a target and a harvest cutting cycle of 20 years. Fuel reduction treatments in currently overstocked stands resulted in an initial peak of removal for the first and second cutting cycles. Yields stabilized in subsequent cutting cycles. Removal of some large reserve trees was crucial for maintaining stand structure and fire resilience.

Hudler, George W. 1976. Bird dissemination of *Arceuthobium vaginatum* subsp. *cryptopodum*. Fort Collins, CO: Colorado State University. 82 p. Dissertation.
Abstract: Long distance dissemination of *Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.) Hawksworth and Wiens was studied at the Manitou Experimental Forest, Teller County, Colorado. Specifically, the role that birds play in disseminating the parasite over long distances was examined. Dwarf mistletoe occurrence in a 0.8 km x 4.

3 km area was plotted on 1:7920 aerial photographs. Thirty two infection centers (satellite centers) were found in 128 h of healthy timber. They were judged to have originated by some means other than or in addition to explosive seed discharge. Satellite centers were 0.1 m to 3000 m in size and up to 458 m from the nearest inoculum source. They occurred on various topographical sites but never in gulches or similar confined drainages. All but two centers originated from seeds yielding female flowers. In 27 satellite centers, original infections were found. They ranged in age from l7 to 120 years. Birds were mist-netted in or near infection centers during seed dispersal in 1974 -1976. A total of 411 birds representing 21 species were trapped. Birds were examined for dwarf mistletoe seeds on feathers and in fecal material. Seeds were found on feathers of mountain chickadees (*Parus gambeli* Ridgway), pygmy nuthatches (*Sitta pygmaea* Vigors), gray-headed juncos (*Junco caniceps* (Woodhouse)), a chipping sparrow (*Spizella passerina* (Bechstein)), and a Williamson's sapsucker (*Sphyrapicus thyroideus* Cassin). Seeds were found rarely in fecal material and were not viable. Dwarf mistletoe seeds were fed to gray-headed juncos, chipping sparrows, pygmy nuthatches, and mountain chickadees. Whole seeds were voided by the latter two species but were not viable. Tests of seed survival at pH levels and temperatures similar to those encountered in birds' digestive tracts suggest that both factors act to render passed seeds nonviable.
Observations made during dwarf mistletoe seed dispersal suggest that birds are struck by explosively discharged seeds and seeds are transferred to pine foliage during subsequent foraging. Mountain chickadees and pygmy nuthatches were the only species observed foraging, apparently for insects, in dwarf mistletoe shoots. Both species were suspected to be important long-distance vectors of the parasite. Populations of pygmy nuthatches were regulated, at least in part by cavity tree frequency and distribution. One quadrant of the study area had 1 cavity tree per 2 h, and 1 breeding pair of pygmy nuthatches per 4 h. An adjacent quadrant had 1 cavity tree per 0.6 h and 1 breeding pair of pygmy nuthatches per 2.4 h.

Hudler, George W.; Oshima, Nagyoshi; Hawksworth, F. G. 1979. Bird dissemination of dwarf mistletoe on ponderosa pine in Colorado. The American Midland Naturalist. 102(2): 273-280. **Abstract**: Dwarf mistletoe [*Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.) Hawksworth and Wiens] distribution and the role of birds as vectors of the parasite were studied in a Colorado ponderosa pine (*Pinus ponderosa* Laws.) forest. Occurrence of the parasite at distances from a source greater than those attributable to explosive seed discharge was erratic and infrequent. In 24 cases, ages of initial infections in single or multiple tree infection centers were determined. Age analyses indicated that long-distance seed transmission followed by successful infection occurred on an average once every 4 years in 150 ha of healthy ponderosa pine. A total of 411 birds representing 21 species were trapped in an infected pine stand during dwarf mistletoe seed dispersal in 1974-1976. Mountain chickadees (*Parus gambeli* Ridgway) and pygmy nuthatches (*Sitta pygmaea* van Rossem) were primary vectors of the parasite. Field observations and laboratory experiments suggested that birds ingested dwarf mistletoe seeds infrequently but such seeds were not viable when voided in feces. Viable seeds apparently were transported by birds only when they adhered to feathers and were transferred to foliage as birds subsequently foraged.

Hull, A. C., Jr.; Johnson, W. M. 1955. Range seeding in the ponderosa pine zone in Colorado. Circular No. 953. Washington, DC: U.S. Department of Agriculture. 40 p. **Abstract**: Twenty-eight studies were made at 20 locations to determine the species and methods for seeding depleted parks and openings in the ponderosa pine zone in Colorado. In addition, records were obtained from 391 other seedings on lands in the ponderosa pine zone. Crested wheatgrass was the best adapted species throughout the ponderosa pine zone. Russian wildrye, intermediate wheatgrass, smooth brome, beardless and pubescent wheatgrasses, meadow brome, Arizona and sheep fescues, and big bluegrass also performed well in most seeding trials. The removal of competing brush, seeding methods, season of seeding, and the grazing of seeded areas were also examined.

Jimenez Esquilin, Aida. E.; Stromberger, Mary E.; Massman, William J.; Frank, John M.; Shepperd, Wayne D. 2007. Microbial community structure and activity in a Colorado Rocky Mountain forest soil scarred by slash pile burning. Soil Biology and Biochemistry. 39(5): 1111-1120. **Abstract**: Tree thinning and harvesting produces large amounts of slash material which are typically disposed of by burning, often resulting in severe soil heating. We measured soil chemical properties and microbial community structure and function over time to determine effects of slash pile burning in a ponderosa pine forest soil. Real time data were collected for soil temperature, heat flux, and soil moisture contents in one of two slash piles burned in April 2004. During the burn, soil temperatures reached 300 °C beneath the pile center and 175 °C beneath the pile edge. Slash pile burning increased soil pH, extractable N and P, and decreased total C levels within the first 15 cm of soil. Burning reduced soil bacterial biovolumes within the first 15 cm of soil and fungal biovolumes within the first 5 cm of soil. One month after the burn, soil microbial communities under the pile center were enriched in Gram-positive bacterial fatty acid markers compared to communities from under the pile edge and control (nonburned) soil. Fifteen months later, soil chemical properties had not returned to background levels, and microbial community structure in fire-affected soil, regardless of pile location, was distinct from communities of control soil. In fire-affected soil, concentrations of fungal fatty acid biomarkers were low and arbuscular mycorrhizal fungal biomarkers were absent, regardless of pile location. Slash pile burning also reduced fungal and bacterial respiration and resulted in large fluctuations in microbial potential N mineralization and immobilization activities. By altering soil properties important to soil conservation and plant reestablishment, slash pile burning negatively impacts forest ecosystems at localized scales.

Jimenez Esquilin, Aida E.; Stromberger, Mary E.; Shepperd, Wayne D. 2008. Soil scarification and wildfire interactions and effects on microbial communities and carbon. Soil Science Society of America Journal. 72(1): 111-118. **Abstract**: Nutrient availability is an important constraint on sustainable forest productivity, and it is crucial to understand the long-term effects of management practices, including soil scarification, on soil microbial communities because they store and cycle nutrients. In addition, because forests are subject to wildfires, it would be useful to understand potential interactive effects of wildfire and management practice on forest soil ecosystems. We

studied the individual and combined effects of soil scarification and a subsequent wildfire on microbial community structure of a ponderosa pine (*Pinus ponderosa* C. Lawson) forest soil in the central Rocky Mountains. Experimental plots were scarified by rototilling in 1981, and in 2002, some of the plots were burned during a mixed-severity wildfire. In 2005, mineral soil samples (0-10-cm depth) were collected and assayed for soil chemical properties, fungal and bacterial biomass, C mineralization potential, and microbial community fatty acid composition. Compared with undisturbed soil, soil from scarified-only plots was relatively high in pH, low in total C and organic matter (OM) concentrations, low in fungal and bacterial biomass, and enriched with Gram-positive biomarkers. Regardless of scarification treatment, soil from burned plots was relatively high in pH and extractable P, low in fungal but not bacterial biomass, and enriched with Gram-negative bacterial biomarkers. Compared with scarified-only plots, scarified-plus-burned plots had greater soil C and OM concentrations. Carbon mineralization rates were not different among the plot soils. While scarification is a positive practice for aiding seedling establishment, we found long-term effects on soil C reserves and microbial communities.

Johnson, Steven R. 1978. Impact of cattle grazing on the surface water quality of a Colorado Front Range stream. Fort Collins, CO: Colorado State University. 115 p. Thesis. **Abstract**: The purpose of this study was to quantify the impact and evaluate the local and immediate downstream pollution potential of range cattle grazing with free stream access. Emphasis was placed on suspended solids, ammonia-nitrogen, nitrate -nitrogen, orthophosphate, fecal coliform and fecal streptococci concentrations. Samples were collected at four sites along a 2.6 km section of Trout Creek, the only perennial stream within the Manitou Experimental Forest. The study was broken down into eight periods covering the two year period 1977 -1978; two included 150 cows in the lower pasture, two involved grazing by 40 cows in an adjacent pasture while four periods involved no grazing in either pasture. The findings of this study indicate that only fecal coliform and fecal streptococci concentrations reflected a cattle grazing impact. Ammonia-nitrogen and nitrate-nitrogen concentrations suggest a grazing impact while orthophosphate concentrations appeared to be independent of cattle grazing. During most of the study the suspended solids analyses were confounded by an area of breached beaver darns. Cattle location and defecation trends help to explain the low concentrations of the parameters involved. In many instances the contribution by grazing cattle was minor in comparison to background concentrations measured at upstream sites.

Johnson, Steven R.; Gary, Howard L.; Ponce, Stanley L. 1978. Range cattle impacts on stream water quality in the Colorado front range. Research Note RM-359. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 8 p. **Abstract**: Studies on two adjacent pastures along Trout Creek in central Colorado indicated only minor effect of cattle grazing on water quality. Bacterial contamination of the water, however, significantly increased. Following removal of the cattle, bacterial counts dropped to levels similar to those in the ungrazed pasture.

Johnson, W. M. 1938. Artificial reseeding on abandoned farm lands and other eroding areas in Manitou Park, Colorado. Progress Report 1937. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p. **Abstract**: The objective of this progress report is to determine the best species and methods for reseeding denuded lands as an erosion control measure. Preliminary results suggest the superiority and adaptability of sweet clover as a species suitable for artificial reseeding on eroding areas in the Manitou Park area. Smooth brome, crested wheatgrass, and blue grama failed to germinate in sufficient quantity to indicate merit for reseeding purposes.

Johnson, W. M. 1942. The interception of rain and snow by a forest of young ponderosa pine. Transactions, American Geophysical Union. 23: 566-570. **Abstract**: This study measured the amount of precipitation reaching the forest floor under stands of immature ponderosa-pine on small watersheds. Results indicated that: (1) On these watersheds an average of 81.4% of the total precipitation reached the ground under tree-crowns. This amount varied significantly among the watersheds, probably because of a variation in density of the crown-canopies. (2) About 0.03 to 0.05 inch of precipitation is required to saturate the forest-canopy in each storm. After this initial storage is filled, practically all of the rainfall reaches the ground. (3) After adjustment to values expected for the average gross precipitation, there was no significant difference in net precipitation among the three seasons studied. Apparently the interception of snow by tree-crowns is quite similar in magnitude to the interception of rain; at least in this cover-type and climate.

Johnson, W. M. 1943. Do steers gain faster than heifers? Western Farm Life. 45: 3. **Abstract**: A three year study at the Rocky Mountain forest and range experiment station in northeastern Colorado evaluated weight gain differences between steers and heifers. Steers and heifers were grazed together on short-grass range. Results indicated that there was not a significant difference between the weight gains made by yearling steers and heifers. There was also no significant difference in monthly gains between the sexes.

Johnson, W. M. 1944. Studies show cattle shrink 47 pounds in corral overnight. Western Farm Life. 46: 6. **Abstract**: During a study of range management at the Central Plains Experimental Range in northeastern Colorado, observations were made on the amount of shrink of yearling Hereford range cattle held overnight in a dry lot. On average cattle lost 47 pounds per head while in the corral overnight.

Johnson, W. M. 1944. It pays to stock your ranges conservatively. The Westerner. 7: 7, 40-41. **Abstract**: Cattle weight gains were evaluated under three different stocking rates near Woodland Park, Colorado during the 1943 summer grazing season. Moderate stocking was found to produce more beef with fewer animals than heavy stocking. Furthermore, at the end of the grazing season, cattle grazed in the lightly stocked pastures were valued higher than the cattle grazed in the heavily grazed pastures. The end-of –season return was highest for cattle grazed on lightly stocked pasture, followed by moderately stocked, and finally heavily stocked.

Johnson, W. M. 1945. Natural revegetation of abandoned crop land in the ponderosa pine zone of the Pike's Peak region in Colorado. Ecology. 26(4): 363-374. **Abstract**: This study examines the rate of revegetation and the stages of secondary succession on abandoned farm lands in the vicinity of the Manitou Experimental Forest, Colorado. Detailed studies of ten fields in various stages of succession were initiated in 1936 and were concluded in 1944.

Johnson, W. M. 1947. Grass-the West's greatest commodity. The Westerner. 11: 48-49. **Abstract**: This article describes the differences between high and low quality forage and grazing conditions on rangelands. Recommendations on how to maintain high quality forage and prevent degraded rangelands are provided.

Johnson, W. M. 1947. Return of abandoned fields to forage production can be hastened by reseeding. Colorado A & M News. 1: 6-7. **Abstract**: This article provides advice on reseeding practices in the CO ponderosa pine zone in order to return abandoned fields to productive forage. Reseeding suggestions include ensuring: 1) the proper amount of good, clean, viable seed of a species adapted to the locality; 2) a good firm seedbed reasonably free of competition from other plants; 3) careful planting and covering of the seed to desirable depths for proper germination; 4) sufficient moisture to cause germination; 5) favorable climatic conditions following germination. Additionally, a few species that have shown successful establishment are recommended.

Johnson, W. M. 1951. Which grass is best? American Cattle Producer. 32: 11-13, 26. **Abstract**: This article reviews the adaptability and forage potential of a variety of grass species seeded on Manitou Experimental Forest. For the species considered, attributes such as: seedling establishment, herbage and root growth, seed production, phenology, and persistence are discussed.

Johnson, W. M. 1953. The effect of grazing intensity upon vegetation and cattle gains on ponderosa pine-bunchgrass ranges of the Front Range of Colorado. Circular No. 929. Washington, DC: U.S. Department of Agriculture. 36 p. **Abstract**: This study examines the relationship between grazing intensity to herbage production, herbage utilization, and amount and value of cattle gains on ponderosa pine-bunchgrass ranges. Results suggest that heavy grazing lead to lowered production of grass and sedge herbage. Under moderate and light grazing, herbage production was maintained throughout the study. Cattle weight gain was associated with grazing intensity and season of grazing. An optimum of 5- to 40-percent utilization of the grass and sedge herbage on pine-bunchgrass ranges is recommended as being a grazing intensity that will maintain forage values and make efficient use of available forage for beef production.

Johnson, W. M. 1954. Supplements on fall range. Colorado Rancher and Farmer. 8(14): 10. **Abstract**: Supplemental feeding of yearling heifers on fall range at the Manitou Experimental Forest during the fall season of 1953 increased weight gains 22.4 pounds per head, increased market values 75 cents per cwt., and resulted in $3.93 more value

per animal after cost of feed had been deducted.

Johnson, W. M. 1955. The place of research in range management. Ames Forester. 42: 14-16. **Abstract**: This article makes an argument in support of research in range management and highlights the research performed at Manitou Experimental Forest. Three major topics studied at Manitou Experimental Forest and reviewed here include: (1) management of native bunchgrass ranges; (2) management of degraded and abandoned farmlands that have been reseeded to grass; and (3) the relation of water runoff and soil erosion to different conditions resulting from different types of range management.

Johnson, W. M. 1956. The effect of grazing intensity on plant composition, vigor, and growth of pine-bunchgrass ranges in central Colorado. Ecology. 37(4): 790-798. **Abstract**: This study examines the changes in native vegetation in relation to past grazing use on six experimental pastures on native ponderosa pine-bunchgrass range at the Manitou Experimental Forest. Individual forage plants and herbaceous vegetation grazed under three intensities were examined for changes in growth habits and composition.

Johnson, W. M. 1959. Grazing intensity trials on seeded ranges in the ponderosa pine zone of Colorado. Journal of Range Management. 12(1): 1-7. **Abstract**: This study examines grazing intensity on several grass species that are commonly seeded on abandoned farm lands in Manitou Experimental Forest, CO. Individual grass species, and one mixture of species were grazed to various stubble heights to represent the different grazing intensities. While seeding can yield highly productive rangelands, this study found large fluctuation in herbage from one year to the next. Individual grass species varied in their response to grazing intensity. Crested wheatgrass was grazed to a 2-inch stubble height without seriously injuring its growth and production, while a 4-inch stubble should be left on smooth brome, and intermediate wheatgrass was seriously injured when grazed to a 2-inch stubble height.

Johnson, W. M. 1978. More grass from an acre. Colorado Ranger and Farmer. 2: 25. **Abstract**: This article describes the results of studies designed to measure the effect of reseeding experimental pastures and applying different stocking levels on forage yields and cattle weight gain. Reseeding with smooth brome, crested wheatgrass, and sweet clover, meadow brome, intermediate wheatgrass, meadow fescue, and Russian wild rye produced high forage yields. Results from the stocking experiments suggest that cattle grazed on lightly and moderately stocked pastures gain more weight and are valued higher than cattle grazed on heavily stocked pastures.

Johnson, W. M.; Hull, A. C., Jr. 1949. Range forage species for seeding in ponderosa pine areas. Research Notes No. 5. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 3 p. **Abstract**: Abandoned farms in the ponderosa pine zone were experimentally reseeded at Manitou Experimental Forest. The success of establishment was evaluated for 82 species that were seeded in either fall or spring, 1945-1947. Of the 82 seeded species, intermediate

and crested wheatgrass, smooth and meadow brome, Russian wild-rye, and big bluegrass appeared to be the most vigorous and adapted to the area.

Johnson, W. M.; Niederhof, C. H. 1941. Some relationships of plant cover to run-off, erosion, and infiltration on granitic soils. Journal of Forestry. 39(10): 854-858. **Abstract**: The fact that plant cover influences run-off, erosion, and infiltration has been firmly established by past research. Only under a few special conditions, however, has the degree of this influence been determined quantitatively. The study reported in this article was undertaken to secure a usable measure of this quantitative relationship, and to provide data for watershed management in the mountains of Colorado. With the use of small plots, results have been secured which evaluate plant cover as a watershed factor and at the same time demonstrate that under certain circumstances, soil conditions may overshadow and nullify the effects of vegetation.

Johnson, W. M.; Reid, Elbert H. 1958. Herbage utilization on pine-bunchgrass ranges of Colorado. Journal of Forestry. 56(9): 647-651. **Abstract**: This paper examines the response of several forage species grazed under three intensities in ponderosa pine-bunchgrass ranges in Colorado. Palatability, availability, and growth period affected the utilization of each species. Two of the most productive and palatable grasses in the ponderosa pine-bunchgrass range are Arizona fescue and mountain muhly. On ranges grazed during the growing season, grazing that removed 30 to 40 percent of the herbage was found to maintain both species.

Johnson, W. M.; Reid, Elbert H. 1964. Range condition classification of bunchgrass range at the Manitou Experimental Forest in Colorado. Journal of Range Management. 17(3): 137-141. **Abstract**: This paper describes a method of determining range condition of grassland areas in the ponderosa pine forest of the Colorado Front Range based on relative herbage production of desirable forage species.

Kent, Brian; Shepperd, Wayne D.; Shields, Deborah J. 2000. The Colorado Front Range Ecosystem Management Research Project: Accomplishments to date. In: Smith, Helen Y., ed. The Bitterroot Ecosystem Management Research Project: What we have learned: symposium proceedings. Proc. RMRS-P-17; 1999 May 18-20; Missoula, MT. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station; 119-124. **Abstract**: This article briefly describes the goals and objectives for the Colorado Front Range Ecosystem Management Project (FREM). Research under this project has addressed both biophysical and human dimensions problems relating to ecosystem management in the Colorado Front Range. Results of completed work are described, and the status of the ongoing demonstration project at Manitou Experimental Forest is given.

Kim, S.; Karl, T.; Guenther, A.; Tyndall, G.; Orlando, J.; Harley, P.; Rasmussen, R.; Apel, E. 2009. Emissions and ambient distributions of biogenic volatile organic compounds (BVOC) in a ponderosa pine ecosystem: interpretation of PTR-MS mass spectra. Atmospheric Chemistry and Physics. 10(4): 1759-1771. **Abstract**: Two proton-transfer-reaction mass spectrometry systems were deployed at the

Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H2O, Organics and Nitrogen-Southern Rocky Mountain 2008 field campaign (BEACHON-SRM08; July to September 2008) at the Manitou Forest observatory in a Ponderosa pine woodland near Woodland Park, Colorado USA to simultaneously measure BVOC emissions and ambient distributions of their oxidation products. Here, we present mass spectral analysis in a wide range of masses (m/z=40+ to 210+) to assess our understanding of BVOC emissions and their photochemical process inside of the forest canopy. The biogenic terpenoids, 2-methyl-3-butene-2-ol (MBO, 50.2%) and several monoterpenes (MT, 33.5%) were identified as the dominant BVOC emissions from a transmission corrected mass spectrum, averaged over the daytime (11 am to 3 p.m., local time) of three days. To assess contributions of oxidation products of local BVOC, we calculate a oxidation product spectrum with the OH- and ozone-initiated oxidation product distribution mass spectra of two major BVOC at the ecosystem (MBO and β-pinene) that were observed from laboratory oxidation experiments. A majority (~73%) of the total signal could be explained by known compounds. The remainder are attributed to oxidation products of BVOC, emitted from nearby ecosystems and transported to the site, and oxidation products of unidentified BVOC emitted from the Ponderosa pine ecosystem.

Kim, S.; Karl, T.; Rasmussen, R.; Apel, E.; Harley, P.; Waldo, S.; Roberts, S.; Guenther, A. 2008. Emissions and photochemistry of BVOCs in a ponderosa pine woodland. In: American Geophysical Union, fall meeting 2008; 2008 December 15-19; San Francisco, CA. Washington, DC: Eos Transactions, American Geophysical Union: A31A-0057. Abstract. **Abstract**: We deployed two proton-transfer-reaction mass spectrometry instruments (PTR-MS, IONICON ANALYTIK) for ambient and branch enclosure measurements at the Manitou Experimental Forest, located in the Southern Rocky Mountain area as a part of the Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H2O, Organics and Nitrogen (BEACHON) field campaign in 2008. Vegetation at the field site is dominated by Ponderosa Pine. BVOC emissions from Ponderosa Pine along with temperature, photosynthetic photon flux density (ppfd), relative humidity, and CO2 uptake were measured from two branch-enclosures (shade and sun). Diurnal variations and the emission response to environmental conditions are described and compared to existing models. In addition, we analyzed the speciation of BVOCs from enclosures by GC-MS. We will present quantitative and qualitative characteristics of BVOC emissions from Ponderosa Pine and analytical characteristics of PTR-MS such as fragmentation patterns of semi-volatile compounds (sesquiterpene, bornyl acetate etc) that we identified as major emissions from the enclosures. BVOC emissions observed in the enclosures will be quantitatively compared to BVOC distributions in ambient air. We explore the presence of possibly unidentified BVOCs in the forest canopy by examining PTR-MS mass spectra of enclosure and ambient air samples based on mass scans between 40 - 210 amu.

Klipple, G. E. 1946. Natural recovery from cropland. Green Thumb. 10-11. **Abstract**: This article reviews the natural recovery of abandoned farmland in Manitou Experimental Forest. Stages of succession are discussed and associated common plant species are given.

Klipple, G. E. 1953. Weight gains made by range cattle while grazing summer ranges. Research Notes No. 2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 2 p. **Abstract**: The average monthly weight gain by cattle on summer range in Manitou Experimental Forest is assessed. Monthly average weight gains made by yearling steers, yearling heifers, 2-year-old heifers, and cows follow a similar pattern. Sixty to 90 percent of the total summer gains are made during the first half of the summer season. Calf weight gains per month, however, were less for both May and June than they were during July and August; and September gains were equal to those for May and June. Low October weight gains by yearling and 2-year-old cattle indicate the desirability of moving all cattle intended for fall sale by early October.

Knowe, Steven A.; Hay, Ron. 2002. Ecosystem prescription preparation: a Rocky Mountain high! Natural Resources and Environmental Issues. 9(1): 36. Abstract. **Abstract**: Forest Resources Management majors, during their junior year in the professional forestry curriculum at the University of Tennessee, participate in a field camp, Forestry Spring Block, for the entirety of the spring semester. Courses range from woodland surveying through silviculture and forest measurements. The final course, a capstone course, involves the development of an ecosystem prescription on a designated woodland. During the spring field camps, 2000 and 2001, the students were invited to the Manitou Experimental Forest (USDA Forest Service) north of Woodland Park, Colorado, to develop their ecosystem prescriptions. Four scenarios were used: pre-Columbian restoration of uneven-aged ponderosa pine; emphases on wildlife management or wildfire protection in a wildland/urban interface; wilderness recreation; and timber management in unevenaged ponderosa pine. Students gathered data, completed analyses, used FVS and SUPPOSE models to project stand development, and drafted their prescription. On the last day each crew made a PowerPoint presentation to the audience for review and discussion. The presentation will relate some of the teaching and learning experiences of the students and the faculty.

Lacey, John Robert. 1971. Estimated forage production under ponderosa pine canopy with the heterodyne vegetation meter. Tucson, AZ: University of Arizona. 98 p. Thesis. **Abstract**: Herbage production on a ponderosa pine-bunchgrass range was measured with the Heterodyne Vegetation Meter. A double sampling system comparing meter read plots to clipped plots was utilized.
Correlation coefficients between vegetation meter reading and dry weight herbage data averaged 0.82 and ranged from 0.57 to 0.99. Although correlations using green weight or water data were higher, dry weight data should be used. This eliminates a potential sampling error inherent in meter response to "plant moisture" content.
Reliability distinguished meter performance on all sampling sites. Timber stand variation did not impair sampling. Although a single vegetation type can be sampled on different dates, the use of a pooled prediction equation for the 1200-acre study site is not advocated. Variation in life form among herbage components could impair sampling. Although distinction between grasses and forbs is not necessary, bearberry is atypical and required a separate prediction equation.

Equations computed the sampling intensity necessary for a given confidence level and showed the optimum ratio of meter read plots to clipped plots approached 5:1. Herbage production correlated negatively with timber volume. Yield estimates ranged from 79 to 1891 lb per acre and corresponded to basal area measurements of 97 and 32 sq ft per acre, respectively. This timber influence obscured the effects of differential grazing history and logging treatment on herbage production.

Leaf, Charles F. 1998. An analytical framework for evaluating channel maintenance flows in Colorado. Journal of the American Water Resources Association. 34(4): 865-876. **Abstract**: An accounting procedure is developed which determines a flow regime that is capable of transporting an amount of bedload sediment necessary to ensure channel stability downstream. The method allows for sediment buildup in the channel within geomorphic threshold limits during low flow periods. During periods of high runoff, enough water is bypassed to transport the stored sediment. The procedure utilizes only those flows of sufficient magnitude to maintain channel stability over the long run (25–50+ years). An example is presented which determines the volume of water and frequency of release for channel maintenance purposes downstream from a hypothetical water diversion project. Of some 1,200,000 acre feet generated during a 59-year period, 86,500 acre feet was required for channel maintenance flows. Bypass flows were not required each year, but only during those years when average daily flow reached bankfull or greater. Such releases were made on 202 of the 411 days when average flows either equaled or exceeded bankfull discharge.

Levin, E. J.; Prenni, A. J.; Petters, M. D.; Ortega, J.; Smith, J. N.; Demott, P. J.; Kreidenweis, S. M. 2010. Long-term measurements of aerosol hygroscopicity at a forested site in Colorado. In: American Geophysical Union, fall meeting 2010; 2010 December 13-17; San Francisco, CA. Washington, DC: Eos Transactions, American Geophysical Union: A41E-0143. Abstract. **Abstract**: The BEACHON field study is a large, multi-investigator, inter-disciplinary effort to understand the interactions and feedbacks among the atmosphere, biosphere and hydrosphere through the carbon and water cycles. Aerosols play a vital role in these interactions by acting as cloud condensation nuclei (CCN) and ice nuclei. In this presentation, we will describe long-term, size-resolved (14-350 nm), CCN measurements being conducted as part of the BEACHON project. These measurements began at the Manitou Experimental Forest in Colorado in March 2010 and will continue for one year. Measurements are aimed at determining the aerosol hygroscopicity parameter, kappa, at five supersaturations between ~0.13% and ~0.90. Typical values of kappa are 0.5 - 1.4 for hygroscopic salts such as sodium chloride, ~0.1 for secondary organic species and 0 for nonhygroscopic components. Data from the first 6 months of this study suggest that kappa remains relatively constant over time with an average kappa of 0.17 ± 0.08 over all supersaturations. Despite the relative constancy of the measurements, some variability was observed. For example, kappa values are dependent on supersaturation, indicating heterogeneous aerosol composition with size. Further, a small increase in kappa (~0.05) is generally observed in the mid afternoon at all supersaturations, and there was a modest change in kappa with season, particularly for the largest particles, where average kappa decreased from 0.28 during March through May to 0.19 during

June through August. Atmospheric processes that may be influencing aerosol hygroscopicity at this site, such as new particle formation, will be discussed in this presentation.

Lezberg, Ann L.; Battaglia, Michael A.; Shepperd, Wayne D.; Schoettle, Anna W. 2008. Decades-old silvicultural treatments influence surface wildfire severity and post-fire nitrogen availability in a ponderosa pine forest. Forest Ecology and Management. 255(1): 49-61. **Abstract**: Wildfire severity and subsequent ecological effects may be influenced by prior land management, via modification of forest structure and lingering changes in fuels. In 2002, the Hayman wildfire burned as a low to moderate-severity surface fire through a 21-year pine regeneration experiment with two overstory harvest cuttings (shelterwood, seed-tree) and two site preparations (scarified, unscarified) that had been applied in a mature ponderosa pine forest in the montane zone of the Colorado Front Range in 1981. We used this event to examine how pre-fire fine fuels, surface-level burn severity and post-fire soil nitrogen-availability varied with pre-fire silvicultural treatments. Prior to the wildfire, litter cover was higher under both shelterwood and unscarified treatments than seed-tree and scarified treatments. Immediately after the fire in 2002, we assessed burn severity under 346 mature trees, around 502 planted saplings, and in 448 4-m2 microplots nested within the original experimental treatments. In one-fourth of the microplots, we measured resin-bound soil nitrate and ammonium accumulated over the second and third post-fire growing season. Microplots burned less severely than bases of trees and saplings with only 6.8% of microplot area burned down to mineral soil as compared to >28% of tree and sapling bases. Sapling burn severity was highest in unscarified treatments but did not differ by overstory harvest. Microplot burn severity was higher under the densest overstory (shelterwood) and in unscarified treatments and was positively related to pre-fire litter/duff cover and negatively associated with pre-fire total plant cover, grass cover and distance to tree. In both years, resin-bound nitrate and ammonium (NH4+-N) increased weakly with burn severity and NH4+-N availability was higher in unscarified than scarified plots. The lasting effects of soil scarification and overstory harvest regime on modern patterns of surface burn severity after two decades underscores the importance of historic landuse and silviculture on fire behavior and ecological response. Unraveling causes of these patterns in burn severity may lead to more sustainable fire and forest management in ponderosa pine ecosystems.

Linkhart, Brian D.; Reynolds, Richard T. 1987. Brood division and postnesting behavior of flammulated owls. The Wilson Bulletin. 99(2): 240-243. **Abstract**: This article examines the post fledging behavior of adults and young and describes the occurrence of brood division in flammulated owls in Manitou Experimental Forest. This study is the first to demonstrate brood division in strigiforms.

Linkhart, Brian D.; Reynolds, Richard T. 2004. Longevity of flammulated owls: additional records and comparisons to other North American strigiforms. Journal of Field Ornithology. 75(2): 192-195. **Abstract**: A male Flammulated Owl (*Otus flammeolus*), banded as a breeding adult (age unknown) on 8 July 1988 in central Colorado, was last recaptured on 8 July 2001. On the same study area, a female Flammulated Owl was

banded as a breeding adult (age unknown) on 7 July 1988 and was last recaptured on 22 June 1995. These data establish longevity at a minimum 14 yrs for males and 8 yrs for females. The data suggest that Flammulated Owls may be relatively long-lived, and support evidence that this species has a life history strategy similar to larger raptors.

Linkhart, Brian D.; Reynolds, Richard T. 2006. Lifetime reproduction of flammulated owls in Colorado. Journal of Raptor Research. 40(1): 29-37. **Abstract**: We investigated lifetime reproductive success (LRS) of 22 male and 46 female adult Flammulated Owls (*Otus flammeolus*) in Colorado from 1981–2003. Sexual differences in LRS were at least partially attributable to incomplete breeding histories of females, due to females having a higher estimated emigration rate from the study area than males. The mean number of lifetime breeding attempts for males was 3.4 ± 0.6 (SE; range =1–12), and for females it was 1.9 ± 0.3 (range =1–8). Adjusted for emigration beyond the study area, the estimated mean number of lifetime breeding attempts was 3.6 for males and 2.5 for females. The mean number of lifetime successful breeding attempts (fledging at least one owlet) was similar to lifetime breeding attempts for each sex, reflecting the fact that 84% (85 of 101) of all breeding attempts were successful. Breeding lifespan was correlated with lifetime reproduction for both sexes. Males tended nests that produced 6.9 ± 1.2 fledglings over 4.3 ± 0.8 yr, while females produced 4.0 ± 0.6 fledglings over 2.0 ± 0.3 yr; adjusted for emigration beyond the study area, males tended nests that produced 7.2 fledglings over 4.5 yr, while females produced 5.2 fledglings over 2.6 yr. Relatively few individuals of each sex produced most of the offspring, as 18% of females and 24% of males produced 50% of total owlets. Our finding that relatively few adults accounted for most offspring appears to be associated with habitat quality in territories. Flammulated Owls tend to have a life-history strategy similar to larger raptors by having a relatively low annual reproductive rate and a relatively long lifespan.

Linkhart, Brian D.; Reynolds, Richard T.; Jaksic, F. M. 2007. Return rate, fidelity, and dispersal in a breeding population of flammulated owls. The Auk. 124(1): 264-275. **Abstract**: We estimated annual return rate, fidelity, and breeding dispersal in a migratory population of Flammulated Owls (*Otus flammeolus*) in central Colorado. Return rates, based on capture-recapture histories of 39 males and 52 females from 1981 to 2003, were higher for males (84%) than for females (45%). Annual recapture probability was higher for females, because breeders are easier to capture than nonbreeders and females always attempted to nest, whereas some males were unpaired (did not nest) for up to four years. Territory fidelity was male biased (92%, vs. 56% for females, adjusted for undetected emigration), and mean tenure on territories was more than twice as long for males as for females. Females, but not males, had lower return rates to territories in the year following nesting failure compared with females whose nests were successful. Most males appeared to occupy one territory their entire reproductive lives, countering predictions of habitat-selection models that individuals should move to higher-quality habitats when they become available. We estimated that 74% of pairs retained the same mate in consecutive nesting attempts, but mates that bred together for multiple years had no reproductive advantages over mates that bred together for the first time. In most cases, females dispersed from

territories if their mates did not return. When females dispersed, they went to territories where total productivity over the study and lifetime reproductive success of new mates were higher than on original territories, which supports the hypothesis that dispersal by females increases individual fitness.

Linkhart, Brian D.; Reynolds, Richard T.; Ryder, Ronald A. 1998. Home range and habitat of breeding flammulated owls in Colorado. The Wilson Bulletin. 110(3): 342-351. **Abstract**: We used radiotelemetry to determine habitat use by flammulated owls (*Otus flammeolus*) during the breeding season on 452 ha of montane conifer forest in central Colorado in 1982-1983. Mean size and SD of home ranges was 11.1 ± 1.9 ha (range = 8.5-12.5 ha, n = 4) in 1982 and 18.3 ± 5.1 ha (range = 14.0-24.0 ha, n = 3) in 1983. Habitat use by nesting males was affected by distribution of old forests of ponderosa pine (*Pinus ponderosa*) mixed with Douglas-fir (*Pseudotsuga menziesii*), by topography, and by juxtaposition of home ranges of conspecifics. In spring, both new and returning owls settled into areas containing more old ponderosa pine/Douglas-fir than in other overstory types available in the study area. After settling, males foraged significantly more often in old ponderosa pine/Douglas-fir than in other overstory types available within home ranges. Eighty-one percent of foraging locations by males occurred in one to four intensive foraging areas within each home range. Mean size of intensive foraging areas was 0.5 ± 0.4 ha (range = 0.1-1.4 ha). Eighty percent of intensive foraging areas consisted entirely of old ponderosa pine/Douglas-fir. Use of this overstory type by flammulated owls is probably related to its composition and structure, and prey availability.

Love, L. D. 1953. Watershed management experiments in the Colorado Front Range. Journal of Soil and Water Conservation. 8: 213-218. **Abstract**: This article reviews watershed management experiments on the Colorado Front Range, and specifically in Manitou Experimental Forest. Studies include the effect of grazing intensity on runoff and erosion rates, and comparisons of runoff and erosion rates on different soil and vegetation types. Grazing studies suggest that runoff is most pronounced during the summer rainfall period especially during the high-intensity rainstorms. Plots that were heavily grazed resulted in nearly double the normal amount of erosion. Comparisons of runoff rates on different cover types, suggest that runoff was greatest on the abandoned field, intermediate on the bunchgrass on alluvial soil, and least on the bunchgrass on residual soil. Other erosion studies found that the aspen type offers superior watershed protection, while the ponderosa pine type, although having a moderately high infiltration rate, had also an accelerated erosion rate but was not as serious as that found on the mountain-brush type.

Love, L. D. 1958. The Manitou Experimental Forest-- its work and aims. Station Paper No. 7 (revised). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 21 p. **Abstract**: This report describes the land-use history and current (1958) research in Manitou Experimental Forest. Research objectives include: 1. How to manage ponderosa pine watersheds to improve water yields; 2. How to restore depleted ponderosa pine watersheds to minimize flood and sedimentation damages from cloudburst storms; 3. How to obtain maximum

livestock production on ponderosa pine and improved ranges consistent with wise management of other resources; 4. How to manage cutover and improperly stocked ponderosa pine forests for timber production consistent with wise management of other resources; and 5. How to provide for increased recreation uses of ponderosa pine lands and maintain desirable water, timber, and livestock production. The impact of various grazing intensities on range and watershed quality is also examined.

Love, L. D. 1959. Rangeland watershed management. In: Proceedings, Society of American Foresters; [1958 September 28 - October 2]; [Salt Lake City, UT]. Washington, DC: Society of American Foresters: 198-200. **Abstract**: Rangeland watershed management in Sierra Ancha and Manitou Experimental Forest is reviewed. In most of the studies reviewed, increased plant cover reduces surface runoff and erosion. This reduced surface runoff and erosion is most associated with summer rainstorms than with periods of snowmelt. Curtailment of surface runoff and erosion is closely related to the abundance of desirable bunchgrasses, amount of litter on the soil surface, the amount of bare soil, and the percent large pores in surface soil. Additionally, most studies suggest that heavy grazing leads to poor hydrologic conditions.

Love, L. D.; Johnson, W. M. 1952. The Manitou Experimental Forest--its work and aims. Station Paper No. 7. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 23 p. **Abstract**: The Manitou Experimental Forest was established in 1936 to study problems of land use as they relate to the management of all the resources of the Front Range. Of economic importance are water supply, recreation, livestock grazing, farming, and timber production. The objective of research work on the Forest is to develop better methods of management to perpetuate or restore the natural resources for long-time productivity. Studies are divided into (l) Range Management, (2) Artificial Revegetation, and (3) Watershed Management.

MacDonald, Lee H.; Stednick, John D. 2003. Forests and water: a state-of-the-art review for Colorado. Colorado Water Resources Research Institute completion report no. 196. Fort Collins, CO: Colorado State University. 65 p. **Abstract**: The basic purpose of this report is to provide a state-of-the- art summary on how forest management in Colorado affects water quantity and quality, and to identify key gaps in knowledge. This synthesis should help guide public policy and decision- making, and help identify future research priorities.

Mackes, Kurt; Shepperd, Wayne; Jennings, Christopher. 2005. Evaluating the bending properties of clear wood specimens produced from small-diameter ponderosa pine trees. Forest Products Journal. 55(10): 72-80. **Abstract**: The bending properties of clearwood test specimens produced from small-diameter pine trees were evaluated to provide a basis for determining how to better utilize this resource. Specimens (16 in by 1 in by 1 in) were processed from 57 small-diameter trees harvested from the Manitou Experimental Forest located near Woodland Park, Colorado. Trees were categorized into three groups, 20 "normal" disease-free trees harvested from dense stands typical of

the region, 21 mistletoe-infested trees from similar stocking conditions, and 16 disease-free trees from more open growing conditions. Test specimens were tested in bending and data for 542 specimens were evaluated statistically using a nested design, considering both within- and between-tree variation. This analysis revealed that property variation was much greater transversely across the cross section than longitudinally along the length of the tree. Modulus of elasticity (MOE) and modulus of rupture (MOR) values were highest for test specimens from normal trees. Specimens produced from open-grown trees had significantly lower MOE and MOR values than specimens from both normal and mistletoe-infested trees. While mean MOE and MOR values for specimens from mistletoe-infested trees were lower in comparison to normal wood values, only the difference between mean MOE values was statistically significant. No significant differences existed in the mean specific gravity between the groups. There was not a linear relationship between specific gravity and either MOE or MOR; however, there was a weak linear relationship between sample growth increments per inch and both MOE and MOR, which may provide an opportunity for visually evaluating (grading) small-diameter trees.

Madronich, Monica B.; Wessman, Carol A.; Guenther, Alex. 2011. Influence of landscape configuration on monoterpene emissions from a Ponderosa Pine forest. In: ESA 96th annual meeting--Preliminary program; 2011 August 7-12; Austin, TX. Washington, DC: Ecological Society of America: Abstract. **Abstract**: The objective of this work is to address the relevance of landscape structure on terpenoid emissions, using *Pinus ponderosa* (Ponderosa pine) as the study species. *Pinus ponderosa* is a tree species that can form forests with different densities. It is known to possess different monoterpenes in their tissues and it is also known be an important terpenoid emitter. Ponderosa pine will provide the opportunity to study landscape structure as a factor that could affect terpenoid emissions. The main questions are: 1) What are the factors that have the major influence on Ponderosa pine emissions: Light or temperature? 2) Does landscape structure affect terpenoid emissions (dense vs. not-dense forest)? Preliminary results show that there is a significant difference on Ponderosa pine emissions between sun and shaded branches. Statistical analysis shows that PAR has a stronger relationship with the emissions than temperature does.

Mak, John E.; Su, Luping; Evans, Tracey; Knopf, Daniel. 2011. Spatial and temporal variations of VOC in a ponderosa pine ecosystem. In: 3rd iLEAPS science conference; 2011 September 18-23; Garmisch-Partenkirchen, Germany. Helsinki, Finland: iLEAPS: 1 p. Abstract. **Abstract**: A Proton-Transfer-Reaction Time-of-Flight Mass Spectrometry (PTR-ToF-MS) was deployed during 2010 BEACHON-ROCS campaign in the Manitou Experimental Forest. Several VOCs were quantified, including methanol, acetonitrile, acetaldehyde, acetone, methyl vinyl keton, 2-methyl-3-buten-2-ol, benzene, toluene, methyl ethyl keton and monoterpenes. Monoterpenes have been identified as one of the dominant BVOCs emitted in this sampling area, and combined observation and modeling analyses in a similar pine forest shows that during the summertime ozone loss to the forest is dominated by gas-phase chemistry, most probably contributed by BVOCs (monoterpenes, sesquiterpenes et al.), the oxidation of monoterpenes, in turn, could lead to secondary organic aerosol formation. The spatial and temporal variations

of monoterpenes show that most of the compound emitted are within the forest canopy (~18 m), and could extend to above the canopy during high mixing ratio episodes. A clear diurnal variation pattern is observed, with high mixing ratios occurring between midnight and early morning and low mixing ratios during the most of the daytime. Here we discuss the observations of the monoterpenes and other selected VOCs during the BEACHON-ROCS campaign.

Malechek, John C. 1966. Cattle diets on native and seeded ranges in the ponderosa pine zone of Colorado. Res. Note RM-77. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p. **Abstract**: This report examines the diets of cattle grazing on ranges of the Manitou Experimental Forest. One herd grazed native ranges; and the other grazed both seeded and native ranges. Forage maturity at time of consumption was a major factor determining general nutritive quality of range cattle diets. Cattle grazing seeded forage in spring and fall had higher quality diets than cattle grazing native range yearlong, because seeded ranges started growth earlier in the spring and became dormant later in the fall.

Malechek, John C. 1966. Cattle diets on pine-bunchgrass range. Fort Collins, CO: Colorado State University. 69 p. Thesis. **Abstract**: Forage samples collected by freely grazing ruminal fistulated steers were analyzed chemically and botanically to ascertain the quality of the diets selected by two herds of Hereford range cows managed under separate grazing systems. The herd grazing native and seeded ranges on an integrated basis was maintained on a high plane of dietary crude protein and phosphorus for a longer period of time than was the herd grazing native ranges only. The response was attributed to earlier initiation of spring growth and 1ater attainment of winter dormancy by the seeded forage species. Seasonal trends in dietary protein and phosphorus indicated that the stage of forage maturity at time of consumption was of major importance in determining the general nutritive quality of the diet of both herds. Ash in the diets of the two herds differed little and exhibited a slight decline from early spring to late winter. No seasonal trends in dietary calcium were noted. Botanical compositions of the diets were highly variable, particularly on native ranges. The variability reflected heterogeneity of the ranges sampled rather than changes in animal preference.

Marchand, Peter; Johnson, Samuel; Drossman, Howard. 2006. Long-term effects of mechanical fuel treatments, Manitou Experimental Forest, Colorado: first-year results. Research joint venture agreement between the Catamount Institute and the Rocky Mountain Research Station. 04-JV-11221616-298. [Woodland Park, CO]: [Catamount Center for Geography of the Southern Rockies]. 29 p. **Abstract**: The purpose of this study is to assess the long-term ecological effects of mechanical fuel treatments in a mixed ponderosa pine-Douglas-fir forest following two different thinning strategies: (a) chip-harvesting with all biomass retained on-site, and (b) whole-tree harvesting with all thinned material removed from the site. Changes in forest community structure under each of the above treatments are being tracked and compared with unthinned control plots over a 10-year period by monitoring the following parameters: (1) soil chemical properties, including ammonia and nitrate-N pools, net mineralization, nitrification, and

total C:N ratios, (2) understory plant composition, (3) small mammal population dynamics, and (4) insect emergence patterns.

Marcus, Steven R. 1973. Geology of the montane zone of central Colorado-- with emphasis on Manitou Park. Research Paper RM-113. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 20 p. **Abstract**: Geologic features of four parts of the Montane Zone of central Colorado are described: (1) the Front Range, (2) the Sangre de Cristo Mountains, (3) the Spanish Peaks, and (4) the Wet Mountains. Detailed description and geologic map of the Manitou Experimental Forest are included, which provide some of the information useful in determining applicability of study results to other parts of the Zone.

Mark, Walter R.; Hawksworth, Frank G. 1974. How important are bole infections in spread of ponderosa pine dwarf mistletoe? Journal of Forestry. 72(3): 146-147. **Abstract**: The relation between vigor of dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*) bole infections and diameter of ponderosa pine was evaluated in several areas in Colorado. Infections which occur where the bole is over 5 inches in diameter seem to pose little threat to surrounding trees.

Martinson, Erik; Omi, Phillip N.; Shepperd, Wayne. 2003. Effects of fuel treatments on fire severity. In: Graham, Russell T., tech. ed. Hayman Fire case study. Gen. Tech. Rep. RMRS-GTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 96-126. **Abstract**: The role played by the fuel conditions within the Hayman Fire severity was complex and does not lend itself to a single conclusion or simple summary. Uncertainties in the original treatment prescription, its implementation, discerning the coverage, extent, and condition at the time of the fire made it difficult for us to clearly determine treatment effects and relate them to treatment type or amount. Available fire documentation such as the fire growth and severity maps compiled by the fire management and BAER (Burned Area Emergency Rehabilitation) teams were immensely helpful, but they oversimplify inherent complexities in fire behavior and ephemeral weather conditions and may contain random or systematic errors (for example, classification of burn severity). Nevertheless, each of the different types of fuel modification encountered by the Hayman Fire had instances of success as well as failure in terms of altering fire spread or severity.

Massman, W.; Frank, J.; Stromberger, M. 2008. Long term consequences of a prescribed burn and slash mastication to soil moisture and CO_2. In: 2008 European Geosciences Union General Assembly; 2008 April 13-18; Vienna, Austria. Geophysical Research Abstracts, Vol. 10. EGU2008-A-02283. Abstract. **Abstract**: Thinning of forest stands is frequently used to reduce the risk of catastrophic fire. But thinning requires that the refuse (or slash) be removed from the site, which can be done either by burning it or by mastication and dispersal. Either method has long term consequences to the soil and to soil moisture and soil CO2 levels. This study presents 2+ years (2004-2006) of continuous soil moisture and CO2 measurements at two

experimental slash treatment sites within Manitou Experimental Forest in the Rocky Mountains of southern Colorado: (i) a prescribed burn site and (ii) a site at which the slash was masticated and dispersed.

Massman, W. J. 2005. Impacts of controlled burns on the heating and ecology of soils. In: ESA 2005 annual meeting, joint meeting of IX International Congress of Ecology; 2005 August 7-12; Quebec, Canada. Washington, DC: Ecological Society of America: Abstract. **Abstract**: Heat flow in and out of soils is a major energy source for driving soil ecological processes. Input of this thermal energy into soils is largely determined by surface processes, which occur both naturally, as with the daily and seasonal cycles of solar energy, and catastrophically, as with intense fire. However, the movement of this surface energy into the soil is largely controlled by the soil's thermal properties. By altering soil structure, fire has the potential to alter a soil's thermal properties as well. This in turn would change the pre-fire thermal environment for life within that soil and may impact the rate of soil recovery and the trajectory of the soil's (post-fire) ecological development. This presentation discusses a controlled burn experiment performed at Manitou Experimental Forest (southern Colorado, USA) and intended to assess the impact controlled fires can have on the thermal properties of soils. After the site was selected it was instrumented for profiles of soil temperature and heat flux. The burn pile was then constructed over the instruments and the soil thermal data were monitored before, during and after the burn. Models of soil temperature and heat flux before, during, and after the fire were used to chart the movement of the fire-caused thermal pulse through the soil and to assess if and how the fire may have altered the soil's thermal properties.

Massman, W. J.; Frank, J. M. 2004. Effect of a controlled burn on the thermophysical properties of a dry soil using a new model of soil heat flow and a new high temperature heat flux sensor. International Journal of Wildland Fire. 13(4): 427-442. **Abstract**: Some fires can be beneficial to soils but, if a fire is sufficiently intense, soil can be irreversible altered. We measured soil temperatures and heat fluxes at several soil depths before, during, and after a controlled surface burn at Manitou Experimental Forest (southern Colorado, USA) to evaluate its effects on the soil's thermophysical properties (thermal conductivity and volumetric specific heat capacity). During the burn the soil was heated to over 400 degrees C at a depth of 0.02 m and to almost 100 degrees C at 0.30 m. Relatively high temperatures persisted for several hours to days even over 1 m deep into the soil. At these intensities and durations significant changes in soil chemistry, structure, and nutrient cycling are likely. However, soil thermophysical properties, estimated before and after the fire with a new model of periodic heat flow in soils, were not significantly changed between the times shortly after sensor installation (October 2001) and 1 month after the fire (February 2002). Estimates of the soil thermophysical properties derived with the new model underestimate laboratory analyses performed on soil samples obtained after the fire. Also presented in this study are some of the first soil heat flux measurements made during a surface fire. Furthermore, data and analyses of the type discussed in this study should aid modeling studies of the soil thermal pulse associated with fire. The ultimate goal of this experiment was to provide tools to assist land managers in the use of prescribed fire to

benefit ecosystems and to reduce the potential for harm by examining how the soil's physical properties and different fuel amounts, geometries, and loading densities influence soil recovery and forest regeneration after fires.

Massman, William J.; Frank, J. M. 2004. An in situ investigation of the influence of a controlled burn on the thermophysical properties of a dry soil. In: 26th conference on agricultural and forest meteorology; 2004 August 23-27; Vancouver, BC. Boston, MA: American Meteorological Society: 1.8. Abstract. **Abstract**: Fire can be beneficial or detrimental to soils. If a fire is sufficiently intense soils can suffer irreparable change. This paper examines the possibility that fire can alter soil thermal conductivity and volumetric specific heat capacity of a dry soil. Measurements of soil heat temperatures and heat fluxes were made at several soil depths before, during, and after a controlled surface burn. During the burn the soil was heated to over 400 C at a depth of 0.02 m. At this intensity significant changes in soil chemistry, structure, and nutrient cycling are likely. Using a new soil heat flow model, developed for this study to account for a time lag of about 2.5 hours between the measured soil heat fluxes and the soil temperatures, indicates that the soil thermophysical properties were unchanged by the fire. Estimates of the soil thermophysical properties derived with the new model are in good agreement with laboratory analyses performed on soil samples obtained after the fire. Also presented in this study are some of the first soil heat flux measurements made during a surface fire. Data and analyses of the type discussed in this study should aid modeling studies of the soil thermal pulse associated with fire.

Massman, William J.; Frank, J. M. 2006. Effects of controlled burns on the bulk density and thermal conductivity of soils at a southern Colorado site. In: 27th conference on agricultural and forest meteorology; 2006 May 22-25; San Diego, CA. Boston, MA: American Meteorological Society: 2.4. Abstract. **Abstract**: Fire can play an important role in managing and maintaining ecosystems in many areas of the world. However, if the fire is sufficiently intense, soil can be irreversibly altered. The present study outlines an experiment to determine the effect that controlled burns can have on the bulk density and thermal conductivity of the soils at the Manitou Experimental Forest in the Rocky Mountains of southern Colorado. Previous studies indicate that soil bulk density nearly always increases as a result of fire, but virtually no studies exist on the impact of fire on soil thermal conductivity. Vertical profiles of soil bulk density, thermal conductivity, and volumetric soil moisture were obtained at two burn locations. Measurements were made before and after the burns within the burn areas, as well as outside the burn areas (controls).

Massman, W. J.; Frank, J. M.; Jimenez Esquilin, A. E.; Stromberger, M. E.; Shepperd, W. D. 2006. Long term consequences of a controlled slash burn and slash mastication to soil moisture and CO_2 at a southern Colorado site. In: 27th conference on agricultural and forest meteorology; 2006 May 22-25; San Diego, CA. Boston, MA: American Meteorological Society: 2.2. Abstract. **Abstract**: Thinning of forest stands is frequently used to reduce the risk of catastrophic fire. But thinning requires that the refuse (or slash) be removed from the site, which can be done either by burning it or by mastication and dispersal. Either method has long term consequences to the soil and to

soil moisture and soil CO2 levels. This study presents 2+ years of continuous soil moisture and CO2 measurements at two experimental slash treatment sites within Manitou Experimental Forest in the Rocky Mountains of southern Colorado: (i) a controlled burn site and (ii) a site at which the slash was masticated and dispersed. Each experimental site has a separate control plot (with no treatment). The instrumentation was installed before each treatment (either burning or mastication).

Massman, W. J.; Frank, J. M.; Massman, S. M.; Shepperd, W. D. 2003. Performance of high temperature heat flux plates and soil moisture probes during controlled surface fires. In: 5th symposium on fire and forest meteorology joint with 2nd international wildland fire ecology and fire management congress; 2003 November 16-20; Orlando, FL. Boston, MA: American Meteorological Society: 1.8. Abstract. **Abstract**: Natural and prescribed fires play an important role in managing and maintaining most ecosystems in the western US. The high soil temperatures associated with fire influence forests and their ability to regenerate after a fire by altering soil properties and soil chemistry and by killing soil microbes, plant roots, and seeds. Because prescribed fire is frequently used to reduce surface fuels, it is important to know how fuel conditions, soil moisture, and soil properties interact to determine the nature and extent of the soil heat pulse and the response of the soil biota. This report presents the results of experimental tests of a high temperature soil heat flux plate and a high temperature soil moisture probe. These sensors are intended to provide data before, during, and after a prescribed burn and to support long term monitoring of soil microbial response to fires. In both experiments the upper 2 cm of soil was heated to about 400 C while each sensor had a nominal depth of 5 cm. Results suggest (1) that the soil heat flux plate, rated to at about 750 C, performed successfully and (2) that a simple redesign of the soil moisture probe, which is rated to about 250 C, should permit it to survive higher temperatures than achieved during these preliminary tests. Nevertheless, the soil moisture probe did provide some of the first observations of soil moisture dynamics during and after a controlled burn.

Massman, William J.; Frank, John M.; Mooney, Sacha J. 2010. Advancing investigation and physical modeling of first-order fire effects on soils. Fire Ecology. 6(1): 36-54. **Abstract**: Heating soil during intense wildland fires or slash-pile burns can alter the soil irreversibly, resulting in many significant long-term biological, chemical, physical, and hydrological effects. To better understand these long-term effects, it is necessary to improve modeling capability and prediction of the more immediate, or first-order, effects that fire can have on soils. This study uses novel and unique observational data from an experimental slash-pile burn to examine the physical processes that govern the transport of energy and mass associated with fire-related soil heating. Included in this study are the descriptions of 1) a hypothesized fire-induced air circulation within the soil, and 2) a new and significant dynamic feedback between the fire and the soil structure. The first of these two hypotheses is proposed to account for the almost instantaneous order-of-magnitude increase in soil CO2 observed during the initiation of the burn. The second results from observed changes to the thermal conductivity of the soil, thought to occur during the fire, which allow the heat pulse to penetrate deeper into the soil than would occur without this change. The first ever X-ray computed tomography images of

burn area soils are consistent with a change in soil structure and a concomitant change in soil thermal conductivity. Other ways that current technology can be used to aid in improving physically-based process-level models are also suggested.

Massman, W. J.; Frank, J. M.; Reisch, N. B. 2008. Long-term impacts of prescribed burns on soil thermal conductivity and soil heating at a Colorado Rocky Mountain site: a data/model fusion study. International Journal of Wildland Fire. 17(1): 131-146. **Abstract**: Heating any soil during a sufficiently intense wild fire or prescribed burn can alter that soil irreversibly, resulting in many significant, and well studied, long-term biological, chemical, and hydrological effects. On the other hand, much less is known about how fire affects the thermal properties and the long-term thermal regime of soils. Such knowledge is important for understanding the nature of the soil's post-fire recovery because plant roots and soil microbes will have to adapt to any changes in the day-to-day thermal regime. This study, which was carried out at Manitou Experimental Forest (a semiarid site in the Rocky Mountains of central Colorado, USA), examines three aspects of how fire can affect the long-term (post-fire) thermal energy flow in soils. First, observational evidence is presented that prescribed burns can alter the thermal conductivity of soils to a depth of at least 0.2m without altering its bulk density. Second, data are presented on the thermal properties of ash. (Such data are necessary for understanding and modeling the impact any remaining post-fire ash layer might have on the daily and seasonal flow of thermal energy through the soil.) Third, observational data are presented on the long-term effects that prescribed burns can have on soil surface temperatures. In an effort to quantify long-term changes in the soil temperatures and heat fluxes resulting from fire this study concludes by developing and using an analytical model of the daily and annual cycles of soil heating and cooling, which incorporates observed (linear variation of) vertical structure of the soil thermal properties and observed changes in the surface temperatures, to synthesize these fire-induced effects. Modeling results suggest that under the dry soil conditions, typical of the experimental forest, the amplitudes of the daily and seasonal cycles of soil heating/cooling in the fire-affected soils will greatly exceed those in the soils unaffected by fire for several months to years following the fire and that these effects propagate to depths exceeding one meter.

Massman, W. J.; Frank, J. M.; Shepperd, W. D.; Platten, M. J. 2003. In situ soil temperature and heat flux measurements during controlled surface burns at a southern Colorado forest site. In: Omi, Philip N.; Joyce, Linda A., tech. eds. Fire, fuel treatments, and ecological restoration: conference proceedings. RMRS-P-29; 2002 April 16-18; Fort Collins, CO. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 69-87. **Abstract**: This study presents in situ soil temperature measurements at 5-6 depths and heat flux measurements at 2-5 depths obtained during the fall/winter of 2001/2002 at seven controlled (surface) fires within a ponderosa pine forest site at the Manitou Experimental Forest in central Colorado. Six of these burns included three different (low, medium, and high) fuel loadings under both a closed-canopy forested site and an open forest with a grassy meadow understory. The fuel loading for the seventh burn was a conical pile of slash about 6 m in height and 9 m in diameter and was intended to duplicate the structure and loading of a slash pile

resulting from mechanical harvesting activities. One basic purpose of this initial experiment was to assess how well some commercially available soil heat flux plates would perform at high temperatures. The data presented here include soil temperatures, heat fluxes, and depth and duration of the thermal energy penetration into the soils. The maximum surface heat fluxes were estimated to be about 2400 Watts/meter2 [Wm-2] at the slash pile burn site, 2300 Wm-2 at the high fuel meadow site, and 3000 Wm-2 at the high fuel forested site. Extrapolated surface temperatures are about 436 C at the slash burn site, 359 C at the high fuel meadow site, and 95 C at the high fuel forested site. Recovery of a normal daily temperature cycle depended on fire duration and fuel loading. The recovery times were between 16 and 20 hours at the high fuel sites, about half this time at the medium fuel sites, and less than 2 hours at the low fuel sites. However, the recovery time at the slash pile site was about 2 weeks. Although further tests and refinements are planned, the present results suggest not only that soil heat flux can be reliably measured during controlled burns, but that soil temperatures and heat flux can differ significantly with different fuel loadings.

Mayland, H. F. 1986. Factors affecting yield and nutritional quality of crested wheatgrass. In: Johnson, Kendall L, ed. Crested wheatgrass: its values, problems and myths; symposium proceedings; 1983 October 3-7; Logan, UT. Logan, UT: Utah State University: 215-266. **Abstract**: This paper reviews the literature on factors affecting the yield and nutritional value of crested wheatgrass (*Agropyron cristatum, A. desertorum, A. fragile*). The Agropyrons are cool-season perennial bunch granges that are grown in the western United States and Canada where annual precipitation ranges from 9 to 18 inches (230 to 460 mm) and forage yield ranges from 400 to 3000 pounds of dry matter per acre (450 to 3360 kg/ha). Forage production in the northern Great Plains is best correlated with April to June precipitation whereas in the area west of the Rooky Mountains production is best correlated with total autumn to spring precipitation.

Mayo, Talea; Mauldin, L.; McGrath, J.; Petaja, T. 2009. Hydroxyl radical and sulfuric acid concentrations in Manitou Experimental Forest. In: Eighth annual AMS student conference of the 89th American Meteorological Society annual meeting; 2009 January 10-11; Phoenix, AZ. Boston, MA: American Meteorological Society: P1.41. Poster. **Abstract**: The hydroxyl radical (OH) is an important chemical species. It is the primary oxidizing agent in the troposphere, reacting with many pollutants and consequently maintaining the purity of the air. It also plays an important role in the formation of sulfuric acid (H2SO4), which is important to aerosol production. It is this role that made concentrations of OH a measurement of interest to the Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H2O, Organics and Nitrogen (BEACHON) Project, a study that aimed to improve earth system models by quantifying geophysical systems. High reactivity, short lifespan, and low concentrations of OH make this molecule is particularly difficult to measure. Chemical Ionization Mass Spectrometry (CIMS) is one reliable method of measuring OH concentrations and was used in this study. The CIMS instrument measures OH by first converting it to sulfuric acid by the addition of isotopically labeled sulfur dioxide (34SO2), allowing naturally occurring H2SO4 to also be measured. Concentrations of both OH and H2SO4 were taken in Manitou Experimental Forest (MEF) in Manitou Springs, Colorado in summer 2008.

Decay rates of OH were also determined. While OH concentrations and decay rates were unavailable at the conclusion of this research, concentrations of OH and H2SO4 as well as OH decay rates were measured in a similar study conducted in Morgan-Monroe Experimental Forest in May 2008

McCallum, D. Archibald. 1994. Review of technical knowledge: flammulated owls. In: Hayward, G. D.; Verner, J., tech. eds. Flammulated, boreal, and great gray owls in the United States: A technical conservation assessment. Gen. Tech. Rep. RM-253. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 14-46. **Abstract**: Technical, biological, and ecological knowledge is reported in this review of the flammulated owl. The flammulated owl (*Otus flammeolus*) is a tiny, common predator on invertebrates that nests in cavities in western North American coniferous forests. It was thought by early workers to be rare, but more recent opinion is that it is common but secretive. The combination of its very small size, ventriloquial but low-pitched voice, strictly invertebrate diet, and probable migratory behavior suggests an unusual adaptive strategy. Understanding all aspects of this strategy will lead to wise management decisions.

McCambridge, W. F. 1981. Duration of effectiveness of carbaryl in protecting ponderosa pines from attack by mountain pine beetles. Research Note RM-408. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 3 p. **Abstract**: The residual toxicity of carbaryl, at 2% and 4% strength, was compared by field and laboratory methods. Two percent carbaryl spray provided minimally acceptable protection of ponderosa pines from mountain pine beetle attacks 13 months after application. At 4% strength, protection was satisfactory for 15 months, as tested by laboratory bioassay.

McHugh, Charles W.; Gleason, Paul. 2003. Fire behavior, fuel treatments, and fire suppression on the Hayman Fire - Part 5: Fire suppression activities. In: Graham, Russell T., tech. ed. Hayman Fire case study. Gen. Tech. Rep. RMRSGTR-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 131-144. **Abstract**: The purpose of this report is to document the suppression actions taken during the Hayman Fire. The long duration of suppression activities (June 8 through July 18), and multiple incident management teams assigned to the fire, makes this a challenging task. Original records and reports produced independently by the various teams assigned to different portions of the Hayman Fire had different reference locations and time frames. Nevertheless, this report reviews the success of those crews in achieving their planned tactics but did not attempt to equate this performance to their overall effectiveness on suppressing the fire or in producing changes in fire growth and behavior.

Mead, Roy A. 1974. Factors affecting computer recognition of ponderosa pine forest from ERTS-1 imagery. Fort Collins, CO: Colorado State University. 85 p. Thesis. **Abstract**: Regression models were developed relating the mean spectral response from ponderosa pine forests, measured by the multispectral scanner of the Earth Resources Technology Satellite (ERTS-I), with tree canopy cover, and the slope steepness. It was

found that varying cover of ponderosa pine forest produced different spectral responses and could subsequently effect classification accuracy. However, the relationship between the spectral response from ponderosa pine forests and slope steepness was not reliably determined.
Comparison of the spectral response from plots of ponderosa pine forest on east and west aspects was made, but a trend due to aspect was not apparent. A correlation between the within plot distribution of the forest and non-forest vegetation and the standard deviation of the mean spectral response from the plots of ponderosa pine forest was noted. A multiple linear regression equation was developed, incorporating both the mean and the standard deviation of the spectral response, for predicting the percent crown cover of ponderosa pine.
Channel ratioing was considered as a means of improving the distinguishability of forest and grassland classes, and the relationship between the reflectance of these two classes, that would be most desirable for classification is discussed.

Mead, Roy A.; Driscoll, Richard S.; Smith, James A. 1979. Effects of tree distribution and canopy cover on classification of ponderosa pine forest from LANDSAT-1 data. Research Note RM-375. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 3 p. **Abstract**: Many factors confound computer-assisted classification of forest types from LANDSAT-1 digital data in a mountainous area of central Colorado. Tree distribution and variable forest canopy cover were considered in this study to determine if classification could be improved by accounting for these factors.

Meiman, James R. 2005. The legacy of collaborative watershed research between the Rocky Mountain Forest and Range Experiment Station and Colorado State University. In: American Geophysical Union Hydrology days; 2005 March 8; Fort Collins, CO. Fort Collins, CO: Colorado State University: 273-278. **Abstract**: This paper gives brief overview of watershed research collaboration between the Rocky Mountain Forest and Range Experiment Station and Colorado State University. Reference is made to several publications that give a more exhaustive accounting.

Metz, Harley E. 1974. Relationship between ponderosa pine and understory herbage production. Fort Collins, CO: Colorado State University. 90 p. Thesis. **Abstract**: This study predicts herbage production from various overstory and understory parameters. The overstory parameters of trees/acre, basal area, crown canopy cover and crown canopy density were all significantly correlated with understory yields. The layers of forest floor accumulation were also correlated with understory herbage yields. The factors of soil nitrate-nitrogen were not found to be significantly correlated with understory yields.
The growth rates and growth curves of the major herbaceous species were developed. These growth curves indicated the pattern of precipitation received in July and August influences the growth of blue grama, fringed sagebrush, Arizona fescue and mountain muhly which were growing in natural forest openings. For Arizona fescue and mountain muhly under a pine canopy the precipitation influence was not as strong. In addition, peak herbage production of Arizona fescue under a pine canopy was 716 lbs/acre and

in a natural forest opening 1103 lbs/acre. For mountain muhly under a pine canopy peak herbage production was 305 lbs/acre and in a natural forest opening 714 lbs/acre.

Milchunas, Daniel G. 2006. Responses of plant communities to grazing in the southwestern United States. Gen. Tech. Rep. RMRS-GTR-169. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p. **Abstract**: Grazing by wild and domestic mammals can have small to large effects on plant communities, depending on characteristics of the particular community and of the type and intensity of grazing. The broad objective of this report was to extensively review literature on the effects of grazing on 25 plant communities of the southwestern U.S. in terms of plant species composition, aboveground primary productivity, and root and soil attributes. Livestock grazing management and grazing systems are assessed, as are effects of small and large native mammals and feral species, when data are available. Emphasis is placed on the evolutionary history of grazing and productivity of the particular communities as determinants of response. After reviewing available studies for each community type, we compare changes in species composition with grazing among community types. Comparisons are also made between southwestern communities with a relatively short history of grazing and communities of the adjacent Great Plains with a long evolutionary history of grazing. Evidence for grazing as a factor in shifts from grasslands to shrublands is considered. An appendix outlines a new community classification system, which is followed in describing grazing impacts in prior sections.

Mooney, K. A. 2001. The life history of *Dasypyga alternosquamella* Ragonot (Pyralidae) feeding on the Southwestern dwarf mistletoe (*Arceuthobium vaginatum*) in Colorado. Journal of the Lepidopterists' Society. 55(4): 140-143. **Abstract**: The immature stages, feeding and oviposition behaviors, patterns of larval abundance, and associated arthropod fauna of *Dasypyga alternosquamella* Ragonot (Pyralidae) on *Arceuthohium vaginatum* susp. *cryptopodum* (Hawks.), the Southwestern dwarf mistletoe, are described and illustrated. The study was conducted at the Manitou Experimental Forest, U.S.D.A. Rocky Mountain Research Station, Woodland Park, Colorado, where the Southwestern dwarf mistletoe parasitizes *Pinus ponderosa* (Laws.) *scopulorum*.

Mooney, Kailen A. 2002. Quantifying avian habitat use in forests using track-plates. Journal of Field Ornithology. 73(4): 392-398. **Abstract**: I constructed track-plates resembling short pine branches and attached them to pairs of neighboring pine trees distributed over a 1000-ha area in the Colorado Front Range. I checked track-plates after four and eight days between 24-31 August 2000 and scored each for the presence or absence of tracks. Half of all track plates were marked within four days. I found a positive correlation between scores of paired trees, indicating that track-plating accurately reflected the relative abundance of birds among habitat patches. A power analysis showed that to test for a 15% difference in bird visitation among habitats with a power of 0.75 required a sample size of 25 trees.

Mooney, Kailen A. 2003. *Promylea lunigerella glendella* Dyar (Pyralidae) feeds on both conifers and parasitic dwarf mistletoe (*Arceuthobium* spp.): one example of food plant

shifting between parasitic plants and their hosts. Journal of the Lepidopterists' Society. 57(1): 47-53. **Abstract**: Larvae of *Promylea lunigerella glendella* Dyar (Pyralidae, Phycitinae) feed on *Arceuthobium vaginatum* susp. *cryptopodum* (Hawks.) (Viscaceae), the southwestern dwarf mistletoe, a parasite of *Pinus ponderosa* (Laws.) *scopulorum* (Pinaceae) at the Manitou Experimental Forest, U. S.D.A. Rocky Mountain Research Station, Woodland Park, Colorado. A previous food plant record for *P. lunigerella* describes the larvae as feeding on a variety of conifers. A careful evaluation of this record suggests it is reliable, and I conclude that *P. lunigerella* is actively shifting between dwarf mistletoe and conifer feeding, or has done so recently. My review of the literature on food plant use by lepidopteran herbivores of dwarf mistletoe and their relatives suggests that food plant shifts between parasitic plants and their hosts, and vice versa, have occurred multiple times and may be common among taxa that feed on parasitic and parasitized plants. These findings support a model of food plant shifting in which the close proximity necessarily maintained by parasitic plants and their hosts provides an ecological opportunity that facilitates food plant shifts between these taxonomically and chemically very dissimilar plants. Finally, I describe the life history of *P. lunigerella* larvae and compare them to those of *Dasypyga alternosquamella* Ragonot (Pyralidae), a closely related phycitine that also feeds on dwarf mistletoe at this same location.

Mooney, Kailen A. 2006. The disruption of an ant-aphid mutualism increases the effects of birds on pine herbivores. Ecology. 87(7): 1805-1815. **Abstract**: Predators affect herbivores directly and indirectly, by consumptive and nonconsumptive effects, and the combined influence of multiple predators is shaped by interactions among predators. I documented the individual and combined effects of birds (chickadees, nuthatches, warblers) and ants (*Formica podzolica*) on arthropods residing in pine (*Pinus ponderosa*) canopies in a factorial field experiment. Birds and ants removed herbivores but simultaneously benefited them by removing predatory arthropods. Birds and ants had net negative and positive effects, respectively, on the abundance of herbivore prey, supporting the notion that vertebrate predators have stronger negative effects on herbivores than do arthropod predators. Aphids (ant-tended and untended species) constituted three-quarters of herbivore biomass. The effect of birds on ant-tended aphids was twice that on untended aphid species or tended aphid species without ants. This was not due to there being more ant-tended aphids for birds to prey on; tended and untended aphid species were in similar abundances in the absence of birds. Instead, the effects of birds were strengthened by attributes of the mutualism that rendered tended aphids susceptible to predation. These dynamics led to nonadditive effects of birds and ants: birds only reduced tended aphid species and total herbivore abundances on trees with ants, while ants only increased tended aphid species and total herbivore abundances in the absence of birds. Consequently, top predators in this system only influenced total herbivore abundance when they disrupted an ant-aphid mutualism.

Mooney, Kailen A. 2007. Tritrophic effects of birds and ants on a canopy food web, tree growth, and phytochemistry. Ecology. 88(8): 2005-2014. **Abstract**: Insectivorous birds and ants co-occur in most terrestrial communities, and theory predicts that emergent

properties (i.e., nonadditive effects) can determine their combined influence on arthropods and plants. In a three-year factorial experiment, I investigated whether the effects of birds on pine and its arthropods differed based on the presence of ants that were predators of most arthropods, but mutualists with tended aphid species. Birds and ants reduced the abundance of most herbivorous and carnivorous arthropods in an additive fashion, with the effects of ants being stronger than those of birds. In sharp contrast, the opposing influences of birds and ants on tended aphid species interacted strongly; ants only increased tended aphid abundance in the absence of birds, while birds only reduced their abundance in the presence of ants. This interaction was mirrored in total herbivore abundance because tended aphids dominated the herbivore community. I develop a novel lexicon to discuss the emergent properties from these effects of opposing sign (predation, mutualism). Despite having emergent effects on herbivores, birds indirectly increased pine wood and foliage growth to a similar extent whether or not ants were present, while ants had no detectable effects. Birds also indirectly increased the abundance of some pine phloem monoterpenes, but these effects differed based on the presence or absence of ants. Thus, I report on a novel yet possibly widespread indirect interaction between intraguild predators, herbivore mutualists, and plant traits (growth, secondary chemistry) mediated through a species-rich community of arthropods.

Mooney, Kailen A.; Geils, Brian W.; Linhart, Yan B. 2006. Linking parasitic plant-induced host morphology to tritrophic interactions. Annals of the Entomological Society of America. 99(6): 1133-1138. **Abstract**: We investigated the tritrophic interactions among southwestern dwarf mistletoe *[Arceuthobium vaginatum* (Willd.) Presl subsp. *cryptopodum*], mistletoe herbivores, and host pine (*Pinus ponderosa* Dougl. ex Laws. and C. Laws. variety *scopulorum* Engelm.)-associated predators. In an observational study, we characterized differences in pine-associated arthropods and pine branch morphology between branches either parasitized by mistletoe (brooms) or not visibly infected. Compared with noninfected branches, brooms had a more reticulate branching structure, collected 36 times more dead needles and supported 1.7 times more arthropod predators. In a manipulative field experiment, we investigated whether pine-associated predators fed upon lepidopteran herbivores of mistletoe and thereby reduced herbivore damage to the parasite. Over a 30-d trial, herbivores fed upon approximately two-thirds of available mistletoe shoots. Predator removal increased herbivore survival by 56% but had no detectable effect on the level of herbivory damage. We speculate that herbivores compete for mistletoe shoots and that increased per-capita feeding compensated for predator reduction of herbivore abundance. In summary, our results demonstrate that mistletoe parasitism altered the pine arthropod community, including an increase in the density of predators that likely feed upon mistletoe herbivores.

Mooney, Kailen A.; Gruner, Daniel S.; Barber, Nicholas A.; Van Bael, Sunshine A.; Philpott, Stacy M.; Greenberg, Russell. 2010. Interactions among predators and the cascading effects of vertebrate insectivores on arthropod communities and plants. Proceedings of the National Academy of Sciences. 107(16): 7335-7340. **Abstract**: Theory on trophic interactions predicts that predators increase plant biomass by feeding

on herbivores, an indirect interaction called a trophic cascade. Theory also predicts that predators feeding on predators, or intraguild predation, will weaken trophic cascades. Although past syntheses have confirmed cascading effects of terrestrial arthropod predators, we lack a comprehensive analysis for vertebrate insectivores—which by virtue of their body size and feeding habits are often top predators in these systems—and of how intraguild predation mediates trophic cascade strength. We report here on a meta-analysis of 113 experiments documenting the effects of insectivorous birds, bats, or lizards on predaceous arthropods, herbivorous arthropods, and plants. Although vertebrate insectivores fed as intraguild predators, strongly reducing predaceous arthropods (38%), they nevertheless suppressed herbivores (39%), indirectly reduced plant damage (40%), and increased plant biomass (14%). Furthermore, effects of vertebrate insectivores on predatory and herbivorous arthropods were positively correlated. Effects were strongest on arthropods and plants in communities with abundant predaceous arthropods and strong intraguild predation, but weak in communities depauperate in arthropod predators and intraguild predation. The naturally occurring ratio of arthropod predators relative to herbivores varied tremendously among the studied communities, and the skew to predators increased with site primary productivity and in trees relative to shrubs. Although intraguild predation among arthropod predators has been shown to weaken herbivore suppression, we find this paradigm does not extend to vertebrate insectivores in these communities. Instead, vertebrate intraguild predation is associated with strengthened trophic cascades, and insectivores function as dominant predators in terrestrial plant-arthropod communities.

Mooney, Kailen A.; Haloin, Jon R. 2005. Nest site fidelity of *Paraphidippus aurantia* (Salticidae). Journal of Arachnology. 34(1): 241-243. **Abstract**: We investigated the nest building behavior of *Paraphidippus aurantia* (Lucas 1833) (Salticidae) following the experimental destruction of their nests. We located 61 nests on 52 pine saplings (43 saplings with one nest, nine with two nests) and carefully displaced all spiders and destroyed their nests. On saplings with two spiders, we removed one spider. Of the 52 nests in which the resident spider was left in place, 29 new nests were constructed in the identical location as the nests we removed. Of the 9 nests in which the resident spider was removed, no new nests were constructed. There were no nests constructed in new locations. Despite other suitable nest site locations, *P. aurantia* showed extreme nest site fidelity following the disturbance.

Mooney, Kailen A.; Jon, R. Haloin. 2006. Spider size and guarding of offspring affect Paraphidippus aurantius (Araneae, Salticidae) response to predation threat. Journal of Arachnology. 34(1): 98-103. **Abstract**: We tested the hypothesis that the response of *Paraphidippus aurantius* (Lucas 1833) (Salticidae) to a simulated threat of predation would depend on a combination of spider size and reproductive status. In ponderosa pine forests of Colorado we located nests with spiders of varying sizes that were either adult female spiders guarding offspring or juvenile female and male spiders. To simulate a predator threat we applied a disturbance to the sides of spider nests using repeated puffs of air expressed from a rubber bulb or by blowing. We recorded the threat intensity (number of puffs) required to displace spiders from their nests, and then monitored the

immediate responses of spiders to this threat. The threat intensity required to displace spiders guarding offspring was 2.3 times that of non-guarding spiders, and guarding spiders fled less than half as far as non-guarding spiders. Spider size had no effect on the threat intensity required for displacement, but larger spiders fled further than small ones. We then destroyed nests and monitored the long term responses of the spiders. Nests containing offspring were constructed with 4.6 times the mass of silk as those without offspring. When spiders rebuilt their nests, spider tenure in rebuilt nests did not differ between guarding spiders and non-guarding spiders. Spider size was negatively related to nest tenure for non-guarding spiders, but there was no such relationship for guarding spiders. These results suggest that both the short term and long term outcomes of interactions between P. aurantius and other predators may be influenced by a combination of spider size and offspring guarding behavior.

Mooney, Kailen A.; Linhart, Yan B. 2006. Contrasting cascades: insectivorous birds increase pine but not parasitic mistletoe growth. Journal of Animal Ecology. 75(2): 350-357. **Abstract**: 1. Intraguild predation occurs when top predators feed upon both intermediate predators and herbivores. Intraguild predators may thus have little net impact on herbivore abundance. Variation among communities in the strength of trophic cascades (the indirect effects of predators on plants) may be due to differing frequencies of intraguild predation. Less is known about the influence of variation within communities in predator–predator interactions upon trophic cascade strength.
2. We compared the effects of a single predator community between two sympatric plants and two herbivore guilds. We excluded insectivorous birds with cages from ponderosa pine Pinus ponderosa trees parasitized by dwarf mistletoe Arceuthobium vaginatum. For 3 years we monitored caged and control trees for predatory arthropods that moved between the two plants, foliage-feeding caterpillars and sap-feeding hemipterans that were host-specific, and plant damage and growth.
3. Excluding birds increased the abundance of ant-tended aphids on pine and resulted in an 11% reduction in pine woody growth. Mutualist ants protected pine-feeding aphids from predatory arthropods, allowing aphid populations to burgeon in cages even though predatory arthropods also increased in cages. By protecting pine-feeding aphids from predatory arthropods but not birds, mutualist ants created a three-tiered linear food chain where bird effects cascaded to pine growth via aphids.
4. In contrast to the results for tended aphids on pine, bird exclusion had no net effects on untended pine herbivores, the proportion of pine foliage damaged by pine-feeding caterpillars, or the proportion of mistletoe plants damaged by mistletoe-feeding caterpillars. These results suggest that arthropod predators, which were more abundant in cages as compared with control trees, compensated for bird predation of untended pine and mistletoe herbivores.
5. These contrasting effects of bird exclusion support food web theory: where birds were connected to pine by a linear food chain, a trophic cascade occurred. Where birds fed as intraguild predators, the reticulate food webs linking birds to pine and mistletoe resulted in no net effects on herbivores or plant biomass. Our study shows that this variation in food web structure occurred between sympatric plants and within plants between differing herbivore guilds.

Mooney, Kailen A.; Linhart, Yan B.; Snyder, Marc A. 2011. Masting in ponderosa pine: comparisons of pollen and seed over space and time. Oecologia. 165(3): 1-11. **Abstract**: Many plant species exhibit variable and synchronized reproduction, or masting, but less is known of the spatial scale of synchrony, effects of climate, or differences between patterns of pollen and seed production. We monitored pollen and seed cone production for seven *Pinus ponderosa* populations (607 trees) separated by up to 28 km and 1,350 m in elevation in Boulder County, Colorado, USA for periods of 4—31 years for a mean per site of 8.7 years for pollen and 12.1 for seed cone production. We also analyzed climate data and a published dataset on 21 years of seed production for an eighth population (Manitou) 100 km away. Individual trees showed high inter-annual variation in reproduction. Synchrony was high within populations, but quickly became asynchronous among populations with a combination of increasing distance and elevational difference. Inter-annual variation in temperature and precipitation had differing influences on seed production for Boulder County and Manitou. We speculate that geographically variable effects of climate on reproduction arise from environmental heterogeneity and population genetic differentiation, which in turn result in localized synchrony. Although individual pines produce pollen and seed, only one-third of the covariation within trees was shared. As compared to seed cones, pollen had lower inter-annual variation at the level of the individual tree and was more synchronous. However, pollen and seed production were similar with respect to inter-annual variation at the population level, spatial scales of synchrony and associations with climate. Our results show that strong masting can occur at a localized scale, and that reproductive patterns can differ between pollen and seed cone production in a hermaphroditic plant.

Mooney, Kailen A.; Mandal, Kunal. 2010. Competition hierarchies among ants and predation by birds jointly determine the strength of multi-species ant–aphid mutualisms. Oikos. 119(5): 874-882. **Abstract**: Protection mutualisms often involve multiple species of protector that vary in quality as mutualists. Because protectors may compete for access to mutualists, concordance between competitive ability and degree of benefit will determine the overall strength of multi-species mutualisms. We compared the abilities of two similarly sized congener ants as competitors for, and mutualists of pine-feeding aphids, and how insectivorous birds affected each ant–aphid mutualism. *Formica planipilis* and *F. podzolica* were indistinguishable in forager abundance, but the former was 13-fold more abundant at competition baits and provided 11-fold more benefits to aphids. These results highlight how, in a single environment, a great ecological distance can exist between two congener ants of similar size. Insectivorous birds disrupted the two mutualisms to a similar extent, reducing aphid and ant abundance by 91% and 39% respectively. Nevertheless, birds had an important influence on the relative benefits of the two ants to aphids: where *F. planipilis* consistently benefited aphids, *F. podzolica* only did so in the absence of birds. Consequently, the presence of insectivorous birds and ant species identity jointly determined whether ant–aphid mutualisms occurred in pine canopies and the strength of such interactions. Our study highlights the inter-relatedness of competition, predation and mutualism, and how competition can serve to strengthen mutualism by filtering inferior mutualists.

Mooney, Kailen A.; Tillberg, Chadwick V. 2005. Temporal and spatial variation to ant omnivory in pine forests. Ecology. 86(5): 1225-1235. **Abstract**: To understand omnivore function in food webs, we must know the contributions of resources from different trophic levels and how resource use changes through space and time. We investigated the spatial and temporal dynamics of pine (*Pinus ponderosa*) food webs that included the omnivorous ant, *Formica podzolica*, using direct observation and stable isotopes. *Formica podzolica* is a predator of herbivorous and predatory arthropods, and a mutualist with some aphids. Observations in 2001 of foragers showed that in early summer (June) ants fed upon equal parts non-mutualist herbivores (31% prey biomass), mutualist aphids (27%), and predators (42%); ant trophic position was thus between that of primary and secondary predator (trophic level = 3.4). In late summer (September), ant feeding remained relatively constant upon non-mutualist herbivores (53%) and mutualist aphids (43%), but ant feeding upon predators fell (4%), thus shifting ant trophic position to that of a primary predator (trophic level = 3.0). Feeding on honeydew increased from 25% of ants in early summer to 55% in late summer. By increasing the frequency of their interactions with mutualist aphids, ants maintained a constant supply of arthropod prey through the summer, despite a two–thirds decline in arthropod biomass in pine canopies. Stable isotope analysis ($\delta^{15}N$, $\delta^{13}C$) of six pine food webs dispersed over 150 ha placed ant trophic level at 3.3 for early summer in 2002. There was significant variation among these trees in ant trophic position (range 3.2–3.6), but no indication of positive spatial autocorrelation. The combined results from this work shows that, across two years, *F. podzolica* fed, on average, at or slightly above the trophic position of primary predator, but trophic positioning varied both temporally and spatially by 0.4 trophic levels.

Morris, Meredith J.; Reid, Vincent H.; Pillmore, Richard E.; Hammer, Mary C. 1977. Birds and mammals of Manitou Experimental Forest, Colorado. Gen. Tech. Rep. RM-38. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 17 p. **Abstract**: Seasonal occurrence, relative abundance, and habitat preference are listed for 90 bird and 41 mammal species that can be found at Manitou Experimental Forest. An annotated list is given also for an additional 70 casual or accidental bird species. Manitou Experimental Forest is located near Colorado Springs in the montane zone of the Colorado Front Range.

Myers, Clifford A. 1974. Multipurpose silviculture in ponderosa pine stands of the montane zone of central Colorado. Reseach Paper RM-132. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 15 p. **Abstract**: This article presents silvicultural prescriptions for ponderosa pine in an area where several uses and products of the forest are important but scenic and recreation values predominate. Although far from virgin condition, the pine stands now bear little resemblance to a managed, regulated forest. Present diversity within and between vegetative types can and should be maintained.

Myers, Clifford A.; Currie, Pat O. 1970. Simulation techniques in forest-range

managment. In: Jameson, Donald A., ed. Modelling and systems analysis in range science. Series 5. Fort Collins, CO: Colorado State University, Range Science Department: 17-22. **Abstract**: This chapter reviews the necessary components for creating a simulation of a forest-range system that can be used as a research and land management tool. The program MANAGD is provided as an example of a simulation of a forest where tree density is controlled throughout the life of each forest stand.

Nakashima, Y.; Kato, S.; Kajii, Y.; Greenberg, J.; Karl, T.; Turnipseed, A.; Apel, E. C.; Guenther, A. B.; Harley, P. C.; Smith, J. N. 2009. Total OH reactivity measurements at Manitou Experimental Forest in summer season during BEACHON-SRM08. In: American Geophysical Union, fall meeting 2009; 2009 December 14-18; San Francisco, CA. 1. Washington, DC: Eos Transactions, American Geophysical Union: A21C-0182. Abstract. **Abstract**: The hydroxyl radical (OH) is well known to play a central role in initiating the oxidation of a number of atmospheric species. Measurement of total OH reactivity is important not only to understand mechanisms of oxidant formation in the troposphere but also to estimate the total amount of trace gas species, especially volatile organic compounds (VOCs). We have developed an OH reactivity measurement system using a laser pump probe technique. OH was artificially generated by the photolysis of ozone to produce O(1D) followed by reaction of O(1D) with water vapor. The lifetime of OH was then measured by a laser induced fluorescence technique. We measured OH reactivity at urban and suburban areas of Tokyo and confirmed the existence of unknown reactive species. The measurement of OH reactivity in rural areas where the effect of anthropogenic emissions is thought to be small is another essential test to ascertain the existence of unknown species and their oxidant formation potential. Total OH reactivity was measured at Manitou Experimental Forest (MEF) during August 8th-6thand 22th-28th, 2008. MEF is located in the southern part of the Rocky Mountains and about 80 km south from Denver. MEF is covered with ponderosa pine and observations indicate that the effect of anthropogenic emissions is small. The value of OH reactivity was about 5-10 s-1, smaller than that measured in urban or suburban areas of Tokyo. During the measurement period, a strong thunderstorm and tornado formed near MEF: this coincided with a rapid increase in OH reactivity. Sporadically high OH reactivity was also observed during some days due to transport of pollutants from the Front Range Urban Corridor. Together with the measurement of OH reactivity, traces species such as CO, NO, NOy, O3 and SO2 were analyzed. VOCs were analyzed by GC-FID and PTR-MS techniques. From the calculation of OH reactivity based on the analysis of traces species, about 60% of OH reactivity for VOCs came from biogenic VOCs that are dominated by a hemiterpene, 2-methyl-3-butene-2-ol(MBO), and five monoterpene species. A comparison of observed and calculated OH reactivity shows that the calculated OH reactivity is about 50% less than the observed value. These measurements were carried out at the part of the BEACHON-SRM08 project.

Neal, Donald L.; Currie, Pat O.; Morris, Meredith J. 1976. Sampling herbaceous native vegetation with an electronic capacitance instrument. Journal of Range Management. 29(1): 74-77. **Abstract**: Dry matter yields of herbaceous native vegetation were effectively estimated with electronic herbage meters. Yields were estimated on

vegetation types varying from a low-elevation annual type to a high-elevation alpine type. Phenology, dead organic matter, plant stature, composition, and meter placement within the vegetation affected efficiency of yield estimates. Double sampling techniques are necessary. Optimum sample size for either a fixed-cost or fixed-variance estimate should be determined for each vegetation type.

Niederhof, C. H. 1942. Main Range watershed yields five times as much water as produced by a Front Range watershed. Rocky Mountain Region Bulletin. 25(4): 4-5. **Abstract**: Stream gaging stations were built to measure water yields from watersheds on the Manitou and Fraser Experimental Forests. First-year runoff and precipitation records are presented with possible explanations for the difference in runoff between watersheds.

Noble, Daniel L.; Edminster, Carlton B.; Shepperd, Wayne D. 1979. Effects of watering treatments on germination, survival and growth of ponderosa pine: a greenhouse study. Research Note RM-369. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 6 p. **Abstract**: Amount and distribution of water from 0.0 to 2.0 inches per month (0.0 to 5.1 cm) affected germination, survival, and growth of ponderosa pine seedlings. Germination was less variable when water was applied once during the month than when water was evenly distributed. Seedling survival and growth was best when seedlings received 1 inch or more of water evenly distributed throughout the month.

Peterson, David L.; Arbaugh, Michael J.; Robinson, Lindsay J. 1993. Effects of ozone and climate on ponderosa pine (Pinus ponderosa) growth in the Colorado Rocky Mountains. Canadian Journal of Forest Research. 23(9): 1750-1759. **Abstract**: Long-term radial growth trends of ponderosa pine (*Pinus ponderosa* var. *scopulorum*) were studied in second-growth stands in the Front Range of the Colorado Rocky Mountains to determine if there has been any impact from oxidant air pollution. Although ozone concentrations are relatively high at some locations, visible pollutant injury was not found in any trees. Time series of basal area increments are generally homogeneous within stands. Concurrent periods of increasing and decreasing growth can be found in stands throughout the Front Range, which indicates that there are temporal growth trends at the regional level. Most of these trends appear to be related to the effects of stand dynamics and climate. Correlation analysis with climatic variables indicates that soil moisture supply is the dominant factor controlling interannual variation of basal area growth. Palmer hydrological drought index is highly correlated (positively) with growth during the summer months; total precipitation in spring is positively correlated with growth, and mean temperature in spring is negatively correlated with growth. There are no recent changes in growth trends that might be associated with elevated levels of ambient ozone in the Front Range.

Ponce, Stanley L.; Gary, Howard L. 1979. The effect of lake-based recreation and second home use on surface water quality in the Manitou Experimental Forest. Research Paper RM-211. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p. **Abstract**:

Measurements during one summer indicated dispersed fishing, picnicking, and use of sealed-vault outdoor toilets did not significantly degrade water in Manitou Lake. Poor siting of four long-established second homes on private lands along a stream increased total coliform, fecal coliform, suspended solids, and orthophosphate concentrations.

Price, Raymond. 1976. The Rocky Mountain Forest and Range Experiment Station, 1935-53. In: History of Forest Service research in the central and southern Rocky Mountain Ranges, 1908-1975. Gen. Tech. Rep. RM-27. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 34-57. **Abstract**: This chapter presents the history of the Rocky Mountain Forest and Range Experiment Station between 1935 and 1953. The establishment history and early research of Manitou and Fraser Experimental Forests and Central Plains Experimental Range are provided. The key personnel and reorganization of research programs of the Rocky Mountain Forest and Range Experiment Station are also discussed.

Quinn, James A.; Miller, Roy V. 1967. A biotic selection study utilizing Muhlenbergia montana. Bulletin of the Torrey Botanical Club. 94(5): 423-432. **Abstract**: Collections of mountain muhly, *Muhlenbergia montan*a (Nutt.) Hitchc., from the Manitou Experimental Forest near Woodland Park, Colorado, were investigated as to possible biotic selection resulting from the grazing of domestic livestock. Plants were collected in 1963 from an exclosure and from an adjacent, moderately to heavily grazed area located on the same soil type and topography. Clonal materials were then compared in a transplant garden during the 1964 and 1965 growing seasons. Data analyses showed no significant differences in comparative growth and development between the grazed and ungrazed materials in either 1964 or 1965. Maximum height growth curves indicated similar periods of active growth, and the times of occurrence of first emergence of inflorescence and first anthems were essentially the same. No significant differences were shown in height, production, crown area, or number of reproductive culms. The implications of this lack of evidence for population differentiation are discussed.

Radloff, David L. 1983. Wildland classification with multivariate analyses and remote sensing techniques. Fort Collins, CO: Colorado State University. 106 p. Dissertation. **Abstract**: Wildland classification is a prerequisite to many tasks in the land management planning process. This study was conducted to examine three related aspects of wildland classification at the detailed level. The utility of multivariate analysis techniques in developing an ecologic land classification for a specific area, the similarity between two independently developed classifications for the same area, and the use of remote sensing data for identifying detailed land classification units on the ground were evaluated.

Radloff, David L.; Betters, David R. 1978. Multivariate analysis of physical site data for wildland classification. Forest Science. 24(1): 2-10. **Abstract**: Multivariate statistical techniques were utilized to classify and analyze sites within the Manitou Experimental Forest, Pike National Forest, Colorado. A hierarchic, agglomerative clustering

procedure was applied to a random sample of 147 sites. A set of twelve site classes were developed for the area. This classification scheme was then utilized with discriminant analysis and canonical ordination techniques to identify functions for determining class membership and to examine the class separability in coordinate space. Cluster analysis was found to be a useful tool for aggregating multivariate site data and identifying a classification scheme. Discriminant analysis provided an objective means of determining the class membership of sites and canonical ordination was determined to be an appropriate means of further examining the separability of class groups.

Reich, Robin M.; Lundquist, John; A. Bravo, Vanessa. 2000. Spatial relationship of resident and migratory birds and canopy openings in diseased ponderosa pine forests. Environmental Modelling and Software. 15(2): 189-197. **Abstract**: A method is described for predicting the spatial distribution of individual birds using presence data. The approach is demonstrated using a statistical habitat association model developed for resident and migratory birds on a 12 ha plot of ponderosa pine (*Pinus ponderosa*) heavily infested with southwestern ponderosa pine dwarf mistletoe (*Arceuthobium vaginatum* subsp. *Cryptopodum* (Englemann) Hawksworth and Weins). Bird locations and densiometer readings of canopy opening were recorded on a 5 m x 5 m sampling grid. Minimum threshold theory was used to fit a logistic regression model to the presence data as a function of canopy opening. Highest occupancy of birds occurred at 61% canopy density. Higher probability of birds occurred in more dense canopy than less dense. Model validation indicated that the model adequately described the spatial distribution of the presence of individual birds with respect to canopy opening. Such a model could be used to determine stand conditions that are conducive and/or necessary for certain bird species, and to characterize and quantify the likely ecological consequences of changes to stand structure caused by diseases and other small scale disturbances.

Reppert, Jack N.; Driscoll, Richard S. 1970. 70-mm aerial photography-- a remote sensing tool for wild land research and management. In: Range and wildlife habitat evaluation-- a research symposium. Miscellaneous Publication No. 1147; 1968 May; Flagstaff and Tempe, AZ. [Washington, DC]: U.S. Department of Agriculture, Forest Service, Branch of Range and Wildlife Habitat Ecology and Management Research: 190-193. **Abstract**: New remote sensing techniques will be widely used in wild land research and management in the years ahead. A review of our initial efforts with one facet of remote sensing –large-scale 70-mm. color aerial photography will stimulate appreciation of its vast potential. This potential can be categorized into possibly valuable applications with unique advantages. This system can ultimately be related to more powerful sensor systems, whose efficient use awaits only research and development.

Retzer, John L. 1949. Soils and physical conditions of Manitou Experimental Forest. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 19 p. (+ appendices). **Abstract**: A survey was made of the soils and the physical conditions of the Manitou Experimental Forest during

the summers of 1946, 1947 and 1948. The survey was made as a basis for (1) selection of sites for future experiments, (2) interpretation of results for experiments already in progress, and (3) obtaining a detailed knowledge of the soils of an area representative of the Pike National Forest and much of the Colorado Front Range. The field work was done on aerial photographs and placed upon a controlled base by the Division of Engineering in the Denver Regional Office of the Forest Service.
The survey has certain definite characteristics. The soils were classified on a soil series and type basis, but because of time and mapping limitations, the cartographic units in some instances contain more than one soil. For example, the soil area on the map shown as developed from granitic bedrock includes several different soils, such as those developed on north slopes, those developed on south slopes, and variations from acid podzolic soils on top of the Rampart Range to less acid and less podzolized soils at low elevations. For plots and areas where intensive research is concentrated, it will be necessary to make a much more refined soil study.

Reynolds, Richard T.; Linkhart, Brian D. 1992. Flammulated owls in ponderosa pine: evidence of preference for old growth. In: Kauffman, Merrill R.; Moir, W. H.; Bassett, Richard L., tech. coords. Old-growth forests in the southwest and Rocky Mountain regions: Proceedings of a workshop; 1992 March 3-5; Portal, AZ. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 166-169. **Abstract**: In Colorado, nesting flammulated owls (*Otus flammeolus*) showed a preference for old trees and stands of ponderosa pine and Douglas-fir. Owls more often settled in areas dominated by older forests then young forests when they returned in the spring to nest. Flammulated owls used old trees and forest stands more often for foraging and for defending territories. Individual owls returned more often to territories that were in old stands of ponderosa pine mixed with Douglas-fir compared to territories composed of mosaics of stands of other tree species and ages.

Reynolds, Richard T.; Linkhart, Brian D.; Jeanson, Judy-Jo. 1985. Characteristics of snags and trees containing cavities in a Colorado conifer forest. Res. Note RM-455. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 6 p. **Abstract**: In Colorado a 160-ha forest of mature ponderosa pine-Douglas fir contained 6.5 snags and spike-top trees per hectare. Of these, 0.9 per hectare had one or more cavities. In addition, there were 0.4 live cavity-trees per hectare. Most snags and spike-tops that contained cavities were in the larger diameter classes. The proportion of snags with cavities was equal among ponderosa pine, Douglas fir, limber pine, and quaking aspen.

Robertson, Philip A.; Bowser, Yvonne Hall. 1999. Coarse woody debris in mature Pinus ponderosa stands in Colorado. Journal of the Torrey Botanical Society. 126(3): 255-267. **Abstract**: During summer of 1994, 328 0.1 ha circular plots were sampled to determine the volume of coarse woody debris (CWD) and standing dead density and basal area in 53 mature or older *Pinus ponderosa* stands in the Front Range and Southwestern mountains of Colorado. Standing dead volume was estimated using height derived from living trees in the plots. Generally, CWD amounts were lower in

these forests than have been reported for *Pinus ponderosa* forests in Arizona and New Mexico and other forest types in North America. Mean volume for all plots was 15.9 m^3/ha ± 20.85 SD. Mass, estimated from published wood density values, was 3.4 Mg/ha ± 5.07. CWD in the Southwestern mountains of Colorado averaged about 7.5 m^3/ha > in the Front Range. Sixty-three percent of the CWD was in decay class 4 followed by class 5 with 16%. CWD showed considerable variation across stands and habitat types with generally higher amounts in more mesic conditions. No significant relationships existed between CWD and the various environmental factors measured. CWD volume and variability both increased with stand age. Standing dead density was highly variable with a mean density of 11.9 stems/ha. Most standing dead trees were small with a mean diameter of 34.6 cm and mean basal area of 1.25 m^2/ha. Eighty-eight percent of the class 1 CWD was standing dead, but class 1 comprised only 8% of the total CWD. High values of standing dead may be related to disturbance and stand age. In *Pinus ponderosa* stands, it appears CWD is affected by disturbance, such as fire, timber harvesting and insect infestation > by physical factors of the environment.

Rusterholz, Kurt A. 1981. Niche overlap among foliage-gleaning birds: support for Pianka's niche overlap hypothesis. The American Naturalist. 117(3): 395-399. **Abstract**: This paper presents niche overlap data for a guild of insectivorous birds in Arizona and Colorado. Data on microhabitat use is recorded for eight species of forage-gleaning birds in ponderosa pine forests. The results support two predictions of the niche overlap hypothesis: (1) average (nonzero) niche overlap decreases with the number of species in the guild and (2) average niche overlap is greater in years when resources are more abundant. The data also suggest that mean pairwise niche overlap within a guild or community is inversely proportional to the intensity of interspecific competition.

Schuster, Joseph L. 1959. The relation of root development of native plants to grazing intensity on ponderosa pine ranges. Fort Collins, CO: Colorado State University. 142 p. Thesis. **Abstract**: This study investigated the effects of various intensities of grazing on root development of plants native to the ponderosa pine zone in Manitou Experimental Forest, Colorado. Intensities of grazing were light use (10-20% utilization), moderate use (30-40% utilization), and heavy use (50% or more utilization). Composition and density of the sampled vegetation indicated that the more desirable species, Arizona fescue and mountain muhly, gave way to less desirable species, blue grama, fringed sagebrush, and pussytoes, under moderate grazing. While grazing intensity response varied by species, root patterns became progressively fewer branched, sparser, and shorter under moderate and heavy grazing compared to under no grazing.

Schuster, Joseph L. 1964. Root development of native plants under three grazing intensities. Ecology. 45(1): 63-70. **Abstract**: The purpose of this study was to determine the effects of various intensities of grazing upon roots and root systems of plants native to the ponderosa pine zone of the Colorado Front Range. It was designed to ascertain the root characteristics of certain species of the plant community and any changes in root distribution induced by 17 years of moderate and heavy grazing by

cattle. The cumulative effects of such grazing are also illustrated.

Schuster, J. L.; Wasser, C. H. 1964. Nail-board method of root sampling. Journal of Range Management. 17(2): 85-87. **Abstract**: A method of exposing root systems of individual plants or plant communities has been developed and used successfully at the Manitou Experimental Forest in Colorado. Called the nailboard method, it incorporates techniques used by Pavlychenko (1937), Weaver and Darland (1949), and especially adapts those of de Roo (1957). Soil monoliths containing root samples are excavated in a nail-studded frame. The nails retain the roots in their natural positions while the soil is washed away. The method proved effective in sampling root systems of native ranges and should be adaptable to crop plants.

Shepperd, Wayne D.; Edminster, Carleton B. 1997. The value of long-term silvicultural research studies. In: Communicating the role of silviculture in managing the national forests: Proceedings of the national silviculture workshop; 1997 May 19-22; Warren, PA. Gen. Tech. Rep. NE-238. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 110-114. **Abstract**: Reductions in research operating budgets and recent trends in research management philosophy have in many instances forced Forest Service scientists to realign their research programs to compete for short-term grants and other sources of funding. This approach may prove detrimental in silviculture, a discipline where long-term research is critical for: (1) research in the regeneration and establishment of forests, (2) testing management alternatives in established stands, (3) retaining research installations for future remeasurement; using them as laboratories for other disciplines, and adapting them to meet current and future needs. We present specific examples from our own experience where long-term studies have been utilized in these capacities.

Shepperd, Wayne D.; Edminster, Carleton B.; Mata, Stephen A. 2006. Long-term seedfall, establishment, survival, and growth of natural and planted ponderosa pine in the Colorado front range. Western Journal of Applied Forestry. 21(1): 19-26. **Abstract**: Seedfall, natural regeneration establishment, and growth of planted seedlings was observed from 1981 to 2001 under shelterwood and seedtree overstories in a replicated study in ponderosa pine in the Manitou Experimental Forest in the Colorado Front Range. Good seed crops were produced only every 4 to 6 years, with almost no viable seed produced in intervening years. With seed predation, only 14% of total seedfall was available for germination. Shelterwood overstories containing between 6 and 14 m(2) ha(-1) stem basal area over scarified seedbeds provided optimal conditions for natural seedling establishment. Survival and growth of planted seedlings was much better than that of natural seedlings. However, poor survival and slow initial growth may require many years to establish a fully stocked forest of natural seedlings.

Short, Robert A.; Ward, James V. 1980. Life cycle and production of Skwala parallela (Frison) (Plecoptera: Perlodidae) in a Colorado montane stream. Hydrobiologia. 69(3): 273-275. **Abstract**: The life cycle and production of *Skwala parallela*, a perlodid stonefly, was investigated in a third-order Colorado montane stream. The species exhibited a univoltine life cycle with a distinct cohort. Small nymphs appeared in May.

Rapid growth was exhibited throughout summer and autumn. During winter, growth slowed somewhat but was continuous until April. Maximum density of 34 nymphs/m2 occurred in July. Based upon the instantaneous growth method, annual production was 395.3 mg/m2 or 3.95 kg/ha dry weight with a P/B ratio of 4.4

Short, Robert A.; Ward, James V.; Gary, Howard L.; Currie, Pat O. 1978. Aquatic biota of Trout Creek, Manitou Experimental Forest, Colorado. Gen. Tech. Rep. RM-54. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 13 p. **Abstract**: A survey of macroinvertebrates, periphyton and fishes in Trout Creek and in two of its tributaries was conducted from June through October 1976. Identified were 57 genera of algae, 5 species of fish and 78 taxa of macroinvertebrates. A generally diverse and abundant aquatic fauna and flora prevailed at most study locations. A site below a surface-release reservoir (Manitou Lake) exhibited reduced macroinvertebrate diversity, although standing crop was enhanced, presumably due to contributions of limnetic seston from the lake, compared with other sites on Trout Creek. Species diversity and equitability index values did not indicate any significant degradation of water quality.

Smith, Dwight R. 1967. Effects of cattle grazing on a ponderosa pine-bunchgrass range in Colorado. Technical Bulletin No. 1371. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 60 p. **Abstract**: This study investigated the plant and animal responses to three grazing intensities on ponderosa pine ranges on the Manitou Experimental Forest from 1940 to 1959. The broad aim of this study was to help answer the question, "How closely can a ponderosa pine-bunchgrass range be grazed and still maintain maximum sustained production of forage and beef?" More specific questions concerned the relationships of three intensities of cattle grazing to: (1) range utilization, (2) herbage production, (3) other plant responses, (4) soil conditions, and (5) cattle weight gain.

Smith, Dwight R.; Bass, Louis N. 1973. Germinability of true mountain mahogany achenes as influenced by soil and other environmental factors. Proceedings of the Association of Official Seed Analysts. 63: 126-134. **Abstract**: Differences in percent germination, percent filled, and weights of true mountain mahogany achenes collected on four mountain soils were highly significant (p=.01). Germination, fill and weight were greater, also at the .01 level, for achenes from northwest aspects than for achenes from southwest aspects. Achenes with highest germination were from plants on northwest aspects in the least fertile soil, which had the lowest natural population of mahogany. Contrastingly, achenes with lowest germination were from southwest aspects on the most fertile soil, where mahogany plants were most abundant. Reasons for this apparent contradiction are explored. Microenvironmental factors are important in determining mountain mahogany achene viability.

Stromberger, Mary E. 2008. Microbial communities of fire-affected soil. Final report. Joint Venture Agreement between U. S. Forest Service, Rocky Mountain Research Station and Colorado State University. No. 03-JV-11221616-093. Fort Collins, CO: Colorado State University, Department of Soil and Crop Sciences. 34 p. **Abstract**: The

objectives of the three studies included in this report were to determine soil ecosystem consequences of various mastication treatments, applied at different scales within the same ponderosa pine forest, with an emphasis on soil microbial community structure, function and soil carbon (C). The first study examined the three-year effects of forest floor chipping amendments on soil fungi, soil carbon, and soil enzyme activities relevant to C substrate decomposition. A second study was conducted to determine chip amendment effects on soil microbial properties and C. Finally, a third study was conducted to investigate the effects of a lop and scatter mastication treatment on soil microbial properties and C.

Taylor, John. 1972. Nutritive value of Colorado range plants. Fort Collins, CO: Colorado State University. 75 p. (+appendices). Dissertation. **Abstract**: This study was undertaken to investigate the nutritive value of some of the more important forage species grazed by livestock in various areas of Colorado. The samples were analyzed for energy, protein, cellulose, vitamin A, calcium, phosphorus and magnesium. The digestibility coefficients of the plants, protein, energy and cellulose were also determined by the in vivo nylon bag technique.
All species studied were deficient in at least one of the elements analyzed at some phenological stages. The nutrient deficient at more growth stages than any other element was phosphorus. The next most deficient, based on nutritive requirement for gestation and maintenance was digestible protein. To assure that animals are not subjected to nutrient deficiencies a variety of plant species should be available for grazing so that a deficiency in one can be offset by an excess in another.

Teves, Nani Bay; Stednick, John D. 2005. Effectiveness of forestry related best management practices in the Trout Creek watershed, Colorado. Colorado Water Resources Research Institute. Completion Report No. 202. Fort Collins, CO: Colorado State University. 109 p. Thesis. **Abstract**: In multiuse forests the majority of nonpoint source pollution is typically sediment. Best management practices (BMPs) are implemented to reduce or prevent this pollutant, however little research has been done to quantify the effectiveness of individual types of BMPs. The overall goal of this project was to evaluate the effectiveness of three BMPs implemented to reduce sediment in Trout Creek: cattle fences, off-road vehicle (ORV) signs, and road culverts.
Fenced, unfenced, and ungrazed control pastures were measured. In the unfenced pasture, on average, a cow spent 1.0 min/day in the creek, and 11.5 min/day on the banks. The fenced, unfenced, and control pastures had significantly different ($p<0.05$) eroded bank areas, 363 m^2, 780 m^2, and 683 m^2 of eroded bank area per km, respectively. Total suspended solids (TSS) and turbidity samples were collected above and below each pasture, and no significant differences ($p<0.05$) were found. These results suggest fences are an effective BMP.
ORV signs were installed in the Trout Creek watershed to discourage use of illegally created trails. Illegal trails were used by 5.8% of the ORVs, and of this, signed trails were used by 3.4% of the ORVs, unsigned trails used by 2.4%, and control areas (no ORV activity) were never used. 94.2% of ORV activity was not on the illegal trails, and remained on legal trails. Mean total suspended solids (TSS) were similar between above and below ORV area samples. Soil erosion was measured from 14 runoff events,

and had no significant difference ($p<0.05$) between signed and unsigned trails. Mean trail erosion was higher on signed trails than unsigned trails, 44 g/m^2 and 28 g/m^2. The use and erosion results suggest that ORV signs are ineffective on illegally created trails. Culverts were installed along the unpaved Rampart Range Road to control and direct road drainage. Gully erosion volumes at road sections with and without culverts were not significantly different ($p<0.05$). Mean erosion at the road sections with culverts was 29 kg/m^2 and 9 kg/m^2 at road sections without culverts.
The effectiveness of the combined BMPs in the land-use area was evaluated by comparing water quality and Wolman pebble counts with an upstream reference area. A reference area was selected based on soil type, vegetation type, elevation, and absence of cattle grazing and ORV use. But the reference area had a narrower floodplain, and was separated from the land-use area by a reservoir used for recreation. The selection of a reference area is difficult, and the variability in results between the water quality and WPCs, and instream effects, make determining BMP effectiveness at this scale difficult at best.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 1948. Notes from the Manitou Experimental Forest. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p. **Abstract**: This article reviews the reviews the current (1948) research conducted at Manitou Experimental Forest. Studies about grazing practices, cattle weight gain, range reseeding, and watershed management are described.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 1957. Watershed management research meeting; 1957 May 6-10; Manitou Experimental Forest, CO. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 97 p. **Abstract**: The 1957 Watershed Management Meeting held at Manitou Experimental Forest reviewed the measurements and processes involved in watershed research. Topics included in these notes include: weather factors, measurement of precipitation, streamflow measurement, sediment measurement, soil structure, soil moisture movement, measurement of soil moisture, soil erosion, water relations of trees, ecology, snow hydrology, forest influences on snow hydrology, experimental methods, Workman Creek watershed study, research opportunities, servicewide watershed research program, and how statisticians aid research.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 1966. Current range management research and results at the Manitou Experimental Forest Rocky Mountain Forest and Range Experiment Station. [Fort Collins, CO]: [U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station]. 20 p. **Abstract**: This article reviews the reviews the current (1966) research conducted at Manitou Experimental Forest. Studies about grazing practices, range reseeding, cattle weight gain and forage nutrition are described. Additionally, studies that are currently (1966) being installed are listed.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Reseach Station.

[n.d.]. A retrospective look at the Rocky Mountain Research Station, [Online]. 7 p. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station (Producer). Available:http://www.fs.fed.us/outernet/rm/main/rmrs_reports/history.pdf [2011, September 22]. **Abstract**: This article describes the history of the Rocky Mountain Research Station from 1903-present. The establishment of Experimental Forests and Ranges and Research Stations are discussed.

VanReken, Timothy; Mwaniki, George; Callen, Logan. 2009. Cloud-forming potential of atmospheric particles at the BEACHON southern Rocky Mountains site in Colorado. In: American Association for Aerosol Research 28th annual conference; 2009 October 26-30; Minneapolis, MN. [Mount Laurel, NJ]: American Association for Aerosol Research: 1257. Abstract. **Abstract**: Biogenic sources are a major source of particulate mass and number globally, and as such have a significant impact on regional air quality and global climate. To better understand these impacts and how they may feed back onto ecosystem processes, an intensive field study was conducted at the Manitou Experimental Forest in the Colorado Rocky Mountains in Summer 2008. As part of that study, we measured cloud condensation nuclei concentrations at five supersaturations ranging from 0.3 to 0.8% using a Droplet Measurement Technologies CCN Counter. CCN concentrations varied by more than an order of magnitude over the course of the four-week measurement period. We present those results in the context of changing meteorological conditions, new particle formation events, and bulk water-soluble PM1.0 composition. These last data were made at one-hour time resolution using a Particle–Into-Liquid Sampler (PILS), with subsequent analysis via ion chromatography and a total organic carbon analyzer.

Vavra, Martin; Mitchell, John. 2010. Experimental forests and ranges as a network for for long-term data. In: Adams, Mary Beth; NcNeel, Joe; Rodriguez-Franco, Carlos, Meeting current and future conservation challenges through the synthesis of long-term silviculture and range management research. Gen. Tech. Rep. WO-84. Washington, DC: U.S. Department of Agriculture, Forest Service: 15-23. **Abstract**: In the new millennium, national leaders and policymakers are facing profound issues regarding people and the environment. Experimental Forests and Ranges (EFRs), managed by the Forest Service, U.S. Department of Agriculture (USDA), form a network of locations amenable to the development of long-term data collection across many major ecosystems of the continental United States, Alaska, and Hawaii. Truly long-term data sets dealing with range and grasslands are rare but do exist. Unfortunately, the status of older studies, in terms of longevity and variables monitored, are incompletely documented. The paucity of long-term data sets is related to personnel turnovers and a lack of ownership of long-term studies that may be sampled only every 5 or 10 years, coupled with limited funds available to hire personnel for data collection. Any long-term monitoring program should start with the basics of seasonal and daily precipitation and daily maximum and minimum temperatures. Change in plant species composition is an important indicator of the integrity of the plant association. Photographs can be taken at permanent points to qualitatively measure how vegetation changes over time, for the detection of changes in vegetation structure and for visually documenting vegetation

change. To successfully provide long-term biotic and abiotic data that can support broad-scale research into contemporary issues, such as climate change, species invasions, desertification, and fire, these EFRs must be connected in a network.

Ward, J. V.; Short, R. A. 1978. Macroinvertebrate community structure of four special lotic habitats in Colorado, USA. International Association for Theoretical and Applied Limnology. 20: 1382-1387. **Abstract**: The purpose of this paper is to compare the macroinvertebrate communities of four regulated streams and to identify taxa potentially useful as indicators of regulation.

Weimer, Carl; Ramond, Tanya. 2010. An Electronically Steerable Flash Lidar (ESFL). In: Earth science technology forum 2010; 2010 June 22-24; Arlington, VA. [Greenbelt, MD]: [NASA Earth Science Technology Office]: 4 p. **Abstract**: Current space-based lidar systems for earth remote sensing have a number of inherent limitations that impact their use for broader science applications. These include no cross-track coverage, fixed spatial sampling that forces pointing control to be performed by the spacecraft, cloud loss over many types of scenes, and, in general, lifetimes set in part by the number of laser shots fired. The Electronically Steerable Flash Lidar (ESFL) is a new concept developed to help in overcoming these limitations. It combines a new “Flash” focal plane technology that allows both imaging and waveform ranging, with a multibeam steering capability. Steering is achieved via an acoustooptic beam deflector that splits the laser into multiple beams that can be independently accessed and pointed without the need for mechanical scanners or boresight mechanisms. A full demonstration unit of ESFL was completed and successfully tested both in laboratory and aircraft flight tests. One to ten beams were controlled at the full frame rate (30Hz) of the focal plane. Laboratory testing showed that ESFL can be used to point between clouds identified by a separate visible camera. Multiple operating modes were demonstrated including a geolocation mode where a beam tracked a pre-defined transect defined by its GPS determined latitude/longitude as the aircraft carrying the lidar passed over. ESFL was flight tested over a broad range of land and forest scenes illustrating its ability to terrain map as well as profile forest canopies.

Welch, Jack F.; Terrell, Charles L. 1948. Rodent control activities in connection with grass adaptability studies. Journal of Forestry. 46(5): 379-380. **Abstract**: Rodent damage was observed on plots seeded with grasses in Manitou Experimental Forest. It appeared that the largest seeds that were planted were attacked before smaller seeds. Rodent control measures (poison bait) seemed to deter seed predation in the following growing season.

Wilm, H. G. 1941. Methods for the measurement of infiltration. Transactions, American Geophysical Union. [22]: 678-685. **Abstract**: The objectives of this research were to: (1) determine the relative reliability of various infiltration measurement instruments; (2) evaluate the comparative importance of various factors such as "rainfall"-intensity, soil temperature, and characteristics of the soil and plant-cover which might influence infiltration; (3) suggest efficient methods for future experiments, which should successfully isolate and control at least the more important sources of variation, and

provide maximum accuracy and efficiency in the appraisal of infiltration as measured by sprinkled plots.

Wilm, H. G. 1942. New gaging station for mountain streams: Forest Service installation combines a San Dimas flume with two broad-crested weirs. Civil Engineering. 12(10): 548-549. **Abstract**: One of the many duties of the Forest Service of the U.S. Department of Agriculture is the investigation of watershed management. A phase of this subject is the measurement of the flow of mountain streams, which varies through a wide range. To measure and record these varying quantities, a type of gaging stations which combines a flume and two broad-crested weirs has been developed at the Rocky Mountain Forest and Range Experiment Station at Fort Collins, Colorado. Mr. Wilm discusses the accuracy with which extremes of flow in flashy mountain streams may be measured by this type of installation.

Wilm, H. G.; Collet, M. H. 1941. A portable electric water-depth gage. Civil Engineering. 11(5): 305. **Abstract**: This article describes a new portable electric device used to measure water depths in wells and channels. The gage was developed by the U.S. Forest Service and has proved to be efficient at measuring water stages in flumes, weirs, ground-water wells, and runoff collector tanks.